




2008

## A Watershed Analysis of Pattee Pond: Implications for Water Quality and Land Use Management

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

Colby Environmental Assessment Team, Colby College

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# A WATERSHED ANALYSIS OF PATTEE POND

IMPLICATIONS FOR WATER QUALITY  
AND LAND USE MANAGEMENT



COLBY  
COLLEGE  
2009

PROBLEMS IN ENVIRONMENTAL SCIENCE  
WATERVILLE, MAINE 04901





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



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# **Water Quality and Watershed Analysis of Pattee Pond**

## **Executive Summary**

**Colby Environmental Assessment Team**  
**Colby College, Waterville, ME 04901**

The Colby Environmental Assessment Team (CEAT) investigated the impact of land use patterns on the water quality of Pattee Pond in Winslow, Maine during the summer and fall of 2008. Physical, chemical, and biological characteristics of water quality were analyzed to evaluate the current health of the lake. Data collected were compared with previous studies conducted by the Maine Department of Environmental Protection (DEP) and CEAT to examine changes in water quality and land use over time. Trends in Pattee Pond water quality suggest an improvement since the 1970s. However, the lake is still experiencing algal blooms resulting from phosphorus concentrations over 12 to 15 ppb. Furthermore, Pattee Pond is on the Chapter 502 Maine DEP List of Lakes Most at Risk from New Development and the Maine DEP Nonpoint Source Priority Watershed List. In addition to water quality analyses, a macrophyte study was performed to document the aquatic plant community and search for invasive species. CEAT studied the development patterns in the watershed, examining subsurface wastewater disposal systems and zoning regulations. A buffer strip survey was also conducted to identify potential sources of phosphorus loading along the shoreline. Historical and current aerial photographs were used to investigate and quantify land use changes throughout the watershed over the last 40 years and to estimate the impact of these changes on phosphorus loading. Findings from demographic research were used to make projections for future development and the related potential changes in phosphorus inputs to the lake.

The following is a brief summary of findings from the study of Pattee Pond and its watershed carried out by the Colby Environmental Assessment Team:

### **Lake Characteristics:**

- Pattee Pond is a relatively shallow, dimictic lake. The lake and its watershed have surface areas of 211 ha (522 acres) and 3,339 ha (8,250 acres), respectively. The lake has a mean depth of 4.6 m (15 ft), with a maximum depth of 8.8 m (29 ft).
- The flushing rate of the lake, including the input from Mud Pond, is 2.72 flushes per year. Consequently, if non-point source nutrient loading can be reduced, nutrients accumulated in the lake could be flushed out over time, improving water quality. Almost 80% of the water entering the lake annually comes from watershed runoff, suggesting land use patterns in the watershed strongly affect water quality.
- Water transparency in Pattee Pond, as measured using a Secchi disk, has gradually improved over the last 40 years. CEAT recorded Secchi depth of 3.5 m in early June. Depths then increased to 4.5 to 5.0 m through the summer. Secchi disk readings dropped rapidly beginning in early August as a result of an algal bloom caused by the fall turnover.
- Historic total phosphorus (TP) levels are variable, but have recently shown a declining trend. The mean epicore phosphorus concentration from the Characterization Site (Site 1) was 12.5 ppb. Beginning in early June and extending to late August, the water column was stratified. Anoxia developed below 6.0 to 6.5 m. The anoxic zone covered almost 30% of

the lake. Total phosphorus concentrations from bottom samples taken at Site 1 reached a peak at 293 ppb in early August. This spike indicates that phosphorus is being released from the sediments during the anoxic period. Approximately 18% of the phosphorus concentration in Pattee Pond is from internal recycling.

- Farber Brook is a significant source of sediment loading into Pattee Pond. Water runoff from the stream after major rain events contributes large amounts of phosphorus and sediments. Remediation specifically for this stream and the surrounding land is recommended.
- Although results of field tests have been mixed, a lake remediation technique potentially suitable for Pattee Pond is the introduction of alewives into the lake. These fish will accumulate nutrients as they feed and grow, and then remove these nutrients from the lake when they leave to spawn. This experimental technique may help provide an inexpensive, in-lake management strategy for phosphorus loading. However, because non-point source runoff contributes the majority of phosphorus loading into the lake, remediation techniques that focus on reducing external phosphorus loading should be a top priority.
- The most common macrophytes found in Pattee Pond were common rush (*Juncus effuses*) and pickerelweed (*Pontederia cordata*). Purple Loosestrife (*Lythrum salicaria*) was the only invasive plant species found along the Pattee Pond shoreline and was localized to four points in the lake. It was not dominant at any site, and could be easily be removed by hand. Areas in the lake with depths less than 16 ft (45% of the lake) are at risk for invasive species colonization because invasives prefer shallow water.

### **Land Use and Development**

- Land use in the Pattee Pond watershed has undergone numerous changes between 1965 and 2007. The maturation of existing forests and the decrease in agricultural land have reduced potential phosphorus loading in the watershed. Land uses likely to promote phosphorus loading including residential and commercial development, recreational areas, and roads have also increased in the watershed. These increases tended to be close to roads, the shoreline, and inlets to Pattee Pond. Wetland area, particularly close to the lake and its inlets, was found to have declined.
- The three main anthropogenic sources of phosphorus in the watershed are residential development (21.7%), septic systems (shoreline – 1.7%, non-shoreline – 7.0%), and roads (camp roads – 10.2%, municipal and state roads – 4.5%). Seventy percent of the phosphorus loading from roads comes specifically from camp roads. Although these sources do not have large areas, they have disproportionate effects on phosphorus loading.
- The lakeshore of Pattee Pond is densely developed with seasonal residences located on small lots along sections of the west and east shores of the lake. There are 105 seasonal and 5 year-round residences along the shoreline (less than 250 ft from the lake). There are 20 seasonal and 361 year-round residences in the remainder of the watershed. The current zoning codes stipulate a minimum lot size of two acres, with additional restrictions for lot frontages and setbacks. The State of Maine and Town of Winslow have also adopted Shoreland Zoning rules that govern development within 250 ft of water bodies. Many of the homes in the Pattee Pond watershed were built before implementation of restrictive zoning began in 1974 and are considered legally non-conforming.
- Owners of small, legally non-conforming homes on lots close to the lake should implement best management practices (BMP) to mitigate impacts of runoff from their lots.



Manuals describing different types of BMP methods are available from the Maine DEP among other sources. Individual landowners can play a major role in helping to solve erosion problems that cause sediment and phosphorus loading into the lake.

- The buffer strip survey indicated that 69 percent of shoreline properties had fair or poor quality buffers that need improvement. The properties that fell into the smallest shoreline frontage category (grandfathered under current zoning restrictions) had the highest percentage of poor buffers. The quality of buffers depends on individual property owners, who are responsible for their upkeep and improvement.
- 94.5% of the non-shoreline properties have septic systems. Shoreline properties have either holding tanks (49.3%) or septic systems (37.3%). The overall condition of subsurface wastewater disposal systems is good because of strong code enforcement, but continued periodic inspections of legally non-conforming systems to check for system failures should occur.
- Almost one half of the camp road surface around Pattee Pond requires substantial repair to reduce runoff into the lake. Whitefish Lane and Pickerel Point Road are two camp roads of particular concern. Whitefish Lane has many steep driveways leading straight down to the lake that would benefit from the installation of water diversions. Pickerel Point Road lacks adequate crowning, ditching, and water diversions on the steep section. These repairs are critical to mitigating phosphorus loading because 22% of the erosion sites that contribute significant amounts sediment to the lake are associated with private roads (Pattee's Pond Association report).
- Although the population of Winslow is stable, the mean household size is decreasing. This suggests that residential development may continue. Development is likely to occur along existing roads and close to the lake. The proposed 2008 Winslow Comprehensive Plan outlines a new zoning strategy that includes a Conservation District designed encourage growth in the town center and to limit development in the Pattee Pond watershed. The Winslow Comprehensive Planning Committee is keeping environmental concerns a top priority by promoting the plan to help protect the water quality of Pattee Pond.

Although Pattee Pond has shown improvements in water quality since the 1970s, the lake still experiences algal blooms. The trophic status of Pattee Pond is eutrophic, but appears to be improving based on historical and current data. Pattee Pond is expected to respond rapidly to mitigation techniques for phosphorus loading because of its high flushing rate. Efforts should be made to follow best management practices, to implement appropriate land use mitigation techniques, and to regulate new development within the watershed. The recommendations presented in this report all have the ultimate goal of reducing the frequency of algal blooms and restoring lake water quality.





# **WATERSHED ASSESSMENT INTRODUCTION**

## ***GENERAL NATURE OF STUDY***

There are over 5,000 lakes and ponds in the State of Maine and much of Maine's culture revolves around them (MDEP 2005a). From duck hunting to water skiing, Maine families derive great pleasures from the opportunities afforded by lakes. However, with increased human activity in and around these vibrant water bodies comes a very real danger: water quality degradation. It is essential that Maine lakes and their watersheds be studied to identify problems associated with human activity and to determine their solutions.

The most dangerous facet of lake degradation in the Pattee Pond watershed is eutrophication, a human-accelerated, but natural, process that leads to an increase in the amount of nutrients available to lake biota. An increase in nutrients, especially limiting nutrients, results in an increased ability for bacteria, algae, and plant-life to grow. When plant life dies, its decay (by decomposers) causes a large decrease in the amount of dissolved oxygen in the lake, which can harm other plant species and fish (Dodds and Welch 2000). In Maine lakes, the nutrient that limits the rate of eutrophication and growth of undesired plant, algae, and bacteria is phosphorus (MDEP 2008a). Unfortunately, many human activities near a lake, such as residential and commercial development, farming, and transportation, can work to hasten the loading of phosphorus (Carpenter et al. 1998, Baker et al. 2008).

Pattee Pond, located in Winslow, ME, is a valuable resource to its region (MDEP 2008a). With a watershed of over 3,500 ha that extends through four separate towns (Albion, China, Vassalboro, and Winslow), it is a source of outdoor recreation for hundreds of families as well as a valuable source of income for the community. This study, performed by the Colby Environmental Assessment Team (CEAT) 2009, takes a look at the human activities occurring in and around this watershed as well as the anthropogenic effects on the water quality of Pattee Pond. Field data and residential data, from the town offices of Albion, China, Winslow, and Vassalboro, were collected and pertinent scientific literature was reviewed. In addition to these data, CEAT utilized chemical testing and GIS-based and mathematical model-based analyses to assess lake water quality. Ultimately, this report identifies specific problems contributing to the degradation of water-quality within the Pattee Pond watershed and provides recommendations to help remediate them.

## ***BACKGROUND***

### **Lake Characteristics**

#### **Distinction Between Lakes and Ponds**

Lakes and ponds are inland bodies of standing water created either naturally through geological processes or artificially through human intervention (Smith and Smith 2009). Lakes and ponds differ in their size and depth profiles: lakes have greater surface area and depth than ponds (Smith and Smith 2009), and generally develop both vertical stratification and horizontal zonation while ponds do not. Horizontal zonation divides lakes into zones based on sunlight penetration and the growth of vegetation. The littoral or shallow-water zone is the area in which sunlight can penetrate to the bottom, allowing vegetation to grow from the substrate. The deep-water area is divided into the upper limnetic and lower profundal zones where rooted plants are unable to grow. Ponds do not have this zonation and are shallow enough that vegetation can be rooted throughout (Smith and Smith 2009). The vertical stratification found in lakes depends on water density differences that occur as a result of temperature. Deep lakes will stratify with the densest (coldest) water on the bottom until a threshold of 4° C and the least dense (warmest) water toward the surface. Ponds and shallow lakes do not stratify because disturbance from wind and waves causes constant mixing and temperature circulation.

#### **General Characteristics of Maine Lakes**

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

The majority of Maine lakes were formed during the Wisconsinian glaciation of the Pleistocene Epoch (Davis et al. 1978). Glacial activity in Maine has left most lake basins comprised of glacial till, bedrock, and glaciomarine clay-silt. These deposits and the underlying granite bedrock are infertile and as a result, most of Maine's lakes are relatively nutrient poor. The movement of glaciers in Maine was predominantly to the southeast, carving out Maine lakes in a northwest to southeast direction (Davis et al. 1978). This orientation, along with lake surface

area and shape, plays a fundamental role in the effect of wind on the water body, which is an important factor for lake turnover, or the mixing of thermal layers.

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

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

### **Annual Lake Cycles**

Water has the unique physical property of being most dense at 4° C (Smith and Smith 2009). Water decreases in density at temperatures above and below 4° C, allowing ice to float on the surface of lakes and ponds and warm water to stratify above cold water. In the summer, direct solar radiation warms the upper levels of the water column forming the epilimnion, which hosts the most abundant floral communities (Davis et al. 1978). The photosynthetic capabilities of the plants create an oxygen rich stratum. However, available nutrients in the epilimnion can be depleted by algal populations growing in the water column, and may remain depleted until the turnover of the water column in early fall (Smith and Smith 2009). The process of lake turnover is summarized in Figure 1.

Below the epilimnion is a layer of sharp temperature decline, known as the metalimnion (Smith and Smith 2009). Within this stratum is the greatest temperature gradient in the lake, called the thermocline. The thermocline separates the epilimnion from the hypolimnion, the lowest stratum of a lake. The hypolimnion, only found in deeper lakes, is beyond the depth to which sufficient light can penetrate to facilitate effective photosynthesis (Figure 1). It is in the



substrate below the hypolimnion where most decomposition of organic material takes place, through both aerobic and anaerobic biological processes. While aerobic (requiring oxygen) bacteria break down organic matter more quickly than anaerobic (not requiring oxygen) bacteria, they also significantly deplete the oxygen at these depths (Figure 1; Davis et al. 1978).

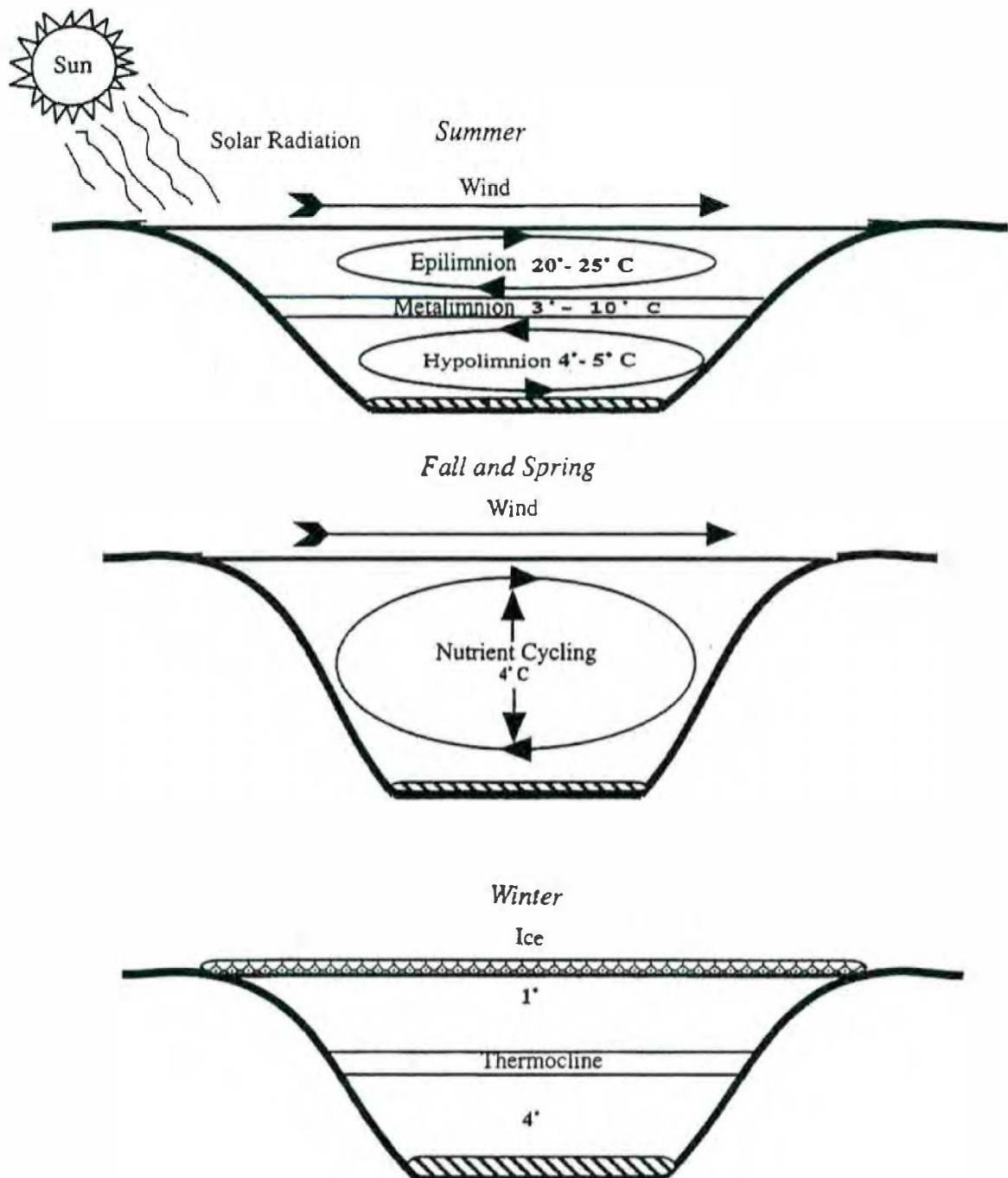
As the weather becomes colder, water temperature decreases and wind facilitates thermal mixing until the vertical profile of the water column is uniform in temperature. This event, known as turnover, re-oxygenates the lower depths of the lake and mixes nutrients throughout the strata. The cold water near the surface can hold increased levels of oxygen, which is redistributed with turnover. Through this process, organisms at depth receive oxygenated water. A similar turnover event also occurs in the spring (Smith and Smith 2009). A lake that has two turnover events per year is classified as dimictic, whereas shallow lakes that may turn over at anytime of the year are known as polymictic.

In winter, lakes in Maine are covered with ice for four to five months, wherein the stratification is reversed as the coldest water and ice are on the surface and the warmest water (roughly 4° C) extends to the bottom because water is densest at 4° C. Significant snow cover on the ice may affect the photosynthetic processes under the ice by blocking some of the incoming solar radiation. Ice prevents diffusion of oxygen into the water and photosynthetic activity decreases, reducing oxygen production from phytoplankton thus decreasing the dissolved oxygen levels enough to cause significant fish kills (Smith and Smith 2009).

After the ice has melted in the spring, solar radiation warms the upper stratum of the lake. The freshly melted water sinks and this process continues until the water column is uniform in temperature and oxygen and nutrients are mixed throughout the water column. As late spring approaches, solar radiation increases, stratification occurs, and temperature profiles return to that of summer in dimictic lakes, preventing water column mixing (Smith and Smith 2009).

### **Trophic Status of Lakes**

The biological classification of lakes by their eutrophic state is based on nutrient levels in the water (Maitland 1990). Lakes are divided into four major trophic states: oligotrophic, mesotrophic, eutrophic, and dystrophic (Table 1). The mesotrophic characterization is not included in Table 1, because it is referred to as a transitional stage between oligotrophic and eutrophic states (Chapman 1996). Oligotrophic lakes tend to be deep and oxygen rich with steep-



**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.**

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

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

sided basins, creating a low surface to volume ratio. They are low in suspended solids such as nitrates and more importantly phosphorus, the limiting nutrient for plant productivity in most freshwater ecosystems. The shape of a lake can also influence its productivity: steep-sided oligotrophic lakes are not conducive to extensive growth of rooted vegetation because there is little shallow margin for attachment (Table 1).

Eutrophic lakes are nutrient-rich and have a relatively high surface to volume ratio compared to oligotrophic lakes (Maitland 1990, Chapman 1996). These lakes have a large phytoplankton population that is supported by the increased availability of dissolved nutrients. Low dissolved oxygen levels at the bottom of a eutrophic lake are the result of decomposers using oxygen. Anoxic (oxygen deficient) conditions lead to the release of phosphorus and other nutrients from the bottom sediments, resulting in their eventual recycling through the water column (Chapman 1996). This phosphorus release and recirculation stimulates further growth of phytoplankton populations (Smith and Smith 2009). Eutrophic lakes tend to be shallow and bowl-shaped as a result of sediment loading, allowing for the establishment of rooted plants in shallow areas.

Dystrophic lakes have slightly lower water quality and receive large amounts of organic matter from the surrounding land, particularly in the form of humic (dead organic) materials (Smith and Smith 2009). The large quantity of humic materials stains the water brown. Dystrophic lakes have highly productive littoral zones, high oxygen levels, high macrophyte productivity, and low phytoplankton numbers (Table 1). Eventually, the invasion of rooted aquatic macrophytes chokes the habitat with plant growth, leading to the filling in of the basin, ultimately developing into a terrestrial ecosystem (Goldman and Home 1983).

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

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

- Decreasing hypolimnetic dissolved oxygen concentrations.
- Increasing nutrient concentrations in the water column.
- Increasing suspended solids, especially organic material.



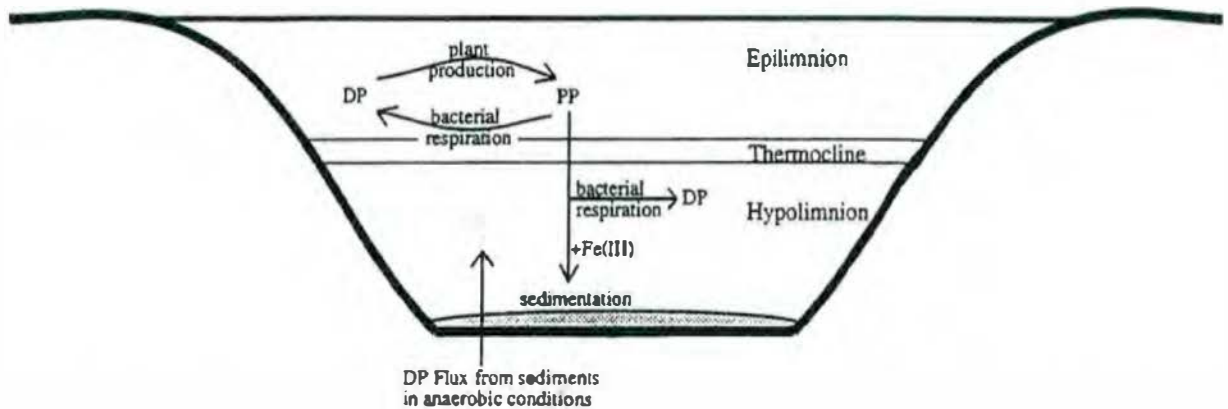
- Progression from a diatom population to a population dominated by cyanobacteria and/or green algae.
- Decreasing light penetration (e.g., increasing turbidity).
- Increasing phosphorus concentrations in the sediments (Henderson-Sellers and Markland 1987).

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

### **Phosphorus and Nitrogen Cycles**

In freshwater lakes, phosphorus and nitrogen are the two major nutrients required for the growth of algae and macrophytes (Smith and Smith 2009). Each nutrient has its own complex chemical cycle within the lake (Overcash and Davidson 1980), and it is necessary to understand these cycles to devise better techniques to control high nutrient levels.

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



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

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

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

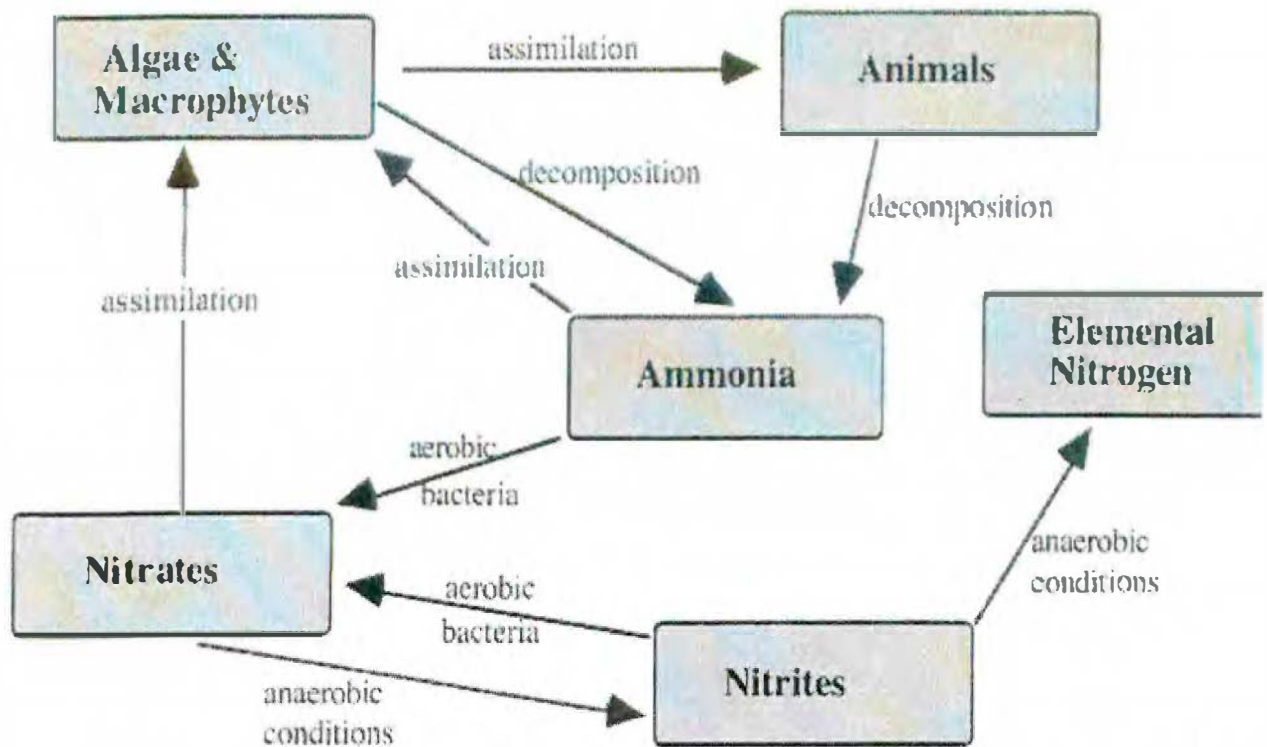
approaches and the dead organic matter settles to the bottom where PP is converted back to DP and reaccumulates, allowing for another large nutrient input to surface waters during spring turnover (Bouchard, pers. comm.).

Nitrogen, the other major plant nutrient, is usually not the sole limiting factor for plant growth in a lake (Chapman 1996), but it is still important to understand its cycle because high concentrations can lead to algal blooms in the presence of phosphorus. Available nitrogen exists in lakes in three major chemical forms: nitrates ( $\text{NO}_3^-$ ), nitrites ( $\text{NO}_2^-$ ), and ammonia ( $\text{NH}_3$ ) (Figure 3). The majority of free nitrogen in a lake exists in the form of nitrates (Maitland 1990), a form that is directly available for assimilation by algae and macrophytes. In eutrophic lakes, there may be so much algae and macrophyte growth that most of the nitrates in the lake are incorporated into plant tissues (Maitland 1990). Plants, however, cannot use nitrites. In aerobic conditions, nitrate-forming bacteria convert nitrites to nitrates. Ammonia enters the lake ecosystem as a product of the decomposition of plant and animal tissues and their waste, and is processed in one of three ways. Macrophytes can assimilate ammonia directly into their tissues. Alternatively, under oxygen-rich conditions, aerobic bacteria will convert the ammonia directly to nitrates, the more usable form of nitrogen. Finally, anaerobic decomposition, characteristic of the sediments of stratified lakes, can reduce nitrates to nitrites. If these anaerobic conditions persist, the nitrites can be broken down to elemental nitrogen ( $\text{N}_2$ ). 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).

The underlying pattern evident from this cycle is that all forms of nitrogen added to the lake will eventually become available for plant use. The various forms of nitrogen, as well as the oxygen concentrations (aerobic and anaerobic conditions) in the water, must be considered to understand the availability of this nutrient for plant growth. Several in-lake mitigation techniques exist to deal with the problem of excessive nutrients (Henderson-Sellers and Markland 1987). None of these techniques are without disadvantages, but for lakes with serious algal growth problems they may become necessary (Henderson-Sellers and Markland 1987).

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





**Figure 3. 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.**

## Watershed Land Use

### Land-Use Types

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

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



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

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

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

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

The use of chemicals in and around the home is potentially harmful to water quality. Products associated with cleared and residential land include fertilizers, pesticides, herbicides, and detergents that often contain nitrogen, phosphorus, other plant nutrients, and miscellaneous chemicals. These products can enter a lake by leaching directly into ground water or traveling with eroded sediments. Heavy precipitation aids the transport of these high nutrient products due

to increased surface runoff near residences (Dennis 1986). Upon entering a lake, these wastes have adverse effects on water quality. It should be noted that more environmentally friendly soaps and detergents containing low phosphorus levels are now available and recommended (Figure 4; MDEP 1992a). Septic systems associated with residential and commercial land are significant sources of nutrients when improperly designed, maintained, or used (EPA 1980). Proper treatment and disposal of nutrient-rich human waste is essential in maintaining high lake water quality.

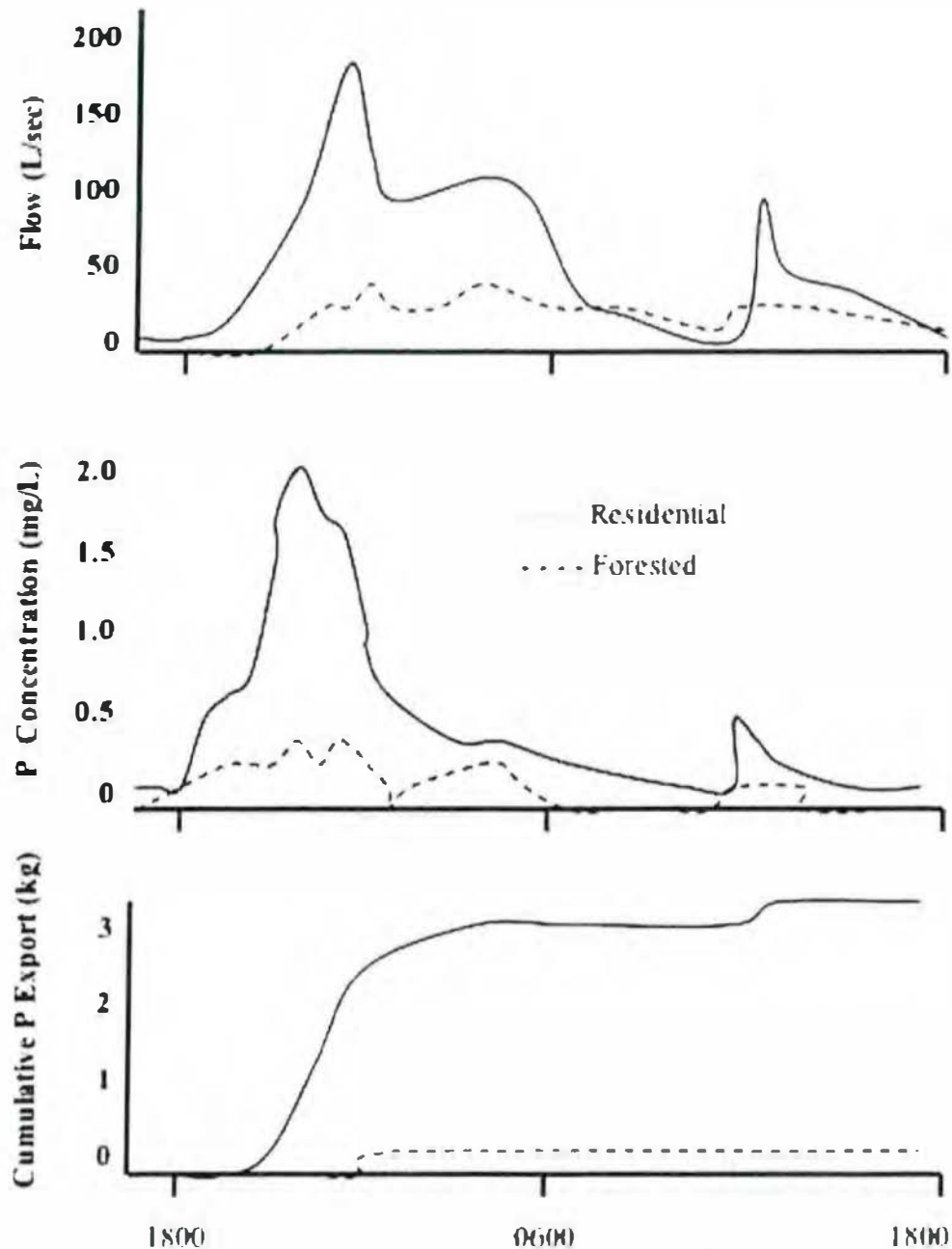
Commercial uses of forested land can have detrimental effects on lake water quality. Activities that remove the cover of the canopy and expose the soil to direct rainfall increase erosion. Two studies by the Land Use Regulation Commission on tree harvesting sites noted that erosion and sedimentation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

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

### **Buffer Strips**

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

A good buffer should have several vegetation layers and a variety of plants and trees to maximize the benefit of each layer (MDEP 1990). Native vegetation forms the most effective buffer. Trees and their canopy layer provide the first defense against erosion by reducing the

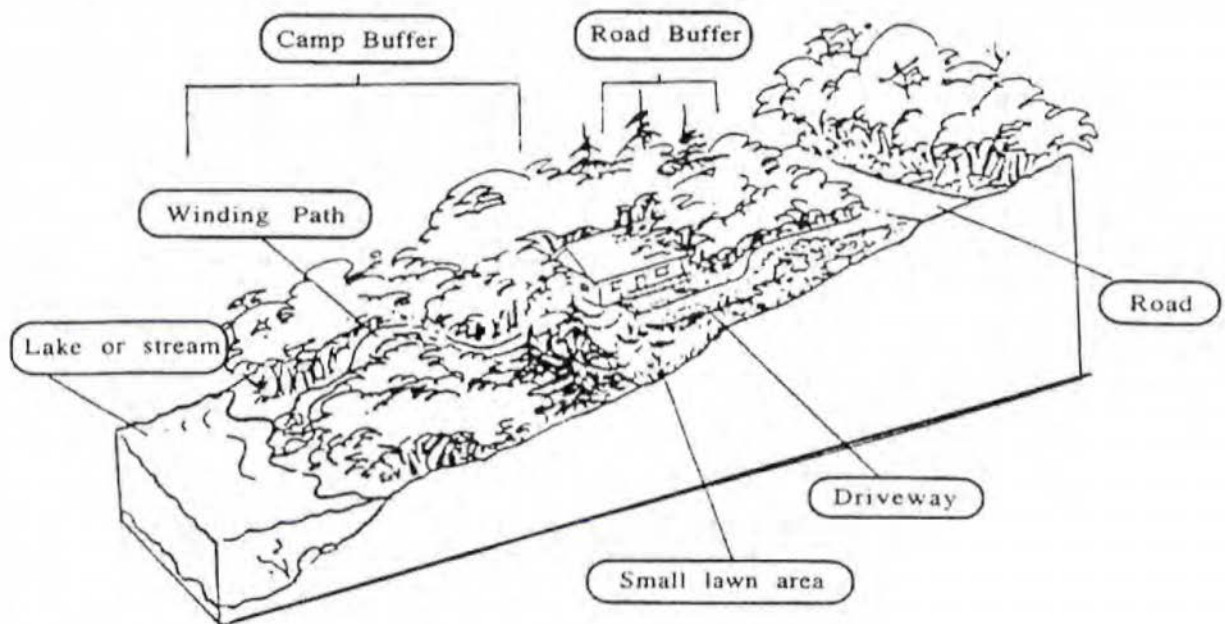


**Figure 4. Comparisons of runoff after an April rainstorm in two neighboring watersheds near Augusta, ME. Top: volume of immediate runoff over a 12 hour period; Middle: phosphorus concentration in the runoff; Bottom: total amount of phosphorus exported into local streams and lakes from the storm (Dennis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

impact of rain and wind on the soil; their deep root systems absorb water and nutrients while maintaining the topographical structure of the land. The shallow root systems of the shrub layer also aid in absorbing water and nutrients and help to hold the soil in place. The groundcover layer, including vines, ornamental grasses, and flowers slows surface water flow and traps sediment and organic debris. The duff layer, consisting of accumulated leaves, needles, and other plant matter on the forest floor, acts like a sponge to absorb water and trap sediment. Duff also provides a habitat for many microorganisms that break down plant material and recycle nutrients (Figure 5; MDEP 1990).

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

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



**Figure 5. Diagram of an ideally buffered home.**



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

### **Nutrient Loading**

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

### **Soil Types**

Nutrient loading in a lake ecosystem is partially a function of the soil types and their respective characteristics. The physical characteristics of soil (permeability, depth, particle size, organic content, and the presence of an impermeable layer or "fragipan"), as well as the

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

### **Zoning and Development**

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

### **Shoreline Residential Areas**

Shoreline residential areas are of critical importance to water quality because of their proximity to the lake. This study considered houses less than 250 ft from the shoreline to be shoreline residences. Any nutrient additives from residences (such as fertilizers) have only a short distance to travel to reach the lake. Buffer strips along the shore are essential in acting as sponges for the nutrients flowing from residential areas to the lake (Woodard 1989). Residences that have lawns leading directly down to the shore have no barriers to slow runoff, allowing phosphorus to pass easily into the lake. Buffer strips, when used in conjunction with appropriate setback laws for house construction, can dramatically reduce the proximity effects of shoreline residences (MDEP 1992b).

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

### **Non-shoreline Residential Areas**

Non-shoreline residential areas (greater than 250 ft from the shoreline) can also have an impact on nutrient loading, but generally less than that of shoreline residential areas. Runoff, carrying fertilizers and possibly phosphorus-containing soaps and detergents, usually filters through buffer strips consisting of forested areas several acres wide, rather than a few feet wide. In these cases, phosphorus has the opportunity to be absorbed into the soils and vegetation; the majority will not reach the lake, but will enter the forest nutrient cycle.

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

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

### **Subsurface Wastewater Disposal Systems**

Subsurface wastewater disposal systems are defined in the State of Maine Subsurface Wastewater Disposal Rules as devices and associated piping including treatment tanks, disposal

areas, holding tanks, and alternative toilets which function as a unit to dispose of wastewater in the soil (MDHS 2002). These systems are generally found in areas with no municipal disposal systems, such as sewers. Examples of these subsurface disposal systems include pit privies, holding tanks and septic systems.

### Pit Privy

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

### Holding Tank

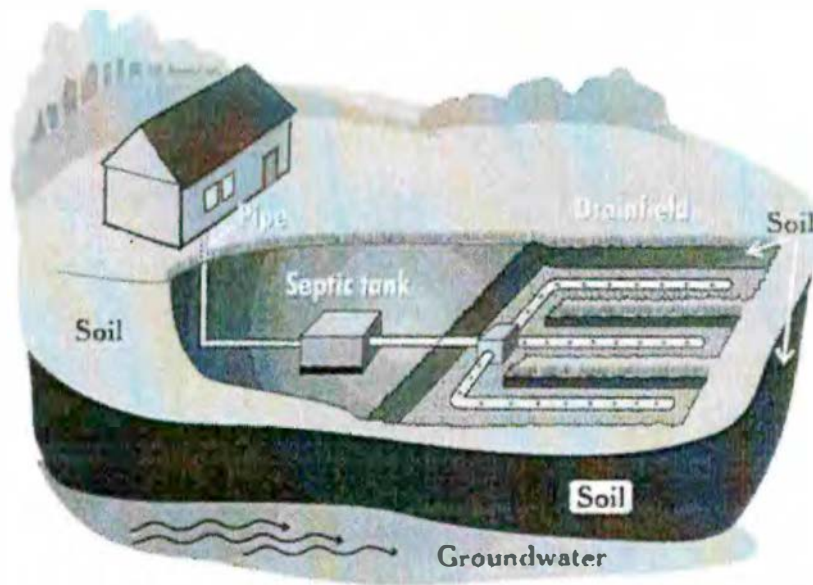
Holding tanks are watertight, airtight chambers, usually with an alarm, which hold waste for periods of time. The tanks are durable and made of either concrete or fiberglass (MDHS 2002). The minimum capacity for a holding tank is 1,500 gallons. These must be pumped or they could back up into the structure or leak into the ground, causing contamination. Although purchasing a holding tank is less expensive than installing a septic system, the owner is then required to pay to have the holding tank pumped on a regular basis.

### Septic System

Septic systems are the most widely used subsurface disposal system. The system includes a building sewer, treatment tank, effluent line, disposal area, distribution box, and often is connected to a pump (Figure 6). The pump enables effluent to be moved uphill from the shoreline to a more suitable leach field location (MDHS 1983). Septic systems are an efficient and economical alternative to a sewer system, provided they are properly installed, located, and



maintained. Septic systems that are not installed or located properly lead to nutrient loading and groundwater contamination. The location of the systems and the soil characteristics determine the effectiveness of the system.



**Figure 6. Cross-section of a typical septic system showing a septic tank and drainfield (EPA 2005).**

The distance between a septic system and a body of water should be sufficient to prevent contamination of the water by untreated septic waste. However, many parcels of land are grandfathered, which means their septic systems were installed before the passage of current regulations.

Those systems may be closer to the shore than is currently permitted; any replacement systems in these grandfathered areas must follow the new regulations. Replacement systems can either be completely relocated, or an effluent pump installed on the outside of the existing treatment tank can be used to move the sewage uphill to an alternative disposal area further from the water body (MDHS 1983).

Human waste and gray water are transferred from a residence through the building sewer to the treatment tank. There are two kinds of treatment tanks, aerobic and septic, both of which are tight, durable, and usually made of concrete or fiberglass (MDHS 1983). The aerobic tanks rely on aerobic bacteria, which have a greater rate of respiration than anaerobic bacteria. Unfortunately, aerobic bacteria are also more susceptible to condition changes. Tanks containing aerobic bacteria also require more maintenance, more energy to pump in fresh air, and are more expensive. Septic tanks rely on anaerobic bacteria. Solids are held until they are sufficiently decomposed and suitable for discharge (MDHS 1983). As the physical, chemical, and biological breakdowns occur, scum and sludge are separated from the effluent (Figure 6). Scum is the layer

of grease, fats, and other particles that are lighter than water and move to the top of the treatment tank. Baffles trap scum so that it cannot escape into the disposal area. Sludge is composed of the solids that sink to the bottom of the tank. Over time, much of the scum and sludge is broken down by anaerobic digestion. The effluent then travels through the effluent line to the disposal area.

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

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

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

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

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

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

Federal, state, and local laws are in place to protect land and water quality. The federal government sets minimum standards for subsurface waste disposal systems. States can then choose to make their rules stricter, but not more lenient, than federal guidelines. The Maine Comprehensive Land Use Plan sets standard regulations that each city and town must follow

(MLURC 1976). Individual municipalities have the ability to establish their own comprehensive land-use plan in accordance with the state regulations. However, many towns develop local ordinances that consider specific issues, such as shoreline zoning. The Maine Department of Environmental Protection (MDEP), Maine Department of Conservation (MDC), and local Code Enforcement Officers are responsible for overseeing the enforcement of these laws.

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

## **Roads**

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

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

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



road location, road area, road surface material, road cross-section, road drainage (ditches, diversions, and culverts), and road maintenance (MDEP 1992a).

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

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

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

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

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

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

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

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

removed. These practices will help to preserve the water quality of a lake and improve its aesthetic value.

### **Agriculture and Livestock**

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

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

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

## **Forestry**

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

## **Successional 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 2009). An open field ecosystem moves through various transitional stages before it develops into a mature forest. The earliest stages of open field succession involve the establishment of smaller trees and shrubs throughout a field. Intermediate and later successional stages involve the growth of larger, more mature tree species. The canopy becomes more developed, allowing less light to reach the forest floor. A developed canopy also slows rainfall, reducing its erosion potential. This land type, in which a forest is nearing maturity and contains over 50% tree cover, is referred to as transitional forest. Mature forest is defined as areas of closed canopy that predominantly contain climax species.

## **Wetlands**

There are different types of wetlands that may be found in a watershed. A bog is dominated by shrubby vegetation, large quantities of sphagnum moss, and typically has a low



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

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

Wetlands are important transitional areas between lake and terrestrial ecosystems. Wetland soil is periodically or perpetually saturated, because wetlands usually have a water table at or above the level of the land and contain non-mineral substrates such as peat. Growing in this partially submerged habitat is hydrophytic vegetation, meaning it is adapted for life in saturated and anacrobic soils (Chiras 2001). Wetlands support a wide range of biotic species (Table 2; MLURC 1976). Wetlands also help to maintain lower nutrient levels in an aquatic ecosystem because of the efficiency in nutrient uptake by their vegetation (Niering 1985, Smith and Smith 2009). Finally, wetlands have the potential to absorb heavy metals and nutrients from various sources including mine drainage, sewage, and industrial wastes (Chiras 2001).

Although there are regulations controlling wetland use, a lack of enforcement leads to development and destruction of wetlands. Wetland areas should be protected by the Resource Protection Districts and other means, which prevent development within 250 ft of the wetland.

Due to their location, wetlands along the shoreline may be prone to illegal development (Chiras 2001). A decrease in wetlands will have negative effects on the water quality of a lake due to increased runoff, erosion, and decreased natural buffering (Table 2).

**Table 2.** Descriptions of site characteristics and plant populations of different types of freshwater inland wetlands (Smith and Smith 2009).

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

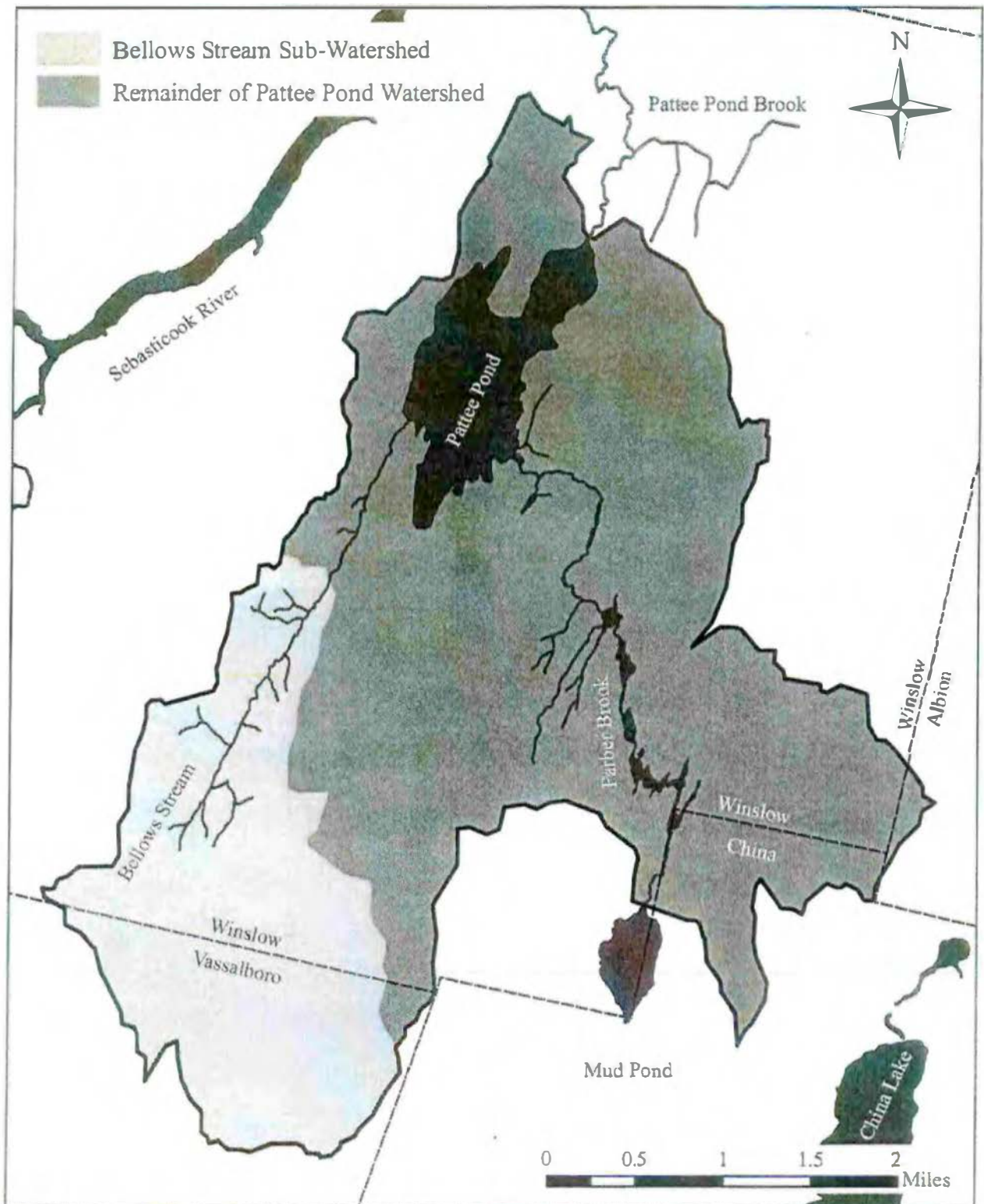
## **Description of Pattee Pond and its Watershed**

### **Physical Characteristics**

Pattee Pond is located in the Town of Winslow in the northeastern section of Kennebec County, Maine (Figure 7). It is part of the Kennebec River watershed and the smaller Sebasticook River watershed. Pattee Pond drains into Pattee Pond Brook, which flows into the Sebasticook River then into the Kennebec River. The lake has two major inlets: Bellows Stream and Farber Brook. Bellows Stream flows into the southern portion of the lake and drains the southwest part of the Pattee Pond watershed. Farber Brook flows into the eastern shore and drains the southeastern portion of the watershed. Mud Pond, located to the south of the watershed on the Winslow-China town border, drains into Pattee Pond through Farber Brook. There are also two minor inlets, one located on the northeast shore and the other on the western shore.

Pattee Pond has an area of 215 ha (523 acres) (Vaux 2005). This puts it in the top 20 percent of lakes in the Kennebec River watershed and Kennebec County by size (Vaux 2005). Larger lakes have lower flushing rates, meaning nutrients entering the lake will remain there for extended periods of time. Lower flushing rates would indicate longer response time for remediation techniques (Michaud 1991). Larger lakes tend to be deeper (Michaud 1991). Pattee Pond has an average depth of 4.6 m (15 ft) with a maximum depth of 8.8 m (29 ft). Lakes of this size will stratify and can become anoxic at deeper depths, but this stratification can be weakened by wind events (Lövstedt and Bengtsson 2008). Prevailing winds on Pattee Pond are generally from the east-southeast during the summer. Because the lake is oriented along this axis, wind speeds can accumulate and promote this mixing (Snow, pers. comm.). Prevailing winds in this direction can also promote wave erosion along the west-northwest shore of the lake.

Pattee Pond has three major coves as well as a number of smaller ones. Coves are more productive biologically because they tend to be shallower and have more light penetration to the substrate. Wind can mix nutrients released from the sediments into the water column. Consequently, they are less likely to become anoxic. Coves also make the shoreline irregular and longer, allowing more shoreline houses to be built. This in turn can exacerbate the impacts of development on water quality.



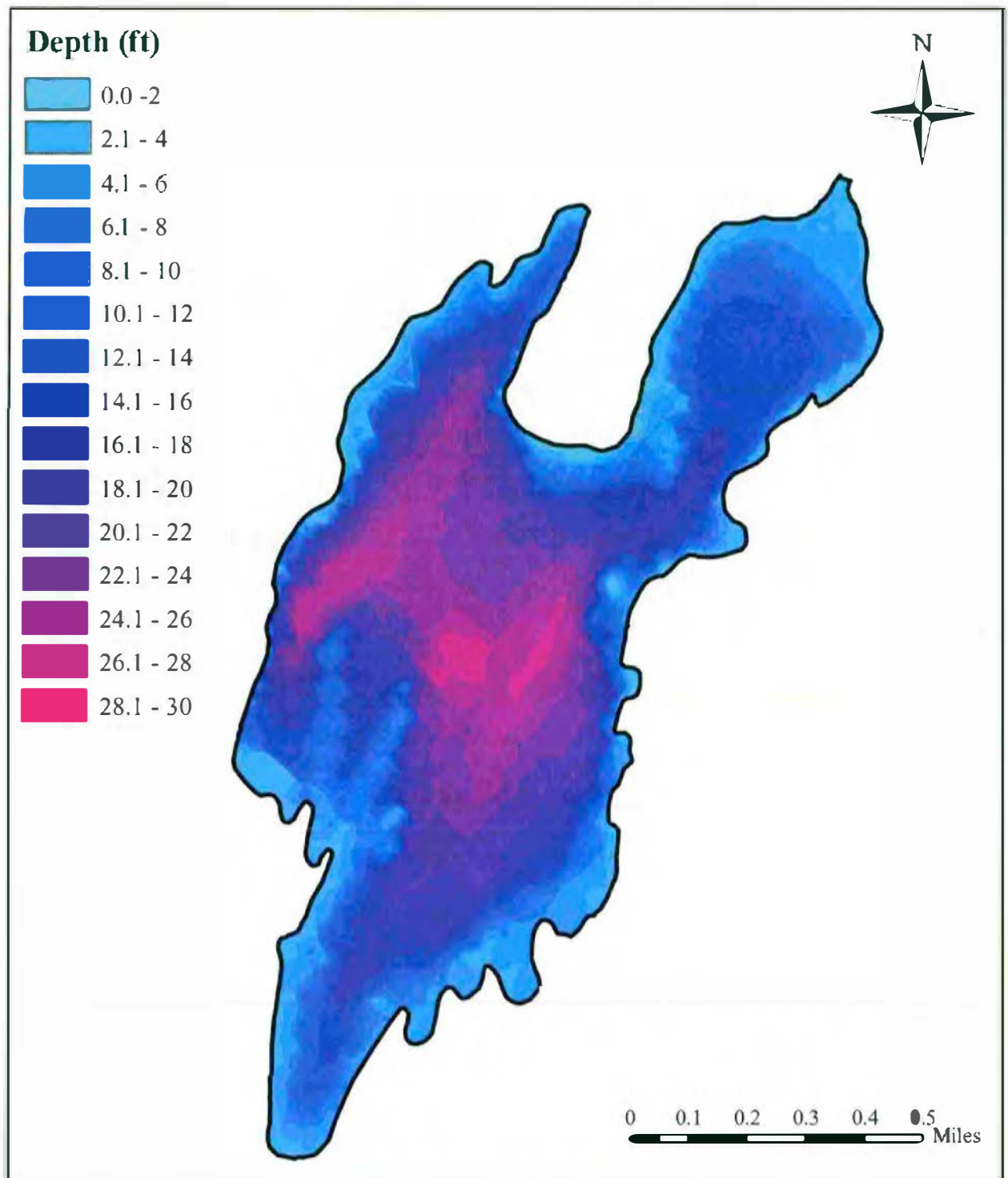
**Figure 7.** Overview map of Pattee Pond showing town boundaries, nearby waterbodies, major inlets and outlets. The Pattee Pond watershed is shaded; because certain areas of the watershed may have more impact on water quality than others, the Bellows Stream sub-watershed is also indicated.



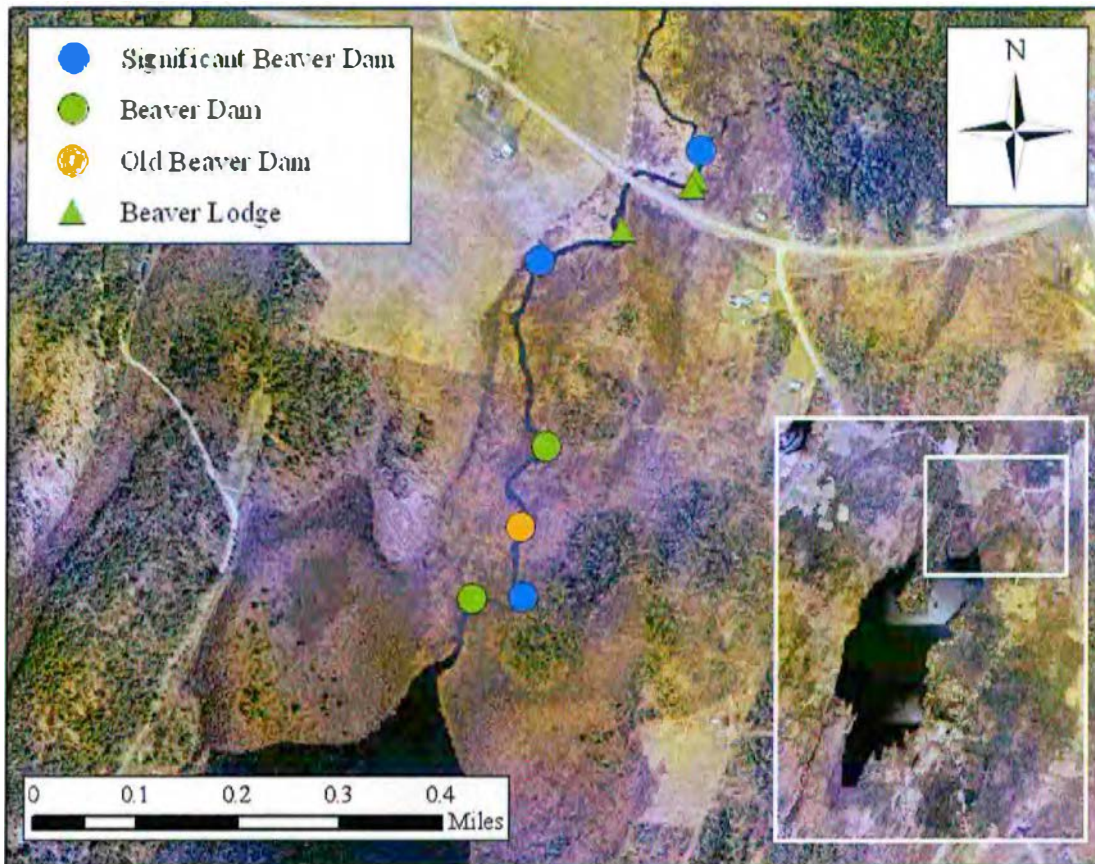
To provide a better understanding of the basin shape of Pattee Pond, this report includes a bathymetry map (Figure 8). Data on depth were obtained in two different ways. A boat equipped with a Lowrance, a combined Geographic Positioning System (GPS) and Sonar device, made transects roughly 10 meters apart over the surface of the entire lake. The Lowrance continuously collected data on the boat's position and the depth at that point. Nearly 25,000 data points were collected in this manner. In shallower areas that the boat could not access, CEAT members in canoes used handheld sounding devices to record depth and GPS units to record location at about 50 points. Using ArcGIS 9.2, the data points were converted to raster format using a Kriging method of interpolation. The end result of this procedure was a map estimating the depth at any point in the lake. The map shows extensive shallow areas along the southern shores and the northeast cove as well as deep areas in the center and along the western shore. An average depth of 4.6 m (15 ft) and a maximum depth of 8.8 m (29 ft) was found. This is slightly deeper than the DEP reported value of 8.5 m (27 ft) (Vaux 2005).

Another unique characteristic of Pattee Pond is the regulation of its water level. Although human-established dams regulate the water level of most lakes in Kennebec County, beaver dams regulate the water level of Pattee Pond. At least five active dams were identified by CEAT along Pattee Pond Brook, the outlet to Pattee Pond (Figure 9) in September, 2008. This has led to periodic changes in water level. Such changes can modify macrophyte communities along the shoreline (Hudson et al. 2005). Lower water levels can also promote shoreline erosion (Håkanson 1977).

The watershed surrounding Pattee Pond is 3,339 ha (8,251 acres). This area was calculated using ArcGIS 9.2. This area is higher than the Maine DEP reported value of 3,256 ha (8,045 acres), the result of a slightly different watershed boundary used in this study. The topography is moderately hilly. Slope is generally less than 10 percent though higher slopes (up to 50 percent) are seen in the western part of the watershed. This is especially critical along the western shore where slope is between 15 and 35 percent. In these steeper areas, erosion is more likely to occur bringing sediments and phosphorus into the lake (Figure 10). It is not uncommon to see sediment in the water along the western shore after rain events (Snow, pers. comm. and Whitaker, pers. comm.).



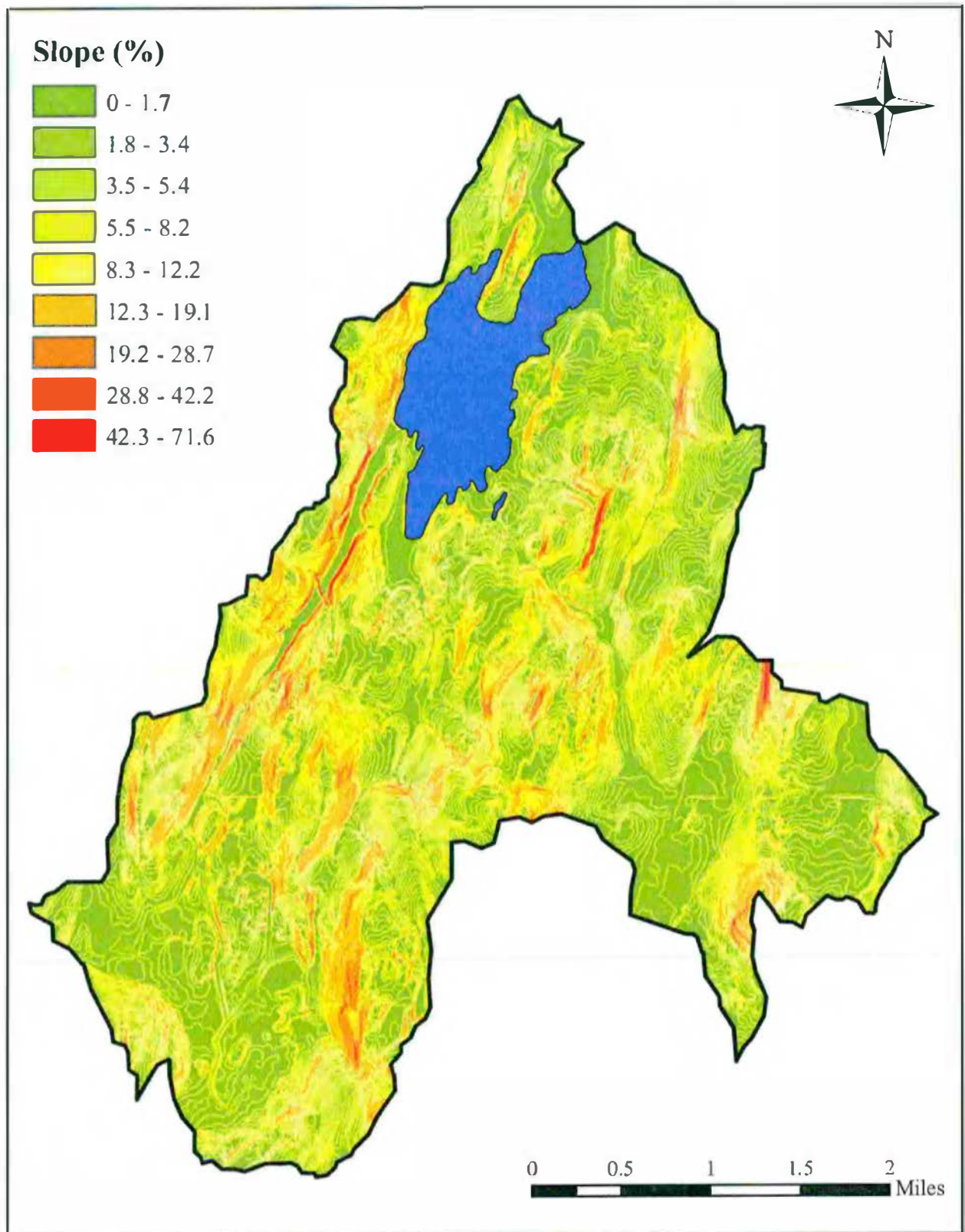
**Figure 8.** Bathymetry map of Pattee Pond showing the water depth in feet throughout the lake. Map is based on over 25,000 data points collected using a Lowrance and hand-held sounding devices, and analyzed using ArcMap 9.2. Maximum depth is 29 ft; mean depth is 15 ft.



**Figure 9. Locations of beaver-related activity on Pattee Pond Brook, the outlet to Pattee Pond. "Significant Beaver Dams" are those regulating the water level. "Beaver Dams" are dams that do not have a major impact on water level. "Old Beaver Dams" are those not regulating water level. "Beaver Lodge" indicated the presence of a lodge.**

Several nearby lakes have characteristics similar to Pattee Pond (Table 3). All are shallow lakes that do not have high maximum depths. East Pond, on the Oakland-Smithfield town border, is most similar in comparison to basin shape and depth. Lovejoy Pond, located in Albion, has a similar watershed. Like Pattee Pond, Lovejoy Pond is small compared to the size of its watershed. Both East Pond and Lovejoy Ponds have historically had very poor water quality. By studying the origins of their poor water quality and what remediation techniques have been most effective for these two lakes, a lot could be learned about the best ways to prevent or remediate potential problems in Pattee Pond. Other nearby lakes with similar basins and watersheds include North Pond in Smithfield, Webber Pond in Vassalboro and Threemile Pond in China.





**Figure 10.** Map showing the percent slope in the Pattee Pond watershed based on Digital Elevation Models (DEM) provided by the Maine Office of GIS and analyzed with ArcMap



**Table 3. A comparison of Pattee Pond with six other nearby lakes. Results are from Vaux (2005) unless indicated. CEAT results for the Pattee Pond Flushing rate may differ from Vaux (2005) due to the inclusion of Mud Pond in the Water Budget.**

Waterbody Name	Town	Area (acres)	Mean Depth (ft)	Max. Depth (ft)	Drainage Area (mi <sup>2</sup> )	Flushing Rate
Pattee Pond						
PEARL (2008)	Winslow	523	15	27	12.57	2.13
CEAT		522	15	29	12.89	2.72
East Pond	Smithfield	1,717	18	27	4.33	0.25
Lovejoy Pond	Albion	379	15	32	8.21	2.63
North Pond	Rome	2,531	13	20	3.31	1.00
Threemile Pond	China	1,174	17	37	9.32	1.00
Togus Pond	Augusta	674	20	49	3.41	0.81
Webber Pond	Vassalboro	1,233	18	41	8.07	1.52

## Biology

### Native Aquatic Flora/Fauna

Two depth zones are recognized in lakes: littoral and limnetic. The littoral zone is closest to the shoreline and subject to high levels of sunlight, which penetrate to the bottom sediments, and is where most rooted aquatic plants are found (Molles 2005). This zone typically consists of waters 15 ft deep and shallower. (see Figure 8). The limnetic zone is the water offshore beyond the limit of rooted plants and is not subject to influences from the shoreline (i.e., human activity or eroding shorelines) and the bottom of this zone is not penetrated by sunlight. Both these zones are subject to change daily and seasonally and rarely remain stagnant (Molles 2005).

Photosynthesis is one of the processes that help sustain all life within a lake. Photosynthesis by algae and aquatic plants releases organic material and oxygen into the water that can be taken up by other organisms (Freeman 2008). Algae and aquatic plants are determinants of the fauna composition of the entire water body via their influence oxygen and nutrient availability as well as habitat structure (Freeman 2008).

Macrophytes are defined as rooted and floating aquatic plants and are extremely important to lake ecology (Axler and Hagley 2004). Macrophytes provide structural habitat and food for a variety of fauna, stabilize shoreline soils and bottom sediments, and can prevent algal growth by absorbing phosphorus, nitrogen, and other nutrients (Borman et al. 2001). Because

native macrophytes stabilize lake ecology in these ways and because macrophyte roots take up space along the lake bed, native macrophytes help prevent the spread of invasive aquatic plants. Invasive aquatic plants require a perturbed ecosystem with available sediment to colonize and become established in a water body (Axler and Hagley 2004).

The emergent plant community of a lake is typically contained in the area between the shoreline and waters that are knee-deep (Borman et al. 2001). Emergent plants have flowers and leaves that are found above water level. With strong lateral root systems and durable leaves, these plants are well-adapted for life along the shore, which is exposed to wave action and human impact. Some native emergent plants include cattail, pickerelweed, arrowhead, great bulrush, and eel-grass (Axler and Hagley 2004).

The floating plant community can also be found along the shoreline and out to chest-deep water (Borman et al. 2001). Floating plants have leaves and/or flowers that rest on top of the water. Most floating plant species have durable, waxy leaves, with slack and elastic leaf stalks, which provide flexibility to survive wave action. Some examples include yellow pond lily, white water lily, floating brown leaf, and watershield (Axler and Hagley 2004).

The submerged plant community can grow in shallow areas or in waters up to fifteen feet deep; the depth at which sunlight penetration is greatly decreased (Borman et al. 2001). Almost all portions of a submerged plant are located underwater, but some species also have floating leaves or emergent flower stalks. There are many species of submerged plants, including common waterweed, bladderwort, water marigold, coontail, and slender naiad (Axler and Hagley 2004).

Several large bird species can also be found near Maine lakes and ponds. These species include great blue heron, loon, bald eagle, osprey, and belted kingfisher (Axler and Hagley 2004). In particular, the loon is a species, which can indicate water and habitat quality (PEARL 2004). Loons prefer extremely clean lakes, ones with very few, if any, algal blooms, and also require sheltered shorelines and a large amount of plant material to build their nests. The fact that loons are found on Pattee Pond indicates, at the very least, that the macrophyte community is suitable for loon nest building (PEARL 2004).

Aquatic insects provide an important food resource for many fish and birds (Axler and Hagley 2004). Seven native and five non-native fish species are present in Pattee Pond (see Fish

Stocking). Fish species rely on macrophytes for habitat and spawning areas (Borman et al. 2001). Fish feed upon algae, macrophytes, insects, or other fish (Axler and Hagley 2004).

### Trophic Status

The trophic status of a lake is a measurement of the total biomass of primary production (Chapman 1996). Primary production is the creation of organic compounds from carbon dioxide and occurs in lakes through the process of photosynthesis. Primary producers called autotrophs are the basis of the aquatic food chain. Zooplankton and fish (heterotrophic species) control the relative abundance of autotrophs in a lake through consumption. A buildup of biomass, such as dead algae, can occur on the lake substrate if primary production exceeds the feeding capacities of consumer species. The decomposition of excess biomass can deplete dissolved oxygen levels in the hypolimnion, which create anoxic conditions in deeper sections of the lake during the summer months when the lake is stratified (Chapman 1996). When dissolved oxygen levels fall below one part per million (ppm), phosphorus trapped in bottom sediments can be released into the water column, a process known as internal loading or recycling (see Background: Trophic Status of Lakes).

Trophic status can also have a large impact on the fish species found in a lake (Chapman 1996). As a lake becomes more eutrophic and the number of autotrophs increases, planktivorous fish species such as minnows become more abundant; whereas piscivore species are more common in oligotrophic lakes (Jeppesen et al. 2000). Anoxic conditions in lakes with excess nutrient loading may create conditions unable to support coldwater fish species.

To measure the primary productivity of a lake and determine its trophic status transparency readings, phosphorus concentration levels, and chlorophyll *a* concentrations were taken. Maine lakes may be oligotrophic, mesotrophic, eutrophic, or dystrophic (see Background: Lake Characteristics: Trophic Status of Lakes). ●ligotrophic lakes are relatively unproductive and are characterized by high transparency (above 8 m), low phosphorus concentrations (less than 6 ppb), and low chlorophyll *a* concentrations (less than 1 ppb) (Chapman 1996). Mesotrophic lakes are moderately productive with transparency readings between 2 and 4 m, moderate chlorophyll *a* concentrations (2.6 to 7.3 ppb), and intermediate phosphorus levels (12 to 24 ppb) (Carlson and Simpson 1996). Eutrophic lakes are highly productive with poor

transparency readings (less than 2 m), high chlorophyll *a* concentrations (greater than 7.3 ppb), and high phosphorus levels (greater than 24 ppb) (Chapman 1996). Dystrophic lakes have large quantities of organic matter and experience anoxia in the hypolimnion during the summer, limiting their potential for recreational use (Chapman 1996).

Data collected by CEAT at Pattee Pond Site 1 from 31-May-08 to 23-Sep-08 showed a mean transparency of 4.0 m, a mean surface phosphorus concentration of 12.5 ppb, and a mean chlorophyll *a* concentration of 4.0 ppb. These data were used to calculate the trophic status index (TSI) for Pattee Pond in three ways (Bouchard, pers. comm.). The TSI values determined were 47.0 (chlorophyll *a* concentration), 53.3 (phosphorus concentration), and 60.3 (transparency). Under the Carlson Trophic State Index, mesotrophic lakes have TSI values of 30 to 50 and eutrophic lakes have TSI values ranging from 50 to 70 (Carlson 1977). Pattee Pond is eutrophic but near the boundary of being a mesotrophic lake, which is an important consideration when deciding upon remediation techniques.

### Fish Stocking

The Maine Department of Inland Fisheries and Wildlife (MDIFW) classifies Pattee Pond as a warm water fishery, but has historically managed it as a mixed cold/warm water fishery to encourage sport fishing (Halliwell, pers. comm.). Pattee Pond has a total of twelve identified fish species, consisting of seven native fish species and five introduced species (Table 4; MDIFW 2000). Historically, the MDIF&W has stocked two cold-water salmonid species (brook trout and brown trout) infrequently when unscheduled hatchery fish became available (MDIFW 2000; Halliwell, pers. comm.).

Presently the MDIF&W stocks an estimated one and one quarter million fish annually in over 600 lakes and streams throughout the state of Maine (MDIFW 2007a). Brown trout is the most common salmonid species stocked in Region B, the Central Maine region that encompasses Pattee Pond (MDIFW 2007b). Almost all of the brown trout fisheries in Region B are annually stocked, although Pattee Pond is stocked less frequently.

Given the infrequency of stocking, Pattee Pond has a very limited coldwater sport fishery, consisting of a small number of brook and brown trout (Halliwell, pers. comm.). Similar



to other Region B lakes, anglers at Pattee Pond fish primarily for warm water species. Most of the warm water game fisheries in Maine are in Region B, where anglers prefer to fish for white and yellow perch (MDIFW 2007b). Of the two, white perch is more popular with anglers because of its year-round abundance and pleasing taste (MDIFW 2007b). White and yellow perch are two “fast action” species (meaning they are quick to bite), which makes them good species for introducing children to angling (Halliwell, pers. comm.). In Pattee Pond, smallmouth and largemouth bass are the most sought-after species for anglers, followed by white perch and chain pickerel (MDIFW 2000; Whitaker, pers. comm.).

**Table 4. Fish species present in Pattee Pond with origin, general habitat depth, and common spawning habitat. Fish more common to waters greater than seven meters were designated as deep-water fish (Higginbotham 1988, Steiner 2000, MDIFW 2000, PEARL 2008).**

Common Name	Scientific Name	Native	Habitat	Spawning Habitat
American eel	<i>A. rostrata</i>	Yes	Shallow	Ocean Waters
Brown bullhead	<i>A. nebulosus</i>	Yes	Bottom	Shallows
Chain pickerel	<i>E. niger</i>	Yes	Shallow	Shallows/Weedy
Pumpkinseed sunfish	<i>L. gibbosus</i>	Yes	Shallow	Shallows
Redbreast sunfish	<i>L. auritus</i>	Yes	Shallow	Shallows
White sucker	<i>C. commersoni</i>	Yes	Bottom	Shallows/Streams
Yellow perch	<i>P. flavescens</i>	Yes	Shallow	Shallows
Brook trout	<i>S. fontinalis</i>	No	Shallow	Streams/Gravel
Brown trout	<i>S. trutta</i>	No	Shallow	Streams/Gravel
Smallmouth bass	<i>M. dolomieu</i>	No	Deep	Streams
Largemouth bass	<i>M. salmoides</i>	No	Shallow	Shallows/Weedy
White perch	<i>M. americana</i>	No	Shallow	Cold Waters

The MDIF&W does not have data on the actual number of individuals per species in Pattee Pond, but anecdotal evidence suggests that there are significant bass and pickerel populations (Whitaker, pers. comm.). This anecdotal evidence must be used cautiously, however, as anglers are likely to under report species that are not of interest to sport fishermen (Whitaker, pers. comm.).

## Invasive Plants

Not all non-native plants are considered invasive. Invasive species have the ability to disperse and colonize a new environment. An invasive species is one that originates from elsewhere and can take better advantage of its new environment than natives can because that invasive species lack natural checks and balances (i.e., other competitors or natural predators; MVLMP 2008a). An invasive plant has also been defined as a species which is likely to cause economic or environmental harm, or harm to human health (MVLMP 2008a). Invasive aquatic plants in particular have the ability to easily propagate via small stem or leaf fragments from a mother plant (MVLMP 2008a). Because native plants cannot compete, and the ecosystem itself changes with the introduction of an invasive plant, the native plant community is impacted alongside the fish populations (LEA et al. 2008). Fish populations are impacted since fish rely on specific native macrophytes for habitat, spawning areas, and food (see Native Aquatic Flora/Fauna). Areas most susceptible to invasive aquatic plant infestations are ones that have sparse native vegetation, and waters 15 ft or shallower.

Once an invasive plant species has colonized and become established in a water body, recreational use of that lake may decline dramatically (LEA et al. 2008). Boating may become difficult if boat launches are overrun with an invasive plant; sport fishing will decrease as fish populations decline; and people are less likely to swim in a weed-infested area (LEA et al. 2008).

In 2000, the first bill concerning invasive aquatic plants was introduced in Maine. In this bill, the State of Maine considered the struggles of neighboring states with invasive aquatic plants and developed the “Eleven Most Unwanted” aquatic plant list (see Appendix A). Several bills have passed since then to help prevent the spread of invasive species and encourage awareness (LEA et al. 2008). Many bills are specifically concerned with boating, since the primary way to spread an invasive aquatic plant is via hitch-hiking plant fragments on boat motors and props, or in purge valves. Currently, boaters must purchase a Lake and River Protection sticker along with their boating registration sticker each year. A game warden will fine boaters up to \$250 if both of these stickers are not clearly displayed on the boat. The money raised from selling stickers goes towards education, eradication, and enforcement of rules concerning invasive plants. Boaters can also be fined up to \$500 by a game warden if plant fragments are found on their boat (LEA et al. 2008).

As of March 2008, twenty-eight lakes, ponds, and streams in Maine were infested with an invasive aquatic plant (Fredenburg 2008). The following species have been found in these infested lakes: variable water-milfoil, eurasian water-milfoil, hydrilla, and curly-leaf pondweed. Another documented infestation of eurasian water-milfoil was discovered in Salmon Pond of the Belgrade Lakes region in August 2008 (Calder 2008). Messalonskee Stream, Messalonskee Lake, and Belgrade Stream, water bodies geographically near Pattee Pond, have documented infestations of variable water-milfoil (Fredenburg 2008). These data are important when assessing the risk of invasive aquatic plant infestation and methods of prevention in Pattee Pond (see Recommendations: Invasive Species Monitoring and Prevention).

## ***STUDY OBJECTIVES***

### **Introduction**

This study examines Pattee Pond and its associated watershed comprehensively. The field research done by the Colby Environmental Assessment Team (CEAT) includes a land use assessment of the watershed, water quality sampling, a review of the watershed zoning laws, and surveys of roads, shoreline buffers, subsurface wastewater disposal systems, macrophyte distribution and abundance, and the number of houses in the watershed. These studies were used to estimate nonpoint source phosphorus loading into the lake and to assess its impact on the water quality of Pattee Pond. By investigating land use patterns, water quality, and development patterns in the Pattee Pond watershed, CEAT was able to make predictions and recommendations for the maintenance and improvement of the water quality of Pattee Pond.

### **Land Use Assessment**

Land use patterns in a watershed significantly affect the health of the associated water body. Different land uses produce different types and amounts of nutrient and pollutant loading, as well as different rates of runoff. For example, sufficient buffers (such as trees, bushes, and shrubs) along the shore of a water body are beneficial to water quality. Plants slow down surface flow so nutrients and sediments from runoff can be absorbed before entering the water. It is



important to understand how land use types interact because eutrophication can be accelerated when runoff carrying nutrients, pollutants, and sediments enters a water body.

The goal of the land use assessment was to identify and quantify the current patterns of land use in the Pattee Pond watershed. Historical land uses were also compared to current uses because historical trends can help explain the current status of the lake. These data were used to create a phosphorus model to identify and evaluate the significance of different phosphorus sources contributing to nutrient loading into Pattee Pond.

## **Water Quality Assessment**

The main goal of measuring water quality was to determine the ecological health of Pattee Pond so appropriate recommendations for water quality management could be developed. Water quality measurement provides a good indicator of the nutrient load coming from non-point pollution sources as well as the ecological status of the lake (EPA 1990). CEAT measured multiple chemical, physical, and biological parameters to assess lake water quality. Water samples were collected from 30-May-08 to 22-Sep-08 to determine the current status of the lake and seasonal changes in water quality. Findings were compared to previous water analyses conducted by the Maine Department of Environmental Protection (Maine DEP) and the 1993 CEAT study of Pattee Pond to examine the long-term effects of human activity on the trophic status of the lake.

## **Mitigation and Remediation**

After identifying important concerns for lake quality and land use, it is useful to identify appropriate remediation techniques. CEAT presents several recommendations for remediation techniques that might be utilized for improving the water quality of Pattee Pond.

## **Development and Future Trends**

One important purpose of monitoring water quality is to facilitate informed planning for future development and protection of the lake. CEAT developed a water budget and phosphorus loading model to predict the effects of land use changes on nutrient loading in Pattee Pond. Through looking at historical and current changes in development (residential and commercial)



and population demographics, future land use projections were made. CEAT also recommends measures that can be taken to prevent invasive plant species from entering the lake, improve watershed management and regulations, and promote community awareness measures to ensure a clean, healthy lake.

# ANALYTICAL PROCEDURES AND RESULTS

## *GIS*

### **Introduction**

The analysis of data collected from Pattee Pond relied heavily on the Geographic Information System (GIS) produced by the Environmental Systems Research Institute (ESRI). ArcGIS 9.2® is a computer program capable of compiling spatial data in multiple forms and combining them to display trends and patterns that may not otherwise be apparent (ESRI 2008).

ArcGIS 9.2® uses two basic types of data known as vector and raster data. Vector data can be broken down further into point, line, and polygon data (ESRI 2008). Point data are any markers representing specific locations. For example, the site map uses point data to designate the exact locations where water quality samples were collected (see Water Quality Study Sites: Sample Map). Line data illustrate linear information, such as roads, as is the case with the road quality map (see Roads: Methods). Polygon data are unique in that they share common characteristics. Polygon data are essential when trying to generalize certain areas. They are useful for displaying features such as soil types (see Soil: General Introduction, Methods, and Types) and the land use (see Land use Types of Pattee Pond Watershed: Introduction).

Another type of datum used in ArcGIS 9.2® is raster data (ESRI 2008). Raster data are similar to polygon data but on a much smaller scale. The polygons have been reduced to individual cells that each contain one characteristic. The easiest way to understand this is to consider a photograph, which is one example of raster data. Each pixel correlates to a cell and displays just one value, in this case color. The combination of many cells creates a useful image. The bathymetry map of Pattee Pond was created using raster data with each GIS cell containing one depth value (see Figure 8). These data are then combined into layers to be manipulated in ArcGIS 9.2®.

When information relating to the same subject such as the roads of Kennebec County is imported into ArcGIS 9.2®, it is added as a layer. This layer can then be overlaid with other layers to illustrate how certain features interrelate spatially. For instance, the road layer could be

laid on top of a layer containing polygons of the Pattee Pond watershed to reveal which roads fall within the boundary and may influence water quality.

Data used in ArcGIS 9.2® came from various sources. Much of the point data used were collected using handheld GPS devices. Polygon data and raster data were either downloaded from one of several online databases, or scanned in as documents or pictures and assigned spatial data through a process called georeferencing. These documents ranged from previously made maps to photographs of the watershed and were georeferenced by correlating and joining them to the image and the existing data in ArcGIS 9.2® (see Development: Future Projections for Development; see Land use Types of Pattee Pond Watershed: Introduction). Once georeferenced, the images correlate to features located on the surface of the earth. In this way, photographs can be added to better illustrate points of interest.

A deeper analysis of the data made it possible to identify specific land use types from photographs and organize that data into distinct polygons. Once polygons were created from the images, certain characteristics were assigned to them, making further analysis possible. A comparison of past and present land use types shows how the land has changed, which is essential in making informed predictions about the future of the watershed.

GIS is also capable of more complex analysis using several layers and features. This type of analysis process is often referred to as a GIS model. When factors contributing to a process of interest are known and their relative importance is calculated, the input can be weighted accordingly, creating appropriate outcomes (see Erosion Potential Model: Results and Discussion).

## ***LAND USE ANALYSIS***

### **Introduction**

Land use has been shown to be the primary predictor of phosphorus concentrations in a water basin (Robertson 1996). Because land use types can expose or protect soils from erosion, sediment loading can be projected by studying land use mosaics. High erosion rates increase the amount of nutrient-carrying sediments that enter the water basin (Drewry et al. 2008, Hejduk 2008). Increases in land use types that have high phosphorus loading potentials such as agriculture, residential, and roads are strongly correlated with nutrient loading in a watershed

(Boggess et al. 1995, Robertson 1996, Robertson et al. 2006). Land use types that prevent erosion tend to be rich in vegetation and can be used as buffer strips between the water basin and land areas with higher rates of erosion or available nutrients (see Watershed Development Patterns: Buffer Strips).

Choices involving land use in a watershed are one of the few ways in which residents can directly affect water quality. Soil type, annual precipitation, climate, and the dimensions of a water basin are all factors that influence how a lake ages, but it is how residents work in relation to these parameters that determines if the process of eutrophication progresses at a faster rate or not. Land management decisions on the state and town level lead to zoning laws that frame the overall management plan (see Watershed Development Patterns). Within that framework, individual land users decide how to use local resources and influence water quality. The purpose of this section is to provide both individuals and lawmakers with information about the impacts of different land use types for future policy decisions and individual choices, and to provide information on historical and current land use patterns in the Pattee Pond watershed.

## **Methods**

To gain a holistic understanding of the potential trends and effects of land use change in the Pattee Pond watershed, CEAT collected both historical and current aerial photography of the region. CEAT scanned aerial photographs from 1965 at the Department of Conservation Office for the Maine Geological Survey in Augusta. These photographs had a scale of 1:20,000 and were compiled using Photoshop software to create a seamless historical aerial view of the watershed. An updated National Agriculture Imagery Program (NAIP) file from the year 2007 with a scale of 1:24,000 was downloaded from the Maine Office of GIS. This file was used to determine recent land use in the watershed to compare with the historical data.

ArcGIS 9.2® software was used for the majority of data analysis and map creation. The aerial photographs were used as a background reference for polygon digitizing. CEAT members identified visual parameters for each land use/cover type and used these to determine the physical attributes of each polygon (see Appendix B). Using the computer mouse and ArcGIS® editor tools, each polygon boundary was created in relation to its location on the aerial photographs. After the

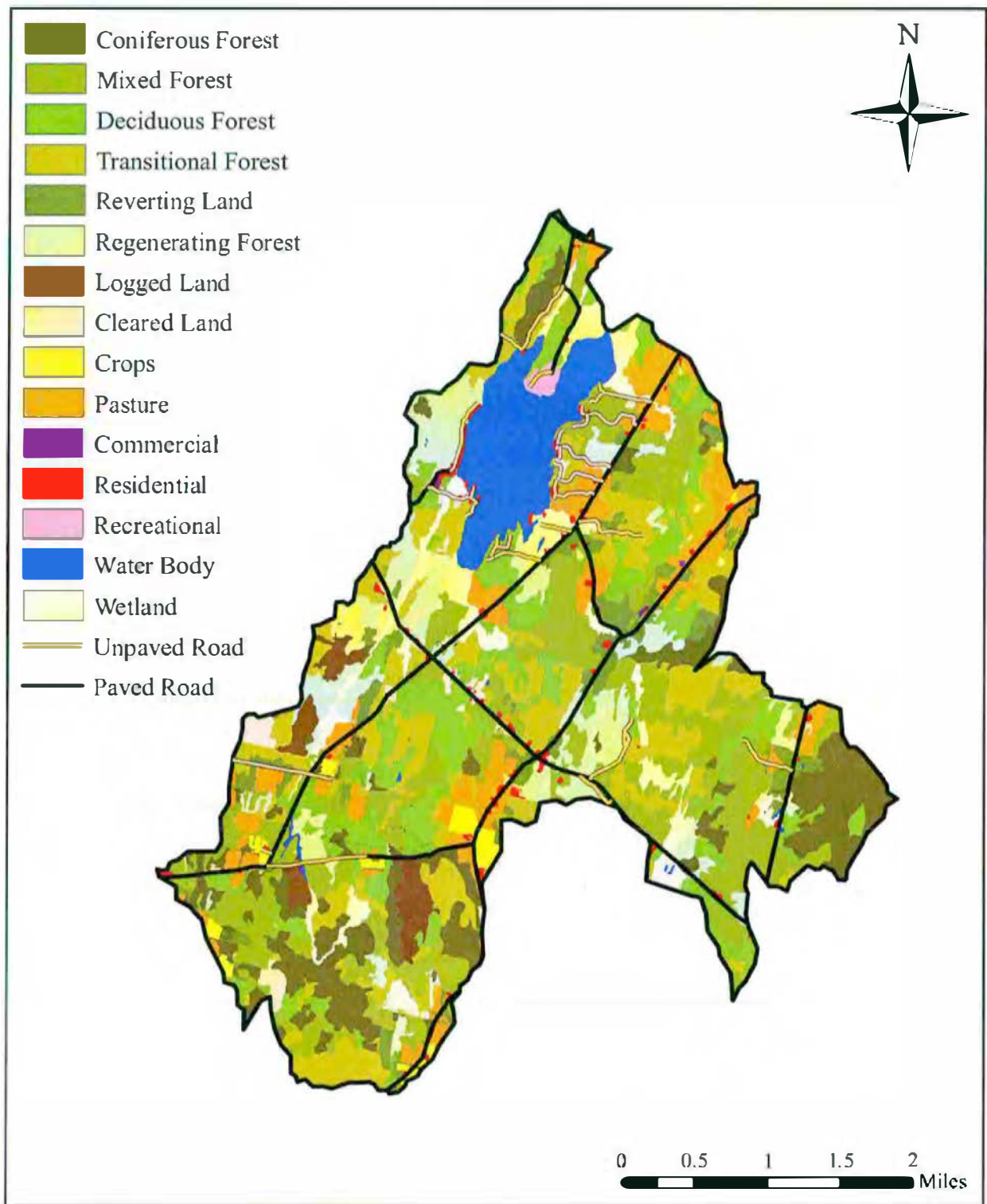


polygon was created, it was associated with a land use/cover type for future analysis. Final maps show land use patterns for the watershed in 1965 and 2007 (Figure 11 and Figure 12).

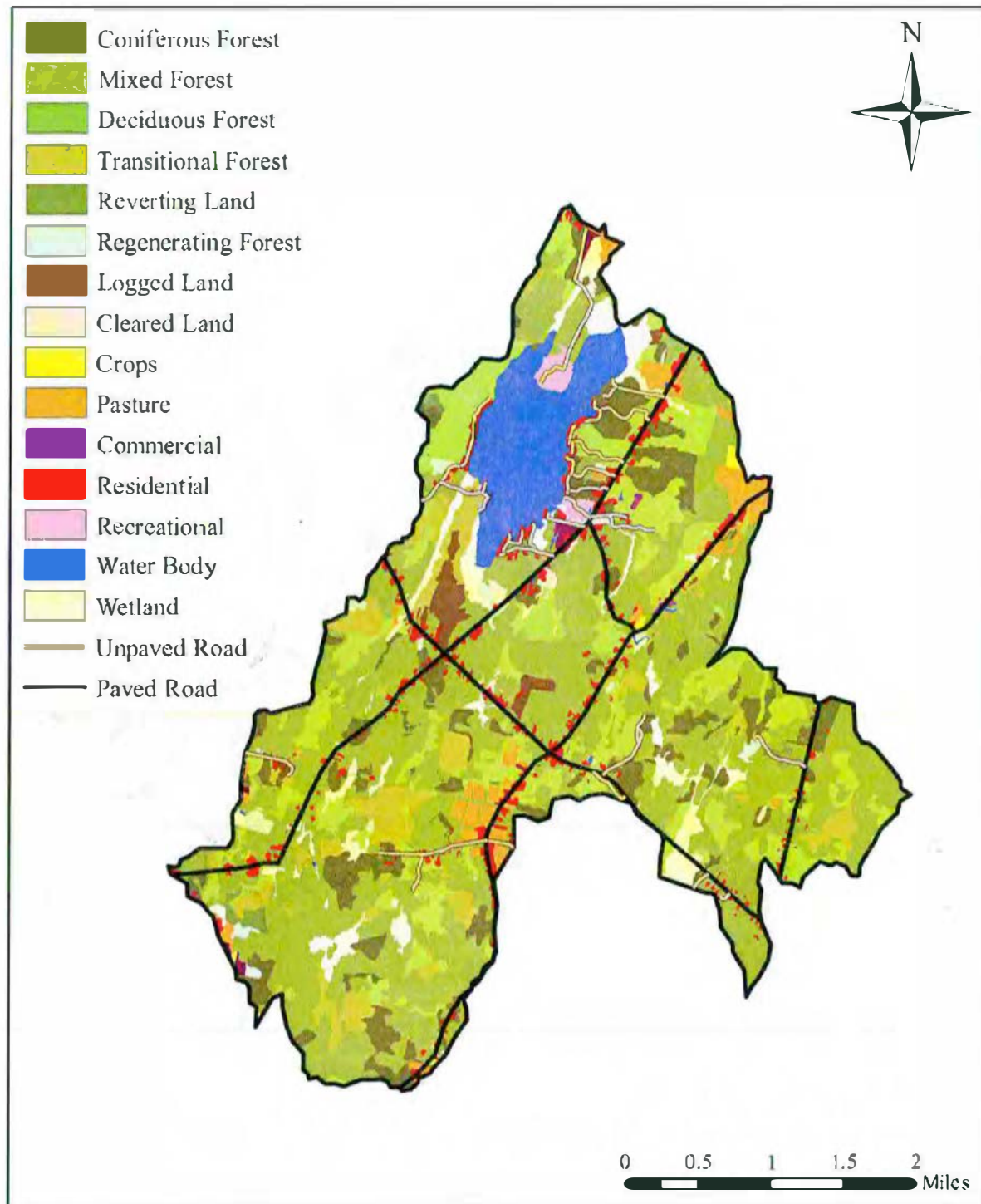
## **Quality Control and Analyses**

To ensure that the correct land use type was assigned to each digitized polygon, CEAT members reviewed the aerial photographs and agreed upon examples of each land use type. This step was critical in maintaining continuity throughout the digitizing process as well as assuring the validity of our resulting data and analyses. This method of quality control proved to be accurate once the final products were compared and analyzed.

Other than for the purpose of visually representing the land use/cover of the Pattee Pond watershed in the past and present, the maps were digitized to create a foundation on which to base future predictions of land use/cover. After digitizing the 1965 and 2007 maps CEAT used ArcGIS 9.2® to calculate the area in the watershed allocated to each land use. These numbers were compared as percentages of the total watershed to exhibit how land use/cover has changed over the past 40 years. These numbers helped the team determine trends in land use and make predictions concerning the future landscape mosaic of the area. Land use/cover areas were also used in the erosion and phosphorus loading models to determine the effects these factors have on the watershed and on Pattee Pond. Maps were created to visually convey how erosion and phosphorus loading potentials have changed since 1965. Changes in the watershed can have many implications for the health of the ecosystem. By focusing on these changes, CEAT could interpret the significance of trends and make relevant suggestions for lake and watershed mitigation.



**Figure 11.** Land use types for the Pattee Pond watershed in 1965. Land use polygons were determined using scanned and merged aerial photographs from the Maine Geological Survey as a backdrop. Colors for each polygon represent a different land use type (see Land Use Types of Pattee Pond Watershed).



**Figure 12.** Land use types for the Pattee Pond watershed in 2007. Land use polygons were determined with the use of a National Agriculture Imagery Program (NAIP) aerial photograph. A layer was digitized using the photograph and colors were chosen to represent distinct land attributes (see Land Use Types of Pattee Pond Watershed: Forested Land).



## ***LAND USE TYPES OF PATTEE POND WATERSHED***

### **Forested and Successional Land**

#### **Land Use Definitions and Identifying Characteristics**

Visual examples of aerial photographs help explain how CEAT was able to distinguish between different land use types (see Appendix B).

Forested Land includes three types:

Deciduous Forest areas are mature forests, with at least 75 percent canopy cover. This land cover type is dominated by tree species that shed foliage in response to seasonal change. Because of defoliation that occurs in the fall, these areas can be determined by comparing land cover in winter and summer months. Otherwise, coverage type may be hard to determine depending on the season.

Coniferous Forests are also mature forests, with at least 75 percent canopy cover. However, these areas are dominated by trees species that maintain their leaves all year, meaning that green foliage is always present. Coniferous forest stands are easier to identify in comparison to deciduous forests because of their darker color and narrow canopy cover.

Mixed Forests are areas of mature forest (at least a 75 percent canopy cover) dominated by a combination of coniferous and deciduous tree species where neither species accounts for more than 75 percent of total tree cover.

Successional Land includes three types:

Transitional Forested areas are within a range of 50 to 75 percent canopy cover. Trees are a variety of heights and species. These areas may have both coniferous and deciduous trees and are usually located between forest cover and a different land use.

Regenerating Forests are areas of previously logged land that have begun secondary succession. This forest contains a uniform cohort of individual trees that succeed as a group. Seedling to sapling sized trees of uniform height (age) are expected. Canopy cover is less than 50 percent. These sites will return to mature forests through succession unless otherwise interrupted.



Reverting Land refers to an old field that is in early successional stages. It may be somewhat rectangular in shape due to previous agricultural use. Field boundaries are unclear because of tree and shrub invasion, and vegetation is more substantial than in pasture/grassland.

### **Importance**

Forests play an important role in the watershed. They may affect the hydrology of the region in positive ways, including stabilizing soils, regulating water flow rates, and reducing the nutrient load of runoff (Revenga et al. 1998). Forests also help to create a more structurally complex habitat for many terrestrial species. These processes give forests the ability to influence watershed quality.

Root systems, especially shallow roots, act as drag on runoff, both by slowing it down and by absorbing some of this water, while deep roots stabilize slopes (Casermeiro et al. 2004, Whisenant 2005, Reubens et al. 2007). The layer of accumulated plant matter on the forest floor (called "duff") acts as a sponge, similarly slowing and absorbing water (Whisenant 2005). Duff and root systems protect soil from erosion by holding particles in place and by providing a protective barrier, allowing runoff to be filtered and added to the water table (Whisenant 2005, Reubens et al. 2007). When this barrier is broken, soil is left exposed, and the water running over it travels faster.

Canopy layers can catch precipitation and either slow its speed or cause the water to roll down plant stems to the ground in a more controlled manner, protecting soil from the impact of precipitation (Levia and Frost 2006). Mature forests tend to have the most developed canopy layers, providing more protection from erosion than immature forests (see Watershed Land Use).

### **Historical Cover**

There were six land use types that CEAT included in the forested category; combined, the forested land in 1965 covered 73 percent (2595 ha) of the Pattee Pond watershed (Figure 13). The largest area of forest land was that of mixed forest, which covered 19 percent (692 ha) of the watershed area. Transitional forest followed, comprising 16 percent (552 ha) of the watershed. Deciduous and coniferous forest cover accounted for 14 percent (483 ha) and 11 percent (392 ha) respectively. Regenerating land covered 9 percent (316 ha) of the total area and reverting land

five percent (161 ha). The fact that almost three-quarters of the Pattee Pond watershed was covered in forested land types in 1965 (74%) likely played a positive role in lake quality. In particular, the mature forest types (coniferous, deciduous, and mixed) that have the most positive effect on the watershed were found by CEAT to cover 44 percent (1566 ha) of the watershed in 1965. However, this figure is low when comparing the Pattee Pond watershed to 1965 data from neighboring watersheds. In six studies previously conducted by CEAT, the Long Pond South, China Lake, East Pond, and North Pond watersheds all had much greater coverage of mature forest in 1965 ranging from 60 percent to 90 percent (CEAT 1997, CEAT 2000, CEAT 2006, CEAT 2008). Only the watersheds of Great Pond and Messalonskee Lake had lower percentages of forest cover (Table 5; CEAT 1998, CEAT 1999).

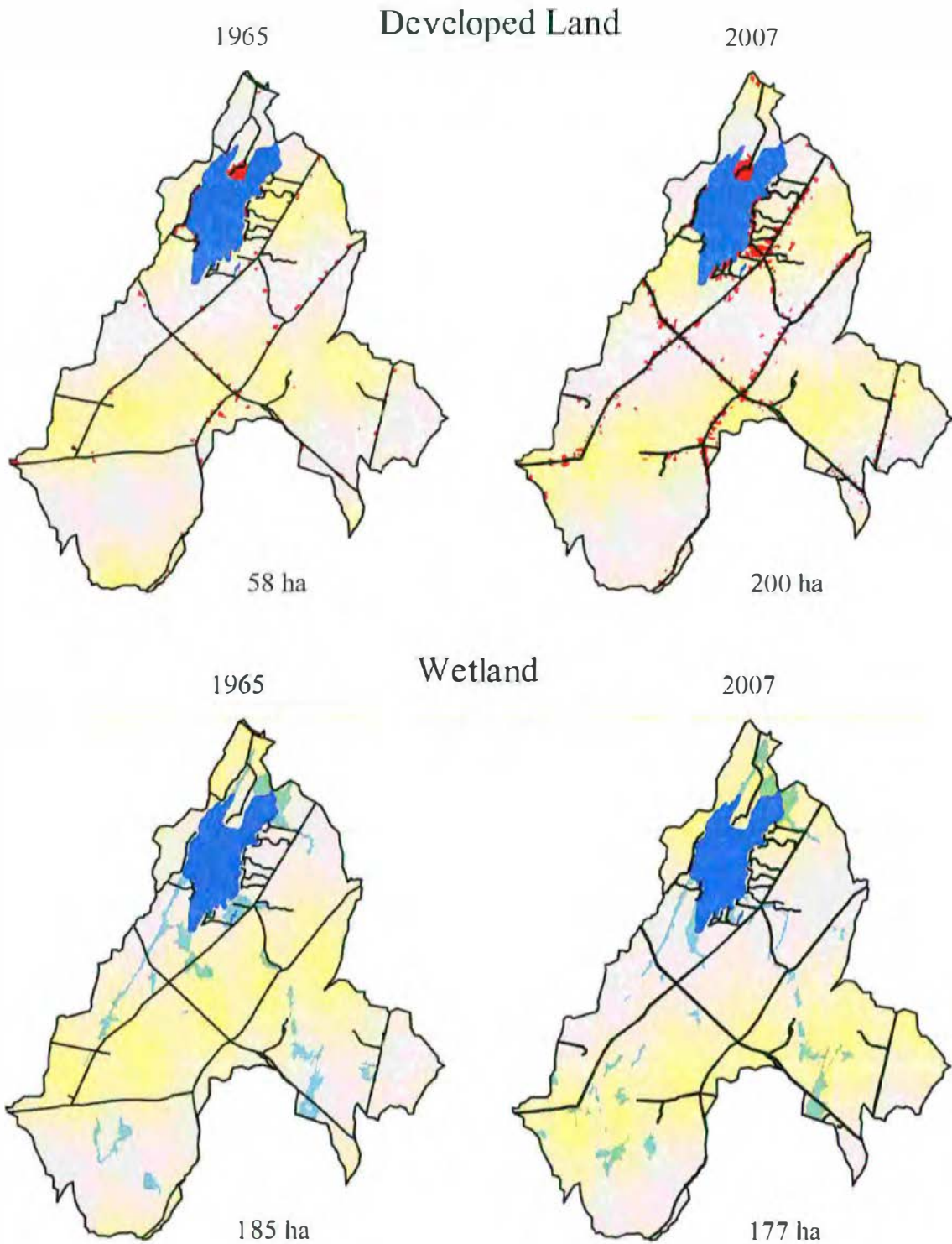
Although there was a large area of forested land within the watershed, there were many areas immediately around the lake periphery that CEAT identified as other cover types (Figure 13 and Figure 14). It is possible that the water quality of Pattee Pond was reduced as a result of the lack of forested buffer directly surrounding the lake.

**Table 5. Land cover areas in percentages from watersheds near the Pattee Pond Watershed (CEAT 1997, CEAT 1998, CEAT 1999, CEAT 2000, CEAT 2006, CEAT 2008).**

	Great Pond		Messalonskee Lake		Long Pond South		China Lake		East Pond		North Pond	
Land Use	1965	1998	1965	1991	1965	2003	1965	2003	1965	1999	1965	1991
Forest	74.4	76.6	66.1	62.5	79.4	83.9	68.8	65.2	90	88	78.6	77.1
Agriculture	-	-	-	-	10.6	6.3	-	-	-	-	-	-
Developed	2.8	5.9	3.8	8.8	0.3	2.4	2.7	10	4	9	8.6	4.5
Cleared/Logged	10.7	9.6	17.5	13.9	1	1.2	21.3	14	3	0	12.4	10.1
Wetlands	11.4	7.0	-	13.5	8	11.8	7.2	9.5	2	2	7.1	7.1
Roads	0.4	0.7	-	1.3	-	0.7	-	1.1	1	1	0.4	0.6

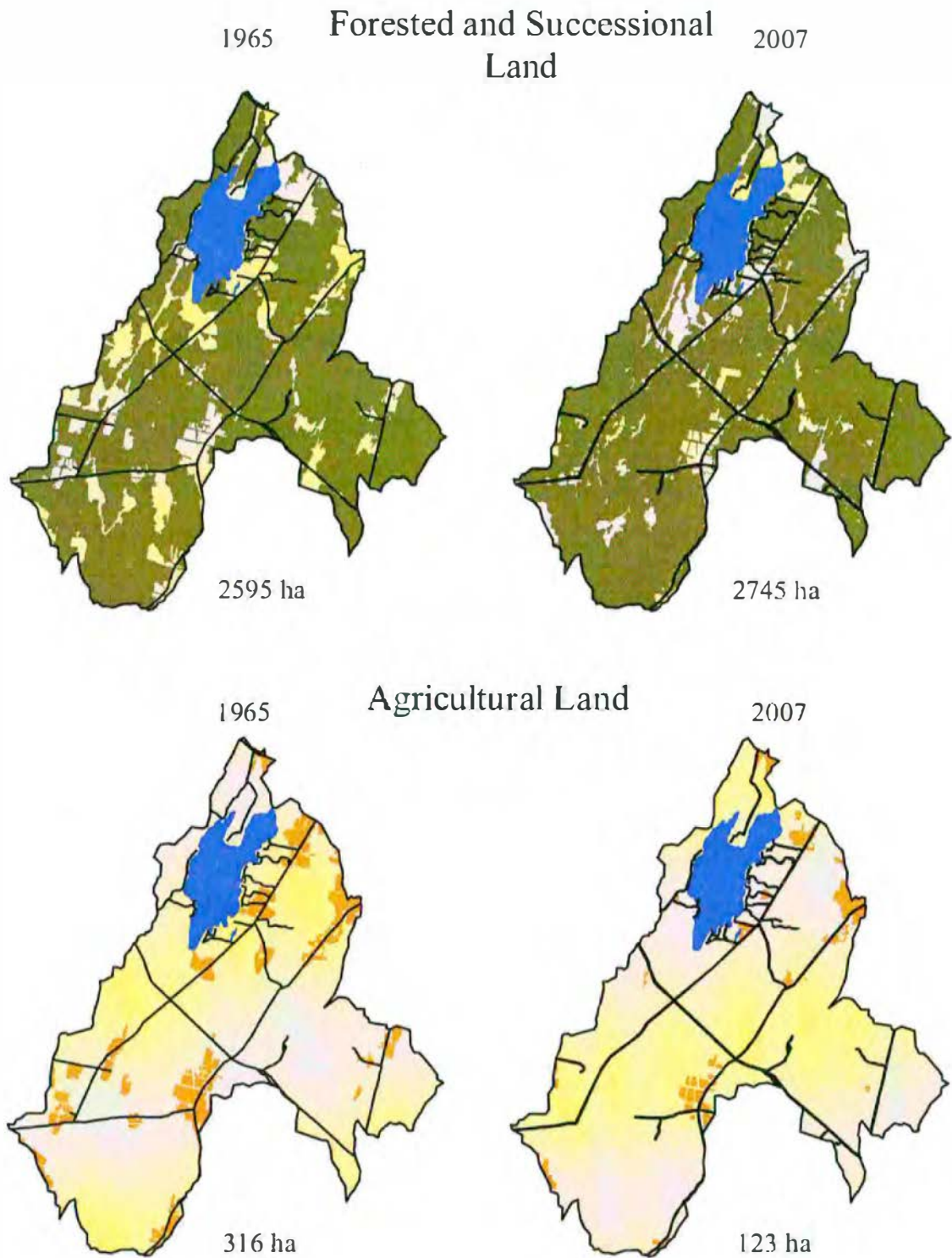
### Current Cover

Forested areas are currently dispersed throughout the watershed covering 83 percent (2745 ha) of its area. In 2007, mixed forests were the most prevalent forest type, comprising 45 percent (1605 ha) of the watershed. Deciduous and coniferous forests covered 16 (555 ha) and 9.6 (333 ha)



**Figure 13.** The top two images depict the total area of developed land (residential, commercial, recreational) in 1965 and 2007 within the Pattee Pond watershed. The bottom two images represented the total area of wetland within the watershed in 1965 and 2007.





**Figure 14.** The top two images depict the total area of forested land (coniferous forest, deciduous forest, mixed forest, transitional forest, regenerating forest, reverting land, and successional land) in 1965 and 2007 within the Pattee Pond watershed. The bottom two images represented the total area of agricultural land (crop land, grassland/pasture, tree farm) within the watershed in 1965 and 2007.



percent, respectively. Transitional forest covered 5.8 percent (207 ha), regenerating forest 0.8 percent (30 ha), and reverting land 0.6 percent (18 ha). Most of the Pattee Pond watershed is forested, however, the location of these forests prevent it from providing a natural buffer directly along the shoreline (see Figure 12).

In four studies done by CEAT in 1998, 1999, 2000, and 2008, it was found that the Great Pond, Messalonskee Lake, China Lake, and North Pond watersheds had lower amounts of forested land than the Pattee Pond watershed (Table 5; CEAT 1998, 1999, 2000, and 2008). The Long Pond South and East Pond watersheds had higher percents of forested land (see Table 5; CEAT 1997 and 2008).

## **Agricultural Land**

### **Land Use Definitions and Identifying Characteristics**

Crop Lands are characterized by clear rows of vegetation in a rectangular patch (see Appendix B).

Pasture/Grassland are areas dominated by grassy vegetation. These areas can be naturally occurring or mowed and may or may not be utilized for grazing. These lands are categorized by having canopy that is low to the ground. They are visually similar to crop lands, but have greater covering and lack narrow rows.

Tree Farms are areas characterized by uniformly-spaced trees of a single species. Tree farms include Christmas tree farms and fruit orchards.

### **Importance**

Agricultural land can import large quantities of phosphorus by way of commercial fertilizer use, livestock grazing, and manure deposits that are left exposed to leaching by runoff water (Robertson 1996, Robertson et al. 2006). Commercial agricultural fertilizers, unlike lawn fertilizers, are legal in the State of Maine (MRSAA 2007). Providing good buffers between these agricultural areas and the lake is key to mitigating their potential impact on water quality.

Farm management practices influence how much erosion and nutrient loading occurs from agricultural fields (Wheaton and Monke 2001, Huggins and Reganold 2007). No-till practices leave topsoil less disturbed and less vulnerable to erosion, though they may require

more initial fertilization (Huggins and Reganold 2007). On sloped farmland, owners may consider terracing crops to reduce water runoff speed and erosion (Wheaton and Monke 2001). Terraces are stair-shaped rows that help slow the speed of runoff water, causing sediments and nutrients to be dropped before runoff leaves the field (Wheaton and Monke 2001). Legislation setting minimum distance from the water basin and inlets, required buffer zone width, or fertilizer standards can also lower the adverse effects of farming on water quality.

### **Historical Cover**

CEAT identified two of the three different agricultural land use types in 1965; tree farms were not present. These combined made up 8.9 percent of the watershed. Pasture/grassland comprised the overwhelmingly majority of the agricultural land, at 7.7 percent (274 ha) of the total watershed area (see Figure 13).

The tendency of agricultural land to contribute high amounts of phosphorus and other nutrients to the watershed likely warranted concern for the water quality in 1965. However, the agricultural land in the Pattee Pond watershed comprised a smaller percentage of the total watershed area in comparison to other watersheds in 1965. The watersheds of China Lake and Messalonskee Lake had agricultural areas of 21 percent and 17 percent (CEAT 1998, CEAT 2006), and that of Long Pond South was 10.6 percent (Table 5; CEAT 2008). In the instance of Pattee Pond, lower percentages of agricultural land might have contributed to higher water quality in relation to nearby lakes. Improved water quality was likely a result of the fact that the majority of the agricultural land in the Pattee Pond watershed was pasture or grassland, which contributes less phosphorus than cropland. This is because lower levels of fertilizers are used to maintain grasslands. Proximity to the water body, however, plays an important role in determining the influence that each land use type will have on the water quality. Crops only covered 1.2 percent (42 ha) of the watershed area in 1965, but much of this land was very close to Pattee Pond, possibly resulting in a future increase in nutrient loading and a reduction of water quality.

## **Current Cover**

CEAT found that agriculture makes up 3.7 percent (123 ha) of the watershed with crops covering 1.5 percent (54 ha), pasture/grassland 1.6 percent (57 ha), and tree farms 0.3 percent (12 ha) in 2007. There are two tree farms in the watershed; one located southeast of the water basin and another north of the lake. Agricultural land makes up a very small percentage of the total watershed in 2007 and is not found in very close proximity to the lake, which decreases the chances of nutrients reaching the lake from these sources. Decreasing trends in agricultural land may prove to be beneficial to the improvement of water quality.

## **Developed Land**

### **Land Use Definitions and Identifying Characteristics**

Commercial/Industrial lands are areas which include all business complexes, public facilities, and other impervious surfaces (such as paved lots for parking and storage) constructed for common use (see Appendix B).

Residential areas are high or low density areas of privately owned land. These areas are mostly comprised of homes and the cleared acreage included around the property. The Mandatory Shoreland Zoning Act enacted in 1971 and enforced by Winslow and other municipalities defines development regulations along waterways. Maine DEP estimates of disturbed and impervious surfaces associated with residences were used in calculations along with house counts to determine the total amount of residential land use area in the watershed (Bouchard, pers. comm.).

- **Shoreline Residences:** Private land and homes within 250 ft of the normal high waterline. Residential areas are estimated to be approximately 0.5 acres per house.
- **Non-Shoreline Residences:** Private land and homes more than 250 ft away from the normal high waterline. Residential areas are estimated to be approximately 1.0 acres per house.

Recreational Land includes areas with a mixture of some buildings and vegetation in the form of lawn grasses. These areas can be characterized by multiple small buildings and road networks. They are used by groups of people and usually include open land with variable features such as trails or picnic areas, these spaces can function as parks, athletic fields, golf courses, tennis courts and others.

- Youth Camp refers to Camp Caribou located on the northern shore of Pattee Pond. It is a cluster of buildings and recreational facilities, in a wooded area removed from other development.
- Giordano's Market and Campground is located on the southeast shore of Pattee Pond. This area is of seasonal use and consists of RV parking and camping as well as a public boat launch and a market.

## **Importance**

Developed areas are composed mostly of impervious surfaces and structures where people reside and/or work (King et al. 2005). Areas that are frequently used and/or altered to fit human designs tend to add more phosphorus and sediments to the lake ecosystem because of impervious surfaces and the leaching of human wastes (sewage, garbage, synthetic products) into the soil from improper disposal practices (see Water Quality Assessment: Phosphorus Model). Developed areas also decrease biodiversity through habitat destruction. Residential, commercial, and recreational land use types encourage additional road construction, further increasing areas covered by impermeable surfaces.

The key to managing these challenges will be to weigh the costs and benefits of each development, and to identify suitable areas. Changes made to land in the watershed should maintain a low impact on water quality. Key considerations will include distance from the lake or inlet streams, soil type, and slope.

Lawns can contribute a significant amount of phosphorus, and in the case of shoreline residences are in close proximity to the lake (Waschbusch et al. 1999). Current Maine legislation prohibits the retail sale of non-agricultural lawn fertilizers that contain phosphorus, with few exceptions (MRSAa 2007). Phosphorus loading from fertilizers is not the only concern, though. Lawns are also poor buffers, as they lack layers of vegetation to slow water and absorb nutrients (see Watershed Development Patterns: Buffer Strips).

Residential and commercial areas increase the need for waste management because they are located where human activity is most frequent. Holding tanks, leach fields, and other waste management systems can contribute to nutrient loading into the lake if improperly managed (see Watershed Development Patterns: Subsurface Wastewater Disposal Systems). Domestic



wastewater such as from laundry, dishwater, and bathing, called “gray water,” is an additional source of phosphorus. Many household products, including soaps, detergents, and cleaners contain high quantities of phosphates (Manitoba 2007). Although current Maine regulations ban the sale or use of high phosphorus (8.7% phosphorus by weight or higher), additional ways to manage gray water and reduce the impact on water quality should be implemented (see Watershed Development Patterns: Subsurface Wastewater Disposal Systems; MRSAA 2007).

Recreational lands are characterized by a variety of surfaces, which tend to be poor buffers (see Watershed Assessment Introduction: Watershed Land Use). Although some recreational land is a mixture of woods and trails, most identifiable recreational land is characterized by lawns (sport fields), pavement, and buildings. Unlike residential areas, recreational land can have highly variable waste management needs, depending on the type of recreation and season. Each recreational area should be considered individually based on the specific uses of each area.

In the Pattee Pond watershed, two recreational areas were identified: Giordano’s Market and Campground on the south east shore, and Camp Caribou, a boy’s summer camp, on the northern peninsula. Both are shoreline properties, characterized by fields, paved areas, and buildings. The waste management needs of both are considerably higher during the summer because of the summer camp and RV camping seasons. There are a large number of people in a concentrated area intensifying effects on the lake.

## **Historical Cover**

Developed land consisted of three different types within the watershed. Combined, they covered 1.6 percent (58 ha) of the Pattee Pond watershed in 1965. Residential land was the most prevalent, making up 1.3 percent (45 ha) of the watershed area. The residential areas were scattered along the major roads of the watersheds, particularly clustered around the crossroads (see Figure 14). There was also significant development directly adjacent to Pattee Pond, mostly along the western and eastern shorelines. The ratio of the shoreline to non-shoreline residences was 61 to 81 houses. It is important to consider this relationship when considering the water quality because phosphorus from houses on the shoreline is more likely to transfer into the water body due to direct contact with the water body. While the Pattee Pond watershed had lower

residential development than five out of the six watersheds studied by CEAT with data from 1965, some of these watersheds had considerably fewer residences along the lake shoreline, such as Long Pond South, which had few to no shoreline houses in 1965 (CEAT 2008).

CEAT categorized both the youth camp (Camp Caribou) and Giordano's Market and Campground as being recreational areas. In 1965, however, Camp Caribou was the only recreational land use. The youth camp took up 0.28 percent (10 ha) of the watershed in 1965. The camp was located then, as it is now, on the northern peninsula in the lake, just to the west of the outlet of Pattee Pond. Despite its small area, the proximity of the camp to the lake as well as the fact that it had high numbers of occupants during the summer months meant that it was likely to have an impact on the water quality.

Lastly, the commercial land in 1965 covered only 0.08 percent (3 ha) of the Pattee Pond watershed. This includes buildings and other structures associated with logging practices which were found in the southern portion of the watershed. Overall, however, the commercial land made up a very small portion of the watershed when compared to other watersheds in 1965. The North Pond watershed was an exception with 12.4 percent land in commercial or industrial use (Table 5; CEAT 1997, CEAT 1998, CEAT 1999, CEAT 2000, CEAT 2006, CEAT 2008).

### **Current Cover**

In 2007, developed land covered 5.4 percent (200 ha) of the watershed. Residential land was the most common of the developed land use types, covering 5 percent (176 ha) of the watershed. Residential areas were concentrated along the east and west shorelines of Pattee Pond and along major roads. CEAT used information from road and shoreline surveys to determine total house counts in the watershed. There were 491 homes and 110 shoreline residences and 381 non-shoreline residences. Only 5 of the shoreline residences are permanent, year-round homes while 361 of the non-shoreline residences are permanent. Residential areas in the Pattee Pond watershed cover a smaller percent of the watershed area compared to residential areas in the Long Pond North watershed (5.5 percent) and the Great Pond watershed (4.5 percent) (CEAT 1999, CEAT 2007).

Recreational land covers 0.6 percent (20 ha) of the Pattee Pond watershed. Camp Caribou is located directly on the shoreline of Pattee Pond, covering 0.4 percent (14 ha) of the

watershed. Giordano's Market and Campground is a private campground located on the southeast shoreline of Pattee Pond, covering 0.2 percent (7 ha) of the watershed. Other commercial land covered only 0.1 percent (3 ha) of the watershed in 2007. The recreational land uses have the potential to impact water quality due to their close proximity to the lake. Other commercial land uses made up such a small percentage of the watershed, and were farther from the water basin, and most likely had a smaller impact on the lake.

## **Wetlands**

### **Land Use Definitions and Identifying Characteristics**

Wetlands are transitional zones between land and water bodies. These areas are easily identified because their soils are saturated with water all year long. Wetlands may or not may not be forested (see Appendix B).

### **Importance**

Due to the peat moss and porous soils that characterize wetlands, wetlands are able to retain a great deal of water. Wetlands function as a source and a sink for nutrients, runoff, and other pollutants, which can positively or negatively affect the water quality of nearby ponds and lakes. Their numerous niches support diverse wildlife including rare and endangered species as well as keystone species, like the beaver, that have the ability to shape and transform wetlands (see Background: Wetlands).

### **Historical Cover**

Wetlands made up sections of the shoreline of the Pattee Pond in 1965, which served as a buffer and made up 5.2 percent (185 ha) of the total watershed area. Wetlands have a high capacity to filter nutrients and other pollutants out of runoff (see Background: Wetlands), which likely contributed to higher water quality in 1965. This is especially true due to the fact that many of these wetlands were located in close proximity to the lake where they are the most useful (see Figure 14). Wetland areas scattered throughout the rest of the watershed helped the water quality by filtering out nutrients farther away from the lake, such as the nutrients that came from Mud Pond as an input into the lake. Both the proximity of wetland to the lake and the high

percentage of shore that was covered in wetland likely played a positive role in improving the quality of Pattee Pond in 1965. The percent of wetland area in the watershed was close to that of other watersheds in the 1960s (Table 5; CEAT 1997, CEAT 1998, CEAT 1999, CEAT 2000, CEAT 2006, CEAT 2008).

### **Current Cover**

In 2007, wetlands also provided a natural buffer around parts of the lake. They bordered Pattee Pond on both the northern and southern shores. Wetlands covered 5.0 percent (177 ha) of the watershed. The percent of wetlands in nearby watersheds ranges, accounting for 2.8 percent of the Long Pond North watershed in 2003, 7.0 percent in the Great Pond watershed in 1998, and 11.8 percent in the Long Pond South watershed in 2003 (CEAT 2007, CEAT 1999, CEAT 2008).

### **Cleared and Logged Land**

#### **Land Use Definitions and Identifying Characteristics**

Cleared Land areas appear brown and uniform on photos, with no clear tilled rows for crops or hay. Tree stumps are not visible and the ground is bare. These areas have high erosion potential (see Appendix B).

Logged Land consists of areas of thinned forest cover, with irregular dirt roads weaving through. Some residual mature trees may remain. These areas may be structurally similar to Agriculture or Grassland, but tree stumps and felled trees may be visible and previous aerial photographs indicate that the areas were once forest. These locations may return to forest cover through succession.

#### **Importance**

Logging land removes the natural protection provided by forest canopy, making additional nutrients readily available to erosive forces (Hannam et al. 2005, Hazlett et al. 2007). Nutrients such as phosphorus, nitrogen, and carbon that had previously been inaccessible as living tissue are now readily carried by runoff (Hannam et al. 2005, Hazlett et al. 2007).

Types of logging practices and proximity to the water body should be considered for watershed managers. Steeper slopes have a naturally higher potential to erode, since water flows



faster over greater inclines. Logging and clearing in steep areas will increase sediment and nutrient loading more so than in flat areas. The loss of root systems compounds amplifies erosion because roots that once held particles together are now gone. This may result in landslides.

Cleared land similarly to logged land leaves the soil surface exposed to weathering. Less residual plant matter is left on the surface, so there are fewer nutrients available to leach away than on logged land. However, because phosphorus is attached to soil particles, erosion of these areas is as much a concern as on logged land.

### **Historical Cover**

CEAT determined that logged land covered 1.9 percent (69 ha) of the watershed area in 1965. A large portion of this logged land was in the southern portion of the watershed, far from Pattee Pond. There were several other smaller areas scattered throughout the rest of the watershed. Despite logged land's ability to contribute phosphorus, in 1965 most logged land was a large distance away from the water body and covered a minimal area. It is not likely that the logged land in 1965 substantially altered the water quality of the lake. Logged land was not found by CEAT in any of the other watersheds that reported data from 1965 (CEAT 1997, CEAT 1998, CEAT 1999, CEAT 2000, CEAT 2006, and CEAT 2008).

Additionally, cleared land was found to equal 2.2 percent (77 ha). This is also a relatively small area of land that most likely did not have a large impact on water quality in 1965.

### **Current Cover**

Cleared land covered 0.6 percent (20 ha) of the watershed in 2007. Logged land covered 1.1 percent (40 ha) of the Pattee Pond watershed. In 2007, logged areas were found south of the water basin along Bellows Stream, in close proximity to the lake. This logging resulted in sediment loading into Pattee Pond (Fleury, pers. comm.). Although wetlands are located in between these logged areas and the lake, providing a buffer. However, the logged areas still may contribute to decreased water quality.

## **Roads**

### **Land Use Definitions and Identifying Characteristics**

Road areas include all paved or unpaved surfaces that aid in the transport of goods and people.

State Roads are maintained by the state and paved due to their more frequent use. State roads tend to be wider than municipal roads, because of their large shoulders and higher volumes of traffic.

Municipal Roads these are paved roads and are maintained by the town due to their frequency of use.

Camp Roads are smaller roads constructed of gravel and natural materials that are typically located around the periphery of the lake.

### **Importance**

Roads are large, impervious surfaces that inhibit water, nutrients, and sediments from being absorbed over their entire area. Camp roads have the greatest impact, because they are often constructed using dirt and gravel and have a high propensity to wash out, adding additional nutrients to run off water (see Phosphorus Model). Camp roads also tend to be located closer to the water basin, and are often maintained less frequently because the town/state is not responsible for their upkeep (see Watershed Development Patterns: Roads). Culverts under roads help prevent washout of the road, but poorly-maintained culverts, or those that are too small, may contribute to sediment loading as well (see Watershed Development Patterns: Roads).

Although roads have a relatively high impact on water quality, they are a necessary land use that make many other land uses possible. Good residential planning will reduce the number of roads necessary. Decisions limiting road construction along or leading runoff directly into the water basin will decrease the impact of roads on water quality. Best management practices for roads will be discussed later (see Watershed Development Patterns: Roads).

## **Historical Cover**

CEAT found the road cover in 1965 to be 0.8 percent (27 ha) of the watershed area. Camp roads made up 7 ha and municipal and state roads comprised 20 ha. It is important to note that because the majority of the camp roads are in very close proximity to the lake they have the potential to contribute a great deal of runoff and sediment loading into the lake (see Figure 11). This area of road cover is very similar to that of other watersheds studied by CEAT in 1965.

## **Current Cover**

Roads cover 0.8 percent (28 ha) of the watershed. In the current layout of the watershed, the majority of roads closest to the lake are camp roads. Camp roads comprise 12 ha, municipal roads 10 ha, and state roads 6 ha. Municipal and state roads are paved and further away from the lake basin and less likely to impact lake water quality.

## **Trends: 1965-2007 changes in land use type percentages**

Comparisons of 1965 land use with 2007 land use show the succession of forests (860.5 ha), as well as increases in some high-impact land uses (e.g., roads, commercial and residential development) (Table 6 and 7). High impact land uses contribute disproportionate amounts of phosphorus to the water basin and are further analyzed in the Phosphorus Model section of the report. Residential land and commercial land both have a relatively high potential to add phosphorus to the water basin. In both of these land use categories, an increase of over 100 percent was seen (Table 6). Residential land and commercial land both have a relatively high potential to add phosphorus to the water basin. In both of these land use categories, an increase of over 100 percent was seen (Table 6). Although their absolute change in area is comparatively small (132 ha), this increase contributes a significant amount of phosphorus because each hectare contributes a large amount of phosphorus, especially those areas nearest the lake and inlets. Most new residential area had been grassland or forested in 1965 (Table 7).

Shoreline residences in particular have the highest phosphorus loading potential among commercial and residential categories because of their proximity to the lake. Since 1965, most of the land converted to shoreline residences (10 ha) was originally low impact land use types,

including mature forests, wetlands, and transitional forests (see Figure 11 and 12). Not only has there been an increase in this high-impact land use area, but also shoreline residences have replaced important buffer areas that had been naturally filtering out sediments and nutrients.

Another high-impact land type, cleared land, has dropped over 200 percent (55 ha). This land has primarily been converted into mature and immature forests, with smaller portions being converted into residential developments, pastures, and crops (Table 6 and 7). These changes have decreased phosphorus loading in the watershed.

**Table 6. A comparison of historical and current land use areas in the Pattee Pond watershed. Historical data were collected from 1965 aerial photographs; current data were collected from 2007 aerial photographs (see Analytical Procedures and Results: Land Use Types of Pattee Pond Watershed). Percent change is net change divided by mean value of land use area.**

<b>Land Use Type</b>	<b>1965 Area (ha)</b>	<b>2007 Area (ha)</b>	<b>Net Change (ha)</b>	<b>Percent Change</b>
Commercial/Industrial	3	3	+1	+14.7%
Camp Caribou	10	14	+4	+31.2%
Giordano's	0	7	+7	+200.0%
Crops	42	7	-35	-143.3%
Pasture/Grassland	279	100	-180	-94.9%
Tree Farm	0	9	+9	+200.0%
Forest, Deciduous	486	555	+70	+13.4%
Forest, Coniferous	394	333	-61	-16.8%
Forest, Mixed	696	1605	+909	+79.0%
Forest, Transitional	552	207	-344	-90.7%
Forest, Regenerating	316	30	-286	-165.6%
Land, Cleared	77	21	-55	-112.7%
Land, Reverting	161	18	-143	-159.9%
Land, Logged	69	43	-26	-45.8%
Wetland	185	177	-8	-4.6%
Open Water	2227	2174	-53	-2.4%
Roads, Camp	7	12	+5	+51.6%
Roads, Municipal & State	20	15	-4	-23.7%
Development, Shoreline	12	22	+10	+57.3%

Regenerating and transitional forests have both been replaced by mixed, deciduous, and coniferous forest types (Table 7). This successional change has had a positive effect on reducing phosphorus loading in the water basin. Smaller portions of regenerating and transitional forests



were converted to high-impact land uses, primarily residential (23 ha) and logged areas (12.9 ha).

Wetlands have not decreased significantly in size (Table 6). While a large portion of this change appears to be a natural succession to forested areas, or possibly an increase in canopy density masking some of the wetlands along the Bellows Stream corridor, the southeast shore of Pattee Pond is a noteworthy exception. Here, 43.6 percent (9.3 ha) of the wetlands have been converted into residences, Giordano's Market and Campground, and a tree farm (see Figure 11 and 12). Not only are these high-impact areas, but they are also replacing an efficient, natural filtration system for the lake (see Background: Watershed Land Use: Wetlands). This land conversion has not only increase the phosphorus loading from that area, but also from the areas uphill as well that drain into Farber Brook (see Water Quality Assessment: Chemical Analyses).

**Table 7. Land use types in 1965 that exhibited the highest rates of conversion to different land uses in 2007. Land uses are listed by amount of area occupied in Pattee Pond watershed in 1965. Each 1965 land use is broken down into number of hectares (ha) of the 1965 area that was converted to particular land types in 2007 (See Land Use Analysis: Introduction). Land uses for 2007 are listed by phosphorus loading potential in descending order from left to right.**

1965 Land Use		Land Use Converted in 2007 (ha)									
Type	Area (ha)	Crops	Residential	Cleared	Logged	Transitional	Pasture	Coniferous	Deciduous	Mixed	Other
Transitional	551	0	10	12	0	-	0	48	106	326	49
Deciduous	483	2	13	3	2	30	0	53	-	292	89
Coniferous	391	0	3	1	0	40	1	-	59	223	64
Regenerating	315	0	13	4	13	19	0	16	120	121	9
Pasture	278	45	29	5	3	11	-	40	31	60	54
Reverting	160	1	13	1	2	6	5	17	27	80	9
Cleared	77	0	9	-	0	12	1	7	10	30	7
Crops	42	-	7	0	0	0	17	9	0	10	0
Commercial	3	1	0	0	0	0	0	0	0	1	0

In addition to the establishment of Giordano's Market and Campground on the southeast shore, another recreational land area, Camp Caribou, also increased in size since 1965 (Table 6).

Because of its location on the shoreline, this increase has the potential to have a considerable impact on the lake. Efforts should be made to protect the wetland and transitional forest currently buffering the lake from this source of phosphorus.

Agricultural land (cropland, pastures/grasslands, and tree farms) has decreased overall. Tree farms were non-existent in the Pattee Pond watershed in 1965, but cover a small area (9 ha) so do not contribute a substantial amount of phosphorus (see Phosphorus Model). Because of disproportionately high phosphorus loading potentials of agricultural lands, any increases in this land use should be carefully monitored.

Logged land has decreased moderately (26 ha) in the watershed. Most of this decrease has occurred in the Bellows subwatershed (discussed below). In the main watershed, the area of logged land has actually increased, from no logged land in 1965 to 40 ha in 2007 (Table 8).

**Table 8. A comparison of historical and current land use areas in the Bellows subwatershed of the Pattee Pond Watershed (see Analytical Procedures and Results: Land Use Types of Pattee Pond Watershed and Trends). Percent change is net change divided by mean value of land use area.**

<b>Land Use</b>	<b>1965 Area (ha)</b>	<b>2007 Area (ha)</b>	<b>Net Change (ha)</b>	<b>Percent Change</b>
Cleared	46	5	-41	-163%
Commercial	0	0	-0	-200%
Coniferous	169	116	-53	-37%
Crops	22	1	-20	-175%
Deciduous	104	121	+17	+15%
Logged Land	69	3	-66	-186%
Mixed	183	506	+323	+94%
Open Water	4	1	-3	-151%
Pasture	65	10	-55	-145%
Regenerating	72	17	-54	-123%
Residential	3	17	+14	+134%
Reverting	46	0	-46	-200%
Transitional	129	106	-23	-20%
Tree Farm	0	4	+4	+200%
Wetland	40	41	+1	+2%

### **Bellows Stream**

In the Bellows subwatershed, several high-impact land uses have decreased in area, which has likely contributed to the improvement in water quality in Pattee Pond since 1965 (Table 8). Of particular note are the decreases in cleared, commercial, logged, pastures, and

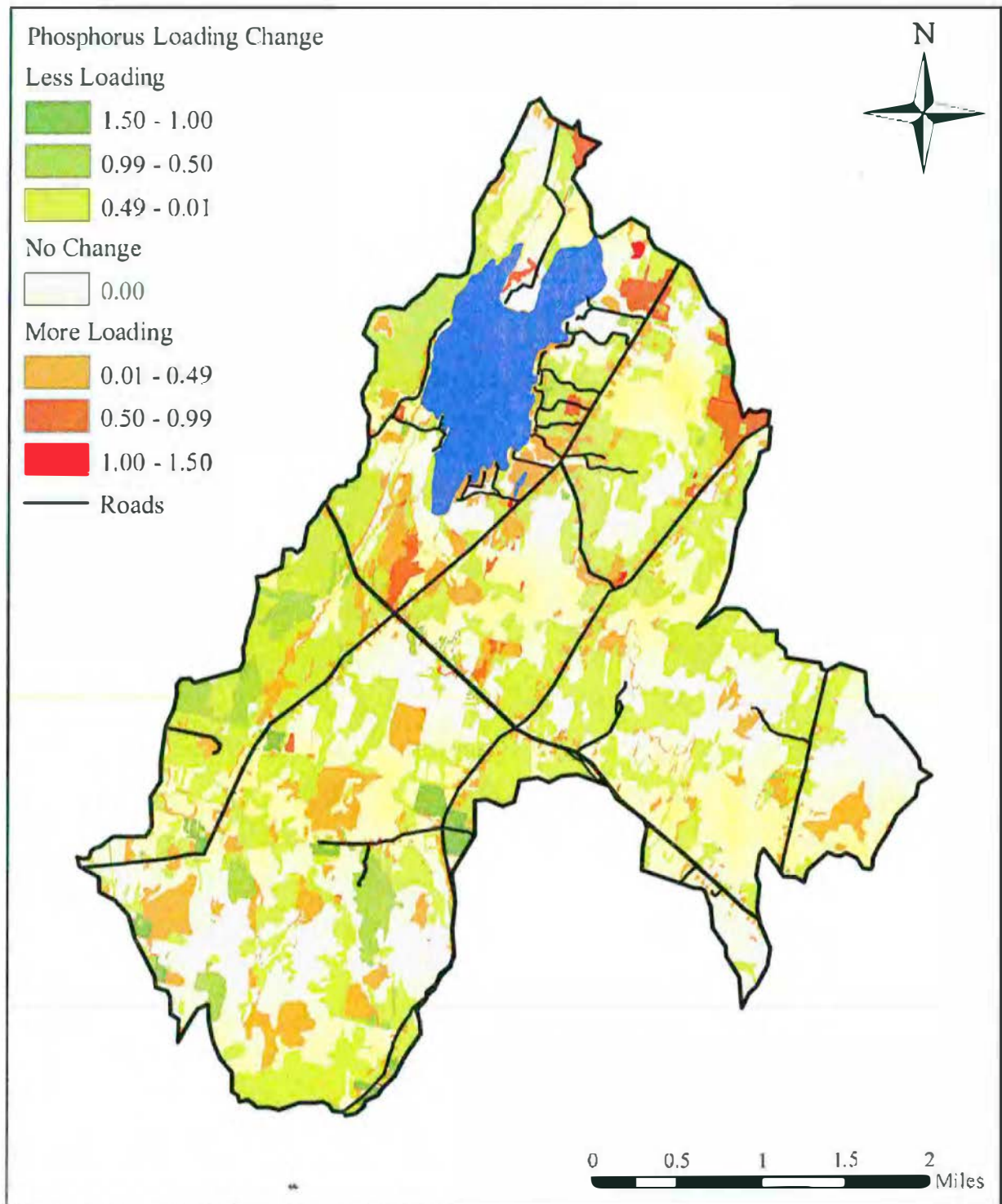
cropland. Residential land increased by 14 ha (134 percent), but this increase seems to be more than off-set by the other positive changes seen.

Although logged land decreased overall in the Bellows subwatershed, the location of recent logging is of concern. In 1965, logged land was on the far edges of the watershed (see Figure 11). Current logging is just south of Pattec Pond, along Bellows Stream (see Figure 12). This logging activity has increased sediment and phosphorus loading into the lake via Bellows stream more than if land further from the lake and stream had been logged.

## **Summary**

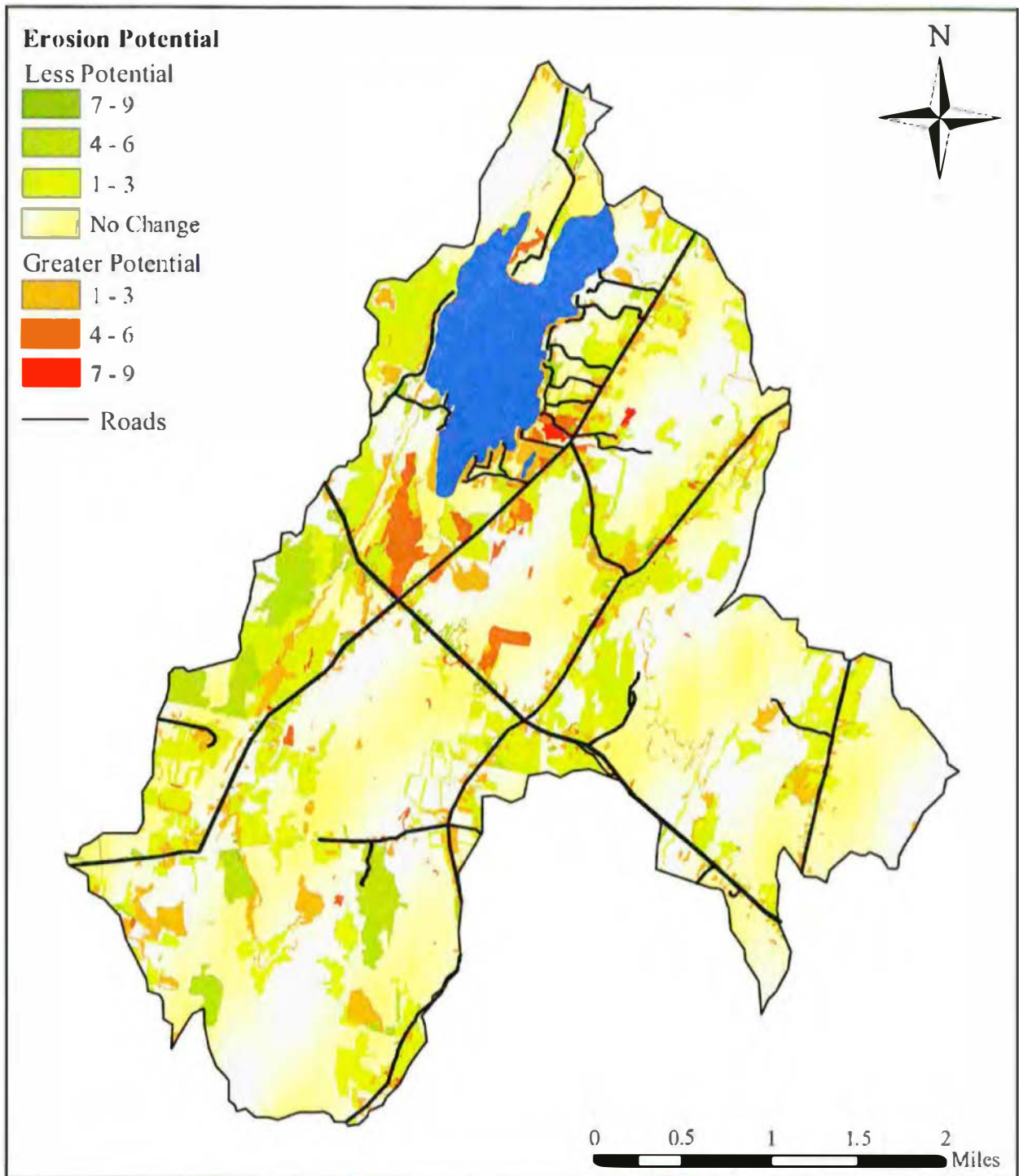
Changes in erosion potential and phosphorus potential show areas of concern concentrated closest to the lake, Bellows Stream and Farber Brook (Figure 15 and Figure 16). In these areas, the logging of land and conversion of wetlands to a residential area, a tree farm, and Giordano's Market and Campground have significantly increased the erosion and phosphorus loading potentials in these areas. Changes expected to decrease phosphorus loading and erosion are concentrated along the western edge of the watershed and along Nowell Road because of the succession of forests and decreases in cropland in those areas.

Overall, the Pattec Pond watershed has undergone many land use changes that are expected to decrease phosphorus loading into the lake. A number of smaller changes have had a relatively high impact on phosphorus loading, however, because of their proximity to the lake and its inlets. Of particular note is the increase in shoreline residences (from 61 houses in 1957 to 110 houses in 2007) that have replaced natural habitat with buffering capabilities around the lake, and the conversion of wetlands to commercial, residential, and agricultural area on the southeast shore.



**Figure 15.** Change in phosphorus loading potential in Pattee Pond watershed between 1965 and 2007. This map was based on phosphorus loading coefficients assigned to land use types (see **Phosphorus Model: Results and Discussion**). The scale represents the change in these coefficients, with negative numbers and green areas being indicative of positive change and positive numbers and orange to red areas indicative of negative change.





**Figure 16.** Changes in erosion potential in the Pattee Pond watershed between 1965 and 2007. These changes are based solely on potential erosion rankings assigned to each land use type and the change in land use that occurred (see Erosion Potential Model: Land Use). The color scale visually represents the degree of change in erosion potential. Green areas indicate land which went from a higher erosion potential in 1965 to a lower potential in 2007. Red colors represent the opposite effect.

# ***WATERSHED DEVELOPMENT PATTERNS***

## **Residential Zoning**

### **Introduction**

Municipalities use zoning restrictions in watersheds and along lake shorelines to regulate development and protect water quality (Spalatro and Provencher 2001). CEAT focused on zoning in this study because development has a strong impact on the environmental characteristics of the Pattee Pond watershed (Baker et al. 2008).

Often, zoning ordinances are not tangibly implemented until development or redevelopment of an area occurs, so their effects can take decades to emerge (Baker et al. 2008). As the water quality implications of heavy development have become clear, more stringent zoning regulations have been applied to watersheds across the country (Baker et al. 2008).

Zoning restrictions along lakes can have major implications for water quality and waterfront property values. In a study of lakes in northern Wisconsin, minimum lakeshore frontage zoning restrictions for each lot were shown to have a positive economic gain by preserving lake amenities and limiting development (Spalatro and Provencher 2001). This suggests that current zoning codes in Winslow have a beneficial effect on property values around Pattee Pond because the restrictions minimize development. Uninhibited development throughout the watershed would have serious negative impacts on the water quality of Pattee Pond and would cause declines in property values as well as aesthetic value because water quality is directly linked to property value (Michael et al. 2000, Spalatro and Provencher 2001). CEAT performed an extensive study of development in the watershed to further elucidate the factors influencing water quality and the character of Pattee Pond.

### **Regulations**

#### Shoreline zoning

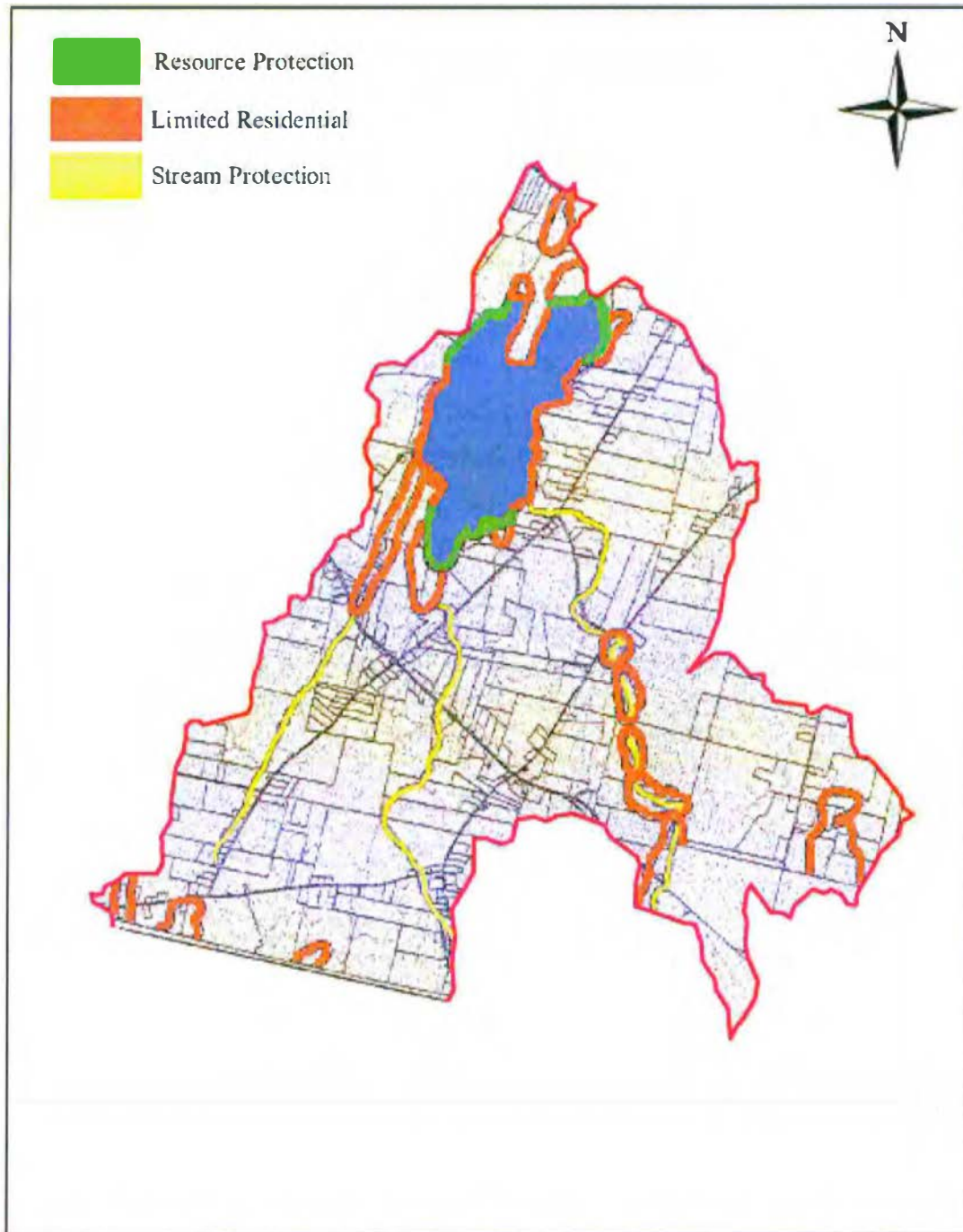
In 1971, the Maine State Legislature passed the Shoreland Zoning Act, which mandates that all land along shorelines throughout the state be subject to specialized zoning restrictions (MDEP 2003b). For great ponds (defined as ponds and lakes greater than 10 acres and including Pattee Pond), land within 250 ft of the normal high water line is governed by Shoreland Zoning

(MRSA, MDEP 2008b). Towns are required to enforce the Shoreland Zoning Act either by adopting the state stipulations or creating their own more restrictive codes (MDEP 2003b). Homes built before the enactment of strict zoning codes in 1989 are considered to be grandfathered, or legally non-conforming, and allowed to remain as originally constructed (Stankevitz, pers. comm.). Subsurface wastewater systems were grandfathered if they were constructed prior to 1974.

The Town of Winslow has its own Shoreland Zoning Code, adopted on 08-Feb-93, that governs all land within 250 ft of water bodies throughout the town (Town of Winslow 1997a). Each home that is considered “shoreline” in this study is subject to these zoning rules because they are within 250 ft of the Pattee Pond shore. The Winslow Shoreland Zoning Code divides shoreland areas into several categories including Limited Residential, Resource Protection, and Stream Protection (Figure 17; Town of Winslow 1997a). The Stream Protection category is the only district that extends 75 ft from the water, and restricts development directly along streams (Town of Winslow 1997a). Limited Residential areas encompass land within 250 ft of the shore that is suitable for less-intensive development and include areas not covered by Stream Protection or Resource Protection (Town of Winslow 1997a). Resource Protection includes land within 250 ft of water where development would adversely affect water quality, and is comprised of wetlands and other sensitive areas (Town of Winslow 1997a). In Resource Protection areas, most types of development are expressly forbidden, but the construction of a single-family residential unit may occur with a special permit from the planning board (Town of Winslow 1997a). In all shoreline areas, conversion of a seasonal home to a year-round residence requires a special permit from the planning board (Town of Winslow 1997a). The minimum lot size for residences in shoreland areas throughout Winslow is two acres, with a shoreline and road frontage of at least 200 ft. The code also requires a setback of 100 ft from the normal high water line for all buildings and roads (Town of Winslow 1997a).

Many of the properties surrounding Pattee Pond have legally non-conforming (i.e., grandfathered) buildings and lots. If a non-conforming structure is being renovated or altered significantly, it must adhere to the 30 percent expansion rule (MDEP 2003c). The 30 percent rule stipulates that structures may not be expanded by more than 30 percent in either floor area or the volume, and that the renovation cannot increase non-compliance by expanding further towards





**Figure 17.** Town of Winslow shoreland zoning districts in the Pattee Pond watershed. Limited residential areas are zoned for minimal development within 250 ft of the shore. Resource protection areas include wetlands and other sensitive land within 250 ft of the shore where development is prohibited except by special permit from the planning board. Stream protection areas extend 75 ft from the water.

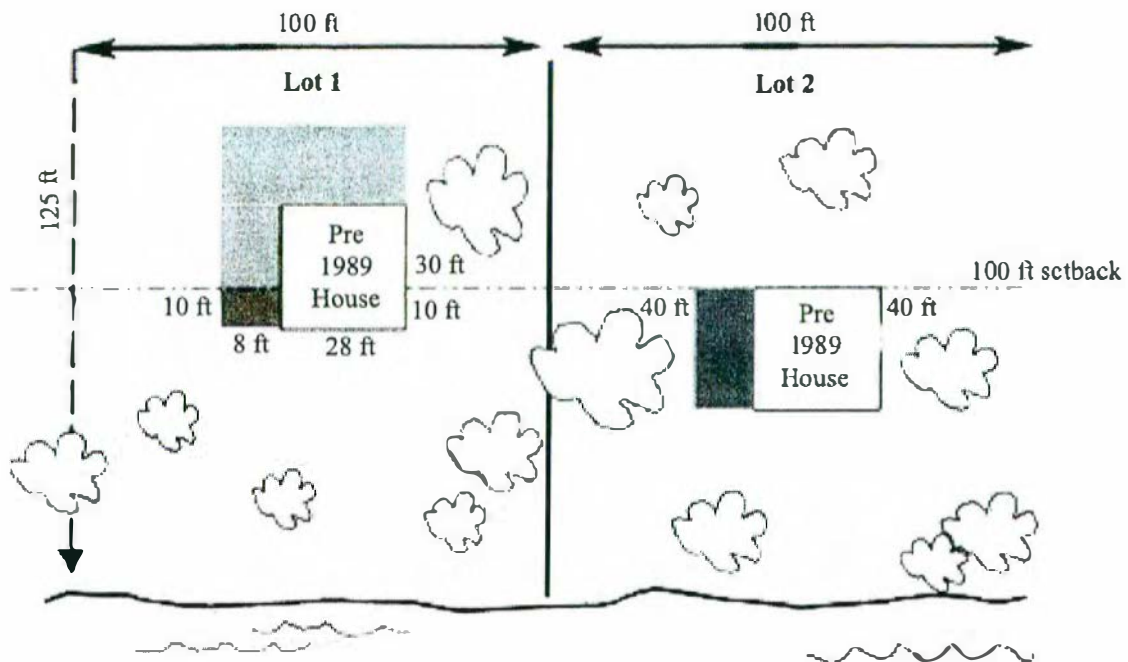


shore. This restriction only applies to the area of a structure that does not comply with the 100 ft setback (Figure 18). To be granted the right to expand at all, the lot must be at least 125 ft deep and 100 ft wide, with at least 15,000 sq ft of total property area (Town of Winslow 1997a). These regulations are designed to protect water quality, limit heavy development, and reduce phosphorus loading.

### Seasonal Residential Zoning

In addition to its Shoreland Zoning, Winslow has created a zoning district that surrounds Pattee Pond, called the Seasonal Residential District (see Appendix C). The Seasonal Residential District encompasses areas designated as Limited Residential under the Shoreland Zoning ordinances. Shoreland Zoning rules apply within 250 ft of the water, while the SRD extends further back from the waterfront along the camp roads. The Town of Winslow created the SRD specifically to improve water quality in Pattee Pond (Town of Winslow 1997a). The majority of the lots in the SRD are already developed with small shoreline seasonal residences, although some remain undeveloped (Town of Winslow 1997a). The minimum lot size in the SRD is two acres; with a lot width of 200 ft and depth of 250 ft. There are some undeveloped lots that do not meet these requirements because they were delineated before 1989, but those lots may not be developed. Structures on SRD lots must be at least 400 sq ft in area with a maximum height of 35 ft (Town of Winslow 1997a).

Residences in the SRD are designated as seasonal in almost every case, meaning that they may only be occupied between the first of April and the first of December (Town of Winslow 1997a). However, occasional overnight use in the off-season is permitted to allow for activities such as ice fishing. In the late 1980s and early 1990s, the Town of Winslow began to strictly enforce the seasonal home regulation (Stankevitz, pers. comm.). Several year-round residents were evicted from shoreline residences that were designated as seasonal, and now only five legitimate year-round homes remain on the Pattee Pond shoreline (Stankevitz, pers. comm.). Homes may be converted from seasonal to year-round only on the basis of a conditional use permit from the Town of Winslow planning board. Any lot considered for conversion must meet the minimum size requirements of the SRD (Town of Winslow 1997a). The SRD is effective in



**Figure 18. Legally non-conforming homes may be expanded with special permission if the lot is at least 100 ft wide and 125 ft deep. The home may not be expanded by more than 30 percent in either volume or floor area. Thirty percent expansion guidelines apply only to the portion of the structure that does not comply with the 100 ft setback from the lakeshore. Expansions may not increase the non-compliance of the structure by extending towards the lake. Lots must be at least 200 ft wide and 250 ft deep for new construction to take place. (Modified from MDEP 2003c).**

limiting development in the immediate vicinity of Pattee Pond and in restricting expansions of shoreline seasonal residences.

### Rural District

The majority of the Pattee Pond watershed is currently zoned as the Rural District, which is designed to limit development and protect the rural character of the Winslow countryside (Town of Winslow 1997a). Rural zoning provides for some residential and commercial development, but is mainly focused on the protection of open space and agricultural land. These zoning goals benefit the watershed as a whole by limiting impervious surfaces and encouraging open space, although agricultural land can contribute a large amount of phosphorus to a lake (see Phosphorus Model). Minimum lot sizes in the Rural District are the same as those in the Seasonal Residential District, with a two-acre minimum and 200 ft lot width (Town of Winslow

1997a). Compared with the more dense zoning districts and heavily-built areas that surround the Kennebec and Sebasticook Rivers in Winslow, the Pattee Pond watershed is more rural and sparsely populated, with fewer roads and houses. The moderate development in the watershed helps to mitigate stormwater runoff and ultimately maintains the quality of the lake water.

## **Methods**

To examine the development patterns in the watershed, CEAT performed a house count throughout the watershed and recorded information about each lot from property cards. In the CEAT shoreline and road counts, residences were classified as shoreline (within 250 ft of the water) or non-shoreline (more than 250 ft from the water), and as seasonal or year-round. Homes were considered to be year-round residences if they had enclosed basements, chimneys, visible oil tanks or woodpiles, or other evidence of year-round use. Seasonal residences were identified by a lack of winterization, by being closed for the season, or by being identified as seasonal homes along the shoreline by local residents (Whitaker, pers. comm.).

On 15-Sep-08, a road survey was conducted that included a residence count. CEAT members drove the roads within the watershed and counted residences, classifying them as shoreline or non-shoreline and as seasonal or year-round. To ensure an accurate shoreline count, CEAT also surveyed residences from the water during the buffer strip survey. The shoreline survey residence count was conducted on 22-Sep-08. In the development analysis, CEAT used the shoreline house count from the shoreline survey and the non-shoreline house count from the road survey to obtain the accurate number of residences in the watershed.

Along with residence counts, CEAT gathered additional specific information about the lots within the watershed from property cards held in the town offices. CEAT visited the town offices of Winslow, Vassalboro, China, and Albion on several occasions throughout September and October of 2008 to record information from property cards and related databases. The majority of the watershed is located in Winslow, with smaller sections in the other three towns (see Figure 7). The most detailed descriptions were found in the Town of Winslow office, where CEAT collected information on building type and size, sewage disposal systems, and property acreage. Property card lot counts were used in analyses of undeveloped lots and building types throughout the watershed.

## Results and Discussion

Along the shoreline (within 250 ft of the high-water line), CEAT identified 105 seasonal residences (95.5 percent) and five year-round residences (4.5 percent; Table 9). The vast majority of non-shoreline residences are year-round homes, with 361 year-round (94.8 percent)

**Table 9. House count data from the 15-Sep-08 road survey and the 22-Sep-08 shoreline survey in the Pattee Pond watershed. Shoreline homes are within 250 ft of the shore while non-shoreline homes are in the rest of the watershed. Seasonal homes were identified by a lack of winterization, open foundations, or apparent closure for the winter.**

Location	Seasonal	Year-Round	Total
Shoreline	105	5	110
Non-Shoreline	20	361	381
Total	125	366	491

and only 20 seasonal (5.3 percent) homes (Table 9). Overall, shoreline residences accounted for 22.9 percent of all homes in the watershed. Two commercial properties are located on the shoreline of Pattee Pond: Camp Caribou and Giordano's Market and Campground. Because of their heavier use, these businesses likely contribute more phosphorus to the lake than individual private seasonal residences (see Phosphorus Model).

CEAT surveys revealed extensive development along the shoreline of Pattee Pond, mainly consisting of small seasonal residences. Based on our research using property cards, CEAT found that the vast majority of shoreline homes are legally non-conforming lots and structures because they were constructed before the current zoning regulations were put into effect in 1989. The high density of structures situated extremely close to the Pattee Pond shoreline negatively impacts water quality because inadequate buffer strips do not prevent runoff from reaching the lake (see Buffer Strips). Small lots and structures close to the water also present challenges for adequate subsurface wastewater management because there may not be enough space on the lot for a septic system. Disposal of gray water, which is waste from showers, sinks, and laundry machines, is also an issue along lakeshores because waste from these sources may contain phosphorus (see Subsurface Wastewater Disposal Systems).

The shoreline of Pattee Pond is approximately 6.3 miles in length. Density of shoreline development along the entire shore is 17.5 homes per mile of shoreline. The total shoreline



residential density of Pattee Pond is comparable to those of Webber Pond, Togus Pond and Threemile Pond, with 16.6, 17.9, and 20.5 homes per mile, respectively (Table 10). Within the length of the shoreline, there are particular stretches that are more densely developed. Wetlands and resource-protected areas prevent development of some sections of the shoreline. There are only two undeveloped lots greater than two acres on the shoreline of Pattee Pond that are not in wetlands, meaning that new development on the lakefront is limited. The remaining undeveloped lots larger than two acres along the shoreline are located in the Resource Protection shoreland area and require special planning board permits for construction to occur. There are also a few undeveloped lots smaller than two acres on the shore that cannot be developed because they do not meet minimum requirements. However, lots could be merged to meet minimum lot size restrictions.

The developed section of the eastern side of the lake, stretching from Robin Lane to Brown Trout Road, has a residential density of 29.6 homes per mile of shoreline. Along the western side, development is more than twice as dense, with a density of 64.8 homes per mile in the section between Pickerel Point Road and the end of White Fish Road. Extensive development on this stretch of the lakeshore is particularly problematic because of the steep slopes in the area. Compared to other similar local lakes, Pattee Pond is much more densely developed because a large percentage of the shoreline is wetlands included in the Resource Protection District, which prevents most development. Approximately 50 percent of the Pattee Pond shoreline is undeveloped, while approximately 30 percent of the shorelines of Webber Pond, Togus Pond, and Threemile Pond remain undeveloped. Each of these ponds has a total residential density similar to Pattee Pond, but the development is spread around the lakeshore more evenly (Table

**Table 10. Shoreline (within 250 feet of the shore) house counts and shoreline residential density in houses per shoreline mile for selected Maine watersheds (CEAT 2003, CEAT 2004, CEAT 2005, CEAT 2006).**

Lake	Number of Shoreline Homes	Residential Density (homes/mile shoreline)
Webber Pond	153	16.6
Pattee Pond	110	17.5
Togus Pond	184	17.9
Threemile Pond	203	20.5
East Basin of China Lake	472	30.2

10). The areas of dense development on the east and west shores of Pattee Pond are of particular concern for their phosphorus loading impacts.

Throughout the non-shoreline areas of the watershed, development is less dense and is clustered along a few state and municipal roads. Many of the non-shoreline lots are larger than those located along the shoreline. Based on the CEAT road survey, there are 14 commercial properties throughout the watershed, accounting for two percent of the lots in the Pattee Pond watershed. Residential lots identified during CEAT road and shoreline surveys represent 68 percent of the total properties. Lots that are undeveloped or only have sheds on them comprise 30 percent of the lots and represent land that could be developed in the future. The mean age of buildings in the Winslow section of the watershed is 42 years, or built in 1966. Many buildings were constructed before the passage of strict environmentally-based zoning laws and now have grandfathered status. As every property potentially contributes to the health of Pattee Pond, utilizing proper environmental practices is extremely important. Each parcel of land would benefit from the implementation of best management practices to protect and improve water quality in Pattee Pond (see Mitigation Techniques: Best Management Practices).

Overall, CEAT found development to be fairly limited throughout the majority of the watershed, which helps to mitigate phosphorus loading in Pattee Pond. However, the large number and high density of shoreline seasonal residences does disproportionately impact the potential health of Pattee Pond and can contribute to algae blooms. This is especially the case for the densely developed stretches of shoreline along the east and west shores of the lake. Zoning regulations in Winslow currently help to protect water quality in Pattee Pond and the proposed new zoning laws will strengthen protection strategies (see Future Projections: Development). To further improve the health of Pattee Pond, the Town of Winslow should work with landowners to mitigate the impacts of legally non-conforming properties on the lake by implementing best management practices. The Town of Winslow and the Pattee's Pond Association have made a concerted effort to protect water quality in Pattee Pond by limiting development and improving existing lots. This effort has resulted in the trend of improving water quality in the last several years.

## Soil

Soil characteristics play a critical role in determining how developmental decisions within a watershed can affect the nutrient and sediment loading of the lake. Soils are categorized by texture and parent material (Barnes et al. 1998). The soil texture refers to particle size and can be determined by finding the relative amounts of sand, silt, and clay within the soil. Sand is the largest particulate component of soil with a size of 0.05 to 2 mm, and clay is the smallest with a size of less than 0.002 mm (Brown 1990). The sizes of the particles within a soil influence the rate and extent to which water and nutrients drain. Sand has a relatively low surface area to volume ratio, so the attractive forces between water and soil particles are not able to hold water in the soil as effectively, causing fast and extensive drainage. Clays, on the other hand, compact more easily and have a very high surface area to volume ratio, so water and nutrients can not drain as quickly (Barnes et al. 1998). Since it takes longer for water to seep through clay sediments, more of it drains downhill along the surface. This allows for a higher percentage of water falling on these types of soils to become runoff which brings nutrients and sediments into the lake.

Using data obtained from the Natural Resources Conservation Service (NRCS), eleven soil series were identified within the Pattee Pond watershed (USDA 1978). They are the Buxton, Biddeford, Hollis, Monarda, Paxton, Ridgebury, Saco, Scantic, Scio, Togus, and Woodbridge series. Buxton, Biddeford, Scantic, Saco, and Scio soils developed out of fine sediments deposited by marine or lacustrine systems along the coastline or in river valleys. Hollis, Monarda, Paxton, Ridgebury, and Woodbridge soils were all formed from glacial till and are found in areas of Maine that experienced glaciation. Finally, Togus soils were formed from decomposing organic materials above a sandy mineral material, and are often found among bogs and lakes (NRCS 2008).

When particles of different sizes mix in significant quantities within one of the main soil series, they create what is known as a loam (Barnes et al. 1998). The extent to which each particle size is present in the mix determines whether the resulting soil is a silty loam, fine sandy loam, or similarly descriptive loams. Each soil type has a unique rate of drainage, permeability, and surface runoff that can affect the rate and degree of eutrophication that Pattee Pond

experiences (Brown 1990). These unique variations of the eleven originally identified soil series created seventeen distinct soil types found within the Pattee Pond watershed.

The seventeen soils found in the Pattee Pond watershed are well distributed, with several large concentrations of Hollis, a very well drained soil with minimal runoff, along the western side of the watershed and Hollis-Rock Outcrop in the center of the watershed (Figure 19; NRCS 2008). The soil names shown have been abbreviated, but can be seen in their entirety in Appendix D.

## **Erosion Potential Model**

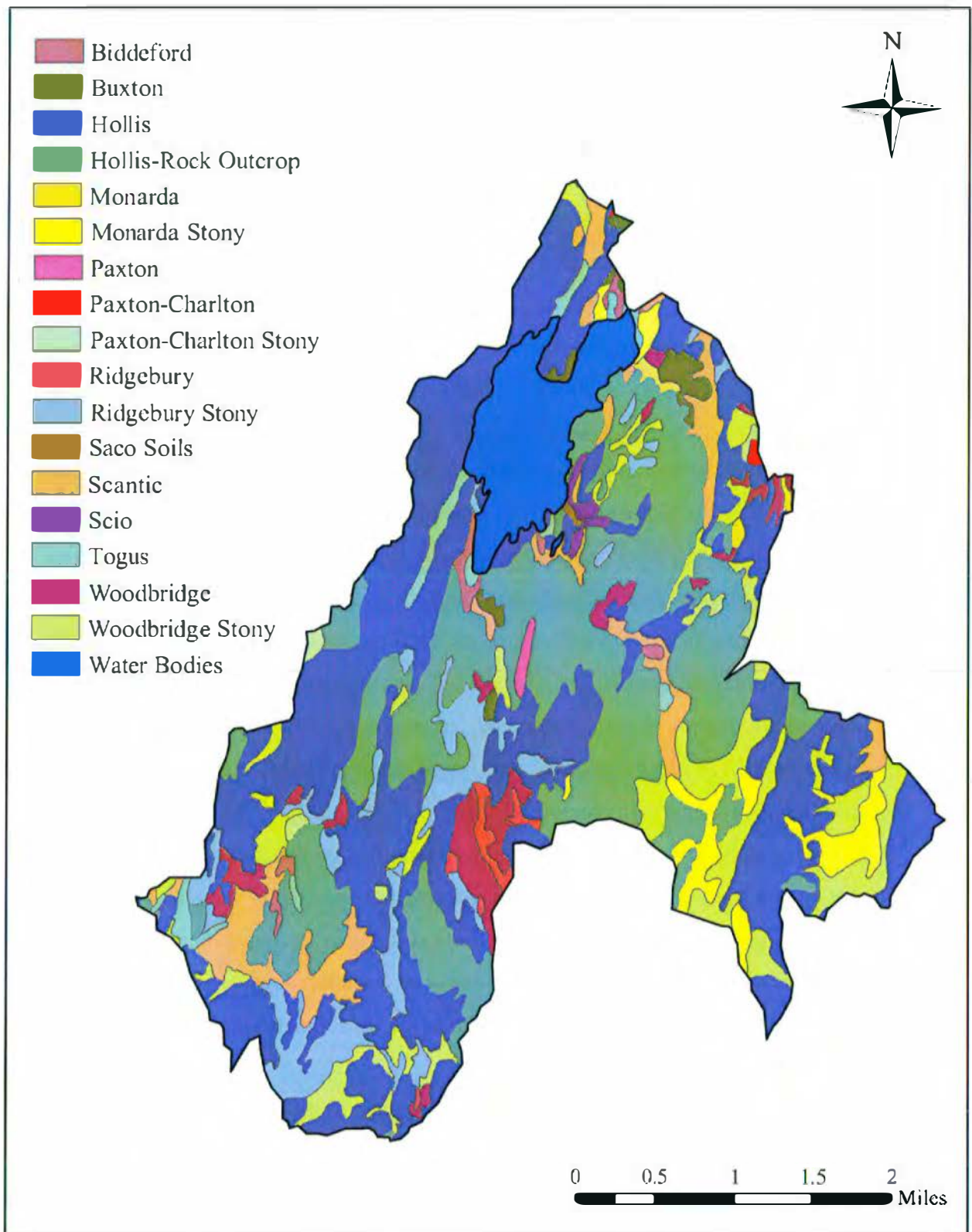
### **Introduction**

Erosion is defined as the gross amount of soil moved by raindrop detachment or runoff (Barrow 1991). In the United States, this type of erosion moves over three billion metric tons of soil per year (Brady 1990). Eroded sediment can find its way into streams, rivers, and ultimately lakes carrying with it nutrients, pathogens, and chemicals. The result of this loading is typically an increased eutrophication rate. Because soil erosion can lead to faster eutrophication, it is essential that potential erosion and, if necessary, appropriate remediation be considered when building within the Pattee Pond watershed. To get an idea of the potential for soil erosion within this watershed, CEAT examined soil type, slope, and land use, the three landscape characteristics contributing most heavily to erosion.

The effect of slope on soil erosion stems from its effect on the flow rate of surface water. Water flowing over a steeper topography will have a greater speed than water flowing over more-level topography. Any surface water flow can erode soil, but as its speed increases, surface water gains momentum and, consequently, more power to carry sediment. Moreover, greater momentum facilitates the ability of surface water flow to break up soil aggregates into smaller, more-easily-carried bits of sediment (Brady 1990).

The effect of land use on soil erosion is related to the properties of the vegetation and man-made structures associated with each specific use. A greater amount of canopy and vegetation cover reduces erosion by decreasing the intensity with which rain hits the soil. A deeper, more extensive network of roots prevents aggregate break-up and hinders the ability of surface water flow to carry soil away. Land with impervious surfaces, such as parking lots,





**Figure 19.** Major soil types and their distribution within the Pattee Pond Watershed (USDA 1978).

prevents nutrients and chemicals that are washed up onto it during rainstorms, blown onto it on a windy day, or carried onto it by humans from being absorbed into and filtered through soil. This amplifies erosion-based loading by accumulating those nutrients and chemicals until surface water flow washes them into or closer to the lake.

Both slope and land use affect soil erosion, but soil type is a slightly more potent actor (Morgan 2005). Research has shown that the potential for erosion is most affected by the variances of structure, aggregate stability, and shear strength (the measure of soil cohesiveness and resistance to gravity, moving fluids, and mechanical loads). The soils least resistant to erosion are fine sands and silts, and the soils most resistant to erosion are those with large particles and a high content of base minerals.

## **Methods**

### Soil

Erosion characteristics of the different soil types within the Pattee Pond watershed were obtained in the form of k-factor values from the Soil Survey Geographic Database (SSURGO) provided by the Natural Resource Conservation Service (NRCS 2008).

The k-factor is a representation of soil erodibility based on the measure of soil surface roughness on a scale of 0.00 to 0.69, with higher k-factors representing an increased vulnerability to soil erosion (Barrow 1991). To use these data for the erosion potential model, it was necessary to fit them to a whole-integer scale of 1 to 9. CEAT fit the k-values to this scale by entering them into this formula:

$$\text{scaled k-factor} = (\text{raw k-factor} \times 11.6) + 1$$

Using the resulting values, a raster image was created for the varying soil types in Pattee Pond watershed.

### Slope

Because slope can have a considerable effect on erosion, CEAT incorporated it into the erosion potential model. This was performed by obtaining DEM (slope) raster images of 10 m by 10 m plots of the Pattee Pond watershed from the Maine Office of Geographic Information Systems (MEGIS 2008). ArcGIS 9.2® was used to convert these raster images into slope

percentages. As with the soil type k-factors, the varying slopes in Pattee Pond watershed were reclassified into nine categories (see Figure 9). These categories were assigned in accordance with the relationship between slope and erodibility—erodibility increases with slope on a negatively convex curve (Morgan 2005).

## Land Use

To employ the ascertained land use data in the erosion potential model, it was necessary to break up the fifteen land use types (see Land Use Types of Pattee Pond Watershed) into nine categories and rank them in order of erosion potential. After much deliberation on the properties of these land use types and a careful review of the phosphorus-loading coefficients attributed to

**Table 11. Land use types and their erosion potential rankings on a scale of 1 (low erosion potential) to 9 (high erosion potential).**

Land Use Type	Erosion Potential
Commercial	9
Cleared	8
Logged Land	7
Recreational	6
Residential	5
Crop	4
Pasture	4
Regenerating	3
Reverting	3
Transitional	2
Tree Farm	2
Deciduous	2
Coniferous	2
Mixed	2
Wetland	1

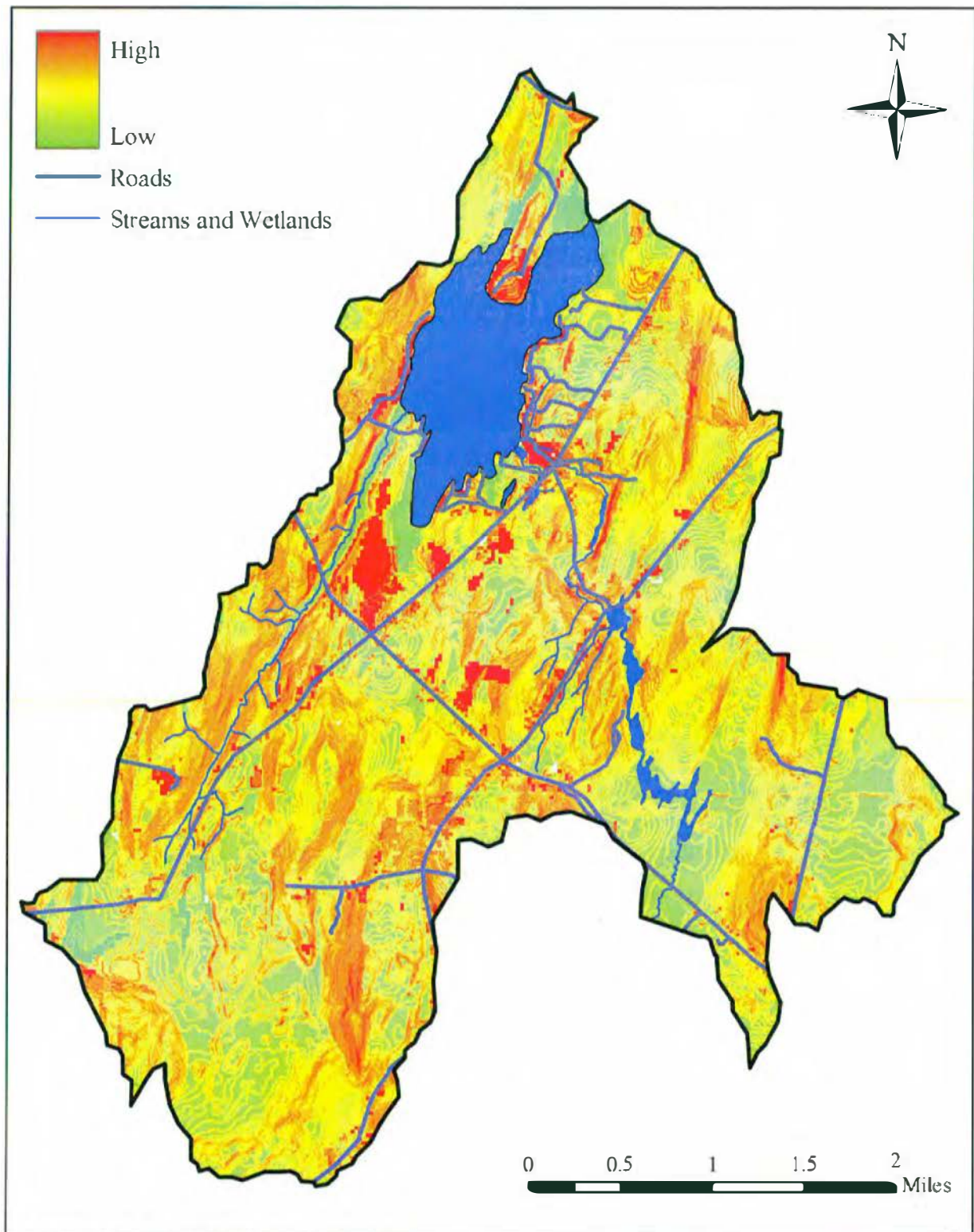
them by the Maine Department of Environmental Protection in past Total Maximum Daily Load reports (MDEP 2001a, MDEP 2001b, MDEP 2003d), the groupings and rankings were elected (Table 11). These data were then reclassified in a raster image to reflect the re-grouping and ranking.

## Results and Discussion

The final result of this weighted overlay was a map displaying the erosion potential for 10 m by 10 m plots in the Pattee Pond watershed (Figure 20). The map indicates that the watershed shares an almost even split between low erosion potential areas, indicated by shades of green, and mild and high erosion potential areas, indicated

by a scale shaded from yellow to red, respectively. It is important to note that in this map, erosion potential is separated by unequal increments that are categorized by standard deviations from the mean. This method shows a greater distinction between areas appropriate for unremediated development and those that are not than an equal increment-based categorization.





**Figure 20.** The erosion potential map of Pattee Pond watershed indicates the erodibility of land within the Pattee Pond watershed and the proximity of that land to major streams. Created using ArcGIS 9.2, this map is the result of a weighted overlay of slope (30%), land use (30%), and soil type (40%) layers.



One specific area that may need to be considered for mitigation is the large peninsula at the northern end of the lake, which shows a mild to high erosion potential (Figure 20). The central-eastern shore of Pattee Pond also demonstrates a high erosion potential. Another area of concern is along the eastern shore of Bellows Stream in the central-western section of the watershed, near the southern tip of Pattee Pond.

It is worthy of note that while areas of higher erosion potential are less suitable for development and human activity, mitigation techniques exist to permit such endeavors to proceed with reduced impacts (see Mitigation Techniques).

## **Erosion Impact Model**

### **Introduction**

While the Erosion Potential Model examined the vulnerability of land within the watershed to development, the Erosion Impact Model used those data in conjunction with information concerning proximity to Pattee Pond and its tributaries to create a more specific map outlining areas of the watershed that potentially pose the biggest threats to the health of the lake. If an area is moderately erodible based on soil type, land use, and slope, but is located adjacent to Pattee Pond, it is likely to be more capable of negatively influencing water quality than a highly erodible area that is located along the watershed boundary. For this reason, land that is located near the pond or along a tributary that will ultimately feed into the pond must be considered more capable of leading to sediment and nutrient loading.

### **Methods**

The Erosion Impact Model relies on three separate data sets. The first data set consists of erosion potential. This information had already been compiled and calculated to create the Erosion Potential Model (see Figure 20). The second data set refers to the proximity of a given area of land within the watershed to Pattee Pond. To acquire this, the lake was isolated and nine concentric zones were created with increasing distance from the lake within the watershed boundary. The first zone included all land within 250 ft of the lake. The distance between that boundary and the furthest point in the watershed was then divided into eight zones of equal width. These eight zones measured approximately 2500 ft wide. They were then assigned impact

values from one to nine with nine being the zone closest to the lake and one being the zone furthest from the lake. This numbering system ensured that areas closest to Pattee Pond, and most capable of influencing water quality, were weighted more heavily in the model.

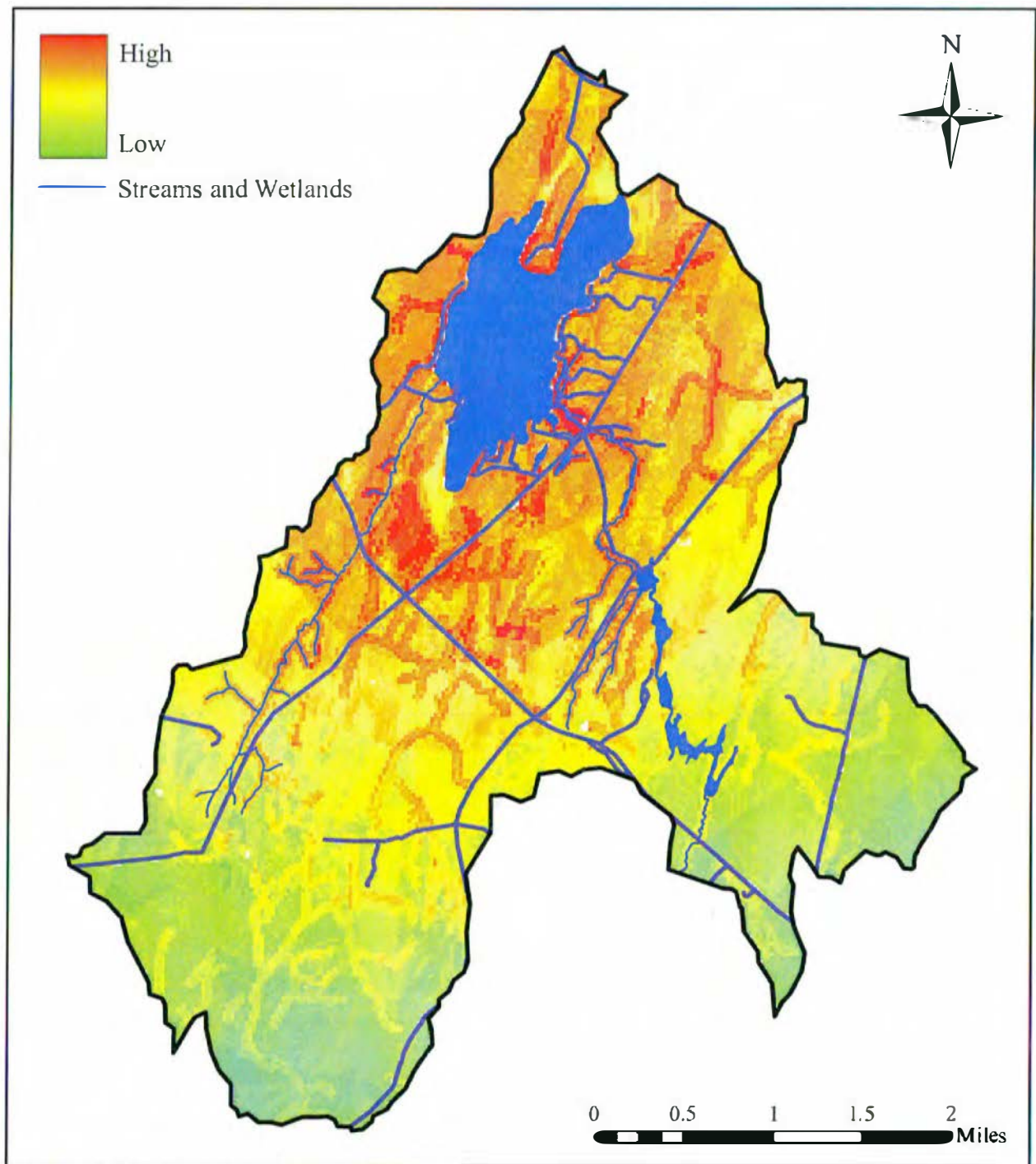
The final data set accounts for proximity to tributaries that could provide an avenue for sediments and nutrients to move from eroded soils into the lake. Just as was done with Pattee Pond, all stream systems were isolated and a buffer of 75 ft was created around them. All land found within this boundary was assigned an impact value of eight, and all land falling outside this buffer was assigned an impact value of zero. The value of eight was chosen because the extreme proximity to the streams makes the soil particularly susceptible to erosion, but it is still not a direct input to the lake as the 250 ft buffer around Pattee Pond is. These newly created buffer layers were then converted to raster data.

Once these three aspects were created, they were weighted to reflect their relative importance and combined to create the erosion impact map. Since erosion potential is an important factor in the impact of erosion on the lake, it was given a weighting of 50 percent. Because nutrients and sediments are still able to settle out of waterways or be taken up by macrophytes between their entry point into a stream and the point at which that stream empties out into Pattee Pond, proximity to tributaries was given a weighting of only 10 percent, while proximity to the lake was given a weighting of 40 percent since it poses such an immediate and direct threat to the lake.

The resulting map was separated by unequal increments that are categorized by double standard deviations from the mean. This method shows a greater distinction between areas of high concern and those that are not than an equal increment-based categorization.

## **Results and Discussion**

Areas immediately surround Pattee Pond have a high potential to affect the lake through erosion (Figure 21). As distance from the lake increases, erosion risk diminishes significantly to virtually zero along the southern boundary of the watershed. This reduced threat is denoted by the lighter yellow shade. All waterways create an elevated risk of erosion, but that potential impact on the lake diminishes as the distance that those sediments need to travel downstream to



**Figure 21.** Impact of erosion map for the land within the watershed of Pattee Pond. Susceptibility of erosion is calculated using ArcGIS 9.2 by overlaying three layers; the Erosion Potential Model weighted to 50 percent, proximity to Pattee Pond weighted to 40 percent, and proximity to streams that can provide an access to the lake weighted to 10 percent (see Figure 20). Areas where the impact of erosion is highest are denoted by dark red coloration and areas where erosion will likely not severely impact the lake are denoted by a deep green color.



the lake increases. Land surrounding Farber Brook shows an elevated risk of erosion and will require more specific attention. CEAT observations verified these projections with stream samples taken after rainfall events. Farber Brook contributes considerable amounts of sediments and nutrients into the lake after rain runoff enters into the brook from this vulnerable area (see Chemical analysis: Total Phosphorus). Areas around Bellows Stream are also particularly vulnerable to erosion. This is especially dangerous considering the easy access eroded sediments have to Pattee Pond through the stream. Sediment and phosphorus loading may be significantly affecting the lake at this entry point (Whitaker pers. comm., Fleury pers. comm.).

## **Subsurface Wastewater Disposal Systems**

### **Introduction**

Subsurface wastewater disposal systems are important because they are mechanisms for safely disposing of gray water (liquid waste from sinks, showers, and laundry machines) and black water (waste from toilets). This wastewater may contain phosphorus, nitrogen, and pathogens, which can be a threat to the environment and human health (EPA 2002). If wastewater is disposed of improperly, these pollutants can leach into groundwater and surface waters causing eutrophication of water bodies and contamination of drinking water. People rely on subsurface wastewater disposal systems to reduce the impact of wastewater pollutants on water quality (EPA 2002). Three common types of subsurface wastewater disposal systems are septic systems, holding tanks, and pit privies (see Background: Subsurface Wastewater Disposal Systems). Over 50 percent of Maine residents rely on septic systems and holding tanks for sewage disposal and the rest of the residents use city or town sewer systems or alternative means of disposal (EPA 2002). The type of disposal system used on a particular site is based on various factors such as lot size and location. Septic systems are suitable for lots with sufficient space for a disposal field whereas holding tanks are ideal for small lots in environmentally sensitive areas (EPA 2002).

### **Regulations**

The majority of properties in the Pattee Pond watershed are located in Winslow, ME. Winslow has adopted the Maine Subsurface Wastewater Disposal Rules as the official town



plumbing code (Stankevitz, pers. comm.). These rules provide siting and design requirements for subsurface wastewater disposal systems (MRSA 2005). According to these rules, a state licensed site evaluator decides which type of disposal system will be suitable for a property based on setback distances, soil condition and profile, location, slope, elevation, and design flow. The site evaluator must also consider the proximity of the property to a water body (MRSA 2005). Properties that are within 250 ft of a major body of water are in the shoreline zone and have different system design requirements because they have a more direct impact on water quality than properties outside this zone. Shoreline properties have a setback distance of 100 ft for a disposal field from the water's edge to prevent wastewater pollutants from flowing directly into the waterbody without filtration (MRSA 2005). Once a site evaluator has determined the appropriate type of subsurface wastewater disposal system, a permit may be obtained from a town licensed inspector. Inspections are performed by the town plumbing inspector after site preparation and after system installation to ensure that the system is in compliance with the Maine Subsurface Wastewater Disposal Rules (MRSA 2005). The current rules regarding wastewater disposal systems were enacted on 01-Jul-74. Once these rules were adopted, many existing properties in Maine no longer met the system requirements (MDHHS 2003). Properties existing prior to 01-Jul-74 were "grandfathered", which means that they were allowed to continue to exist without modifying their disposal systems to meet the new standards. However, if a legally non-conforming disposal system malfunctions it must be replaced with a subsurface wastewater disposal system that complies with the new rules as closely as possible (MDHHS 2003).

## **Methods**

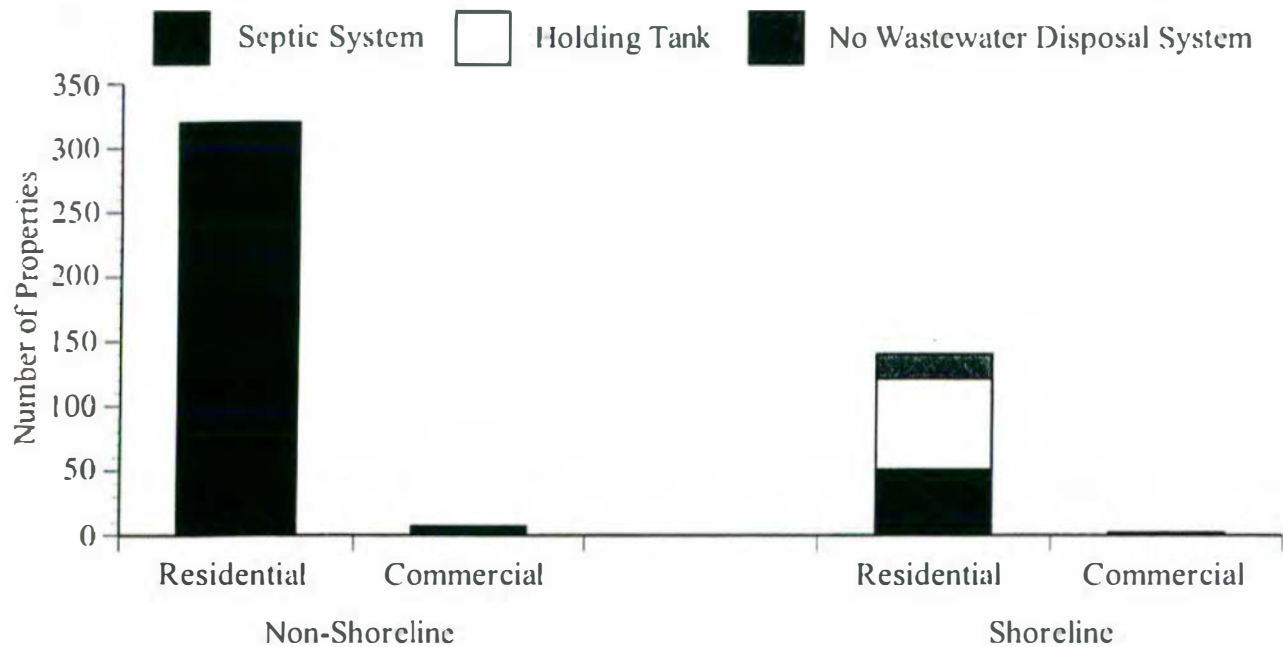
A shoreline survey was conducted by CEAT on 22-Sep-08 to determine the general characteristics of properties along the Pattee Pond shoreline. CEAT surveyors looked at the size and slope of the lots and the setback distance of the houses. This survey aided in the preliminary assessment of the types of subsurface wastewater disposal systems found on lake properties. Using tax maps obtained from the Winslow Town Office, members of CEAT then determined which properties were located in the Pattee Pond watershed. Shoreline properties (within 250 ft of Pattee Pond) and non-shoreline (greater than 250 feet from Pattee Pond) properties were

identified on the tax maps. Members of CEAT went to the Winslow Town Office to view property cards for each property in the Pattee Pond watershed. When information was available, the property type (commercial, residential, or land only), sewage utilities (holding tank, septic system, or no system), and the date of construction for residential properties was recorded. Interviews were conducted with the Winslow Code Officer, Mr. Frank Stankevitz, to determine his view of the history of subsurface water disposal systems in the Pattee Pond watershed.

## **Results and Discussion**

In general, the west side of Pattee Pond has a high density of fairly steep small lots that are close to the edge of the water. Most of these shoreline properties appeared to have insufficient setback distances for disposal fields. The shoreline survey indicated that holding tanks, as opposed to septic systems, are more suitable for properties on the west side. Lots on the east side of the lake are generally larger and less steep, with residences that are set back from the edge of the lake. Many of these properties seem to be better suited for septic system use because they have adequate room for disposal fields. However, there were some small lots on the east side that probably use holding tanks.

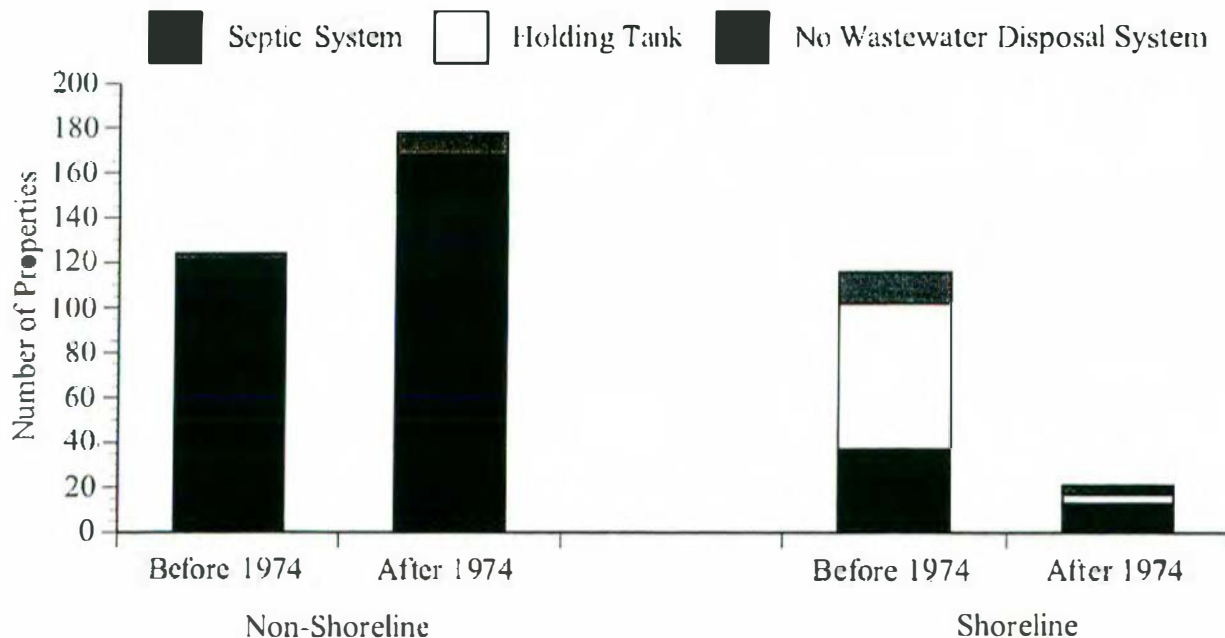
Sewage disposal data were available for 460 residential properties and nine commercial properties in the Pattee Pond watershed. Properties with no buildings (land only) were not taken into consideration because they do not contribute wastewater. For non-shoreline properties, data were obtained from the property cards for 327 commercial and residential properties. There were 142 commercial and residential shoreline properties with sewage disposal data available on the property cards. Of the 327 non-shoreline properties, there were 309 with septic systems (94.5 percent), one with a holding tank (0.3 percent), and 17 with no wastewater disposal systems (5.2 percent). For shoreline properties, there were 53 with septic systems (37.3 percent), 70 with holding tanks (49.3 percent), and 19 with no wastewater disposal systems (13.4 percent). There were 320 residential and seven commercial non-shoreline properties with available sewage disposal information and 140 residential and two commercial shoreline properties with available information. Members of CEAT analyzed the different types of sewage disposal systems found at these properties (Figure 22).



**Figure 22. Types of subsurface wastewater disposal systems for commercial and residential properties in the Pattee Pond watershed. Data are from the Town of Winslow property cards for 327 non-shoreline and 142 shoreline properties.**

For residential properties, 439 had the date in which the house was built on the property card. For non-shoreline properties, 124 houses were built before 1974 and 178 were built after 1974. There were 116 shoreline houses built before 1974 and 21 houses built after 1974. Homes built before 1974 could have been grandfathered into the current Maine Subsurface Wastewater Disposal Rules. Members of CEAT used these data to determine the number of houses built before and after 1974 with each type of disposal system (Figure 23).

Prior to the implementation of the Maine Subsurface Wastewater Disposal Rules in 1974, there were more holding tanks, cesspools, and pit privies found on non-shoreline properties in the Pattee Pond watershed. Cesspools and pit privies are inexpensive and low maintenance disposal systems that contribute to water contamination (EPA 2002). Though some non-shoreline properties were grandfathered, almost all of the legally non-conforming systems have malfunctioned and have been forced to upgrade to be in accordance with the current Maine Subsurface Wastewater Disposal Rules (Stankevitz, pers. comm.). Today, most of the non-shoreline properties with sewage utilities have efficient septic systems (Stankevitz, pers. comm.).



**Figure 23. Types of subsurface wastewater disposal systems for “grandfathered” residential properties in the Pattee Pond watershed. Data is from the Town of Winslow property cards for 302 non-shoreline and 137 shoreline residences.**

Non-shoreline and shoreline properties that had been identified as having no subsurface wastewater disposal systems are residences known as “day camps” where owners are not allowed to stay overnight (Stankevitz, pers. comm.).

Most of the shoreline properties in the Pattee Pond watershed have holding tanks because the houses are in close proximity to the lake. The shoreline properties with septic systems have suitable disposal field setback distances and slopes.

Many of the properties on the lake were built before 1974 and were grandfathered. Most of the legally non-conforming systems have failed since 1974 and many were replaced with holding tanks instead of septic systems because holding tanks are more suitable for shoreline lots (Stankevitz, pers. comm.). An issue of concern for shoreline residences is the disposal of gray water. Though gray water has little solid waste, it often contains phosphorus and other pollutants that can leach into the lake if disposed of improperly. Like black water, gray water needs to be treated before it enters a waterbody to avoid potential environmental damage. Residents should pump gray water into their septic system or holding tank rather than directly into Pattee Pond.



Homeowners should also be encouraged to routinely check their wastewater disposal systems for leaks and cracks to prevent untreated wastewater from flowing directly into the lake.

In general, the condition of subsurface wastewater disposal systems found in the Pattee Pond watershed is good. Due to inspections and code enforcement, most failed systems have been replaced with those that comply with Maine Subsurface Wastewater Disposal Rules. This is important because better quality systems reduce the impact of wastewater on Pattee Pond.

## **Septic Suitability Model**

### **Introduction**

Studies have shown that septic effluent can leave unwanted nutrients and pathogens in surface and sub-surface soils of lake watersheds (Yates 1985, Zanini et al. 1998). These leachates eventually find their way into the lake, affecting its water quality as well as creating health risks for residents. The magnitudes of these effects are determined by the absorption characteristics of the soil in which a septic system rests (Canter and Knox 1986).

The two aspects of a septic system site that most affect soil absorption are soil type and slope (Canter and Knox 1986). To allow for good absorption of leachates (and less drainage into the lake), the soil at the site must have a slow percolation rate and the slope must be relatively flat. The percolation rate is the rate at which water drains through a soil and is defined by the texture and structure of that soil. Sandy soils with loamy textures and strong granular, prismatic structures are most desirable, whereas unstructured soils that are gravelly and cobbly with slowly permeable clay have poor percolation rates.

Slope greatly affects the rate of effluent runoff from septic system discharges. To provide for the best possible effluent absorption, a septic system should be positioned on a convexed plot with a gentle slope (Canter and Knox 1986, Morgan 2005).

Because soil type and slope have considerable effects on the septic-effluent-caused degradation of a lake, it is essential to the maintenance of Pattee Pond that these characteristics be taken into consideration when installing or renovating septic systems in the Pattee Pond watershed.

## **Methods**

CEAT incorporated both soil type and slope into the Septic Suitability Model. The same methods for gathering and manipulating soil and slope data were used for this model as were utilized in the creation of the Erosion Potential Model (see Erosion Potential Model: Methods). This data manipulation resulted in a raster image of slope with percentage values divided up into nine parts as well as raster image of soil according to k-factor values ranging from 1 to 9 (see Appendix C).

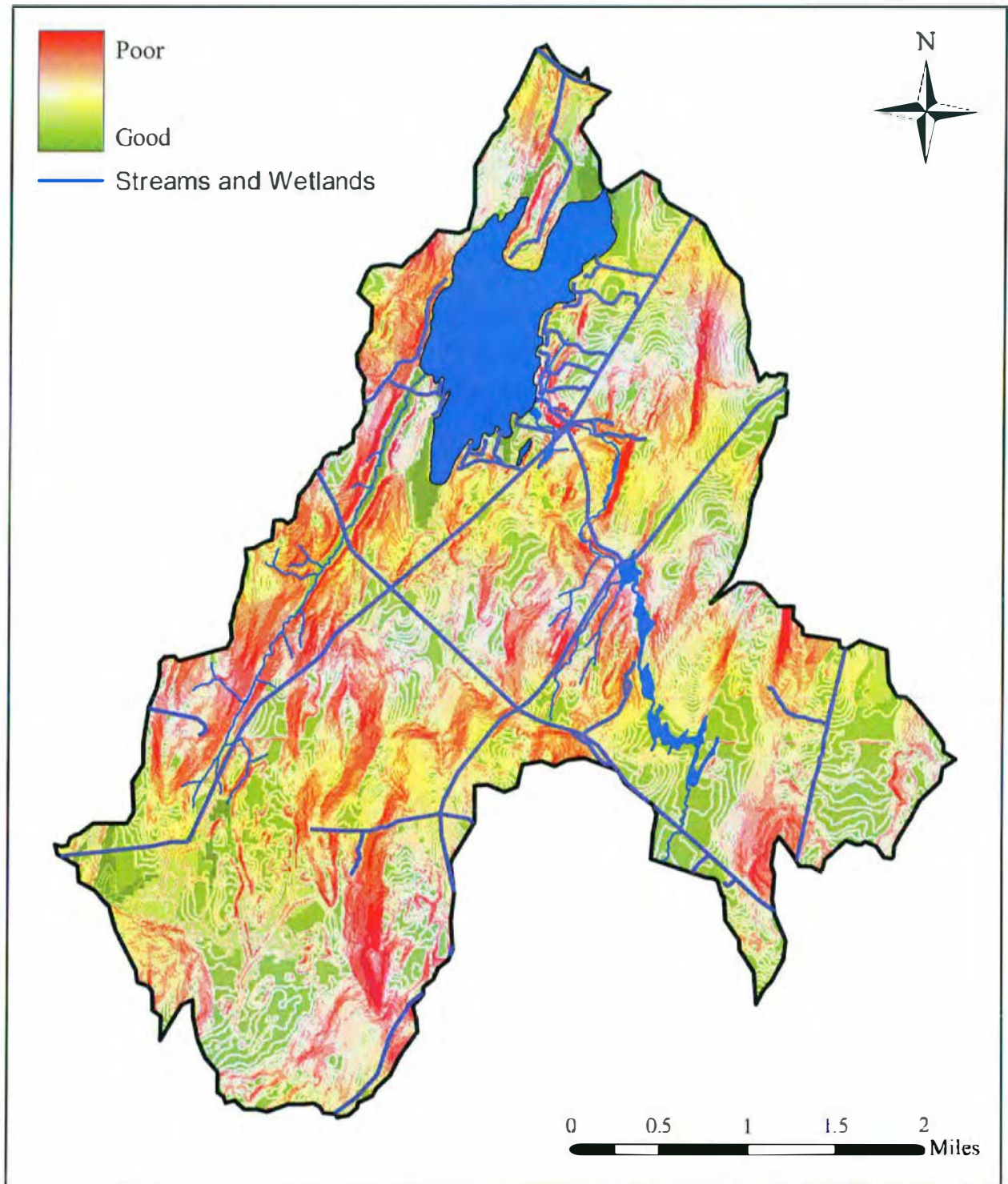
Slope and soil type appear to affect septic-caused lake degradation to similar degrees. With this in mind, an equal overlay model of the slope and soil raster images was created using ArcGIS 9.2<sup>®</sup>.

## **Results and Discussion**

The end result of the unweighted overlay of the manipulated slope and soil raster images was the Septic Suitability Map (Figure 24). This map depicts the appropriateness of building septic systems on specific 10 m by 10 m plots within the Pattee Pond watershed using a color spectrum ranging from green (best) to yellow (poor) to red (worst). It is important to note that in this map, septic suitability is separated by unequal increments that are categorized by standard deviations from the mean. This method shows a greater distinction between areas of concern and areas appropriate for septic system installment than an equal increment-based categorization.

A redder shade on a plot indicates that a more careful consideration of remediation measures during septic system installment or modification is necessary (Figure 24). Some plots may not have been scrutinized properly prior to the installment of current septic systems. These septic systems may require modification to keep effluent-based degradation of the lake to a minimum.

The majority of land tangent to Pattee Pond is well to fairly-well suited for septic system installment (Figure 24). The only exceptions to this prediction occur on the western and central-eastern shores of the lake, which likely require septic system remediation. The highest incidence of low eligibility for septic development was seen along Bellows Stream. Overall, about two thirds of the watershed appears to be well-suited for septic system installation and use, whereas



**Figure 24.** The septic suitability map indicates the ability of land in the Pattee Pond watershed to receive septic systems without remediation. Sites marked with colors shaded towards the red end of the spectrum have a lower septic suitability and may require more mitigation during septic system installation. Created using ArcGIS 9.2, this map is the result of an equally weighted overlay of slope and soil type data.



the remaining third, particularly along Bellows Stream, may require septic-system remediation if new systems are installed.

## **Buffer Strips**

### **Introduction**

Buffer strips are an essential component of any shorefront property, as they maintain lake health and decrease nutrient and sediment loading. They are composed of a mixture of trees, shrubs, groundcover, and semi-aquatic plants, and serve to hinder runoff containing sediments, chemicals, nutrients, and other pollutants from entering water bodies (Hardesty and Kuhns 1998). Each plant type plays a unique and important role in the filtering process.

Tall trees and shrubs comprise the canopy of the buffer and help slow the movement of precipitation and allow for evaporation or absorption. Plants at ground-level aid in purifying runoff that may contain nutrients, which will be taken up by their roots. A high density of plants near the water also maintains shoreline stability and reduces potential soil erosion (Dreher and Murphy 1996). Lakes with high residential densities will be more protected from degradation and eutrophication processes if well-constructed buffers are in place. Because of the many environmental benefits a buffer offers, environmental professionals recommend all residences adjacent to water incorporate buffer strips into their properties (USDA 2008). Information for the public about adequate buffer construction is available on-line at both the Maine DEP website and on the EPA website (Hardesty and Kuhns 1998).

Excessive sediment loading into a water body lowers water clarity, decreasing the depth of sunlight penetration, which is essential for plant growth (USDA 2008). Input of excess nutrients from lawn fertilizers, particularly phosphorus and nitrogen, stimulates aquatic plant growth, and leads to nuisance algal blooms (USDA 2008). Murky, green water makes a water body less attractive for recreational activities, which translates to decreased shorefront property values (USDA 2008). Buffer strips also afford property owners increased privacy, shade, and a noise barrier (Hardesty and Kuhns 1998).

An ideal buffer is inexpensive and uncomplicated to create (see Background: Watershed Land Use) While the first thought of a homeowner may be to cover their property in grass, this is



an ineffective method of buffering since surface area for water absorption is low, and grass requires much more maintenance than well-chosen, ground cover plant species (Hardesty and Kuhns 1998). Most plants suggested for use in buffering shoreline lots require little to no maintenance or fertilization once established and protect water quality without human effort. Vegetation comprising the buffer strip should run along the entire shorefront, with few or no man-made interruptions, such as paths, docks, or boat launches, and extend inland 75 ft if possible.

Steeper properties are more susceptible to erosion and have quicker runoff rates, so a dense buffer with many deep-rooted plants would be necessary. Paths leading down to the water should have a winding shape to avoid runoff channeling, and be composed of permeable material; wood chips or bark mulch are the simplest and most inexpensive options, and will allow for water to permeate into the ground (Dreher and Murphy 1996). If these simple recommendations are followed in designing buffer strips, damage to water bodies from human sources can be minimized (Hardesty and Kuhns 1998).

## **Regulations**

The Maine State Mandatory Shoreland Zoning Act provides several development restrictions for property owners to take into account. Cleared openings should not occur within the first 100 ft of land set back from the high water mark, and winding pathways cutting through these vegetated areas to the water should not exceed 6 ft in width (MDEP 2008b). Any selective cutting of canopy-layer species should not comprise more than 40 percent of the total vegetation on a property over a 10-year period. Maintenance of trees and shrubs ought to be minimal; trees should only be pruned in the lowest third of the trunk, and shrubs should only be pruned in such a way that promotes healthy plant growth and allows for water views. The final point is that natural vegetation indigenous to the area should be allowed to thrive in a buffer, and no vegetation removal can occur within 75 ft of the lake edge. Another component of the Shoreland Zoning Act that aids in lake protection are the zoning laws themselves, because houses must be set back from the high-water mark by 100 ft (see Residential Zoning). An exception exists, however, in that houses built before implementation in 1974 are effectively “grandfathered”, and many are far too close to the shore for a buffer to be completely effective at intercepting

pollutants (MDEP 2008b). Some form of buffering is always better than only grass, or no vegetation at all.

## **Methods**

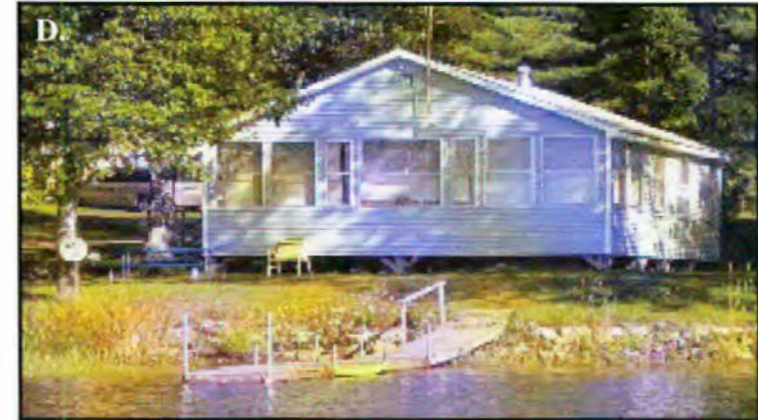
Shoreline surveys of the properties surrounding Pattee Pond were conducted by boat on 22-Sep-08. The lake was divided into an East and West side, and one boat team surveyed each side. Survey forms were used to standardize data collection (see Appendix E), and each property was marked with a GPS point and scored for its buffer quality. The quality of a buffer was determined by a combination of factors, including slope of the property, percent of the shoreline that was vegetated, and relative amounts of vegetation types present. These scores were later used for a buffer quality rating calculation, in which the values were converted to a percent of the optimal buffer score. All buffer strips were grouped into the categories good (100-76 percent), acceptable (75-51 percent), fair (50-26 percent), and poor (25-0 percent) (Figure 25).

## **Results and Discussion**

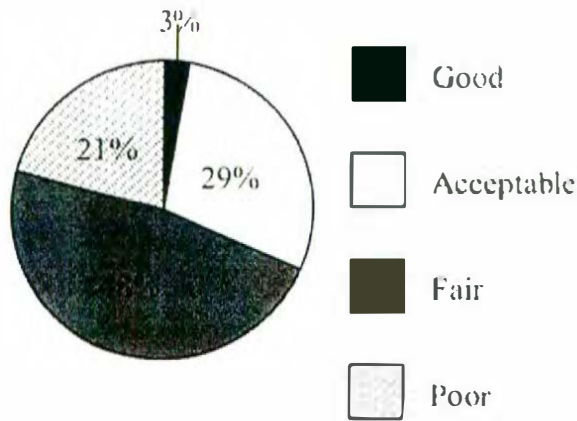
Buffer strips earning a fair or poor quality rating were deemed in need of immediate work; these accounted for 69 percent of all surveyed buffer strips (Figure 26). Of the remaining 31 percent, 29 percent garnered acceptable quality ratings, which meant that they do not to require prompt attention, and 2 percent received a good rating (Figure 25). For the purpose of this analysis, buffers receiving good and acceptable quality ratings were grouped together into one category, in order to focus the analysis on those in need of the most urgent remediation.

Lot frontage for each property was not included in the ranking scheme, since the length of frontage does not directly correspond with buffer quality, and so the rankings were compared with lot frontage in a separate analysis (Figure 27). Forty percent of the properties had very small lot frontage (less than 60 ft). Properties with frontage lengths between 60 and 120 ft made up 38 percent of the total, and properties with 120 ft to 180 ft, and greater than 180 ft lengths each comprised 11 percent of the total number around the lake. Properties with less than 60 ft of frontage, many of which are grandfathered under current zoning legislation, accounted for the largest proportion of poor buffer quality ratings, at 29 percent of all properties in that size range, suggesting a negative correlation between frontage length and buffer quality. Properties with





**Figure 25.** Examples of buffers on the Pattee Pond shoreline. **A:** A buffer on Pattee Pond given a good rating. The buffer extends along almost all of the shoreline and several feet inland towards the residence. It is comprised of dense, varied vegetation, and there is no paved pathway leading down to the dock. **B:** A buffer on Pattee Pond given an acceptable rating. The buffer extends along most of the shorefront and up to the residence, providing adequate buffering capacity. Adding trees and tall shrubs and covering the bare patch of land on the far right of the photograph could elevate this buffer to a good quality rating. **C:** A buffer on Pattee Pond given a fair rating. Although trees and shrubs are present, their densities are very low. An increase in vegetative land cover instead of dirt and scattered rocks would aid in runoff and erosion mitigation. **D:** A buffer on Pattee Pond given a poor rating. The house is very close to the shore, so that any precipitation landing on the roof travels directly into the lake. The dock may also provide a means for runoff to be channeled into the lake. Increased buffer vegetation is necessary to reduce the impacts these impermeable surfaces have on runoff potential.



**Figure 26. Buffer quality rating for shoreline properties in percent. Buffer quality was assessed on 22-Sep-08 by shoreline survey. Each buffer was given a quality rating of good, acceptable, fair, or poor (see Buffer Strips).**

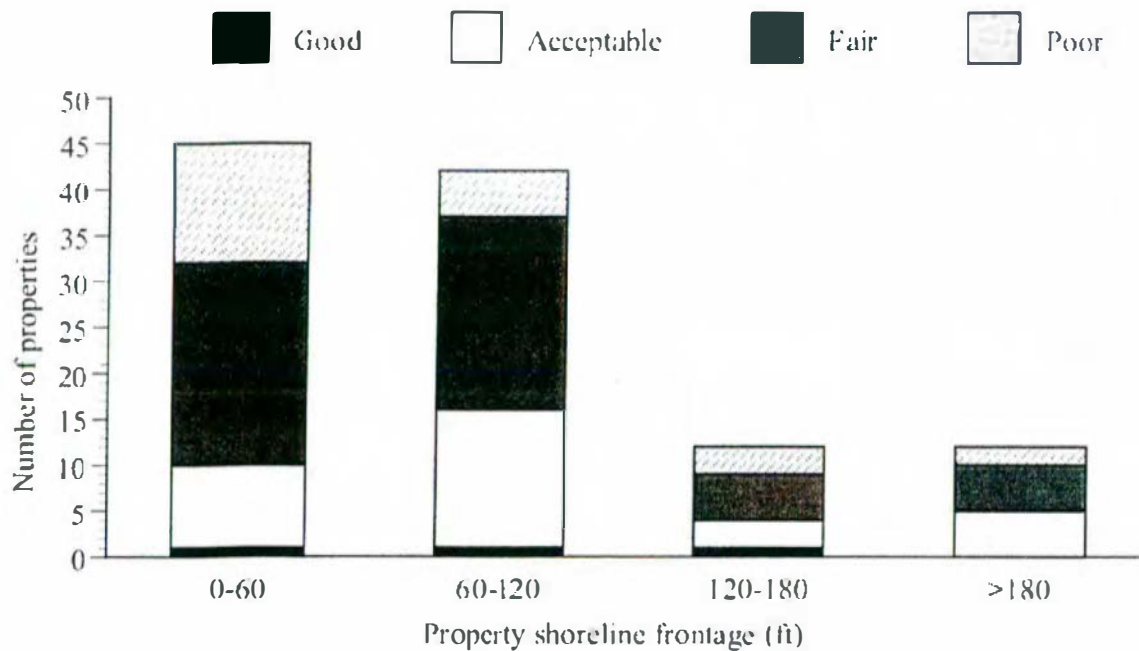
longer frontages simply had more land area for an increased variety and density of vegetation to be planted, leading to typically more effective buffers.

When the shoreline of Pattee Pond was assessed as a whole, no distinct concentrations of poor or fair buffers emerged (Figures 28, 29, 30, and 31). The quality of a buffer does not depend on the location in which a property is located, but is rather more heavily influenced by individual property owners and their attention to their own buffer strips. The most significant

erosion problem along Pattee Pond occurs along the western shore, where lots are steep and extensive sediment loading occurs after heavy rain events. Private boat launches are also major sources of erosion, especially when poorly constructed, and were observed to occur on twice as many properties on the western shore (approximately six) than on the eastern shore (approximately three) (Figure 32). These act to interrupt buffer strip continuity and are major channels for runoff into Pattee Pond.

The proportion of properties with good or acceptable buffer quality ratings is extremely low (Two percent) (see Figure 26). This could be the result of a need for more education of the residents on the construction of effective buffers, coupled with the high percentage of very small, steep lots surrounding the lake. The Pattee's Pond Association has worked with shoreline residents on effective buffer strip construction, and is a valuable educational resource. The correlation between smaller lot size and greater proportion of fair and poor buffers also suggests a correlation between older, grandfathered residences and poorer buffer quality ratings. Residences currently may not be built so close to one another or so close to the high water mark. Buffers marked as fair or poor totaled 69 percent of all those examined, which means that over two-thirds of properties on Pattee Pond are likely responsible for significant runoff of pollutants into the water, leading to environmental degradation of the lake. The western shoreline should

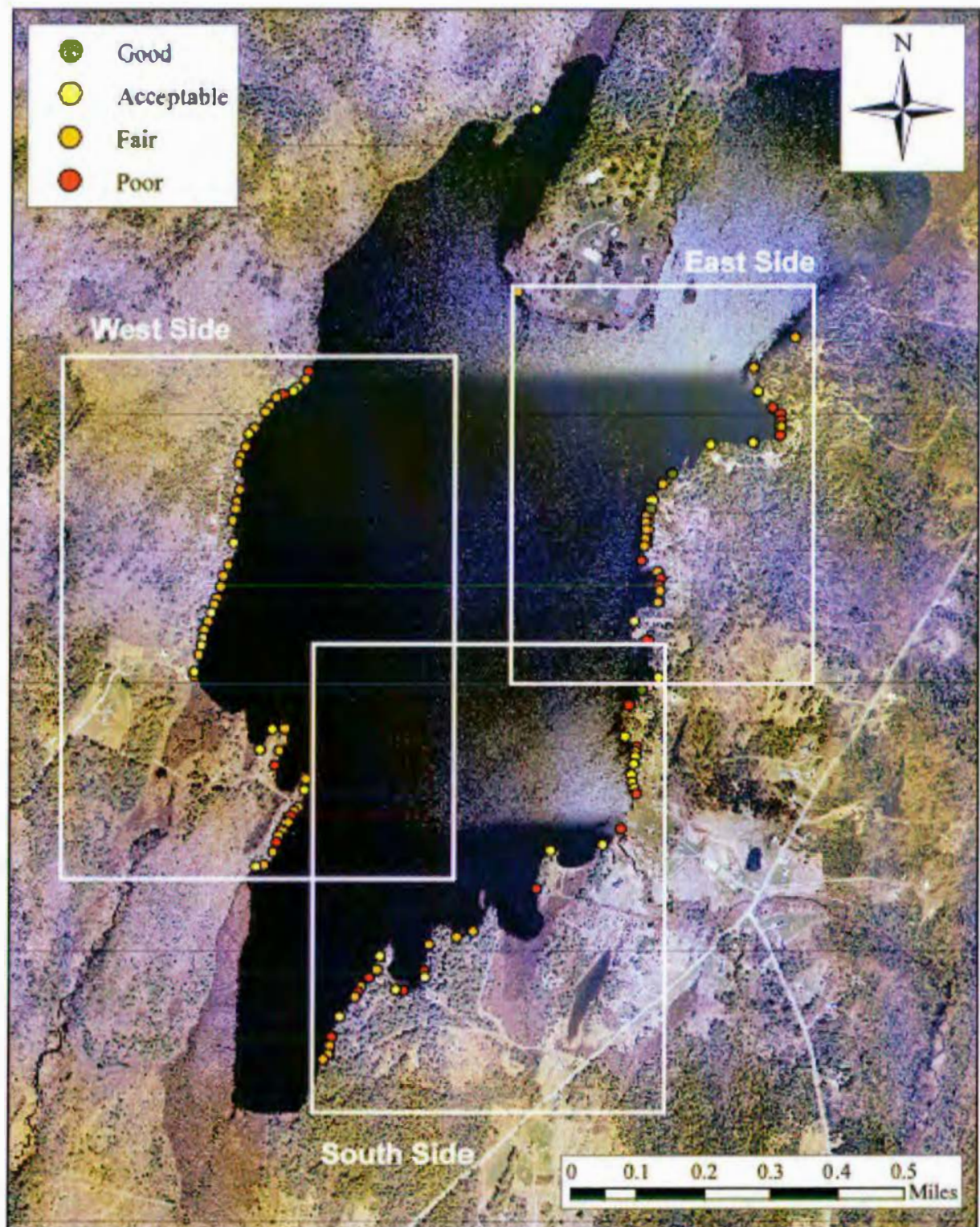




**Figure 27. The distribution of properties (n=110) along the Pattee Pond shoreline sorted by shoreline frontage and buffer quality rating. Data were collected during the 22-Sep-08 shoreline survey.**

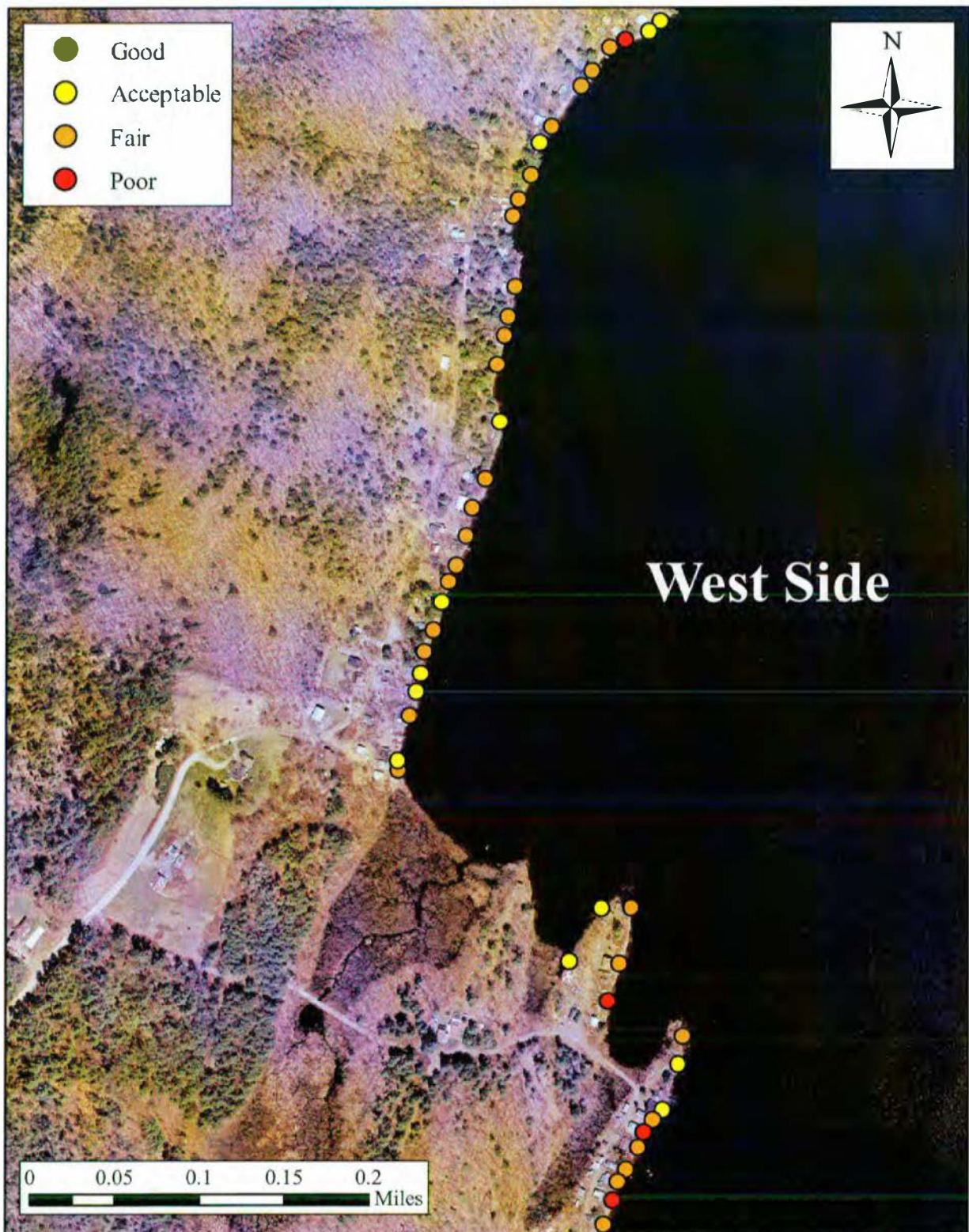
be a priority for remediation measures, because erosion and runoff rates from this area significantly impact water quality.

Frontage for each property also has an effect on both how a buffer should be constructed and on the magnitude of degradation that lot will cause on the lake (see Figure 27). Many of the residences on the water are grandfathered under the current shoreline zoning laws, and so they are much closer to the water than current building laws would allow (see Residential Zoning). Additionally, the lots are very small and steep, so there is little space for buffer vegetation to be planted. Runoff travels quickly down the predominately steep, bare slopes, eroding sediment on its path into the lake. Mitigation techniques need to be taken to minimize the human impacts on Pattee Pond.



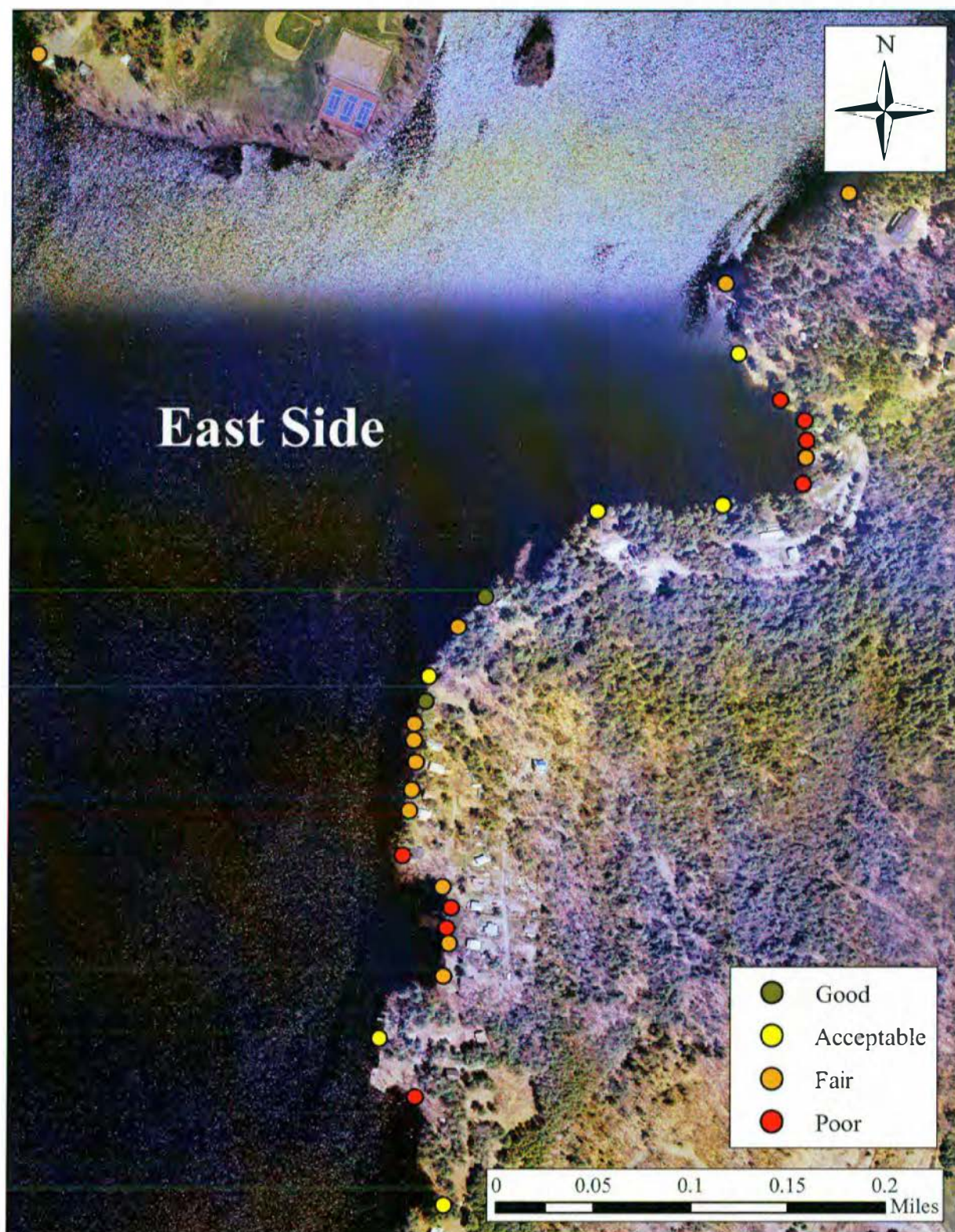
**Figure 28.** Buffer quality ratings for Pattee Pond (see Buffer Strips: Methods). Dots corresponding to quality ratings were placed at the location of each residential buffer strip. Residences along the lake were grouped into west, east, and south shorelines, and magnified for ease of viewing in Figures 29, 30, and 31.





**Figure 29.** Buffer quality ratings for the west shoreline of Pattee Pond (see Buffer Strips: Methods). Dots corresponding to quality ratings were placed at the location of each residential buffer strip.





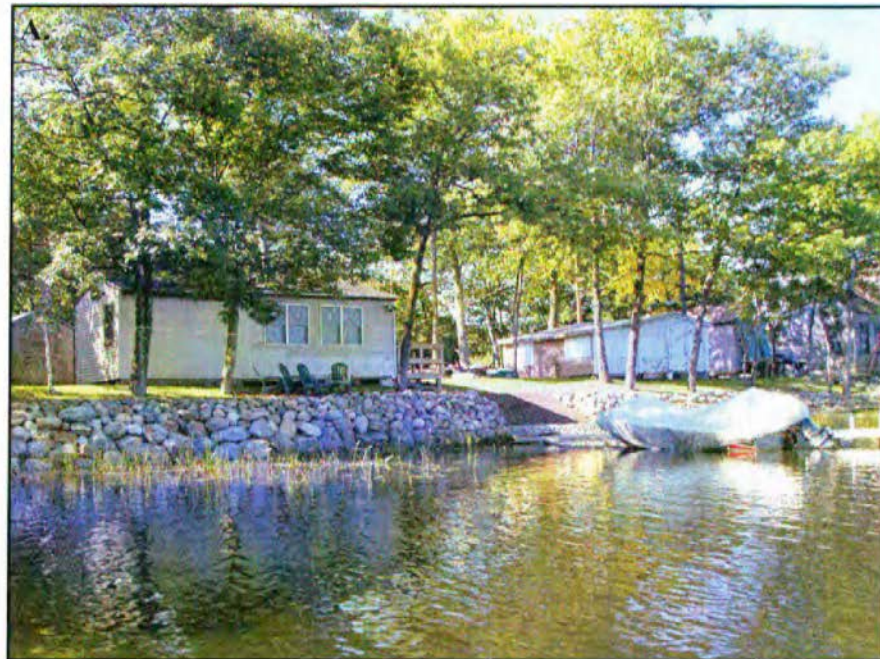
**Figure 30.** Buffer quality ratings for the east shoreline of Pattee Pond (see Buffer Strips: Methods). Dots corresponding to quality ratings were placed at the location of each residential buffer strip.





**Figure 31.** Buffer quality ratings for the south shoreline of Pattee Pond (see Buffer Strips: Methods). Dots corresponding to quality ratings were placed at the location of each residential buffer strip.





**Figure 32.** An example of a well-constructed private boat launch (A) and a poorly-constructed private boat launch (B) along the Pattee Pond shoreline. Boat launches composed of permeable material, such as mulch or wood chips, and lined with riprap, aid in slowing runoff so it can be absorbed before reaching the water, and stabilize the shoreline. Bare boat launches, especially on steep properties, channel water and increase erosion potential.

## **Roads**

### **Introduction**

Road conditions within the Pattee Pond watershed are influential in determining water quality. Sediments that make their way into the lake from road runoff can increase phosphorus loading and cause algal blooms (see Watershed Land Use: Nutrient Loading). Most of the roads directly around the lake are camp roads. Because of their proximity to the shoreline, camp roads can be a large source of potential sediment loading into the lake. Up to 85 percent of all erosion and sedimentation issues in watersheds are caused by poorly constructed and maintained camp roads (KCSWCD 2008). Driveways on camp roads around the lake can be another contributor to sedimentation and a major source of phosphorus loading. Driveways can allow water to flow freely from the road down to the lake, carrying any nutrients directly into the water, which can negatively affect turbidity, phosphorus levels and lake biota (see Pattee Pond Characteristics: Biological Perspective). Driveways around the lake can be designed to avoid sedimentation by adding curves to slow water flow down the driveway and adding some simple water diversions.

### **Regulations**

Roads within the watershed can be grouped into three classifications: state roads, municipal roads, and camp roads. The state roads and municipal roads fall under the jurisdiction of state and local governments and are regularly maintained. These roads are paved and tend to stay in fairly good condition, reducing their potential to harm the lake. The Town of Winslow, however, does not maintain the camp roads around the lake. According to Winslow town codes, a road will be deemed a private road until it meets certain standards (Town of Winslow 1997b). Until this point, private owners or road associations are responsible for maintaining the roads. This situation causes many camp roads to fall into disrepair due to lack of funding or organization of road associations or private owners.

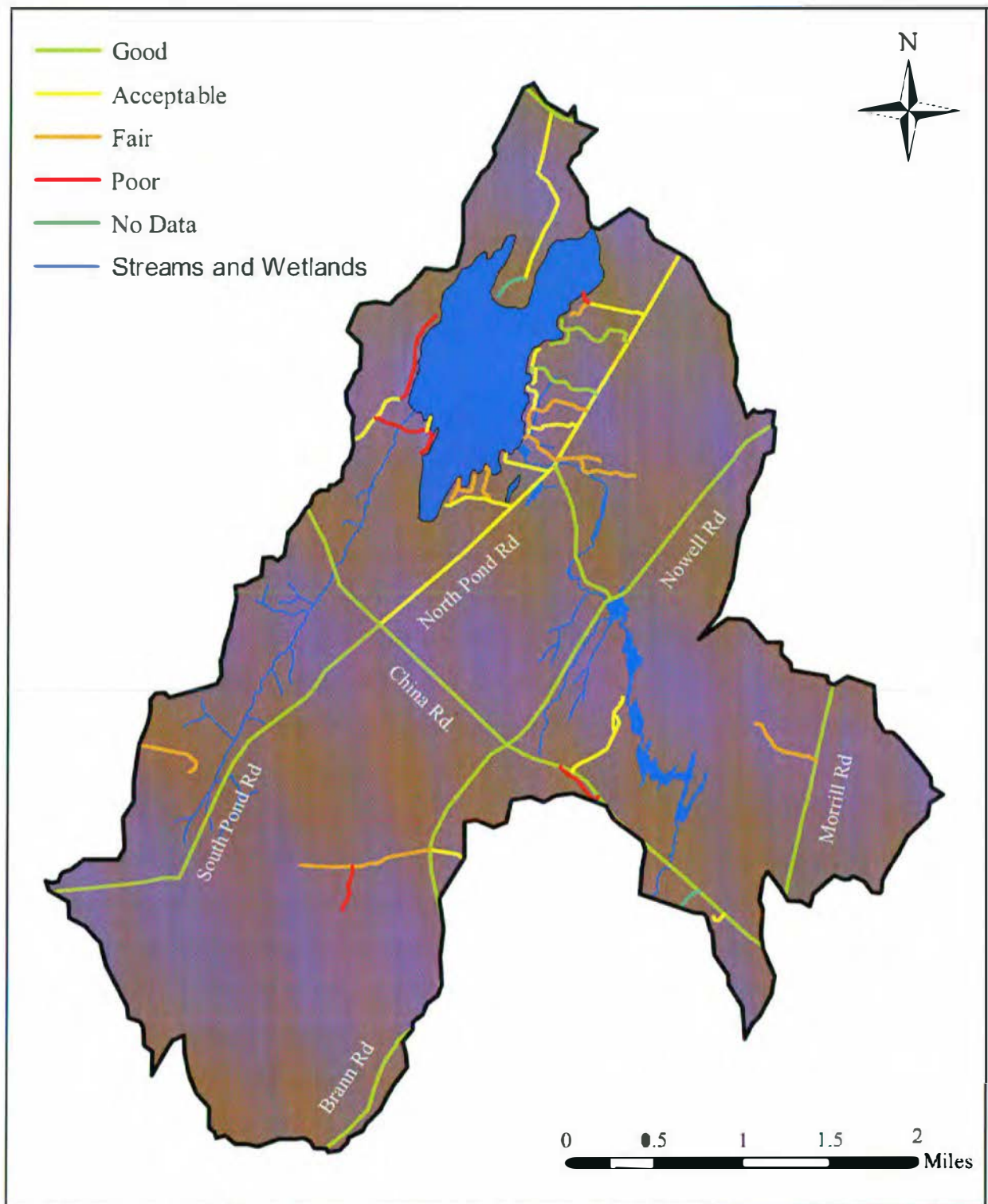
In the State of Maine there are three major laws that affect camp road maintenance and construction. The Erosion and Sedimentation Control Law states that before any activity that may disrupt the soil occurs, erosion-preventing devices must be installed until the site is permanently stabilized (KCSWCD 2008). The Natural Resources Protection Act (NRPA)

requires a permit from the Maine Department of Environmental Protection (MDEP) before beginning any activity within 100 ft of lakes or any other body of water. The Mandatory Shoreland Zoning Act regulates development within 250 ft of lakes, wetlands, tidal areas, and other water bodies. The act requires a setback for all roads and structures of at least 100 ft from water sources.

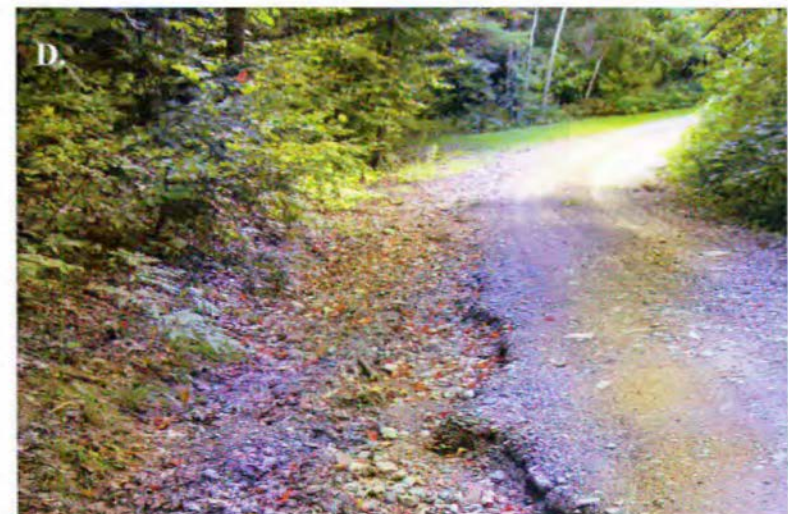
## **Methods**

On 15-Sep-08 and 18-Sep-08, CEAT performed road surveys on most of the roads within the Pattee Pond watershed. The watershed was divided into six areas and analyzed by groups of three surveyors each. The roads were qualitatively assessed based on ditch presence and condition, crown height, road materials, water diversions, and surface conditions, including evidence of erosion. Ditches, culverts, crowns, and surface materials of roads are all important factors in preventing phosphorus loading into the lake (see Watershed Land Use: Roads). The roads were rated as one of the following: good, acceptable, fair, or poor (Figure 33 and 34). Good meant that the road had a sufficient crown, had well maintained ditches if necessary, and little to no erosion problems. Acceptable meant that there were minor problems such as a lower crown, and the presence of some potholes, but no fixes are needed immediately. Fair meant that there were more moderate problems, such as little to no crown, missing or blocked ditches, damaged or blocked culverts, or medium areas of erosion and work should be done to fix them. Poor meant that there were major problems with the road, such as exposed or buried culverts, large berms, and large areas of erosion, and they should be fixed immediately to prevent further damage to the road. Major problem areas were marked with GPS points and were recorded on the Road Survey Data Sheet (see Appendix F). The lengths of the roads were measured with odometers and GPS points were taken at the ends of each road for use in GIS models. The width of each road was measured at multiple points using a Distance Wheel and averaged together. The crown height was measured at multiple points using a meter stick and rope level and averaged together. The surface condition of the road was also recorded, making note of materials (see Appendix F).





**Figure 33.** Road quality assessment performed by CEAT on 12-Sep-08 and 15-Sep-08. Road assessments were based on surface conditions, evidence of erosion, ditch presence and condition, culvert presence and condition, and presence of water diversions. Criteria for each rating is described in the text.



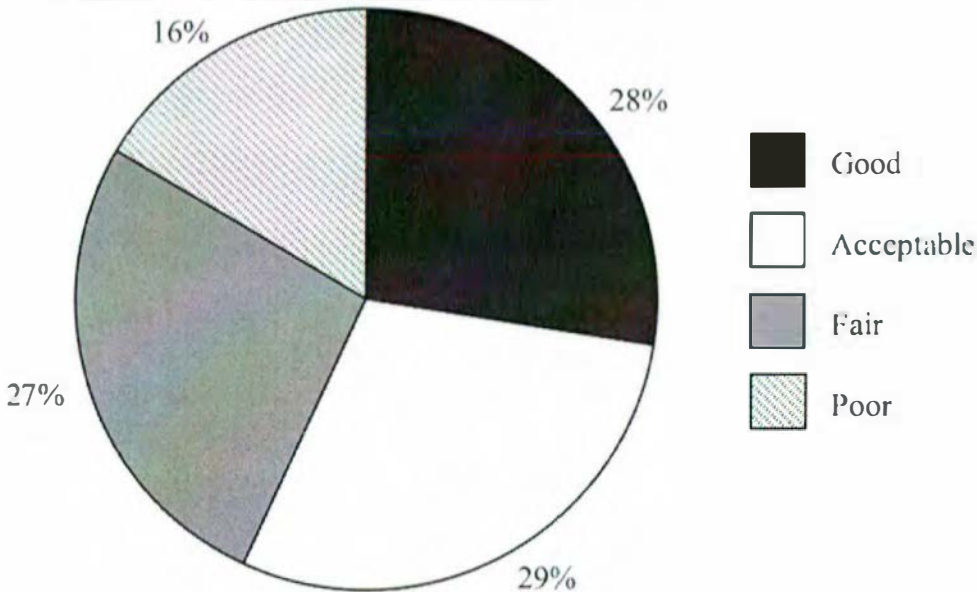
**Figure 34.** Examples of different quality roads in the Pattee Pond watershed. **A.** A road rated good. The surface is in good condition and has a sufficient crown. There is also a well-designed ditch with vegetation to absorb the runoff. **B.** A road given an acceptable rating. The road surface is not in as good condition and there are no ditches, but there is extensive vegetation on the sides of the road and no erosion problems evident. **C.** A road given a fair rating. The road has no crown and has evident potholes and water gullies running across the road. Repair is recommended. **D.** A road given a poor rating. There is extensive erosion on the side of the road and tire ruts run down the road. This road should be repaired quickly to prevent runoff from



## Results and Discussion

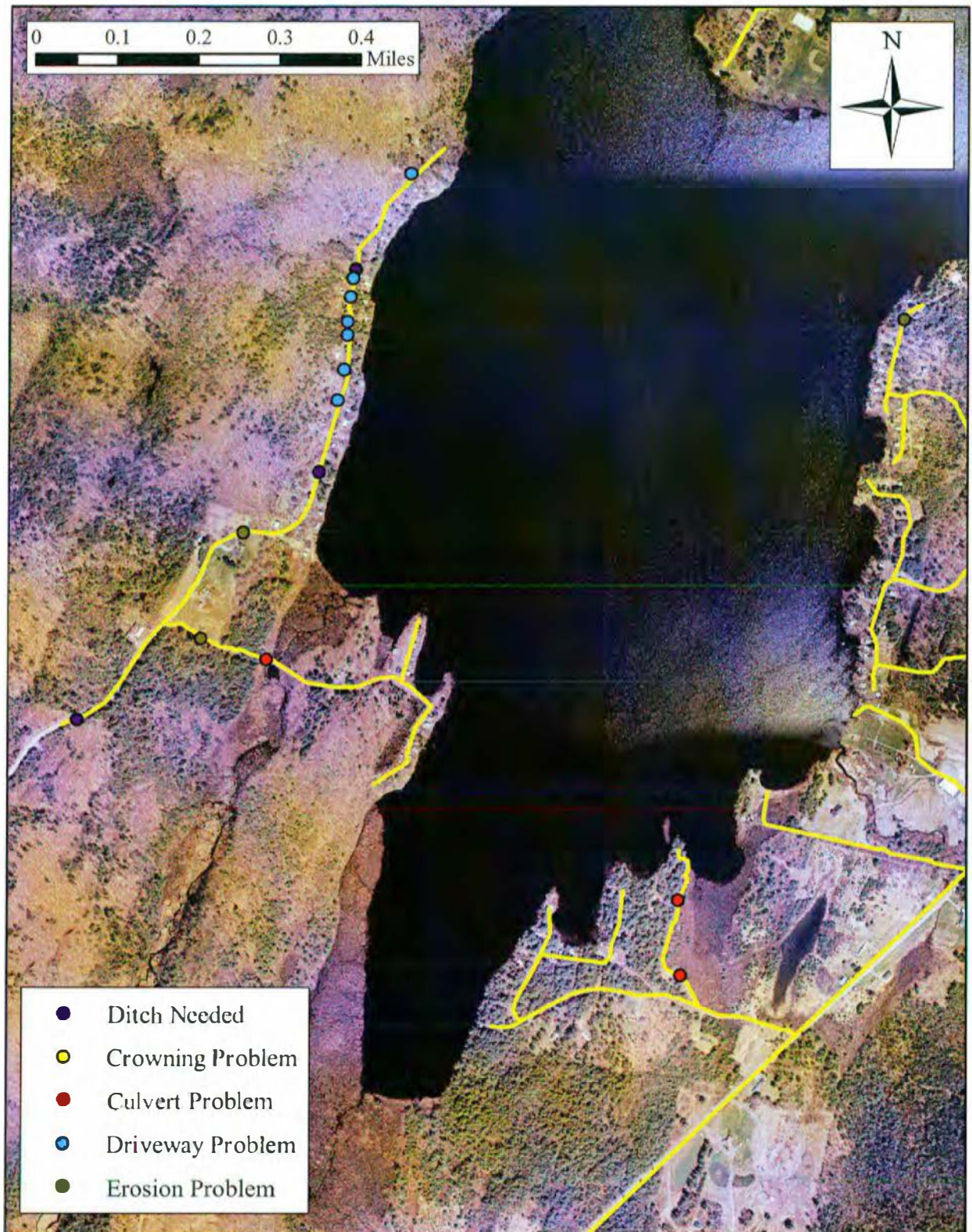
The total surface area of roads within the watershed was calculated to help determine their relative effect on phosphorus loading. State and municipal paved roads covered 44 acres (17.9 ha) and camp roads covered 18 acres (7.3 ha). CEAT focused on camp roads in our analysis due to their increased potential effect on phosphorus loading and close proximity to the lake (see Background: Roads). A little over half of the area of camp roads around Pattee Pond was assessed as either good or acceptable. (Figure 35) The camp roads qualified as fair or poor, unfortunately, were found directly around the lake and likely to cause more phosphorus loading.

CEAT used GIS to locate specific road problems found along camp roads on a watershed map (Figure 36). Most of the problems in the watershed occurred on camp roads around Pattee Pond. These roads have been listed alphabetically and are accompanied by suggested remediation techniques. Addressing these problems could greatly reduce nutrient loading into the lake. Roads rated poor or fair are recommended to be dealt with immediately. Roads rated acceptable will eventually need work if they worsen, but work is not needed right away.



**Figure 35. Surface area of camp roads organized by quality rating. Quality was assigned by CEAT based on road surveys conducted on 15-Sep-08 and 18-Sep-08. CEAT recommends repairing the roads labeled as Fair or Poor.**





**Figure 36.** Ditch, culvert, driveway, and erosion problems on camp roads around Pattee Pond identified by CEAT during the 12-Sep-08 and 15-Sep-08 road surveys.

## **Road Problems**

### **White Fish Road**

Rating: Poor

Problem(s): Erosion prone driveways, no ditches, and a lack of vegetation along the lakeside of the road.

Remediation: Add water diversions on troublesome driveways, add ditches/culverts/other water diversion to the road, and improve buffers on lakeside.

### **Pickerel Point (Steep section)**

Rating: Poor

Problem(s): A steep section with tire rutting, no ditches, berms and evidence of erosion down to wetlands.

Remediation: Add water diversions along road, remove berms along the edge and install ditches with turnouts towards vegetation.

### **Pickerel Point (Flat section)**

Rating: Poor

Problem(s): Flat areas with little to no crowning.

Remediation: Consider regrading the road and adding water diversions to remove water from road surface.

### **Road 1**

Rating: Poor

Problem(s): Poor crowning, standing water on road, and no ditches.

Remediation: Consider regrading the road surface and adding ditches to remove water from the road surface.

### **Bald Eagle Lane**

Rating: Fair

Problem(s): Poor crowning with potholes.

Remediation: Fill in potholes to avoid more erosion and ultimately regrade road.

### Kingfisher Lane

Rating: Fair

Problem(s): Tire rutting, exposed culverts

Remediation: Add more surface material to cover culvert, regrade road to eliminate rutting, add water diversions.

### McClasin Drive

Rating: fair

Problem(s): Heavy erosion in steep areas, no ditching.

Remediation: Add diversions and ditching to reduce erosion.

### Osprey

Rating: Fair

Problem(s): Poor ditching, small areas of erosion.

Remediation: Dig more effective ditches and regrade road or fill in areas of erosion.

### Sunfish Road

Rating: Fair

Problem(s): Severe road erosion, exposed and obstructed culvert.

Remediation: Fill in areas of erosion, cover and clear out ends of the culvert, add ditches.

### West Palmer Road

Rating: Fair

Problem(s): Berm all the way along the road.

Remediation: Remove the berm, add turnoff for water flow towards vegetation.

### Camp Caribou

Rating: Acceptable

Problem(s): Poor crowning with potholes, and water body beside the road.

Remediation: Consider regrading road to improve the crown and add diversions away from the water.



#### Catfish Corner and Robin Lane

Rating: Acceptable

Problem(s): No crown and some areas of washout present.

Remediation: Consider regrading road and add water diversions.

#### Cote Lane

Rating: Acceptable

Problem(s): Tire rutting, potholes, and stagnant water in culvert.

Remediation: Fill in the potholes and rutting, and clear out edges of culvert to allow free flow of water.

#### My Way

Rating: Acceptable

Problem(s): No crowning.

Remediation: Consider regrading road to appropriate crown height.

#### Pattee Pond Road

Rating: Acceptable

Problem(s): An abrupt change from asphalt to gravel with erosion evident.

Remediation: Fill in more material at edge of asphalt and add water diversions.

#### Pike Road

Rating: Acceptable

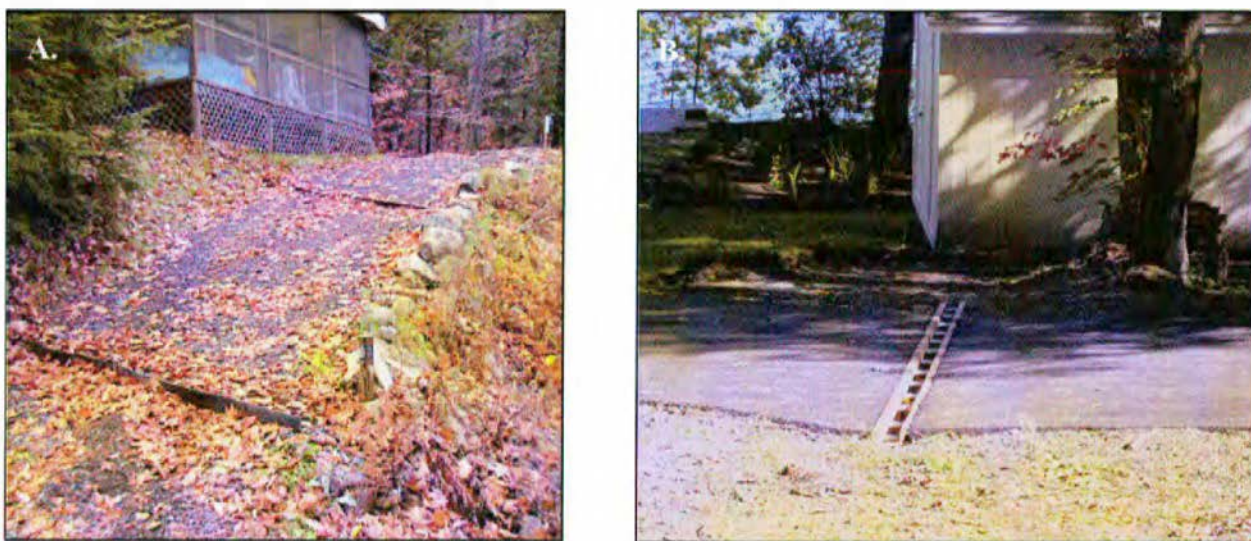
Problem(s): Some tire rutting.

Remediation: Fill in the tire ruts to reduce further erosion.

Although some of these projects may be costly to individuals and to road associations, having to constantly repair recurring erosion problems is a waste of time and money. Beneficial maintenance on these roads could help reduce sediment loading into the lake as well as minimize or eliminate recurring erosion problems (MDEP 2004).

In surveys of camp roads around the lake, CEAT found many erosion prone driveways leading from the camp road down slope to the lake. This problem is especially prevalent along

the west side of Pattee Pond along Whitefish Lane. Many of the driveways along Whitefish Lane potentially provide a direct path for runoff to enter the lake. Some simple water diversion techniques can be used to reduce this runoff (Figure 37). Rubber Bars, or open top culverts could be installed on the driveway to divert the water to plants on the side instead of the water flowing down the driveway. Rubber Bars are made of two pieces of plywood and pieces of old conveyor belts or strips of rubber (KCSWCD 2008). They are not recommended for areas that will be plowed regularly in the winter because the plows will likely rip the rubber. Open top culverts work like regular culverts in that they allow water to pass from one side of the roadway to the other, but they have an open top and can catch water flowing across the road and divert it to the side. They consist of a few pieces of plywood and thin pipe and are relatively easy to make (KCSWCD 2008). Open top culverts need to be cleaned occasionally because leaves and other debris can get caught in them. These like rubber bars are not recommended for areas with winter traffic because plows can damage them. Especially steep and straight driveways should incorporate multiple tiers of water diversions to slow the water that flows down toward the lake. Where possible, CEAT recommends that curves be added to these driveways to help slow runoff, but this will not be possible in most cases due to the small size of the lots around the lake. Driveways with turns downhill can help to slow the water flowing down toward the lake and



**Figure 37. Two examples of water diversions that can be used on driveways. A. Two rubber bars have been installed on this driveway to divert water towards the vegetated side of the driveway. B. An open top culvert installed across a driveway. Water flowing alongside or down the driveway can be diverted across by the open top culvert.**

diverts some of the water off of the driveway. Water diversions should be put along these curves to further assist in moving the water off of the driveway.

## **Macrophytes**

### **Introduction**

Brad Whitaker, President of the Pattee's Pond Association, indicated that because invasive plants are now becoming all too common in shallow water bodies throughout Maine, Pattee Pond shoreline residents were interested in learning more about the aquatic plants present. Since macrophytes are key elements of any aquatic ecosystem (see Background: Native Aquatic Flora/Fauna), CEAT investigated the abundance and density of the macrophyte community in Pattee Pond.

### **Methods**

Macrophyte surveys were performed on 22-Sep-08 and 25-Sep-08. Two canoes were employed per survey team. Each canoe had two plant identifiers and one data recorder. The canoes traveled together and parallel to the shore. One canoe was within ten feet of the shoreline and the other canoe was roughly twenty feet away from the shoreline. GPS points were taken every twenty feet, and macrophyte data were collected at each GPS point (see Appendix G).

At each sample site, the waypoint and coordinates from the GPS unit were recorded, along with water depth, which was used in other analyses (see Background: Physical Characteristics). The overall density of vegetation, which included all emergent, floating, or submersed macrophytes, within a ten-foot radius of the sample site was recorded as either none, sparse, medium, or dense. "None" defined areas of no vegetation. "Sparse" referred to areas with few individual aquatic plants present. "Medium" defined areas with many aquatic plant individuals present, but room still remained for the roots of more individuals to establish. "Dense" represented heavily vegetated areas where there was no space for the roots of any additional vegetation to potentially grow. Aquascopes were used at sample sites where the plant identifiers could not see to the bottom sediment and to reduce surface reflection. Of the vegetation present within the ten-foot radius, percentages of each plant species were recorded. The categorization of sample site plant density and plant species percentages were discussed and



agreed upon by both plant identifiers. Samples of any unknown plants were collected for later identification and noted on the survey forms.

## **Results and Discussion**

Upon reviewing the macrophyte survey forms, both a composite list (Table 12) and comprehensive field guide (see Appendix H) were created of all identified aquatic plants from Pattee Pond. Analyzing these data, the seven most common combinations of plant species were identified and a community classification scheme was created to categorize the aquatic macrophyte community (Figures 38, 39, 40 and 41). Common rush (*Juncus effusus*) and pickerelweed (*Pontederia cordata*) were by far the most common plant species noted with 159 and 157 total observations, respectively. None of the plants observed were invasive aquatic macrophytes on the State of Maine unwanted list (see Appendix A).

Purple loosestrife, a non-native and invasive perennial herb, was found at four separate survey points. This species is found in every state except Florida (Swearingen 2005). This plant grows rapidly, easily outcompeting and replacing native grasses, sedges, and other flowering plants (Swearingen 2005). While purple loosestrife is most commonly found in dense, homogenous stands, the infestations found along Pattee Pond were very limited (Swearingen 2005). Purple loosestrife was not dominant at any of the four locations, with only a few individuals visible. The infestation of purple loosestrife poses a potential threat to the lake because of its ability to rapidly and abruptly takeover and replace both native aquatic and terrestrial plants. The very localized purple loosestrife infestation on Pattee Pond should be monitored or removed to prevent this species from expanding any further along the shoreline.

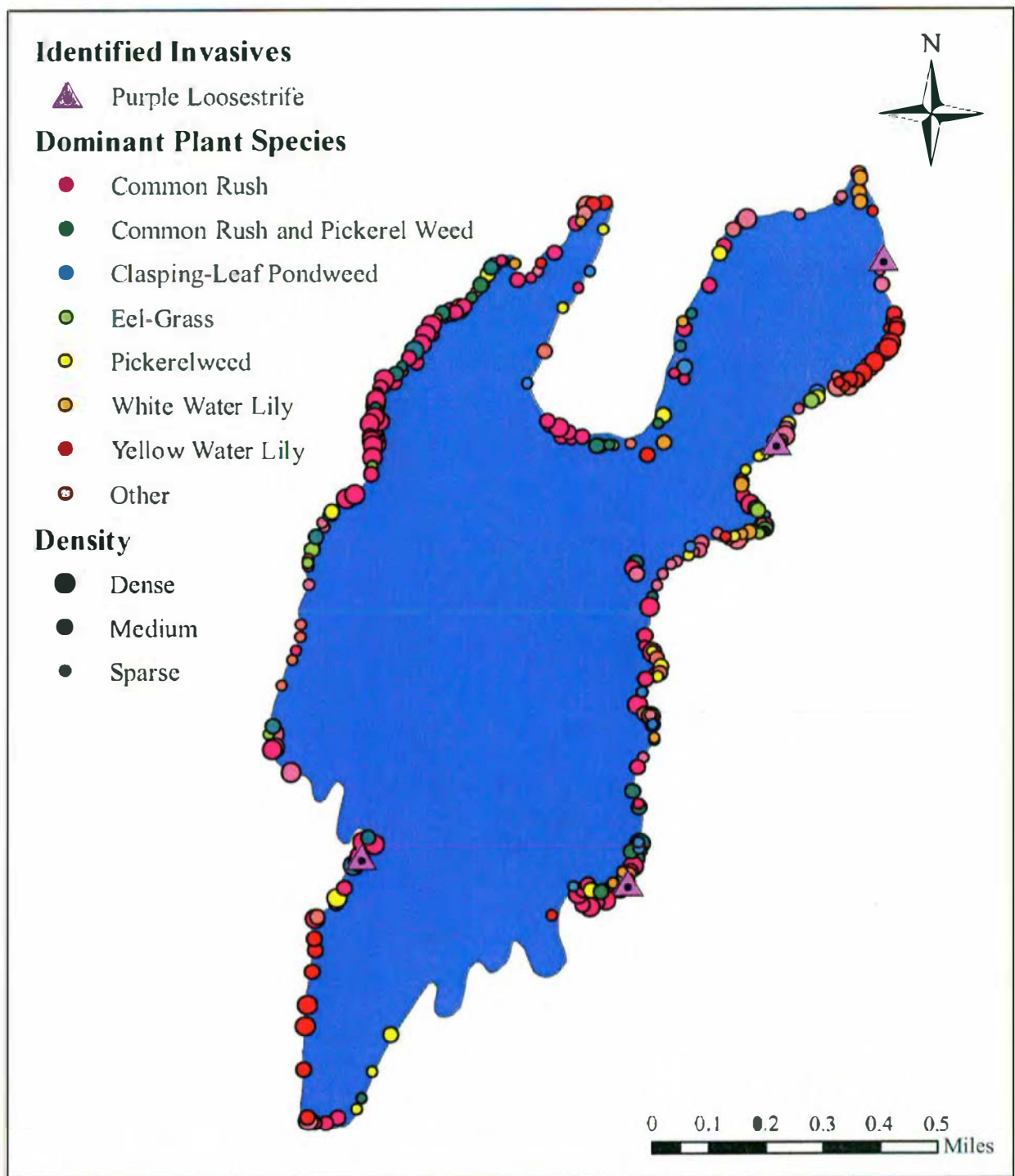
This macrophyte survey provides homeowners around the lake with information about the plant species near their properties. By being able to identify common species, residents can be more vigilant in looking for invasive aquatic plants and report any observations immediately. Although purple loosestrife was found on the lake, CEAT believes that this plant could easily be eradicated by physical removal before flowering occurs, inhibiting the spread of the species to other parts of the lake. A comprehensive field guide to the identified aquatic plants found on Pattee Pond (see Appendix H) and a field guide to the eleven invasive aquatic plants on Maine's unwanted list (see Appendix A) are included in this report. CEAT hopes that these field guides

will provide residents with the ability to identify aquatic plants and other important information regarding these species. CEAT hopes this macrophyte survey provides an effective way to spread awareness about native and non-native plants and strengthens a resident's role concerning monitoring for invasive aquatic plants (see Background: Invasive Plants).

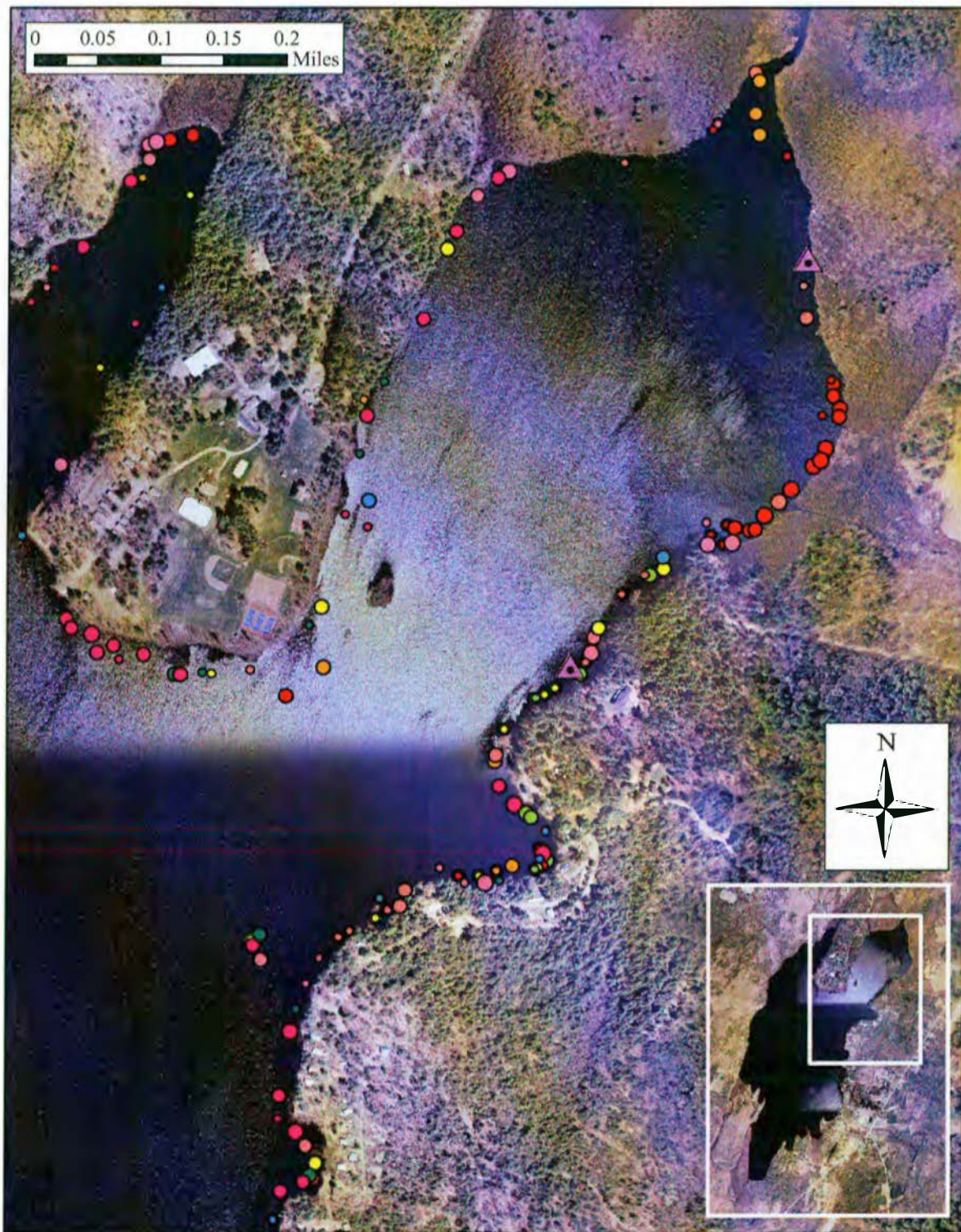
**Table 12. A comprehensive listing of aquatic plants found along the shoreline of Pattee Pond sorted according to the total number of observations during macrophyte surveys performed on 22-Sep-08 and 25-Sep-08 (see Macrophytes). A plant was considered dominant if that particular species composed more than 20% of a specific sample site. A species was considered non-dominant if it composed 20% or less of a sample site. There were 316 sample sites in total.**

Scientific Name	Common Name	Number of Appearances		
		Dominant	Non-Dominant	Total
<i>Schoenoplectus tabernaemontani</i>	Common rush	130	29	159
<i>Pontederia cordata</i>	Pickerselweed	77	80	157
<i>Nymphaea odorata</i>	White water lily	33	32	65
<i>Nuphar advena</i>	Yellow pond lily	37	20	57
<i>Potamogeton richardsonii</i>	Clasping-leaf pondweed	21	22	43
<i>Vallisneria</i> spp.	Eel-grass	14	20	34
<i>Scirpus acutus</i>	Hardstem bulrush	13	19	32
<i>Eriocaulon aquaticum</i>	Pipewort	13	15	28
<i>Typha latifolia</i>	Broad-leaved cattail	9	11	20
<i>Elodea Canadensis</i>	Common waterweed	6	12	18
<i>Cephalanthus occidentalis</i>	Buttonbush	3	14	17
<i>Ceratophyllum demersum</i>	Coontail	6	10	16
<i>Potamogeton natans</i>	Floating-leaf pondweed	6	9	15
<i>Leersia oryzoides</i>	Rice cut-grass	6	9	15
<i>Potamogeton robbinsii</i>	Robbins pondweed	9	2	11
<i>Arundo donax</i>	Giant reed	2	6	8
<i>Bidens beckii</i>	Water marigold	5	2	7
<i>Utricularia vulgaris</i>	Common bladderwort	4	2	6
<i>Potamogeton foliosus</i>	Leafy pondweed	1	4	5
<i>Najas flexilis</i>	Slender naiad	1	4	5
<i>Brasenia schreberi</i>	Watershield	0	5	5
<i>Lythrum salicaria</i>	Purple loosestrife	0	4	4
<i>Dulichium arundinaceum</i>	Three-way sedge	0	3	3
<i>Sagittaria</i> spp.	Arrowhead	0	2	2
<i>Sparganium chlorocarpum</i>	Short-stemmed bur-reed	0	2	2
<i>Decodon verticillatus</i>	Swamp loosestrife	0	2	2
<i>Sparganium eurycarpum</i>	Common bur-reed	1	0	1
<i>Fontinalis antipyretica</i>	Common water moss	0	1	1



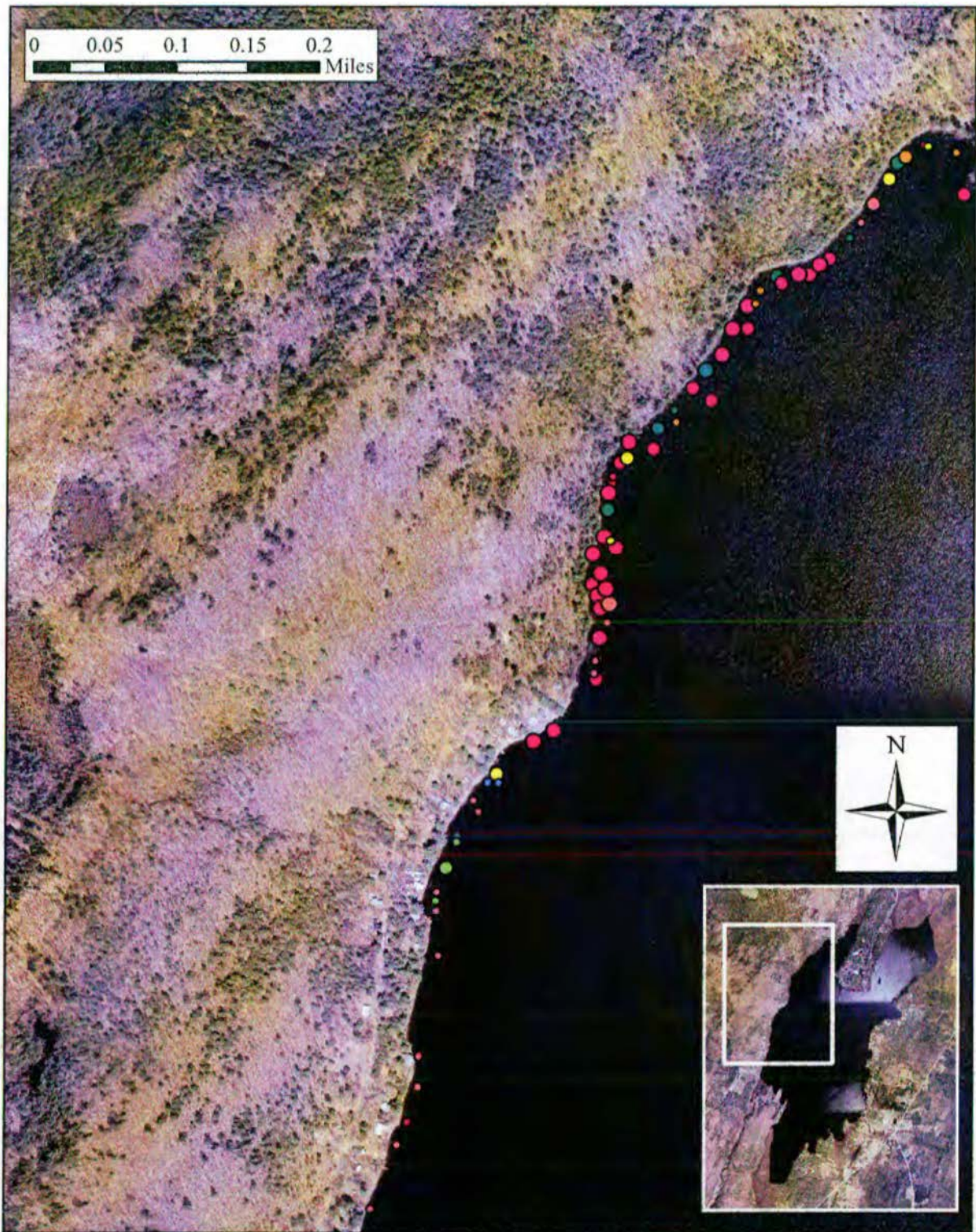


**Figure 38.** Macrophyte community distribution for Pattee Pond based on macrophyte surveys performed on 22-Sep-08 and 25-Sep-08. Location of macrophytes and the dominant plant species in a patch are indicated by dot colors. A plant was considered dominant if that particular species composed more than 20% of a specific sample site. Dot size indicates the density of the macrophyte patch (see Macrophytes: Methods). No data were collected along the southeastern shore.



**Figure 39.** Macrophyte community distribution for the northeast shore of Pattee Pond based on macrophyte surveys performed on 22-Sep-08 and 25-Sep-08. The dominant plant species is indicated by dot color. A plant was considered dominant if that particular species composed more than 20% of a specific sample site. Dot size indicates the density of the macrophyte patch. Refer to Figure 38 for dominant plant species identification key.





**Figure 40.** Macrophyte community distribution for the west shore of Pattee Pond based on macrophyte surveys performed on 22-Sep-08 and 25-Sep-08. The dominant plant species is indicated by dot color. A plant was considered dominant if that particular species composed more than 20% of a specific sample site. Dot size indicates the density of the macrophyte patch. Refer to Figure 38 for dominant plant species identification key.





**Figure 41.** Macrophyte community distribution for the south shore of Pattee Pond based on macrophyte surveys performed on 22-Sep-08 and 25-Sep-08. The dominant plant species is indicated by dot color. A plant was considered dominant if that particular species composed more than 20% of a specific sample site. Dot size indicates the density of the macrophyte patch. Refer to Figure 38 for dominant plant species identification key.

# ***WATER QUALITY ASSESSMENT***

## **Water Quality Study Sites**

A total of nine sites were chosen to investigate the water quality of Pattee Pond, one characterization site and five spot sites on the lake and three additional tributary sites (Figure 42). The Characterization Site (Site 1) was the deepest part of the lake and the site used by the Maine Department of Environmental Protection in past studies of the lake. CEAT performed comprehensive sampling 30-May-08 to 22-Sep-08 at five Lake Sites (1 through 5). A sixth spot site was sampled on 22-Sep-08, as well as three tributary sites. Spot sites were chosen to investigate the water quality at different locations around the lake to explore potential differences. In addition, water quality samples were taken at the two primary inlets and at the outlet. The three tributary sites were chosen to examine potential inputs of phosphorus as water enters or leaves the lake.

The parameters that were measured during our study include: dissolved oxygen, temperature, transparency, turbidity, color, conductivity, pH, total phosphorus, nitrates, hardness and chlorophyll *a*. Sampling began on 30-May-08 and concluded on 22-Sep-08. For specific dates and locations of all tests performed, please see Appendix I.

The study site map shows the location of all nine sample sites (Figure 42). The Global Positioning System (GPS) coordinates for the all the Lake Sites were collected on a Lowrance GPS unit, converted and imported into ArcGIS 9.2<sup>®</sup>. The locations for the three tributary sites were obtained using a handheld GPS unit. The Universal Transverse Mercator (UTM) Zone 19 N coordinate system was used when plotting the sample sites.

## **Pattee Pond Sample Site Descriptions**

### Characterization Site

**Site 1:** Easting: 455365 E                      Northing: 4931194 N                      Depth: 8.1 m

Located in the middle of Pattee Pond at the deep hole, approximately 420 m from the eastern shore. The Maine DEP collects water quality samples at Pattee Pond Site 1 once a year. For continuation of historical data CEAT chose to sample at Site 1 as well.



### Spot Sites

**Site 2:** Easting: 456229 E                      Northing: 4932369 N                      Depth: 2.5 m

Located roughly 280 m to the southwest from the outlet at the Northeast end of Pattee Pond. Samples from this site were used to look at the water quality as water has moved across the lake.

**Site 3:** Easting: 455679 E                      Northing: 4930648 N                      Depth: 0.8 m

Located roughly 35 m to the west from the shore of Giordano's Campground, and roughly 45 m to the northwest from the Farber Brook inlet. This site was sampled because it is adjacent to Giordano's Market and Campground, and Farber Brook inlet.

**Site 4:** Easting: 454886 E                      Northing: 4930246 N                      Depth: 3.6 m

Located roughly 100 m to east from the western shore of the south bay where there is a fairly high density of houses.

**Site 5:** Easting: 455396 E                      Northing: 4932165 N                      Depth: 5.6 m

Located roughly 80 m from the shore of Camp Caribou. Samples from this site were studied because of the presence of the youth camp and the associated potential impacts on water quality.

**Site 6:** Easting: 454886 E                      Northing: 4931534                      Depth: 6.7 m

Located 90 m from the western shore of Pattee Pond, this site was studied because of the high density of houses, limited buffers along the shoreline, and reported erosion during storms.

### Tributary Sites

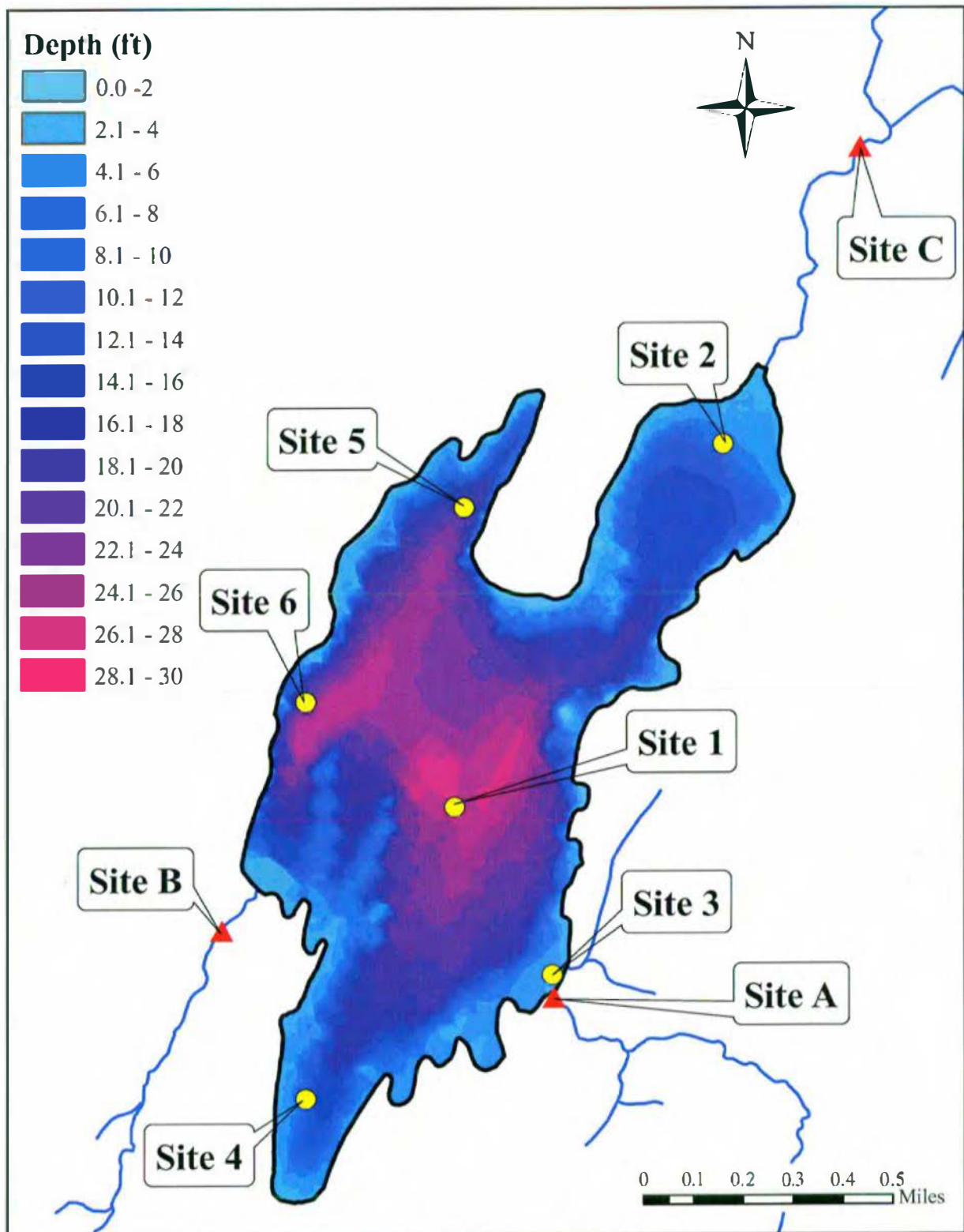
#### **Site A:**

Located roughly 15 m from the lake shoreline upstream in Farber Brook, the inlet adjacent to Giordano's Campground. This site was chosen because of the potential for phosphorus loading coming from the campground. Furthermore, this was also the site used for a stream sampler.

#### **Site B:**

Located roughly 180 m from lake shoreline of Pattee Pond upstream in Bellows Stream, this site was the inlet on the western shore, and there was a potential for increased phosphorus loading due to the steep slope near this inlet.





**Figure 42.** The locations of all water sampling sites used during the study. These sampling sites are classified as either Lake Sampling Sites (Sites 1-6) or Stream Sampling Sites (Sites A-C). Site 1 is the Lake Sampling Site used by the Maine DEP.

## **Site C:**

Located roughly 780 m from the lake shoreline, this site was down stream in Pattee Pond Brook, the outlet at the north end of the lake.

## **Physical Measurements**

### **Dissolved Oxygen and Temperature**

#### Introduction

Dissolved oxygen (DO) and temperature are important indicators of water quality. DO is a measure of the amount of available oxygen ( $O_2$ ) held in the water measured in parts per million (ppm) (Kegley and Andrews 1998). Temperature refers to the amount of heat in the water measured in degrees Celsius ( $^{\circ}C$ ). Oxygen is essential for the survival of most aquatic organisms. When DO levels get too low, organisms that need oxygen to respire weaken and can eventually die. Low levels of dissolved oxygen frequently indicate a high concentration of decaying organic matter because as bacteria and other decomposers digest organic matter, they use up oxygen, leaving little for other aquatic life (Kegley and Andrews 1998). Oxygen is introduced into water through photosynthesis and through diffusion facilitated by wind-mixing and wave action (MVLMP 2008a).

Two related properties of water influence the concentration of dissolved oxygen in a lake, temperature and density (PEARL 2008b). Water solubility depends on water temperature. Colder water contains more oxygen than warmer water, so as temperature increases, DO decreases. The limit to this trend occurs at  $4^{\circ}C$ , where water is most dense and holds the most oxygen. Temperature is related to “heat loading,” which can come from direct sunlight, inputs of warm surface water from smaller or shallower ponds, industrial effluents, and summer runoff from rooftops and pavement (Kegley and Andrews 1998). Also, the density of water increases as temperature decreases, which means cold water sinks to the bottom of lakes and warmer, less-dense water floats on the top. This pattern is called thermal stratification. Lakes tend to be stratified during the summer months into three layers: the epilimnion, metalimnion, and hypolimnion.

When lakes are stratified, the oxygenated surface waters and oxygen deprived bottom waters do not mix. The water on the bottom of eutrophic lakes can become anoxic, meaning there is less than 1 ppm of oxygen present (PEARL 2008c). Under aerobic conditions, iron reacts with inorganic phosphorus to form compounds. When conditions become anoxic in the bottom waters of a lake, these complexes breakdown, taking phosphorus out of solution and making it available in the water column (see Background: Phosphorus and Nitrogen Cycles). Pattee Pond is a dimictic lake; the water column mixes twice a year in the spring and fall (see Background: Annual Lake Cycles). These turnover events redistribute dissolved oxygen and make the temperature uniform throughout the lake profile. Wind mixing also brings sediments up from the lake bottom and resuspends these particles in the upper layers. When these nutrient rich bottom sediments are redistributed throughout the water column, nutrients such as phosphorus become available, which can lead to algal blooms. Algal blooms further reduce DO in the lake water (PEARL 2008b).

High DO concentrations indicate a healthy lake. If levels reach below 5 ppm, fish and other organisms become stressed, resulting in slow growth and increased susceptibility to disease. When waters become anoxic (below 1 ppm) fish and other organisms cannot survive (Boyd 2000).

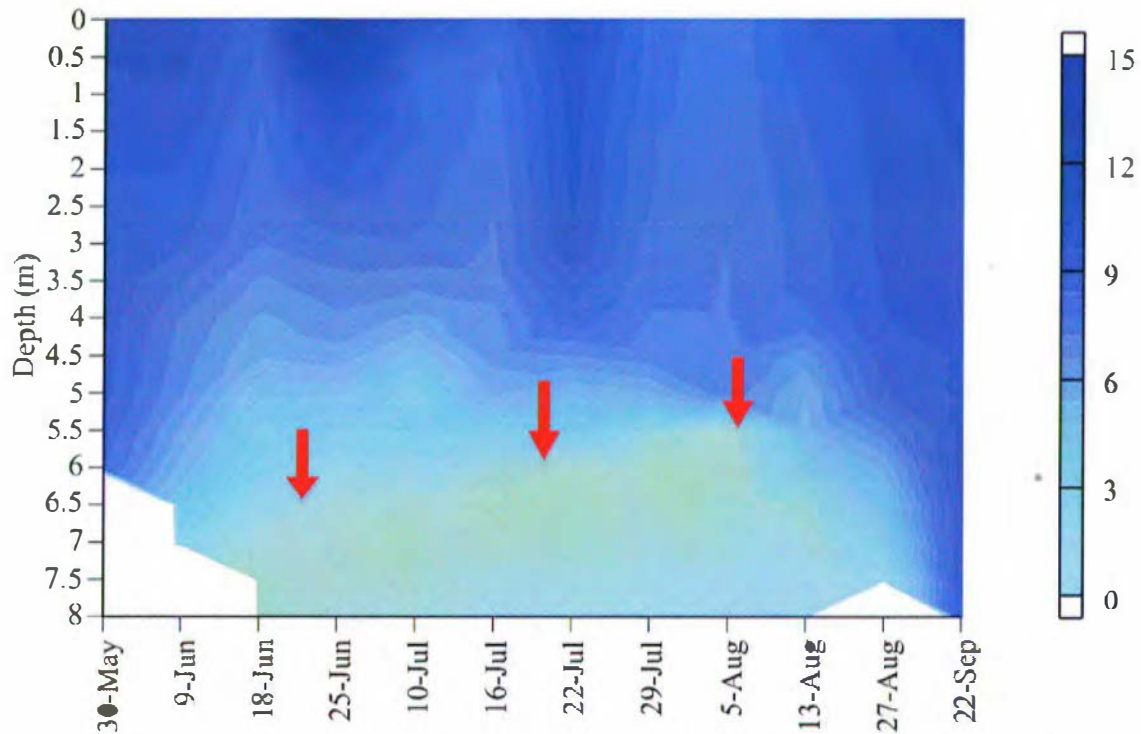
### Methods

A YSI 6820 Sonde was used to measure the dissolved oxygen and temperature profiles at each of the six test sites (see Appendix J). DO and temperature were measured at least every meter and usually at every half meter in depth during each sampling date. Sites 1 through 5 were sampled throughout the summer and Site 6 was sampled only on 22-Sep-08. DO and temperature data were not collected at any of the three tributaries (Sites A, B, and C).

### Results and Discussion

The DO at Site 1, the deepest point of the lake, was highest in surface waters during May and early June. The concentration throughout the water column decreased over the summer and was lowest during August, but then increased in September when the fall mixing event began to homogenize the oxygen levels and temperature (Figure 43).



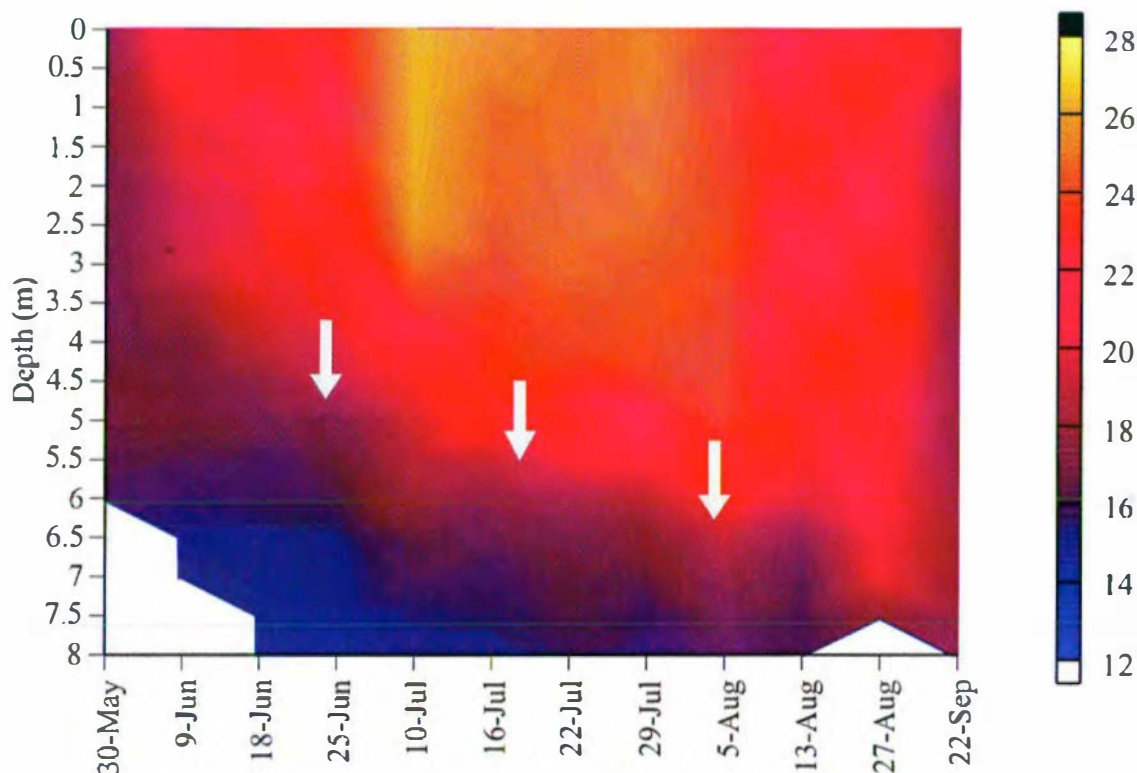


**Figure 43. Dissolved oxygen (ppm) profile at Site 1 in Pattee Pond as measured by CEAT from May to September 2008 (see Figure 42 for site locations). DO scale runs from high DO to low DO (dark blue to light blue). Arrows indicate depths experiencing anoxic conditions. Values lower than 1 ppm are defined as anoxic. White regions denote no data available.**

Throughout the summer, the DO was higher in the first 4 m of the water column (the epilimnion), ranging from about 14 ppm (surface) to 6 ppm (bottom). Below the 4 m mark (the metalimnion), the DO dropped off quickly to less than 5 ppm and, starting on 18-Jun-08, the water became anoxic below 7 m (the hypolimnion). Depths below 7 m remained anoxic and, in early August, anoxic conditions started below 6 m. When turnover commenced on 27-Aug-08, the bottom depths were no longer anoxic. Throughout the summer, the mean DO values measured throughout the water column at Sites 1 through 5 ranged from 10 ppm to 7 ppm (n = 13).

The temperature at Site 1 was highest in the epilimnion layer ranging from about 26 °C at surface to 17 °C at the bottom of the epilimnion. Temperatures decreased with depth and began to stabilize around 7 m at about 16 °C (Figure 44). The temperatures from 30-May-08 to 18-Jun-08 were lower throughout the water column and increased as the summer went on, with highest

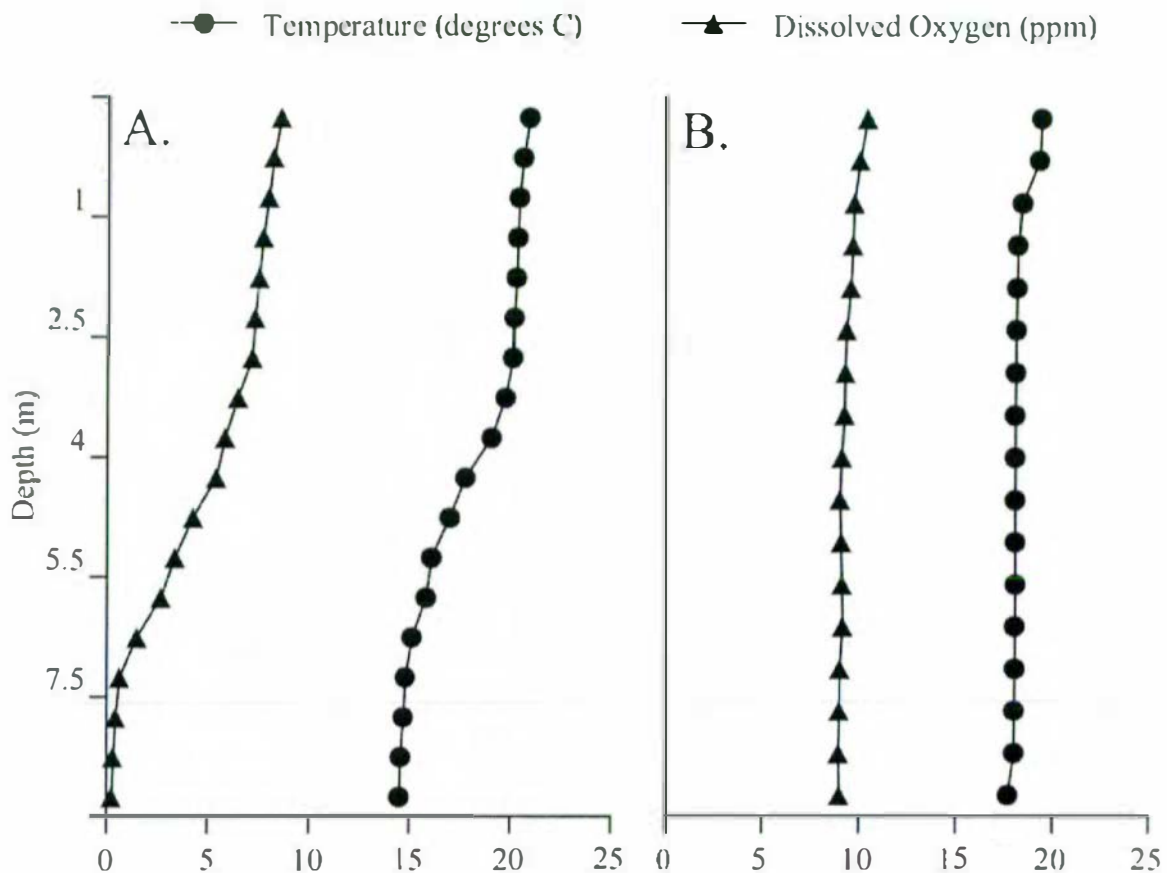
values observed on 10-Jul-08. The temperature then began to slowly decrease again throughout the water column as late summer moved into early fall. Mean temperatures from 30-May-08 to 22-Sep-08 throughout the water column at Spot Sites 2 through 5 ranged from 21.8 °C to 23.7 °C.



**Figure 44. Temperature (degrees C) profile at Site 1 in Pattee Pond measured by CEAT from May to September 2008 (see Figure 42 for site locations). Arrow indicates a clear drop in the epilimnion as the summer progresses. White regions denote no data available.**

At the beginning of the summer when the lake was stratified, the drop in DO and temperature occurred at the temperature-defined metalimnion. As the summer progressed, CEAT observed a clear descent of the epilimnion until, at the end of the summer, when fall turnover began, the DO and temperature profiles became uniform throughout the water column and the metalimnion and hypolimnion disappeared (Figure 45). The temperature range on 18-Jun-08 was 20.9 °C (surface) to 14.5 °C (bottom), while on 22-Sep-08 the range was narrower from 19.5 °C (surface) to 17.7 °C (bottom). The DO range on 18-Jun-08 was 8.6 ppm (surface) to 0.25 ppm

(bottom) matched the wide temp range, while on 22-Sep-08 concentrations extended from 10.4 ppm (surface) to 9.0 ppm (bottom). This effect, caused by mixing, is also shown in both the DO

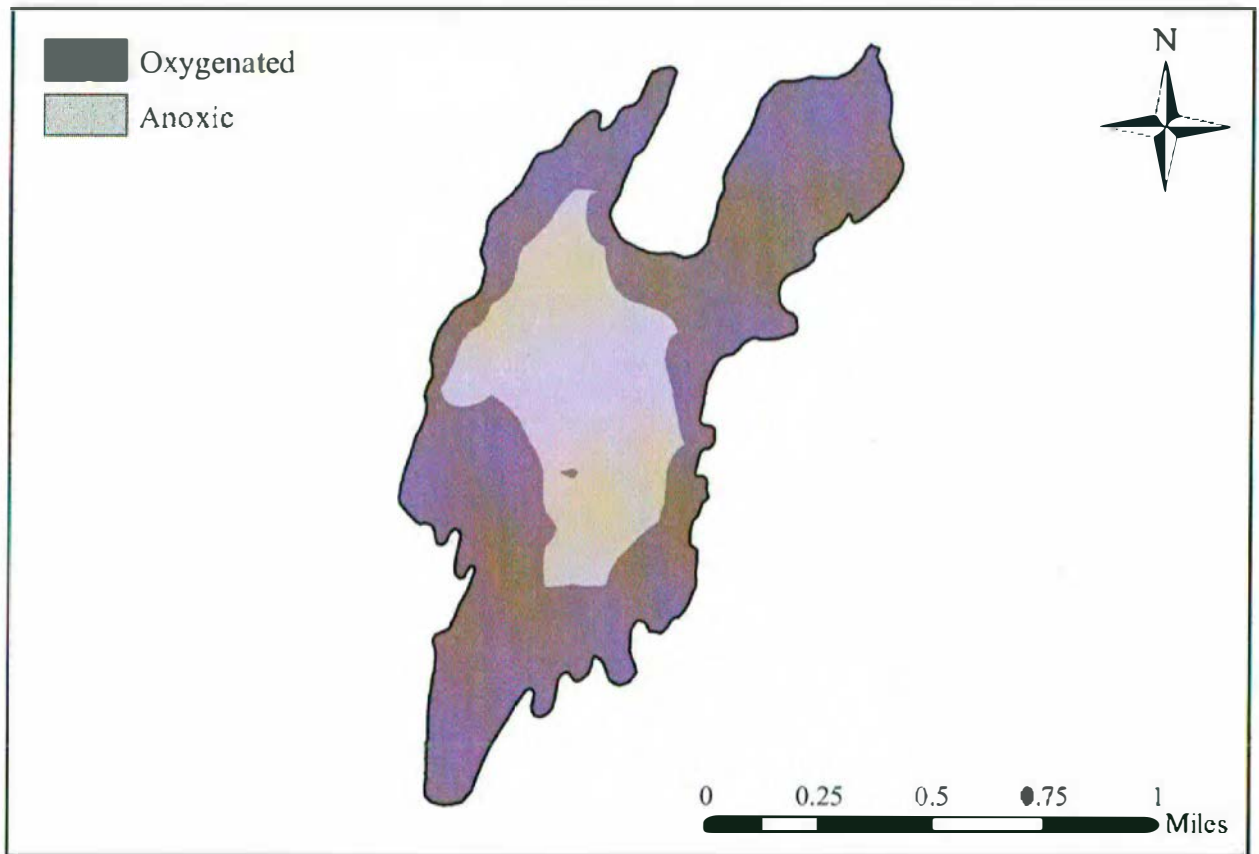


**Figure 45. Dissolved oxygen and temperature profiles measured by CEAT on 18-Jun-08 when stratification had been established (A.) and 22-Sep-08 when turnover had taken place (B.) for Pattee Pond at Site 1 (see Figure 42 for site locations).**

and temperature profiles (see Figure 43 and Figure 44).

The DO at the bottom of a lake decreased, even reaching anoxic levels, during the summer months (Figure 46). This pattern occurred because, despite the low temperatures at the lake bottom, stratification prevents the water from mixing and replenishing DO. Throughout the summer, depths below 6 m to 7 m were anoxic. The shallower Sites 2, 3, 4, and 5 were not as strongly stratified and did not reach anoxic levels.

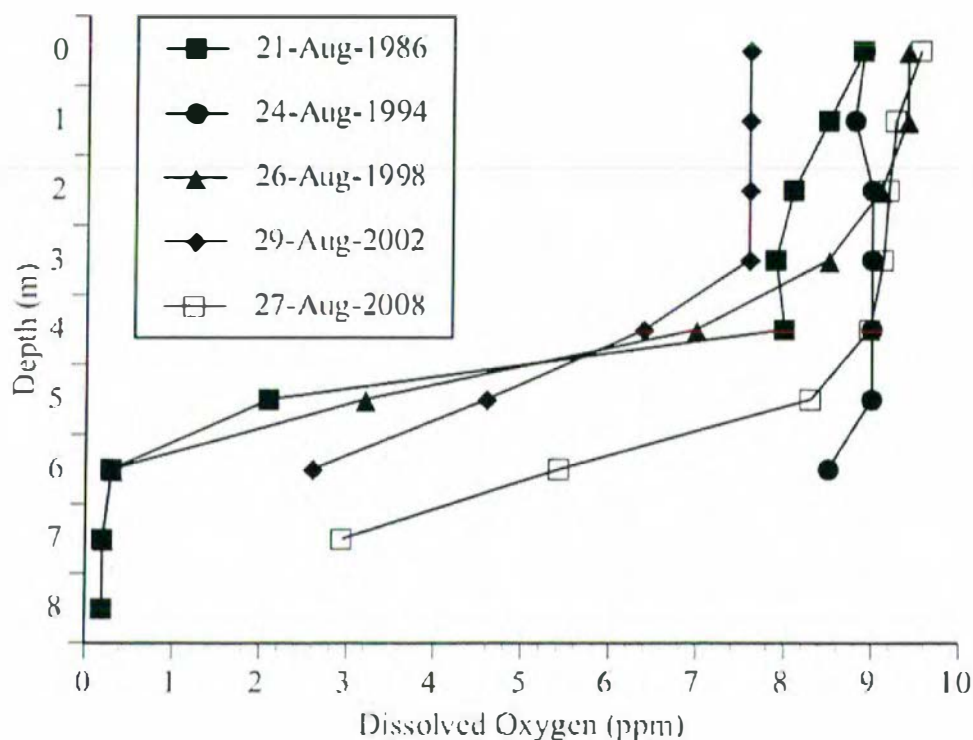




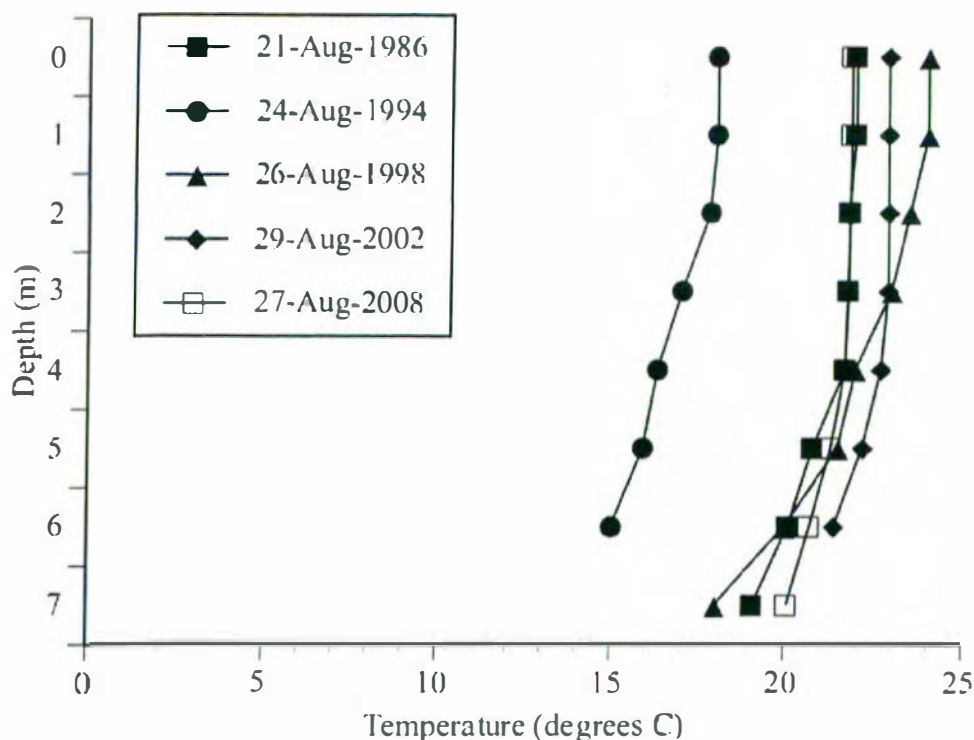
**Figure 46.** Areas of Pattee Pond projected to be anoxic in summer 2008. Anoxic areas defined by DO levels lower than 1 ppm. Light gray area represents depths below six meters (see Figure 8 for detailed bathymetry profile).

Historical DO and temperature data for Pattee Pond Site 1 show similar trends to data obtained by CEAT in 2008. The DO measurements taken, for example, in August of 1986, 1994, 1998, and 2002 show a stratified lake with surface DO levels starting at about 8 ppm and dropping to as low as 0.2 ppm at a depth of 6 m (Figure 47). The depth at which the lake becomes anoxic has not changed significantly over the years, shown by historical profiles, which means that there is no trend toward a greater volume of water becoming anoxic over time (PEARL 2008b). The waters of Togus Pond and Webber Pond also experience anoxic conditions at depths of around 8 m (CEAT 2003, CEAT 2004).

The temperature profiles measured in August 1986, 1994, 1998, and 2002 show a water column beginning to show the effects of seasonal mixing (Figure 48). The temperatures are close to homogenous, ranging from around 22 °C on the surface to 18 °C on the bottom, with the exception of the 1994 profile, which shows slightly colder temperatures throughout the column.



**Figure 47. Dissolved Oxygen (ppm) profile measured by Maine DEP at Pattee Pond Site 1 in summers of 1986, 1994, 1998, and 2002 and by CEAT in 2008 (see Figure 42 for site locations).**



**Figure 48. Temperature (degrees C) profile measured by Maine DEP at Pattee Pond Site 1 in summers of 1986, 1994, 1998, and 2002 and by CEAT in 2008 (see Figure 42 for site locations)**

## Transparency

### Introduction

Transparency is a measure of water clarity determined by the depth one can see down into the water column (MVLMP 2008d). The parameter of transparency is important because it measures to how far light can penetrate into the water (PEARL 2008d). The photic zone, where light is able to penetrate, is the area of the lake where algae and aquatic plants are able to photosynthesize. These photosynthetic organisms provide a large portion of the dissolved oxygen found in the water and also form the base of the food chain (autotrophs) in lake ecosystems (see Background: Trophic Status; PEARL 2008d). The ability of light to penetrate into the water column decreases with depth as light is absorbed and scattered by dissolved and particulate matter in the water. For this reason, transparency is highly correlated with turbidity. Examples of matter that may scatter or absorb light include dissolved organic carbon, which comes from the



decomposition of plants, and suspended particles such as sediments, phytoplankton, zooplankton, and algae (PEARL 2008d). Just as with turbidity, changes in transparency can influence the entire lake ecosystem.

Transparency values vary widely in Maine lakes (MVLMP 2008a). Unless a lake is highly colored or turbid from suspended sediment, transparency readings of 2 m or less generally indicate a severe algal bloom. The majority of Maine lakes maintain transparency depths between 3 m and 6 m, while a few lakes have Secchi disk readings below 1 m or above 9 m.

### Methods

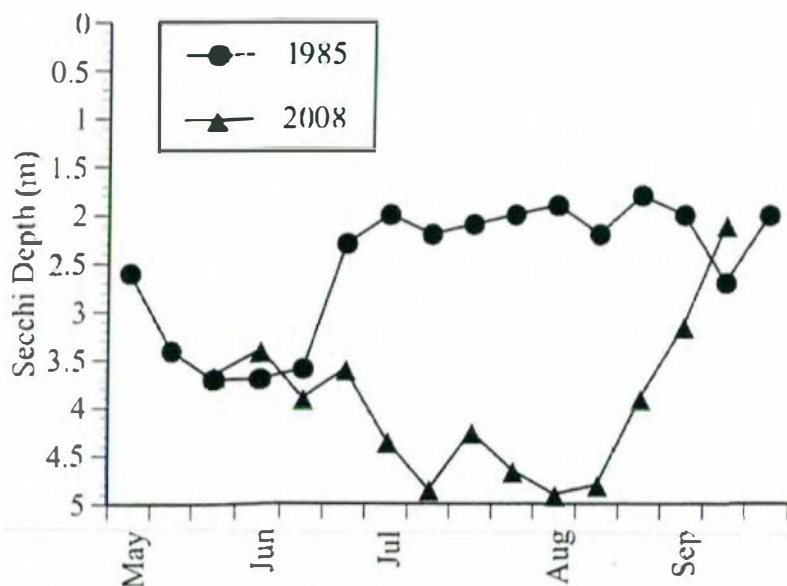
A Secchi disk and Aquascope were used to measure transparency at Site 1 every week from 30-May-08 to 27-Aug-08 and again on 22-Sep-08 (see Appendix J). No transparency data were taken at any of the other test sites.

### Results and Discussion

Secchi depth at Site 1 increased throughout the summer from about 3.5 m in May down to about 5 m in July. Secchi depth sharply decreased, from August forward, to about 2 m on our last sampling day in September (Figure 49). The mean ( $\pm$  SE) Secchi depth from 30-May-08 to 22-Sep-08 was  $4.0 \pm 0.2$  m ( $n = 13$ ), slightly below the state mean of approximately 4.5 m for Maine lakes (KVCOG 2008). Togus Pond, Webber Pond, and East Pond, three similar lakes had means ( $\pm$  SE) lower than Pattee Pond,  $3.0 \pm 0.5$  m and  $1.3 \pm 0.1$  m, and 3.3 m, respectively (CEAT 2000, CEAT 2003, CEAT 2004). The lower mean transparency readings in these neighbor lakes indicate poorer overall water quality and an increased presence of algal blooms.

The Secchi depth for Pattee Pond Site 1 (the only reading taken that year), measured on 28-Sep-92, was 2.0 m, which is much lower than the 2008 mean ( $4.0 \pm 0.2$  m) (CEAT 1993). The historical maximum and minimum Secchi depths in Pattee Pond from 1970 to 2007 are 5.2 m and 1.0 m, respectively (Figure 50; Bouchard, pers. comm.). This maximum does not exceed the range of most Maine lakes, but the minimum is very low and suggests that Pattee Pond has experienced algal blooms in the past. Historically, the transparency readings in Pattee Pond have been steadily improving and, as seen in the comparison of 1993 and 2008 data, the lake now enjoys a higher transparency than previously, suggesting that the water quality has improved.

The pattern of fluctuating Secchi depths has not always been the same in Pattee Pond. In summer 2008, transparency increased from May forward to reach a maximum Secchi depth of 4.9 m on 29-Jul-08 and then proceeded to decrease throughout the rest of the summer into the fall (Figure 49). In contrast, the transparency pattern in summer 1985 shows Pattee Pond experiencing a maximum Secchi depth of 3.7 m in May and then decreasing to about 2 m, a

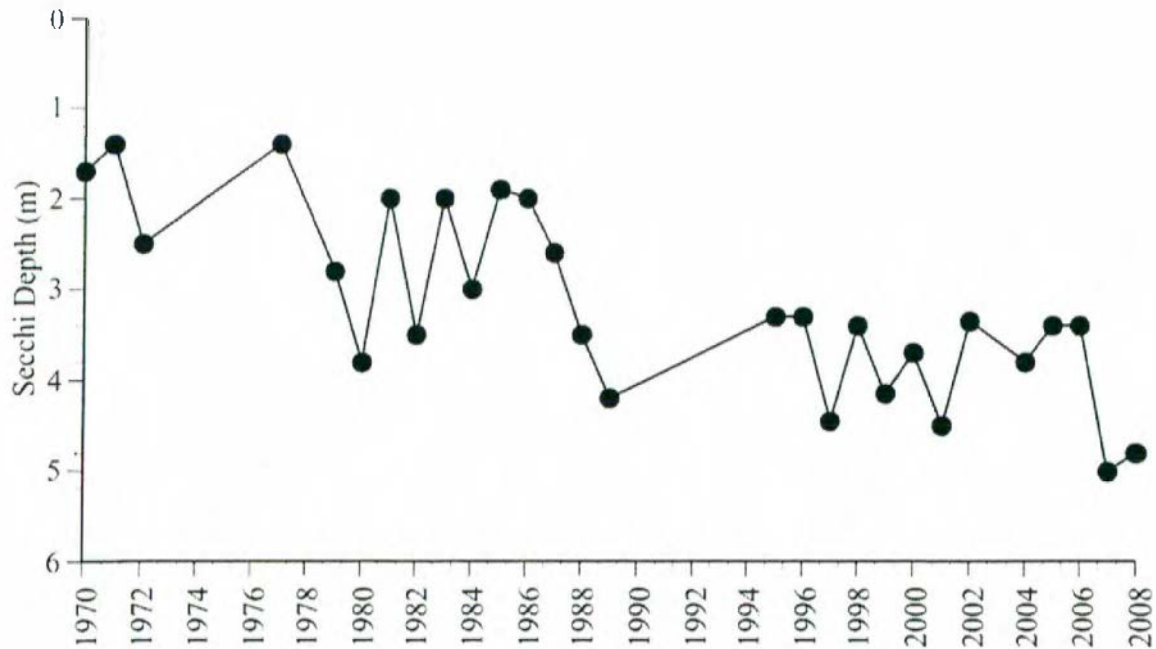


**Figure 49. Transparency measured by Secchi depth (m) by CEAT at Pattee Pond Site 1 from 30-May-08 to 22-Sep-08 and by Maine DEP from 15-May-85 to 30-Sep-85 (See Figure 42 for site locations).**

reading that persists for the rest of the summer into September. It is clear to see that transparency was low for the majority of summer 1985 and high for most of summer 2008.

There is a pattern of increasing Secchi disk readings that suggest Pattee Pond has been experiencing improvement in water quality over time (KVCOG 2008). Although the water quality has improved from the 1970s and 1980s, the lake is still in a precarious position,

susceptible to algal blooms and phosphorus loading, and could experience a decline in water quality if mitigation efforts are not continued to improve the water body. The west bank is a significant source of sediment pollution especially after rain events. Transparency readings in Pattee Pond have been observed to decrease to almost half of the original depth after rainstorms (Snow, pers. comm.). Measures to impede this pattern of erosion and sediment loading need to be continued or the lake could slip back into a state of very poor water quality.



**Figure 50. Historical transparency measured by Secchi depth (m) by Maine DEP at Pattee Pond Site 1 based on readings taken between 26-Jul and 13-Aug in summers from 1970 to 2008 (See Figure 42 for site locations).**

## Turbidity

### Introduction

Turbidity is the measure of the amount of suspended matter in the water (Lenntech 2008). Particles contributing to turbidity include soil from erosion, particulates in wastewater discharge, resuspended soil from the lake bottom, phytoplankton, and algae. Sediments from erosion can carry nutrients, heavy metals, and pesticides, which can be harmful to the lake ecosystem. In addition, particles absorb heat from the sun, causing turbid waters to become warmer and reducing the oxygen concentration. Many aquatic organisms require a certain concentration of oxygen, so any drop in oxygen concentration could affect their ability to survive. Particles in the water column also scatter light, preventing it from penetrating deeper into the water column and decreasing photosynthetic activity. This decrease in photosynthetic activity results in a lower concentration of dissolved oxygen. Excessive suspended particles can damage or clog the gills of fish, weakening or even killing them (Lenntech 2008).



Boat activity and turbulence in shallow areas of the lake can also increase turbidity. Wave action caused by boats increases the amount of suspended particles in the water because the increased turbulence causes bottom sediments to resuspend. When these bottom sediments, rich in nutrients such as phosphorus, are resuspended into the upper layers, the nutrients become available, creating potential for algal blooms. (Lake Access 2007; see Background: Phosphorus and Nitrogen Cycles).

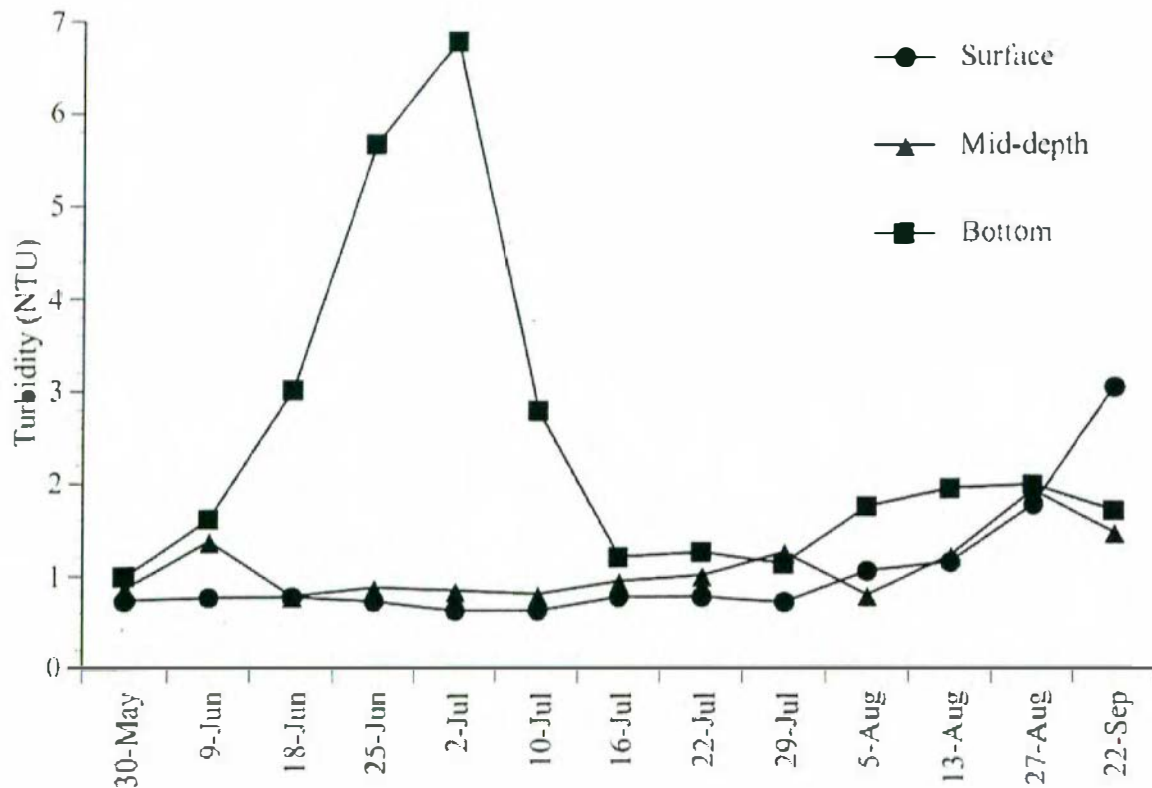
### Methods

Water samples were taken from the surface, mid-depth, and bottom depths of Sites 1 and 5. Sites 2, 3, and 4 were too shallow to sample at all three depths, so surface and bottom samples were taken at Sites 2 and 4, and mid-depth samples were taken at Site 3. These samples were taken every week from 30-May-08 to 27-Aug-08 and again on 22-Sep-08. A HACH 2100P Turbidimeter was used to measure turbidity in Nephelometric Turbidity Units (NTU) (see Appendix J). No turbidity data were collected on any of the tributary sites.

### Results and Discussion

Throughout the summer, surface turbidity readings at Site 1 ranged from 0.62 NTU to 3.05 NTU with a mean ( $\pm$ SE) of  $1.04 \pm 0.19$  NTU. Mid-depth turbidity readings closely mirrored the pattern of surface turbidity readings. Bottom turbidity readings, however, were much higher and much more varied, beginning at about 1.0 NTU at the end of May, spiking to about 6.75 NTU in early July, and then declining and staying between 1.0 NTU and 2.0 NTU for the rest of the summer (Figure 51). The higher readings for bottom turbidity in July are likely due to an increase in accumulated organic matter (dead algae) (CEAT 2007). The algae populations that were present in late spring or early summer settled to the bottom as they died and were broken down by decomposers. This accumulation of decomposing organic matter contributes to this midsummer, higher bottom turbidity reading.

Mean surface turbidity for Sites 2, 4, and 5 were approximately equal throughout the summer, about 1.0 NTU with Site 3 displaying a slightly higher mean, about 1.2 NTU. Site 3 was approximately 1 m deep, which is too shallow to have strong stratification. The wind and



**Figure 51. Surface, mid-depth, and bottom turbidity (NTU) at Pattee Pond Site 1 measured by CEAT from May to September 2008 (See Figure 42 for site locations).**

turbulence caused more mixing at this site, which would explain the higher mean surface turbidity.

Turbidity levels are generally less than 50 NTU in natural waters, but values can range from 1 NTU to 1000 NTU (Boyd 2000). The overall mean turbidity readings in Pattee Pond,  $1.30 \pm 0.08$  NTU, are lower than other similar lakes. For example, Togus Pond, Webber Pond and East Pond, three similar lakes, had mean ( $\pm$  SE) turbidity readings of  $7.2 \pm 1.3$  NTU,  $5.9 \pm 2.7$  NTU, and 8.0 NTU, respectively (CEAT 2000, CEAT 2003, CEAT 2004). Turbidity readings are expected to be higher because of the large amount of erosion on the west side of the lake bringing sediments into the water, especially after rain events (Snow, pers. comm.). However, Site 6, the only sampling site close to the erosive west bank, is one that CEAT only sampled on 22-Sep-08, showing a high surface turbidity reading of 3.7 NTU. The other sample

Sites 1 through 5 were open water sites where sediments may have already settled in the water column before measurements by CEAT could catch the impact of this sediment loading.

## **Color**

### Introduction

The concentration of suspended and dissolved particles influences the color of a water body (PEARL 2008d). The color of a lake can be measured in two ways: apparent and true color. Apparent color is a measure of both dissolved and suspended particles in the water column. The true color of water is the value taken after the suspended particles have been filtered out (Tomar 1999). Suspended particles can be a result of soil erosion, plant decomposition or natural weathering of surrounding substrates. Tannic and humic acids, which result from plant material decomposition, are the dissolved compounds that cause lake water to have a tea-like color (PEARL 2008d). Wetlands have a high rate of plant matter decomposition, which leads to elevated levels of dissolved and particulate matter in the water. These compounds can influence the color of a lake (PEARL 2008c). Several factors within the watershed can influence the different types of particles that are present in a lake including land use activity, tree and plant composition, and substrate rocks and soils (PEARL 2008e).

Lakes with color concentrations above 20 Platinum-Cobalt units (Pt-Co) are considered to be colored (Canfield et al. 2007). Higher color levels can be an indicator of reduced transparency in a lake because of an increased concentration of particulates, which could also indicate higher phosphorus levels (MVLMP 2008b).

### Methods

Surface samples were taken at each of the six lake sites and the three tributary sites on 22-Sep-08. Before analyzing each sample a 47 mm, 0.45 micron membrane filter was rinsed with Epure water and then used to filter the lake water. The samples were analyzed using a HACH 4000 DR Spectrophotometer to obtain true color readings. The spectrophotometer analyzed the color reflectance within the visual light spectrum of the sample and produced a value in Pt-Co.



## Results and Discussion

Lake Sites 1 through 6 and Tributary Sites B and C had readings ranging from 36 Pt-Co to 68 Pt-Co, meaning they are colored. Tributary Site A, entering the lake from the southeast bank, was highly colored, with a reading of 158 Pt-Co. The high color reading at this site was likely due to erosion in the area surrounding the tributary. In addition, the wetlands around Site A contain a large amount of decaying organic matter (see Figure 12).

Color values in Maine lakes vary greatly from non-colored to highly colored. Pattee Pond has higher color values than other comparable lakes. Togus Pond, Webber Pond, and East Pond, three lakes similar to Pattee Pond, were all found to be non-colored lakes (MDEP 2001a, MDEP 2002a, MDEP 2005b, PEARL 2008f). Relative to the size of the lake area, the Pattee Pond watershed includes a larger amount of wetland area than the watersheds of these other lakes, which may account for the higher color readings.

## **Conductivity**

### Introduction

Conductivity is a measure of the ability of a solution to conduct electricity and is directly related to the concentration of ions. Solutions with a greater concentration of ions will conduct more electricity. These ions include bicarbonate, calcium, sulfate, chloride, sodium, magnesium, and potassium (Jarrell 1999). For freshwater systems, conductance is measured in micro Siemens ( $\mu\text{S}$ ). Conductivity is the measure of the conductance between two parallel plates and is expressed as S/cm or  $\mu\text{S}/\text{cm}$ .

The conductivity of rainwater is 20  $\mu\text{S}/\text{cm}$  to 40  $\mu\text{S}/\text{cm}$ . Conductivity of surface waters varies with levels of pollution and other factors such as geology. The normal range for surface water is 30  $\mu\text{S}/\text{cm}$  to 400  $\mu\text{S}/\text{cm}$ . In comparison sewage treatment plants can cause high nutrient loading and release water with conductivity as high as 300  $\mu\text{S}/\text{cm}$  to 1000  $\mu\text{S}/\text{cm}$  (Kegley and Andrews 1998). Ions in wastewater include chloride, sodium, potassium, sulfate, nitrate, and phosphate.

Because conductivity is not a sensitive parameter when measuring water quality, increases in conductivity serve as a cue to scientists that there is a significant pollution problem.

Conductivity can increase due to human activities such as agricultural runoff, animal husbandry, sewage systems, septic tanks, and swimming pools (Ecological 1998; Kegley and Andrews 1998).

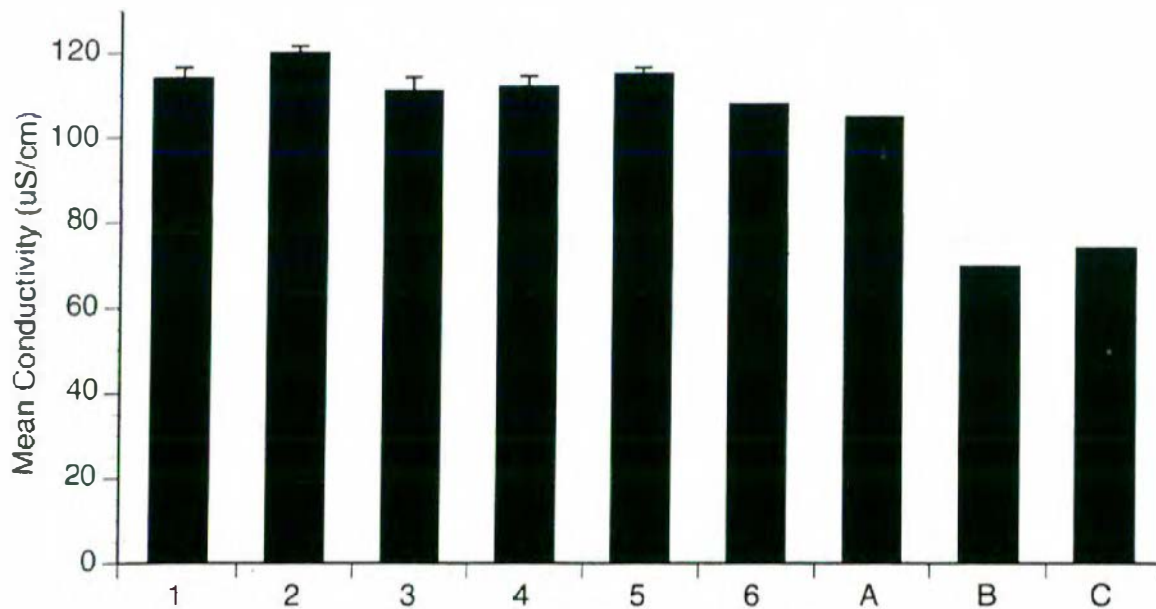
### Methods

Conductivity was measured using the YSI Sonde 6820 (see Appendix J) approximately once a week at the Sites 1-5 from 30-May-08 to 22-Sep-08. On the first day study sites were still being established, and measurements were only taken at Sites 1, 2, and 4. Subsequent measurements were taken at all five sites (Sites 1-5). For the first two weeks of the study, data were recorded for every meter of depth at each site. Beginning on 18-Jun-08 conductivity data were recorded at half-meter intervals to increase the number of sample points. On 08-Aug-08 no conductivity readings were recorded. Conductivity was measured at a sixth site near the western shore of the lake, a potential problem area, on 26-Sep-08. Water samples were taken from three tributary sites (see Figure 42) on 15-Sep-08 and put on ice. They were refrigerated until conductivity was measured using an Orion 140 conductivity and salinity on 16-Oct-08 meter (see Appendix J and K).

### Results and Discussion

Surface conductivity means were calculated for each site across collection dates. The mean conductivity for all sites falls within the unpolluted surface water range of 30 to 400  $\mu\text{S}/\text{cm}$  (Figure 52). The mean ( $\pm\text{SE}$ ) surface conductivity among all lake sites (Sites 1-6) is  $113 \pm 1.7$   $\mu\text{S}/\text{cm}$ . For the tributary sites, conductivity was 104.8  $\mu\text{S}/\text{cm}$ , 69.7  $\mu\text{S}/\text{cm}$ , and 74.0  $\mu\text{S}/\text{cm}$  for sites A, B, and C, respectively.

The higher reading at Site A suggests that the tributary is a source of erosion loading. Land use surrounding Site A is composed of residential, recreational (Giordano's market and summer campground), and commercial. These land uses have less vegetation than forested lands, causing greater runoff during rain events. Moreover, the runoff from these land uses has a greater concentration of nutrients than runoff from forested lands because there is less vegetation to absorb nutrients.



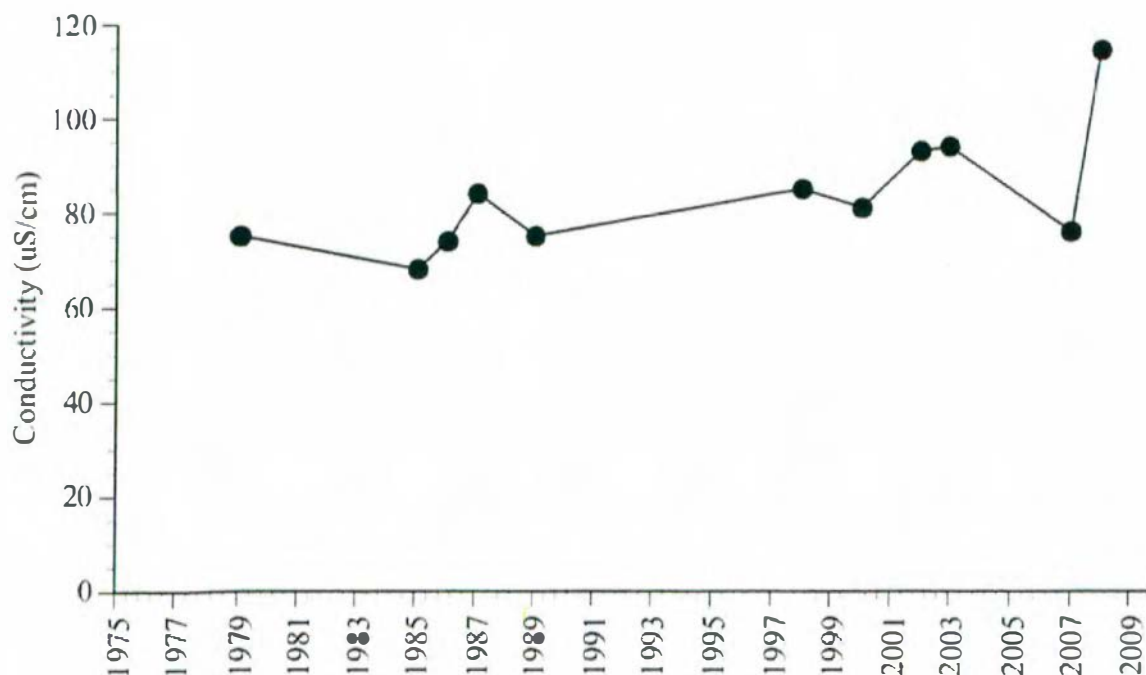
**Figure 52. Mean surface conductivity ( $\mu\text{S}/\text{cm}$ ) at Lake Sites 1-5 on Pattee Pond was measured by CEAT using a YSI Sonde 6820 from 30-May-08 to 22-Sep-08, and at Site 6 on 22-Sep-08. At Tributary Sites A-C conductivity was measured using an Orion 140 conductivity and salinity meter on 22-Sep-08.**

In contrast, Tributary Site B is surrounded by transitional, mixed, and wetland habitat. Tributary Site C is surrounded entirely by wetland habitat (see Figure 12). Wetlands absorb nutrients and filter wastewater (see Background: Wetlands). Moreover, there are more roads that are in closer proximity to Site A than Sites B or C. Site A has five roads within one half mile, Site B is crossed by two roads that are a mile apart, and Site C is nearby the only road within two miles.

For similar Maine lakes, East, Webber, and Togus Ponds, mean conductivities were found to be  $27.5 \mu\text{S}/\text{cm}$  (1999),  $39 \pm 1.0 \mu\text{S}/\text{cm}$  (2003), and  $58 \pm 2.03 \mu\text{S}/\text{cm}$  (2004) respectively (CEAT 2005). The mean for Pattee Pond falls well above all of these readings. Historical data from Pattee Pond suggest an increase in conductivity in the lake over time (Figure 53). Conductivity data from 1993 on Pattee Pond ranged from 15.00 to  $18.75 \mu\text{S}/\text{cm}$  (CEAT 1993), while our study had a range of 99 to  $155 \mu\text{S}/\text{cm}$ .

This severe increase could be a sign of recent increased erosion within the watershed or due to an unusually rainy summer. A CEAT stream sampler showed that Farber Brook near Giordano's market and campground is a major source of sediment loading during major rain





**Figure 53. Historical annual mean conductivity (µS/cm) for Pattee Pond (PEARL 2008). Data for 2008 were measured by CEAT from 20-May-08 to 22-Sep-08 using the YSI Sonde 6820 (see Appendices I, J, and K). High readings for 2008 may suggest increased sediment loading, or be the result of a very rainy summer.**

events (greater than 0.5 in of rain). Therefore, an exceptionally rainy summer could lead to an increase in conductivity readings for the lake as a whole. Homeowners around Pattee Pond have also noted erosion after rain events near the steeper western bank of the lake (Fleury, Snow, Whitaker, pers. comm.). Fleury also reported having noticed increased erosion from Bellows Stream after logging that occurred further upstream.

## Chemical Analyses

### pH

#### Introduction

The pH of a liquid is a measure of the hydrogen ( $H^+$ ) ion concentration of a sample, and samples with higher concentrations of hydrogen ions are considered to be more acidic. The pH is measured on a logarithmic scale, where pH represents the negative log of the hydrogen ion concentration. A one-unit change in pH is equivalent to a tenfold change in the concentration of

hydrogen ions. The pH scale ranges from 1 (highly acidic) to 14 (highly basic). Pure water has a neutral pH of 7 (PEARL 2008g).

During the process of photosynthesis, plants use carbon dioxide and uptake hydrogen ions, increasing the pH of the water (PEARL 2008g). However, plants also produce carbon dioxide during respiration, releasing hydrogen ions and decreasing pH of the water (PEARL 2008g). Because photosynthesis can only occur during daylight, there is often both daily and seasonal variation in the pH. pH will generally decrease with depth because at greater depths, where less light is able to penetrate through the water column and photosynthesis is severely diminished, respiration by decomposers still occurs.

Acidity can have a large impact on aquatic organisms and influence their survival. Various plant species have different pH tolerances. The pH of a water body can limit which species are able to grow and survive. The pH of the water affects the reproductive processes of fish species. Acidic conditions inhibit development and increase malformations in embryos (Ikuta et al. 1999). Finally, pH has a large impact on the solubility of various molecules. Two examples are mercury and aluminum, both of which are more soluble in acidic water. Both undergo bioaccumulation through the food web, harming many species including humans. This increase in the solubility of toxic metals can also cause a release of phosphorus, because as the pH drops, the metals dissolve in the water. This decreases the number of metal species available to bind with the phosphorus and remove it from the water column.

## Methods

A YSI 6820 MDS Sonde was used at Sites 1 through 5 from 30-May-08 through 27-Aug-08 and again on 22-Sep-08 at these sites in addition to Site 6 to obtain a pH profile for the lake (see Appendix I). The surface pH was measured using a Fisher Scientific Accumet Basic pH meter (see Appendix J).

## Results and Discussion

The mean pH for the Characterization Site on 22-Sep-08 was 7.74 and ranged from 7.62 to 7.82. Over the entire course of the study, the pH at the Characterization Site varied from 6.53 to 7.92. For the majority of the study, the pH at the Characterization Site remained slightly basic

(see Appendix J) however the very deepest readings at Site 1 showed slightly acidic conditions. This would suggest that the expectations of higher acidity because of the lack of photosynthesis but continued respiration at those depths was correct. As the study progressed, CEAT recorded rising acidic conditions in the water column, and CEAT found slightly basic conditions down to 6.5 meters until 22-Jul-08, after which at this depth, the water became acidic. This is likely due to continued respiration throughout the summer combined with a well defined epilimnion that prevents the water from mixing, allowing the hydrogen ion concentration to increase at depth. This hypothesis is supported by the fact that at Site 5 (only 5.6 m deep) the water remained slightly basic at the bottom while at Site 1 the water became more acidic at the deepest points. For historical comparison, the mean pH at Site 1 as determined by the MDEP was 7.2 during the period from 1979 to 1989. The mean found during our study is 7.4, close to the historical average.

The pH levels at the five Spot Sites ranged from 7.05 to 8.09, and the pH levels of the three Tributary Sites ranged from 6.27 to 6.51. The acidic conditions of the tributaries are most likely because the tributaries run through a marsh and wetland area, which if they have enough productivity, will result in a lower pH. However, these pH levels likely not sufficiently acidic to significantly affect species health in the lake since all of the sites around the lake are very close to a neutral pH of 7.

## **Total Phosphorus**

### Introduction

In many freshwater lakes, including those in Maine, phosphorus is the limiting nutrient for phytoplankton growth (Bronmark and Hansson 2005). As a result, biomass growth of the algae population is dependant upon an increase in phosphorus levels increase. Increased phosphorus in the water (on the order of parts-per-billion, or “ppb”) can lead to significant algal blooms in lakes and a resulting decline in the water quality.

Phosphorus in a lake occurs in both organic and inorganic forms. The inorganic form is the orthophosphate ion, and the organic forms are dissolved phosphorus compounds that are produced by living organisms (see Background: Phosphorus). As these concentrations of phosphorus change, the trophic state of the lake can be affected (Tomar 1999). Oligotrophic



lakes tend to have an annual mean total phosphorus concentration between 4 ppb and 10 ppb. The Maine DEP states that phosphorus levels as low as 12 ppb to 15 ppb could cause a significant algal bloom (see Background: Phosphorus). The typical level of phosphorus in eutrophic lakes ranges from 35 ppb to 100 ppb (O'Sullivan and Reynolds 2005). Lakes with high concentrations of phosphorus have a greater likelihood of experiencing algal blooms, including floating algal mats. As algae die, they settle out on the bottom of the lake, increasing turbidity as well as the amount of decomposition occurring. In larger, deeper lakes that lack consistent mixing, the oxygen concentration at the bottom of the lake becomes seriously depleted as bacteria facilitating the decomposition process respire. Light does not penetrate to the bottom of larger lakes, so there is no way to restore depleted oxygen levels because of the lack of photosynthesis. In some cases, decomposition and the resulting consumption of oxygen can lead to anoxic conditions in the hypolimnion, prohibiting the survival of fish (see Background: Phosphorus and Nitrogen Cycles).

If the hypolimnion of a lake becomes anoxic, there is a chance that the phosphorus concentrations will increase as a result. When the hypolimnion is aerobic, iron exists as insoluble ferric compounds. These compounds can complex with the phosphorus to form ferric phosphate, making phosphorus unavailable to plants (Maitland 1990). However, when anoxic conditions set in, iron is reduced to a water-soluble ferrous state. The bonds that were previously formed with the phosphorus are broken, releasing phosphorus, making it available to plants for growth (Maitland 1990). This process is known as internal phosphorus loading because the bottom sediments in a lake release phosphorus as opposed to external sources of phosphorus in the watershed adding phosphorus to the lake.

External loading of phosphorus is the primary source of phosphorus in a lake. Phosphorus is also generally considered a non-point source pollutant, meaning that many different factors contribute to phosphorus concentrations in a lake. The phosphorus concentration in a lake can be attributed to many different sources within a watershed (e.g., camp roads, driveways, lawn and garden fertilizers, and leaky or faulty septic systems). This wide array of sources and their distribution throughout a watershed can make it very difficult to minimize external phosphorus loading into a lake.

## Methods

CEAT sampled Pattee Pond weekly from 30-May-08 through 13-Aug-08 and again on 27-Aug-08 and 22-Sep-08. Surface, mid-depth, bottom and epicore samples were taken at the Characterization Site (Site 1). Because of the shallow depth at Sites 2 and 4, only surface and bottom samples were taken. However, at Sites 5 and 6 surface, mid-depth, and bottom samples were taken. Only a mid-depth sample was taken at Site 3, and only surface samples were taken at the three tributary sites (see Appendix I).

The ascorbic acid method was used to determine the total phosphorus concentration, however two different instruments were used for the final analysis (see Appendix J). After samples were collected in the field, they were put in coolers filled with ice and transported back to the Colby Environmental Analysis Center. For the so-called “Manual Method” for total phosphorus measurements, the water was split into two 50 mL samples and 1 mL of 1.75 N ammonium peroxydisulfate and 1 mL of 11 N sulfuric acid were added to each sample. The samples were then placed in an autoclave for 30 minutes at 15 psi and 120 °C. This digestion process converts all the phosphorus in the sample to the orthophosphate form, which is the measurable form of phosphorus. Once digestion is complete, 11 N sodium hydroxide was added to raise the pH to 6. After adjusting the pH, 8 mL of combined color reagent (5 N sulfuric acid, potassium antimonyl tartrate, ammonium molybdate, and ascorbic acid) were added to each sample. This color reagent reacts with the orthophosphate to produce a phospho-molybdate compound that turns the solution blue, with absorbance measurements taken between 12 and 30 minutes after the reagent was added. The intensity of this blue color was measured using a Thermo Fisher Spectrophotometer with a 10 cm path length. The absorbance of each sample was measured, then compared to a standard addition curve and the final concentration of phosphorus was recorded in parts per billion.

A second method was also used to measure phosphorus. This method utilized a Lachat Quikchem system with a Flow Injection Analysis system, autosampler and inline digester. The Lachat method number is 10-115-01-3-F for measuring total phosphorus (Harbridge 2008). For this system, CEAT again placed all samples on ice in a cooler for transportation back to the Colby Environmental Analysis Center. Concentrated sulfuric acid was then added to the samples to get the pH to 2 or lower and the samples were placed in the refrigerator. The acid and cold-

storage were used to prevent organic compounds from sticking to the sides of the sample bottles as well as prevent any further biological growth. This system uses the same chemistry as the manual method, adding sulfuric acid and peroxydisulfate to convert the phosphorus to orthophosphate. However, the Lachat system has an inline digester containing a heating block at 135 °C and a UV lamp. When the samples travel through tubing around the heating block and UV lamp, and are mixed with the persulfate and sulfuric acid, the phosphorus in the samples is converted to the orthophosphate ion. After that reaction is complete, the samples are mixed with separate ascorbic acid and molybdate solutions. Once those two solutions are added, the sample then travels around another heating unit, at a lower temperature than the inline digester that accelerates the phospho-molybdate blue complex formation, before absorbance measurements are made.

### Results and Discussion

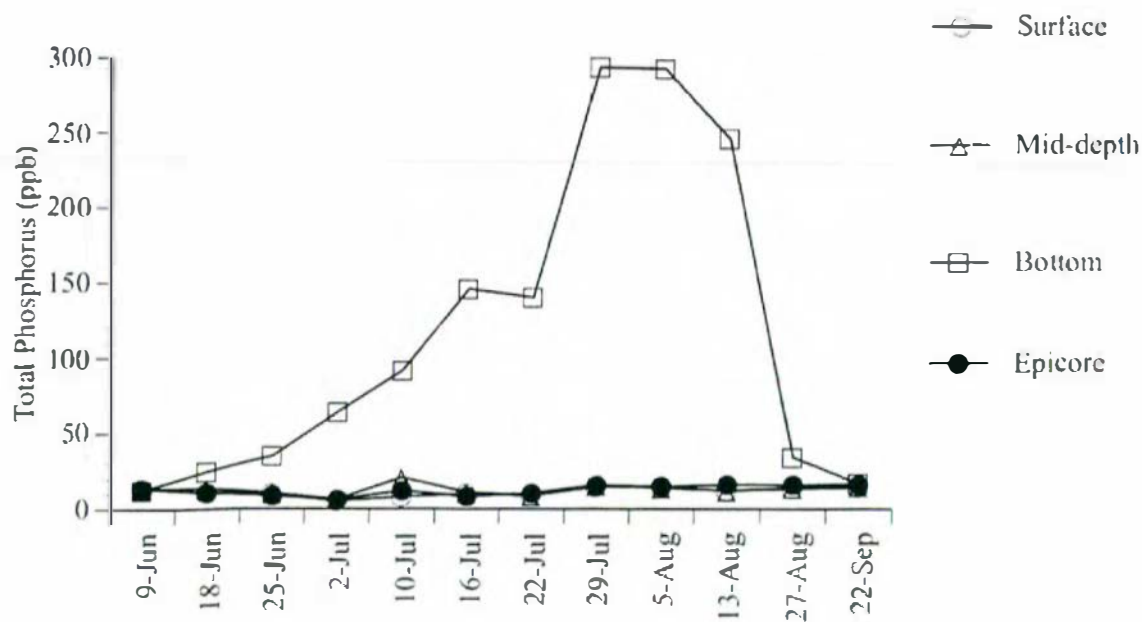
At Site 1, the mean ( $\pm$  SE) summer surface, mid-depth, bottom, and epicore phosphorus levels were  $12.1 \pm 1.1$  ppb,  $13.7 \pm 1.2$  ppb,  $108.9 \pm 29.2$  ppb, and  $12.5 \pm 1.0$  ppb, respectively. The high variability in the bottom sample resulted from low readings in the beginning and end of the summer, with extremely high values obtained in the middle of the summer testing (Figure 54). The epicore samples are used to characterize the concentration of phosphorus in the entire lake because it includes a larger proportion of the water column. Instead of using a grab sample with a small amount of water from one small portion of the water column, the epicore sample is a combination of the waters throughout the depth of the epilimnion.

Comparing the tributary site phosphorus levels, CEAT would expect that the levels for the inlets into the lake, Site A and Site B, would have higher concentrations of phosphorus than the outlet, Site C (see Figure 42). CEAT reasoned that inlets carry sediments and other phosphorus-laden materials into the lake, which is used by biota in the lake and settles to the bottom tied up in dead material, resulting in less phosphorus leaving through the outlet waters. Our results for total phosphorus at Sites A, B, (inlets) and C (outlet) are 23.8 ppb, 20.1 ppb, and 11.2 ppb respectively, and these results support our hypothesis. A comparison of the three tributary sites with the Spot Sites around the lake is also interesting (Figure 55). Those results show that the tributary inlet phosphorus levels are higher than the mean phosphorus levels for the

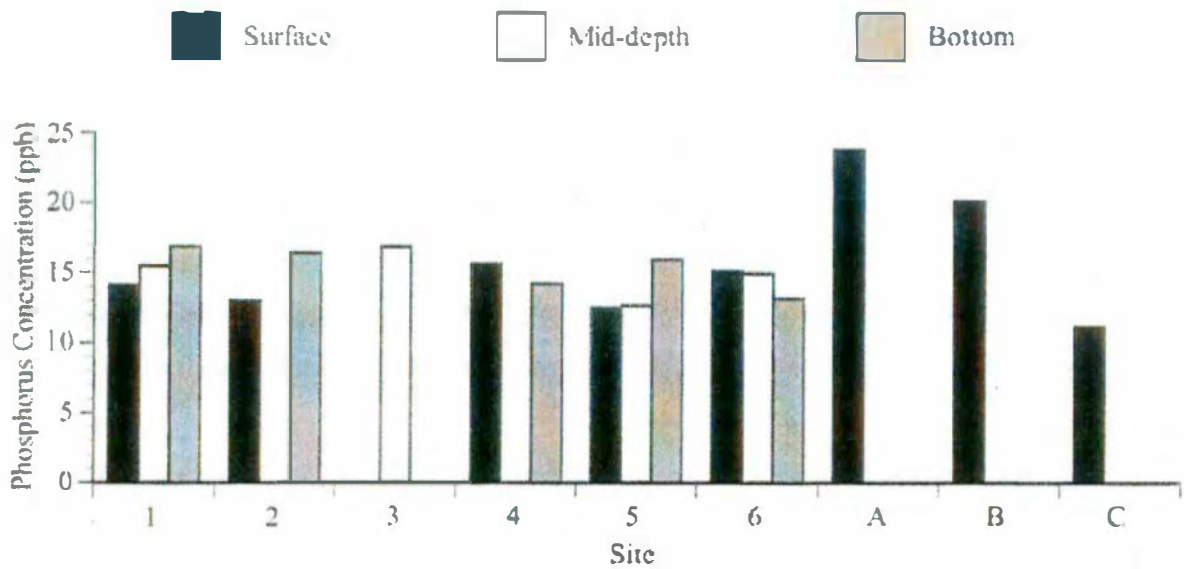


Spot Sites, which would be expected, as the inlets will bring more phosphorus into the lake, and some of that phosphorus is removed before the water reaches the outlet.

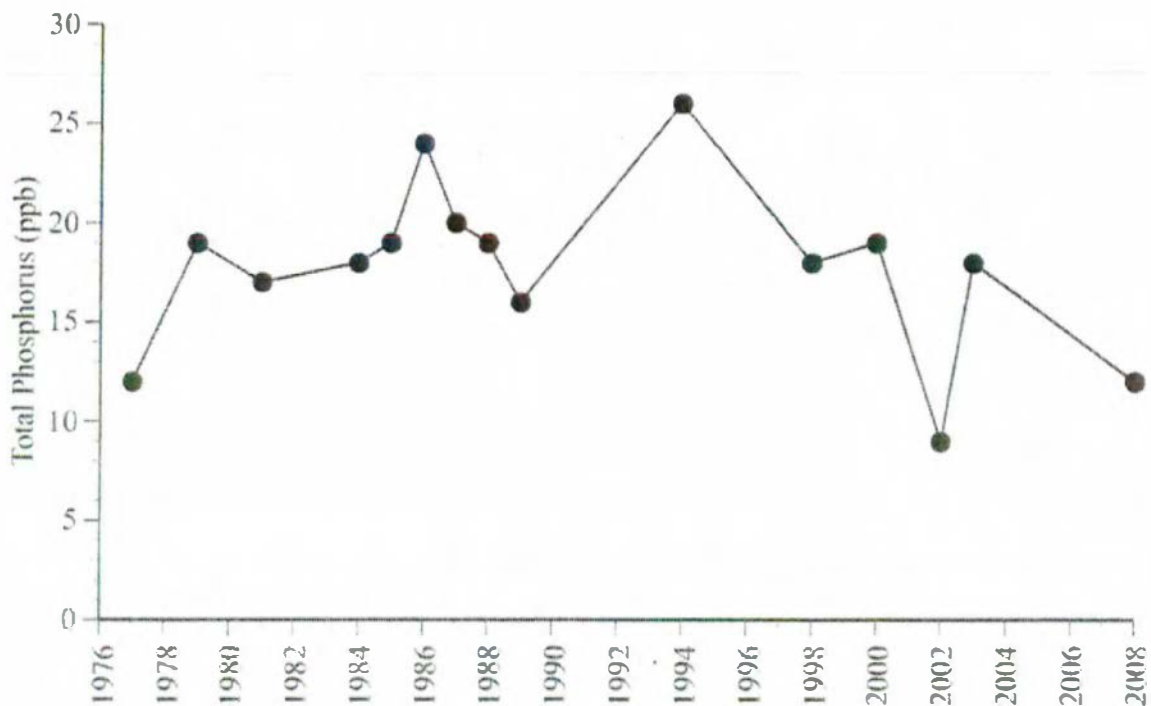
In comparison to data provided by the Maine DEP, Pattee Pond phosphorus concentrations are currently lower than in past studies (Figure 56). This is a good indication that the water quality of the lake has been improving, and is in part a reflection of the previous work done by the Pattee Pond Association. Comparisons to previous data collected during specific studies also reflects this decrease in phosphorus levels, as a study conducted during the summer of 1981 by the Maine DEP showed a mean ( $\pm$  SE) of  $15.6 \pm 1.9$  ppb and  $16.3 \pm 1.8$  ppb of phosphorus for the surface and mid-depth samples, respectively. These data show a higher concentration of phosphorus than what was found by CEAT during the summer 2008.



**Figure 54.** The total phosphorus concentrations (ppb) from Pattee Pond at Site 1 measured by CEAT from May 2008 through September 2008 (see Figure 42 for site locations).



**Figure 55. Phosphorus concentrations (ppb) at Sites 1-6 and Tributary Sites A-C. Surface, mid-depth, or bottom measurement were taken based upon site depth (see Appendix J). Measurements were made by CEAT for all sites on 22-Sep-08.**



**Figure 56: Mean total phosphorus concentration (ppb) from 1977 to 2008 for Pattee Pond Site 1 (Maine DEP; see Figure 42 for site locations). Data from 2008 were collected by CEAT. All other data are from Maine DEP.**

## Nitrates

### Introduction

Nitrate and phosphorus are considered the two most important limiting factors to algae growth (Kegley and Andrews 1998, Boyd 2000, Brönmark and Hansson 2005). Unwanted algal blooms in Maine lakes have traditionally been attributed to human-caused increases in nitrate and phosphate levels. Human impacts on the natural environment (changes in land use) can alter the hydrology of an area and increase nutrient levels in the associated body of water (Tietjen 1988, Ecological 1998).

Agricultural operations are a major source of nitrates. Most fertilizers are made of ammonium nitrate, potassium nitrate, and ammonium dihydrogen phosphate (Kegley and Andrews 1998). In the 1940s there was almost zero production of nitrogen-containing fertilizers, but production was up to approximately 80 million metric tons in 1998 (Ecological 1998). Soil leaching and lack of a buffer between farms and bodies of water can lead to enormous increases in nitrate concentrations. There are no major agricultural operations within the Pattee Pond Watershed, but there is a tree farm near Tributary Site A.

Animal feedlots are a major source of additional nitrates. The average steer produces 27 kg of waste daily, containing 180 g of nitrate and ammonia. Runoff from these operations can enormously increase nitrate concentrations in a body of water (Kegley and Andrews 1998). Currently there is less pastureland in the Pattee Pond Watershed than there was in 1965 (see Figure 12). Moreover, this land use has also moved further away from the watershed, providing more opportunity for nutrients in animal waste to leach out.

Human waste or wastewater seeping into water can also be a cause of increased nitrate levels (Jarrell 1999, Tomar 1999). Within the Pattee Pond watershed, sources of human waste could include improperly installed septic systems or overflowing septic tanks.

Nitrite and nitrate are the most common ionic forms of nitrogen found in “natural waters” at levels that rarely surpass 0.1 ppm (Chapman 1992). Levels greater than 5 ppm strongly suggest contamination. Extreme cases may have concentrations greater than 200 ppm (Chapman 1992).

Although there is strong evidence that nitrate levels in water bodies are affected by human activities, research has recently shown that nitrates play a less important role contributing



to increased algal growth in lakes than was once suspected (Brönmark and Hansson 2005). Rather production rates have been strongly correlated to phosphorus concentrations regardless of nitrate concentrations (Brönmark and Hansson 2005).

Redfield (1958) found the ratio of carbon: nitrogen: phosphorus produced optimal growth at about 40:7:1 by weight. This became known as the Redfield ratio. This study was used widely as evidence to manipulate nitrogen levels to control unwanted biological growth. New studies done by Schindler et al. (2008) over a 37-year period demonstrate, through the manipulation of entire lakes, that biological production is more strongly correlated to phosphorus concentrations. They conclude that phosphorus, rather than nitrates, should be the focus for the management of water quality (Schindler 1974 and Schindler 2008).

### Methods

The Nitrate Low Range Test (Calcium Reduction Method) was performed using the HACH DR 4000U (see Appendix J). Surface samples were taken at Sites 1 to 6 and at the three tributary Sites A to C on 25-Sep-08. All samples were analyzed on the same day (see Appendix I and J).

### Results and Discussion

The mean ( $\pm$  SE) nitrate concentration for all lake sites is  $0.01 \pm 0.005$  ppm  $\text{NO}_3$ . The mean ( $\pm$  SE) for tributary sites is  $0.073 \pm 0.053$  ppm  $\text{NO}_3$ . There appears to be a difference between all mean nitrate concentrations and the concentrations found at Site A (0.18 ppm  $\text{NO}_3$ ). The calculated mean for tributary sites without Site A is  $0.02 \pm 0.00$  ppm  $\text{NO}_3$ . These concentrations of nitrate are not great enough to be a primary cause of algal growth even if older theories of nitrogen:phosphorus ratios are correct.

Nonetheless, the raised levels at Site A suggest increased pollution from this tributary. The land use types surrounding Site A are residential, recreational (market and summer campground), and commercial. These land uses have less vegetation than forested lands, causing greater runoff during rain events. Moreover, the runoff from these land uses has a greater concentration of nutrients than runoff from forested lands because there is less vegetation to absorb nutrients.

In contrast, Tributary Site B is surrounded by transitional, mixed, and wetland habitat. Tributary Site C is surrounded entirely by wetland habitat (see Figure 15). Wetlands absorb nutrients and filter wastewater (see Background: Wetlands).

There are more roads that are in closer proximity to Site A than Sites B or C. Site A has five roads within one half mile, Site B is crossed by two roads that are one mile apart, and Site C is nearby the only road within two miles (see Figure 12). Nitrate levels at Site A may also be affected by the nearby tree farm (see Land Use Types of Pattee Pond watershed).

Nitrate levels in a 1993 study of Pattee Pond showed a mean level of 0.02 ppm (CEAT 1993). Tributary sites in this study showed slightly higher nitrate levels with a mean of 0.06 ppm. This suggests that nitrate levels have not changed in recent years. Nitrate levels are similarly low in comparable Maine lakes: East Pond 0.04 ppm (CEAT 2000), Webber Pond 0.07 ppm (CEAT 2003), and Togus Pond 0.95 ppm (CEAT 2005).

## **Hardness**

### Introduction

Hardness is a measure of the concentration of inorganic cations, mainly calcium and magnesium ions, in a solution. Other inorganic cations that contribute to water hardness occur in insignificant amounts (Chapman 1992, Boyd 2000). Water hardness is generally calculated as the sum of calcium and magnesium ions, expressed as ppm of  $\text{Ca}^{2+}$ . These ions come mostly from natural weathering of rock containing minerals such as “gypsum, limestone, and dolomite” (Chapman 1992). The dissolution of limestone, however, is the primary source (Boyd 2000). Calcium concentrations are usually below 15 ppm with higher concentrations in areas with calcium-rich rocks. Magnesium concentrations have a broader range from 1 to greater than 100 ppm depending upon rock formations in the area (Chapman 1992).

One common effect of hard water is the decreased lathering capabilities of sodium-containing soaps. Calcium and magnesium ions react with soap to form an “insoluble precipitate” causing the soap to lose its surfactant or suds-ing capabilities (Kegley 1998, Tomar 1999, Boyd 2000). When hard water is heated, these ions precipitate out with carbonate, forming a scale or crust on water heaters, boilers, or even teapots that are routinely used to heat

hard water (Kegley 1998). This precipitate can stick to tubs, sinks, and dishwashers and can damage or reduce the efficiency of these appliances (Tomar 1999, Boyd 2000).

Although classification systems for water hardness vary somewhat, the United States Geological Survey classifies water as soft (0 to 60 ppm  $\text{Ca}^{2+}$ ), moderately hard (61 to 120 ppm  $\text{Ca}^{2+}$ ), hard (121 to 180 ppm  $\text{Ca}^{2+}$ ), or very hard (180 ppm  $\text{Ca}^{2+}$ ) (USGS 2008). Many lakes similar to Pattee Pond contain soft waters (CEAT 2005). Because calcium ions in hard water can tie up phosphorus, softer waters have the ability to hold more phosphorus that is available for plant life. Due to the soft waters in these lakes, algal blooms can occur more easily (Firmage, pers. comm.).

### Methods

Water was sampled through the water column up to a depth of seven meters, using the epicore sampling technique (see Appendix J). The sample was taken on 22-Sep-08 at Characterization Site 1, immediately put on ice, and tested the same day. Our sample was analyzed using the EPA approved HACH titration method adapted from the EDTA Titrimetric Method (see Appendix I and J).

### Results and Discussion

Total hardness was found to be 6.13 ppm, the sum of  $\text{CaCO}_3$  (4.14 ppm) and  $\text{Mg}^{2+}$  (1.99 ppm). This falls within the normal range for natural waters (Chapman 1992), and places Pattee Pond waters within the soft range (USGS 2008). This corresponds to the geology of the area. The underlying beds are calcareous sandstone and are not composed of limestone, gypsum, or dolomite (Maine 1985).

A previous study, using the same testing method, classified Pattee Pond water as soft, with hardness levels ranging from 29.9 ppm to 31.6 ppm (CEAT 1993). Togus, Webber, and East Ponds, all lakes similar to Pattee Pond, had soft waters with mean hardness readings of 22.2 ppm (CEAT 2005), 2.9 ppm (CEAT 2003), and 3.9 ppm (CEAT 2000) respectively.



## **Chlorophyll *a***

### Introduction

Chlorophyll is a nutrient commonly used to estimate algae growth in a lake. There are three forms of chlorophyll (*a*, *b*, and *c*). Chlorophyll *a* constitutes 2 to 5 percent of the dry weight of an algal cell and is relatively easy to measure (Brönmark and Hansson 2005). For these reasons, type *a* is usually used to estimate algal biomass.

When chlorophyll *a* levels and other nutrients levels, such as phosphorus or nitrates, are measured during the same time frame any relationships between algal growth and these nutrients can be studied. (Chapman 1992, Florida Lakewatch 2000, PEARL 2008h).

Chlorophyll *a* in Maine lakes has a mean of 4 ppb, with a minimum of 1 ppb and a maximum of 51 ppb (PEARL 2008h). Chlorophyll *a* concentrations, along with transparency measurements and phosphorus concentrations, can be used to determine lake productivity and trophic state. (MVLMP 2008b). Productivity categories based on chlorophyll *a* are defined as low (less than 1.5 ppb), medium (1.5 to 7.0 ppb), and high (greater than 7.0 ppb) (MVLMP 2008b).

Lakes are also classified by trophic status, which can be defined by several parameters, including chlorophyll *a* concentrations (O'Sullivan and Reynolds 2005). Classification and the corresponding chlorophyll *a* concentration are as follows: Oligotrophic (<3 ppb); mesotrophic (<10 ppb); eutrophic (10 - 40 ppb); polytrophic (40 - 60 ppb); and hypertrophic (>60 ppb). A more general trophic status classification system is discussed in the background (see [Trophic Status of Lakes](#)).

### Methods

Chlorophyll *a* was measured using the YSI Sonde 6820 (see Appendix J) approximately once a week at the Characterization Site (Site 1) and Sites 2-5 from 30-May-08 to 22-Sep-08. On the first day of research, study sites were still being established and measurements were only taken at Sites 1, 2, and 4. Subsequent measurements were taken at Sites 1-5. For the first two weeks, data were recorded for every meter at each site. Beginning on 18-Jun-08, chlorophyll *a* data were recorded at half-meter intervals to increase the number of sample points. On 08-Aug-08 no chlorophyll *a* readings were recorded. Chlorophyll *a* was measured at a sixth site (Site 6)

near the western shore of the lake, a potential problem area, on 26-Sep-08 (see Appendix J).

## Results and Discussion

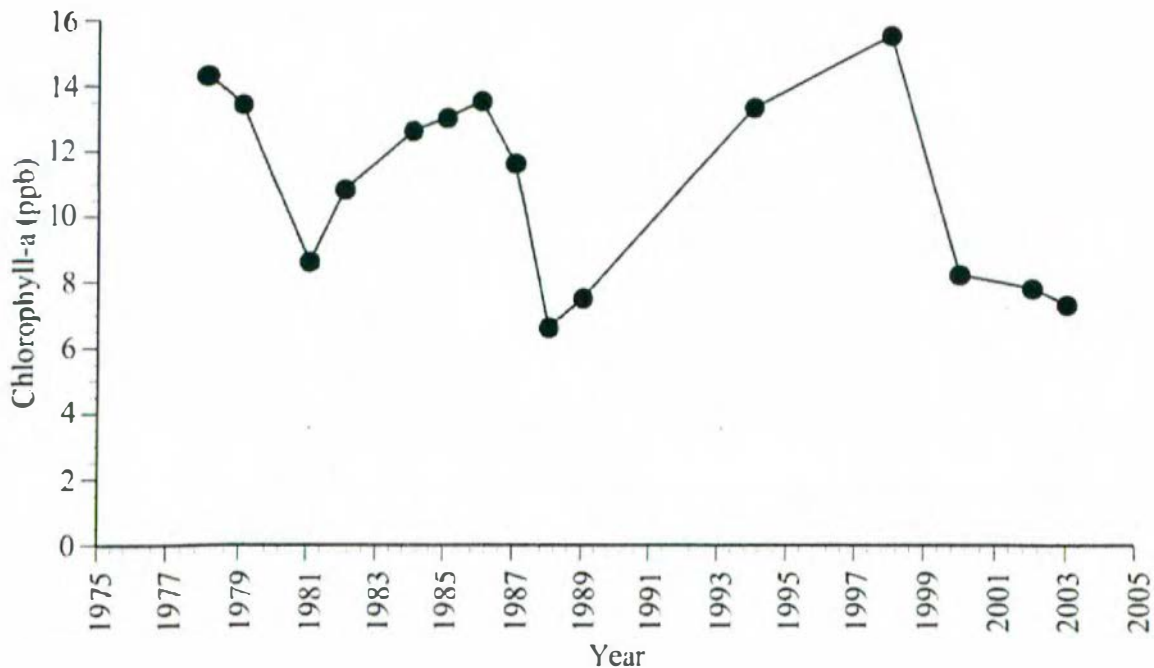
There is no apparent relationship between historical time and chlorophyll *a* concentrations at Pattee Pond (Figure 57). There were clear chlorophyll *a* spikes in the late 1980s and in 1998. More recent data suggests a decrease in chlorophyll *a* concentrations. However, these historical data are based upon samples taken one time each summer at Site 1. Chlorophyll *a* data fluctuate with season. Therefore these data could represent seasonal fluctuations and not historical trends.

A study of Pattee Pond in 1993 reported a chlorophyll *a* concentration of 8.6 ppb at Site 1 on 28-Sep-92 (CEAT 1993). In this study, CEAT took a similar reading at Site 1 on 22-Sep-08 with a reading of 3.4 ppb, demonstrating a decrease in chlorophyll *a* concentrations over recent history.

For the Characterization Site (Site 1), chlorophyll *a* concentrations were highest at depths below six meters, with a spike on 13-Aug-08 (Figure 57). The mean chlorophyll *a* concentration for Site 1 for the entire summer across all depths is 4.0 ppb, which places Pattee Pond in the medium level of productivity as defined by the Maine Volunteer Lake Monitoring Program (MVLMP 2008c). According to chlorophyll readings only, this also places Pattee Pond within the mesotrophic trophic category (O'Sullivan and Reynolds 2005). Chlorophyll *a* concentrations in Pattee Pond match the mean for all Maine lakes (PEARL 2008h).

There were similar high concentrations of chlorophyll *a* at bottom depths for other Spot Sites (see Appendix J). This combined with an early season turbidity spike suggest an early spring algal growth (see Figure 51). After dying, these algae would sink to the bottom of the lake, causing increased turbidity. The chlorophyll *a* in these dead algae may also still fluoresce during measurement, causing a spike in bottom chlorophyll *a* readings from the YSI Sonde 6820 (Firmage, pers. comm.).

During anoxic conditions phosphorus can be released from sediments at the bottom of lakes, leading to increased phosphorus concentrations at bottom depths. After lake mixing in the fall, there will be an increase in phosphorus concentrations that can stimulate algal growth (see Background: Phosphorus and Nitrogen Cycles). Our data agree with this process. The



**Figure 57: Annual mean chlorophyll-*a* concentrations (ppb) for Site 1 at Pattee Pond (PEARL 2008).**

Characterization Site (Site 1) went anoxic below six meters on 22-Jul-08 (see Figure 43). A week later, 29-Jul-08, water samples taken from the bottom at Site 1 reached their peak phosphorus concentration, and stayed at this concentration till 5-Aug-08 (see Figure 54). On 8-Oct-08 and 24-Oct-08 mild algal blooms were witnessed by CEAT members. On 20-Oct-08 Larry Fleury, a homeowner and pond association member, witnessed a significant bloom in which parts of the lake turned bright green (Figure 58).

East and Togus Ponds are lakes similar to Pattee Pond and have been studied by CEAT in past years. In the East Pond study chlorophyll *a* was analyzed using different methods, and the results are not comparable (CEAT 2000). In the study of Togus Pond in 2004 chlorophyll *a* ranged from less than 1 ppb to over 7 ppb (CEAT 2005). The mean at Characterization Site 1 on Pattee Pond was 4 ppb, within the range at Togus Pond. In the Togus Pond study, there were also spikes at depths of 7 m to 13 m, explained by dead sinking algae that will still fluoresce using the Sonde instrument (CEAT 2005).





**Figure 58. A late season algal bloom on 20-Oct-08 photographed by homeowner Larry Fleury. Milder algal blooms were witnessed on 8-Oct-08 and 24-Oct-08 by CEAT members.**

## **Water Budget**

### **Introduction**

The water budget estimates the amount of water flowing in and out of Pattee Pond on an annual basis. A water budget is important for two reasons. First, it enables a calculation of the flushing rate of the lake. The flushing rate is the theoretical number of times that all the water in a water body is replaced per year. Lakes with a rapid turnover do not retain nutrients or pollutants for as long a period of time and are less likely to experience algal blooms than lakes with a slow turnover (Michaud 1991). However, they are also more highly influenced by the quality of the surface water entering the lake (Michaud 1991). Because turnover is slow, the water quality of ponds with low flushing rates is mostly determined by ground water quality.

Lakes with a high flushing rate will respond to many remediation techniques faster. Second, the water budget is also important for this study because it is used in the Phosphorus Loading Model to (see Phosphorus Loading Model).

## **Methods**

Water enters a lake through precipitation, runoff, and inputs from stream and point-sources. Water leaves through outlets and evaporation. Ground water can be either a source or a sink for water, depending on soil type and location (Healy et al. 2007). The rate of precipitation was calculated as the ten-year mean annual rainfall reported at the Augusta State Airport (NCDC 2008). The rates of evaporation and runoff were obtained from Prescott (1969) and the North Kennebec Regional Planning Commission (unpublished report), respectively. The flow of water into the soil as well as change in lake volume was assumed to be zero. Pattee Pond has one external water input coming from Mud Pond (see Figure 7). Inputs and outputs from ground water were assumed roughly equal. Volume was assumed to be consistent from year to year. To determine the volume of water gained or lost from each source, each rate was multiplied by an area: the rate of runoff was multiplied by the watershed land area to calculate the volume of water running off the watershed and into the lake. Rates of evaporation and precipitation were multiplied by the area of the lake to determine the volumes of water gained and lost through these two processes. The input of water from Mud Pond was calculated as the volumes of runoff and precipitation minus evaporation for the Mud Pond watershed.

## **Results and Discussion**

Net inputs of water into Pattee Pond were calculated as 21,828,784 cubic meters (see Appendix K). Surface runoff was the greatest source of water, comprising 79 percent of net inputs (Table 13).

The net water input gives Pattee Pond a flushing rate of 2.72 flushes per year. This rate is higher than expected considering the low volume of water observed flowing into the lake during the fall. It is also higher than the MDEP reported rate of 2.13 (Vaux 2005). Differences in the flushing rate may be attributed to difference methods used to define the watershed boundary and calculate its area. Also, Mud Pond may not have been included in the MDEP calculation

**Table 13. Water Budget for Pattee and Mud Ponds showing the four sources and losses of water in cubic meters. Net Inputs equals the sum of runoff, precipitation and inputs minus evaporation.**

	Pattee Pond	Mud Pond
Net Inputs	26,228,313	4,399,807
Runoff	20,767,878	4,213,515
Precipitation	2,243,797	394,108
Inputs	4,399,807	—
Evaporation	1,183,170	207,816

(Bouchard, pers. comm.). Removing Mud Pond from the calculations would give a flushing rate of 2.26. Compared to area lakes, Lovejoy Pond has the most similar flushing rate (see Introduction: see Table 3).

## Phosphorus Model

### Introduction

A phosphorus loading model was created to estimate the annual amount of phosphorus entering Pattee Pond from different sources. A phosphorus loading model is a critical assessment tool used to determine the overall water quality and identifying point and non-point sources of phosphorus pollution. Knowing the approximate amount of phosphorus released from each land use type in the watershed has important management implications. The model can also be used to predict the impact of future changes in how land use and population trends will affect the water quality of Pattee Pond.

### Methods

The Pattee Pond phosphorus loading model was adapted from Chapra and Reckhow (1983) as well as past studies of Maine lakes (CEAT 2005, CEAT 2007). The equation used to calculate the phosphorus loading model is shown below:

$$W = (E_{ca} \times Area_{ls}) + (E_{cc} \times Area_{c}) + (E_{cp} \times Area_{p}) + (E_{cfr} \times Area_{fr}) + (E_{cw} \times Area_{w}) + (E_{cdr} \times Area_{dr}) + (E_{cfc} \times Area_{fc}) + (E_{cfm} \times Area_{fm}) + (E_{cft} \times Area_{ft}) + (E_{cfr} \times Area_{fr}) + (E_{cle} \times Area_{le}) + (E_{clr} \times Area_{lr}) + (E_{cli} \times Area_{li}) + (E_{ccl} \times Area_{cl}) + (E_{crc} \times Area_{rc}) + (E_{crm} \times Area_{rm}) + (E_{crs} \times Area_{rs}) + (E_{cds} \times Area_{ds}) + (E_{cdn} \times Area_{dn}) + [(E_{cyc} \times \# \text{ capita years}_{ss} \times (1-SR_1)) + (E_{cyc} \times Area_{yc})] + [(E_{cg} \times \# \text{ capita years}_{ss} \times (1-SR_1)) + (E_{cg} \times Area_g)] + [(E_{css} \times \# \text{ capita years}_{ss} \times (1-SR_1)) + (E_{cnss} \times \# \text{ capita years}_{nss} \times (1-SR_2))] + (S_d \times Area_{ls})$$

W is the total amount of phosphorus entering Pattee Pond in kg/year. The  $E_c$  terms, measured in kg/ha/year, represent the export coefficients for individual land use types. The



export coefficients estimate the amount of phosphorus loading from each land use type (see Appendix I.). The land use types included in this model are: atmosphere (a), crops (c), pasture/grassland (p), tree farm (tf), wetland (w), deciduous forest (fd), coniferous forest (fc), mixed forest (fm), transitional forest (ft), regenerating forest (fr), cleared land (lc), reverting land (lr), logged land (ll), commercial/industrial (ci), camp roads (rc), municipal roads (rm), state roads (rs), shoreline residential development (ds), non-shoreline residential development (dn), Camp Caribou (yc), Giordano's market and campground (g), shoreline septic systems (ss), non-shoreline septic systems (ns), and sediment release (sr). Each export coefficient was multiplied by the area of its respective land use to estimate the amount of phosphorus it contributed to Pattee Pond (see Land Use Land Use Patterns: Methodology). Areas were measured in hectares (ha). The atmospheric coefficient was multiplied by the surface area of the lake. Land use areas were found using ArcGIS 9.2® and digital orthophoto quadrangles of the Pattee Pond watershed (see Watershed Land Use Patterns: Methodology).

The shoreline and non-shoreline soil retention capacity for phosphorus were denoted as  $SR_1$  and  $SR_2$ , respectively. In accordance with the model created by Chapra and Reckhow (1983), soil retention coefficients ranged on a scale from 0.0 to 1.0 based on phosphorus adsorption capacity, natural drainage, permeability, and slope. The greater the soil capacity is for phosphorus sequestration, the higher the soil retention coefficients.

To calculate phosphorus export values from shoreline and non-shoreline septic systems, the respective export coefficients were multiplied by the number of capita years and by one minus the associated soil retention coefficient ( $SR_1$  or  $SR_2$ ). The term "capita year" refers to the mean number of people per household multiplied by the number of days per year that the residence was occupied. The household occupancy estimate used was 2.35, obtained from the 2000 census (K VCOG 2008). It was estimated that permanent residences were occupied 355 days per year (providing for a ten-day vacation); seasonal residences were occupied an estimated 105 days per year (Stankevitz, pers. comm.). A long season was used to account for the fact that most Pattee Pond seasonal residents are retired and spend the majority of their time from late spring to early fall at the lake; although there are some families with younger children (Stankevitz, pers. comm.). Septic systems for year-round homes are used more frequently than septic systems in seasonal residences, resulting in non-shoreline septic systems contributing a

greater amount of phosphorus to the lake than shoreline systems. Residences with holding tanks were not included in the septic system category, because no phosphorus should leak from this sub-surface wastewater treatment method.

The total amount of phosphorus loading in Pattee Pond was calculated using low, best, and high estimates for each export coefficient. By using a range of export coefficients the model accounts for discrepancies between calculated estimates and real phosphorus loading values. These inconsistencies arise from annual lake water quality fluctuations and the difficulty of assigning non-point sources phosphorus loading values. Best estimates represent what CEAT believes to be the most accurate estimates of phosphorus inputs within the established range. Low, best, and high total phosphorus loading values (W) were generated with and without sediment release from the coefficient values, area of land-use types, and water budget data. Model values were then compared to CEAT chemistry data and adjustments were made based upon reasonable assumptions.

Estimates of total phosphorus, areal annual loading, and phosphorus settling velocity in Pattee Pond were calculated using formulas adapted from Chapra and Reckhow (1983) (see Appendix M). Phosphorus data collected by CEAT was used to determine internal loading values. The amount of phosphorus released through internal loading was estimated to be the difference between the mean summer and fall turnover phosphorus concentrations.

## **Results and Discussion**

The phosphorus loading model predicted that 252.76 to 1208.76 kg of phosphorus per year enters Pattee Pond, with a best estimate of 593.97 kg/yr. This estimate increased when sediment release (internal phosphorus loading) was included in the model, resulting in a range of 295.02 to 1441.17 kg/yr and a best estimate of 731.31 kg/yr. The total phosphorus concentration, including sediment release, ranged from 5.66 to 27.65 ppb with a best estimate of 14.03 ppb. The mean total phosphorus concentration for epicore samples collected by CEAT 31-May-08 to 23-Sep-08 at Site 1 was 12.5 ppb. When sediment release was not taken into account the model predicted a best estimate of 12.4 ppb, which corresponds closely to CEAT findings. When internal loading was accounted for the best estimate was found to be 15.0 ppb, which is close to the phosphorus concentration of 16.0 ppb collected by CEAT during fall turnover on 23-Sep-08.

Residential development (21.7%), septic systems (shoreline – 1.7%, non-shoreline – 7.0%), and roads (camp roads – 10.2%, municipal and state roads – 4.5%) contributed the most phosphorus of any anthropogenic, non-point sources in the Pattee Pond watershed (Figure 59). These land use types contribute a disproportionately large amount of phosphorus in relation to their areas. Together shoreline and non-shoreline residences contributed 129.3 kg phosphorus/yr to Pattee Pond. While shoreline homes account for only nine percent of residential development they release 34 percent of the phosphorus attributed to that land use group. Compared to other central Maine lakes Pattee Pond has a very high density of legally non-conforming shoreline residences, many of which are built on the steep western shore. Residences contribute to phosphorus loading in many different ways, such as increasing impermeable surface areas (roofs and driveways) and through the improper disposal of grey water. Shoreline and non-shoreline septic systems contribute an estimated 51.92 kg phosphorus/yr to Pattee Pond (8.7 percent of the non-point source budget). Given that 91 percent of residences in the Pattee Pond watershed are permanent, it is not surprising that non-shoreline septic systems contributed more to phosphorus loading. It is important to note however, that while shoreline residences comprise only nine percent of watershed homes, they contribute 20 percent of the phosphorus exported from septic systems. These residences have a disproportionally high impact on water quality due to their proximity to the lake (see Watershed Development Patterns: Subsurface Wastewater Disposal Systems).

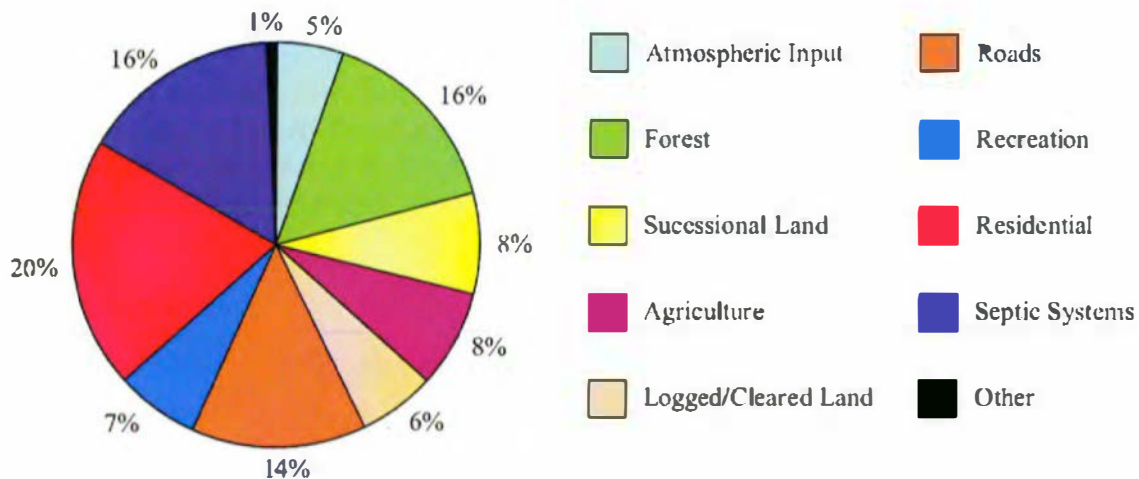
Forests contributed the third largest percentage of phosphorus from non-point sources comprising 16 percent of the total budget (99.7 kg/yr). Of the three forest types classified under this category (deciduous, coniferous, and mixed), mixed forests contributed the largest amount of phosphorus. Forests account for 70 percent of the Pattee Pond watershed, and 64 percent of that area is classified as mixed forests. Since most of the watershed is forested, this land use type exports a significant amount of phosphorus, even though per hectare forests contribute little phosphorus to the system relative to other land use types (see Figure 12).

Roads (camp, municipal, and state) contributed large amount of phosphorus to Pattee Pond, comprising 15 percent of the budget. Camp roads around Pattee Pond, especially along the western lakeshore, are susceptible to erosion with washouts having occurred as recently as the spring of 2008 (Whitaker, pers. comm.). Future efforts to reduce phosphorus loading should



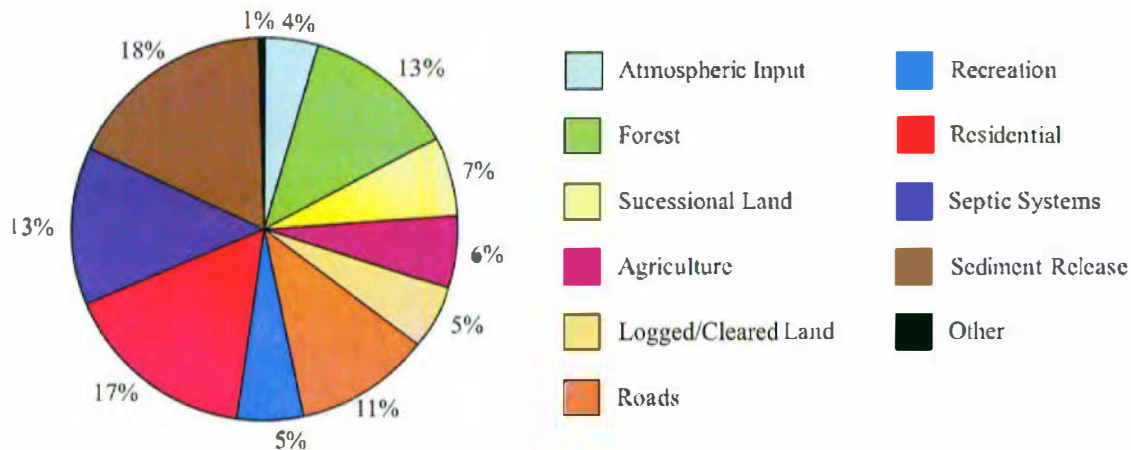
focus on improving camp roads and private driveways, because the cost of modifying legally non-conforming seasonal residences is often too expensive.

When sediment release was included in the model it was found to be the highest source of phosphorus in Pattee Pond. Sediment release accounted for 19 percent of the total phosphorus budget (137.3 kg/yr) (Figure 60). The sediment coefficient range used to calculate the low, best, and high estimates of phosphorus loading with sediment release was 0.2 to 1.1, with a best estimate of 0.65. CEAT found increased phosphorus concentrations on 23-Sep-08 compared to mean summer data, indicating that phosphorus from internal loading is distributed throughout the lake during fall turnover.



**Figure 59. Non-point sources of phosphorus from runoff loading for Pattee Pond. Percentage values reflect the amount that each source contributes to the total phosphorus budget in Pattee Pond. Some land use types were grouped: forest (deciduous, mixed, coniferous), successional land (transitional forest, regenerating forest, reverting land), agriculture (crops, pasture/grassland, tree farms), roads (camp, municipal, state), recreation (Camp Caribou, Giordano's Market and RV Camp), residential (shoreline and non-shoreline development), and septic systems**

Using the phosphorus model a 25-year projection was run to estimate the impact of building 100 new non-shoreline homes in the Pattee Pond watershed. A lower household occupancy average of 2.17 individuals was used and new residential area was subtracted from mixed forests, reflecting historic population and land use trends. Phosphorus concentrations are expected to increase by 0.3 to 1.7 ppb (with a best estimate of 0.8 ppb) for every 100 new non-shoreline, year round houses constructed. Phosphorus concentrations are expected to increase by



**Figure 60. Sources of internal and external phosphorus loading for Pattee Pond. Percentage values reflect the amount that each source contributes to the total phosphorus budget in Pattee Pond. Some land use types were grouped: forest (deciduous, mixed, coniferous), successional land (transitional forest, regenerating forest, reverting land), agriculture (crops, pasture/grassland, tree farms), roads (camp, municipal, state), recreation (Camp Caribou, Giordano's Market and RV Camp), residential (shoreline and non-shoreline development), and septic systems (shoreline and non-shoreline).**

0.4 to 2.4 ppb (with a best estimate of 1.3 ppb) for every 100 new shoreline, seasonal houses constructed. Considering current building codes it is much more conceivable for 100 new non-shoreline residences to be constructed, compared to shoreline homes. The construction of each new home (shoreline or non-shoreline) increases the amount of phosphorus exported into Pattee Pond through converting mixed forest to residential land and increased septic waste.

CEAT used the Pattee Pond phosphorus model in conjunction with population and land use trends obtained from the Town of Winslow and the Kennebec Valley Council of Governments (KVCOG) to predict the future impact of residential development on lake phosphorus levels (KVCOG 2008). Three scenarios were adapted from the KVCOG 2008 Comprehensive Plan to model residential development over the next twenty-five years: no development (zero new homes), predicted development (100-125 new homes), and heavy development (200 new homes) (KVCOG 2008). CEAT predicts that there will be 100-125 new homes built in the watershed over the next 25 years assuming that the population in the watershed will remain stable, household size will continue to decrease slightly, and more than half of residential development will occur in rural areas. The scenarios do not take into account

the newly proposed zoning codes, which if approved would limit residential development within the watershed. The phosphorus model assumes that all develop will occur on previously forested land. Using the phosphorus model CEAT calculated the impact of all three scenarios upon Pattee Pond water quality. No development resulted in phosphorus levels remaining at 15.0 ppb, predicted development caused phosphorus levels to increase to 15.9 ppb, and phosphorus levels rose to 17.3 ppb with heavy development. Even without additional residential development Pattee Pond water quality remains at risk and phosphorus estimates fall within the range where lakes experience algal blooms.

## **Mitigation Techniques**

### **In-Lake Management**

#### Introduction

Lakes suffering from extensive algal blooms and the pressure of invasive plants are candidates for lake remediation, which focuses on returning a polluted or eutrophied body of water to its original condition by using ecologically sound management strategies (Olem and Flock 1990). The choice of techniques used for restoration is dependent on numerous characteristics of the lake including depth, surface area, bottom composition, and flushing rates. Because of variations among lakes, the ideal strategy for one lake could be detrimental to another lake. In addition, the cost and probability of success for each of the techniques varies.

Remediation techniques for Pattee Pond should focus on phosphorus and nitrogen control because of the current problems with algal blooms on the lake. The remediation techniques can be divided into three categories: physical, chemical, and biological. Some techniques immediately treat algal blooms but others offer a long-term approach to mitigating phosphorus loading and internal recycling that cause algal blooms.

#### Physical Mitigation

##### *Water Removal Techniques*

##### **Water Drawdown**



The water drawdown technique can be used to mitigate invasive species and remove nutrient-laden water. Invasive plant species tend to grow along the edges of lakes in the littoral zone, lowering the water exposes the shallower areas to dry and either hot or cold atmospheric conditions, which can kill many of the plants that once were either completely or partially submerged. Once the water level is lowered and the necessary invasive plants are killed, any water that is added to the lake to bring the water level back up should ideally be free of phosphorus.

This technique successfully reduced populations of invasive Eurasian milfoil (*Myriophyllum spicatum*) on Lake Chelan in Washington (Hamel 2008). At strategic times, a dam on the lake was opened to lower the water level. After exposure to desiccation and freezing conditions, the invasive plant species were unable to reestablish (Hamel 2008). For the Belgrade Lakes in Belgrade, Maine, water drawdown is common for preparing the lake for the large volume of runoff in the spring and for partly removing nutrients.

This technique can be expensive if a water control system, such as a dam, is not already in place. The beaver dams on the Pattee Pond outlet do not control the water level to a great enough extent for systematic manual opening to have any significance. Also, lowering the water level can kill beneficial plant species and reintroduce decaying nutrient-rich matter back into the lake ecosystem, causing additional phosphorus loading, if done improperly. Because Pattee Pond is already a shallow water body, applying the water drawdown method could significantly limit water access and lead to aesthetic concerns with all the exposed areas. Pumps used by shoreline residents of Pattee Pond would also be exposed if the water level decreased. Because this method seriously disrupts the ecosystem by altering the natural state of the lake, the best method for removing invasive plants is localized manual removal.

### Hypolimnetic Withdrawal

The hypolimnion, or bottom level of stratified lake water, may contain large amounts of phosphorus (see Background: Introduction). For hypolimnetic withdrawal, pipes are installed that pump water from the hypolimnion into a lake outlet. In addition, inlet water can be channeled into the hypolimnion to increase the dissolved oxygen content at depth and prevent anoxia that leads to increased phosphorus loading from internal recycling. Dams help maintain

an appropriate pressure differential, which is important because water is being pumped simultaneously into and out of the lake (Olem and Flock 1990).

Hypolimnetic withdrawal was used by a team of researchers in a study of seventeen European lakes in 1987 where total phosphorus levels decreased in the epilimnetic and hypolimnetic layers of the lakes (Nürnberg 1987). Similarly, research on Lake Kortowo, Poland, showed lower concentrations of nutrients after limited withdrawal was performed (Dunalska 2002).

For this method to work the researchers recommend the water level must stay constant and the thermostructure remain intact (Nürnberg 1987). To optimize the effects of the technique, water should be withdrawn in the late summer and early fall when sediments release the most phosphorus (Dunalska 2002). However, the nutrient-rich hypolimnetic water being dumped into outlets could cause the same problems downstream for other water bodies. One solution to this is to inject the water into a fast moving current nearby which would help oxygenate the water and keep the phosphorus from settling (Olem and Flock 1990). Lakes that undergo this technique have a large hypolimnion, which makes this technique less ideal for Pattee Pond, which has a smaller hypolimnion. Also, the installation and maintenance of pipes makes this technique expensive.

### *Dilution and Flushing*

This technique works by increasing the inflow of nutrient-poor water to the lake ecosystem to flush out excess phosphorus and dilute the nutrient-rich lake water to help prevent phosphorus recycling (Olem and Flock 1990). To maintain a steady water level, the flushing rate of the lake needs to be increased.

This technique was used successfully in the Moses and Green Lakes in Washington, which showed a fifty percent or greater improvement in water quality and fewer algal blooms (Welch 2007). Water from the Columbia River was found to be low in nutrients and was diverted through the lake (Welch 2007). Because the facilities for supplying nutrient poor water for the dilution inflow were already in place, the cost was relatively low for these lakes (Olem and Flock 1990).

For this method to be successful, lakes must have high initial flushing rates to decrease concentrations within the lake system as water is added, unless the water being diverted into the system is free of phosphorus (Olem and Flock 1990). Also, substantial research is required to determine the nutrient budgets to avoid severe environmental damage. Finally, the increased outflow could damage outlets that are unable to accommodate a large volume of outflow (Olem and Flock 1990). The absence of a local low-nutrient water source makes this technique unreasonable for Pattee Pond.

### *Artificial Circulation*

#### **Air Injection (Diffuser) System**

This type of artificial aeration employs an air injection system and is the most common technique for lake destratification (IEPA 2007a). A compressor on shore pumps air through pipes connected to a diffuser, which releases the air into the hypolimnetic layer. Bubbles pull the water from the bottom up to the surface where it is oxygenated and mixed with the epilimnion (IEPA 2007a). The mixing of the lake layers eventually causes the destratification of the lake. The pH decreases when water is exposed to surface air through circulation, which creates a less favorable environment for blue-green algae (Olem and Flock 1990). Circulation can also improve zooplankton survival rates, which can mitigate algal blooms because zooplankton eat phytoplankton algae. When zooplankton are circulated to the lake bottom where fish species are less common, the plankton are not as vulnerable to predatory fish. Photosynthetic organisms that typically live within the epilimnion, such as algae, are also circulated to the bottom, but have lower survival rates due to limited access to light (IEPA 2007b).

Air injection systems work best in deeper lakes, which have a significant hypolimnetic layer and can be expensive depending on the amount of compressed air that is needed (Olem and Flock 1990).

#### **Mechanical Axial Flow Pumps**

Unlike air injection systems, mechanical axial flow pumps work by pushing water from the epilimnion downwards. A propeller attached to a floatation platform spins a few feet below the surface of the lake and pushes water from the surface downwards, creating a circulating

current that eventually destratifies the lake. As with the air injectors, the destratification allows oxygen-deprived bottom water to reach the surface and become oxygenated, reducing phosphorus loading from sediments (IEPA 2007a).

These artificial circulation techniques are still relatively expensive and would significantly disrupt the lake ecosystem of Pattee Pond.

### *Hypolimnetic Aeration*

Unlike with the artificial circulation techniques, destratification is not an objective with hypolimnetic aeration. Oxygen is pumped into the hypolimnion and released in small bubbles, which are absorbed into the oxygen-deprived layer of water (Singleton and Little 2006). Oxygenating the hypolimnion increases the aerobic environment above the sediment on the lake floor and limits the release of phosphorus from the sediments (WSDE 2008). In addition, this technique helps reduce phosphorus release from the sediments by introducing additional iron (III) to the water system, resulting in the formation of phosphate complexes that inactivate the phosphorus. Once the phosphates precipitate out of the water, the rate of internal phosphorus loading of the lake is reduced with the help of the increased dissolved oxygen (Jaeger 1994).

In 1992, a hypolimnetic aeration system was installed in Newman Lake, Washington, to deal with high nutrient concentrations and consequent algal blooms (NLFCZD 2007). An alum treatment (see Alum Treatment) was also administered three years prior in 1989. In 1997, after five years of use, research on the lake reported higher dissolved oxygen levels and fewer algal blooms. Similar results were found on Lake Krupunder, Germany, although a heavier emphasis was placed on iron-phosphate precipitation (see Chemical Remediation Techniques), with chlorophyll *a* concentrations decreasing by a maximum of ninety percent in two years (Jaeger 1994).

Due to the fragile balance of temperature and dissolved oxygen between lake water layers, avoiding destratification with hypolimnetic aeration is very difficult. This method requires significant research to determine the amount of oxygen needed to oxygenate the hypolimnion without causing the destratification of the lake. In the case of Newman Lake, the hypolimnetic aeration system cost \$539,000 (NLFCZD 2007). Although this may be cheaper



than other techniques, the price does not reflect the extra cost of research or the alum treatment used on the lake.

### *Sediment Removal*

The high concentrations of phosphorus found on the bottom of lakes and the contribution of sediment to internal phosphorus loading make the nutrient-rich top layer on the lake floor especially problematic. One method of removing the sediment is by dredging using a barge and scoop. This is one of the most common techniques to combat excessive sediment buildup, which leads to poor water quality in many lakes across the country.

Suffering from eutrophication, Lake Trummen in Sweden had the top layer of sediment removed from the lake floor using the dredging technique (Cronberg 1982). The nutrient-rich sediment was placed in settling ponds near the lake and run-off water was treated with aluminum sulphate (see Alum Treatment). As a result, the lake experienced significant decreases in nutrient concentrations and algae populations.

However, there are numerous problems with this technique, which requires heavy equipment and intensive planning and execution. First of all, dredging does not prevent further sludge buildup and can be damaging to the ecosystem. This technique is also expensive, as demonstrated with the application of dredging for Lake Jamno in Poland, which reportedly cost 750 million dollars (Blue Planet 2008). In addition, dredging can cause the release of toxic gases caught in the sediment and release the phosphorus that is trapped in the sediment while it is being pulled to the surface. One of the biggest challenges with this technique is finding a proper site to dispose of the dredged nutrient-rich sediment, to prevent the contamination of another water system. Once a site is established, the sediment needs to have time for proper settling without the risk of a nutrient run-off (Olem and Flock 1990).

Unless residents express a profound desire to change the lake bottom profile, this technique is not ideal for Pattee Pond. The research and implementation required is expensive and short-term and the environmental impact is severe.

## Chemical Mitigation

Chemical remediation refers to the addition of a compound (usually in powder or liquid form) to the lake water to reduce the effects of a particular element. With Pattee Pond, CEAT is focusing on the effects of phosphorus on the watershed. Some chemicals to consider because of their potential usefulness to Pattee Pond are polyacrylamide polymers, Phoslock (a modified clay), algicides, and Alum.

Polyacrylamide polymers are the lowest cost method that was investigated. Studies conducted on this powder treatment have shown it has the potential to reduce soil erosion by up to 95 percent (Nishihara and Shock 2001). Polyacrylamide polymers immobilize phosphorus, making it less available for algal growth and addressing concerns about both external and internal nutrient loading. Other benefits of this technique include its ability to remove absorbed pesticides and bacteria. It has also been recommended in the prevention of invasive plant species. However, this method may prove to be less effective on steep slopes and is not suitable for the west shore of Pattee Pond.

Phoslock is a recent approach to water quality management and is similarly low in cost. This product, when applied to a lake, removes phosphorus from the water column by binding to the phosphorus as it settles into a clay form on the substrate (Douglas et al. 1999). In addition to precipitating out phosphorus, it seals the sediments on the bottom of the lake. The clay barrier that forms on the lake bottom can inhibit the internal loading of phosphorus that occurs in the autumn. This product can function under anoxic conditions, which, as CEAT has shown, occur in Pattee Pond (see Dissolved Oxygen and Temperature). Studies of this method conclude that Phoslock does not have any negative effects on the water quality of lakes and is a good choice for non-point source mitigation (McIntosh 2007). These conclusions suggest that Phoslock would be a suitable means for alleviating non-point source nutrient loading in Pattee Pond.

Algicides are a common method of lake restoration because there is a wide variety to choose from (Garling and Wandell 2006). Algicide use may be considered more efficient because users can selectively treat the lake by choosing a particular algicide, but algicides are slightly higher in cost and may require multiple treatments. The side effects that occur once algicide is released into the system, however, are hard to control. Algicides, depending on the chemical chosen, may have harmful effects on beneficial plants of the watershed, which in turn

could impact higher trophic levels in the ecosystem. Algicides may also drift beyond the area of application and toward inlets or outlets. For Pattee Pond, these areas are lush in wetland species that contribute to the watershed biodiversity and buffered water quality. Harm done to these areas could have devastating effects on water quality. Also, some algicides require that recreational activities and use of the lake be halted so as to prevent any harm to people. This is a major concern and may negatively impact the seasonal use of Pattee Pond. However, the absence of algae will improve the aesthetics of the lake area. Unfortunately, this method does not prevent internal loading of phosphorus; without removal of the nutrients, algal blooms may reoccur and the process will have to be repeated. Algicide use initially contributes to eutrophication of the lake. This is because the dead algae and nutrients that have bioaccumulated remain in the lake for future phosphorus cycling.

Alum (Aluminum sulfate) is a metal salt whose impact on phosphorus is similar to that of Phoslock. It binds to phosphorus, creating an insoluble, fluffy precipitate (called floc) that reduces the bioavailability of phosphorus (Welch and Schriever 1994). Once it settles on the bottom of the lake, it creates a sediment barrier that has the potential to reduce the internal loading of phosphorus for up to eight years. Concerns with this method are that it is fairly expensive and its effectiveness is questionable in shallow, non-stratified lakes.

### Biological Mitigation

These techniques refer to the use of living organisms (bacteria, fungi, and plants) to buffer the effects of undesired chemicals/compounds. Buffering is already performed to an extent by the naturally occurring wetlands surrounding the lake. Although none of the biological techniques address the problem of internal nutrient loading, CEAT suggests a focus on manipulation of plant and fish species compositions to help control the consequences of external phosphorus loading. These methods have higher probabilities of success and they will be less costly in terms of funding and management.

Phytoremediation is a technique that harnesses the power of selected plant species to bioaccumulate the nutrients or metals of interest out of the soil/water and into the biomass of the plant (Zhang et al. 2000). This method would be low in cost and easily monitored. Because most plants bioaccumulate phosphorus, plants could be chosen from a wide variety of native species

that can contribute to the biodiversity of the watershed. Plant growth, however, is slow and this technique should be considered for long-term remediation. Phytoremediation should be used in areas with higher runoff rates or near impervious surfaces such as roads and parking lots within the watershed.

Maintenance of buffer strips is similar to that of phytoremediation (see Buffer Strips). It includes the use of vegetation, mainly in the region between property and the lake edge, to remove and bioaccumulate the nutrients from runoff. Plants provide a structural root system to lessen the extent of external sediment loading into the lake through erosion. Similar to phytoremediation, the costs would be low and little monitoring is necessary. This technique would also enhance the habitat and the property values around Pattee Pond. The west shore of the lake would benefit greatly from reinforced buffer strips because of the steep slopes that allow larger amounts of sediments and nutrients to wash directly into the lake. Aesthetically and ecologically, this method would have a significant, positive impact on these properties.

Restructuring fish species is another technique that has been considered in Maine lakes. In 2007, the DEP and cooperating groups attempted to change the fish community of East Pond to slow eutrophication of the lake (Halliwell, pers. comm.). The goal was to remove zooplantivorous fish to enhance the zooplankton community that feed on the photoplankton and algae. Although this does not directly solve the problem of phosphorus availability in lakes through external and internal sources, it potentially creates a natural inhibition of algal blooms and eutrophication and may improve the lake aesthetically (Carpenter et al. 1995). In the context of Pattee Pond, this technique would be most effective by either removing white perch from the lake or stocking more alewives (see Description of Pattee Pond and its Watershed: Fish Stocking). Alewives spawn in freshwater lakes during the spring, then migrate to the Atlantic during the fall, removing any phosphorus they have incorporated into their bodies (PEARL 2008a). In Maine there is still concern that stocking alewives might compete with sportfish species or be detrimental to water quality (PEARL 2008a). There is little conclusive evidence to support these claims, and a ten-year study in central Maine lakes found that study lakes stocked with six alewives per acre were not noticeably affected (Kircheis et al. 2002). Additionally, selling alewives as bait for lobster traps earned anglers at Webber Pond several thousand dollars



in revenue in 2007 (Grow 2008). Fish assemblage modification would require more funds, equipment, and man power to implement successfully than some other remediation techniques.

Given the information of various possible techniques, CEAT suggests an integrated approach to remediation for Pattee Pond. In the case of many physical and chemical remediation methods, consequences and expenses outweigh their potential, positive effects on the lake water quality. Although these methods have been proven successful in some situations, its use has been focused on larger, deeper lakes. The most efficient techniques for Pattee Pond are those of buffer strip enhancement between the lake and properties, phytoremediation along roads in poor condition, and experimental stocking of alewives in the lake. Initiatives have already been taken for the latter technique.

The Department of Marine Resources has agreed to stock alewives in Pattee Pond beginning in the spring of 2009 on the condition that beaver dams are monitored daily (Whitaker, pers. comm.). The Pattee Pond Association will be required to create small breaches in the beaver dams to allow fish migration. Although CEAT agrees with the implementation of fish stocking techniques, they are only beneficial if managed properly and monitored frequently.

This mix of remediation techniques would result in the greatest, positive impact on the watershed for both wildlife habitat and property values. However, these methods must be continuously monitored and refined in order to truly benefit Pattee Pond and surrounding areas. There are many helpful resources on watershed and lake management for further information and support (see Appendix N).

## **Land Use Management**

### Implications of Predicted Land Use Changes

The changes in land use in the Pattee Pond watershed have the potential to critically impact the landscapes and ecosystems. In work with ArcGIS 9.2® performed by CEAT, a significant change in forest cover (mixed, regenerating, and reverting), pasture, and residential land uses was identified between 1965 and 2007. Forests have been defined as areas of low phosphorus loading potential because vegetation absorbs nutrients from the runoff within the watershed (see Land Use Analysis). At the same time, however, there is a trend of increasing residential development in the watershed, which may increase the rate and intensity of runoff.

New residential land is mostly replacing former agricultural and cleared lands (see Table 6). The majority of recent residential development occurred within 1,000 ft of the lake. This results in higher erosion and phosphorus-loading potentials for these areas (see Figure 21; see Figure 15). While runoff from nonshoreline residences may be buffered by forests and wetlands that lie between the residences and lake, residences closer to the shore amplify the loading of phosphorus directly into the lake. These impervious surfaces in close proximity to the lake are the greatest threat to the health of the water body.

### Managing Effects of Land Use Change Patterns

Implications that have weighed heavily on the historical progression of the watershed will be essential in proposing effective management techniques for the future. Of the evolving changes, the most pertinent to our predictions include percent forest cover (established or growing) and percent of human impact land uses (mainly development). Based on patterns in land use changes, a growth in development and impervious surfaces can be predicted (see Land Use Projections). These projections reflect an increase in movement of nutrients through the watershed that could offset the natural components of forest and wetland cover and challenge the stability of the watershed.

To mitigate the consequences of these patterns and prevent a decrease in lake quality CEAT suggests that residents and town leaders of the watershed make some considerations before future development proceeds. The presence of wetlands and increasing forest cover are essential in preserving the lake quality and should be protected. A number of regulations have already been put in place for new developments (see Residential Zoning). However, more needs to be done to balance the threats that new and old developments present to the integrity of the lake and watershed.

Builders and constructors can integrate strategies in their blueprints that will lower potential for higher erosion and phosphorus rates. This may include addition of sufficient culverts and ditching on roads or landscaping in residential areas. Planners can also require an assessment schedule to ensure the proper use/management of properties, roads, and other structures in the watershed. Measurements of lake mitigation and landscape management should be implemented and monitored in the regions closer to the shoreline that affect the direct runoff

and nutrient loading into the lake. CEAT recommends the use of a number of mitigation techniques to buffer the effects of runoff (see In-Lake Management).

## **Best Management Practices**

Best management practices (BMP) are procedures designed to reduce the impacts of development on the natural ecosystem. For new construction in the Pattee Pond watershed, best management practices and low-impact designs should be utilized to mitigate negative effects on the watershed (MDEP 2003d). BMP can also be implemented on existing lots to improve water quality and reduce the environmental impacts of a residence. Runoff flowing across shoreline lots directly into the lake is an important concern for shoreline properties. Homes close to the water increase the amount of impervious surface near the lake and often have cleared lawns that do not impede the flow of runoff. Many best management practices for lakefront homeowners focus on slowing down and stopping runoff before it enters the lake. If runoff continues across shoreline lots, it can create erosion pathways that carry sediment and phosphorus directly into the lake, negatively affecting water quality (Figure 61). Rain gardens, which are plantings specially designed to be effective rainwater catchment basins, are one runoff-hindering mechanism. There are several publications available to homeowners from the Maine DEP and other sources outlining both simple steps and more complex construction techniques that improve the environmental performance of a property (see *Watershed Development Patterns: Buffer Strips*; MDEP 2003d, MDEP 2006, MDEP 2008b, MDEP 2008c). Maine is in the process of developing a certification process for contractors who work on projects in shoreline areas (Stankevitz, pers. comm.). The early stages of this program will likely be on a voluntary basis, though it may become mandatory in the future. Programs such as these are designed to promote compliance with zoning laws and the implementation of BMP during construction and renovation processes. CEAT encourages each landowner to consult BMP and low-impact design techniques to improve environmental practices on their property in order to reduce nutrient loading into the lake.





**Figure 61.** These photos illustrate erosion from steep lots on the shoreline of Pattee Pond that carry sediment and phosphorus into the lake. Lots on the west side of the lake are of particular concern because of the steep slopes on that shore. BMP techniques can help mitigate the flow of runoff across lots and reduce sediment loading into Pattee Pond.

## Future Projections

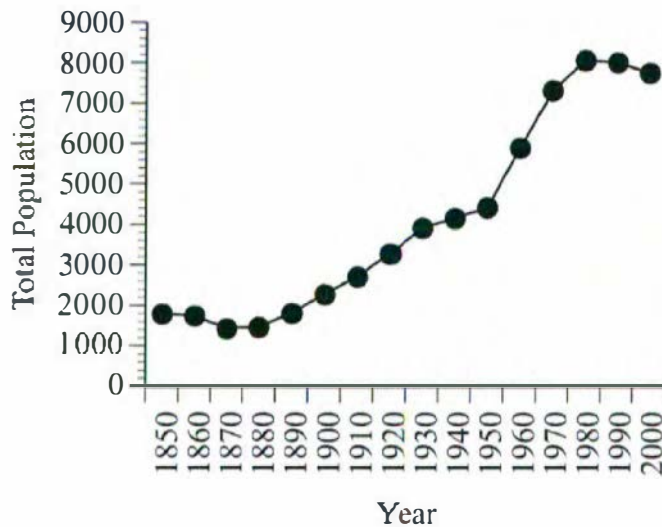
### Population

#### *General Information: Population: Population and Economics*

Understanding the population demography of Winslow and plans for economic development will help predict changes over the next ten to twenty-five years for the town and, consequently, the Pattee Pond watershed. The 2000 census data reported the total population of Winslow to be 7,743 people. Historically, the population of Winslow has increased steadily from 1880 until about 1980 (KVCOG 2008). From 1980 until the most recent 2000 census, the population has been leveling off and actually decreasing slightly (Figure 62). The median household size in 2000 was 2.28 people per household; this number has been steadily decreasing over the past few decades despite the total population declining only slightly (KVCOG 2008).

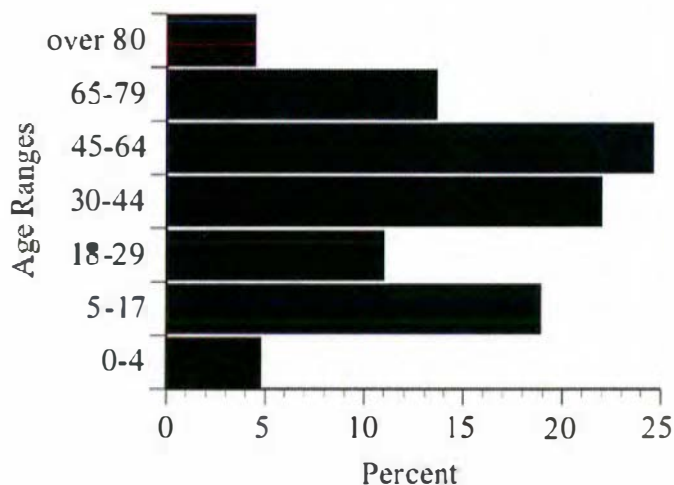
The age structure in Winslow, like much of Kennebec County, shows an aging population. The median age in Winslow in 2000 was 41 years old, which is the highest median





**Figure 62. Historical Winslow, ME population data based on census data from 1850 to 2000 (KVCOG 2008d).**

population growth, please note that because migration accounts for the majority of population changes (approximately 83 percent), this figure alone cannot be used to accurately predict future growth (KVCOG 2005, KVCOG 2007). The aging population can be attributed to two main factors. First, the Baby Boom Generation is reaching retirement age (KVCOG 2008). Second,



**Figure 63. Population age structure of Winslow, ME in 2000. Categories of age ranges on y-axis are not uniformly distributed (KVCOG 2005).**

age in the area (compared to the towns of Albion, Benton, China, Vassalboro, and Waterville) and has also increased the most since the 1990 census, when the median age was 35 years (KVCOG 2008). The age composition of Winslow indicates that a large percentage of the population in Winslow (about 30 percent) is retired or will be retired in the next ten years (Figure 63; Rose 2005). Although age structure graphs are often used to predict future

many people between the ages of 18 and 34 leave the area to pursue education or employment; at the same time there is a large influx of people over the age of 65 moving to the area to retire. This redistribution of people due to emigration and immigration skews the population age make-up in Winslow towards older age ranges (KVCOG 2007).

Economic structure in Winslow can also be used as an indicator of

future development and growth. The median household income was \$39,580 in 2000 with a mean of 1.2 people in each household in the workforce. The unemployment rate has been steadily decreasing in recent years, reaching 3.9 percent in 2006 compared to 4.6 percent for the state. The major industries for employment are: health and education (32.3 percent), services (19.8 percent), wholesale and retail (16 percent), and manufacturing (14.1 percent). It is important to note that Winslow is a net exporter of workers, with about one third of its workforce employed in Waterville compared to about one fifth of Winslow residents employed in Winslow (KVCOG 2008).

### *People and Development*

Economic development in Winslow and the surrounding region will be one of the most important factors influencing future population growth or decline in Winslow. By understanding the goals, barriers, and strategies for development, future changes in population can be assessed (KVEDD 2008).

The economy of Winslow and the economies of the surrounding areas, which are tightly linked, face several constraints for economic growth and development (KVCOG 2007). First, there is an inadequate amount of capital available to finance new enterprises. Second, manufacturing employment (such as paper, textile, leather, and dairy production) is declining due to competition with international markets, changing technologies, higher transportation costs, and inadequacy of domestic price support programs. Third, the educational attainment in Winslow is lower than both the county and state levels. This makes it harder to retain and attract more skilled workers, who often leave in search of more suitable job opportunities. This point ties into the fourth constraint that researchers believe current migration patterns will result in slower economic growth rates. Researchers think this because new businesses are less attracted to the area and working people are under increasing pressure to support the growing elderly population. Finally, because household incomes are fairly low, there is a lower demand for goods and services (KVCOG 2007).

KVCOG and other regional development organizations have outlined goals and strategies to develop the Kennebec County region and stimulate local economies (KVCOG 2007). The main goals they outline in their “Comprehensive Economic Development Strategy, 2008-2012”

include: creating and retaining jobs, investing in infrastructure, expanding public service sectors, ensuring a sufficient supply of affordable housing, promoting more vibrant downtowns, conserving environment and natural resources, supporting community enrichment projects, and offering high quality education and training (KVCOG 2007).

### *Future Population Projections*

Future population growth in Winslow, including the Pattee Pond watershed, depends largely on the success of the current economic development strategies. Because total population has remained steady since the 1980s, looking at historical trends may be misleading, as it is unlikely Winslow will experience the high growth rates of pre-1980 decades again in the near future (KVCOG 2008).

The most likely scenario for the population in the next twenty-five years is that total population will remain fairly stable. If development strategies are successful, and Winslow and the surrounding areas are able to develop targeted economic sectors, they might be able to attract and retain younger workers, which would likely result in an increase in total population (KVCOG 2008, KVCOG 2008). However, because the economy in the nation is currently struggling, the region may not be able to reach the economic development level it seeks to achieve. Economies in Maine and across the U.S. are under significant pressure, but exactly how this will change local economies and shape local populations in the upcoming years is unknown.

Although total population may not change much in the next twenty years, this does not mean that population structures will not change or that development and growth will not occur. If current migration trends continue, the age structure will continue to be skewed towards older generations, which would place a heavier burden on younger workers to support them. Also, researchers attribute decreasing household size in part to the aging population because older homeowners, whose children have moved away from the area, are more likely to have one or two residents. As mean household size decreases, demand for affordable housing will increase (KVCOG 2008). The implications of this development for Pattee Pond and the watershed will be discussed in greater detail in the next section.

## Development

### *Introduction*

Commercial and residential development leads to increased areas of impervious surfaces, less vegetation, and higher traffic on roads. These factors contribute to higher levels of erosion and runoff. It is important to study historical development trends to gain insight on the patterns in the area. Predictions can then be made regarding the location of future development allowing recommendations to be produced to minimize the negative effects of this development on the quality of the lake water.

### *Methods*

Tax maps were obtained from the four towns that share the watershed of Pattee Pond (Winslow, Albion, Vassalboro, and China). The tax maps were scanned into a computer and imported into Adobe Photoshop to clip out extraneous information. Then, they were imported into ArcGIS 9.2<sup>®</sup> and georeferenced in their correct orientation with regards to the watershed (see GIS: Introduction). Each property was then digitized into polygons.

Property cards were reviewed and compiled on a computer spreadsheet at the town offices. The cards contained information about the house construction date, building type, and waste treatment type for each lot. The information was entered into an Excel spreadsheet according to a standardized property labeling system (e.g., W-002-032 for lot number 32 found on tax map 2 in the Town of Winslow). This same labeling system was used to name each polygon on the digitized tax map. The property information, known as attributes, was then imported into GIS and joined to the digitized map based on the correspondence between the polygon names and the property card names. Once these attributes were assigned to the digitized lots, specific attributes could be highlighted to show trends, such as areas of recent development in the watershed.

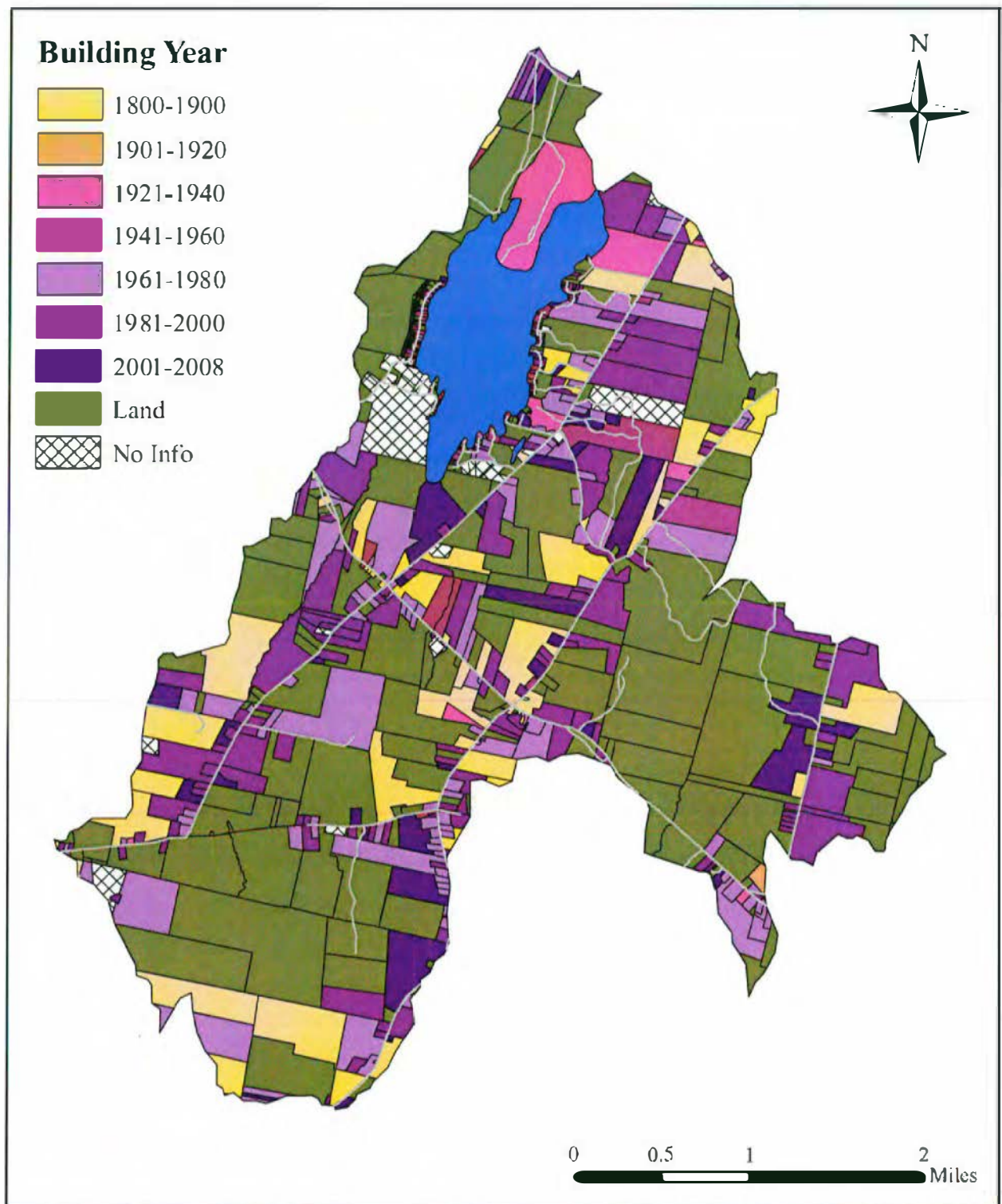
Two maps were produced, one of which is a map showing the location of different types of properties (i.e., commercial, private, or land only) in the watershed. The other map shows when houses were built in the watershed, grouped by twenty-year intervals.



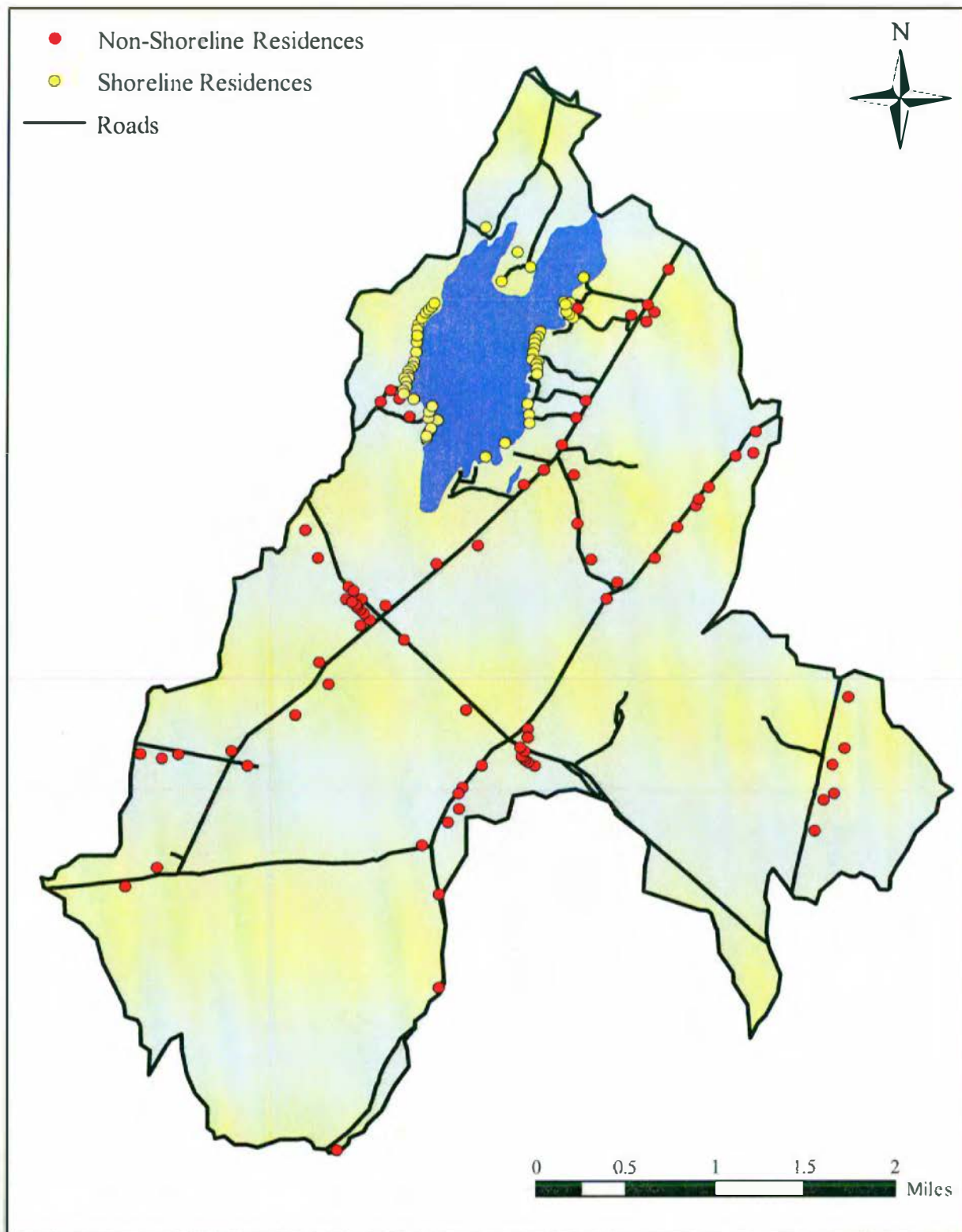
## *Historical Development*

In the Pattee Pond watershed development has increased over time. In 1965 developed lands made up 1.6 percent of the land in the Pattee Pond watershed whereas in 2007 developed lands made up 4.6 percent of the land in the watershed (see Analytical Procedures and Results: Land use Types of Pattee Pond watershed: Developed lands). An analysis of when development has occurred in the watershed provides insight into past and current trends. In the 1960s and 1970s, suburbanization became more popular. The federal government encouraged Americans to move out to suburbs through road construction projects and mortgage interest deduction during this time period (Kahn 2000). Suburbs were promoted as an ideal safe location to raise a family. Since 1960, small lots have been developed alongside major roads in the Pattee Pond watershed (Figure 64). Development prior to this time appears to be spread out in the watershed alongside major roads with larger lot sizes for each residence. Since 1960, smaller lots have been developed in the rural area of the watershed meaning that a larger proportion of each lot is impervious compared to before this point when a larger proportion of each lot was left undeveloped. In the Pattee Pond watershed, the more intense residential development in this rural area appears to be linked to the national trend of moving to a more rural setting.

Since 1957, there has been a significant increase in development in the watershed. In 1957, there were already many houses both on the West and East sides of Pattee Pond as well as a few camp buildings on the Camp Caribou peninsula (Figure 65). In 2007, there were many more buildings on Camp Caribou peninsula and on the Southeastern portion of the lake including Giordano's Market and Campground (Figure 66). Development along major roads has also increased. In 1957, on a state road running northwest to southeast in the watershed, houses were only concentrated where China Road crossed other roads such as Pond Road and Nowell Road. In 2007 residential development was concentrated along the entire road, not just where it crosses another. As a general trend, the biggest increase in development from 1957 to 2007 was residential development along roads that are in close proximity to Pattee Pond but on lots without shorefront property, on paved roads, and at or nearby recreational areas such as Camp Caribou and Giordano's Market and Campground.

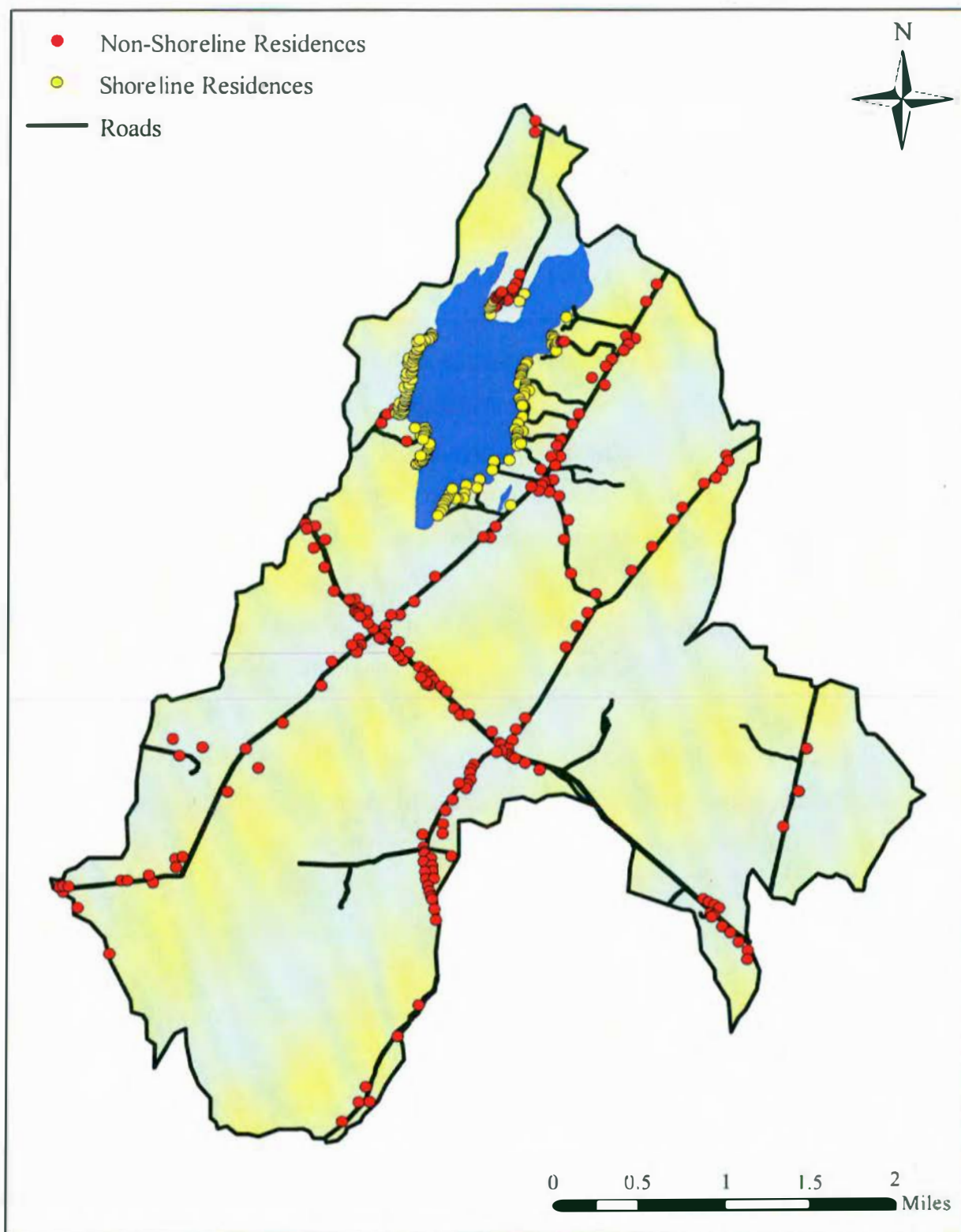


**Figure 64.** Map of the Pattee Pond watershed based on a combination of property tax maps from Winslow, Vassalboro, China, and Albion showing age of buildings on each property in 20 year intervals. Properties with no buildings are categorized as Land. Properties for which where was no information are categorized as No Info. Roads are displayed as white lines.



**Figure 65.** Location of shoreline and non-shoreline residences in the Pattee Pond watershed. Based on a USGS map of the Southeast Waterville quadrangle in 1957.





**Figure 66.** Location of shoreline and non-shoreline residences in the Pattee Pond watershed. Based on USGS map of the Southeast of the Waterville quadrangle in 2007.



### *Future Projections for Development*

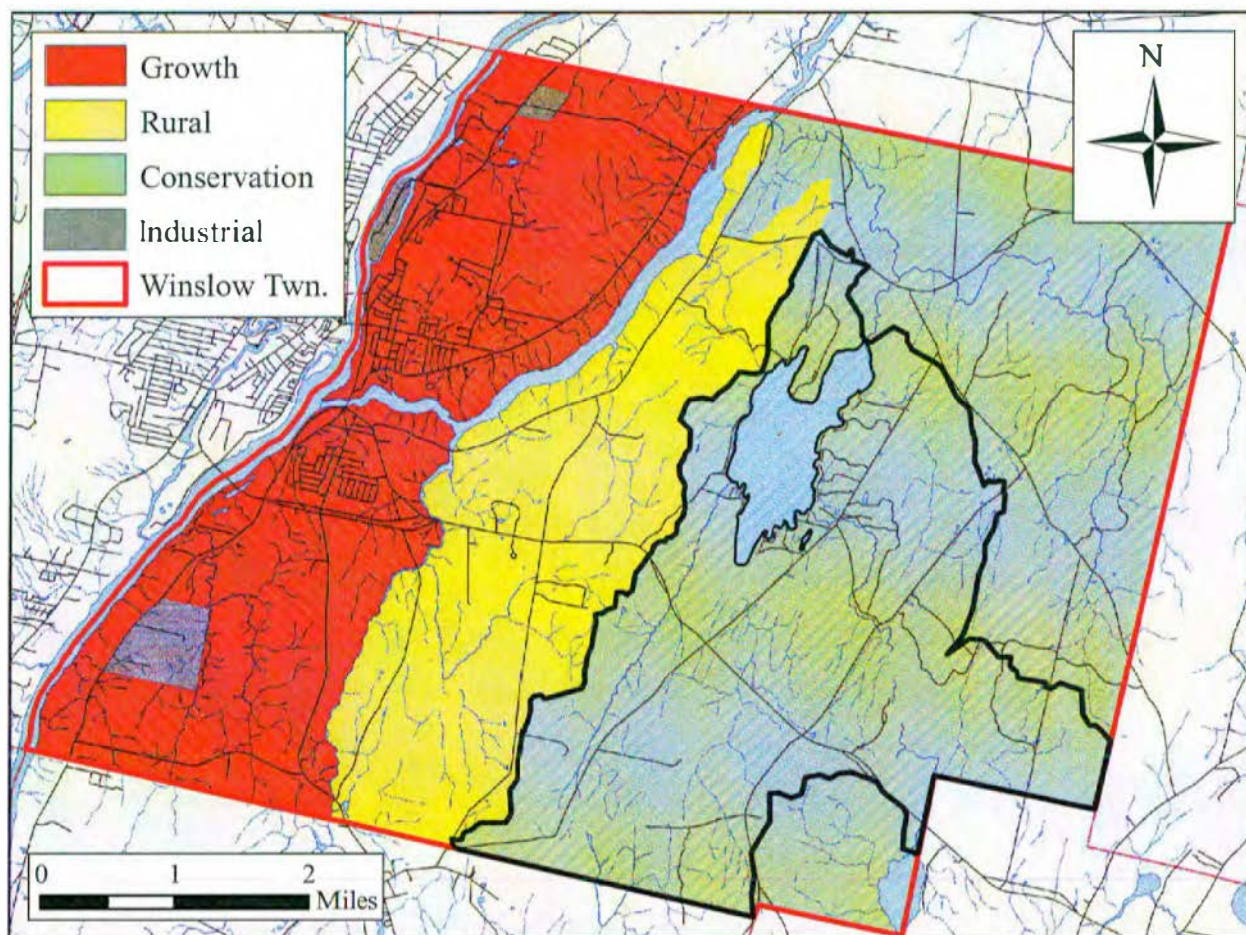
For many, Pattee Pond is an optimal summer retreat. Although it had been a less desirable destination when the water quality was poor and non-conforming waste disposal systems polluted the water, with clearer waters now there is an increased demand for property around the lake. A heightened interest in the lake can be seen by an increase in the selling price of the residences around Pattee Pond (Whitaker, pers. comm.). From 2002 to 2006 selling price increased drastically for a typical shoreline residence from between \$35,000 and \$65,000 in 2002 to \$180,000 three years later (Whitaker, pers. comm.). Recently due to the dip in the housing market, fewer houses have been sold, but at some point the market will likely correct itself and the demand for housing on Pattee Pond again will increase (Whitaker, pers. comm.).

Over the past few years, a heightened interest in Pattee Pond has also been noticed in that residents have noted that lake usage for recreation has more than doubled (Stankevitz, pers. comm.). People who once infrequently visited their seasonal shoreline residences are now spending more time on a regular basis on the lake. Additionally, those who have recently reached retirement age are choosing to spend entire summers on Pattee Pond in comparison to only spending weekends there (Stankevitz, pers. comm.). This increased use of the lake will have environmental impacts and suggests the potential for development in the area. A high level of water quality leads to higher demand for shoreline residences and higher home values. As Pattee Pond becomes a more desirable summer spot, there will be a higher demand for residences on and around the lake suggesting future residential development is likely.

The Town of Winslow is taking steps to encourage development and growth. Winslow is investing in the business and technology center “FirstPark”. The idea is to entice big businesses and employers to this new development so that all of the towns investing in the park can benefit from the tax revenue instead of competing with each other for the business to be located in their town. The building of the infrastructure is complete, but only 10 of the 30 sites have been leased. T. Mobile is currently the tenant with the largest impact, with 700 employees. FirstPark’s location in Oakland, ME, an easy commute from Winslow, could spur residential development in the surrounding area, including within the Pattee Pond watershed. If other large employers lease any of the remaining 20 sites, this would create many jobs, increasing the likelihood of residential development (Stocco, pers. comm.). With the continuing trends of suburbanization

near urban centers it is likely that additional houses will be constructed in rural areas such as the Pattee Pond watershed.

Although in Winslow and around Pattee Pond specifically development appears to be inevitable, there are also restrictions that discourage development in the watershed. The Town of Winslow in conjunction with the Kennebec Valley Council of Governments (KVCOG) has included a proposed new zoning scheme for development in the final draft of the Winslow Comprehensive Plan (Figure 67). In this plan there are four major zoning districts: conservation, rural, growth, and industrial. This proposed plan differs from the current zoning restrictions adding a conservation district in Winslow. Currently the majority of the development is occurring in rural areas, which includes the Pattee Pond watershed. From 2001 to 2006, 63 percent of the building permits issued in Winslow were issued in the rural areas (KVCOG 2008). In the plans for the proposed zoning district, the Pattee Pond watershed would be included entirely within the conservation district, with the western boundary of the proposed district being the Pattee Pond watershed boundary. The main goal for changing the zoning districts is to discourage development in the watershed to protect the water quality, and redirect this development to the growth district alongside the Kennebec River, closer to Waterville (KVCOG 2008). Specific requirements and more stringent regulations on construction are proposed as deterrents to development in the conservation zone, which would include the Pattee Pond watershed. An example restriction of development proposed in the new zoning plan is a limit on the ratio of impervious surfaces to total land area. Only 10 percent of the surface of each lot developed can be impervious in the conservation district, whereas in the rural district it can be 20 percent and in the growth and industrial zones it will be even higher and perhaps unlimited (KVCOG 2008). Another example is that in the conservation district a minimum of 10 acres would be needed for development whereas currently and in the proposed rural district the minimum lot size would be 2 acres. Development in the growth zone does not need to comply with either of these minimum lot size requirements. This is a controversial proposal because 10 acres differs drastically from the current 2-acre minimum (KVCOG 2008). The proposed zoning plans are to be presented to the town council on 8-Dec-2008 and reviewed for a month. If approved the plans may be adopted in January 2009. During the review period, the Planning



**Figure 67.** Town of Winslow Future Land Use. Provided by the Kennebec Valley Council of Governments, Waterville, ME in conjunction with the Town of Winslow and MEGIS. The Pattee Pond watershed, outlined in black, lies in the new conservation district described in the text.



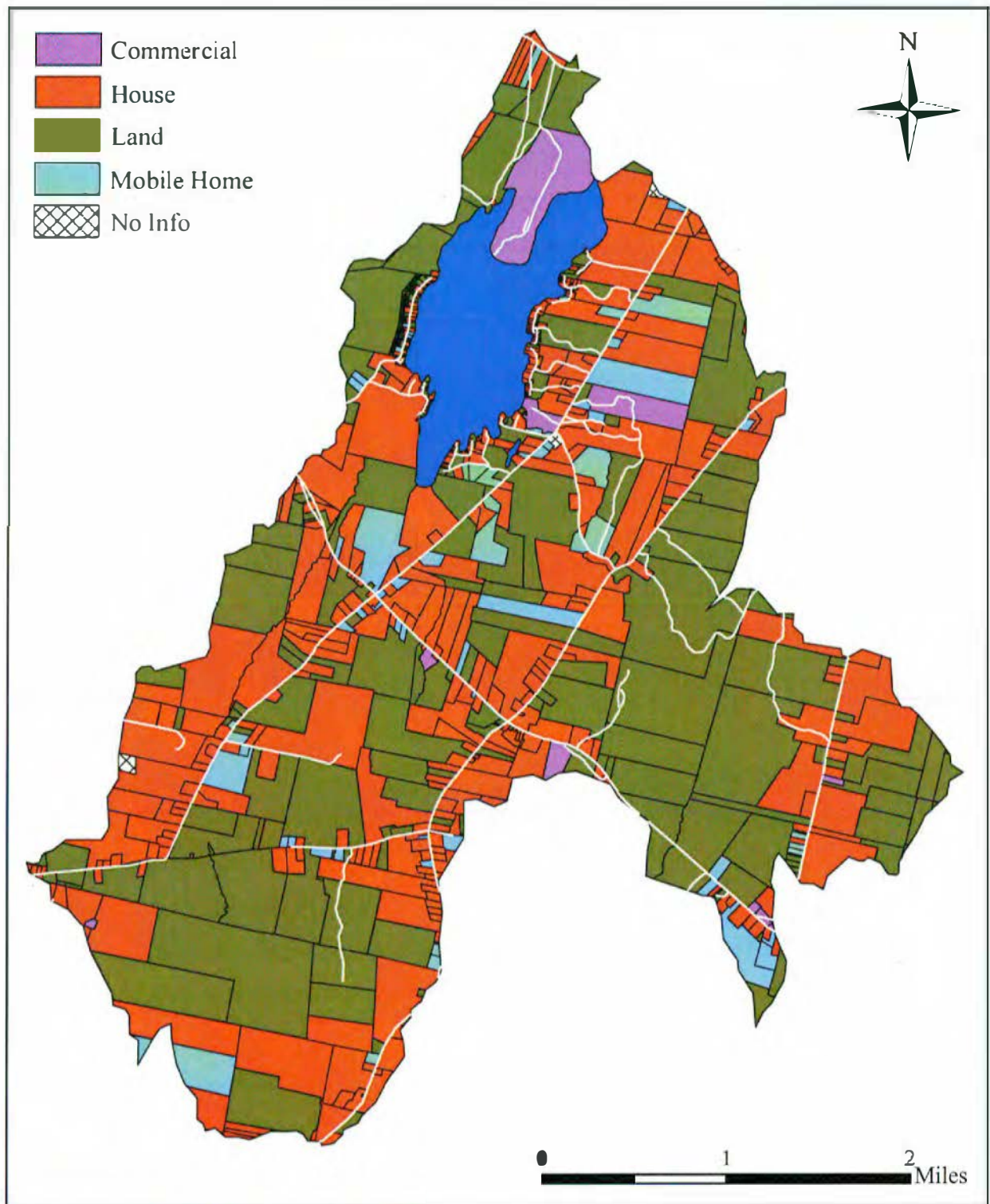
Board and Town Council can make changes where they see fit. The minimum lot size requirement of 10 acres might be reduced during this revision period. The original goal of the change in zoning is to promote a shift of development from inside the watershed to the center of Winslow near the Kennebec River. Protecting Pattee Pond has economic benefits for the Town of Winslow because higher water quality levels are correlated with higher home values.

Although new town policies and zoning codes would encourage growth outside of the watershed and discourage it within, they do not prevent development. There is land yet to be developed within the Pattee Pond watershed (Figure 68 and Figure 69). Due to past development trends, it is predicted that new growth will first occur near the Pattee Pond shoreline or along major roads. An example of a lot on which development is likely is an undeveloped lot of considerable size on Nowell road. This lot is both close to Pattee Pond and has road access. Although there are a few undeveloped lots along the shoreline, all that do not lie on wetlands and resource protection lands are smaller than the proposed 10 acre minimum lot size and most are also smaller than the current 2-acre minimum lot size for new development (Stankevitz, pers. comm.). Unless these lots are combined, they cannot be developed. Examples of shoreline lots that cannot be developed due to its current zoning status of resource protection are in the southwest shoreline and the northwest shoreline of Pattee Pond (see Watershed Development Patterns: Residential Zoning).

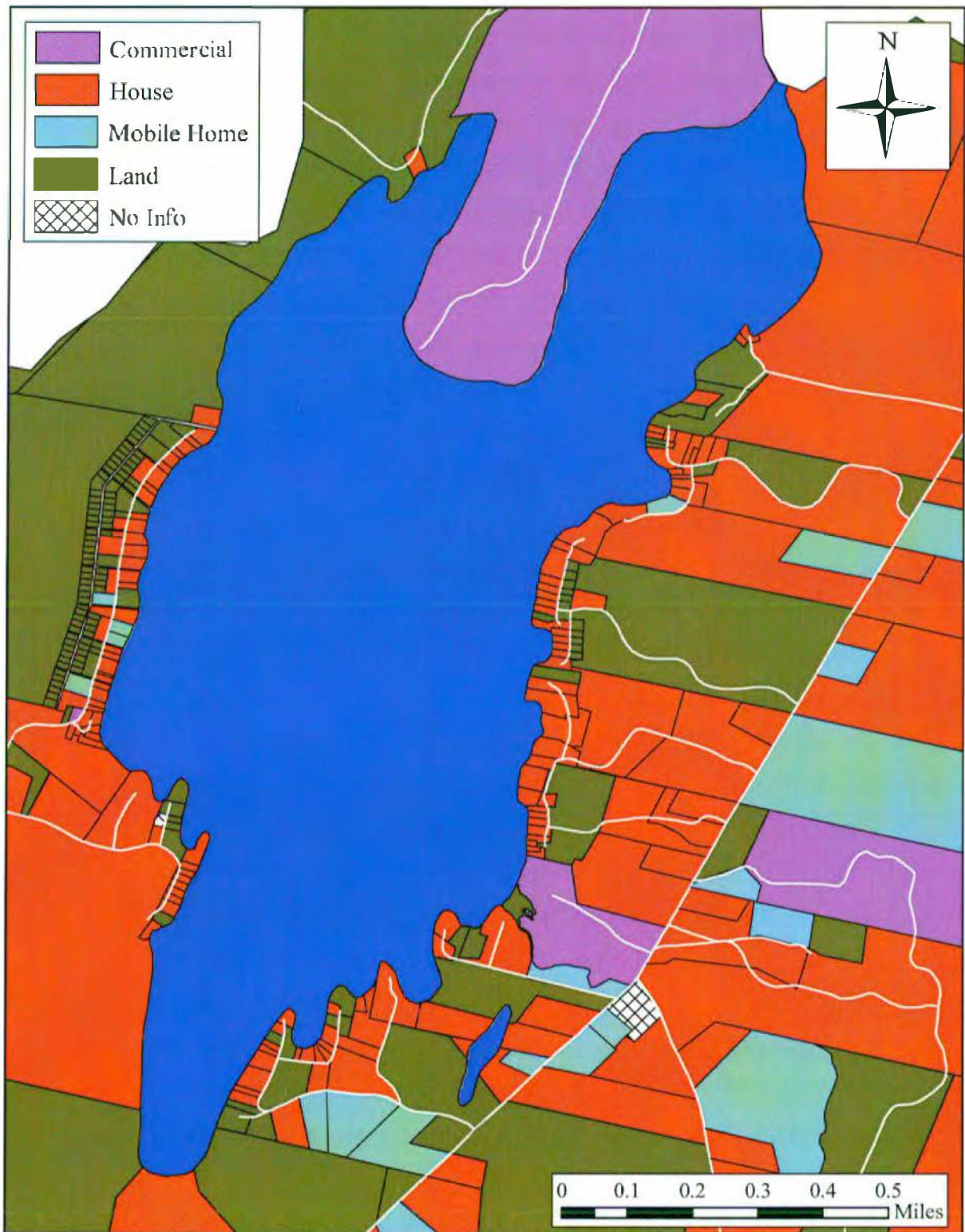
Set back from the western shoreline of Pattee Pond lies a subdivision created in 1925. All of the lots are undeveloped and all are also nonconforming due their small size. Although they can be sold as is, in order to build a house, lots would need to be combined to reach the minimum lot size required. Also although there is a plan for an access road for these subdivisions west of White Fish Road, it does not yet exist, and this is a deterrent to development of these lots.

Development is also likely along Wyman Road in the southwestern portion of the watershed. There are a number of undeveloped lots in this area and each is large enough for development. Almost every one of these lots is larger than the current 2-acre minimum lot size. The majority of these lots are also larger than the proposed 10-acre minimum lot size as well. Development here would be especially influential to Pattee Pond since Bellows Stream is in this





**Figure 68.** Map of the Pattee Pond watershed based on a combination of town tax maps from Winslow, Vassalboro, China, and Albion categorizing structures on each property as: House, Commercial, and Mobile Home. Properties with no structures are categorized as Land. Roads are displayed as white lines.



**Figure 69.** A close up of Pattee Pond and the surrounding area based on property tax maps from Winslow categorizing structures on each property as House, Commercial and Mobile Home. Properties without a structure are categorized as Land. Roads are displayed as white lines.



area. Erosion and runoff from such development could be easily carried into the lake. Best Management Practices should be used in construction in this area to minimize erosion.

There are other areas of undeveloped land that are less likely to experience development in the next 20 years. For example: in the southeast portion of the watershed there are large lots but the absence of roads makes development here in the near future unlikely.

Mr. Frank Stankevitz, the code enforcement officer for Winslow, predicts that new shoreline development would likely only occur if someone buys multiple lots and combines them, demolishing old houses to build a larger house that complies with the new zoning restrictions. If this proves to be the trend, the result would be fewer houses with larger mean lot size fewer residents around the lake. This has environmental impacts because less wastewater and sewage would be created and the camp roads would likely be used less frequently.

It is difficult to predict the degree of development that will occur in Winslow and more specifically in the Pattee Pond watershed. The Town of Winslow has shown that it is taking steps to promote more environmentally conscious development to protect the water quality of Pattee Pond and the wildlife corridors in this area through the proposed zoning plan.

An interesting aspect of development to consider is its relationship with changes in population size and demographics. Another important factor to be considered is the mean household size. In Winslow the mean household size is currently shrinking. In 1970, the mean number of people per household was 3.40. This number decreased to 2.35 people per household by the year 2000 (KVCOG 2008). It is predicted that the mean number of people per household will decrease another 0.18 people over the next 25 years to 2.17 people per household (KVCOG 2008). Although the town population may be staying approximately level, the average household size is decreasing development may increase because the number of housing units in Winslow has increased 56 percent since 1970, whereas population has only increased 5 percent since 1970 (KVCOG 2008). Population in Winslow is stable (see Population). KVCOG forecasts that with zero population change 419 new housing units will be built in Winslow in the upcoming 25 years (KVCOG 2008). If 63 percent of residential development continues to occur in rural areas of Winslow then according to the no growth in population estimate of 419 new residential units in Winslow, 263 of these would be built in rural areas of Winslow in the next 25 years. From this estimate CEAT predicts that 125 of these residences would be built in the Pattee



Pond watershed. This prediction was based on the ratio of the Pattee Pond watershed to the total amount of rural land in Winslow, and also took into account that development in the rural areas will be more likely west of the watershed, closer to Winslow and Waterville centers.

Due to a recent heightened interest in Pattee Pond it appears as though development around the lake and in the watershed would be likely. On the other hand, the new zoning code proposed by the Town of Winslow discourages development in the watershed protect the water quality of Pattee Pond. Very little development in the watershed is likely if the zoning code is passed as it currently reads because very few lots meet the proposed 10-acre minimum lot size. If the minimum lot size requirement were to be reduced before implementation, development would more likely and would probably be concentrated close to the lake and along already existing roads.

### Land Use Projections

#### *Predict Changes in Land Use and Effects*

Without new zoning regulations

If the Town of Winslow rejects the proposed zoning code that would designate the Pattee Pond watershed as part of a conservation area (see Future Projections: Development) the Colby Environmental Assessment Team (CEAT) predicts that:

- Residential development in Winslow will increase to a small degree, and will primarily be residential, seasonal homes
- Commercial development will not increase
- Additional roads and driveways to be built, though not new boat ramps
- Agricultural land is expected to continue to decrease slightly

CEAT expects that because of the projected decrease in average household size and stable population, residential development will continue. CEAT predicts that because of relatively low house prices in the watershed compared to those of other nearby lakes, this development will primarily be residential, seasonal homes. The two lakeside lots that are be developable under current regulations will likely be built on first, followed by combined shoreline lots and other developable land in the watershed (see Watershed Development Patterns: Residential Zoning).

Because of the ageing and retirement of the population, and due to the seasonality of most residences, CEAT does not expect commercial development to increase in the watershed. However, with the predicted increase in residential development within the watershed, CEAT expects additional roads and driveways to be built, though few if any new boat ramps because of limited developable land around the lake (see Watershed Development Patterns: Buffer Strips).

Agricultural land is expected to continue to decrease, as seen in the Pattee Pond watershed since 1965, and Kennebec County overall between 1997 and 2002 (see Analytical Procedures and Results: Trends; USDA 2002). Agricultural land makes up a small portion of the watershed, so this projected decrease is not likely to improve water quality significantly (see Table 7).

Should the new zoning regulations not pass, the expected increase in residential development and supporting roads will contribute additional phosphorus to the water basin. The actual increase will depend on other regulation details relating to lot size, road construction, septic tanks, and buffer strip widths. Additional remediation will be needed to maintain water quality.

If the Town of Winslow passes the new proposed zoning legislation, residential area is likely to still increase, but to a much smaller degree due to the tighter regulations. CEAT expects to see no increase in commercial land in the watershed, both for the reasons previously listed, and due to the stricter regulations on impermeable surface areas. Agricultural land is still expected to decrease slightly.

The decision on the new zoning regulations has the potential to impact water quality in the future. Designating the Pattee Pond watershed as a conservation area is expected to greatly slow, if not halt, cultural eutrophication, and minimize any lake remediation needed to maintain water quality.

### *Property Values*

Residences in the Pattee Pond watershed are a significant source of tax revenues for the Town of Winslow. As most residences are seasonal, proportionately less of the revenue collected is spent maintaining town services in the area. Allowing additional seasonal residences to be built in the Pattee Pond watershed may increase tax revenues for the Town of Winslow.

However, this potential increase in tax revenues needs to be weighed against other projected economic and environmental costs imposed on the town and current residents by further developing the watershed.

Property values tend to decrease as lake water quality and transparency decrease (Michael 1996, WAL). This decline in water clarity is often associated with algal blooms. Clear water for recreational and aesthetic purposes adds personal and economic value to the residences surrounding the water basin (WAL). This is an implied value, since it is related to the property but not specifically attached to it.

A study of the eutrophication of 34 Maine lakes found that property values decreased anywhere between eleven dollars and two hundred dollars per foot of frontage for every one meter change in minimum water transparency (Michael 1996, WAL). The deeper the water transparency the less able residents are to notice a change in transparency depth, impacting property values less. For the seven lakes in the Waterville market, the calculated property value added (per foot frontage) due to water clarity was \$193 multiplied by the natural log of water clarity depth (in meters) (Michael 1996). Adjusting for inflation since 1996, the implied value coefficient of water transparency is \$269.12 (BLS 2008). The trend in water transparency was also significant, so that lakes with a reputation (ten year average) of greater water transparency than current levels had higher property values (Michael 1996). Although property values vary around different lakes, other components of the model account for price differences due to structural differences and distances from town centers so that only the effects of changes in water clarity can be analyzed.

Pattee Pond residents and the Town of Winslow have a significant amount of economic interest tied to the water quality and transparency of Pattee Pond. It would be economical for the town to invest resources in improving lake water quality up until any additional expenditure equals the expected additional increase in tax revenue. That is, at a point, further remediation will increase tax revenues (via higher water transparency and higher property values) by less than it costs the town to achieve. At that point, the town has no further economic incentive to improve water transparency (see Appendix O).

It is likewise economical for residents of Pattee Pond to use resources towards lake remediation up until the point where additional expenditures from the residents equals the



expected additional increase in property values. This is not to say that all of the added value of clear lake water would or should be spent on keeping the water clear. Rather, the extra amount of resources devoted to water quality should be no more than the additional value that residents and the town expect to receive from the increased water quality (see Appendix O).

Lake remediation is best examined in steps: those strategies that have the largest positive impact per dollar should be the first to be implemented (additional considerations to be discussed below). Remediation techniques can be ranked this way, and each additional technique considered separately. At each remediation step, the cost and effect on water quality should be estimated. Once the costs outweigh the positive effects, that remediation step and all subsequent steps are not economical (see Appendix O). In this way, the economic value of Pattee Pond is maximized for residents and the Town of Winslow.

## RECOMMENDATIONS

Pattee Pond has a history of impaired water quality, but recent improvements have been observed. This restoration of water quality is largely due to the efforts of the Pattee's Pond Association, the Town of Winslow, and local residents who have worked to reduce sediment and phosphorus loading into the lake. However, Pattee Pond still experiences algal blooms and more work is necessary to limit nutrient loading. The Colby Environmental Assessment Team (CEAT) suggests the following actions to maintain momentum in improving the water quality and general health of Pattee Pond.

### *IN-LAKE MANAGEMENT*

#### **Invasive Species Monitoring and Prevention**

Invasive plants are undesirable because they compete with and often exclude native species from an area. Invasive species can also negatively alter the habitat for fish and other animals in the lake. It is important to be vigilant to ensure that invasive macrophytes are not accidentally introduced into the lake.

- Boat launches increase the potential for the introduction of invasive species because plants may hitchhike on boats and trailers being moved from infested lakes. All boats should be carefully checked for invasive macrophytes before launching.
- A courtesy boat inspector could be stationed at the Giordano's Market and Campground public boat launch to check for invasive plants and spread awareness. Educational signs should also be installed at this site. Because Giordano's is the only public boat launch, it is a likely entrance point for invasive species.
- Partnerships with the Volunteer Lake Monitoring Program or a similar organization should be established to help educate residents about invasive plants.
- Encourage regular monitoring for invasive species by local residents and lake users.

#### **Alewives**

There are many possible remediation techniques available to help reduce in-lake phosphorus concentrations, but most are expensive. Sediment release of phosphorus contributes

a relatively small percentage of the total phosphorus loading into Pattee Pond. For this reason, an experimental stocking of alewives is an in-lake remediation technique that CEAT suggests. Alewives are a migratory species that return to the ocean after spawning in freshwater lakes. When they return to the ocean, the phosphorus that they have bioaccumulated is removed from the lake. Although recent studies using alewives to mitigate phosphorus loading have produced ambiguous results, CEAT believes this in-lake management strategy is worth exploring.

## ***WATERSHED MANAGEMENT***

### **Land Use Considerations**

CEAT recommends that watershed residents focus on techniques that target eliminating erosion from non-point source runoff because most phosphorus entering the lake comes from external sources. Mitigation techniques that target problematic land uses will likely have longer-lasting impacts on the water quality of Pattee Pond than in-lake strategies that may only be effective for a few years. The Pattee's Pond Association has identified erosion as the primary source of phosphorus loading into the lake. CEAT agrees with this assessment.

- Wetlands act as natural filters and are crucial to maintaining the health of Pattee Pond, and should be protected. Any areas that were historically wetlands but converted to other uses should be restored or buffered to reduce sediment and nutrient loading.
- Erosion along the steeper slopes of the west side of the lake is a major source of phosphorus loading. Further efforts to mitigate this problem are necessary.
- Farber Brook is a major avenue for sediment and phosphorus loading into the lake. Erosion mitigation efforts should be specifically focused on Farber Brook and the adjacent land to reduce nutrient and sediment loading.
- Protection of the wetlands surrounding Bellows Stream should also be a mitigation goal because intact wetlands can serve to trap sediment and phosphorus and prevent them from entering the lake.



## **Residential Lots**

Mitigating erosion from residential lots, especially those on the shoreline, can help reduce phosphorus loading into the lake. The Pattee's Pond Association conducted a study of erosion sites and found 65 percent of the sites were located on residential land. Applying best management practices for sediment-control to these sites, and to residential lots in general, is an inexpensive way to improve lake water quality.

- Improve or remove private boat launches. Mitigate camp roads, driveways, and other avenues that may enable sediment-carrying phosphorus to enter the lake.
- Add rain gardens or other runoff-trapping features to properties, especially around buildings.
- Consult publications describing best management practices for ideas to reduce the erosion potential of residential lots.

## **Buffer Strips and Erosion Prevention**

Adequate buffer strips are crucial on every property along the shoreline as a last line of defense to help prevent sediment and nutrients from entering the lake.

- A good buffer should integrate native species in a progression from inland areas towards the water. Trees and tall shrubs should be planted farthest from the shore, followed by lower shrubs and water-tolerant grasses along the shoreline. Buffers should extend as far inland as possible, ideally up to 100 ft.
- Impervious surfaces should be minimized throughout the lot.
- Specific erosion sites or potential pathways for sediment loading into the lake, such as private boat launches, should be mitigated or eliminated.
- Pathways to docks or the water's edge should be winding and constructed with mulch, grass, or gravel to intercept and slow water entering the lake.

## **Camp Roads**

Camp roads are a major source of phosphorus loading because they are located in close proximity to the Pattee Pond shoreline and typically have dirt or gravel surfaces. Routine maintenance of unpaved, camp roads will help mitigate erosion.

- Camp roads that are closest to the lake and have the most potential for erosion should be targeted for immediate repairs. A Pattee's Pond Association study of the watershed found that 22% of the erosion sites identified were associated with camp roads. CEAT has identified Pickerel Point Road and Whitefish Lane as camp roads that require urgent attention.
- Form road associations to facilitate regular monitoring and maintenance of camp roads.
- Maintain proper crowning of camp roads, keep culverts clear of debris, and plant shrubs and grasses in ditches and along roadsides to slow water flow during rain events. When road repair is necessary use materials not likely to erode, if possible.
- Add water diversions to steep driveways near the lake, especially along the west shore of Pattee Pond. Grade the driveway at the camp road interface to encourage water to not flow down the driveway toward the lake.

## **Subsurface Wastewater Disposal Systems**

Properly functioning wastewater disposal systems are important throughout the watershed, especially near the lakeshore because of their high potential for nutrient loading. Maintenance and proper functioning are crucial because system failures can quickly add nutrients to the lake. Regular pumping of holding tanks is essential to prevent nutrient release. Older holding tanks should also be inspected to ensure that they are watertight. Any system in the watershed not currently in compliance should be updated as soon as possible to comply with the Maine Subsurface Wastewater Disposal Rules.

- Inspect legally non-conforming systems regularly. Replace each legally non-conforming system as necessary, preferably before it fails.
- Educate residents about the importance of properly maintaining their wastewater disposal system.
- Ensure that gray water from residences around the lake is being properly treated, either by being pumped into a septic system or holding tank. Improper handling of gray water can result in phosphorus loading into the lake.

## **Future Development**

New development in the Pattee Pond watershed should be regulated to protect the water quality in the lake. Strict adherence to zoning ordinances should continue. Erosion control best management practices related to erosion prevention must be implemented during all construction and on newly landscaped properties to mitigate sediment loading.

- Septic system remediation should be considered when installing new systems on the central section of the eastern shoreline, the western shoreline, or along Bellows Stream because these areas are more prone to phosphorus loading from septic installation.
- Owners of shoreline homes should implement best management practices to control sediment runoff. This is especially crucial on the steep lots along the western shore of the lake.
- CEAT supports the proposed Winslow Conservation Zoning District described in the 2008 Winslow Comprehensive Plan draft. The proposed Conservation District includes the Pattee Pond watershed. This zoning district change is expected to help improve lake water quality.
- Design any new development plans to minimize additional road construction.

## ***COMMUNITY AWARENESS AND EDUCATION***

The Pattee's Pond Association, working with the Town of Winslow and the Maine DEP, has made significant efforts to improve lake water quality. Continued improvement in water quality can only happen if local residents persist in their efforts to protect the lake. The actions of individual property owners can make a difference. Community education is the most effective way to spread awareness about the factors that affect the water quality of Pattee Pond.

- Design community workshops to inform local residents about lake ecology and protection strategies.
- Include relevant information in local school curricula to help teach children about the importance of protecting lake water quality.
- Regular monitoring by trained volunteers to assess lake water transparency and to search for invasive plants is recommended.

- The Pattee's Pond Association should continue their efforts to protect the lake and present their assessment of the status of Pattee Pond annually to the Town of Winslow.
- Local residents throughout the watershed are encouraged to join the Pattee's Pond Association and learn how they can help protect the lake.

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## LITERATURE CITED

- AWC. 2004. Online Aquatic Plant Identification Utility: Common Water Moss. Aquatic Weed Control. [http://www.awc-america.com/plant\\_id\\_utility/plants/foanant.html](http://www.awc-america.com/plant_id_utility/plants/foanant.html). Accessed: 11/17/08.
- Axler, R. and C. Hagley. 2004. Lake Ecology (Limnology). Water on the Web. [www.waterontheweb.org/curricula/ws/unit\\_01/U1mod2\\_3.html](http://www.waterontheweb.org/curricula/ws/unit_01/U1mod2_3.html). Accessed: 11/02/08.
- Baker, L. A., J. E. Schussler, and S. A. Snyder. 2008. Drivers of change for lakewater clarity. *Lake and Reservoir Management* 24:30-40.
- Barnes, B. V., D. R. Zac, S. R. Denton, and S. H. Spurr. 1998. *Forest Ecology*, 4th ed. John Wiley & Sons, Toronto.
- Barrow, C. J. 1991. *Land Degradation: Development and Breakdown of Terrestrial Environments*. Cambridge University Press, Cambridge, England.
- BLS. 2008. Inflation Calculator. Bureau of Labor Statistics. <http://data.bis.gov/cgi-bin/cpicalc.pl> Accessed: 10/25/08/
- Blue Planet. 2008. Lake Jamno, Poland. <http://www.blueplanetcorp.com/Products/Case%20Study%20Overviews/Municipal/Lake%20Jamno%20Trial.htm>. Accessed: 9/23/08.
- Bogges C., E. Flaig, and R. Fluck. 1995. Phosphorus budget-basin relationships for Lake Okeechobee tributary basins. *Ecological Engineering* 5:143-162.
- Borman, S., R. Korth, and J. Temte. 2001. *Through the Looking Glass: A Field Guide to Aquatic Plants*. Reindl Printing, Inc., Merrill, WI.
- Boyd, C. E. 2000. *Water Quality: An Introduction*. Kluwer Academic Publishers, Boston, MA.
- Brady, N. C. 1990. *The Nature and Properties of Soils*. Macmillan Publishing Company, New York, NY.
- Brennan, S. and J. Withgott. 2005. *Environment: The Science Behind the Stories*. Pearson, San Francisco, CA.
- Brönmark, C. and L. A. Hansson. 2005. *The Biology of Lakes and Ponds*. Oxford University Press Inc., New York, NY.
- Brown, R. B. 1990. Soil Texture. <http://edis.ifas.ufl.edu/SS169>. Accessed: 10/19/08.

- Calder, A. 2008. DEP Removes Eurasian Milfoil from Salmon Lake. Morning Sentinel, Waterville, ME. <http://morningsentinel.maintoday.com/news/local/5300686.html>. Accessed: 11/16/08.
- Canfield, D., S. Linda, and L. Hodgson. 2007. Relations between color and some limnological characteristics of Florida lakes. *Journal of American Water Resources Association* 20:32-329.
- Canter, L. W. and R. Knox. 1986. *Septic Tank System Effects on Ground Water Quality*. Lewis publishers, Inc., Chelsea, MI.
- Carlson, R. E. 1977. A trophic state index for lakes. *Oceanography* 22:361-369.
- Carlson, R. E. and J. Simpson. 1996. *A Coordinator's Guide to Volunteer Lake Monitoring Methods*. North American Lake Management Society, Madison, WI.
- Carpenter, S., N. H. Caraco, D. J. 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.
- Carpenter, S. R., D. L. Christensen, J. J. Cole, K. L. Cottingham, X. He, J. R. Hodgson, J. F. Kitchell, S. E. Knight, M. L. Pace, D. M. Post, D. E. Schindler, and N. Voichick. 1995. Biological control of eutrophication in lakes. *Environmental Science and Technology* 29:784-786.
- Casmermeiro, M., J. Molina, M. Caravaca, J. Costa, M. Massanet, and P. Moreno. 2004. Influence of scrubs on runoff and sediment loss in soils of Mediterranean climate. *Catena* 57:91-107.
- Cashat, J. P. 1984. Design and maintenance of unpaved roads. *Unpaved Roads* 115:154-158.
- CEAT. 1993. *A Watershed Analysis of Pattee Pond: Implications for Water Quality and Land Use Management*. Colby Environmental Assessment Team, Department of Biology, Colby College, Waterville, ME.
- CEAT. 1997. *A Watershed Analysis of North Pond: Implications for Water Quality and Management*. Colby Environmental Assessment Team, Department of Biology, Colby College, Waterville, ME.
- CEAT. 1998. *A Watershed Analysis of Messalonskee: Implications for Water Quality and Management*. Colby Environmental Assessment Team, Department of Biology, Colby College, Waterville, ME.
- CEAT. 1999. *A Watershed Analysis of Great Pond: Implications for Water Quality and Management*. Colby Environmental Assessment Team, Department of Biology, Colby College, Waterville, ME.

- CEAT. 2000. A Watershed Analysis of East Pond: Implications for Water Quality and Management. Colby Environmental Assessment Team, Department of Biology, Colby College, Waterville, ME.
- CEAT. 2003. A Watershed Analysis of Webber Pond: Implications for Water Quality and Land Use Management. Colby Environmental Assessment Team. Department of Biology, Colby College, Waterville, ME.
- CEAT. 2004. A Watershed Analysis of Threemile Pond: Implications for Water Quality and Land Use Management. Colby Environmental Assessment Team. Department of Biology, Colby College, Waterville, ME.
- CEAT. 2005. A Watershed Analysis of Togus Pond: Implications for Water Quality and Land Use Management. Colby Environmental Assessment Team. Department of Biology, Colby College, Waterville, ME.
- CEAT. 2006. A Watershed Analysis of China Lake: Implications for Water Quality and Management. Colby Environmental Assessment Team, Department of Biology, Colby College, Waterville, ME.
- CEAT. 2007. A Watershed Analysis of Long Pond North: Implications for Water Quality and Land Use Management. Colby Environmental Assessment Team, Department of Biology, Colby College, Waterville, ME.
- CEAT. 2008. A Watershed Analysis of Long Pond South: Implications for Water Quality and Land Use Management. Colby Environmental Assessment Team. Department of Biology, Colby College, Waterville, ME.
- Chapman, D. 1992. Water Quality Assessments. Chapman & Hall, London, England.
- Chapman, D., editor. 1996. Water Quality Assessments: A Guide to the Use of Biota, Sediments, and Water in Environmental Monitoring, 2nd ed. E and FN Spon, London, England.
- Chapra, S. C. and K. H. Reckhow. 1983. Engineering Approaches for Lake Management, Volume I: Data Analysis and Empirical Modeling. Butterworth Publishing, Boston, MA.
- Chiras, D. D. 2006. Environmental Science, 7th ed. Jones and Bartlett Publishers Inc., Sudbury, MA.
- City of Augusta. 1998. Growth Management Plan for the City of Augusta, ME. City of Augusta, ME.
- Cooke, G. D., E. B. Welch, S. A. Peterson, and P. R. Newroth. 1986. Lake and Reservoir Restoration. Butterworth, Boston, MA.



- Cronberg, G. 1982. Changes in the phytoplankton of Lake Trummen induced by restoration. *Hydrobiologia* 86:185-193.
- 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 Agricultural Experiment Station. NTIS. 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.
- Dodds, W. K. and E. B. Welch. 2000. Establishing nutrient criteria in streams. *Journal of the North American Benthological Society* 19:186-196.
- Douglas, G. B., J. A. Adeney, and M. Robb. 1999. A Novel Technique for Reducing Bioavailable Phosphorus in Water and Sediments. CSIRO Report. <http://www.phoslock.com.au/A%20Novel%20Technique%20for%20Reducing%20Phosphorus%20in%20Water%20-%20Douglas,%20Adeney%20and%20Robb%20paper.pdf>. Accessed: 9/26/08.
- Dreher, D. and M. Murphy. 1996. Shoreline Buffer Strips. Illinois State Environmental Protection Agency, Springfield, IL. <http://www.epa.state.il.us/water/conservation-2000/lake-notes/shoreline-buffer-strips/index.html>. Accessed: 11/02/08.
- Drewry, J., L. Newham, and B. Croke. 2008. Suspended sediment, nitrogen and phosphorus concentrations and exports during storm-events to the Tuross estuary, Australia. *Journal of Environmental Management* 90:879-887.
- Dunalska, J. 2002. Influence of limited water flow in a pipeline on the nutrients budget in a lake restored by hypolimnetic withdrawal method. *Polish Journal of Environmental Studies* 11:631-637.
- DWFS. 2008. AquaPlant: buttonbush. Texas Agrilife Extension Service. Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX. [http://aquaplant.tamu.edu/database/emergent\\_plants/buttonbush.htm](http://aquaplant.tamu.edu/database/emergent_plants/buttonbush.htm). Accessed: 11/17/08.
- Ecological Society of America Editors. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Issues in Ecology* 3:1-12.
- EPA. 1980. Design Manual On-site Water Wastewater Treatment and Disposal Systems. Office of Research and Development, Municipal Environmental Research Laboratory, United States Environmental Protection Agency, Washington, DC.

- EPA. 1990. Lake and Reservoir Restoration Guidance Manual (2nd edition). Office of Water Assessment and Watershed Protection Division, United States Environmental Protection Agency, Washington, DC.
- EPA. 2002. Onsite Wastewater Treatment Systems Manual. United States Environmental Protection Agency, Washington, DC.  
[http://www.epa.gov/owm/septic/pubs/septic\\_2002\\_osdm\\_all.pdf](http://www.epa.gov/owm/septic/pubs/septic_2002_osdm_all.pdf). Accessed: 10/23/08.
- ESRI. 2008. The Guide to Geographic Information Systems. Environmental Systems Research Institute. <http://www.gis.com/index.html>. Accessed: 11/8/08.
- Florida Lakewatch. 2000. A Beginner's Guide to Water Management- Nutrients. University of Florida Department of Fisheries and Aquatic Sciences & Institute of Food and Agricultural Sciences, Gainesville, FL.
- Fredenburg, J. 2008. Known Locations of Invasive Aquatic Plants in Maine – March 2008. Kennebec Soil and Water Conservation District.  
<http://www.maine.gov/dep/blwq/topic/invasives/invasivesmap.pdf>. Accessed: 11/10/08.
- Freeman, S. 2008. Biological Science, 3rd ed. Pearson, San Francisco, CA.
- Frey, D. G. 1963. Limnology in North America. University of Wisconsin Press, Madison, WI.
- Garling, D. and H. Wandell. 2006. Nuisance Aquatic Plant Control Using Algicides and Herbicides for 2006. Department of Fisheries and Wildlife.  
<http://web1.msue.msu.edu/waterqual/AQPLANT2006.pdf>. Accessed: 9/26/08.
- Grow, M. 2008. China: Fish May Aid Lake. Kennebec Journal.  
<http://kennebecjournal.maine.today.com/news/local/5301447.html>. Accessed: 10/25/08.
- Hakanson, L. 1977. Influence of wind, fetch, and water depth on distribution of sediments in Lake Vänern, Sweden. Canadian Journal of Earth Sciences 14:397.
- Hamel, K. 2008. Aquatic Plant Management Water Level Drawdown. Department of Ecology, State of Washington, Olympia, WA. <http://www.ecy.wa.gov/Programs/wq/plants/management/drawdown.html>. Accessed: 9/26/08.
- Hannam, K., S. Quideau, B. Kishchuk, S. Oh, and R. Wasylishen. 2005. Forest-floor chemical properties are altered by clear-cutting in boreal mixedwood forest stands dominated by trembling aspen and white spruce. Canadian Journal of Forest Research 35:2457-2468.
- Harbridge, J. 2006. Determination of Total Phosphorus by Flow Injection Analysis Colorimetry. Lachat Instruments, Loveland, CO.

- Hardesty, P. and C. Kuhns. 1998. The Buffer Handbook: A Guide to Creating Vegetated Buffers for Lakefront Properties. Bureau of Land & Water Quality, State of Maine Department of Environmental Protection, Augusta, ME. <http://maine.gov/dep/blwq/docwatershed/bulfa.htm>. Accessed: 10/24/08.
- Hazlett, P., A. Gordon, R. Voroney, and P. Sibley. 2007. Impact of harvesting and logging slash on nitrogen and carbon dynamics in soils from upland spruce forests in northeastern Ontario. *Soil Biology and Biochemistry* 39:43-57.
- Healy, R. W., T. C. Winter, J. W. LaBaugh, and O. L. Franke. 2007. Water Budgets: Foundations for Effective Water Resources and Environmental Management. United States Geological Survey, Reston, VA.
- Hejduk, L. 2008. Suspended Sediment and Phosphorus Transport During Storm Events in a Small Agricultural Watershed. 5th International Conference on Hydro-Science and – Engineering, Warsaw, Poland. <http://kfk.baw.de/fileadmin/conferences/ICHIE/2002-Warsaw/ARTICLES/PDF/158C4.pdf>. Accessed: 11/04/08.
- Hem, J. D. 1970. Study and Interpretation of the Chemical Characteristics of Natural Water. United States Government, Printing Office, Washington, DC.
- Henderson-Sellers, B. and H. R. Markland. 1987. Decaying Lakes. John Wiley and Sons, Chichester, Great Britain.
- Higginbotham, B. 1988. Forage Species: Range Description and Life History. Golden Shiner, Somerville, MS.
- Hudon, C., P. Gagnon, J. P. Amyot, G. Letourneau, M. Jean, U. Plante, D. Rioux, and M. Deschenes. 2005. Historical changes in the herbaceous wetland distribution by hydrological conditions in Lake Saint-Pierre. *Hydrobiologia* 539:205-224.
- Huggins, D. and J. Reganold. 2008. No-till: The quiet revolution. *Scientific American* 299:70-77.
- IEPA. 2007a. Artificial Circulation Systems. Illinois Environmental Protection Agency. <http://www.epa.state.il.us/water/conservation-2000/lake-notes/aeration-circulation/artificial-circulation.html>. Accessed: 9/23/08.
- IEPA. 2007b. Management Strategies. Illinois Environmental Protection Agency. <http://www.epa.state.il.us/water/conservation-2000/lake-notes/aquatic-plant-management/algae-management.html>. Accessed: 9/23/08.
- Ikuta, K., T. Yada, and S. Kitamura. Effects of acidification on fish reproduction. UJNR Technical Report 28:39-46.

- Jaeger, D. 1994. Effects of hypolimnetic water aeration and iron-phosphate precipitation on the trophic level of Lake Krupunder. *Hydrobiologia* 275-276:433-444.
- Jarrell, W. M. 1999. Getting Started with TMDLs. Oregon Graduate Institute of Science and Technology and YSI Inc, Beaverton, OR.
- Jeppesen, E., J. P. Jensen, M. Sondergaard, T. Lauridsen, and F. Landkildehus. 2000. Trophic structure, species richness and biodiversity in Danish lakes: Changes along a phosphorus gradient. *Freshwater Biology* 45:201-218.
- Kahn, M. 2000. The environmental impacts of suburbanization. *Journal of Policy Analysis and Management* 19:569-586.
- KCSWCD. 2008. Camp Road Maintenance Manual: A Guide for Landowners. Kennebec County Soil and Water Conservation District, Maine Department of Environmental Protection, Augusta, ME.
- Kegley, S. E. and J. Andrews. 1998. *The Chemistry of Water*. University Science Books, Sausalito, CA.
- King, R. S., M. E. Baker, D. F. Whigham, D. E. Weller, T. E. Jordan, P. F. Kazyak, and M. K. Hurd. 2005. Spatial considerations for linking watershed land cover to ecological indicators in streams. *Ecological Applications* 15:137-153.
- Kircheis, F. W., J. G. Trial, D. P. Boucher, B. Mower, T. Squiers, N. Gray, M. O'Donnell, and J. Stahlnecker. 2002. Analysis of impacts related to the introduction of anadromous alewives into a small freshwater lake in central Maine, USA. Maine Department of Inland Fisheries and Wildlife, Maine Department of Environmental Protection, and Maine Department of Marine Resources, Augusta, ME.
- KVCOG. 2005. Forecast of Town Populations by Age Cohort. Kennebec County. Kennebec County Council of Governments, Fairfield, ME.
- KVCOG. 2007. Comprehensive Economic Development Strategy, 2008-2012. Fairfield. Kennebec Valley Council of Governments, Fairfield, ME.
- KVCOG. 2008. Final Draft: Winslow Comprehensive Plan. Kennebec Valley Council of Governments, Fairfield, ME.
- KVEDD. 2008. Comprehensive Economic Development Strategy Meeting Minutes. Kennebec Valley Economic Development District, Fairfield, ME.
- Lake Access. 2007. An EMPACT Metro Project: Seeing Below the Surface. Lake Access. Duluth, MN. <http://www.lakeaccess.org/index.html>. Accessed: 10/23/08.



- Lea, F., T. Landry, and B. Fortier. 1990. Comprehensive Planning for Lake Watersheds. Androscoggin Valley Council on Governments, Lewiston, ME.
- LEA, Maine COLA, and MDEP. 2008. State of Maine Courtesy Boat Inspector Handbook. Lakes Environmental Association, Maine Congress of Lake Associations, and Maine Department of Environmental Protection, Augusta, ME.
- Lenntech. 2008. Turbidity. Lenntech Water Treatment & Air Purification. <http://www.lenntech.com/turbidity.htm>. Accessed: 9/28/08.
- Lerman, A. 1978. Lakes-Chemistry, Geology, Physics. Spring-Verlag, New York, NY.
- Levia, D. and E. Frost. 2006. Variability of throughfall volume and solute inputs in wooded ecosystems. *Progress in Physical Geography* 30:605-632.
- Lewis, W. M. 2001. Wetlands Explained: Wetland Science, Policy, and Politics in America. Oxford, New York, NY.
- Lövstedt, C. B. and L. Bengtsson. 2008. The role of non-prevailing wind direction on resuspension and redistribution of sediments in a shallow lake. *Aquatic Sciences* 70: 304-313.
- Maine Geological Survey: Department of Conservation. 1985. Bedrock Geologic Map of Maine. Maine's Bedrock Geology. <http://www.state.me.us/doc/nrimc/mgs/explore/bedrock/historical/feb08-map-a.pdf>. Accessed 11/23/08.
- Maitland, P. S. 1990. Biology of Fresh Waters. Chapman & Hall, New York, NY.
- Manitoba Water Stewardship. 2007. Reducing Nutrient Contributions from Urban and Rural Residential sources. Manitoba Water Stewardship Water Quality Management Section, Winnipeg, MB, Canada. [http://www.gov.mb.ca/waterstewardship/fertilizer/proposed\\_approaches\\_to\\_reducing\\_nutrients.pdf](http://www.gov.mb.ca/waterstewardship/fertilizer/proposed_approaches_to_reducing_nutrients.pdf). Accessed: 10/25/08.
- McIntosh, J. 2007. Phoslock Application – Lake Okareka Final Report. Environmental Bay of Plenty; Environmental Publication 2007/23. <http://www.phoslock.com.au/Lake%20Okareka%20Report%202007.pdf>. Accessed: 9/26/08.
- MDC. 1983. Land Use Plan. Land Use Regulation Commission, Maine Department of Conservation, Augusta, ME.
- MDEP. 1990. Comprehensive Planning for the Lake Watersheds. Maine Department of Environmental Protection, Augusta, ME.

- MDEP. 1991. Progress Report, Augusta, ME: Threemile Pond Restoration Project. Maine Department of Environmental Protection, Augusta, ME.
- MDEP. 1992a. Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development. Maine Department of Environmental Protection, Augusta, ME.
- MDEP. 1992b. State of Maine Guidelines for Municipal Shoreline Zoning Ordinances. Maine Department of Environmental Protection. Augusta, ME.
- MDEP. 1998. Maine Shoreline Zoning: A Handbook for Shoreline Owners. Maine Department of Environmental Protection, Augusta, ME.
- MDEP. 2001a. East Pond Somerset and Kennebec Counties Total Maximum Daily (Annual) Load. Maine Department of Environmental Protection, Augusta, ME.
- MDEP. 2001b. China Lake East and West Basins Total Maximum Daily (Annual) Load. Maine Department of Environmental Protection, Augusta, ME.
- MDEP. 2001c. East Pond TMDL Report. Maine Department of Environmental Protection, Augusta, ME.
- MDEP. 2003a. Safe Home Program: Household Wastewater. University of Maine Cooperative Extension. Maine Department of Environmental Protection, Augusta, ME.  
[http://www.maine.gov/dep/rwm/publications/safehomes/shp4/css/shp4\\_1.htm](http://www.maine.gov/dep/rwm/publications/safehomes/shp4/css/shp4_1.htm). Accessed: 9/27/05.
- MDEP. 2003b. DEP Issue Profile: Non-conforming Structures in the Shoreland Zone. Maine Department of Environmental Protection, Augusta, ME.  
<http://maine.gov/dep/blwq/docstand/szpage.htm>. Accessed: 10/16/08.
- MDEP. 2003c. DEP Issue Profile: Mandatory Shoreline Zoning Act. Maine Department of Environmental Protection, Augusta, ME. <http://maine.gov/dep/blwq/docstand/ip-shore.htm>. Accessed: 10/14/08.
- MDEP. 2003d. Maine Erosion and Sedimentation Control BMPs. Maine Department of Environmental Protection, Bureau of Land and Water Quality, Augusta, ME.  
<http://www.state.me.us/dep/blwq/docstand/escbmps/index.htm>. Accessed: 10/3/08.
- MDEP. 2004. Maine Erosion and Sediment Control Budget. Bureau of Land and Water Quality, Maine Department of Environmental Protection, Augusta, ME.

- MDEP. 2005a. Androscoggin Lake's Outlet Delta System.  
<http://www.state.me.us/doc/nrimc/mgs/explore/surfacial/sites/apr05.htm>. Accessed: 11/22/08.
- MDEP. 2005b. Togus (Worromontogus) Pond: Phosphorus Control Action Plan – TMDL. Public Review Draft. Maine Department of Environmental Protection, Augusta, ME.
- MDEP 2005c. Documented Infestations of Invasive Aquatic Plants in Maine. Invasive Aquatic Plants. Bureau of Land and Water Quality. Maine Department of Environmental Protection. <http://www.maine.gov/dep/blwq/topic/invasives/doc.htm>. Accessed: 11/20/08.
- MDEP. 2006. Stormwater Management for Maine. Maine Department of Environmental Protection, Augusta, ME.  
<http://www.maine.gov/dep/blwq/docstand/stormwater/stormwaterbmps>. Accessed: 10/3/08.
- MDEP. 2008a. Pattee Pond Watershed Survey Report. Kennebec County Soil and Water Conservation District, Maine Department of Environmental Protection, Augusta ME.
- MDEP. 2008b. Maine Shoreland Zoning: A Handbook for Shoreland Owners. Maine Department of Environmental Protection, Augusta, ME.  
<http://maine.gov/dep/blwq/docstand/szpage.htm>. Accessed: 10/3/08.
- MDEP. 2008c. Watershed Materials and Reports. Watershed Planning and Management. Bureau of Land and Water Quality, Maine Department of Environmental Protection, Augusta, ME.  
<http://www.maine.gov/dep/blwq/docwatershed/materials.htm>. Accessed: 10/3/08.
- MDHHS. 1983. Site Evaluation for Subsurface Waste Water Disposal Design in Maine (2nd edition). Maine Department of Human Services, State House, Augusta, ME.
- MDHHS. 2002. State of Maine Subsurface Wastewater Disposal Rule - Chapter 241. Maine Department of Human Services, Augusta, ME.
- MDHHS. 2003. Subsurface Wastewater Program Policies. Maine Department of Health and Human Services, Augusta, ME.  
<http://www.maine.gov/dhhs/eng/plumb/policies/policy06.htm>. Accessed: 10/23/08.
- MDIFW. 2000. 2000 Fish Stocking Report. Maine Department of Inland Fisheries and Wildlife, Sidney, ME.
- MDIFW. 2007a. Weekly Fishing Reports by Regional Fishery Biologists.  
[http://www.state.me.us/ifw/fishing/reports/weekly\\_biologist/4-01-07.htm](http://www.state.me.us/ifw/fishing/reports/weekly_biologist/4-01-07.htm). Accessed: 10/25/08.
- MDIFW. 2007b. Regional Fishing Information - Region B (The Central Maine Region).  
[http://www.state.me.us/ifw/fishing/regional\\_information/index.htm](http://www.state.me.us/ifw/fishing/regional_information/index.htm). Accessed: 10/25/08.

- MDOT. 1986. Roadway Fundamentals for Municipal Offices. Maine Department of Transportation, Augusta, ME.
- MEGIS. 2008. MEDEM10. Maine Office of GIS, Augusta, ME.  
<http://mcgis.maine.gov/catalog/catalog.asp?state=2&extent=24k#medem10>. Accessed: 9/15/08.
- Michael, H. J., K. J. Boyle, and R. Bouchard. 2000. Does the measurement of environmental quality affect implicit prices estimated from hedonic models? *Land Economics* 76:283-298.
- Michael, H. and R. Bouchard. 1996. Water Quality Affects Property Prices: A Case Study of Selected Maine Lakes. Maine Agricultural and Forest Experiment Station, University of Maine, Orono, ME.
- Michaud, J. P. 1991. A Citizen's Guide to Understanding and Monitoring Lakes and Streams. Washington State Department of Ecology and the Puget Sound Water Quality Authority, Seattle, WA.
- Michaud, M. 1992. Camp Road Maintenance: A Guide for Landowners. Kennebec County Soil and Water Conservation District. Augusta, ME.
- MLURC. 1976. Comprehensive Land Use Plan. Maine Land Use Regulation Commission, Maine Department of Conservation, Augusta, ME.
- Molles, M. 2005. Ecology Concepts and Applications, 3rd ed. McGraw-Hill, NY.
- Morgan, R. P. C. 2005. Soil Erosion and Conservation, 3rd ed. Blackwell Publishing, Malden, MA.
- MRSA. Mandatory Shoreland Zoning Act Definitions. (Title 38, §436-A).  
<http://www.mainelegislature.org/legis/statutes/38/title38sec436-a.html>. Accessed: 11/9/08.
- MRSA. 2005. Maine Subsurface Waste Water Disposal Rules. (10-144 CMR 241).
- MRSA. 2007. Protection and Improvement of Waters. (Title 38, §419: 1-3).
- MVLMP. 2004. Virtual Herbarium of Aquatic Plants. Maine Center for Invasive Aquatic Plants. Maine Volunteer Lake Monitoring Program. <http://www.mciap.org/herbarium/>. Accessed: 11/20/08
- MVLMP. 2008a. Invasive Plant Patroller's Handbook. Maine Volunteer Lake Monitoring Program, Auburn, ME.



- MVLMP. 2008b. Lake Water Quality Indicators. Maine Volunteer Lake Monitoring Program, Auburn, ME. <http://www.mainevolunteerlakemonitors.org/waterquality/indicators.php>. Accessed: 10/23/08.
- MVLMP. 2008c. Long Term Distribution of Water Quality Data for Maine Lakes through 2007. Maine Volunteer Lake Monitoring Program, Auburn, ME. <http://www.mainevolunteerlakemonitors.org/waterquality/DistributionOfData.php>. Accessed: 10/23/08.
- NCDC. 2008. Augusta Climate-Radar Data Inventory. National Oceanic and Atmospheric Administration, National Climatic Data Center. <http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~StnSrch~StnID~20009754>. Accessed: 10/27/08.
- Niering, W. A. 1985. Wetlands. Alfred A. Knopf, Inc, New York, NY.
- Nishihara, A. and C. Shock. 2001. Benefits and Costs of Applying Polyacrylamide (PAM) in Irrigated Furrows. Malheur County Best Management Practices. Malheur Experiment Station, Oregon State University, Ontario, OR. <http://www.cropinfo.net/bestpractices/bmppamreport.html>. Accessed: 9/26/08.
- NLFCD. 2007. History of the District. Newman Lake Flood Control Zone District. Newman Lake, Washington. <http://www.nlfcd.org/districthistory.asp>. Accessed: 9/23/08.
- NRCS. 2008. Soil Series Classification Database. Natural Resources Conservation Service, United States Department of Agriculture, Lincoln, NE. <http://soils.usda.gov/soils/technical/classification/scfile/index.html>. Accessed: 10/19/08.
- Nürnberg, G. K. 1987. Hypolimnetic withdrawal as lake restoration technique. *Journal of Environmental Engineering* 113:1006-1017.
- Nutrient Management Act. 2006. Office of the Reviser of Statutes. Maine State Legislature, Augusta, ME. <http://janus.state.me.us/legis/statutes/7/title7ch747sec0.html>. Accessed: 11/15/07.
- Nyer, E. K. 1998. Groundwater and Soil Remediation: Practical Methods and Strategies. CRC Press, Boca Raton, FL.
- O'Sullivan, P. E. and C. S. Reynolds. 2005. *The Lakes Handbook: Volume 2. Lake Restoration and Rehabilitation*. Blackwell Publishing, Oxford, England.
- Olem, H. and G. Flock, eds. 1990. *Lake and Reservoir Restoration Guidance Manual*, 2nd ed. North American Lake Management Society, United States Environmental Protection Agency, Washington, DC.

- Overcash, M. R. and J. M. Davidson. 1980. Environmental Impact of Nonpoint Source Pollution, Ann Arbor, MI.
- PEARL. 2004. Loon Counts. <http://www.pearl.maine.edu/Lake2.asp?Watercode=5458>. Accessed: 11/20/08.
- PEARL. 2008a. Fish Species. Pearl Group, Mitchell Center, University of Maine, Orono, ME. [http://www.pearl.maine.edu/windows/community/Anglers\\_Fish/angler\\_fishspecies.htm](http://www.pearl.maine.edu/windows/community/Anglers_Fish/angler_fishspecies.htm). Accessed: 10/22/08.
- PEARL. 2008b. Temperature and Dissolved Oxygen: What Is It? Pearl Group, Mitchell Center, University of Maine, Orono, ME. [http://www.pearlmaine.com/windows/community/Water\\_Ed/Dissolved%20Oxygen/DO\\_whatisit.htm](http://www.pearlmaine.com/windows/community/Water_Ed/Dissolved%20Oxygen/DO_whatisit.htm). Accessed: 10/23/08.
- PEARL. 2008c. Temperature and Dissolved Oxygen: What Does It Tell Us? Pearl Group, Mitchell Center, University of Maine, Orono, ME. [http://www.pearlmaine.com/windows/community/Water\\_Ed/Dissolved%20Oxygen/DO\\_whatdoesittell.htm](http://www.pearlmaine.com/windows/community/Water_Ed/Dissolved%20Oxygen/DO_whatdoesittell.htm). Accessed: 10/23/08.
- PEARL. 2008d. Transparency: What Is It? Pearl Group, Mitchell Center, University of Maine, Orono, ME.
- PEARL. 2008e. Lake Color: What Is It? Pearl Group, Mitchell Center, University of Maine, Orono, ME. [http://www.pearlmaine.com/windows/community/Water\\_Ed/Color/Co\\_whatisit.htm](http://www.pearlmaine.com/windows/community/Water_Ed/Color/Co_whatisit.htm). Accessed: 10/23/08.
- PEARL. 2008f. Lake Color: What Does It Tell Us? Pearl Group, Mitchell Center, University of Maine, Orono, ME.
- PEARL. 2008g. pH and Alkalinity: What Is It? Pearl Group, Mitchell Center, University of Maine, Orono, ME. [http://www.pearl.maine.edu/windows/community/Water\\_Ed/pH/pH\\_whatisit.htm](http://www.pearl.maine.edu/windows/community/Water_Ed/pH/pH_whatisit.htm). Accessed: 10/25/08.
- PEARL. 2008h. Lake Water Quality: Chlorophyll. Pearl Group, Mitchell Center, University of Maine, Orono, ME.
- Prescott, G. C. 1969. Ground Water Favorability Areas and Surficial Geology of the Lower Kennebec River Basin, Maine. Hydrological Investigations Atlas. United States Department of the Interior, United States Geological Survey, Washington, DC.

- Reubens, B., J. Poesen, F. Danjon, G. Geudens, and B. Muys. 2007. The role of fine and coarse roots in shallow slope stability and soil erosion control with a focus on root system architecture: a review. *Tree-Structure and Function* 21:385-402.
- Revenga, C., S. Murray, J. Abramowitz, and A. Hammond. 1998. *Watersheds of the World: Ecological Value and Vulnerability*. World Resources Institute and Worldwatch Institute, Washington, DC.
- Robertson, D. 1996. Sources and transport of phosphorus in the Western Lake Michigan Drainages. United States Geological Survey, Washington, DC.
- Robertson, D., D. Graczyk, P. Garrison, L. Wang, G. LaLiberte, and R. Bannerman. 2006. Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin. United States Department of the Interior, United States Geological Survey, Washington, DC.
- Rose, G. L. 2005. Forecast of Town Populations by Age Cohort. Maine State Planning Office, Augusta, ME.
- Schindler, D. W. 1974. Eutrophication and recovery in experimental lakes: Implications for lake management. *Science* 184:897-899.
- Schindler, D. W., R. E. Hecky, D. L. Findlay, M. P. Stainton, B. R. Parker, M. J. Paterson, K. G. Beaty, M. Lyng, and S. E. M. Kasian. 2008. Eutrophication of lakes cannot be controlled by reducing nitrogen input: Results of a 37-year whole-ecosystem experiment. *Proceedings of the National Academy of Sciences of the USA* 105:11254-11258.
- Singleton, V. L. and J. C. Little. 2006. Designing hypolimnetic aeration and oxygenation systems, a review. *Environmental Science and Technology* 40:7512 -7520.
- Smith, R. L., and T. M. Smith. 2009. *Elements of Ecology*, 7th ed. Pearson, San Francisco, CA.
- Spalatro, F. and B. Provencher. 2001. An analysis of minimum frontage zoning to preserve lakefront amenities. *Land Economics* 77:469-481.
- Steiner, I. 2000. *Pennsylvania Fishes*. Pennsylvania Fish and Boat Commission, Harrisburg, PA. <http://www.fish.state.pa.us/fishes.htm>. Accessed: 10/20/08.
- Swearingen, J. M. 2005. Plant Conservation Alliance's Alien Plant Working Group Least Wanted: Purple loosestrife. National Park Service. [www.nps.gov/plants/ALIEN/fact/lysa1.htm](http://www.nps.gov/plants/ALIEN/fact/lysa1.htm). Accessed: 11/02/08.
- Tietjen, E. 1988. *Avoiding the China Lake Syndrome*. Maine Audubon Society. Holden, ME.

- Tomar, M. 1999. *Quality Assessment of Water and Wastewater*. Lewis Publishers, Boca Raton, FL.
- Town of Winslow. 1997a. Chapter 14: Zoning Ordinance. The Municipal Code of Winslow, ME. <http://www.winslowmaine.org/towncode.html>. Accessed: 9/17/08.
- Town of Winslow. 1997b. Chapter 11: Streets. The Municipal Code of Winslow, ME. <http://www.winslowmaine.org/towncodc.html>. Accessed: 9/17/08.
- USDA. 1978. *Soil Survey of Kennebec County Maine*. United States Department of Agriculture, Washington, DC.
- USDA. 1992. *Engineering Criteria for Soils Mapped in Maine*. United States Department of Agriculture, Washington, DC.
- USDA. 2002. 2002 Census of Agriculture—County Data. United States Department of Agriculture. [http://www.agcensus.usda.gov/Publications/2002/Volume\\_1,\\_Chapter\\_2\\_County\\_Level/Mainc/st23\\_2\\_008\\_008.pdf](http://www.agcensus.usda.gov/Publications/2002/Volume_1,_Chapter_2_County_Level/Mainc/st23_2_008_008.pdf). Accessed: 10/27/08.
- USDA. 2008. *Buffer Strips: Common Sense Conservation*. Natural Resources Conservation Service, United States Department of Agriculture, Washington, DC. <http://www.nrcs.usda.gov/FEATURE/buffers>. Accessed: 10/24/08.
- USGS. 2008. *Explanation of Water Hardness*. Office of Water Quality. United States Geological Survey, Washington, DC. <http://water.usgs.gov/owq/Explanation.html>. Accessed: 10/27/08.
- Vaux, P. 2005. *Maine Lakes: Morphology and Geographic Information*. Pearl Group, Mitchell Center, University of Maine, Orono, ME. <http://www.pearl.maine.edu>. Accessed: 10/24/08.
- WAL. *Economic Benefits of Shoreland Protection*. Wisconsin Association of Lakes, Madison, WI. <http://www.wisconsinlakes.org/AboutLakes/shorelandseconomicbenefits.htm#>. Accessed: 10/26/08.
- Waschbusch, R., W. Selbig, and R. Bannerman. 1999. *Sources of Phosphorus in Stormwater and Street Dirt from Two Urban Residential Basins in Madison, Wisconsin, 1994-95*. United States Geological Survey, Washington, DC.
- Washington State Department of Ecology. 1998. *How Ecology Regulates Wetlands*. University of Washington, Seattle, WA. <http://www.ecy.wa.gov/biblio/97112.html>. Accessed: 11/4/05.
- Welch, E. B. and G. D. Schriever. 1994. Alum treatment effectiveness and longevity in shallow lakes. *Hydrobiologia* 275:423-431.



- Welch, E. B. 2007. The dilution and flushing of technique in lake restoration. *Journal of the American Water Resources Association* 17:558-564.
- Wheaton, R. and E. Monke. 2001. Terracing as a 'Best Management Practice' for Controlling Erosion and Protecting Water Quality. Agricultural Engineering Department, Purdue University. <http://www.ces.purdue.edu/extmedia/AE/AE-114.html>. Accessed: 10/26/08.
- Whisenant, S. 2005. *First Steps in Erosion Control. Forest Restoration in Landscapes*. Springer, New York, NY.
- Williams, S. 1992. A Citizen's Guide to Lake Watershed Surveys: How to Conduct a Non-point 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, ME.
- WSDE. 2008. Algae Control Program. Department of Ecology, State of Washington, Olympia, WA. <http://www.ccy.wa.gov/Programs/wq/plants/algae/lakes/LakeRestoration.html>. Accessed: 9/23/08.
- Yates, V. M. 1985. Septic tank density and ground-water contamination. *Ground Water* 23:586-591.
- Zanini, I., W. D. Robertson, C. J. Ptacek, S. L. Schiff, and T. Mayer. 1998. Phosphorus characterization in sediments impacted by specific effluent at four sites in central Canada. *Journal of Contaminant Hydrology* 33:405-429.
- Zhang, H., T. D. Dao, H. A. Wallace, N. T. Basta, E. A. Dayton, and T. C. Daniel. 2000. Remediation Techniques for Manure Nutrient Loaded Soils. White Paper Summaries. [http://www.cals.ncsu.edu/waste\\_mgt/natlcenter/whitepapersummaries/remediation.pdf](http://www.cals.ncsu.edu/waste_mgt/natlcenter/whitepapersummaries/remediation.pdf). Accessed: 9/26/08.

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<b>Irene Giordano</b>	Owner and Operator of Giordano's Camping and Recreation
<b>Louis Giordano</b>	Owner and Operator of Giordano's Camping and Recreation
<b>Tracey Greenwood</b>	Department of Biology, Colby College, Waterville, ME
<b>Dave Halliwell</b>	Maine Department of Environmental Protection, Augusta, ME
<b>Carl Snow</b>	Pattee's Pond Association, Winslow, ME
<b>Frank Stankevitz</b>	Winslow Code Enforcement Officer, Winslow, ME
<b>MacGregor Stocco</b>	Kennebec Valley Council of Governments Community Planner, Fairfield, ME
<b>Brad Whitaker</b>	President of the Pattee's Pond Association, Winslow, ME

## APPENDICES

### ***APPENDIX A. ELEVEN MOST UNWANTED INVASIVE AQUATIC PLANT GUIDE***

A field guide including pictures and descriptions of the eleven most unwanted invasive aquatic plants in Maine. Pictures were extracted from Maine VLMP 2004, and photo credits are listed underneath each respective species name. This guide was created in order to provide information about invasive aquatic plant identification for residents. An asterisk (\*) indicates a plant species that has been discovered in a Maine water body (MDEP 2005c).

#### **Brazilian elodea (*Egeria densa*)**

[http://ipm.ppws.vt.edu/scott/weed\\_id/eldde.htm](http://ipm.ppws.vt.edu/scott/weed_id/eldde.htm)



Brazilian elodea is a rooted, submersed perennial with bright green leaves, densely arranged in whorls of 4 to 6 leaves on slender, brittle stems. (Note: the lower leaves may be opposite or in whorls of 3 leaves.) The leaves are finely-toothed, strap-shaped with a pointed tip, 1 to 3 cm long, and up to 5 mm wide. (Having more than 3 leaves per whorl, and leaves more than 1 cm in length help to distinguish this plant from Maine's native waterweeds.) Branches form irregularly along the stems in areas where two whorls appear to be joined (known as "double nodes"). The small flowers (averaging 2 cm in diameter) have three white petals and a yellow center, and emerge just above or at the surface on slender stalks projecting from leaf axils near the stem tips. The slender roots are pale and un-branched. Unlike hydrilla, Brazilian elodea does not produce tubers.

**\*Curly-leaf pondweed (*Potamogeton crispus*)**

<http://www.lakehubert.org/curlyleaf.html>



Curly-leaf pondweed is a submersed aquatic perennial with submersed leaves only. The slightly flattened stems emerge from slender rhizomes and sprouting turions, often branching profusely as they grow, giving the plants a busy appearance. Mature stems average 0.4 to 0.8 m in length. Stipules when visible (they disintegrate early) are slightly joined to the stem at the base and 4 to 10 mm long. Flower spikes appear above the surface of the water from June through September. The small flowers are arranged in a terminal spike on a curved stalk measuring about 7 cm in length. The fruits (seeds) have a prominent cone shaped beak and a bumpy ridge along the "crown." Turions form in the leaf axils during the growing season. The turions, resembling small ruffled pinecones, are hard (like stiff plastic) and typically 1 to 2 cm long.

**\*Eurasian water-milfoil (*Myriophyllum spicatum*)**

<http://www.aqua-fish.net/show.php?h=myriophyllumspicatum>



Eurasian water-milfoil is a submersed aquatic plant with feather-like finely divided leaves, typically with 12 to 24 pairs of thread-like leaflets on each leaf. The leaves are arranged in whorls (3 to 6 leaves per whorl). The whorls are openly spaced along the stem, with 1 to 3 cm between whorls. Flowers occur in the axils of the bracts, arranged in whorls around a slender spike that emerges generally upright from the surface of the water. The bracts have smooth margins and the flowers are generally larger than the bracts. Eurasian water-milfoil does not form winter buds.



### European frogbit (*Hydrocharis morsus-ranae*)

<http://flickr.com/photos/28113115@N00/2809337443/>



European frog-bit is a small free-floating aquatic plant. Its small kidney or heart shaped water-lily like leaves (1.3 – 6.3 cm long) are not anchored to the bottom substrate. The floating leaves have elongate stalks, 4-6 cm long, and form a rosette from the short submerged stem. Simple unbranched root-like tendrils (resembling slender bottle brushes) dangle below. The flowers of European frog-bit have three white petals with a yellow center.

### European naiad (*Najas minor*)

<http://www.dnr.state.md.us/bay/sav/key/najas3.html>



Seedlings grow from slender roots; developing stems up to 2.5 m long that often branch profusely near the top. Leaves may appear to be opposite, sub-opposite, in whorls or clumps. The leaves are small (rarely more than 3.5 cm long) and very slender (0.3 – 0.5 mm wide), strap-shaped, pointed and serrated. The leaf serrations of European naiad, though tiny, can usually be observed without magnification (separating it from native naiads). A second characteristic that distinguishes European naiad from two of Maine's three native naiad species is the abruptly protruding blocky or fan-shaped leaf base. The upper margin of the leaf base is finely toothed or "fringed" in appearance. Like all naiads, the flowers are small, inconspicuous, and borne in the leaf axils. The seeds are purplish, 1.5 to 3.0 mm long, spindle shaped and slightly curved, with rectangular indentations arranged in distinct longitudinal rows.

### Fanwort (*Cabomba caroliniana*)

<http://aquarium-journal.com/2007/05/carolina-fanwort-cabomba-caroliniana.html>



Fanwort is a submersed perennial with stems emerging at intervals along horizontal rhizomes. The plant has two distinct leaf types. The submersed leaves are finely divided, widely branched, and held apart from the stem on slender petioles, resembling tiny fans with handles. The leaves are arranged in opposite pairs along the main stem. The orderly formation of leaves and stems gives the plant a “tubular” appearance underwater. Plants range in color from grass green to olive green to reddish. Floating leaves, when present, are inconspicuous (1 cm long), elongate and elliptical. They are arranged alternately on slender petioles attached to center of each leaf. Small white flowers (1 cm in diameter) develop among the floating leaves.

### \*Hydrilla (*Hydrilla verticillata*)

[http://weeds.hotmeal.net/weeds/List\\_A.html](http://weeds.hotmeal.net/weeds/List_A.html)



Hydrilla is a perennial submersed aquatic plant with long slender, branching stems emerging from horizontal underground rhizomes and above ground stolons. The leaves are strap-like and pointed with claw-like serrations along the outer margins. The leaves are typically arranged in whorls of 4 to 8. Small white flowers rise to the surface on slender stalks from the upper leaf axils. Hydrilla produces two types of overwintering structures. Spiny green turions (5 to 8 mm long) are produced in the leaf axils. Small, somewhat crescent-shaped tubers (5 – 10 mm long), form along the rhizomes and stolons. The tubers have a scaly appearance under magnification and are pale cream to brownish in color.



### Parrot feather (*Myriophyllum aquaticum*)

<http://www.waterwereld.nu/vederkruidenteng.php>



Parrot feather has both emergent and submersed leaves. The bright green emergent leaves are 2.5 cm to 5 cm long, and are the plant's most distinctive characteristic, growing like a dense stand of miniature fir trees to a height of one foot above the surface of the water. The feather-like finely divided leaves have 10 to 18 pairs of thread-like leaflets and are arranged in whorls of 4 to 6 around the stem. The submersed leaves are less vibrant, on tough, often thickly entangled cord-like stems. Small white flowers are inconspicuous and borne in the axils of the emergent leaves.

### \*Variable water-milfoil (*Myriophyllum heterophyllum*)

[http://www.missouriplants.com/Others/Myriophyllum\\_heterophyllum\\_page.html](http://www.missouriplants.com/Others/Myriophyllum_heterophyllum_page.html)



Variable water-milfoil is a submersed, aquatic plant that is often characterized by a dense "bottle brush" appearance and thick, robust reddish stems. Feather-like divided leaves are arranged in densely packed whorls. There are generally 4 to 6 leaves per whorl and 5 to 14 pairs of thread like leaflets on each leaf. The plant produces spike-like flowers that emerge above the surface of the water from mid to late summer. The bracts and flowers are whorled. Minute white flowers develop in the axils of the bracts. The bracts are typically deeply toothed, blade-shaped and more than twice the length of the tiny flowers. The flower spikes are often essential to confirming species identification.

### Water chestnut (*Trapa natans*)

<http://www.thebeatnews.org/Issues/Invasives/Invasive%20species.html>



Water chestnut has two distinct leaf types. The floating leaves are four-sided but somewhat triangular (or fan shaped) with conspicuously toothed margins along the outside edges. The upper surface of the leaf is glossy; the undersides are covered with soft hairs. The leaves are arranged in a radiating pattern or rosette and joined to the submersed stem by long petioles (up to 15 cm long). The rosettes are anchored to the sediments on slender stems reaching lengths of up to 5 m. White flowers appear above the rosettes in mid to late July, each emerging from its own stalk from the axils of the floating leaves. When the fruits form they submerge and dangle beneath the rosette. The fruits are woody and nut-like, typically with four sharp barbs.

### Yellow floating heart (*Nymphoides peltata*)

<http://www.pondplantgirl.com/ebay/heart.htm>



Yellow floating heart is a bottom-rooted perennial that produces branched stolons just below the water surface. Each rooted stem supports a loosely branched group of several leaves. The leaves are nearly round to heart-shaped. (Note that all heart-shaped floating leaved plants that are native to Maine produce only one leaf per rooted stem.) The leaves are typically wavy (shallowly scalloped) along the outer edges and have purplish undersides. Leaves average 3 to 10 cm in diameter. The flowers are showy (3 to 4 cm in diameter), bright yellow with five distinctly fringed petals. They are held above the water surface on long stalks with 1 to 5 flowers per stalk. The seeds are oval and flat (about 3.5 mm long) and hairy along their outer edges.

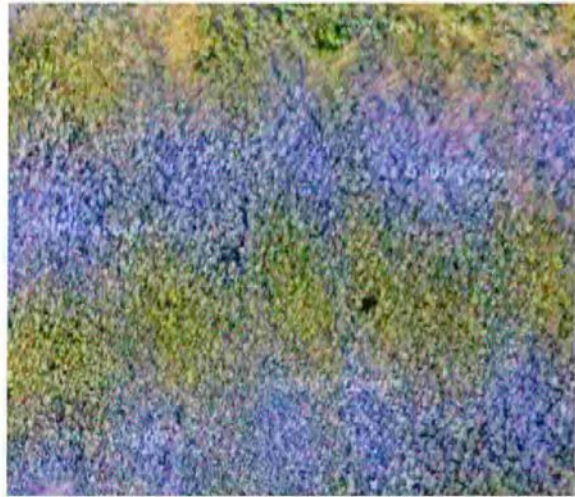


## ***APPENDIX B. LAND USE TYPE EXAMPLES***

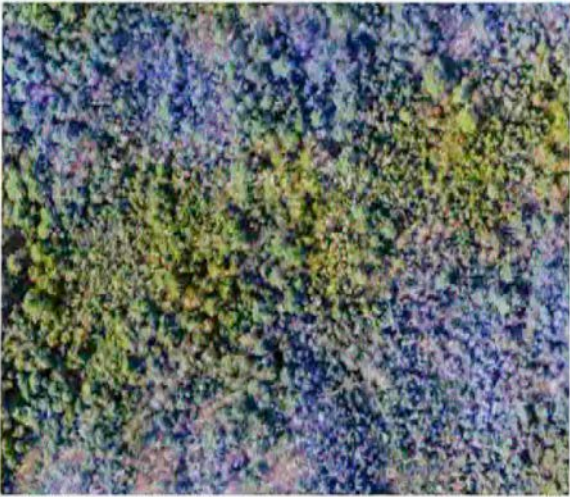
These aerial photographs represent the various land use types identified by CEAT (see Land Use Analysis: Methods). Lines indicate the area of the photograph being referred to by the corresponding category.



Deciduous Forest



Coniferous Forest

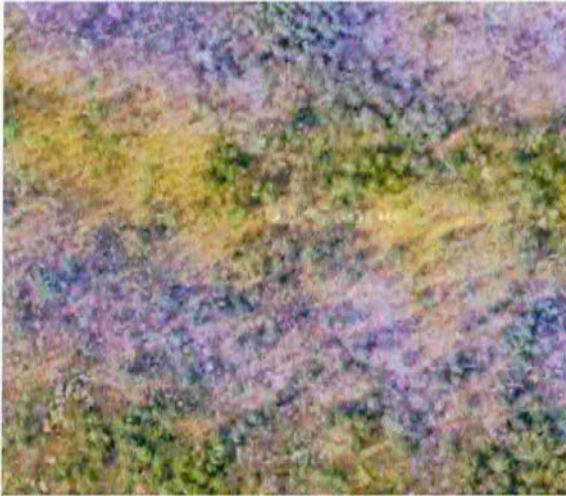


Mixed Forest

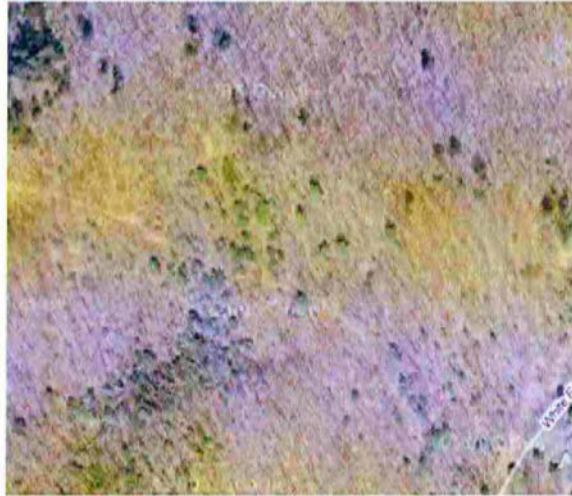


Reverting Land





Transitional Forest



Regenerating Forest



Residential



Commercial

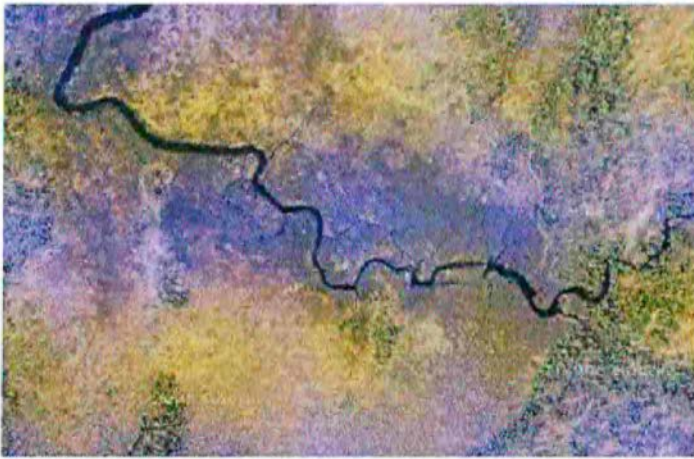


Pasture

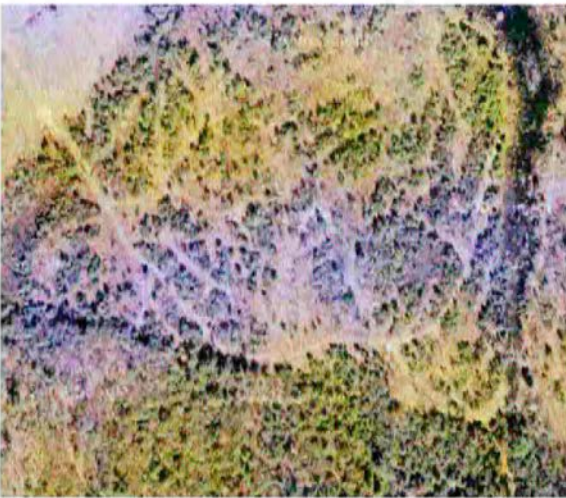


Crops

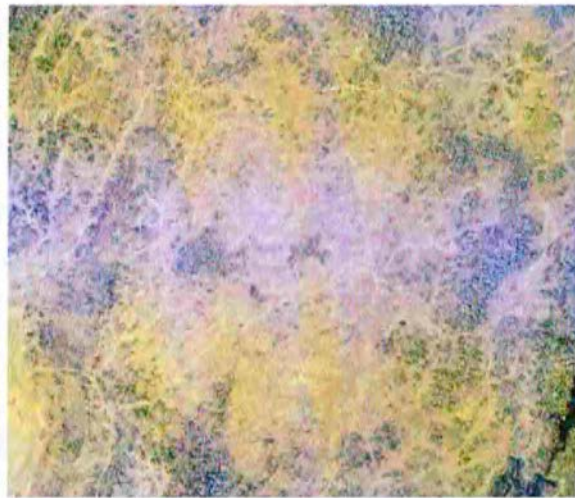




Wetlands



Logged Land



Cleared Land



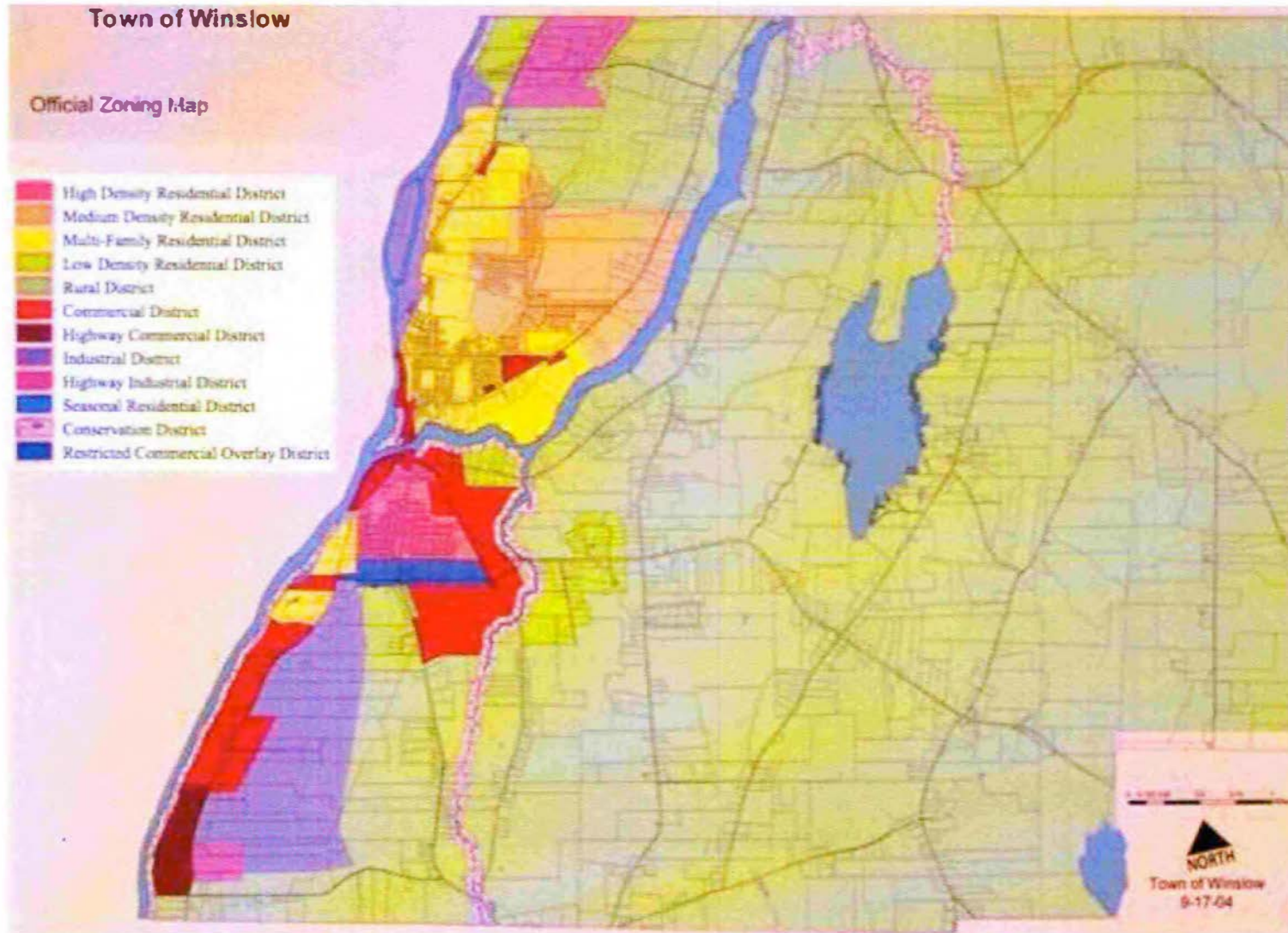
Camp Caribou



Giordano's Campground

## ***APPENDIX C. TOWN OF WINSLOW OFFICIAL ZONING MAP***

Current (2008) zoning districts as published by the Town of Winslow.





## **APPENDIX D. PATTEE POND SOIL SERIES**

Soil series found in the Pattee Pond watershed at 0% slope, soil phases and their abbreviations, and soil k-factors (USDA 1992, NRCS 2008). K-factors indicate soil erodibility on a scale of 0.00, low erodibility, to 0.69, high erodibility.

<b>Soil Series</b>	<b>Soil Phase</b>	<b>k-Factor</b>	<b>k-Factor Fit to a Scale of 1 to 9</b>
Biddeford	Bo—Biddeford Mucky Peat	0.00	1
Buxton	Bu—Buxton Silt Loam	0.32	5
Hollis	Hr—Hollis Fine Sandy Loam	0.28	4
Hollis-Rock Outcrop	Ht—Hollis-Rock Outcrop Complex	0.28	4
Monarda	Mo—Monarda Silt Loam	0.25	3
Monarda Stony	Mr—Monarda Very Stony Silt Loam	0.26	3
Paxton	Pb—Paxton Fine Sandy Loam	0.24	3
Paxton-Charlton	Pd—Paxton-Charlton Fine Sandy Loam	0.24	3
Paxton-Charlton Stony	Pc—Paxton-Charlton Very Stony Fine Sandy Loam	0.24	3
Ridgebury	Rc—Ridgebury Fine Sandy Loam	0.24	3
Ridgebury Stony	Rd—Ridgebury Very Stony Fine Sandy Loam	0.24	3
Saco Soils	SA—Saco Soils	0.28	3
Scantic	Sc—Scantic Silt Loam	0.32	5
Scio	Sk—Scio Very Fine Sandy Loam	0.49	7
Togus	TO—Togus Fibrous Peat	0.10	2
Woodbridge	Wr—Woodbridge Fine Sandy Loam	0.24	3
Woodbridge-Stony	Ws—Woodbridge Very Stony Fine Sandy Loam	0.24	3

## ***APPENDIX E. SHORELINE BUFFER SURVEY FORM***

Surveys of the Pattee Pond shoreline and buffer strips were taken by two boats on 22-Sep-08.

Reference Number (on unit)					
GPS Coordinate:					
% Shoreline w/ Buffer	0	1-25	26-50	51-75	>75
	0	1	2	3	4
Buffer depth from shore (ft)	0	1-10	11-33	34-65	>65
	0	1	2	3	4
Slope Rating		Steep	Moderately Steep	Small Incline	Flat
		1	2	3	4
Building Type	Commercial 1	Permanent Residence 0	Seasonal Residence 2		
Buffer Composition:	100%	75%	50%	25%	0%
Trees	4	3	2	1	0
Shrubs/Herbaceous	10	8	6	4	0
Riprap Needed:	Yes 0	No 2	Exists 2		
					Total:
Lot Shoreline distance (ft)	0-60	60-120	120-180	>180	
Noticeable Outdoor Septic	Yes	No			

## **APPENDIX F. ROAD AND RESIDENTIAL SURVEY FORM**

Data sheet used in the road surveys conducted on 12-Sep-08 and 15-Sep-08.

### **OVERALL ROAD SURVEY DATA SHEET 2008**

DATE:		SURVEYORS:		ROAD NAME:	
GPS at start of road:				ROAD TYPE:	
GPS at end of road:				state road camp road other:	
ROAD LENGTH (MILES):					
AVERAGE WIDTH (FEET, include shoulders):					
NOTE COMMERCIAL LAND USE, GPS (gas stations, stores, farms, etc.):					
TALLY # INACCESSABLE LAKEFRONT DRIVEWAYS:					
SLOPE - General:	Steep	Moderately Steep	Small Incline	Flat	
SLOPE - Lake approach:	Steep	Moderately Steep	Small Incline	Flat	
DESCRIBE CROWN:					
measurement:	0-2 in	2-4 in	4-6 in	6-8 in	
DESCRIBE DITCH CONDITION:					
shape:	V-shape		U-shape		
material:	vegetation	stone-lined	gravel/dirt	dirt	
clear of debris?	yes		no		
DESCRIBE ROAD SURFACE CONDITION:					
material:	pavement	packed gravel	loose gravel	dirt	
age:	new		old		
road use:	year round		seasonal		
BASIC SUMMARY:					
OVERALL CONDITION					
		good	acceptable	fair	poor
HOUSE COUNT (tally # of houses per road)			Number of Houses NOT On Shore:		
Number of Houses On Shore:			#		
# Seasonal:		# Permanent:	# Seasonal:		# Permanent:

Evidence of Septic GPS:

Lot Construction GPS:



Macrophyte survey form used during the two days of macrophyte surveys on Pattee Pond. At each sample site, a waypoint was recorded on a GPS device and the coordinates were also recorded by hand in case of a data download error. The procedures for completing a survey form were uniform for all survey teams (see **Macrophytes IV-9-b**). Depth measurements were also taken, which was used in later analyses (**Figure Michael I-3-c-I-2**).

**SITE:****Date:****GPS #:****GROUP MEMBERS:**

Density is determined from total survey area biomass

Percentage is relative to all species present

Density Key: None, Sparse, Medium, Dense

Percentage ranges: &lt;20, 20-40, 40-60, 60-80, 80-100

<b>Waypoint #</b>								
<b>Coordinate (N)</b>								
<b>Coordinate (W)</b>								
<b>Density</b>								
<b>Depth</b>								
Great Bullrush								
Northern Pipewort								
Pickerel Weed								
Bladderwort								
Clasping-Leaf Pondweed								
Common Waterweed/Elodea								
Coontail								
Crowfoot								
Milfoil/Natives								
Purple Loosestrife								
Slender Naiad								
Water Marigold								
Watershield								
White Water Lily								
Wild Celery/Eel-Grass								
Yellow Pond Lily								

## ***APPENDIX H. COMPREHENSIVE AQUATIC PLANT FIELD GUIDE***

A field guide including pictures and descriptions of the 28 identified aquatic plants on Pattee Pond (Borman et al. 2001). Pictures and data for buttonbush (DWFS 2008) and common water moss (AWC 2004), both found in Pattee Pond, are also included. This guide was created in order to provide information about the aquatic plants found on the lake and to help residents identify which plants are established near their homes.

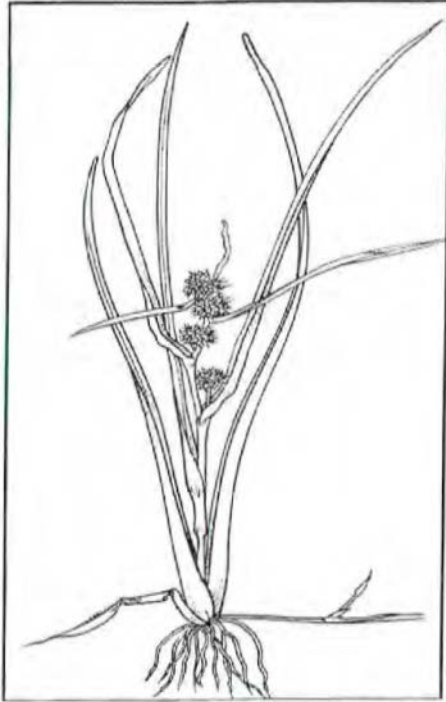
### **Emergent Plants with Narrow Leaves**

#### **Common bur-reed (*Sparganium eurycarpum*)**



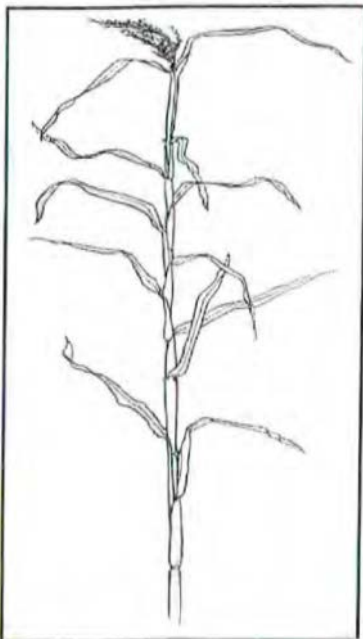
Common bur-reed has emergent leaves (6-12 mm wide, up to 1.5 m tall) that are rather spongy and look like a compressed triangle in cross-section. Ribbon-like floating and submersed leaves may also be produced. The leaves and stems sprout from a shallow, spreading rhizome. The zigzag flower stalk has spherical blooms spaced like sinkers on a fish line. The upper male flowers are the size of small gumballs, while the lower female flowers are the size of jawbreakers. When the female flowers are in bloom, they look like soft, fuzzy balls. When the fruits mature, they have a prickly appearance created by the beaks on the fruits. Each fruit (5-8) in the cluster is square-topped with a terminal beak.

### Short-stemmed bur-reed (*Sparganium chlorocarpum*)



Has erect leaves (2-7 mm wide, up to 1 m tall) that are much taller than the flowering stalk. The basal leaves are often in a fan-shaped arrangement. At least some of the fruiting heads (2-2.8 cm diameter) are spaced above the floral bracts. The nutlets have a shiny, greenish-brown surface above the middle. The beak of the nutlet is fairly long (3-5 mm).

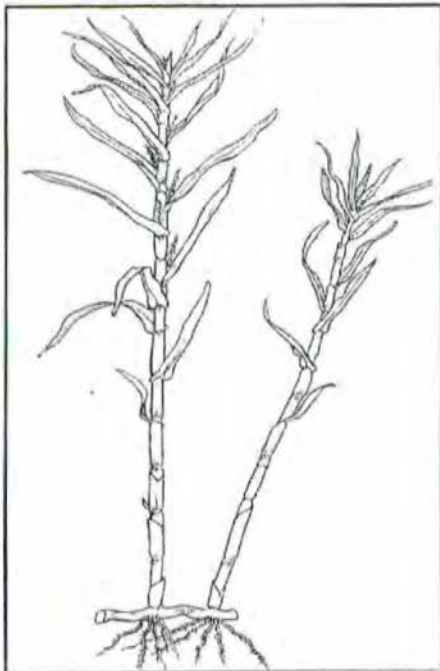
### Giant reed (*Phragmites australis*)



Giant reed has stems (2-4 m tall) that grow out of stout rhizomes. The leaves (up to 60 cm long and 2-3 cm wide) may wave in the wind, like pennants. Some of the stems are topped with spreading clusters of spikelets. Each spikelet (10-15 mm long) has 3-7 florets and long silky hairs that give the overall flowering portions a feather duster appearance.



### Three-way sedge (*Dulichium arundinaceum*)



The stiff stems (30 cm- 1 m tall) of three-way sedge emerge from a spreading rhizome. The leaves are fairly short (5-15 cm long, 2.5-8 mm wide) and stiff, so they stand out from the plant. This gives it the appearance of a dwarf bamboo plant. Unlike the true sedges, whose stems are triangular and solid, the stem of *Dulichium* is round and hollow.

Flowers are arranged in linear spikelets (1.0-2.5 cm long) in two ranks along stalks in the upper leaf axils. The fruit is a beaked nutlet surrounded by 6-9 finely barbed bristles.

### Rice-cut grass (*Leersia oryzoides*)

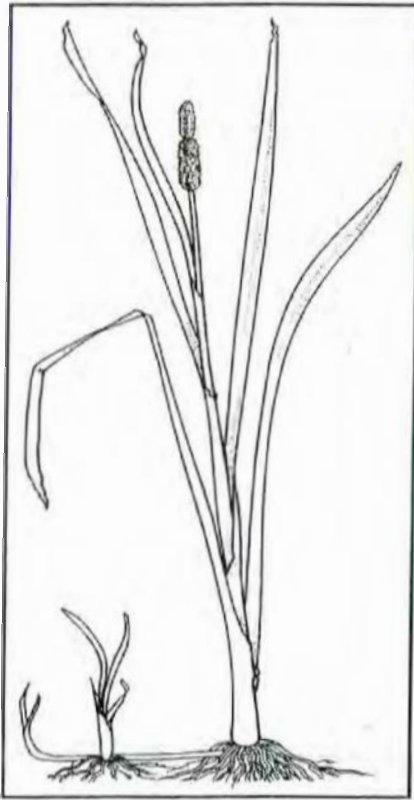


The sprawling stems of rice cut-grass emerge from a slender rootstalk and grow from knee- to shoulder-high, depending on soil and moisture conditions. The leaf blades (15-30 cm long, 6-15 mm wide) have very rough edges with stiff spines that can tear skin or clothing.

The branches bearing spikelets are slender and spreading. The spikelets are in clusters of 3-8 on the ends of the branches. Each spikelet (4-5.5 mm long, 1.4-1.8 mm wide) is flattened and overlaps about half of the one above it (like tiles on a roof).

The surface of the lemma has stiff hairs that tightly adhere to clothing or fur. Spikelets on the open branches are not always fertile. Others form inside the upper leaf sheath and release their seeds as the stems decay at the end of the growing season.

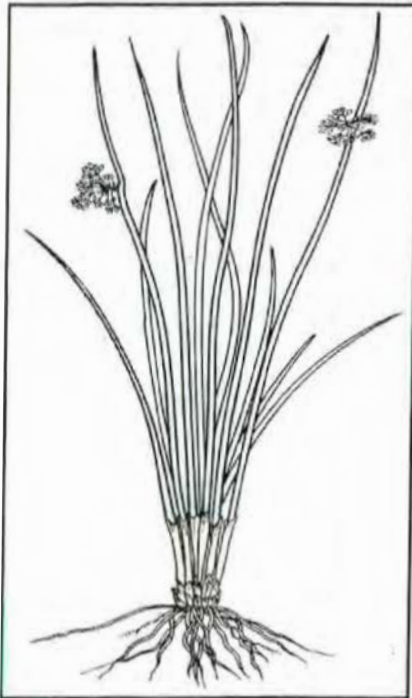
### Broad-leaved cattail (*Typha latifolia*)



Broad-leaved cattail has pale green, sword-like leaves (10-23 mm wide, 1 m or more tall) that emerge from a robust, spreading rhizome. The leaves are sheathed around one another at the base. At the junction of a leaf sheath and blade, the sheath is usually tapered.

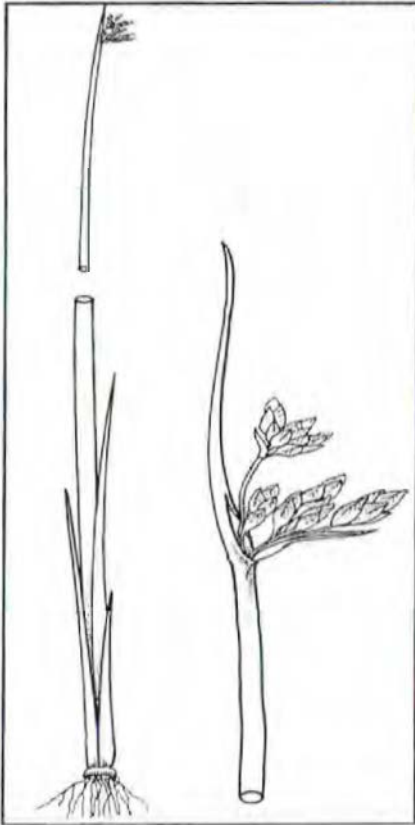
The flower looks like a hotdog on a stick. The lower portion is a cylindrical spike (10-15 cm long, 2-3 cm thick) of thousands of tightly-packed female flowers. Each flower has a broad stigma and many white hairs. Some of these female flowers will produce a nutlet and others are sterile. The top of the female spike is immediately adjacent to the male spike, or sometimes separated by a very small space (less than 4 mm). The male spike has hundreds of anthers that shed pollen to the wind. After the pollen has been released, the male flowers drop off the flower stalk. If you look at the pollen with strong magnification, you can see the pollen grains are in groups of four.

### Common rush (*Juncus effusus*)



Soft rush has smooth, cylindrical stems (1 m or more tall) that emerge from a dense rootstalk. The leaves are reduced to reddish-brown sheaths at the base of the stem. Although the flower clusters appear to grow from the side of each stem, the "stem" portion beyond the flowers is actually a slender floral leaf (15-25 cm long). Each flower is poised on the end of a slender stalk (4-10 cm long). The six straw-colored tepals (three sepals and three petals) eventually surround a capsular fruit.

### Hardstem bulrush (*Scirpus acutus*)



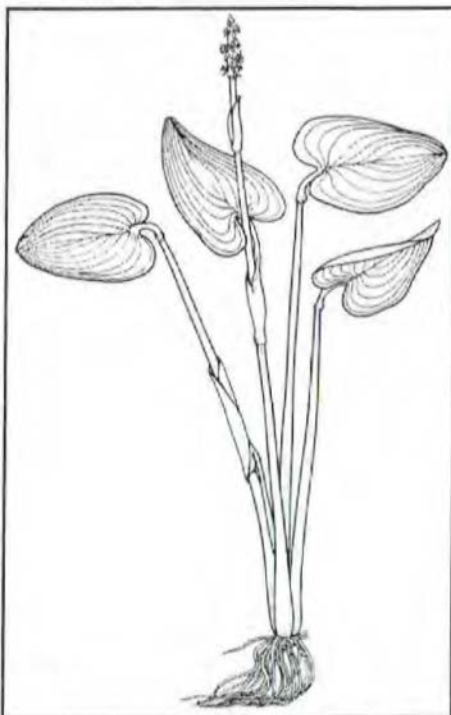
Hardstem bulrush has tall, sturdy stems (1-3 m tall, 0.5-1 cm wide) that emerge from a shallow rhizome. The cylindrical, olive-green stems are firm when pressed between your fingers. This firmness is due to many small chambers that fill the stem.

The stems appear to be leafless, but leaf sheaths and sometimes short blades are present near the base of each stem. There is also a floral leaf called a bract that looks like a continuation of the tip of the stem. The spikelets emerge in the angle of this bract and the end of the stem.

The oval spikelets (about 2-5 times as long as wide) are clustered on the ends of rather stiff stalks. The scales (3-4 mm long) of the spikelet are spirally arranged and have distinctive surface features. Each scale is a dull, grayish-brown with shiny red flecks and a fringed margin. Nutlets (2.2-2.5 mm long) develop under the scales as the growing season progresses.

## Emergent Plants with Broad Leaves

### Pickerelweed (*Pontederia cordata*)



Pickerelweed has glossy, heart-shaped leaves that emerge from a robust, sprawling rhizome. The leaves have long, air-filled stalks with firm blades. A close look at a leaf blade reveals many fine, parallel veins. The flower spike (5-15 cm long) is crowded with small blue flowers. Each blossom has a tubular portion (5-7 mm long) that contains the nectar and flared lobes (7-10 mm long). The inside of the upper lobe is marked with golden spots. The fruit (5-10 mm long) has a corky, ridged surface and is shaped like an elf's hat.

Occasionally plants with white blossoms have been reported. There is also a submersed form that produces narrow, ribbon-like leaves.



### Common arrowhead (*Sagittaria latifolia*)



Common arrowhead usually produces leaves that are true to its name - shaped like an arrowhead. Leaves emerge in a cluster from tuber-tipped rhizomes. The size and shape of the leaf is highly variable. The blades (5-40 cm long, 0.5-25 cm wide) range from a slender "A" shape to a broad wedge. Some very narrow, knife-like leaves may also be present. The flower stem has whorls of short-stalked male flowers on the upper end and longer-stalked female flowers below. At the base of each whorl of flowers there are three boat-shaped bracts (4-15 mm long). The flowers have three rounded, white petals (1-2 cm long). Male flowers have 20-40 stamen with slender, hairless filaments. Female flowers produce a globe-shaped head packed with dozens of nutlets. Each nutlet (2.504 mm long) has a winged margin and a prominent beak (0.6-1.8 mm long) that sticks out at a right angle.

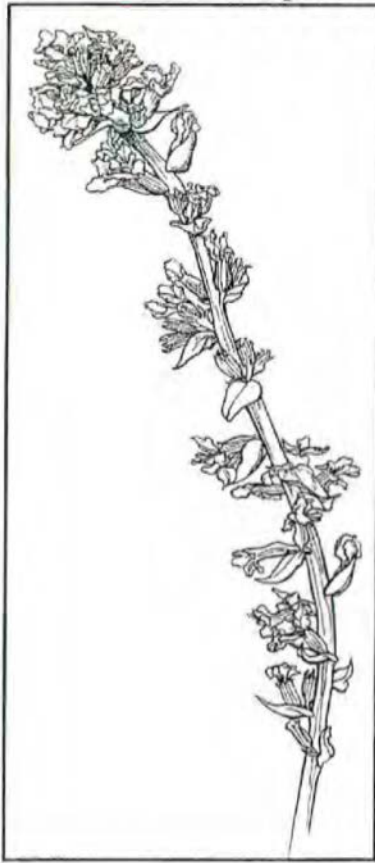
### Swamp loosestrife (*Decodon verticillatus*)



Swamp loosestrife has angled, woody stems that emerge from buried rhizomes. The stems may be several meters long with lance-shaped leaves (5-15 cm long, 1-4 cm wide) that are arranged in pairs or whorls of three. Many of the aerial stem arch over and create a tangled network. Thick spongy tissue develops on the underwater stems as well as the enlarged stem tips that root where they dip into the water. Magenta flowers develop in the upper leaf axils. The petals (10-15 mm long) are narrow and slightly crinkled-looking. The fruit (5 mm thick) is a many-seeded capsule.

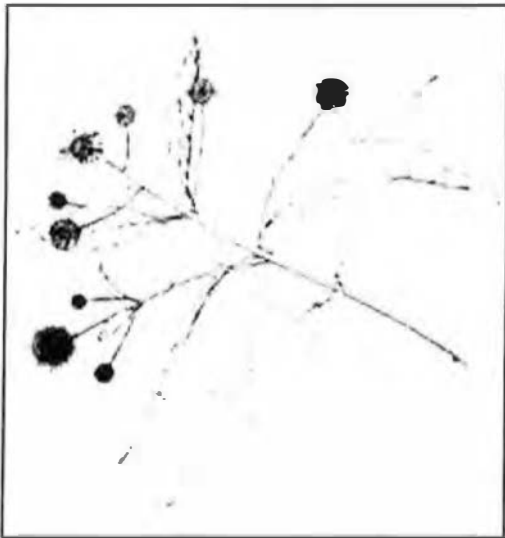


### Purple loosestrife (*Lythrum salicaria*)



Purple loosestrife has angled stems (50-150 cm tall) that emerge from a woody rootstalk. Leaves (3-10 cm long) are lance-shaped, attach directly to the stem, and often have fine hairs on their surface. The leaves may be opposite, in whorls of three, or sometimes spiraled around the stem. This seems to be related to the number of sides on a stem: four-sided stems have opposite leaves, five-sided stems have leaves in a spiral arrangement, and six-sided stems have leaves in whorls. All three stem types can be found on a single loosestrife plant. Clusters of magenta flowers are produced in leaf axils of a terminal spike. Each flower has 5-7 narrow petals (7-12 mm long) that are wrinkled with a tissue paper consistency.

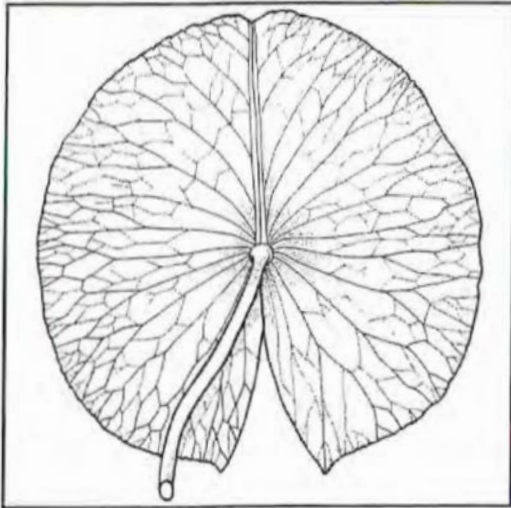
### Buttonbush (*Cephalanthus occidentalis*)



Buttonbush is a woody shrub (3-10 feet tall) that occasionally grows into a small tree and can be found above water or in water up to 4 feet deep. It has shiny dark-green spear- or egg-shaped pointed leaves 3 to 6 inches long. The leaves are opposite or whorled in 3's or 4's along the stem. Flowers of buttonbush are easily identified by their greenish-white tube flowers in dense ball-shaped clusters about 1 inch in diameter. Seed heads are brown.

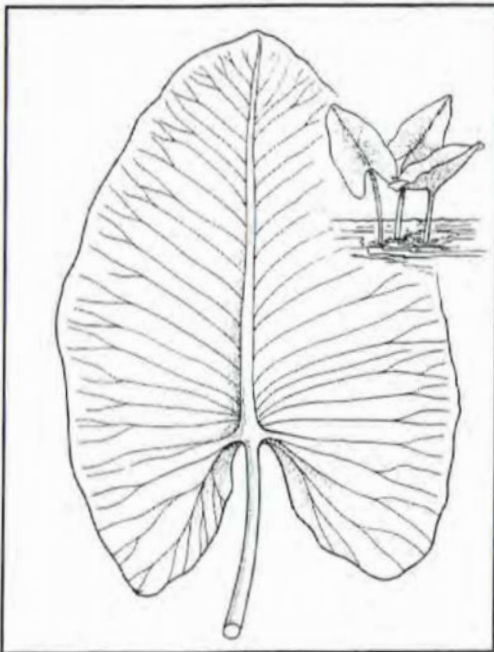
## Floating-leaf Plants

### White water lily (*Nymphaea odorata*)



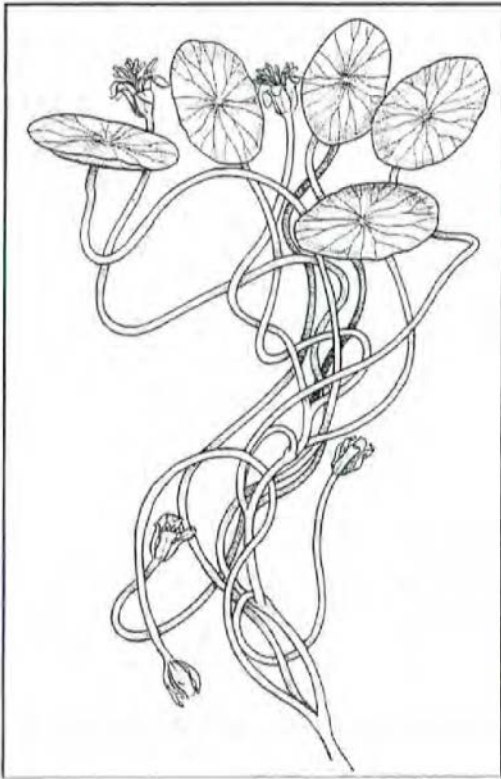
The cylindrical leaf stalks of white water lily emerge from a fleshy, buried rhizome. These flexible stalks are round in cross section with four large air passages. The leaves are round (10-30 cm wide) with a narrow sinus and a reddish-purple underside. Most of the leaves float on the water's surface. The flowers (7-20 cm wide) float on the water's surface and are borne on individual flower stalks that arise directly from the rhizome. They have four greenish sepals and numerous white petals in a circular arrangement around the many yellow stamen attached to the central disc.

### Yellow pond lily (*Nuphar advena*)



The leaf and flower stalks of yellow pond lily emerge directly from a robust, spongy rhizome the diameter of a baseball bat. Stalks can grow to be several meters long. Leaves are heart-shaped (20-40 cm long) with rather pointed lobes and have a triangular notch or sinus at their base that looks like it could accommodate a miniature rack of pool balls. Most of the leaves are emergent, growing at an assortment of angles above the water's surface. Flowers are globular to saucer-shaped (3-5 cm diameter) with five to six yellow sepals (often with a green patch at the base). The sepals curve around many small, strap-like petals, stamen and a yellowish-green disc with the stigmas. This central disc eventually develops into a seed pod.

### Watershield (*Brasenia schreberi*)

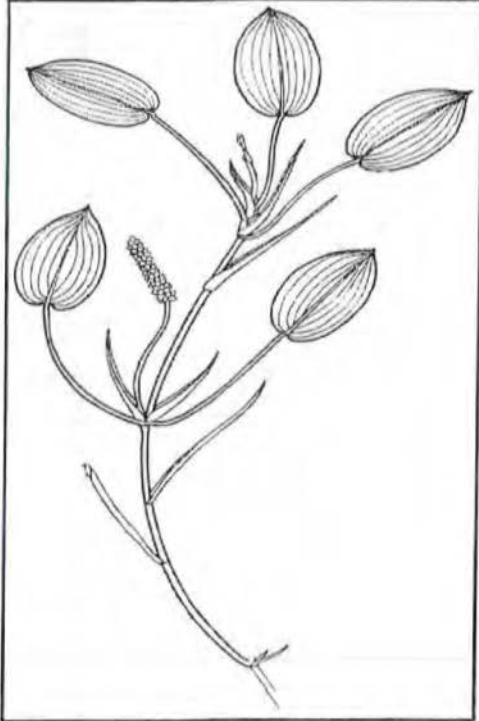


Stems and leaf stalks of watershield are elastic and allow the floating leaves to ride the waves without uprooting the rhizome that serves as an anchor and source of stored nutrients. The leaf stalks attach to the middle of the leaves (4-12 cm long, 2-6 cm wide), creating a bull's eye effect that is reflected in the common name "water target." The leaves have a green upper surface and purple underside. Maroon to purple flowers (less than 3 cm wide) are held just above the water surface by stout flower stalks. All submersed portions of the plant are covered with a thick, gelatinous coating.



## Submersed Plants with Entire Leaves

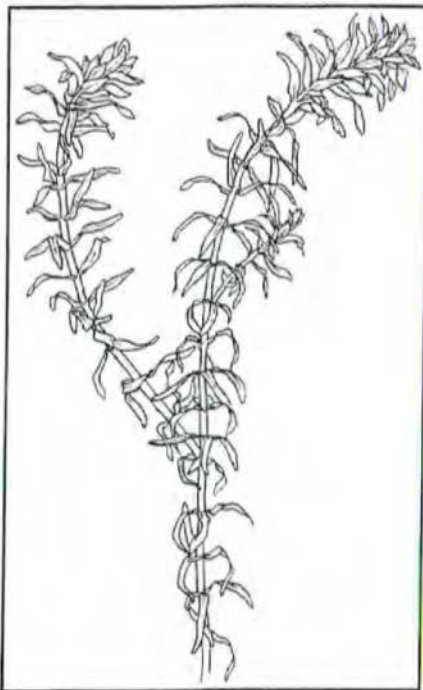
### Floating-leaf pondweed (*Potamogeton natans*)



Floating-leaf pondweed has stems (up to 2 m long) that emerge from red-spotted rhizomes. Submersed leaves (10-40 cm long, 1-2 mm wide) are stalk-like, with no obvious leaf blade. Floating leaves (5-10 cm long, 2-4.5 cm wide) are heart-shaped at their base. The point where the floating leaf attaches to the stalk is distinctive. It looks like someone pinched the stalk and bent it, so the leaf blade is at a right angle to the stalk and lays flat on the water. This "pinched" portion is usually a lighter color than the rest of the stalk. The fibrous stipules of both the submersed and floating leaves are free in the leaf axils.

Flowers and fruit are produced in a dense cylindrical spike (2-5 cm long) that pokes up above the water surface. Fruit (3.5-5 mm long) is oval to egg-shaped in outline and rather plump. The surface of the fruit has a wrinkled appearance on the sides, a very low dorsal ridge and a short beak.

### Common waterweed (*Elodea canadensis*)



Common waterweed has slender stems (up to 1 m long) that emerge from a shallow rootstalk. The small, lance-shaped leaves (6-17 mm long, 1-5 mm wide) attach directly to the stem (no leaf stalk). Leaves are in whorls of three, or occasionally only two and tend to be more crowded toward the stem tips. The branching stems often form a tangled mat that can become a nuisance. Male and female flowers are on separate plants. Female flowers have three small white petals with a waxy surface that improves flotation. They are raised to the surface on a long, slender stalk. Male flowers develop in a vase-like structure called a spathe that is 7-10 mm long. At maturity, the male flowers are also raised to the surface on thread-like stalks. There the anthers split open, releasing pollen to drift away and possibly fertilize female flowers. However, male plants are quite rare. So although you may see dozens of tiny white flowers floating above a bed of common waterweed they are usually all female flowers that will not produce seed.

### Slender naiad (*Najas flexilis*)



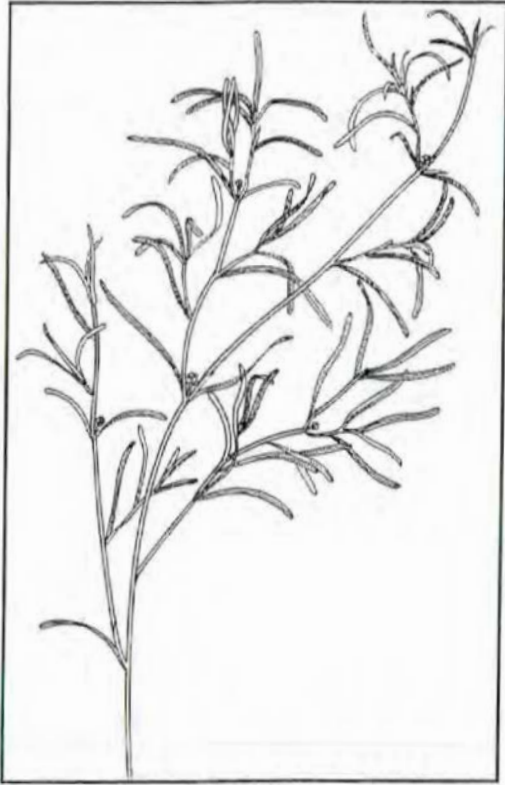
Slender naiad has fine, branched stems (up to 1 m long) that emerge from a slight rootstalk. The leaves are paired, but there are sometimes bunches of smaller leaves crowded in the leaf axils. Size and space of the leaves is extremely variable, depending on growing conditions. Sometimes the plant is compact and bushy, other times trailing and slender. Leaves are narrow with a broad base where they attach to the stem. This base is shaped like sloping shoulders. Each leaf (1-4 cm long, 0.2-1.0 mm wide) tapers to a pointed tip. The leaf margin is finely serrated. Tiny flowers develop in the leaf axils and produce fruit with a paper-thin wall. The seed (2.5-3.7 mm) has a glossy surface with 30-50 rows of small, faint pits.

### Robbins pondweed (*Potamogeton robbinsii*)



Robbins pondweed is a stiff, robust plant with underwater leaves only. It is usually easily recognized because its dark green, closely spaced leaves are arranged in a rigid, flattened spray, giving it a palm frond or fern-like appearance. Robbins pondweed is usually a low-growing plant and only approaches the water surface when flowering. The flowering stalks have more widely spaced leaves that are less fan-like in appearance.

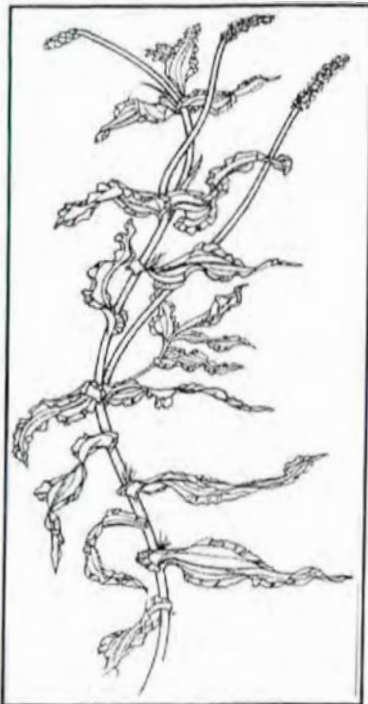
### Leafy pondweed (*Potamogeton foliosus*)



Leafy pondweed has freely branched stems that emerge from slender rhizomes. The narrow, submersed leaves (1.5-8 cm long, 0.5-2 mm wide) have parallel sides that narrow slightly where they attach to the stem. The tip of the leaf usually tapers to a point. There are 3-5 veins, with the midvein sometimes flanked by 1-2 rows of lacunar cells. The membranous stipules are free from the leaves, but when they are young they wrap around the stem. No floating leaves are produced.

Flowers and fruit are produced on short stalks (5-15 mm) in the axils of upper leaves. The fruits (4-10) are in tight clusters about 4 mm in diameter. Each fruit is flattened with a dorsal, wavy ridge and a short beak (0.2-0.6 mm). Winter buds are sometimes produced for vegetative reproduction. These buds are composed of several modified, tightly rolled leaves on the ends of branches.

### Clasping-leaf pondweed (*Potamogeton richardsonii*)



Clasping-leaf pondweed has sinuous stems (1-2.5 mm thick) that emerge from a spreading rhizome. Oval to somewhat lance-shaped leaves (3-12 cm long, 0.5-2 cm wide) clasp the stem. The base of each leaf is heart-shaped and covers one-half to three-quarters of the stem circumference. Leaves have 13-21 veins (some more prominent than others). The axil of each leaf has a fibrous stipule that soon disintegrates, leaving a beard of white fibers at the leaf node. No floating leaves are produced.

Fruiting stalks (1.5-25 cm long) develop in the upper leaf axils. The cylindrical spikes (1.5-3 cm long) are packed with fruit. Each olive-green fruit (2.2-4.2 mm long) is plump and round with a prominent beak (1 mm long).

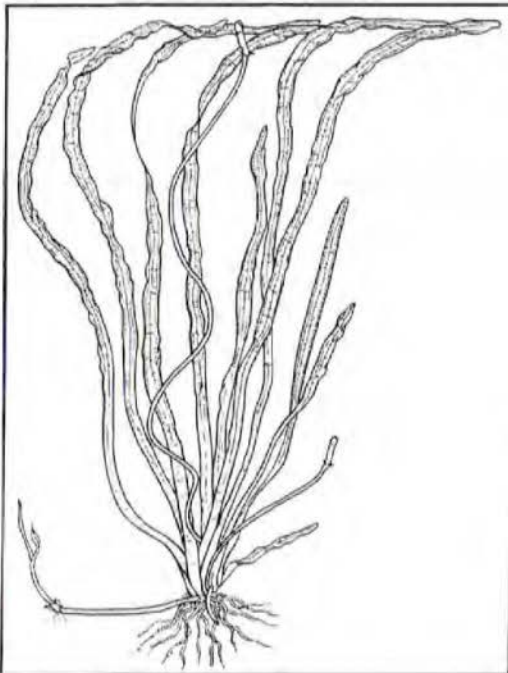


### Common water moss (*Fontinalis antipyretica*)



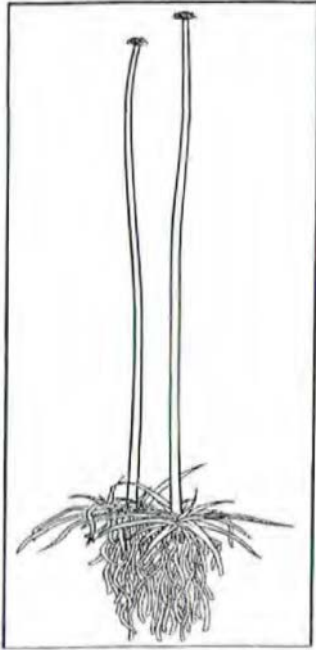
Common water moss is a dark green underwater plant that attaches to rocks or logs in flowing water, or floats loose or attached in still water. The leaves are sharply pointed, ridged, overlapping, and arranged in 3 rows along the entire length of the stems. The stems grow up to 60 cm long and appear triangular if the leaves are removed. It is one of only a few truly aquatic mosses in the Pacific Northwest. It is often found dried and dormant above water in the summer.

### Eel grass (*Vallisneria* spp.)



Wild celery has ribbon-like leaves that emerge in clusters along a creeping rhizome. The leaves (up to 2 m long, 2-10 mm wide) have a prominent central stripe and a cellophane-like consistency. The leaves are mostly submersed, with just the tops trailing on the surface of the water. Male and female flowers are produced on separate plants. The tiny male flowers (1 mm wide) are clustered in a case that develops underwater. As the flowers mature, they are released from the case. Each male flower is in a closed "floral envelope" that contains an air bubble. This helps lift it to the surface. When it reaches the surface, the floral envelope opens and creates a sail that allows it to skim along the surface. The female flowers (3.5-6.5 mm wide) also develop underwater, but then are raised to the surface by a fast-growing, spiral-coiled stalk. These delicate, white flowers bob at the surface creating a dip in the surface tension. When one of the tiny male flowers sails by, it glides down to meet and pollinate the female flower. After fertilization, the female flower is retracted beneath the surface and a long, capsular fruit (5-12 cm) develops.

### Pipewort (*Eriocaulon aquaticum*)



Pipewort has pale unbranched roots with closely-spaced partitions that make them look cross-hatched. The translucent green leaves (2-5 mm wide, 2-10 cm long) grow in a basal rosette. Leaves taper from base to tip and have a checkerboard appearance created by many short cross-veins.

Each rosette usually produces a single flower stalk. The stalk is slightly twisted with 5-7 ridges. It can range from a few centimeters to a couple meters in length depending on the depth of the water. The flower head (4-6 mm) is rounded with many small flowers packed closely together. Sepals and petals of the pearl-colored flowers are tipped with fine white hairs.

### Submersed Plants with Finely-divided Leaves

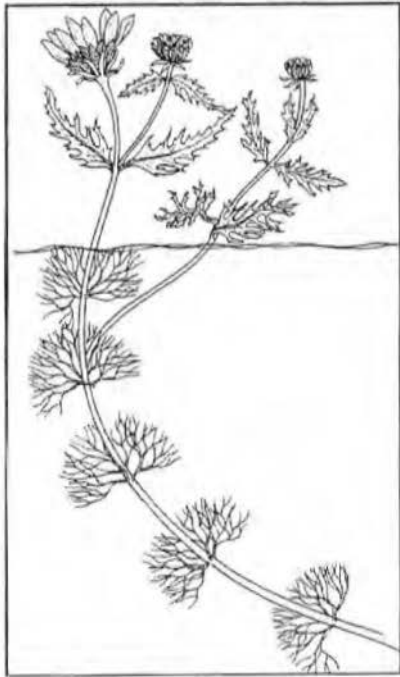
#### Coontail (*Ceratophyllum demersum*)



Coontail has long, trailing stems that lack true roots. However, the plant may be loosely anchored to the sediment by pale modified leaves. The leaves are stiff and arranged in whorls of 5-12 at a node. Each leaf (1-3 cm long) is forked once or twice. The leaf divisions have teeth along the margins that are tipped with a small spine. Whorls of leaves are usually more closely spaced near the ends of branches, creating the raccoon tail appearance.

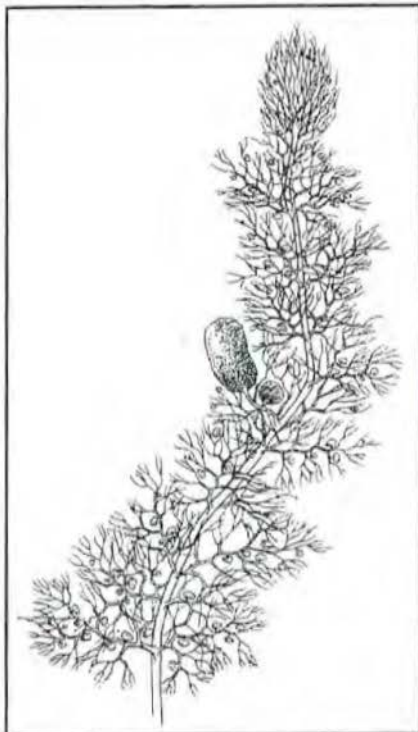
Flowers are tiny and hidden in the axils of leaves. Male and female flowers are on separate plants. The stamen of the male plants float to the surface at maturity and discharge pollen. The pollen sinks down through the water and may or may not land on the tiny female flowers, tucked in the leaf axils. Fruit is rarely produced, partly because of this unpredictable method of pollination. When fruit does develop, it is a nut-like achene with two spines at the base and one on top (the persistent style).

### Water marigold (*Bidens beckii*)



The stems of water marigold emerge from a buried rootstalk. The submersed leaves are finely cut into many thread-like divisions. Often only the underwater portion of the stem is present. When an aerial portion develops, the emerged leaves are lance-shaped, have a toothed margin and attach directly to the stem. When flowering occurs, a yellow daisy-like bloom (2-2.5 cm wide) develops on a sturdy stalk above the water surface. The central portion of the flower produces narrow fruits, each with 3-6 long, barbed bristles.

### Common bladderwort (*Utricularia vulgaris*)



Common bladderwort has floating stems that can reach 2-3 meters in length. Along the stem are leaf-like branches that are finely divided. The divisions are filament-like, have no midrib, and fork 3-7 times. Scattered on these branches are the bladders that trap prey. Young bladders are transparent and green tinted, but they become dark brown to black as they age. The branches also have fine spines (spicules) scattered along their margins. Yellow, two-lipped flowers are produced on stalks that protrude above the water surface. There may be 4-20 flowers per stalk. The upper lip of the flower creates an awning over the saclike pouch and sickle-shaped spur of the lower lip. The plant is branched in several directions at the base of the flower stalk. This creates a stable base that keeps the top-heavy flower stalk from capsizing.





## ***APPENDIX I. WATER QUALITY MEASUREMENTS AND TESTS***

Physical, chemical, and biological tests performed at test sites 1-6 and A-C by CEAT in the summer and fall of 2008 at Pattee Pond (see Figure 42 for site locations). Color and nitrates levels were taken on 22-Sep at Sites 1-6 and A-C. The hardness levels were tested at Site 1 on 26-Sep.

Sample Date	Temp/DO	Transparency	Conductivity	Turbidity	pH	Total Phosphorus
30-May	1,2,4	1	1,2,4	1,2,4	1,2,4	1,2,4
9-Jun	1 to 5	1	1 to 5	1 to 5	1 to 5	1 to 5
18-Jun	1 to 5	1	1 to 5	1 to 5	1 to 5	1 to 5
25-Jun	1 to 5	1	1 to 5	1 to 5	1 to 5	1 to 5
2-Jul	-	1	-	1 to 5	-	1 to 5
10-Jul	1 to 5	1	1 to 5	1 to 5	1 to 5	1 to 5
16-Jul	1 to 5	1	1 to 5	1 to 5	1 to 5	1 to 5
22-Jul	1 to 5	1	1 to 5	1 to 5	1 to 5	1 to 5
29-Jul	1 to 5	1	1 to 5	1 to 5	1 to 5	1 to 5
5-Aug	-	1	-	1 to 5	-	1 to 5
13-Aug	1 to 5	1	1 to 5	1 to 5	1 to 5	1 to 5
27-Aug	1 to 5	1	1 to 5	1 to 5	1 to 5	1 to 5
22-Sep	6	1	1 to 6	1 to 6	1 to 6	1 to 5
26-Sep	-	-	A to C	-	-	6

## ***APPENDIX J: QUALITY ASSURANCE***

The Pattee Pond study followed a quality assurance plan developed by CEAT to standardize the water sampling and analysis procedures used. The following document was modified from CEAT (2008).

### **Bottle Preparation:**

1. To make the acid rinse, use 1 L of E-pure and 1 L concentrated hydrochloric acid. The result is a 1:1 ratio HCl:E-pure water.
2. All phosphorus-sample bottles were triple acid rinsed before use to avoid contamination of the sample.

### **Approaching site and sampling:**

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 facing the wind.
3. When surface sampling, hold the bottle upside down, draw water into the bottle by pushing horizontally away from the boat to 0.5 m down. Then lift the bottle out of the water and cap.
4. Hands should never touch sampled water. Use gloves.
5. Bottle lids should not touch the bottom of the boat. Rinse the lids with distilled water, if they are dropped.

### **Surface Grab:**

1. Remove the cap from the sample bottle being careful not to touch either the cap or bottle.
2. Invert the sample bottle and place in the water.
3. Turn the sample bottle sideways moving the bottle through the water away from the boat, finally tilt the bottle upright and remove the bottle from the water.
4. Place bottle in cooler.

### **Secchi Disk:**

1. Duplicate reading on every 10th sample.
2. Use Aquascope to view the disk.
3. Lower until the disk is out of site, then record the depth.
4. Lower the disk an extra meter, then bring it back into sight and record the depth.
5. Bring the disk back to the surface and repeat the process two more times.

### **Depth Finder:**

1. Put vertically in water column.
2. Push black/yellow button down for a few seconds. Release.



3. Pull up and read depth. Repeat two times.

#### Turbidimeter:

1. Use the HACH 2100 Portable Turbidimeter (HACH 1999), making sure cleaned sample cells were included with the portable turbidimeter.
2. Conduct analysis in the field using the calibrated instrument (calibrated with three standards). Follow surface sampling procedure.
3. Read samples on site.

#### YSI 6820 MDS (Multiparameter Display System) Sonde:

The YSI MDS Sonde was calibrated and used as directed in the YSI 6-Series operating manual (YSI 2002). The Sonde was used to measure the following parameters in the field: Chlorophyll-*a*, pH profile, Temperature, Dissolved Oxygen, and Depth.

#### pH meter:

- A. Calibration: Before any test is performed, the probe of the 6820 MDS Sonde must be calibrated using a 2-point calibration method at pH 4 and pH 10. This should be done once during the testing day, provided the calibration entered into the meter is not accidentally deleted.
  1. Press the POWER button. The pH meter automatically enters the measurement.
  2. Press CALIBRATE and ISEI pH. Then press 2 POINT.
  3. Enter the Sonde standard pH value and insert probe into pH 4 solution. Go to Sonde menu.
  4. After calibration, rinse the sensor thoroughly with E-pure water.
  5. Repeat calibration for pH 10.
  6. Be sure to rinse the probe with distilled water prior to and following each measurement.
- B. Measurement.
  1. Immerse the Sonde 0.5 m to 1.0 m below the surface.
  2. Go to SONDE RUN in the 6820 main menu. Wait for the probe to stabilize.
  3. Highlight "Log One Sample" and press the ENTER arrow at one meter intervals.

#### Dissolved Oxygen:

1. Calibrate the probe of the 6820 MDS Sonde in the saturated air chamber after the proper warm-up time.
2. Lower the Sonde into the water, shaking it gently to make sure there are not bubbles around the probe.
3. Immerse the probe until covered. Record measurements as described above.
4. On the tenth depth profile make three random duplicate readings.
5. Duplicate readings should not vary more than  $\pm 0.2$  ppm.
6. If readings vary more than 0.5 ppm repair of the membrane or meter is advised.

7. The electrode must be in a flow of water.
8. Record a DO measure immediately, and if the reading is decreasing, keep the electrode moving in the water.

#### Grab Sampler:

1. Open and secure two flaps as demonstrated in class.
2. Lower tube into water, counting meters as lowered (demarcated by black lines on rope). Lower to 1 meter above bottom (depth taken with depth finder).
3. Take sample by throwing weight down rope.
4. Raise tube, open blue valves, and pour water into appropriate sample bottles.
5. Repeat for mid-depth sample.

#### Epicore Samples:

1. Rinse the collection tube three times by lowering it down into the lake water and pulling it back out.
2. For sites with sufficient depth for a thermocline to form, lower the tube 1 m below the epilimnion into the thermocline (determined from the DO/temperature profile).
3. For shallow depths, lower the tube to 1 m from the bottom.
4. The tape marks on the tube indicate one meter.
5. Crimp the tubing just above the water (best done by bending it tightly, twisting, and then holding it in one hand).
6. Pull the tubing up, making sure that the excess tubing goes into the water and not the boat. Be careful not to touch the end through which the water comes out.
7. Allow the water to drain into the labeled epicore mixing bottle, being careful not to touch the inside of the tube, the cap, or the end of the tube.
8. Be sure to keep the non-pouring end of the tube up, so the water does not drain out of it, and so that it does not take up surface water.
9. Hold up the crimped area and undo the crimp. Continue to raise the tubing and move towards the draining end.
10. Repeat the process three times, draining all of the water into the 1 L epicore mixing bottle.
11. Pour about 125 mL each of this water into two PPM flasks (fill to just below the neck). Be careful not to contaminate the samples by touching the inside of the bottles or the inside of the caps.
12. Discard the remaining water from the mixing bottle and rinse it with E-pure water. Place all samples into the cooler on ice.

#### Quality Control Sampling:

1. Spike E-pure samples with a known amount of concentrated phosphorus standard and run against a standard curve to confirm the accuracy of technician before water samples were analyzed. This accuracy test is repeated until the values of the test samples are within 10% of each other.
2. Duplicate samples every tenth sample to test the accuracy of sampling procedures.
3. Split samples every tenth sample in the laboratory to test the lab procedure.

4. Run one control with each set of samples analyzed.

Total Phosphorus:

1. Collect and make splits and duplicates for every ten samples.
2. Make standard solutions of known concentrations with each testing to ensure lab precision.
3. Use reagent blanks to make a standard curve to determine the concentration of phosphorus studied. The standard curve should have a minimum of six points.
4. The accuracy of the Absorbic Acid method used for total phosphorus analysis has a detection limit of 2 ppb.
5. Preserve water samples for analysis by digesting with sulfuric acid and ammonium peroxydisulfate, and then autoclave at 15 psi for 30 minutes.
6. Conduct analysis within 28 days of sampling date.

## APPENDIX K. WATER BUDGET VALUES AND CALCULATION

The Water Budget calculates the sources and losses of water to Pattee Pond and the flushing rate of the lake.

Physical Parameters used in the Pattee Pond Water Budget:

Parameter	Value	Unit
Runoff Rate <sup>1</sup>	0.622	meters / year
Precipitation Rate (NCDC 2008)	1.062	meters / year
Evaporation Rate (Prescott 1969)	0.560	meters / year
Pattee Pond Watershed Area	33,388,872	square meters
Pattee Pond Surface Area	2,112,803	square meters
Pattee Pond Volume	9,659,735	cubic meters
Mud Pond Watershed Area	6,774,140	square meters
Mud Pond Surface Area	371,100	square meters

<sup>1</sup> North Kennebec Regional Planning Commission unpublished report

1. Calculating the Net Input ( $I_{net}$ ) of Pattee Pond and its inputs:

$$I_{net} \text{ Pattee Pond} = (\text{runoff} \times \text{watershed land area}) + (\text{precipitation rate} \times \text{lake area}) + (I_{net} \text{ Mud Pond}) - (\text{evaporation} \times \text{lake area})$$

$$I_{net} \text{ Mud Pond} = (\text{runoff} \times \text{watershed land area}) + (\text{precipitation rate} \times \text{lake area}) - (\text{evaporation} \times \text{lake area})$$

$$I_{net} \text{ Pattee Pond} = 26,228,313 \text{ m}^3$$

$$I_{net} \text{ Mud Pond} = 4,399,807 \text{ m}^3$$

2. Calculating the Total Input ( $Q$ ) of water to Pattee Pond used in the Phosphorus Budget:

$$Q = (\text{Pattee Pond } I_{net} + [\text{evaporation} \times \text{lake area}]) + (\text{Mud Pond } I_{net})$$

$$Q = 27,411,483 \text{ m}^3/\text{year}$$

3. Calculating the Flushing Rate of Pattee Pond:

$$\text{Flushing Rate} = (I_{net} \text{ Pattee Pond}) / \text{Pattee Pond Volume}$$

$$\text{Flushing Rate} = 2.72 \text{ flushes/year}$$



## ***APPENDIX L. PHOSPHORUS MODEL***

The values for the following coefficients have been derived from past studies of Central Maine Lakes (CEAT 2005, 2006, 2007, 2008), Chapra and Reckhow (1983), in addition to the sources specifically delineated throughout the appendix.

### **Equation**

$$W = (Ec_a \times Area_{ls}) + (Ec_c \times Area_c) + (Ec_p \times Area_p) + (Ec_{lr} \times Area_{lr}) + (Ec_w \times Area_w) + (Ec_{dr} \times Area_{dr}) + (Ec_{fc} \times Area_{fc}) + (Ec_{fm} \times Area_{fm}) + (Ec_{fn} \times Area_{fn}) + (Ec_{fr} \times Area_{fr}) + (Ec_{lc} \times Area_{lc}) + (Ec_{lr} \times Area_{lr}) + (Ec_{ll} \times Area_{ll}) + (Ec_{ci} \times Area_{ci}) + (Ec_{rc} \times Area_{rc}) + (Ec_{nn} \times Area_{nn}) + (Ec_{rs} \times Area_{rs}) + (Ec_{ds} \times Area_{ds}) + (Ec_{dn} \times Area_{dn}) + [(Ec_{yc} \times \# \text{ capita years}_{ss} \times (1-SR_1)) + (Ec_{yc} \times Area_{yc})] + [(Ec_g \times \# \text{ capita years}_{ss} \times (1-SR_1)) + (Ec_g \times Area_g)] + [(Ec_{ss} \times \# \text{ capita years}_{ss} \times (1-SR_1)) + (Ec_{nss} \times \# \text{ capita years}_{nss} \times (1-SR_2))] + (S_d \times Area_{ls})$$

### **Atmospheric Input**

**$Ec_a$  = export coefficient for atmospheric input (kg/ha/yr)**

Estimated Range = 0.11 – 0.21                      Best Estimate = 0.16

This coefficient was taken from a recently study of a Togus Pond, also located in central Maine (MDEP 2005). Given that there is little industry, agriculture, and development within the Pattee Pond watershed the air particulate content is expected to be similar to that of Togus Pond.

### **Forest**

**$Ec_{fc}$  = export coefficient for coniferous forest (kg/ha/yr)**

Estimated Range = 0.01 – 0.06                      Best Estimate = 0.04

**$Ec_{fm}$  = export coefficient for mixed forest (kg/ha/yr)**

Estimated Range = 0.02 – 0.06                      Best Estimate = 0.04

**$Ec_{dr}$  = export coefficient for deciduous forest (kg/ha/yr)**

Estimated Range = 0.02– 0.06                      Best Estimate = 0.04

Coniferous forests have been given a lower phosphorus export value than deciduous forests, as they produce less leaf litter. Export value for both coniferous and deciduous forests have been adapted from past reports on Maine lakes (MDEP 2001, 2003, 2005). As mixed forests are composed of both deciduous and coniferous tree types they are believed to export an intermediate amount of phosphorus (MDEP 2005).

### **Successional Land**

**$Ec_{ft}$  = export coefficient for transitional forest (kg/ha/yr)**

Estimated Range = 0.08 – 0.20      Best Estimate = 0.18

**$Ec_{fr}$  = export coefficient for regenerating forest (kg/ha/yr)**

Estimated Range = 0.20 – 0.80      Best Estimate = 0.35

**$Ec_{lr}$  = export coefficient for reverting land (kg/ha/yr)**

Estimated Range = 0.15 – 0.90      Best Estimate = 0.30

Coefficients were adapted from a CEAT study on Togus Pond (MDEP 2005). Reverting land was once cleared land and is in the process of slowly regenerating into a forest. There is less than 50 % tree canopy cover, but groundcover such as grasses and shrubs help absorb phosphorus runoff.

### **Agriculture**

**$Ec_c$  = export coefficient for crops (kg/ha/yr)**

Estimated Range = 0.10 – 1.86      Best Estimate = 1.25

In this report the crop export coefficient refers to row crops. The coefficients used were adapted from Chapra and Reckow (1983) and past reports on Maine Lakes (MDEP 2001, 2003, 2008). There is a high usage of fertilizers associated with row crops, which accounts for this high coefficient value.

**$Ec_p$  = export coefficient for pasture/grassland (kg/ha/yr)**

Estimated Range = 0.20 – 1.00      Best Estimate = 0.35

For the purpose of this report this land use type included agricultural pasture and hayland, as well as grassland. The coefficient used reflects the lower range of values used in past MDEP reports (2001, 2003, 2005, 2008) and from Chapra and Reckow (1983), to account for the high percentage of non-agricultural grassland in the Pattee Pond watershed.

**$Ec_{tf}$  = export coefficient for tree farms (kg/ha/yr)**

Estimated Range = 0.05 – 0.10      Best Estimate = 0.08

Tree farms were considered to be passively managed forested land and the coefficients were adapted from a New England regional study (Likens et al. 1977) and a study on Three Mile Pond (MDEP 2003).

### **Logged/Cleared Land**

**$Ec_{lc}$  = export coefficient for cleared land (kg/ha/yr)**

Estimated Range = 0.30 – 1.60      Best Estimate = 0.60

Cleared land is land that has lost forest and ground cover, and is currently undeveloped. This coefficient value reflects a loss in soil retention capacity. The export range was adapted from a past study of Three Mile Pond (Maine DEP 2003) and the Long Pond South CEAT Report (2008).

**$Ec_{ll}$  = export coefficient for logged land (kg/ha/yr)**

Estimated Range = 0.35 – 0.80      Best Estimate = 0.65

The export range was based upon a recent study of Webber Pond (MDEP 2002) and the operated forestland phosphorus loading coefficient from a Cobbossee Lake report (Monagle 1995). Logged land has a significantly higher phosphorus value than tree farms due to management practices that reduce canopy cover and increase soil erosion. Some logging in the Pattee Pond watershed is adjacent to Bellows Stream, which has resulted in an increased percentage of phosphorus runoff reaching Pattee Pond.

### Roads

**$Ec_{rc}$  = export coefficient for camp roads (kg/ha/yr)**

Estimated Range = 2.00 – 10.00      Best Estimate = 5.00

**$Ec_{rm}$  = export coefficient for municipal roads (kg/ha/yr)**

Estimated Range = 0.80 – 4.00      Best Estimate = 1.90

**$Ec_{rs}$  = export coefficient for state roads (kg/ha/yr)**

Estimated Range = 0.70 – 4.00      Best Estimate = 1.50

Roads are a major contributor of phosphorus as they account for a significant percentage of a watershed's impervious surfaces. As in past reports on Maine lakes camp roads were assigned the highest coefficients as they are typically located closest to the shoreline, unpaved, and not as well-maintained as the other two road types (MDEP 2001, 2003, 2008). Soil erosion from camp roads along Pattee Pond's western shoreline is believed to be one of the most significant sources of phosphorus (Whitaker, pers. comm.).

### Recreation

**$E_{yc}$  = export coefficient for Camp Caribou (kg/ha/yr)**

Estimated Range = 0.60 – 2.70      Best Estimate = 0.90

**$E_g$  = export coefficient for Giordano's (kg/ha/yr)**

Estimated Range = 0.60 – 2.70      Best Estimate = 1.00

The coefficient range that was used for Camp Caribou was roughly based upon the CEAT China Lake study (2006). However, since Pattee Pond's youth camp, Camp Caribou, is larger than the camp in the China Lake study the expected export values are higher. Due to its density of

development directly on the shoreline and high septic system usage, it is likely that Camp Caribou contributes a substantial amount of phosphorus into Pattee Pond. Giordano's was given a similar export coefficient, as it is also typified by high residential density, a driveway leading directly to the shoreline and recreational grass fields.

### **Residential Development**

**$Ec_{ds}$  = export coefficient for shoreline development (kg/ha/yr)**

Estimated Range = 0.60 – 3.20      Best Estimate = 2.00

**$Ec_{dn}$  = export coefficient for non-shoreline development (kg/ha/yr)**

Estimated Range = 0.25 – 1.00      Best Estimate = 0.50

The impact of development within 200 feet of a lake's shoreline can contribute large amounts of phosphorus due to run off from exposed surfaces such as lawns, roofs, and decks. Pattee Pond in particular has a large number of grandfathered houses that are directly on or less than 100 feet from the shoreline. Additionally, there is dense residential development along the shoreline, confounded by poor buffer strips. The nutrient loading potential for non-shoreline residences is lower than for shoreline development as homes are farther from the lake. This wider buffer provides more time for nutrients to become absorbed in the soil. The export values for both landuse types were taken from studies of past Maine lakes (MDEP 2001, 2003, 2008).

### **Septic Systems**

**$Ec_{nss}$  = export coefficient for shoreline septic tank systems (kg/cap/yr)**

Estimated Range = 0.40 – 1.50      Best Estimate = 0.80

**$Ec_{nss}$  = export coefficient for non-shoreline septic tank systems (kg/cap/yr)**

Estimated Range = 0.30 – 0.90      Best Estimate = 0.50

The impact of shoreline and non-shoreline septic systems on phosphorus loading depends upon the type of septic system in use, distance from the shoreline, and usage rates. Non-shoreline septic systems are farther from the lake but they are typically used year round. Adversely, non-conforming shoreline septic systems can lead to large increases in phosphorus loading, since runoff is most likely to directly enter the lake. The ranges for both export coefficients were taken from studies of past Maine lakes (MDEP 2001, 2003, 2008). Pattee Pond has a large number of shoreline residences with holding tanks, which contribute significantly less phosphorus to the lake than leach fields.

### **Additional Land Use Types**

**$Ec_{ci}$  = export coefficient for commercial/industrial land (kg/ha/yr)**

Estimated Range = 0.35 – 1.00      Best Estimate = 0.40



Commercial and industrial land contributes to phosphorus loading through impermeable surfaces, such as roofs and parking lots, which contribute to runoff. The coefficient range was based upon a recent study of Togus Pond (MDEP 2005). Similar to Togus Pond, there is little commercial/industrial development within the Pattee Pond watershed, none of which is close to the lake.

**$E_{cw}$  = export coefficient for wetlands (kg/ha/yr)**

Estimated Range = 0.00 – 0.05

Best Estimate = 0.02

The range used corresponds to a recent study on Togus Pond, which found wetlands yielded a range of 0.00 to 0.05 of phosphorus (MDEP 2005). Wetlands, particularly during the summer growing period act as a sink for phosphorus, and shoreline wetlands around Pattee Pond are believed to be vital to preserving the lake's water quality (Whitaker, pers. comm.).

### **Soil Retention Coefficients**

**$SR_1$  = soil retention coefficient for shoreline residences**

Estimated Range = 0.35 – 0.85

Best Estimate = 0.65

**$SR_2$  = soil retention coefficient for non-shoreline residences**

Estimated Range = 0.75 – 1.00

Best Estimate = 0.90

The two major soil types surrounding the shoreline of Pattee Pond (and the entire watershed) are Scio and Hollis-Rock outcrop complex (see Figure 19). Both of these soil types are drained moderately well, meaning that they are able to allow water to percolate through at a rate that allows for phosphorus retention. Non-shoreline residences were given a higher soil retention coefficient because runoff must travel a farther distance to reach the lake, which allows for a larger percentage of nutrients to be retained in the soil. The ranges for both export coefficients were taken from studies of past Maine lakes (MDEP 2001, 2003, 2008).

### **Sediment Release**

**$SR_1$  = soil retention coefficient for shoreline residences (kg/ha/yr)**

Estimated Range = 0.2 – 1.10

Best Estimate = 0.65

The amount of phosphorus released through internal loading was estimated to be the difference between the mean summer and fall turnover phosphorus concentrations in Pattee Pond. The coefficient range was adapted from studies of past Maine lakes, accounting for differences in lake shape and overall water quality (MDEP 2001, 2003, 2008).

## **APPENDIX M. PHOSPHORUS EQUATION**

The Phosphorus Loading Model explained below was created using the methods described by Chapra and Reckhow (1983). The annual total phosphorus input (L) is represented as the annual amount of phosphorus per unit of lake surface (kg/ha/yr). L was estimated by dividing the total annual surface inflow of phosphorus (W) by the lake surface area ( $A_s = 2,110,490 \text{ m}^2$ ).

$$L = W / A_s$$

Annual atmospheric water loading ( $q_s$ ) was calculated by dividing the total inflow water volume ( $Q = 27,411,404 \text{ m}^3/\text{yr}$ ) by lake surface area ( $A_s$ ).

$$q_s = Q / A_s$$

High, low, and best estimates of total phosphorus concentration (mg/L) were calculated by dividing the total atmospheric phosphorus loading by the lake phosphorus settling velocity. P can be converted to parts per billion (ppb) by multiplying the result by 1000.

$$P = \frac{L}{11.6 + 1.2q_s}$$

### **Results of the Phosphorus Loading Equations:**

		Low Estimate	Best Estimate	High Estimate
<b>Without Sediment Release:</b>				
W =	(kg/yr)	287	648	1255
L =	(kg/ha/yr)	0.136	0.307	0.594
P =	(ppb)	<b>5.51</b>	<b>12.4</b>	<b>24.1</b>
<b>With Sediment Release</b>				
W =	(kg/yr)	300	795	1420
L =	(kg/ha/yr)	0.142	0.376	0.672
P =	(ppb)	<b>6.32</b>	<b>15.1</b>	<b>28.5</b>

## ***APPENDIX N. WATERSHED AND LAKE MANAGEMENT RESOURCES***

**Watershed Stewards Program** is a cooperative program presented by the University of Maine and state agencies that allows the exchange of lake volunteer watershed activities for informational training and workshops.

(<http://www.umext.maine.edu/waterquality/watershedstewards/default.htm>)

**Maine Volunteer Lake Monitoring Program** is a non-profit conservation organization that enlists and trains citizen volunteers in technical monitoring skills as well as provides scientific lake water quality data. (<http://www.mainevolunteerlakemonitors.org/>)

**Maine Watershed Web** is a website established by Bowdoin College to collect and provide educational information and research about Maine watersheds.

(<http://learn.bowdoin.edu/apps/hydrology/watersheds/>)

**Conservation Security Program** is a voluntary program from the Natural Resources Conservation Service that provides information, activities, and some funding for eligible watersheds. (<http://www.nrcs.usda.gov/programs/CSP/>)

**Bureau of Land and Water Quality (MDEP)** has a lot of essential information on watersheds, wetlands, and management. There is a list of state buffer plants as well as other manuals useful for property owners near and around the lake. (<http://www.maine.gov/dep/blwq/>)

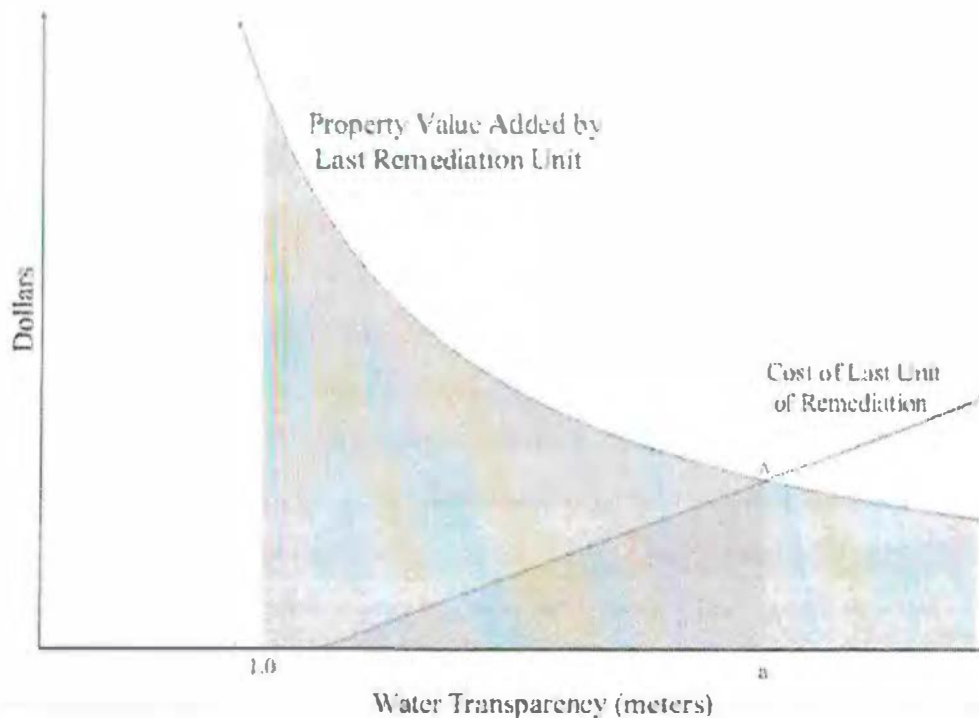
**North American Lake Management Society** is a membership organization focused on lake management and protection and works to form partnerships for the exchange of information and guidance. (<http://www.nalms.org/>)

**Maine Congress of Lake Associations** is a non-profit, charitable organization that provides information specific to Maine lakes and legislations. They hold conferences and establish connections with environmental groups and agencies to support the people of Maine lakes. (<http://www.mainecola.org/>)

**Maine Natural Areas Program** is within the Department of Conservation and works to inform landowners of the importance of Maine's natural features as well as how to care for them. (<http://www.mainenaturalareas.org/>)

## APPENDIX O: BENEFITS AND COSTS OF REMEDIATION

### Property Values and Water Transparency



Water transparency adds value to lake properties and tends to increase with increasing water transparency (Michael 1996).

The “Property Value Added by Last Unit of Remediation” line was derived from a 1996 study of Maine Lakes (Michael 1996). Below a water transparency of one meter, water transparency is a negative asset. For clarity, only positive added property values are shown above.

The “Cost of Last Unit of Remediation” line above is used for illustration only. Actual values depend on actual remediation techniques proposed.

- To increase water transparency beyond point A, the additional cost of improving water clarity exceeds the additional value added.
- Before point A, improving water quality will increase property values by more than the cost of improvements.
- The area shaded (light gray) below the “Property Value Added by Last unit of Remediation” line indicates the total additional property value added by increasing water clarity an additional unit (ex: from 2.0 m to 2.1 m).
- The area shaded (dark gray) below the “Cost of Last Unit of Remediation” line indicates the total cost of improving water quality from 0 m to point A (3.2 m pictured above)
- Property values increase beyond the total cost of improving water quality by the difference between the areas.