An Analysis of the Factors Influencing Eutrophication within the China Lake Watershed

Student Collective Organized Against Lake Eutrophication, Colby College
Problems in Environmental Science course (Biology 493), Colby College

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AN ANALYSIS OF THE FACTORS INFLUENCING EUTROPHICATION WITHIN THE CHINA LAKE WATERSHED

Submitted by SCOALE
(Student Collective Organized Against Lake Eutrophication)
December 19, 1989
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INTRODUCTION

Lake eutrophication is the natural process of aging in the lake body with establishment and multiplication of organisms over time. The sediment and decaying matter accumulate, gradually filling in the lake basin, transforming the lake from a deep lake to dry land. This process affects the physical make-up of the lake as well as the ecological and biological composition. Eutrophication usually takes thousands of years. However, human interference has greatly accelerated the process by increasing rates of sedimentation and phosphorus loading. China Lake has undergone accelerated eutrophication in recent years causing a growing concern for water quality. Algal populations, stimulated by nutrient loading, primarily phosphorus, is a prime indicator of lake eutrophication. The blooms have decreased the aesthetic value of the lake and the quality of drinking water. The small-scale but widespread pollution of China Lake resulting from the everyday activities of residential development and agriculture has accelerated the lake's eutrophication process, causing the most dramatic decline in water clarity ever documented in Maine (Tietjen, 1987).

The intent of the study, conducted by SCOALE, a group of 14 Colby College students, is to examine sources of phosphorus loading through water and land use assessment, and to identify mitigation procedures which would decrease the rate of lake eutrophication and improve water quality. The project is divided into three parts according to the natural divisions of the watershed: lake body, tributaries, and land within the watershed. These divisions exhibit all aspects of phosphorus loading. A major source of phosphorus loading is from soil erosion, and can be accelerated by unregulated land use procedures such as agriculture and silviculture. Present water quality within the lake will be determined and compared with historical patterns by the lake proper division. This component includes testing abiotic and biotic parameters, with the primary focus being on phosphorus loading. The tributary component determined water characteristics of selected tributaries leading into the lake in order to assess potential trouble spots. They sampled during normal conditions and during a storm event. The tributary component then compared the data from the two conditions to determine the changes in phosphorus levels due to increased water flow. The land use division assessed historical and present day land use within the watershed area. This component includes
evaluation of the trends of historical land use patterns in relation to phosphorus levels in the lake proper.

The primary purpose of this report is to provide qualitative information, a data base, and recommendations for improvement programs in the China Lake watershed through an integrated approach describing the etiology and particular problem sources within the watershed. The study will be useful for community education to encourage understanding of the fragile ecosystem of China Lake and to encourage proper land use management.

Physical Characteristics

China Lake covers an area of 1558 hectares and is located on the US Geological Survey topographic map of Vassalboro/Palermo quadrangle of China, Maine (scale of 1:62500). The lake is divided into two basins, the East and West. The East Basin, with a surface area of 908 hectares, contains China Lake's major inlet, and supports the majority of recreation and residential homes on the lake. The East Basin is approximately 14.5 km long with a range in depth from 1.3m to 15.2 m, and includes two sub-basins, the North Sub-basin and the South Sub-basin. The West Basin is oval shaped with a range in depth from 1.3 m to 25.9 m (KWD 1988). Because it is the primary source of potable water for the greater Waterville area, residential development is prohibited and the majority of the surrounding land is wooded primarily with Northern Conifers.

The total drainage area of China Lake is 7034 ha. The majority of the area is within the town of China with portions in Vassalboro and Albion. In this watershed, there are 4 major tributaries and more then 20 minor, intermittent and ephemeral tributaries (Bouchard, 1989). Hunter Brook, emptying into the northern end of the East Basin, is the primary inflow to the lake. Jones Brook, at the southern end of the East Basin, and Starky Brook on the east bank are also major contributors. Ward Brook is the only major tributary flowing directly into the West Basin. The water exits through Outlet Stream located at the western end of the West Basin. China Lake has a relatively low flushing rate— the rate at which the water is removed and replaced— of once every two and a half years. The overall flow of the lake mostly bypasses the southern portion of the East Basin, resulting in periods of stagnation. In the past this area has experienced the most severe algal blooms. (Appendix I)

China Lake's dominant rock formation contains high natural levels of phosphorus (Davis, 1978). The dominant rock formation, Waterville Formation, is
composed of metamorphic apatite, Ca$_5$(PO$_4$)$_3$(OH) and limestone, CaCO$_3$. When dissolved, these rocks yield higher levels of phosphorus. There are four major soil associations on the China Lake watershed. The Hollis-Paxton-Charlton-Woodbridge association is comprised of fine sandy loams, some of them also being very stony. Fine sandy loam, silt loam, and peat make up the Buxton-Scio-Scantic association and the Scantic-Ridgebury-Buxton association. The Hinkley-Windsor-Deerfield association is of least importance of the four soil types and is comprised of coarse and moderately coarse textured soils. The four major soil types, like the bedrock, also yield high levels of phosphorus. In general, many of these soils are sandy loams and are moderately coarse grained and sorted, and therefore have a smaller holding capacity for water and phosphorus. They become saturated more quickly, and water and nutrients, if there is no vegetation to bind them, will either pass through them and into the groundwater or will run-off over the surface of the soil. There are also large areas in the watershed that are dominated by peaty and clayish soils, which also have a smaller holding capacity for water and phosphorus.

**Residential Development**

Residential development is a major contributor to lake phosphorus loading. The population has grown from 1,850 people in 1970 to 3,533, in 1987. At 3 persons per house, the growth represents 120 new houses over the past ten years (Bouchard, 1989). The greatest portion of this development has occurred around the East Basin. This area has a greater number of roads, active farms, summer and year-round houses than the West Basin, all of which are potential sources of phosphorus loading as well as other types of pollution. A current trend of development has been the conversion of farm land into subdivided house lots and condominiums which would generate a larger revenue for the owner. Many seasonal homes are also being converted into year-round dwellings. This transition dramatically increases the stress on septic systems, and sometimes beyond the limits of systems designed only for seasonal use, which increases the sewage input to the lake (China Comprehensive Plan, 1987).

**Historical Perspective**

China Lake is known historically for its sport fishing. A decade ago China lake was known for its brown trout, togue, and land locked salmon cold water fishery, but due to phosphorus loading and the subsequent eutrophication, this fishery has been almost completely interrupted (Bouchard, 1989). Currently, non-sport species
such as white, yellow perch, sunfish, and small mouth bass are the predominant fish in China Lake and these species are also most likely affected by phosphorus loading (Roland Tilton, personal communication).

China Lake is also the primary potable water source to the greater Waterville area. The water quality of China Lake has considerably decreased in the last 6 to 8 years, and in 1983 China Lake experienced its first major algal bloom (Roland Tilton, personal communication). Poor water quality is manifested by changes in taste, odor, and continual clogging of filters by particulates due to aggressive water. From early studies performed on China Lake water conducted by Thurlow (1974) and by Davis et al. (1978), it can be seen that phosphorus levels have increased from 10.5 ppb of total phosphorus, in 1973 to 20 ppb in 1988 (Bouchard, 1989). These increases have stimulated algal blooms with a consequent decrease in water quality.

Due to awareness of the increasing rates of eutrophication and increasing occurrences of algal blooms, citizens of China have formed the China Lake Association. The primary focus of the China Lake Assoc. is to propose legislation to preserve the watershed and to decrease the rate of eutrophication. In 1984, controversial legislation was passed increasing the mandatory lot size of lake shore property up to an acre and minimizing the shore frontage to 250 ft. The legislation also stated that no more of 6% of the plot may be covered by a structure. Another citizen group, The Concerned Citizens of China, was formed oppose the legislation and protect the individual interests and rights of the landowners and developers.

The China Lake Association has been instrumental in studies conducted on China Lake. A volunteer network, of concerned citizens, was established to collect data. From the data collected, an extensive Phosphorus Fact Finding Study of the lake was created and used for the proposal of an EPA Grant to fund mitigative procedures. As a result of the Phosphorus Fact Finding Study three sites in the lake basin have been determined for proposed mitigation with alum treatment. Currently a comprehensive plan for watershed management is being developed by Tim Beckett of Unity College. Colby College C. JETT SeT & ASSOC, organized by Colby students, conducted an extensive study of the China Lake Watershed in the Fall of 1988. All of these studies have uncovered important data about the impact and sources of phosphorus loading on China Lake. The results, of these studies, will be discussed along with comparisons to current data collected from this study. Based on these data, we will propose possible mitigative procedures for the watershed.
LAKE BODY
INTRODUCTION

The lake body is an important component in the examination of phosphorus loading to China Lake. Phosphorus originating from agricultural and residential areas runs directly off the land into the lake or filters into the tributaries, primarily during storm events, eventually reaching the lake. Water sampling of specific areas in the lake body was performed in an attempt to quantify the amount of phosphorus loading and the subsequent extent of eutrophication within China Lake.

Based on data from the alum treatment proposal (Bouchard, 1989), the Environmental Analysis of China Lake (C. JeTT SeT, and ASSOC., 1988), and the field reconnaissance by SCOALE, eleven locations were identified as priorities and chosen for analysis. Stratified samples were taken at five of these sites and surface samples were taken at six. Samples were collected in order to examine thermal stratification and nutrient levels at three depths; one meter below the surface, mid-depth, and one meter above the substrate. The temperature profile of the lake assessed the extent of lake overturn. The phosphorus profiles attempted to describe the internal cycling of phosphorus and the long term capacity for eutrophication. The data collected could then to be compared with data from the alum treatment proposal (Bouchard, 1989), that split the lake into three basins. SCOALE profile sample sites were chosen in correspondence with these described basins. Basin 1 was located in the west basin, basin 2 in the southern east basin, and basin 3 in the central and northern east basin. Moreover, location of profile samples dealt with the comparison of phosphorus concentrations in the east and west basins, and also assessed the changing phosphorus levels with respect to flow from the inlet to the outlet. Profile sites were ordered, increasing in number, according to the direction of flow from the east basin to the west basin.

The surface samples provided spot checks, assessing individual locations contributing phosphorus and coliform bacteria, in order to identify poor land use practices. Also, the samples at the surface sites attempted to describe the phosphorus inputs from residential and agricultural areas.

The sites are described below and shown in Fig. 1.

SITE 1: This site represented the most heavily developed and oldest residential area and is located approximately 1.5 km downstream from the major inlet. Site 1 also represented a site in the proposed alum treatment basin 3. Samples
FIG. 1. Sample sites depicted on a map of China lake and its surrounding watershed. scale: 2.54 cm=1.61 km
from site 1 were taken from the center of the lake and were stratified. Measurements of temperature, dissolved oxygen, total phosphorus, orthophosphate, algal biomass, and BOD were taken.

SITE 2: This site represented a spot check of nearshore residential impacts adjacent to site 1. Samples from this site were taken at the surface approximately 10 m from the eastern shoreline in the center of a small cove, and included measurements of temperature, pH, total phosphorus, orthophosphate, and coliform (total and fecal).

SITE 3: This site represented an indication of recently established residential influence. Alum treatment basin 3 was represented by this site. Site 3 was stratified, located centrally between the eastern and the western shoreline of the east basin. Sampling occurred on the western edge of the lake adjacent to Indian Island, approximately 0.5 km from shore. Tests at this site included temperature, dissolved oxygen, total phosphorus, and orthophosphate.

SITE 4: Site 4 represented a spot check of nearshore residential impacts adjacent to site 3. This surface sample was taken approximately 10 m from the eastern shoreline, in the center of a large cove just southeast of Indian Island. This sample measured temperature, pH, total phosphorus, orthophosphate, and coliform (total and fecal).

SITE 5: Site 5 represented an area of reduced flow, residential development, and high abundance of algal and macrophytic populations. Alum treatment basin 2 is represented by this site. Located approximately 1 km from the southern most part of the east basin, temperature, dissolved oxygen, total phosphorus, orthophosphate, algal biomass, and BOD were measured in stratified sequence at the center of the lake.

SITE 6: This spot check examined a wetland area where the water flow was greatly reduced. This testing site, located downslope from a large agricultural area, also showed indications of a large algal population. Samples were taken in a cove about 10 m from the western shoreline in the southern portion of the east basin. The measurements at this location were taken at the surface and included temperature, pH, total phosphorus, orthophosphate, and coliform (total and fecal).

SITE 7: This area represented the passage between the east and the west basins. Site 7 represented a site in the alum treatment basin 2. The samples were taken on the eastern portion of the passage between the basins. Profiles included measurements of temperature, dissolved oxygen, total phosphorus, and orthophosphate.
SITE 8: This site was used as a spot check to measure the amount of phosphorus and coliform that an adjacent agricultural area may contribute to the west basin. Samples were taken in a large cove approximately 10 m from the western shoreline of the west basin. Temperature, pH, total phosphorus, orthophosphate and coliform (total and fecal) were measured at the surface.

SITE 9: This site measured the influence of the remnants of a large poultry farm located in the west basin. This surface spot check was located approximately 10 m offshore on the eastern shoreline of the west basin, upstream from the poultry farm, and included measurements of temperature, pH, total phosphorus, orthophosphate, and coliform (total and fecal).

SITE 10: The Kennebec Water District draws water from the lake to be used as potable water for the greater Waterville area at this site. Alum treatment basin 1 is also represented by this site. Temperature, dissolved oxygen, total phosphorus, orthophosphate, algal biomass, and BOD were measured in stratified sequence.

SITE 11: This site is a spot check which measures the influence of the same large farming area as site 8. Site 11 is located on the western shoreline of the western basin, further north than site 8, near Jones tributary which flows by the farm. Temperature, pH, total phosphorus, orthophosphate, and coliform (total and fecal) were measured in a surface sample taken approximately 10 m offshore.

The types of tests performed are described below.

1. Algal Biomass: This test determined the amount of algae, using chlorophyll-a (a type of chlorophyll found in all algae). A large algal population is indicative of high nutrient levels and poor water quality. Water samples were analyzed at Northeast Laboratories, Winslow, Maine.

2. Biochemical Oxygen Demand (BOD): BOD measures the rate of oxygen consumption by organisms under dark conditions, and varies with the amount of organic matter and organisms in the water, and thus estimates the relative number of decomposers present. Water samples were analyzed at Northeast Laboratories, Winslow, Maine.

3. Coliform (total and fecal): Fecal coliform are bacteria associated with the fecal matter of warm blooded organisms and represent an indication of fecal pollution and poor water quality. Total coliform is a measure of the presence of enteric bacteria, and indicates, as well, possible fecal contamination. Water samples were analyzed at the Colby College environmental laboratory.

4. Dissolved Oxygen (DO): An oligotrophic lake and its tributaries should exhibit a relatively high level of DO, whereas a eutrophic lake should exhibit
relative oxygen depletion. Severe oxygen depletion in the lake system produces anoxic conditions which result in high phosphorus levels and low trout and salmon populations. Instead, a high density of bass, pickerel, and perch are found. DO is thus an indication of the extent of lake eutrophication. DO was measured using a calibrated YSI dissolved oxygen meter.

5. **Phosphorus**: Phosphorus concentrations were determined by testing for two forms, orthophosphate and total phosphorus. Orthophosphate is the soluble form and is directly available as a nutrient. Total phosphorus is the amount of phosphorus complexed chemically in sediment and in plant material, although it may be soluble as well. Phosphorus is the primary limiting growth factor for plant and algal species. Water samples were analyzed in the Colby College environmental laboratory. Results were reported in terms of phosphorus (ppb).

6. **pH**: pH is a measure of the concentration of H+ ions in the water. It is useful in determining the impact of acid rain and the buffering capacity of the lake and its tributaries. pH was measured in the field using a calibrated Beckman pH meter.

7. **Temperature**: Temperature was measured using a calibrated YSI dissolved oxygen and conductivity meter in order to describe thermal stratification and to determine the extent of lake overturn.

**MATERIALS AND METHODS**

In preparation for the collection of water samples, polypropylene bottles were rinsed with distilled water and labelled appropriately. Coliform bottles were sterilized to eliminate any microbial contamination before entering the field. Water samples were collected on October 12, 1989. The sky was partly cloudy, winds blew approximately 20 to 25 mph, and choppy water was apparent. The temperature of the preceding week averaged 55°C. Occasional showers occurred on the ninth and eleventh of October. Boats circled each site during sampling to prevent drifting from the original site location. At the profile locations, the surface samples were always taken first and away from the boat to avoid petroleum contamination.

At the stratified sites, the water was collected using a Kemmerer water sampler with a weighted line marked at one meter increments. Water samples at surface sites were taken as individual grab samples (Anonymous, 1981), by holding
the bottle near its base and plunging it, neck downward, approximately 15 cm below
the surface. A current was made by the forward motion of the hand away from the
sampler (to avoid contamination through human contact). The bottle was then
turned until the neck pointed slightly upward, which allowed the bottle to fill.

The onsite preservation methods followed standard procedures approved by
the Environmental Protection Agency (Anonymous, 1981). Water for
orthophosphate analysis was filtered in the field through a Buchner funnel with 7
cm diameter No. 1 filter paper. Two milliliters of 5N sulfuric acid were added to
each 125 ml total phosphorus water sample to ensure a pH of less than 2. All
samples were cooled immediately after collection to approximately 4° C in ice
contained in styrofoam coolers.

Water samples were tested for phosphorus in the Colby College
environmental laboratory approximately 24 hours after collection. The expanded
low range orthophosphate test was used in the measurement of orthophosphate
concentrations, following standard methods (Greenberg et al., 1985). Specifically, the
stannous chloride method was used, as described in the Hach Water Analysis
Handbook (Hach Company, 1985). Glassware was rinsed before use with a solution
of 4 ml of ammonium molybdate reagent in 100 ml of demineralized water
followed by a demineralized water rinse to assure complete removal of any
phosphorus that might have been present. 2 ml of ammonium molybdate reagent
was added to a 50 ml water sample. One minute later, 3 drops of stannous chloride
solution was added to the water sample. A blank was then run on reagents and
distilled water. From 10 to 15 minutes later, color of the treated water sample was
measured photometrically at 700 nm using the Hach DR/3000 Spectrophotometer,
and was then compared to a calibration curve. Blue color indicated the presence of
phosphorus. There was assumed to be no interferences.

The organic and hydrolyzable phosphorus test was used in the measurement
to total phosphorus concentrations. To release phosphorus from combination with
organic matter, each water sample was digested and oxidized using the persulfate
digestion method as described in the Hach Water Analysis Handbook (Hach
Company, 1985). Total phosphorus samples were diluted by a factor of four so that
concentrations would fall within the limits of the test. One powder pillow of
potassium persulfate was added to 25 ml of the diluted water sample, followed by 2.0
ml of 5.25N sulfuric acid. The treated water sample was then boiled gently for 30
minutes using a "double broiler" technique. After cooling, 2.0 ml of 5.0N sodium
hydroxide was added and the sample was brought to 25 ml with demineralized
water. Samples were then analyzed using the stannous chloride method described above. Due to over-dilution of certain samples, some were retested one week following collection using a dilution factor of two.

The accuracy of all analyses, orthophosphate and total phosphorus, was checked by the analysis of spiked samples using the standard additions method. The spiked samples were prepared by adding 0.10 ml of 1.0 mg/l phosphate to 50 ml of water samples in approximately one in every ten samples. Each 0.10 ml addition resulted in an increase in approximately 30 µg/l orthophosphate, and thus assured the accuracy of analysis. Duplicate water samples were also collected in several cases and analyzed to assure accuracy. The results from both analyses were divided by three in order to express the results in terms of ppb phosphorus rather than ppb orthophosphate.

Coliform was analyzed following standard techniques for the membrane filtration method (Greenberg et al., 1985). For the total coliform test, absorbent pads that contained desiccated Endo media were placed in three petri dishes. 2 ml of sterile, deionized water was added to each pad. Water sample volumes of 100 ml, 50 ml, and 10 ml were filtered to insure a count within the significant range of 20 - 80 colonies for fecal coliform, and 20 - 60 colonies for total coliform. Samples within these ranges were reported as final results. The samples were membrane filtered (0.45 µm porosity) under vacuum to separate the coliform from the water. The membrane filter was then placed on the medium. The petri dishes were sealed and incubated at 37°C for 24 hours. Characteristic colonies, pink to dark red, with a golden green metallic sheen, were counted and recorded. The procedure for testing fecal coliform was similar but was performed with the following exceptions: the nutrient pads used for detecting the blue fecal coliform colonies contained desiccated mFC media, and the petri dishes were incubated at 44.5°C for 22 hours.

Water samples for algal biomass and BOD, kept at 4°C, were brought to Northeast Laboratory for analysis five days after collection.

RESULTS

Profile Sites
At each site and depth, temperature was similar ranging from 11.4 to 11.9°C (Table 1). Dissolved oxygen at each site decreased slightly from surface to mid-depth
Table 1: Dissolved oxygen (mg/ml) and temperature (°C) data at sampled profile sites.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Site 1</th>
<th>Site 3</th>
<th>Site 5</th>
<th>Site 7</th>
<th>Site 10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temp</td>
<td>D.O</td>
<td>Temp</td>
<td>D.O</td>
<td>Temp</td>
</tr>
<tr>
<td>Surface</td>
<td>11.9</td>
<td>9.2</td>
<td>11.6</td>
<td>9.9</td>
<td>11.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9.8</td>
</tr>
<tr>
<td>Mid-Depth</td>
<td>11.8</td>
<td>8.5</td>
<td>11.6</td>
<td>9.4</td>
<td>11.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9.5</td>
</tr>
<tr>
<td>Bottom</td>
<td>11.7</td>
<td>4.5</td>
<td>11.4</td>
<td>6.2</td>
<td>11.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.3</td>
</tr>
</tbody>
</table>
(ranging from 9.9 to 8.5 mg/ml) and decreased abruptly from mid-depth to bottom depth (ranging from 9.4 to 3.3 mg/ml).

Total phosphorus and orthophosphate data were plotted against site location for each profile depth (Fig. 2). In comparing trends in the depth of each site, site 1 showed an increase with depth in both total phosphorus and orthophosphate concentrations. Total phosphorus concentrations increased with depth at sites 3 and 10. At site 1, depth differences in orthophosphate concentrations were found not to be significantly different (one factor ANOVA, $\alpha=0.05$, n=5, p=0.81). Total phosphorus values at sites 1, 3, and 10 were also found not to be significant when considering all data points (one factor ANOVA, $\alpha=0.05$, n=3, p=0.26). However at site 1, there was one outstanding value of 53 ppb that was abnormally large in comparison to other values at that site. If this outstanding value was removed due to the possibility of experimental error, the concentration differences in depth at the sites remaining would be significant (one factor ANOVA, $\alpha=0.05$, n=3, p=0.05). At site 5, both total phosphorus and orthophosphate concentrations were highest at mid-depth. Two markedly high values were the total phosphorus concentrations at the bottom depth at site 1 and mid-depth at site 7.

In comparing surface concentrations between all profile sites, total phosphorus values were relatively equal ranging from 11 to 16 ppb, and were highest at site 10 and lowest at sites 5 and 7 (Fig. 2). The orthophosphate concentration was highest at site 3 with a value of 12 ppb and lowest at site 5 with a value of 5 ppb. Other surface orthophosphate concentrations ranged from 5 to 8 ppb.

In comparing samples at mid-depth, the total phosphorus concentration was abnormally high at site 7 compared with other sites, with a value of 43 ppb. The lowest value (17 ppb) was found at both sites 3 and 10. The range for all sites excluding site 7 was 17 to 23 ppb. Orthophosphate concentration was highest at site 3 with a value of 16 ppb. The lowest orthophosphate levels were found at both site 7 and 10 with a concentration of 3 ppb.

In comparing bottom samples, the total phosphorus concentration was markedly higher at site 1 (53 ppb) and lowest at site 7 (7 ppb). Sites 3, 5, and 10 ranged from 15 to 20 ppb. Orthophosphate concentrations in the hypolimnion were highest and relatively equal at sites 1 and 3, with 16 and 14 ppb, respectively. Sites 5,
Fig. 2. Total phosphorus (ppb) and orthophosphate (ppb) concentrations for the sampled profile sites of China Lake-12Oct89.
7, and 10 were lower, with values of 6, 5 and 5 ppb, respectively.

In the examination of flow from the north end of the east basin to the west basin, surface values for both total phosphorus concentrations and orthophosphate concentrations were relatively equal and did not change in any pattern due to site location (Fig. 2). Mid-depth concentrations were relatively equal with the exception of a high value at site 7. The orthophosphate concentrations at the bottom sites decreased from the inlet to the outlet, ranging respectively from 16 to 5 ppb. Aside from a slight variation at site 10, total phosphorus concentrations followed a decreasing pattern as well.

A comparison was also made among the proposed alum treatment basins (Bouchard, 1989). The concentrations at sites 1 and 3 were averaged to represent basin 3, located at the northern end of the east basin, and the following results were calculated. The total phosphorus concentration at the surface was 14 ppb, the mid-depth was 19 ppb, and the bottom was 37 ppb. Orthophosphate concentration at the surface was 9 ppb, the mid-depth was 13 ppb, and the bottom was 15 ppb. Concentrations at sites 5 and 7 were averaged to represent east basin 2, located at the southern tip of the east basin. The total phosphorus concentration at the surface was 11 ppb, the mid-depth was 33 ppb, and the lowest depth was 11 ppb. The orthophosphate concentration at the surface was 6 ppb, the mid-depth was 8 ppb, and the bottom was 5 ppb. Site 10 alone represented basin 1 of the proposed alum treatment, and total phosphorus concentration at the surface was 16 ppb, the mid-depth was 17 ppb and the lowest depth was 19 ppb. The orthophosphate concentration at the surface was 8 ppb, the mid-depth was 3 ppb, and the lowest depth was 5 ppb.

Since algal biomass readings for all three sites were below the limits of the test, chlorophyll-a values were analyzed. Chlorophyll-a tests were performed by Northeast Laboratories and yielded the following results: site 1: 0.1 µg/L, site 5: 0.2 µg/L and at site 10: 0.4 µg/L. Data were then corrected to represent algal biomass on the assumption that chlorophyll-a constitutes approximately 1.5% of algal dry weight. The correction was done by multiplying chlorophyll-a values by 67, a computation resulting in the following algal biomass concentrations: site 1: 6.7 µg/L, site 5: 13.4 µg/L, and site 10: 26.8 µg/L.

Biochemical oxygen demand (BOD) was analyzed by Northeast Laboratories. BOD at site 1 was determined to be 3 mg/L, at site 5: <2 mg/L, and at site 10: <2 mg/L.
Surface Sites

Surface spot check sites were categorized as being potentially influenced by either residential areas (sites 2 and 4) or by agricultural areas (sites 6, 8, 9, and 11). Temperature at all of these sites was constant at 13°C. pH, total phosphorus concentration, and orthophosphate concentration were each examined according to site and potential influence (Tables 2 & 3). pH ranged from 5.56 to 7.04 overall. Aside from site 9, the sites potentially affected by agricultural areas had lower pH values than those affected by residential areas. Site 9 was excluded in statistical calculation, because the poultry farm at this location has been recently abandoned, and thus does not technically represent an area of current agricultural use. However, the difference in pH between sites was not statistically significant (one factor ANOVA, =0.05, n=6, p=0.4937).

At sites 6, 8, and 11, total phosphorus concentrations were higher than orthophosphate concentrations, and the converse was true for sites 2 and 4. Total phosphorus concentrations were highest at sites 11 and 6, with relatively equal values of 20 and 18 ppb, respectively. All other sites had concentrations ranging from 7 to 11 ppb, with the lowest values found at sites 8 and 9. The highest orthophosphate concentration was found at site 4 (15 ppb). Site 8 was exceptionally low, with a value of 0.3 ppb. Orthophosphate concentrations for sites 2, 6, 9, and 11 ranged from 8 to 12 ppb.

The average residential total phosphorus concentration was 9 ppb and the average residential orthophosphate concentration was 13 ppb. The total phosphorus concentration for all active agricultural sites (note: site 9 was excluded), was 15 ppb. Average agricultural orthophosphate loading for all sites was 7 ppb. The mean agricultural orthophosphate contribution was 10 ppb, excluding site 8 which showed probable experimental error with an outstandingly low concentration. With the exception of sites 8 and 9, the mean agricultural orthophosphate concentration was 11 ppb.

In comparing mean agricultural versus mean residential loading, total phosphorus concentrations at all sites showed a 39% increase from the residential to the agricultural mean. Statistically however, no significance was found between the
Table 2: pH of surface sampling sites on China Lake - 12Oct89

<table>
<thead>
<tr>
<th>pH</th>
<th>Site 2</th>
<th>Site 4</th>
<th>Site 6</th>
<th>Site 8</th>
<th>Site 9</th>
<th>Site 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.18</td>
<td>6.78</td>
<td>5.56</td>
<td>5.80</td>
<td>7.04</td>
<td>5.94</td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Total phosphorus (ppb) and orthophosphate (ppb) at surface sites on China Lake - 12Oct89

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Residential</th>
<th>Agricultural</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site 2</td>
<td>Site 4</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>11</td>
<td>15</td>
</tr>
</tbody>
</table>
two means (one factor ANOVA, \( =0.05, n=6, p=0.5548 \)). Excluding site 9, (inactive poultry farm), there was a 61% increase from the agricultural mean of total phosphorus to that of residential. The difference was not significant as well when site 9 was excluded (one factor ANOVA, \( =0.05, n=5, p=0.3831 \)).

In comparing mean agricultural versus mean residential loading, orthophosphate concentrations at all sites showed a 45% decrease from the residential to the agricultural mean. However, there was no significant difference between these mean concentrations (one factor ANOVA, \( =0.05, n=6, p=0.2132 \)). With the exclusion of site 8, (low orthophosphate value of 0.3 ppb), the mean orthophosphate concentrations decreased by 28% from the residential to the agricultural mean. Again, there was no significant difference between the mean concentrations (one factor ANOVA, \( =0.05, n=5, p=0.2117 \)). There was also a decrease in the residential to the agricultural orthophosphate mean values excluding both site 8 (low concentration) and an inactive farm at site 9. However, it was found not to be significant (one factor ANOVA, \( =0.05, n=4, p=0.4089 \)).

Fecal coliform values were low, with the exception of sites 4 and 11, having 89 and 20 colonies per 100 ml, respectively (Fig. 3). Extremely high total coliform counts were found at sites 4, 6, and 11, with colonies too numerous to count (TNTC) at sites 4 and 6, and a count of 196 colonies per 100 ml at site 11. Site 9 had a count of 26 colonies which was also notable.

**RESULTS FROM PREVIOUS STUDIES**

Based on results reported in the alum treatment proposal (Bouchard, 1989), total phosphorus concentrations have increased by 91% from 1973 to 1988 in the east basin, and by 67% from 1982 to 1988 in the west basin (Fig. 4). There was a definite increasing trend in the total phosphorus concentrations of the west basin from the early to the late 1980's. Although total phosphorus concentrations dropped between 1983 and 1985, overall, there has been an increasing trend in concentrations since 1970. The total phosphorus concentrations were lowest in 1982, approximately 12 ppb, and highest in 1988, at approximately 20 ppb. Total phosphorus concentrations in the east basin ranged from approximately 10 ppb in 1978 to 22 ppb in 1983. Total phosphorus values for both the east and west basins were high from 1986 to 1988 as
Figure 3: Fecal and total coliform counts from surface sampling sites at China Lake--12 October 1989
FIG. 4. Total phosphorus concentrations (ppb) for the east and west basins from 1973-1988 (Bouchard, 1989).
compared with earlier years. Overall, the phosphorus levels in the west basin were lower than those of the east basin in 1988, with the exception of October, where the high concentrations of phosphorus from the summer flows from the east basin to the west basin. From 1985 to 1988, total phosphorus concentrations for both basins were relatively equal, whereas in 1983, a larger difference in concentrations was seen. The data obtained does not allow us to compare the two basins for any other year.

In 1988, the total phosphorus concentrations increased from April to September with an abrupt decline in October. SCOALE October data parallels the decline and is very similar to DEP data from October 1988. Total phosphorus concentrations from April to October ranged from 15 ppb in basin 1 during April and May to 56 ppb in basin 2 during September (Fig. 5). The mean for basin 1 was 19 ppb while 28 ppb was the mean for both basins 2 and 3. There was a general increasing trend of total phosphorus concentrations from April to September, with an abrupt decrease back to levels as seen in April and May in October. The highest concentrations occurred during July, August, and September in all three basins. In comparing total phosphorus concentrations between the east and west basins, the west basin concentrations were lower than those of the east basin for all months but October.

In comparing SCOALE data, sampled October 12, 1989, to that of the DEP data, sampled on October 10, 1989, SCOALE data for the surface phosphorus concentrations were lower than that of the DEP in all three basins (Fig. 6). The mid-depth phosphorus concentrations of the DEP and SCOALE data were similar in basins 1 and 3, and SCOALE data was higher in basin 2. Data analyzed by SCOALE found higher phosphorus concentrations than those found by the DEP in all three basins at the lowest depth. Both SCOALE and DEP phosphorus concentrations were highest in basin 3 and lowest in basin 2 at the lowest depth. Chlorophyll-a concentrations ranged from 3.2 µg/L in basin 3 during June to 27.1 µg/L in basin 1 during September, based on data outlined in the alum treatment proposal (Bouchard, 1989) (Fig. 7). The chlorophyll-a concentrations in the west basin were higher than the concentrations in the east basin during all months but July. The mean concentration for basin 1 was 13.6 µg/L, for basin 2: 21.6 µg/L, and for basin 3: 10.9 µg/L. In all three basins the lowest concentrations were found in June and the highest concentrations in September. From May to July, values were low, relatively constant, and similar in all three basins. In August and September values were high
Fig. 5. Total phosphorus (ppb) concentrations of the DEP proposed alum treatment basins from April to October of 1988. (North half of the east basin=DEP basin 3, south half of the east basin=DEP basin 2, west basin=DEP basin 1).
Fig. 6. Comparison of total phosphorus concentrations between SCOALE data (12Oct89) and DEP data (10Oct89). (North half of the east basin=DEP basin 3, south half of the east basin=DEP basin 2, west basin=DEP basin 1).
Fig. 7. Chlorophyll-a (ug/L) concentrations for the months of May to September 1988 (DEP). (North half of the east basin=DEP basin 3, south half of the east basin=DEP basin 2, west basin=DEP basin 1).
with an increase from August to September. SCOALE results for all three basins and for all months are low in comparison to DEP's findings.

**DISCUSSION**

Total phosphorus is a measure of organic phosphorus, orthophosphate, and colloidal-bound phosphorus. In lakes undergoing eutrophication, higher concentrations of total phosphorus entering the lake usually result in increased amounts of orthophosphate, the form readily available to the biotic component of the phosphorus cycle. When more orthophosphate enters the food chain, it allows plant growth to increase by providing an otherwise limiting nutrient. Vegetation growth leads to an increase in animal growth, and as the numbers of animals and vegetation die, there is an increase in the amount of organic matter that settles to the bottom and is available for decomposers. Populations of respiring decomposers increase, decreasing the amount of dissolved oxygen found near the substrate. In this process of internal phosphorus loading, phosphorus near the substrate complexes with iron found in the lake sediment. When there are low concentrations of oxygen, the iron releases a portion of phosphorus from the sediment to react with sulfate, such that phosphorus is cycled back into soluble orthophosphate form which again becomes available for primary production in the food chain.

Uniform temperature and dissolved oxygen values throughout the water column are characteristic of complete overturn in the lake. Temperature remained constant at 13°C for all surface spot check sites and ranged only from 11.3 to 11.9°C at profile sites, implying complete overturn at the time of sampling. The slightly higher temperatures at nearshore surface sites were most likely a result of sun exposure in shallow water. Although dissolved oxygen values were highest and similar between the surface and mid-depth of all sites, the difference between these values and the values at the bottom of each site was substantially different, implying incomplete overturn. Large numbers of decomposers assimilate nutrients accumulating low in the water column, and respire high concentrations of oxygen, thereby depleting the available supply. The presence of many decomposers is a possible explanation for lower oxygen values found at the bottom depth of each site. The abundance of these decomposers would also explain the apparent contradiction between temperature values and dissolved oxygen values, in terms of lake
overturn. In this case, it is probable that overturn was complete, or nearly complete as evidenced by uniform values in all temperature values and higher strata dissolved oxygen values. Biochemical oxygen demand values were found to be normal as compared with data in 1988 (C. JETT SeT, 1988), and suggested an abundance of decomposers, consistent with the previous hypothesis.

Chlorophyll-α concentrations were higher in the west basin than in the east basin. Previous work done in the alum treatment proposal (Bouchard, 1989) shows a similar pattern. The difference in concentration may be due to the fact that the water flows from the east basin to the west basin, and in the process carries algae with it. Or perhaps, algal concentrations are really highest in the west basin, contrary to the observation made by SCOALE in the field reconnaissance (Appendix II). Chlorophyll-α concentrations measured by SCOALE were extremely low in comparison to DEP data in 1988. Chlorophyll-α is typically highest in August and early September, due to increased plant growth and algal blooms, and decreases in October as algal populations die off (Bouchard, 1989) (Fig. 7). The chlorophyll-α data obtained by SCOALE supports the fact that there was a decrease in October. However, concentrations found by SCOALE deviated substantially from the lowest values given by the DEP for 1988, and were therefore suspect. The deviation was perhaps due to the length of time between collection and analysis (i.e., samples were given to Northeast Labs five days after collection, and results were returned approximately one month later. The amount of time before analysis at the lab is unknown). However, Roy Bouchard (DEP) believes that in 1989, there was a decrease in the population of algal blooms from recent past years, due to weather conditions rather than a reduction of phosphorus loading.

Among profile sites, phosphorus concentrations were taken at the surface, mid-depth, and bottom. When examining phosphorus concentrations at individual depths between sites, it is important to note that the topography of the lake floor varies and therefore actual depths for different sites do not correspond; sites 1 and 10 = 15 m, site 3 = 10 m, and sites 5 and 7 = 9 m. The mid-depth and bottom samples at each site were thus taken at different depths and therefore variation in phosphorus concentrations between sites may partly be the result of this variation in depth.

In considering surface samples, total phosphorus and orthophosphate concentrations showed no obvious trends. However, there appeared to be a difference in orthophosphate concentrations between the east and west basins at mid-depth. Sites 1, 3, and 5 are all in the east basin and have values of 9, 16, and 13
ppb, respectively, making them high in comparison to the channel and the west basin which had values of 3 ppb at both sites (7 and 10). The total phosphorus concentration at mid-depth at site 7 was exceptionally high (14 ppb), compared to the other mid-depth values from data by SCOALE and DEP, perhaps indicating phosphorus loads carried by the water current from the east to the west basin. The channel is located directly across from Starky Brook, a major contributor of phosphorus to China Lake (see Tributary section of this report). Water currents may draw sediments and excess phosphorus from this tributary across the channel into the west basin. Other sites tested by SCOALE at mid-depth had consistent total phosphorus values between 17 and 23 ppb.

Orthophosphate concentrations at bottom sites followed a decreasing trend from the major inlet in the northern east basin to the outlet in the west basin. Sites 1 and 3, in the northern east basin, were substantially higher than the other sites at the south end of the east basin and the west basin. Water movement is slow in the major inlet stream as it passes through a swampy area and enters the lake (see Tributary section of this report). Since the initial current is weak, phosphorus may precipitate to the bottom of the lake easily near the inlet. High phosphorus concentrations may also be due to increased surface runoff from residential buildup, since the shoreline consists of steep slopes, the water table is high in this area, and the soil type is categorized as having a high runoff risk (see soil description, Appendix III). As well, the municipal roads in this area closely parallel the lake, increasing erosion (see Road section of this report). The precipitation of phosphorus, in combination with residential influence in the areas of sites 1 and 3 may be responsible for the high values. Total phosphorus concentrations at the bottom followed the same decreasing pattern from the inlet in the east basin to the outlet in the west basin, with the exception of a higher value at site 10. Since site 10 was a bottom sample, sediment may have been disturbed in the process of collection resulting in a higher portion of bound phosphorus in the sample. In addition, contamination may have occurred through handling after collection. The total phosphorus concentration at site 7 was lowest in comparison to the other sites. Low amounts of total phosphorus and orthophosphate at the bottom and surface of site 7 may be an indication that the source of phosphorus was not in the area of that site. Rather, the phosphorus at site 7, was concentrated at the middle depth, because it was being carried through the channel by the pattern of water flow from both the east basin and Starky brook. The total phosphorus concentration was highest and exceptional at the bottom of site 1, remaining consistent with exceptional
orthophosphate values in the same region. Probable reasons include settling of phosphorus near the inlet, residential impact, soil composition of surrounding land, and the possibility of internal cycling once phosphorus reaches the bottom sediments of the lake.

When examining differences among total phosphorus at the three depths at each site, the concentrations increased from surface to bottom at sites 1, 3, and 10. Orthophosphate concentrations increased with depth only at site 1. In the proposed alum treatment basins outlined in the Grant Application (Bouchard, 1989), mean concentrations of total phosphorus increased from surface to bottom in west basin 1 (site 10) and east basin 3 (sites 1 and 3). Mean concentrations of orthophosphate increased from surface to bottom in basin 3. This concentration of phosphorus at the bottom is advantageous for treatment, because the aluminum salts would be spread over the bottom of the lake. The aluminum complex resulting would confine the phosphorus to the bottom sediments, eliminating its ability to be recycled into the water column where it would be readily available for biotic use. Normally, higher concentrations of phosphorus at the bottom indicate a larger internal loading capacity, because not as much can be complexed with a limited amount of iron to form bound-phosphorus.

Results by SCOALE, when compared to DEP data (Bouchard, 1989), showed a decrease in total phosphorus levels since 1988; the mean in the west basin was 17 ppb and the east basin was 20 ppb. However, since the decrease was not significant, our data remained consistent with the high values seen between 1986 and 1988. In general, total phosphorus concentrations have increased over the years, according to the previous data from the years 1973 to 1988. This supports the fact that eutrophication is taking place. In addition, since 1973, the east and west basins have become more similar in terms of total phosphorus concentrations. West basin concentrations were lower in 1973, but by 1988 reflect east basin concentrations (Fig. 4). The movement toward equilibrium in the two basins is most likely a consequence of current from the east basin to the west basin. Land surrounding the west basin is less developed and contributed low phosphorus concentrations according to SCOALE surface spot checks in comparison to the higher concentrations found at the profile site in the west basin. This conclusion is supported by the fact that the discharge from the east basin accounts for 59.1% of the phosphorus entering the west basin (Bouchard, 1989). Once the phosphorus exists in the west basin, recycling can prevent it from escaping, because currents only draw small portions of the water through the outlet, making flushing negligible, at best.
Recycling in the east basin is less likely to have such an effect, because currents flush that part of the lake, drawing the phosphorus into the west basin. According to the Grant Application (Bouchard, 1989), the west basin contributes approximately 58% of the lake's internal loading, while east basins 2 and 3 contribute 28% and 14%, respectively. The combination of phosphorus entering from the east basin and the amount of recycling phosphorus within the west basin, as suggested by the DEP, helps to explain the faster rate of phosphorus accumulation in the west.

Total phosphorus and chlorophyll-a concentrations were found in direct proportion to the increase and decrease of algal blooms throughout the year, since growth relies on phosphorus concentrations. Total phosphorus concentrations generally increase in April, perhaps due to thaw and water carrying excess nutrients into the lake. The concentrations are maintained throughout the summer due to the thermal stratification of the lake. As the lake becomes stratified the DO concentration in the hypolimnion decreases. When DO concentrations are low, iron releases the phosphorus back into the water column. The sharp decline in October may be due to plant vegetation and algae dying and settling to the bottom to decay. The phosphorus released during decay complexes with the iron in the substrate, and thus may not be recycled even while turnover is occurring. Overall, the west basin phosphorus levels in 1988 were lower than the east basin. The difference in concentrations between the two basins is due to the probable lag time in water flow, where west basin values are initially lower, but eventually catch up with the east basin.

In analysis of surface spot checks from SCOALE data, it was evident that neither agricultural nor residential practices could be singly targeted as being most responsible for the phosphorus loading in the lake. The calculated means of orthophosphate concentrations suggested residential input as the primary contributor to the problem, while the calculated means of total phosphorus concentrations suggested agricultural inputs, although the differences for both were not statistically significant. Since mean values tended to neutralize the effects of any outstanding data points, individual site evaluations were of greater value in this case. Concentrations measured at individual sites are more applicable in determining sensitive areas of phosphorus loading.

Difference in pH values among surface sites tended to suggest that active agricultural sites (having lower pH than residential sites) may contribute substances with lower pH values than residential sites (e.g., animal waste). Low pH values overall, for both SCOALE and October 1988 DEP data (Bouchard, 1989), were probably
caused by proximity to overturn and mixing of deep waters, in addition to low surface productivity. Higher values collected from 1971 to 1973 were taken at a different time of the year.

Fecal coliform counts were of major significance at sites 4 and 11, indicating high concentrations of fecal matter (Fig. 3). Site 4 was located near one of the most dense residential areas on the lake. Thus, the bacteria most likely indicated recent sewage contamination, possibly from poorly maintained septic tanks. Furthermore, site 4 was located in a sheltered cove. Therefore, indicator bacteria may have tended to build up due to the fact that the water in this area is relatively stagnant. This may have created an illusion of heavy sewage input, when perhaps high concentrations were due to an accumulation over time. However, it must be noted that coliform bacteria are not long lived, so that concentrations must be a result of relatively recent activity. Concentrations were high enough to cause a sufficient health risk. Site 11 represented an area of agricultural input. Thus, significant levels of indicator bacteria were most probably due to fecal pollution by manure. The level at site 11 was notably lower than the level at site 4, however, it still represented an important fecal coliform input to the lake. Fecal coliform counts at the other sites had acceptable concentrations of indicator bacteria (according to Greenberg et al., 1985), and thus did not pose as immediate threats.

Total coliform counts were most startling at site 9, while sites 4, 6, and 11 also had notable concentration levels. Site 9 was the area of an inactive poultry farm, and thus still appeared to contribute a substantial amount of fecal pollution. Sites 4, 6, and 11 were of particular interest because the total coliform counts were so high. One explanation for the high counts at these sites was a combination of inputs from enteric sources (e.g., manure) and indigenous plant and soil sources due to heavy soil erosion.

CONCLUSION

In conclusion, temperature and dissolved oxygen profiles suggested that overturn had completely or partially occurred. Low dissolved oxygen levels after overturn supported the fact that eutrophication still poses a threat to China Lake.

Profile and surface samples identified several sensitive areas. The north end of the east basin appeared to be significantly influenced by the older residential area.
This area drains into Hunter Brook, which flows into the lake near the inlet, and is characterized by poor topography, poor soils, a high water column, and poor erosion control management. The more recent residential areas along the central east bank of the east basin did not appear to pose as great a threat to phosphorus loading. The newer residential areas fall short of the grandfather clause excusing much of the older residential areas from proper environmental practices, and must instead deal with current regulations. Perhaps, these regulations for erosion control and building construction have been effective in reducing phosphorus input into China Lake. However, fecal coliform levels, as well as total coliform levels, were found to be significantly high in a cove on the central eastern shore of the east basin surrounded by an area of dominantly newer establishments. These data suggested faulty septic systems, and the accumulation of coliform bacteria due to relatively stagnant water.

Several sites in the west basin also qualified as sensitive areas. Agricultural practices in the watershed along the western shoreline drain into the Cornfield stream, and appear to contribute high concentrations of phosphorus, consistent with tributary findings, and high coliform counts. High inputs of manure and poor erosion control are primary candidates for the high phosphorus concentrations.

Thus, residential and agricultural practices, road design, topography, and bedrock morphology in the watershed all aid in the contribution of phosphorus to China Lake. Through analysis of lake water samples, eutrophication has been found to have significantly increased in the last fifteen years. Thus, in order to rectify this problem, high phosphorus inputs from the watershed and phosphorus recycling within the lake must be eliminated.

TRIBUTARY INTRODUCTION

Tributaries play an important role in the contribution of dissolved phosphorus to the lake proper by carrying phosphorus laden sediments and organic material into the lake. Through reconnaissance and interviews with personnel from the Department of Environmental Protection (DEP) and members of the China Lake
Association, the tributary component of SCOALE selected eight tributaries as potential sites for high phosphorus input into the lake: the three main water sources for the lake (Hunter, Jones, and Starky), three minor streams (Ward, Fire road #1, Statue Brook), and two intermittent streams (Williams and Corn Field). These chosen sites were all exposed to possible problem land use areas of either agriculture, residential development, or topsoil stripping and clearing. As a result, the tributaries were at a risk of increased phosphorus loading into the lake through erosion.

Fifteen sites were chosen along the 8 tributaries to isolate the possible source of increased phosphorus into the lake. Sampling was performed under both normal and storm conditions. During the storm event, continual sampling was performed to determine how increased water flow effected the levels of phosphorus entering the lake.

With information from both the normal condition and the storm event, a clear assessment was made as to the conditions of the tributaries and the amount of phosphorus entering the lake. This assessment, in conjunction with data obtained by other components of SCOALE was used to develop an overall view of the general condition of the lake and possible mitigations to improve the lake's condition.

**Site Description**

From the reconnaissance it was determined that Hunter, Jones, and Starky brooks, the three main water sources into the lake were potentially major sources for phosphorus loading. Hunter, the major inlet of the lake, had several problem areas prone to phosphorus loading due to the proximity of the tributary to agricultural areas and municipal roads. The inlet is fed through Muldoon Pond which is surrounded by wetlands and a farm. From the pond, the water in Hunter runs under the road before entering the lake. Jones has multiple problems upstream. A logging area causes silt to wash down stream and a recent four acre clearing, causes a noticeable plume of sediment to enter the lake. The Starky tributary passes nearby an approximately five acre land fill site and through farm fields.

The two smaller tributaries with possible phosphorus problems were also identified. Statue brook is a smaller tributary but still a year round contributor of water to the lake. Upstream, an old dirt road frequently used by trucks was found. This use has caused gullying and therefore excessive erosion material to enter the
lake. Fire Road 1 was also found to be a possible problem spot. It is a minor tributary but upstream there are several agricultural fields from which sediments wash down this stream. Ward was another tributary found to be a possible problem site. Although not considered a major contributor of water to the lake it has year round flow and has a large input into the lake. It runs under Stanley Hill Road and is surrounded by wetlands and a recently developed residential area. Also found upstream, in Ward, is a horse farm. Williams Brook, an intermittent stream, is adjacent to the lake outlet. It was found to be a possible problem site due to the fact that the source of this brook is a barnyard field which has no containment facilities for manure run-off. The last spot is the corn field on Rt. 32. There is an ephemeral stream carries water here that comes directly off the fields and is active when heavy run off occurs. This stream is suspected to be a major contributor to phosphorus entering the lake.

MATERIALS AND METHODS

From the 8 streams determined to be possible problem sites, a total number of 15 actual sites were chosen to isolate and identify the sources of the problems. Tests were conducted to assay total phosphorus, orthophosphate, nitrate and coliform entering the lake. These parameters are important because they either contribute to the acceleration of eutrophication characterized by the development of lake algal blooms or, as in the case of coliform, identify the possible source of nutrient input. Total phosphorus is the amount of soluble phosphorus and bound to sediment and plant material, and one component of total phosphorus is orthophosphate, the soluble form directly available as a nutrient to plants and algae. Both orthophosphates and total phosphorus are expressed by using the units, parts per billion (ppb). Water discharge--calculated in cubic liters per second (L/s)--was determined as a product of velocity measured by flowmeter and average stream width and depth. In statistical analysis, output was calculated as a product of total phosphorus (ppb), or orthophosphates(ppb) and water flow (L/s). Total and Fecal coliform were tested, as their presence is a good indicator of bacterial contamination. Total coliform is a measure of the presence of pathogenic enteric bacteria and indicates, as well, possible fecal contamination. Fecal coliform represents an
indication of fecal pollution and poor water quality as it is an indicator of bacteria associated with fecal matter from warm blooded organisms. Fecal coliform is not only associated with raw human sewage, but also with manure from agricultural establishments. Nitrates were tested at sites where agricultural pollution was suspected (Appendix II). Agricultural pollution comes from nitrates and orthophosphates found in manure, septic systems and synthetic fertilizers; and these factors are important as they are limiting growth factors for algal populations. Turbidity (FTU), was also determined because suspended solids are an important indication of phosphorus loading. Much of the phosphorus enters the lake in colloidal and soluble form—bound to sediments and plant material. Moreover, the increase in siltation not only may cause phosphorus loading but could disrupt reproduction of fish.

Two sets of samples were collected: one under normal conditions and the other during a storm event. In both normal condition and storm event, the collecting bottle was first rinsed with water from the site to reduce contamination. The samples were collected with the sampling apparatus pointed upstream and then placed in the labeled polypropylene sample bottle. Polypropylene bottles were used to prevent the phosphorus from leaching out of the water. At the sites located at the mouth of the tributaries, a more comprehensive assay was conducted comprising of total phosphorus, orthophosphates, and discharge during both normal and storm event. Samples at the mouth of the tributary were taken where incoming flow was detected to decrease the probability of collecting lake water back flow. At the upstream sites, only samples for orthophosphates and total phosphorus were taken.

During normal conditions, orthophosphate and total phosphorus were tested at all sites. At particular sites, where fecal matter was suspected to be present, coliform and nitrates were sampled (Appendix II). Once collected, samples were preserved by the following standard techniques (APHA, 1975): addition of 2 ml of sulfuric acid to the total phosphorus bottles, filtration of water sampled for orthophosphate through a Whatman No. 2 paper filter, and storage of all bottles at 4°C.

The following is a list of the sites where normal condition testing were performed (Fig. 1) It is important to note that the sites are labeled beginning with A at the mouth and continue through the alphabet moving upstream:

**Normal Condition Test Sites**

1. Jones Brook
Four sites were tested along the Jones tributary. One sample was taken at the mouth 45 meters upstream from Fire Road 53 (site A). Two were taken on Route 3 across from the fire house (sites B and C) where the stream converges. The samples were taken approximately 2 meters from the convergence on each branch. The fourth sample was taken below a farm pond just above site B and C. The samples were taken 150 yards above the convergence (site D).

2. Starky Brook
Two sites were sampled at Starky: One was sampled at the mouth, just below the culvert on the left hand side of Fire Road 51 (site A), and the second was taken approximately 53 meters below the dump (site C).

3. Hunter Brook
Hunter Brook was sampled only at the mouth. It was taken on the left-hand side of Route 202 below the culvert (site A).

4. Statue Brook
Statue was tested also only at the mouth, off Route 202 across from Aubuchon hardware store. The samples were taken on the left-hand side of the road, below the culvert (site A).

5. Fire Road #1 Brook
Fire Road #1 Brook was tested at the mouth off of Fire Road #1. The sample was taken on the right-hand side of the road, below the small shack (site A).

On October 31, 1989, storm event samples were taken in order to obtain data of phosphorus loading during a storm. Weather prior to the storm event had been dry and relatively warm for 10 days. The rain started at approximately 10:10 pm and testing began at 12:00 am. During the storm event, samples were taken at every 30 minutes for five hours (total of eight samples) at the three major tributaries. Five other "spot checks" were conducted at smaller, intermittent streams. The "spot checks" were one time sampling events and were collected when it was established from the major tributaries, that the water levels were peaked. Samples for total phosphorus and orthophosphate were taken and preserved as in the normal condition. Water discharge was continually monitored by measuring the width and average depth of the stream as well as the flow. Before the storm, 10 ft strips along each continuous testing sites were measured and marked with flags. The flow rate was then measured during the storm by timing the number of seconds a 10-12 inch stick moved down the tributary in the predetermined 10 ft strip. The wind, a
potential factor in effecting the flow rate of the stick, was negligible. In calculating the flow rate, a variance factor of 0.8 was multiplied to the flow rate to account for the fact that the measurement of time was taken at the surface of the water (Bruce Rueger, personal communication). The total discharge was then calculated by the equation: average depth x average width x rate of flow x 0.8 (the variance factor - Bruce Rueger, personal communication). Discharge was converted from discharge (cms) to L/s by multiplying the calculation to 28.57. Output of phosphorus from the tributaries was determined by the following equation: ppb (either total phosphorus or orthophosphate) x discharge (cms). The result from the equation was then converted to output in mg/s by the following equation: output (ppb x cms) x 0.02857.

The following are the sites where storm event testings were performed (Fig. 1):

**Storm Event Test Sites**

1. Jones Brook

   Two sites were chosen for testing on Jones: Eight samples were taken at the first site, the mouth site (A, 1-8)*. The second site was a spot check on the south side of Route 3 below Polly's Gym (E).

2. Starky Brook

   Two sites were also chosen for Starky: The first site was the mouth site (A, 1-8). Eight samples were also collected and analysis. The second site was below the road, across from True Value Hardware on Route 202 and only a spot check was performed at this site (B).

3. Hunter Brook

   Tests were performed at two sites on Hunter: Eight samples were collected at the mouth, the first site (A, 1-8). The second site was off of Route 202 by the dairy farm (B). The sample was taken on the left-hand side of the road. A spot check was performed.

4. Williams Brook

   A spot check was performed at the mouth of Williams Brook, located at the boat ramp on Route 32 (A). The sample was taken below the bridge, 6 meters from the lake.

5. Corn Field
A spot check was performed at the edge of the corn field on Route 32 across from the lake site (A). The sample was collected on the right-hand side of the road, between the corn field and the edge of the woods.

* Note that mouth sites were at the same sampling location under both storm and normal conditions.

Total Phosphorus and orthophosphate were determined using the DR/3000 spectrophotometer. (Hach Company, 1986). Total phosphorus was digested and both total phosphorus and orthophosphate were then prepared for colorimetric analysis according to the DR/3000 spectrophotometer manual (Hach Company, 1986). In the analysis of orthophosphates and total phosphorus, water blanks, spiked samples, and repetitive sampling was used to determine the margin of error. (In a spike sample, 0.1 ml of phosphate were added to a collected sample that had been analyzed and re-analyzed. A correct spiked sample should be close to 30 ppb above the amount of phosphorus determined from the first analysis.) Nitrates and turbidity were tested using the DR/3000 spectrophotometer manual for low range nitrates and turbidity, respectively (Hach Company 1986). Coliform determinations were performed for total coliform and fecal coliform according to standard procedures for the membrane filtration techniques. (APHA, 1975).

A total of six analyses were performed for coliform. Coliform were prepared for analysis according to standard aseptic techniques (Greenberg, 1985). For the three total coliform assays, desiccated Endo media was used on absorbant pads and placed in petri dishes. 2 ml of sterile deionized water were added to the pad. A volume of 10 ml of water sample was filtered through a 0.45µm membrane filter under vacuum. The membrane was then placed in the petri dish in contact with the medium. The dishes were then sealed and incubated at 37°C. After 24 hours, the petri dishes were removed and counted. The coliform colonies were distinguished by their pink to dark red pigmentation with a green metallic sheen. The procedure for fecal coliform determination preparation was similar to that for total coliform. The medium used was desiccated mFC impregnated on to the nutrient pad. After preparation and filtering, the dishes were incubated for 22 hours at 44.5°C. After removal from incubation, the blue fecal coliform colonies were counted.
RESULTS

Normal Conditions

Jones site B had the highest concentrations of total phosphorus of all sites tested in normal conditions, and Fire Road 1 had the lowest levels of total phosphorus and orthophosphates (Table 4). While Starky total phosphorus concentrations are the lowest of the three major tributaries tested (Jones, Starky, Hunter), this tributary had the highest discharge levels of all the tributaries tested. It follows that the highest output (mg/s) was at Starky, where an output of 3.81 mg/s of total phosphorus was found under normal conditions (Fig. 8). Actual output of total phosphorus as measured in milligrams per second was lowest at the mouths of Jones and Fire Rd 1 showing values of 0.062 mg/s and 0.065 mg/s respectively.

Turbidity (FTUs) levels measured at the mouths of Jones, Starky, Statue, Hunter and Fire Road 1 indicate a general pattern of higher turbidity levels corresponding with higher concentrations of total phosphorus (Table 4). The highest levels of turbidity were observed at Statue brook, and the highest levels of total phosphorus were at Hunter which was also highly turbid.

Coliform values from samples collected under normal conditions revealed the presence of moderate concentrations of coliform in some of the tributaries tested. Fecal coliform at Jones Brook mouth, was 30 colonies/100 ml and total coliform was 110 colonies/100 ml. Hunter had no detectable fecal coliform and a total coliform count of 80 colonies/100 ml. Samples from Ward had fecal coliform
TABLE 4: Total phosphorus and orthophosphate concentrations (ppb), turbidity in (FTDs), and discharge (liters per second) for major tributary sites within the China Lake watershed, sampled under normal condition.

<table>
<thead>
<tr>
<th>Normal Sites</th>
<th>Total Phosphorus (ppb)</th>
<th>Orthophosphate (ppb)</th>
<th>Turbidity (FTUs)</th>
<th>Discharge (liters/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones A</td>
<td>30</td>
<td>13</td>
<td>2</td>
<td>2.07</td>
</tr>
<tr>
<td>B</td>
<td>72</td>
<td>52</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>C</td>
<td>46</td>
<td>12</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>D</td>
<td>33</td>
<td>11</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Starky A</td>
<td>53</td>
<td>16</td>
<td>8</td>
<td>71.43</td>
</tr>
<tr>
<td>B</td>
<td>41</td>
<td>10</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Statue A</td>
<td>51</td>
<td>9</td>
<td>12</td>
<td>4.57</td>
</tr>
<tr>
<td>Hunter A</td>
<td>61</td>
<td>7</td>
<td>5</td>
<td>54.85</td>
</tr>
<tr>
<td>Fire Rd 1 A</td>
<td>17</td>
<td>4</td>
<td>1</td>
<td>3.89</td>
</tr>
<tr>
<td>Ward B</td>
<td>37</td>
<td>73</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

TABLE 5: Nitrate concentrations (ppb), sampled at the mouths of five major tributaries of the China Lake watershed, under normal conditions.

<table>
<thead>
<tr>
<th>Normal Sites</th>
<th>Nitrates (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones A</td>
<td>80</td>
</tr>
<tr>
<td>Starky A</td>
<td>90</td>
</tr>
<tr>
<td>Statue A</td>
<td>20</td>
</tr>
<tr>
<td>Hunter A</td>
<td>170</td>
</tr>
<tr>
<td>Fire Rd 1A</td>
<td>30</td>
</tr>
</tbody>
</table>
Fig. 8. Output (mg/L) of total phosphorus and orthophosphates in normal conditions and at the peak of the storm event for the three major tributaries of China Lake.
level of .30 colonies/100 ml and a total coliform level of 150 colonies/100 ml. Nitrates were also analyzed under normal conditions. The highest concentrations were observed at the mouth of Hunter while the lowest concentrations were found at Fire Rd 1. Fluctuations in nitrate concentrations do not seem to correlate with fluctuations in phosphorus concentrations (Table 5).

Storm Event

During the storm event, discharge levels at all tributaries increased, peaked and decreased. The samples seemed fairly turbid with a yellow cloudy appearance. Change in total phosphorus concentrations at Jones, Starky, and Hunter, over the continuous sampling period indicated that Hunter and Jones peaked earlier while Starky peaked last (Fig. 9). The orthophosphate concentrations do not show evident peaks and are considerably lower than the total phosphorus concentrations.

The figures comparing total phosphorus and orthophosphate concentrations against discharge indicate that Jones peaked at a lower discharge level, followed by Hunter and then Starky (Fig. 10). Jones total phosphorus peaked sharply as discharge increased; and the orthophosphate concentrations increased gradually as discharge increased. Starky total phosphorus concentrations also peaked early, with orthophosphate concentrations increasing more gradually. Total phosphorus concentrations at Hunter peaked much later at higher discharge level. Orthophosphates changed only slightly as discharge increased over time. Discharge curves do not significantly follow changes in phosphorus concentrations (Fig. 10), although general increases in discharge do positively effect the output of total phosphorus until the peak. Output of total phosphorus in mg/s during a storm event was markedly higher than total phosphorus output under normal conditions (Fig. 8).

Output levels (mg/s) measured against time at Jones, Starky and Hunter indicate peaks in Hunter and Starky approximately one hour and a half after testing began, while output levels increased throughout the testing period for both total and orthophosphates (Fig. 11). At Jones and Hunter, total phosphorus output curves peaked concurrently with orthophosphate output curves. The orthophosphate curve at Starky, however, still has a positive slope at the end of the sampling curve indicating that the peak has not yet occurred, whereas the total phosphorus curve seems to have peaked 100 minutes prior to termination of sampling.
Fig. 9. Comparison of total phosphorus and orthophosphate over time at the mouth of three major tributaries of China Lake during storm event.
FIG. 10. Comparison of total phosphorus relative to the flow in three major tributaries of China Lake.
Samples gathered during storm event testing were split and samples at each
tributary were analyzed also at the DEP laboratory. Data from the DEP and SCOALE
are compared in Table 6. From this table it can be seen that the total phosphorus
levels analyzed by the DEP vary from 26 ppb at Starky mouth to 1800 ppb at the base
of the corn field. SCOALE's total phosphorus concentrations ranged from 47 ppb at
Hunter mouth to 6183 ppb at the corn field. In all cases phosphorus concentrations
during the storm samples were comparatively larger than those sampled under
normal conditions.

Comparison of Normal Conditions to Storm Event

Silt particles were observed forming plumes in all tributaries during the
storm event and it was also observed that the samples were more turbid and had a
darker yellow coloration, than those sampled under normal conditions. Increased
phosphorus values were also found. The average total phosphorus values (ppb)
were higher at the mouths of the three major tributaries (Jones, Starky, and Hunter),
respectively, during the storm event than total phosphorus values from the
samples taken under normal conditions (Tables 4 and 6). Maximum output of total
phosphorus and orthophosphates as compared to normal conditions of these
tributaries revealed overall, that Starky had the largest output of both total
phosphates and orthophosphates and Jones had the lowest (Fig. 8). At Jones Brook
normal event total phosphorus was half the storm event value. At Starky Brook,
the normal event total phosphorus was 12% lower than during the storm event.
However, total phosphorus at Hunter was found to be 33% greater in the normal
event sample than during the storm sample. Orthophosphate output values were
greater at all three mouth sites during the storm event than during the times of
normal sampling. Jones, Starky, and Hunter revealed 1 mg/s, 14 mg/s, and 2.5
mg/s, respectively (Fig. 8).

Historical Perspective

Many tributaries in China Lake have been historically important as breeding
grounds and nurseries for fish. Jones, a spring fed cold water stream, was known
historically as a good breeding habitat for brown trout. Trout had been found
spawning in the brook as far up as the gravel pits located approximately 1.25 km
from the mouth. Approximately 6 to 7 years ago tests were performed on this
tributary to determine the condition of the stream. It was found that the brook
appeared clear; the rocks and water were relatively clean and there was good
Fig. 11. Comparison of output (mg/s) for total phosphorus and orthophosphates in three main tributaries of China lake throughout storm event.
TABLE 6: SCOALE and DEP total phosphorus values for tributary sites in the China Lake watersheds, during a storm event.

<table>
<thead>
<tr>
<th>Site</th>
<th>Time (min)</th>
<th>SCOALE total P (ppb)</th>
<th>DEP total P (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starky A</td>
<td>120</td>
<td>60</td>
<td>26</td>
</tr>
<tr>
<td>Jones E</td>
<td>150</td>
<td>66</td>
<td>98</td>
</tr>
<tr>
<td>Hunter B</td>
<td>150</td>
<td>198</td>
<td>51</td>
</tr>
<tr>
<td>Jones A</td>
<td>180</td>
<td>67</td>
<td>91</td>
</tr>
<tr>
<td>Hunter A</td>
<td>180</td>
<td>47</td>
<td>27</td>
</tr>
<tr>
<td>Corn Fields A</td>
<td>180</td>
<td>6183</td>
<td>1800</td>
</tr>
<tr>
<td>Williams A</td>
<td>210</td>
<td>883</td>
<td>150</td>
</tr>
<tr>
<td>Starky C</td>
<td>270</td>
<td>62</td>
<td>38</td>
</tr>
</tbody>
</table>
breeding potential in this area (Autopsy of a Brook, 1987). More recent studies have shown a great change, and in recent years, the numbers of brown trout fry and spawning fish has greatly decreased (Roland Tilton personal communication). A study conducted in the summer of 1986 indicated heavy siltation in the brook. Turbid water and plumes from silt, were apparent as far as 90 meters into the lake (Autopsy of a Brook, 1987). It can be assumed that phosphorus levels also increased as a result of stirred sediments releasing phosphorus back into the water column. Siltation also disrupts the reproductive cycle of fish, by killing the eggs once laid. Currently, siltation is still occurring in Jones and brown trout levels are still low (Roland Tilton, personal communication). Jones Brook was the only tributary in China Lake which has been studied in depth but may be used as a model for other tributaries in the watershed with respect to fish population declines. Ward Brook was also an important breeding area for togué and brown trout, which is now inactive (Roland Tilton, personal communication).

Previous studies were also conducted to determine the level of phosphorus entering the lake by the tributaries and to rank the tributaries in terms of contribution of phosphorus to the lake. In studies performed between June of 1984 and October 1985 twenty six areas within the watershed were sampled. Of these, 16 had a mean runoff concentration of more than 100 ppb total phosphorus (DEP Grant Proposal, 1989). The highest values were from residential, agricultural and stream bank erosion areas. The lowest values were from wooded areas (DEP Grant Proposal, 1989).

In this study by the DEP, a storm event analysis was also conducted. In general, a drastic increase in phosphorus concentrations was found from normal condition to storm event, seen by a general increase of 15-100 ppb to higher levels of 200-7000 ppb (DEP Grant Proposal, 1989). This study also determined that topsoil disturbances which have no effect during dry season increase total phosphorus levels during storm events and during the spring thaw. Another study, found that a majority of total phosphorus carried into the lake was found in colloidal form (Thurbow, 1975). Colloidal forms of phosphorus were attached to silt in the suspended load and normally carried into the lake body when the discharge rate of the tributary is high. Therefore, the peak-discharge periods associated with storm events are the times when most phosphorus will be transported (Porter 1975).
DISCUSSION

Normal Condition

Total phosphorus at Jones brook was higher at sites B and C than at the other sites on the tributary. A paved parking lot lies above site B (Fig. 1), where a significant amount of runoff can be expected to occur. The pavement is an impenetrable substrate to nutrient loaded water, and runoff may have occurred, carrying high amounts of colloidal phosphorus, phosphorus from the sealers often used in pavements, and any organic phosphates into the lake. Analyses of sites D and C were conducted in order to isolate a timber harvest area through which the tributary runs. On observation, the water was silty and exposed soils on the banks of the stream were visible upstream from the testing sites. The values of orthophosphate at both sites were relatively equal, but the total phosphorus concentrations were 1.4 times higher at site C than at site D. This suggests significant erosion—which contributes to total phosphorus levels—is occurring in the branch of the tributary above site C. It might be expected that the total phosphorus concentration at the mouth would be higher considering the levels were significantly high upstream, but as a lower flow rate was observed at the mouth, suspended particles may have been settling to the bottom, and therefore were not collected in the water sample. Overall, Jones Brook did not seem to be a major source for phosphorus loading.

Total phosphorus at sites A and C on Starky Brook were three and four times higher than orthophosphate concentration at each site, respectively. Due to erosion which may have been occurring above each site, high concentrations of sediment in the water may have contributed to total phosphorus concentrations. The valley through which this tributary flows is particularly steep, and high erosional areas are commonly associated with this geographic characteristic. In addition to high levels of total phosphorus, a high discharge rate at this tributary allows output (mg/s) to be considerably higher than the other two major tributaries (Fig. 8). These levels of output suggest that Starky was the tributary contributing the most phosphorus into the lake at the times of testing, both under normal and storm conditions.

Total phosphorus levels at Statue brook also suggest high concentrations of sediment in the water which may have been caused by erosion occurring upstream. The dirt road adjacent to the tributary has caused a considerable amount of problems with sediment loading in the past, with several inches of sediment often occurring
on the frozen lake in winter (Tilton, pers. comm.). There continues to be a problem with phosphorus loading from this tributary despite the fact that erosion preventive structures such as waterbars and felled trees have been installed over the road to both reduce erosion and discourage traffic of all terrain vehicle.

While erosion prone areas aggravate the phosphorus problem, undisturbed wetlands are important in helping to decrease phosphorus loading. In the event that a tributary flows through a wetland, water flow rate will decrease, causing sediments to settle out of the water column; and macrophytes native to the habitat may take up soluble phosphorus in the water. Hunter brook flows though wetlands immediately prior to site A, and it was therefore expected that phosphorus concentrations would be low at this site. However, phosphorus values were still considerably high as compared to the other major tributary mouth sites. This may have been due, in part, to runoff from the road that runs over the culvert from which the samples were taken, and also to a dairy farm that is upstream from the test site. In addition, phosphorus loading above the wetlands may have been severe, allowing the wetlands to only mildly buffer the overall concentrations. It was also found that the nitrate concentrations at Hunter were the highest of all areas sampled for nitrates, perhaps due to the dairy farm off of Route 202.

Fire Road 1 was low in both total phosphorus and orthophosphates in comparison to the other tributaries, and the total phosphorus was five times higher than the orthophosphates. Higher concentrations of total phosphorus may be due to agricultural activity upstream. In addition to a dirt road adjacent to the test site, a large area of corn fields, hay fields, and pasture were observed upstream from the test site (Appendix IV).

No conclusive evidence was determined for Ward brook phosphorus levels, except that the orthophosphate concentrations were similar to those of the other tributaries. Ward brook is located very close to a state road and may have been partially affected by runoff in this area. Horse farms located upstream may also be problematic.

Increased turbidity is usually indicative of increased phosphorus levels (Table 4). This relationship is well illustrated in streams such as Starky and Statue that are in erosion prone areas, where turbidity levels are expected to be high.

The highest total coliform values, which occurred at Ward brook, may have been due to the horse farm that is upstream from the testing site. Fecal coliform counts were equal at Jones and Ward and suggest that these two tributaries have equivalent coliform loading sources.
The high nitrate concentration at Hunter suggests a considerable amount of agricultural pollution was coming from the several farms that this tributary runs through (Table 5).

**Storm Event**

A peak of phosphorus loading in the tributaries will occur normally during a storm event due to flushing action of the rain. Erosion may increase as a result of the rain, and consequently we expected a potential peak in total phosphorus levels. Peaks occurred in the three major streams where a sustained storm event sampling was conducted; and the peaks in orthophosphate were less significant than those for total phosphorus.

Concentrations of total phosphorus in Hunter were the first to peak of the three tributaries, and this may be due to the fact that samples were taken next to Route 202, where run off would immediately occur. Precipitation was very heavy during the first three hours of the storm, and since there had been no rain for 10 days prior to the storm event, there may have been more soluble phosphorus in the water, and an accumulation of sediments on the roads and surrounding vegetation that was washed into the tributary as the rainfall began. Hunter has historically peaked later than the other tributaries (Bouchard, pers. comm.), and it may be due to the excessive rainfall early in the storm or preceding weather conditions that caused it to peak early. Hunter runs through many acres of wetlands, and the colloidal phosphorus that may normally settle out in this environment may have been disturbed by rain and increased flow, resulting in an increased number of particulates into the water. It is also possible that the recorded peak may have only been the first of multiple peaks, with a major peak occurring after testing was concluded.

The greatest concentration of total phosphorus in Jones brook occurred approximately two hours after testing began (Fig. 9). This peak may have come from erosion upstream, cleared land above site C, and the parking lot near site B. Starky peaked last of the tributaries at approximately three hours after testing began (Fig. 9). Under normal conditions, the flow rate where Starky ran though the dump was extremely low and almost negligible; and it may have taken a significant amount of rainfall for flow at site C to be significant enough to affect the levels at the mouth of the tributary. Under normal conditions this site on the tributary had very high total phosphorus levels and was very turbid; therefore, it is possible that concentrations were also high during the storm events.
A statistical analysis that examined the correlation of phosphorus concentrations and progression of time showed there was a statistically significant correlation, although it was not high. It is therefore difficult to ascertain the significance of minor fluctuations in the phosphorus peaks during the storm event. Differences may be due to variance in sampling techniques or testing procedures, and not completely representative of actual concentrations in the tributaries. In addition, the margin of error when measuring concentrations in parts per billion may be significant. Clearly, more data points are needed to obtain a high significant correlation between time and phosphorus concentration and for peaks to be readily evident in the figures.

Statistical analysis of discharge and phosphorus showed there was no significant correlation between discharge and levels of phosphorus. Although it has been stated that the most transport of colloidal phosphorus occurs during peak discharge periods (Porter, 1975), our data showed no evidence of this. In theory this statement may appear true, and although the transport capacity may be greater at peak discharge periods, in practice, the levels of colloidal phosphorus may not necessarily correlate directly to discharge levels. An increased water flow by direct rainfall and/or runoff does not necessarily mean that erosion is occurring at the same rates of increase. If in fact there is increased erosion, it may not be detectable because of the potential dilution factor of significantly increased discharge. In addition, sediments in the water may increase even if the width or depth do not change, and rate does. An increased rate of flow may cause more turbulence of the stream bed, so that sediments could potentially be uplifted and transported into the lake. However, if the width and depth did increase, the rate would not increase proportionately to yield the same value of discharge, and disturbance of the sediments may not occur. It is possible that erosion would occur on the banks, but at Hunter, the part of the tributary before the test site is a wetlands, so although the water levels rise and spread, erosion should not occur. In addition, the test site was located in a culvert, and as water level increased erosion did not occur, because there was no soil at this particular site. Despite the variabilities that can occur to alter the correlation between discharge and phosphorus levels, it is possible more data points are needed for significance of correlation to be evident.

Output of total phosphorus and orthophosphates were markedly higher during the storm events. This could have been expected because the increase in discharge was due to increased runoff. Increased output is a possible result of the release of phosphorus from soil and road runoff (Fig. 8 and 11). The output of
phosphorus (mg/s) in Starky was the greatest of all three major tributaries under storm and normal conditions. This is an important observation, as the outputs during spring runoff may be dramatically increased at this site. The slope of the banks to Starky are particularly steep and there are two major roads which cross this tributary, with hay and cornfields also draining into the tributary upstream (Impact of Roads). This site is potentially sensitive to erosional stresses. Although Hunter is the largest tributary in terms of drainage area (Appendix IV), the output values are approximately half of those at Starky, and this may be due to the large area of wetlands that Hunter runs through which soak up the nutrients and excess phosphorus.

Spot checks during the storm event began after the average peak time for the three sustained storm event samplings. The total phosphorus values were in the same range as those found at the major tributary mouths (Table 6). The exceptionally high values occurred at the ephemeral tributary by the corn field, where total phosphorus values were 6183 ppb. However, this water was very silty and high levels of phosphorus would be expected because the tributary directly drains from this agricultural site. More testing must be done in this area in order to accurately assess the actual contributions of this site to the overall phosphorus loading in the lake.

The Jones brook spot check value for total phosphorus was 20 ppb lower than the peak value at the mouth. This value indicates that there may have been excessive sedimentation of the water that may have been occurring downstream from site E. At the time of testing, this check did not suggest a problem with a recently built pond adjacent to the tributary off of Route 3.

Spot check total phosphorus values at Starky were relatively close to those values at the mouth. The spot check, taken at four and a half hours after the first sample had been taken, was the last sample collected in the storm event. As stated earlier, the effects of phosphorus loading from site C may have taken longer to show at mouth sites; and as site B is near the mouth it could be expected that concentrations would have been high at the time it was taken. Had this sample been collected early in the storm total phosphorus concentrations may have been lower. However, as this site was between Route 202 and a gravel parking lot, levels may have been high throughout the storm event due to continual runoff from these sites. More sampling should be conducted to assess the significance of these values.
The total phosphorus values at Hunter, Williams and Corn Field tributary were significantly high. These tributaries pass through agricultural areas, and, in addition, Hunter and Williams pass under roads directly above the spot check sites. It is possible, again, to attribute the high phosphorus levels to erosional circumstances due to agricultural fields and road runoff. The concentrations were expected to be high, however, but cannot be conclusively analyzed.

When samples were collected at the Corn Field tributary, water was running under the grasses at the edges of the field, and it may be possible that a vegetative strip in this area would help to decrease ephemeral runoff. From observation it seemed that water easily eroded a stream through the roots of the grasses, and if vegetation with more substantial roots systems were planted, that erosion would be potentially decreased.

In comparing total phosphorus data of the storm sampling to the data from the DEP, several similarities were found (Table 6). The general trend of the both sets of data were the same. The major differences in the data were found in tributaries with higher phosphorus concentrations. These differences could have been due to several factors. First, the two samples were prepared differently. SCOALE samples were treated in the field with sulfuric acid whereas the DEP samples were not treated. Secondly, the digestion procedure was also different. SCOALE samples were analyzed within the 24 hours as suggested by the HACH spectrophotometer procedure manual, whereas DEP samples were not treated for at least a week.

**SUMMARY**

Tributaries are an important source of phosphorus loading into the lake. It is evident that tributaries most vulnerable to phosphorus loading are those that run near farmlands, roads and residential areas, and these problems are most apparent during storm event when runoff is increased. It is important to note that run off during the storm event is comparable to spring conditions. In the spring season there is considerable runoff from melting snow and that most ephemeral tributaries are active at this time. Therefore, most potential for phosphorus loading occurs during the spring, and testing conducted during these months would be indicative of the extent of the phosphorus loading problem.
Starky brook was the tributary with the highest amount of output, thereby being the most sensitive site during the time when this sampling was conducted. It may be an area in which outputs are high year-round, and would therefore be an important tributary to monitor. Although Hunter is the major inlet to the lake, it did not have as high phosphorus concentrations as Starky. This does not suggest that Hunter is not a sensitive site to phosphorus loading. However, this tributary runs through many acres of wetlands, and these wetlands may be significant in acting as a buffer for the phosphorus levels in Hunter. It is important to recognize the value of the wetlands as natural controls to phosphorus loading, and to maintain and protect these areas from development and phosphorus loading.

The importance of the storm event spot checks lies in the fact that the values may be indicative of consistently high values, in which case measures may need to be taken to amend the possible problems at certain sites. In cases such as the Corn Field tributary, the values are extremely high, and during spring run off this ephemeral tributary may contribute significant phosphorus concentrations to the lake body. Tributaries such as Williams brook may well illustrate the problems associated with tributaries that run under roads.

More research needs to be conducted in order to completely assess the most problematic sites, and where initial action is most important, but from this research it is evident that problems do exist.

THE EFFECT OF LAND USE ON THE PHOSPHORUS LOADING OF CHINA LAKE

INTRODUCTION

Eutrophication of a lake ecosystems is often accelerated when increased amounts of phosphorus enter the lake. Phosphorus is attached to soil particles and can be dissolved into water from soil when erosion or runoff occurs. Different land use practices disturb the soil to different degrees, resulting in varying amounts of erosion and runoff, and are sources of phosphorus loading into the lake. The area of land devoted to specific land use practices within the watershed of the lake, as well as the rate of phosphorus loading contributed by each land use category are important factors to consider when trying to control accelerated eutrophication.
This project compares the phosphorus loading from the China Lake watershed due to five different land use categories between 1965 and 1985. The historical patterns of trends that were discovered from the comparison, were used to make recommendations for existing land use practices as well as future development in the China Lake watershed to help minimize phosphorus loading into China Lake.

**MATERIALS AND METHODS**

**Phosphorus Loading Inventory for the China Lake Watershed**

A topographical map of the China Lake region, containing the watershed divided into the seven sections used by the Phosphorus Fact Finding Committee (Fig. 14), was obtained. The same watershed divisions were used so that the reader can compare the results of this project with that of the Phosphorus Fact Finding Committee. We used 61 cm x 61 cm ("24 x 24") 1965 and 1980 aerial photographs from the United States Department of Agriculture (USDA), and 22.9 cm x 22.9 cm (9" x 9") 1985 aerial photographs from James Sewall Company, Old Town, Maine.

On the 1965 aerial photographs, the agricultural areas, residential practices (shoreline and inland), roads (state, municipal, private and fire roads), reverting agricultural lands (fields released from agricultural use undergoing natural successional changes), forests, wetlands and small water bodies were identified through examination of patterns of vegetation. These land use practices were confirmed with the use of a dissecting microscope when necessary. On the 1985 aerial photographs, the land use practices were additionally confirmed through field reconnaissance and maps from the Soil Conservation Service (SCS). The better resolution of the 1985 aerial photographs made it possible to further break down total agriculture into the three types found within the China Lake watershed: corn fields, hay fields, and pastures.
IG. 14. The China Lake watershed divided into the seven sections (Phosphorus Fact Finding Project) that were used to identify land use practices. Cross-hatched sections indicate aerial photographs not available for 1965. Double cross-hatched sections indicate aerial photographs not available for 1985.
The scale of the 1985 aerial photographs was determined by measuring the length of a large chicken barn in the field and measuring the same barn on the aerial photograph and comparing the two values. The scale (1:12,000) was determined by the ratio of these two lengths and was approximately equal to the scale obtained by the James Sewall Company. Scales for the 1965 (1:8,070) and 1980 (1:16,450) aerial photographs were determined by measuring a length along the border of China Lake on the 1985 aerial photographs and the same length of the lake on the 1965 and 1980 aerial photographs. The ratio of the lengths in 1965 and 1980 were used to produce the scales for the two aerial photographs.

Areas for each of the categories were measured within each section using a Zeiss Interactive Digital Analysis System (ZIDAS). ZIDAS is a versatile image analysis system that derives areas, as well as other measurements, from images traced on a digitizing tablet. The photographs were put together by section in order to be small enough to maneuver on the ZIDAS. A piece of mylar was placed over each section, and the section boundaries were drawn with reference to the topographical map. Fields and wetland areas were also outlined in order to trace the areas with the ZIDAS.

**Land Use Patterns for the China Lake Watershed**

The areas of the wetlands and small water bodies of three sections were measured from both the 1965 and 1985 aerial photographs. The areas were found to remain virtually constant in both years. Because there did not appear to be any construction on or filling in of the wetlands or small water bodies in any sections of the watershed when comparing the aerial photographs of 1965 and 1985, these areas were assumed to remain constant. The wetlands and small water bodies were measured from the photographs of the year in which they were best depicted.

All agricultural practices were grouped together under the category total agriculture in the 1965 data because poor resolution of the 1965 aerial photographs made it difficult to determine the specific agricultural practices occurring in each field of those photographs. The categories measured were the total area of agricultural land, reverting fields, the length of roads and the number of residences within the China Lake watershed. A scale of 100 ha = 153.5 cm² (determined from the scale of the 1965 photograph) was used with the ZIDAS to calculate areas of total agriculture and reverting fields by section. The number of houses (shoreline and inland dwellings) was determined by counting visible houses on the photograph.
using a dissecting microscope when necessary and was then converted to residential area using the DEP average of 0.2 hectares per dwelling (Bouchard, 1989). The length of the roads (state, municipal, and fire) was determined for each section using a map scaling wheel and was converted to area using the DEP width constants of 15.24 m (50 ft) for state and municipal roads and 7.62 m (25 ft) for private roads (Lowell, 1987). Finally, all the measured land use categories were subtracted from the total area of each section to give the total forested area per section in 1965. A density index of shoreline residential development was prepared from the photographs by dividing the number of shoreline homes in each section by the kilometers of shoreline road.

A similar procedure was used with the 1985 aerial photographs with several changes. The scale used in the ZIDAS was 100 ha=69.4 cm². The clearer resolution of the 1985 aerial photographs made it possible to distinguish separate areas of corn fields, hay fields and pastures. Because the set of 1985 photographs only included the part of the watershed area that was in the Town of China, large portions of sections 2 and 3 located in Vassalboro were not available for analysis. The 1980 aerial photographs were compared with the 1985 photograph in sections where both were available. The differences noted were minimal, so the 1980 aerial photographs were used to replace the 1985 photographs for the parts of those sections that were unavailable. The 1980 scale used in the ZIDAS was 100 ha=37.0 cm².

The percentages of the China Lake watershed devoted to each land use category (e.g. agriculture, roads) were calculated from the area values for each individual section. General historical trends were determined for the watershed from the comparison between 1965 and 1985.

**Phosphorus Loading Inventory for the China Lake Watershed**

The impact of each land use category for each section, 1965 and 1985, was numerically estimated by calculating the amount of phosphorus loaded into China Lake as a result of each land use practice. Areas of each land use category in hectares were multiplied by their respective phosphorus loading coefficients (Table 11). This gave the estimated amount of phosphorus loaded into China Lake from the different land use categories per year. The phosphorus loading coefficient for total agriculture in 1965 was computed as the average of the hay fields and pasture coefficient, 1.0 kg/ha/yr, and of the rowcrop coefficient, 1.5 kg/ha/yr. Because hay fields and pasture together, and cornfields each made up approximately one-half of the total agriculture in 1985, we assumed the proportions were similar in 1965,
which enabled us to use this average of 1.25 kg/ha/yr as a coefficient for total agriculture. Sections 4 and 5 on the aerial photographs were not complete, and because of this, total phosphorus loading estimates for these two sections in 1965 could not be calculated. Approximately one-half of each of these sections was available and they were visually compared to the corresponding areas on the 1985 photos. The impact of the phosphorus loading of the entire watershed into China Lake by different land use categories was compared between 1965 and 1985 (not including sections 4 and 5).

**Land Use Overlay**

In order to demonstrate the importance of land use on the phosphorus loading of China Lake, an overlay was prepared. A topographical map was enlarged (using a photocopying machine) to a scale of 1:12,000 equalling the approximate scale of the 1985 aerial photographs. China Lake, the boundary of the China Lake watershed and the seven sections of the watershed used by the China Lake Association's Phosphorus Fact Finding Project were transferred from the topographical map by tracing on to a piece of mylar. The mylar was moved to the 1985 aerial photograph base map and the land use practices were traced from the aerial photographs. Slight changes in the scales of the individual photographs resulted in difficulty in putting together the base map. In order to account for this, the outline of the lake traced on the mylar was adjusted to fit the border of the lake near the area being traced. Agricultural lands (individually identified as corn fields, hay fields and pastures), reverting fields, and residential areas were transferred onto the mylar. The land use categories were labelled with contrasting colors. Very light colors and hash marks were used so that the topographical map could be read while underneath the overlay.

**RESULTS**

Land Use Patterns for the China Lake Watershed
The area (determined through the ZIDAS) computed for the total watershed was 7043 hectares. The total watershed area minus sections 4 and 5 was 5772 hectares. The DEP area for the total watershed was found to be 7042 ha (Bouchard, 1989). The total area within each section and the land use categories of wetlands, and small water bodies were assumed to remain constant between 1965 and 1985. The land use categories that were determined to change over the time period were agriculture, residential, reverting agriculture, forest, and roads. Wetlands and small water bodies make up only 8.5% of the China Lake watershed, ranging from 2% of the total section area in section 5 to 12% of the total area in section 6 (Table 7). The land use patterns within the seven sections of the watershed varied (Fig. 14). Sections 1, 2, and 4 were the smallest sections and were similar in size, 497 ha, 573 ha, and 426 ha respectively. Section 5 was intermediate in size (845 ha), and sections 3 and 7 were large, both approximately 1300 ha. The largest section was section 6 (2120 ha) (Table 7).

**Analysis of Historic Land Use Trends**

Land use patterns changed between the years 1965 and 1985. These changes were consistent within each section and for the total watershed. Agriculture decreased during the twenty year period and every other land use category (residential land, reverting agricultural land, forested land, and roads) increased. There was an increase in the total watershed devoted to residences (96 ha), reverting agricultural lands (54 ha), forest (352 ha), and roads (7 ha) between 1965 and 1985 (Table 8). The only land use area that decreased from 1965 to 1985 was the total agricultural area (568 ha). Percentage of land use for the total watershed area highlights these historical land use trends. The total residential area increased from 1.3% to 3.0%, while total agricultural areas decreased from 24.1% to 15.3% (Fig. 15).

The percentage of residential land increased between 1965 and 1985 in every section, ranging from a high of a 1.2% to 5.2% increase in section 7 to lows of a 0.8% to 1.4% increase in section 6 and a 2.3% to 2.9% increase in section 2(Fig. 16). Also, even though the data were not available for comparison in sections 4 and 5 in 1965,
<table>
<thead>
<tr>
<th>SECTIONS</th>
<th>TOTAL AREA (ha)</th>
<th>WETLANDS (ha)</th>
<th>SMALL WATER BODIES (ha)</th>
<th>AREA OF WETLANDS AND WATER BODIES (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>0</td>
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</tr>
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<td>4.0</td>
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<tr>
<td>5</td>
<td>845</td>
<td>12</td>
<td>4</td>
<td>1.9</td>
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<tr>
<td>6</td>
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<td>236</td>
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<td>7</td>
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<td>109</td>
<td>0</td>
<td>8.5</td>
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</table>
## TABLE 8: Comparison of Land Use Practices Within the China Lake Watershed Between 1965 and 1985

<table>
<thead>
<tr>
<th>Section</th>
<th>Total Area (ha)</th>
<th>Residential (ha)</th>
<th>Total Agric (ha)</th>
<th>Reverting Agric (ha)</th>
<th>Forested Area (ha)</th>
<th>Roads (ha)</th>
</tr>
</thead>
<tbody>
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<td>160</td>
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<td>291</td>
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<td>623</td>
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</tr>
<tr>
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<td>321</td>
<td>25</td>
<td>1476</td>
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</tr>
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<td>16</td>
<td>314</td>
<td>34</td>
<td>773</td>
<td>30.2</td>
</tr>
<tr>
<td>Total</td>
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<td>77</td>
<td>1390</td>
<td>116</td>
<td>3595</td>
<td>95.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>Total Area (ha)</th>
<th>Residential (ha)</th>
<th>Total Agric (ha)</th>
<th>Reverting Agric (ha)</th>
<th>Forested Area (ha)</th>
<th>Roads (ha)</th>
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</thead>
<tbody>
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<td>131</td>
<td>19</td>
<td>298</td>
<td>6.8</td>
</tr>
<tr>
<td>2</td>
<td>573</td>
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<td>86</td>
<td>11</td>
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<td>845</td>
<td>45</td>
<td>129</td>
<td>12</td>
<td>626</td>
<td>17.2</td>
</tr>
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<td>200</td>
<td>22</td>
<td>1587</td>
<td>31.5</td>
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<tr>
<td>7</td>
<td>1276</td>
<td>66</td>
<td>226</td>
<td>55</td>
<td>788</td>
<td>32.3</td>
</tr>
<tr>
<td>Total</td>
<td>7043</td>
<td>252</td>
<td>1103</td>
<td>189</td>
<td>4837</td>
<td>131.0</td>
</tr>
</tbody>
</table>

Total - 4,527,800
FIG. 15. The percentage of land use of the China Lake watershed. Sections 4 and 5 were deleted in 1985 to match data available for 1965.
Section 1

- Residential Land
- Roads
- Agricultural Land
- Reverting Agricultural Land
- Wetlands and water bodies
- Forested Land

1965

1985

Section 2

1965

1985

Section 3

1965

1985

FIG. 16. The differences in land use patterns between 1965 and 1985 for the seven sections of the watershed.
FIG. 16. (Continued)
Section 7

Residential Land
Roads
Agricultural Land
Reverting Agricultural Land
Wetlands and water bodies
Forested Land

1965

1985

FIG. 16. (Continued)
the percentages devoted to residential land in 1985 were high, 8.0% and 5.3% respectively. The section showing the largest decrease in agricultural land is section 3, where the percent of land devoted to agriculture decreased from 38.3% to 18.3% (500 ha to 239 ha). Although the changes in percentage of land use in sections 1 and 2 did confirm the trends of decreasing in only agricultural land and increasing in all other land use categories, the changes in these two sections were comparatively much smaller than the changes in the other sections.

Further breakdowns of these major land use categories were provided for residential areas, roads, and agriculture. A comparison of total residential land between 1965 and 1985 showed that the total area devoted to residential, both shoreline and inland, more than doubled from 1965 to 1985 (Table 9). A comparison of the development in residential shoreline based on an index of abundance, which was the number of homes per kilometer of shoreline road, was created for the period between 1965 and 1985 (Table 10). While the number of homes per kilometer remained fairly constant in sections 1 and 2, the increase in relative abundance in the other sections was significant. Section 7, for example, increased in shoreline abundance from 7.6 homes/km to 27.4 homes/km. Also, in 1985, section 4 showed 60.1 homes per kilometer, which was the highest shoreline abundance of any section. The total area of the roads within the watershed increased by 7 ha. However, state and municipal roads remained relatively constant during this twenty year period while private (fire) roads increased in total area from 10.8 ha to 16.7 ha (Table 9). A breakdown of agricultural land was completed for 1985. The total percentages of each of the three constituents of 1985 total agriculture: corn (45.2%), hay (40.8%) and pasture (14%) showed that corn and hay make up the majority of the agricultural land, whereas pastures constituted a relatively small percentage of the watershed in 1985 (Fig. 17).

**Phosphorus Loading Inventory for the China Lake Watershed**

The phosphorus loading coefficients were used with the calculated areas in hectares to generate phosphorus loading values (Table 11). The phosphorus loading values for 1965 and 1985 showed that the total phosphorus loading values for residential areas doubled in this time period (15.4 kg/yr to 34.6 kg/yr), while the total phosphorus loading for agriculture decreased by 37% (1738 kg/yr to 1106 kg/yr). The total phosphorus loading for the watershed in 1965 was 2062 kg/yr, and the total phosphorus loading for the watershed in 1985 decreased by 28.2% to 1481 kg/yr.
### TABLE 9. Comparison of Changes in Total Area and Total Phosphorus Loading in Residential Areas and Roads Between 1965 and 1985. Assumed export coefficients see map in figure one for testing sites

<table>
<thead>
<tr>
<th></th>
<th>1965</th>
<th>1985</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RESIDENTIAL</strong>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>shoreline (ha)</td>
<td>34.0</td>
<td>84.0</td>
</tr>
<tr>
<td>inland (ha)</td>
<td>43.0</td>
<td>89.0</td>
</tr>
<tr>
<td><strong>TOTAL PHOSPHORUS LOADING</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shoreline (kg/yr)</td>
<td>6.8</td>
<td>16.8</td>
</tr>
<tr>
<td>inland (kg/yr)</td>
<td>8.6</td>
<td>17.8</td>
</tr>
<tr>
<td><strong>ROADS</strong>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>state (ha)</td>
<td>33.8</td>
<td>33.8</td>
</tr>
<tr>
<td>municipal (ha)</td>
<td>50.6</td>
<td>51.9</td>
</tr>
<tr>
<td>fire (ha)</td>
<td>10.8</td>
<td>16.7</td>
</tr>
<tr>
<td><strong>TOTAL PHOSPHORUS LOADING</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>all roads (kg/yr)</td>
<td>172.0</td>
<td>192.0</td>
</tr>
</tbody>
</table>

*Numbers do not include absent 1965 data from sections 4 and 5, and 1985 totals also do not include sections 4 and 5 for comparison.
TABLE 10: Comparison of Development of Residential Shoreline
Based on an Index of Abundance (number of homes/kilometer) Between 1965 and 1985

<table>
<thead>
<tr>
<th>Section</th>
<th>Residential Shoreline (homes/km)</th>
<th>Residential Shoreline (homes/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>1965</strong></td>
<td><strong>1985</strong></td>
</tr>
<tr>
<td>1</td>
<td>9.3</td>
<td>10.8</td>
</tr>
<tr>
<td>2</td>
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<td>14.1</td>
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<td>22.1</td>
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<tr>
<td>7</td>
<td>7.6</td>
<td>27.4</td>
</tr>
</tbody>
</table>
FIG. 17. The breakdown of total agriculture within the watershed in 1985.
Table 11: Phosphorus Loading Coefficients used by the DEP (Grant Application, 1989)

*heavy manured field maybe ten times off if cut once there is no fertilizer

<table>
<thead>
<tr>
<th>TYPE</th>
<th>COEFFICIENT</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forested Land</td>
<td>0.35 kg/ha/yr</td>
<td>Reckhow et al (1980)</td>
</tr>
<tr>
<td>Dwellings</td>
<td>0.2 kg/ha/yr</td>
<td>Dennis (1986)</td>
</tr>
<tr>
<td>Roads</td>
<td>0.75 kg/312.5 m</td>
<td>Dennis (1986)</td>
</tr>
<tr>
<td>Pastures</td>
<td>1.0 kg/ha/yr</td>
<td>DEP</td>
</tr>
<tr>
<td>Hay Fields</td>
<td>0.1-1.5 kg/ha/yr *</td>
<td>DEP</td>
</tr>
<tr>
<td>Reverting Fields</td>
<td>0.1 kg/ha/yr</td>
<td>DEP</td>
</tr>
<tr>
<td>Rowcrop (corn)</td>
<td>1.5 kg/ha/yr</td>
<td>Reckhow et al (1980)</td>
</tr>
</tbody>
</table>
These total figures do not include sections 4 and 5. The total phosphorus loading including sections 4 and 5 for 1985 was calculated to be 1834 kg/yr. The total phosphorus loading from the residential areas increased by more than 50% in both shoreline and inland areas (shoreline: 6.8 to 16.8 kg/yr, inland: 8.6 to 17.8 kg/yr) (Table 9). The total phosphorus loading due to roads increased slightly over the period from 172 kg/yr to 192 kg/yr, however this increase is due almost exclusively to the addition of private roads in the watershed (Table 9).

Land Use Overlay

An overlay showing the land use practices was produced to fit over a topographical map of the China Lake watershed. This overlay 1.22 m x 1.22 m (4' x 4') was used to examine the land use patterns within the watershed, as a function of their topographical surroundings.

DISCUSSION

The increase in percentage of total forested lands in the China Lake watershed between 1965 and 1985 was a result of the decrease in the percentage of total agriculture within the watershed (Figure 15). Data from this study showed an overall decrease in active farmland between 1965 and 1985. Many of the abandoned agricultural fields have been reverting back to forested land (Table 8). The total increase in reverting land between 1965 and 1985 demonstrates successional stages progressing towards climax forest ecosystems.

Total percentages of the China Lake watershed devoted to residential area and roads also increased during the time when the decrease in total agriculture was making more land available for change (Table 9). This implies that while a portion of the abandoned agricultural land reverted back to forest, some abandoned agricultural land was converted to residential land. During the period between 1965 and 1985, total phosphorus loading into China Lake decreased by 25%. A reason for the decrease in total phosphorus loading was that total phosphorus loading from new residences and roads did not increase as rapidly as did the decrease of phosphorus loading from the agricultural lands. Because percentage of land devoted to agriculture within the China Lake watershed was larger than the amount
of land devoted to residences and roads and the phosphorus loading coefficient for agriculture is approximately six times higher than the coefficient for residential, our study showed that agriculture contributed more to the total phosphorus loading than did residential land (Table 12).

It is difficult to comment on what will be the major contributor of phosphorus in the future because it depends heavily on whether the abandoned agricultural fields will be converted to forest, residential land, or roads. SCOALE foresees problems in enforcing regulations if agricultural land (managed by few owners) is subdivided into residential land with many owners. It is important for the town of China to decide how much phosphorus loading is acceptable, and then utilize future developmental indexes to create zoning laws within the watershed that will allow only the predetermined amount of phosphorus to enter China Lake.

With the increase of residential development within the watershed of China Lake, there is increased chance for poor septic systems or septic system failure. Septic system problems that allow the leaching of raw sewage into the lake cause many problems in lake ecosystems, including increased phosphorus loading.

Although the phosphorus loading has been substantially decreasing since 1965, eutrophication is still occurring at accelerated rates in China Lake (Tietjen, 1986). Continued eutrophication results from the internal cycling of phosphorus in the sediments on the bottom of the lake. Phosphorus that has built up in the abiotic component of the phosphorus cycle (the sediments) can remain in the lake for very long periods of time bound in iron compounds. After algal blooms, decomposition of the algae causes low concentrations of dissolved oxygen in the water column. This low oxygen water causes the release of phosphorus from the sediments. More algae consume the excess phosphorus, causing the next years algal blooms that are characteristic of eutrophication. China Lake is showing the symptoms of this type of internal phosphorus loading by continuing rapid eutrophication with the decrease in external phosphorus loading.

With data from this study, it was possible to identify the relative sensitivity of each section of the China Lake watershed. The water district has placed restrictions on development of sections 1, 2 and the part of section 3 bordering on the west basin, making them the least sensitive sections to future development. The part of section 3 bordering on the east basin, and sections 4 and 5 are more sensitive to development. They do not have the same water district restrictions and also have no vegetative buffer strips because the shoreline areas are so densely populated. While section 4 is relatively small, its shoreline it very crowed and the contribution
TABLE 12. Comparison of Total Phosphorus Loading Between 1965 and 1985

<table>
<thead>
<tr>
<th>Section</th>
<th>Total Area (ha)</th>
<th>Residential (kg/yr)</th>
<th>Total Agric (kg/yr)</th>
<th>Reverting Agric (kg/yr)</th>
<th>Forest (kg/yr)</th>
<th>Roads (kg/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
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<td>0.9</td>
<td>15.1</td>
<td>18.7</td>
</tr>
<tr>
<td>3</td>
<td>1306</td>
<td>3.4</td>
<td>625</td>
<td>4.4</td>
<td>21.8</td>
<td>33.8</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2120</td>
<td>3.6</td>
<td>401</td>
<td>2.5</td>
<td>51.7</td>
<td>52.2</td>
</tr>
<tr>
<td>7</td>
<td>1276</td>
<td>3.2</td>
<td>393</td>
<td>3.4</td>
<td>27.1</td>
<td>52.7</td>
</tr>
<tr>
<td>Total</td>
<td>5772</td>
<td>15.4</td>
<td>1738</td>
<td>11.6</td>
<td>126.0</td>
<td>171.0</td>
</tr>
</tbody>
</table>

| 1985    |                |                     |                     |                         |                |                |
| 1       | 497            | 4.2                 | 194                 | 1.9                     | 10.0           | 14.0           |
| 2       | 573            | 3.4                 | 120                 | 1.1                     | 15.0           | 21.8           |
| 3       | 1306           | 7.8                 | 283                 | 6.3                     | 29.0           | 39.0           |
| 4       | 426            | 6.8                 | 111                 | 0.7                     | 9.0            | 19.8           |
| 5       | 845            | 9.0                 | 138                 | 1.2                     | 22.0           | 29.7           |
| 6       | 2120           | 6.0                 | 252                 | 2.2                     | 56.0           | 57.3           |
| 7       | 1276           | 13.2                | 257                 | 5.5                     | 28.0           | 59.7           |
| Total   | 7043           | 50.4                | 1355                | 19.0                    | 169.0          | 241.0          |
| Total - row 4,5 | 5772 | 34.6                | 1106                | 17.0                    | 131.0          | 192.0          |
of phosphorus loading due to inland land use practices cannot change dramatically because most of this section has already been developed. Section 5 is more sensitive than section 4 because although it is heavily populated in the shoreline region it has a larger total area and more inland area to be developed. Sections 6 and 7 are perhaps the most sensitive to future development because some shoreline land is still available for development and the inland part of these sections is relatively large and undeveloped in both cases.

Our analysis indicated that the watershed boundary of the China Lake watershed was changed to include some additional farm land in section 6 of the watershed. The new section of the boundary was designed with the use of topographical maps of the watershed. SCOALE calculated the total area of the watershed to be 7043 ha, this area included the new watershed boundary which was slightly larger than the watershed defined by the DEP.

Originally we were concerned with possible error in the processes of determining the scales for and tracing of areas using ZIDAS from the three aerial photographs. However, our measurement of the total area of the watershed, 7043 ha, came very close to the values calculated by the DEP for the total area, 7042 ha (Bouchard, 1989). This shows that the error in scale and human error was not considerable. Residences were also difficult to locate because many homes were out of view due to the heavily forested areas of the watershed.

**CONCLUSION**

In conclusion, our study has revealed major historical trends in the China Lake watershed. There has been a decrease in area devoted to agricultural land and an increase in area of all other land use categories (residential land, reverting agricultural land, forested land, and roads). The most sensitive areas to future development are in sections 6 and 7, the central and southern portions of the east basin of the watershed. While potential shoreline development is a concern, inland development within the watershed also needs to be considered because a decrease in agricultural land provides opportunities for future development. The major controversy over phosphorus loading has been centered on the relative contributions of phosphorus due to residential and agricultural lands. Our study revealed that roads, which are directly related to residential development, makes a
far more significant contribution to phosphorus loading than do residences. In 1985, roads contributed more than six times as much phosphorus to the lake than did residences. Therefore, from our study it is clear that roads need to receive significantly more attention than they have in the past, and the town of China needs to address the question of what will happen to the decreasing agricultural land.

IMPACT OF ROADS
INTRODUCTION

Upon the initiation of this project the probable impact roads have on the phosphorus loading of China Lake was unknown to SCOALE. Based on the initial reconnaissance and observations of aerial photographs, it did not appear that roads made up a great amount of the surface area of the watershed and therefore wouldn't contribute much of the phosphorus entering the lake or its tributaries.

What was noticed during the reconnaissance, however, was the proximity of many roads to the lake and its tributaries. This combined with conversations with Roy Bouchard from the Department of Environmental Protection lead to the study. The purpose was to determine if roads do impact the quality of China Lake and if it does, to what degree.

MATERIALS AND METHODS

Two techniques were employed in studying the impact that roads within the watershed have on phosphorus levels of China Lake. The first was an extensive field reconnaissance in October of 1989 detailing aspects of the state, municipal, and private road design that might affect phosphorus loading. The second was conversations with the Road Commissioner of the Town of China, the Town Manager of Vassalboro, and a representative of the Design Division of the State Department of Transportation. These personal conversations resulted in information regarding environmental considerations during construction and
economic feasibility of environmentally sound maintenance or alteration of the state, municipal, and fire roads.

During the field reconnaissance a checklist was followed which was developed based on suggestions from Roy Bouchard. He described aspects of roads that contribute to their phosphorus loading capabilities. The checklist is as follows:

1. Condition of the road surface: Good roads are evenly graded with no dirt or turf berms along the sides to restrict runoff from the surface. They are also crowned to facilitate even flow off to the sides. Dirt roads should show no signs of erosion and be pack down tightly to minimize loose sediment. Paved roads should have even pavement with few cracks, potholes, or other inconsistencies.

2. Location of roads: If at all possible, they should avoid passing over or directly next to open water to minimize passage of runoff into the lake or its tributaries. Most private fire roads will be poor in this category because they all lead to residential areas at the lakes edge. High gradient roads are prone to problems as well.

3. Condition of ditches: Good ditches are trapezoidal in shape with a shallow gradient, vegetation throughout, and no signs of active erosion.

4. Frequency and quality of ditch turnoffs: Ditches should have frequent turnoffs to allow their emptying of water. These turnoffs should be directed into stable ground so as to avoid any erosion.

Two trips were taken to the China Lake area. The first was to look at all state and municipal roads. 27 km of state roads and 48 km of municipal roads exist within the watershed and all were examined. The second trip was to investigate the private fire roads. Of the 60, 13 were randomly chosen. For both trips, almost the same techniques were employed. Roads were traced by a car with frequent stops to document either good or bad sites according to the checklist. Often pictures were taken to correspond with the written documentation. Those photographs and their descriptions can be found in Appendix II. The only difference in technique was when studying the fire roads the examination did not continue all the way to their end because many of the dwellings on them them were occupied. Enough distance on each was traveled to establish a full understanding of their status.
Upon completion of the reconnaissance trips, the documentation was compiled and placed in tabular and figure form. A scoring technique was employed. State, municipal, and private roads were separated and given scores ranging from 1 (lowest) to 3 (highest) for each of the checklist categories. For example 1 would mean no crown with berms along the side, close proximity to a tributary or the lake, or no ditching. 3 would indicate grading with no berms and a good crown, distance from the lake or tributaries, or good ditches with frequent turnoffs into stable ground. Averages were then taken and placed into figures to allow a full comparison of the three categories in terms of their quality.

RESULTS

Reconnaissance

State road results can be found in Table 13. An overall average comparison showed that the road surfaces and ditch conditions were the best of the four categories with values of 2.75. The average total value was 10.25. Municipal roads did not show values as high (Table 14). The conditions of their surfaces were the best of the characteristics looked at with an average value of 2.27. Their total average value was 6.73. Private fire roads data can be found in Table 15. Again, their best quality was surface condition with an average value of 1.38. Their total average value was 4.69.

Each of the checklist categories and the total average values were placed in figure form to enable a comparison of state, municipal, and private roads. In categories (Fig. 19), state roads showed the highest values. Private roads were lowest in all average values except for ditch turnoff frequency and quality where municipal roads had the lowest value (Fig. 18).

Interviews

Information regarding construction and maintenance of roads at all three levels was obtained from phone conversations. Available funding for the upgrading of roads in an environmentally sound manner inherent in this process were the focus of the conversations.

According to a representative from the Design Division of the Department of Transportation the funding for maintenance projects along state roads would come
most likely from state revenue obtained by a gasoline tax. Gasoline taxes may not be the only contributor, however, other revenue from state taxes may also be used. This money is primarily used to ensure that roads are safe for travel, their environmental impact is a secondary consideration. When the funds are available and a location is identified as having strong environmental impact, an extensive study takes place to determine if there is a feasible way to improve the situation without causing a greater one.

In speaking with the Road Commissioner of the Town of China and the Town Manager of Vassalboro, it is understood that there are problem spots on municipal roads within the watershed. Based on the reconnaissance, the worst locations were Danforth Road at the entrance of Hunter Brook and at another
TABLE 13: A comparison of state roads within the watershed of China Lake. (1 is the worst and 3 is the best ranking in each category)

<table>
<thead>
<tr>
<th>State Road Number</th>
<th>Condition of Road Surface</th>
<th>Proximity to Tributaries or Lake</th>
<th>Ditch Condition</th>
<th>Frequency and Quality of Ditch Turnoff</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route 9 &amp; 292</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Route 3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Route 32 (N-S)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Route 32 (E-W)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>2.75</td>
<td>2.5</td>
<td>2.75</td>
<td>2.25</td>
<td>10.25</td>
</tr>
</tbody>
</table>
TABLE 14: A comparison of municipal roads within the watersed of China Lake. (1 is the worst and 3 is the best ranking in each category)

<table>
<thead>
<tr>
<th>Municipal Road Name</th>
<th>Condition of Road Surface</th>
<th>Proximity to Tributaries or Lake</th>
<th>Ditch Condition</th>
<th>Frequency and quality of Ditch Turnoff</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danforth</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Bumps</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>McCaslin</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Pleasant Ridge</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Cross</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Hanson</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Bog Brook</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Adler</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Stanley Hill</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Maple Ridge</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Neck</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>2.27</strong></td>
<td><strong>2.00</strong></td>
<td><strong>1.55</strong></td>
<td><strong>1.09</strong></td>
<td><strong>6.73</strong></td>
</tr>
</tbody>
</table>
TABLE 15: A comparison of private roads within the watershed of China Lake. (1 is the worst and 3 is the best ranking in each category)

<table>
<thead>
<tr>
<th>Private Fire Road Number</th>
<th>Condition of Road Surface</th>
<th>Proximity to Tributaries or Lake</th>
<th>Ditch Condition</th>
<th>Frequency and quality of Ditch Trunoff</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road #1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Road #2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Road #3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Road #4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Road #5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Road #51</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Road #49</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Road #47</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Road #45</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Road #41</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Road #39</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Road #31</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Road #29</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td><strong>1.38</strong></td>
<td><strong>1</strong></td>
<td><strong>1.15</strong></td>
<td><strong>1.15</strong></td>
<td><strong>4.69</strong></td>
</tr>
</tbody>
</table>
Fig. 18 Farms located in the watershed.
location where it passes over the same brook. Cross road was also in poor condition and passed next to wetlands. Bog Brook Road was a problem where it passed over Hunter Brook. Bog Brook Road was also the site of increased residential areas placing more stress on the small dirt road.

At the current time, however, nothing substantial can be done to municipal roads for two reasons. Neither town has the money or the time to work on projects to improve the roads to an environmentally sound level. The primary objective for municipal roads is to ensure that they are safe for travel. According to some, that in itself uses all the revenue and manpower they can spare. To also factor in ecological impact is a luxury. For more money to become available, either town taxes must be raised which would anger many of the residents or state grants must be made available. At this time, neither person spoken to was anticipating the possibility of the state handing over funds.

In talking with the same people in Vassalboro and China, the issue of private roads was discussed. Their impression of the condition of fire roads was similar to what was found during the reconnaissance. Almost all were in poor condition. Most had poor surface conditions with turf or sediment berms along the sides and no ditching. The only good road observed was Fire Road #47 which had a good crown, no wheel ruts and new ditches with stable turnoffs.

These people felt that the reason for their poor quality is because they are private. This causes two problems. Most of the roads were constructed prior to 1974 when the Shoreland Zoning Act came into place. As a result, neither the state nor the towns can mandate how they are set up. Also, the owners of the roads cannot employ town or state funds to upgrade their roads to an environmentally sound level because those funds do not exist. The funds have to come from owners and therefore there is little incentive for change to take place.

**DISCUSSION**

As was stated in the introduction of this section, initially it was not understood how much impact roads have on the phosphorus loading of China Lake. The Land Use group determined the total distance of state, municipal, and private roads within the watershed and multiplied those values by phosphorus coefficients in order to determine their total input in kilograms per year. It was
found that the roads in 1985 accounted for 192 kg/yr phosphorus into the lake compared to a value of 34.6 kg/yr phosphorus by residential areas (17.8 kg/yr inland residences, 16.8 kg/yr shoreland residences). These values indicate clearly that roads do have a tremendous impact on phosphorus loading of China Lake. The data found from the reconnaissance trips demonstrate their problems and that they are not in very good condition. State roads showed the least problems, and private fire roads showed the most.

From the data produced in this report by the tributary and lake body groups, areas of particular concern around the lake were identified. The high phosphorus values from the major tributaries and sample sites 1 and 7 on the lake proper could all have been influenced by the roads in the area.

Sample site 1 on the lake is close to where Danforth Road passes across the northern point of the East basin. The road extends a considerable distance directly next to the water, traverses Hunter Brook, and serves as the access for a public boat ramp. There are no ditches and it is very easy for runoff to enter directly into the lake. From the soil profile map it shows that the soils in that area are high risk meaning runoff can easily pass through it without being absorbed and erosion of more sediment is possible.

Sample point 1 is where Hunter Brook enters the lake. Hunter Brook passes under poor sections of four roads before spilling into the lake. One is Danforth at the location already mentioned. Another is a different part of Danforth Road which is newly paved. The third is Route 202 & 9 where it passes under at a low point of the road (see #'s 28-32 of Appendix II). The fourth road Hunter passes under is Bog Brook Road, a small dirt road set back in the woods(see #11 of appendix II). All of these locations are places where runoff can enter the brook.

Sample site 7 on the lake proper was at the lower part of the East basin. Route 202 & 9 passes near there along the East bank. The topography of the area is very steep sloping down to the water and the soils are of medium to high risk indicating the moderate ease that runoff could travel from the road down to the lake. The road has some ditching with efforts to build new ones on the side opposite the lake but on the lake side of the road, ditching is not adequate.

This point is also where Starky Brook enters the lake. Immediately before entering, the brook passes under two roads. One is 202 & 9 which was already described. Where Starky passes under the state route there are steep slopes form the road down to the brook. It would be easy for water to spill off the road and run rapidly down the slopes carrying sediment into the brook. It also passes under a
small back road between Route 202 and the lake. The structure at that location is quite similar with the edge of the road turning immediately into steep slopes down to the brook.

At the outlet of the lake in the West basin very high phosphorus levels were found. At a low point between two hills along Route 32 there is a bend in the road bringing it very close to the lake at the outlet. On this bend the road was pitched down towards the water and a side turn sloping down to a public boat access. At this location runoff was free to pass unfiltered and in a large quantity into the lake proper.

To improve some of these conditions would be very costly and require a great deal of change. For example, Danforth Road extending along the upper end of the East basin would need major work to keep it from passing over Hunter Brook. Since the Town of China has low funds to cover that cost, it is not realistic to expect that kind of change. Other changes could be less costly. Bog Brook Road could be graded better to remove the berms leading up to the bridge. If the berms were not in place, runoff could enter the stable soil of the woods rather than directly into the water. The state could construct more ditches along the lake side of Route 202 & 9 as they are opposite the lake side. What that would mean is more labor hours to dig the ditches and more soil stabilization mats and hay bails to secure them and minimize erosion as stable vegetation becomes established.

Although, the fire roads cannot as easily be linked to direct impact of a certain location on the lake, the results from observing them would indicate that they do impact the water quality. As was already mentioned, the cost of improving those roads has to come from the owners. If many people live along the same road and they pool their resources, the individual costs may not be too high. Simple alterations like even grading, ditches, and vegetation would have very positive results.

**SUMMARY OF SCOALE FINDINGS**

It appears that the "China Lake syndrome" is not diminishing; eutrophication poses a major threat to the existence of China Lake. Conclusions are described below and are divided into their respective sections.

Lake Body:
Temperature, dissolved oxygen levels, and phosphorus concentrations supported the fact that eutrophication is still taking place. Phosphorus inputs appeared to originate from poor residential and agricultural practices, most probably due to lack of erosion control devices, poor soils, and topography allowing land to slope directly toward to lake. High fical coliform counts at specified sites showed various problem areas as well, including possible leakage from one or more septic tanks and high maure inputs. The high total coliform counts at various locations were combinations of some fecal pollution.

**Tributaries:**

Tributary results also supported the eutrophication of China Lake. The tributaries that contributed the greatest amount of phosphorus were those that were within a drainage area near farmland and were susceptible to high erosion. This was extremely clear during a storm event; as the water level rose, the flow increased, streams widened, and the phosphorus (mg/sec) increased. Starky had the highest output overall and was deemed a sensitive site where erosion control is necessary. Hunter brook contributed the second greatest amount, and was buffered by wetlands at its' mouth. The Cornfield stream was the smallest by far but had a high spot check value. Finally, Williams was characteristic of tributaries that run under roads. Buffer zones between farmland, fields, roads and tributaries are important; and careful monitoring of erosion prone areas and constructin sites is necessary.

**Mini-Watersheds, Topography, And Soils:**

The examination of mini-watersheds aided the identification of the drainage areas of tributaries showing high nutrient inputs, for the assessment of poor land use practices whose nutrients would eventually reach the lake. In addition, due to the topography and soil types in teh China Lake watershed, certain areas were shown to have high-risk potential. These included areas with high ridges sloping directly into the lake, and soils with a low porosity and low permeability. The northern shoreline and the eastern shoreline of the east basin proved to be the two highest risk areas, easing the path for nutrients into the lake.

**Land Use:**

The Land Use component of SCOALE found important information dealing with how changing land use practices form 1965 to 1985 have influenced total
phosphorus loading in China Lake. Within these years, the increase in total phosphorus was due to the increase in land use for residential development, road construction, reverting agricultural lands, and forested lands. A decrease in agricultural land contributed to a decrease in total phosphorus more so than residential development has augmented it. Land set aside for wetlands and water bodies has not changed and, if anything, has decreased total phosphorus input due to the natural buffering capacity of wetlands. Among sites, it was postulated that older developments (concentrated along the north shore of the east basin) contributed a higher phosphorus input than did newer residential areas (along the east shore), since recent development would probably have homes designed and built with greater environmental awareness.

**Agriculture:**

Agricultural practices in the watershed were a major contributor to phosphorus loading in China Lake. Proper management of these practices is necessary for the improvement of water quality of China Lake. Although much has been done to initiate this reform, economic problems inhibit farmers from complete involvement. Also, suggested alternative farming practices sometimes deviate substantially from traditional methods. Farmers are typically discouraged at the mere thought of changing practices that have been used for centuries. Hopefully, these obstacles will be overcome, since the loss of agriculture encourages residential development in the watershed, which also poses a threat to the China Lake watershed both environmentally and to the character of the region.

**Roads:**

The roads in and around the China Lake watershed were examined in an independent road reconnaissance after research with several state organizations. The classification of roads was based on factors such as the condition of the paved surface, its location, and the quality of ditching. Of the three types considered, state roads were superiorly built and maintained, municipal roads were less well maintained, and the private fire roads were in poor condition and allowed for substantial erosion. Some particular areas of concern were where roads pass over or near tributaries, those that run closely to the lake, and poorly ditched and steep driveways that sloped directly to the lake.

**Recommendations:**
In order to decrease the rate of eutrophication of China Lake, phosphorus input must be slowed to the greatest extent possible. Techniques include proper land use management by residential and agricultural practices, and corrections in road and building construction design to account for topography and bedrock morphology. However, although phosphorus input from the watershed contribute significantly to eutrophication, a large concentration of phosphorus already exists in the lake proper where it is recycled and the problem is perpetuated. An aluminum treatment is suggested which would remove the phosphorus from the cycle and thus render it unusable by the biotic component. Once these two problems are remedied, only then can China Lake return to a state of being the clear and highly oxygenated lake it was.

FUTURE PROGNOSIS FOR ROADS

Due to the fact that SCOALE's study of China Lake indicates roads as having a significant impact on phosphorus loading of the lake, they have received a great deal of attention in this report. Recommendations for methods of mitigating their contribution have been discussed. These recommendations are specifically designed for the China Lake situation and should be considered as a possible way to cut back on the phosphorus contribution they cause.

During the years of 1965 to 1985, there was not tremendous growth in either the surface area of all roads in the watershed nor was there a large increase in the total phosphorus loading by roads. This is not to say that since the numbers are not increasing, there is no need to consider them as a problem. Those stable numbers are causing constant damage because the problem in China Lake is one where the amount of phosphorus in the lake accumulates. That build up enhances eutrophication.

The population of China and Vassalboro is increasing. That increase has not yet caused a great need for new or changed roads but the possibility is there. If environmental aspects of construction are not considered for those possible future roads, the yearly phosphorus loading of the lake will increase. Also, more roads will be in need of attention to minimize their impact. Considering the fact that there is not enough money now to abate the damage being done, more problem spots will be even less likely to receive attention.
For the roads already in existence, there remains the possibility that their impact will increase. During the road reconnaissances, erosion could be seen on many of the private fire roads and some of the municipal roads. Erosion, once started, has the tendency to expand and with expanded erosion comes more probability of higher phosphorus levels in the lake and its tributaries.

Removing phosphorus from China Lake through any means will not be successful unless sources of phosphorus into the lake are eliminated as well. If no environmental considerations factor into future roads and nothing is done for the roads existing presently, there is little hope for that need to become reality.

**RECOMMENDATIONS**

**LOCATION OF SENSITIVE AREAS**

SCOALE identified several sensitive areas within the watershed. The criteria for a sensitive area was any area that was increasing the phosphorus impact of the lake by poor land use management. Low quality soil, topography, or a particular area of the lake or a tributary that seemed to be in direct contact with a land use area that was contributing high amounts of phosphorus are also identified with the sensitive area.

1. Site 4 of the Lake Body division, located in the middle of the east basin, was found to have abnormally high fecal coliform counts. Fecal coliform is thought to have originated from the nearby residential areas due to possible septic tank leakage (see Lake Body).
2. At site 1, located at the northern tip of the east basin, exceptionally high total phosphorus concentrations were found. Site 1 is next to a high density residential area, mapped on high-risk soils (see soil section), and is also located near major roads adjacent to the lake (see roads section).
3. High total phosphorous concentrations were found in Jones Tributary (see Tributary section) and at sites 6, 8, and 11 (see Lake Body), this area drains a large section of agricultural land where there appears to be poor land use management.
4. The Tributary Division identified Starky Brook, located in the southeastern part of the east basin, as the tributary loading the highest amount of phosphorus into the lake (see tributary section).

5. The Land Use Division indicated that Phosphorus Fact Finding sections 3, 4, 5, 6, and 7, are areas with already high shoreline density. These sections are in need of monitoring.

6. The poor quality of many of the roads within the watershed, particularly those near Hunter and Starky Brook contribute phosphorus loading. The high concentrations of private fire roads along the East basin (see roads section) are also a concern.

7. Analysis of the mini-watersheds within the China Lake watershed revealed that natural ridges exist, particularly along the northern tip and middle section of the east basin that channel runoff directly into the lake (see soil section).

RECOMMENDATIONS

SCOALE has many recommendations for monitoring these sensitive areas, and increasing the water quality of China Lake. The recommendations can be divided into two major categories. First, the amount of phosphorus reaching the lake needs to be reduced and redirected. Secondly, it will be necessary to decrease the present amount of phosphorus in the lake by lowering the amounts of phosphorus that were trapped in the sediments for many years, but are now being released.

Reducing existing phosphorus levels in China Lake

There are several methods for mitigation of the internal cycling of phosphorus. However, while some of the methods are more effective, they may also be more expensive and labor intensive than others. Only a few options for reducing phosphorus cycling are discussed, and SCOALE has analyzed these methods, comparing their short term or long term effects as well as their cost and feasibility.

1. Chemical treatment: The most effective chemical reduction of phosphorus is the alum treatment. Alum treatments remove and inactivate phosphorus
through the use of aluminum compounds, which reduce the amount of phosphorus available for algal populations. Alum treatments have such as the Cocknewagon Lake that received a treatment in 1986 and the phosphorus levels fell to less than half of the pretreatment levels. There has been a proposal for an alum treatment by the DEP (Bouchard, 1989), but the entire treatment will cost approximately $500,000 and would only be a short term treatment if the amount of external phosphorus entering the lake is not reduced considerably. However, alum treatment can be an efficient long term mitigative approach if the lake treatment is coupled with a major effort to reduce external loading.

2. Dredging may in certain cases be a long term successful method of reducing the internal cycling of phosphorus in lakes. Dredging involves deepening the lake, which helps to remove nutrient rich sediments and macrophytes from the bottom of the lake. This reduces algal blooms and winter fish kills that result in shallow waters.

3. Dilution and flushing can also reduce internal cycling of phosphorus through dilution by the addition of low nutrient water to the lake combined with flushing to increase water exchange rate. Although dilution and flushing would seem to provide the cheapest methods of mitigation, their effectiveness is limited and short term.

Reducing Land Use Phosphorus Loading

State Roads
From the information gathered from the Design Division of the State Department of Transportation, the possibility of changes to state roads is low. Safety for the travelers is a priority. If severe environmental impact is identified at a particular spot, a study is done to see if there is a possible, inexpensive change that can be made to improve the situation. Only after a detailed study is action taken. If possible, SCOALE recommends the following:

1. Place a certain amount of state gasoline tax funds aside for environmental improvements.
2. Make China Lake a priority for those funds due to its being in critical condition and a drinking water supply for a large population.
3. Concentrate a study at the public boat access on Route 32, and where Route 202 & 9 passes over Hunter Brook.
4. Establish a work plant that will both preserve the safety of the roads while minimizing their ability to direct runoff into the lake and tributaries.

**Municipal Roads**

The Road Commissioner of China understands the problems that municipal roads have. However, he also said that the town does not have the funds for the workers to change those roads that are contributing most heavily to the problem. SCOALE recommends:

1. Separate some of the water districts' tax money to be used solely for environmental improvements to roads. Those funds are not currently available but if planned for, it is possible that it could be found.
2. If necessary, after this study, execute another detailed road reconnaissance of all roads within the watershed to identify specific areas of concern. Focus the reconnaissance on Danforth Road, Neck Road, and Bog Brook Road due to their poor quality and proximity to the lake or tributaries.
3. Publicize the improvement attempts and encourage volunteers to help both with the reconnaissance and eventual manual work. Many residents currently understand the degree of the problem the lake is facing. Perhaps they would be willing to take some time to work on improvements.
4. Begin detailed growth trend studies. By locating areas where residential areas are expanding, it will be possible to locate where roads will be needed in the future. If this is done, funds and construction plans can be set up in order to build those roads in a safe and environmentally sound manner.

**Private Roads**

Private roads are the most difficult to improve because they are under the jurisdiction of individual citizens. The money to improve their condition must, at this time, come from the owners. Most of the changes that can be done like grading, ditch construction, and culverts, are not expensive if divided between residents. The problem however, is that there is little organization of the road owners. Here are SCOALE’s recommendations:
1. Encourage the Towns of Vassalboro and China take a more active role in the issue of private road maintenance. Currently, they are very separated from the owners and most of the efforts made to contact them have come from the DEP. If they do become more involved in communicating with residents, the residents will become more knowledgeable on the situation with China Lake.

2. Encourage the organization of road associations by all owners along each private road. From these associations, a representative should be appointed to be the liaison between the town and the individuals. This will allow for a direct line of information to the owners regarding possible methods of improvement. The association will also allow pooling of funds to carry out any necessary changes.

3. Free visits by a state or town representative to actually walk the road with its owners and educate them on areas where changes should be done and why they are important would be very influential.

4. These visits should be followed up by phone calls, mailings, and more visits to keep open the lines of communication.

5. If work takes place, that representative should make frequent visits to be sure that the construction is being done properly.

**Residential Areas**

Although SCOALE's data shows that residential areas do not contribute as much phosphorus to the lake as do roads, they are still an important area to focus on. Phosphorus fact finding sections 3, 4, 5, 6, and 7 were identified in the Land Use section of this report as having high shoreline residential concentrations. The majority of problems that shoreland lots have stem from their set up. Many of the houses are too close to the water which cannot be changed. Other lots have lawns extending down to the water, no vegetated buffer zones, or poorly constructed private boat access points.

The Shoreland Zoning Act came into existence in 1974. The majority of the houses on the water were already built at that point. As a result, the state or towns have no say in how those lots are set up. They do, though, have the ability to educate those owners to the situation and how they can do little changes to decrease their impact.

Houses built since 1974 are required to follow the Shoreland Zoning Act but due to inadequate monitoring, construction is often not done properly. To
minimize both these and the grandfathered lots, here are some recommendations:

1. Before construction of a new home or an addition to an existing one, a code enforcement officer should survey the area and point out spots that may need special attention like high erosion spots, steep slopes, and poor soil quality. Since construction almost always means loosening soil, methods should be employed to keep that soil from flowing into the lake.

2. After construction begins, that officer should make frequent visits to make sure that those procedures outline are being followed.

3. For already completed lots, periodical mailings could be sent to the owners. The mailings should discuss the problem with China Lake, educate the people on what they can do to minimize their lot's impact, and give updates on the condition of the lake and actions that are being taken by citizens.

3. Follow up the mailings with phone calls to establish a relationship with the owners and get a feeling for their interest in doing anything.

4. If there is interest, a free visit by a state or town representative should take place. During the visit, the representative should walk the property with the owners to point out where problems are and how they can go about improving them.

5. Follow up the visits to monitor progress.

APPENDIX I

AGRICULTURE INTRODUCTION

Agriculture is among the major sources of phosphorus loading in the China Lake watershed. Agriculture has been credited with 45 to 65% of the total phosphorus loading of the lake.\(^1\) As a result, The Department of Environmental Protection (DEP), The Agricultural Stabilization Service, Soil

\(^1\)The figure of 45% of the total phosphorus loading for farms is provided by the SWC. The figure of 65% is provided by the China Lake Association in The China Lake Syndrome (pg 1).
Conservation Service (SCS), and The China Lake Association (CLA) have taken special interest in the management of farms within the watershed. The majority of farmers within China Lake watershed have responded positively to reform efforts, by filing conservation plans, and by making changes which help reduce phosphorus loading.

Problems involving the affordability of reforms and the quality of interaction between farmers and environmental personnel have arisen. The cost of reforms suggested by the government and the China Lake Association is a concern, and some farmers have suggested that the maximum aid allowed is not adequate to displace the costs of reform measures.

The goal of this investigation was to gather statistical data on individual farms and to discuss the major issues concerning farmers and the environmental effort. To complete this study, nine farmers were contacted and interviews were conducted by telephone and personal visit. Six of the farms were toured on foot and areas perceived to be environmentally problematic were identified by sight. Information on the size, type, yearly gross production, assessed value, and cost of reforms was gathered for each farm from the records and maps available at the town offices of China and Vassalboro, as well as from interviews. It should be noted that all money values are estimates, and do not necessarily reflect fluctuations in the housing, farming, and construction markets. The report of the China Lake Phosphorus Finding Committee (PFC) was utilized in obtaining background information for each farm contacted. Information and guidance provided by the Department of Environmental Protection and the Soil and Water Conservation District (SWC) have been instrumental in the production of this report. In an attempt to preserve the privacy of farmers, individual farms are labeled by letter.

The location of each farm surveyed is given in Figure 18.2 Six farms are located on the western half of the watershed, and two in the eastern half. Data concerning the make-up of each farm was compiled in Table 16. Using the points raised in the report of the Phosphorus Finding Committee, the suggestions of the SWC, as well as site checks, a table was compiled listing the reforms needed on each farm. Table 17 lists these reforms, and their present

2 Source: DEP
status as "done" indicating completion of the reform or "to do," indicating the reform has yet to be carried out.
TABLE 16: Breakdown of the eight farms surveyed in China Lake Watershed:
Livestock Count, Crop Production, Gross Production, Assessed Value.

<table>
<thead>
<tr>
<th>Farm</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
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<tr>
<td>Beef Cattle</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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<td>Farmstead</td>
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<td>2</td>
<td>3</td>
<td>5</td>
<td>4</td>
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<tr>
<td>Gross Production</td>
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<td>$150,000</td>
<td>$30,000</td>
<td>$200,000</td>
<td>$12,000</td>
<td>$21,000</td>
<td>$160,000</td>
<td>$5,050</td>
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<tr>
<td>Assessed Value</td>
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<td>$93,800</td>
<td>$458,800</td>
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<td>$93,960</td>
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<td>Est Subdivision Value</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>$550,000</td>
<td>NA</td>
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</table>
TABLE 17: Reforms in compliance with environmental awareness that are completed or pending on the eight farms surveyed in China Lake Watershed.

<table>
<thead>
<tr>
<th>Farm</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
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<tbody>
<tr>
<td>Concrete manure pit</td>
<td>Done</td>
<td>To do</td>
<td></td>
<td>Done/To</td>
<td>done</td>
<td></td>
<td>done</td>
<td></td>
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<td>Concrete pit alterations</td>
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<td></td>
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<tr>
<td>Enlarged manure storage</td>
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<td></td>
<td>To do</td>
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<td></td>
<td></td>
<td>To do</td>
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<tr>
<td>Concrete feeding area</td>
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<td></td>
<td></td>
<td>To do</td>
<td>To do</td>
<td></td>
<td>done</td>
<td></td>
</tr>
<tr>
<td>Non-use of feeding area</td>
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<td></td>
<td></td>
<td>To do</td>
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<td></td>
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<td>Animal watering system</td>
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<tr>
<td>Farmstead drainage</td>
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<tr>
<td>Milking room waste management</td>
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<tr>
<td>Buffer zones</td>
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<tr>
<td>Seeding down land</td>
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<tr>
<td>New spreading techniques</td>
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<td></td>
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<tr>
<td>Fencing</td>
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<td>To do</td>
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<td>Sedimentation Basin</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Non-use of fragile land</td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
The following are the results of barnyard sight-checks of farms B,C,G, and I. That these farms are highlighted is not indicative of any uniquely poor or exemplary condition, but merely that it was possible to make more in-depth observations of these farms than others. Only the barnyards of these farms were observed.

Farm B

Upon visiting this farm, I found very muddy conditions, and numerous incidences of broken soil. The farmland is mostly a heavy clay which appears to be especially soft and easily torn up under wet conditions. In back of the barn, towards the brook, there is a tractor road, deeply scored by tractor tread and hoof-prints, and to the left is a large area of disturbed earth estimated to be around 550m². These fields drain into a low valley-like formation which leads to the road and to a brook through a single culvert. On Nov 11th, after a substantial rain, the ground in the valley was waterlogged and the brook was running very quickly. On the lake-side of the barn, it was estimated that there was 700m² of wet disturbed earth 250m from the lake with no intervening buffer zones. At the base of the field was standing water over an area of roughly 7m². This side of the barn was extremely wet, and heavily laden with manure. The wetness was increased by the apparent overflow of a watering trough, fed by a hose running from the barn. Off the end of the barn was another 450m² of wet, disturbed, manured earth.

Among other reforms suggested in the Phosphorus Finding Committee (PFC) report is the establishment of 9-10 acres of buffer zones between some of his grazing land and the brook running through his land. It has been suggested that livestock should not be allowed to graze in the pasture next to the tributary. A wet pond for manure storage has been suggested, as well as a septic system to control the runoff from the feeding area.

Farm C

Upon touring Farm C, several problems were noted. Waste from the milk house was inadequately drained into a nearby field. According to the owner, there is not adequate storage space available for the cold months. It
seems likely that the farm will need a new manure containment facility. The feeding area around the farmstead is presently very muddy and constantly disturbed by the livestock. The barn at present is not well drained and a drainage system should be installed. The PFC has suggested that some fields be left unfertilized because of the high water table, and that some land be set aside for a buffer strip.

**Farm G**

The barnyard of Farm G seemed well drained and sanitary. There is an adequate-sized manure pit and mechanized manure removal system in place. The farm is presently running at a low capacity, so there is little stress placed on the system.

**Farm I**

This farm is characterized by a pole-barn system, and the storage of manure did not seem to be a problem. In a pole barn, the manure is left on the ground and mixed with sawdust. Once a year, the manure is cleaned out and spread over the hay fields. This method of manure management appears environmentally sound, but it is important to note that the pole barn is only practical for the raising of beef cows. The yard here is reasonably dry, although the feeding area outside of the barn is muddy and rutted.

In order to qualify for federal conservation aid, farms must file a conservation plan with the ASCS. In this plan are recommendations for reform made with the help of the DEP to reduce the phosphorus runoff of their operations. Farmers must agree to conform to these standards in order to receive funding for environmental reform. For most farms, matching grants of up to 75% of reform costs are available through the ASCS, though there is a $3,500 yearly ceiling on these grants. A farmer may apply for up to ten years worth of ASCS help in advance for reforms in one year. In 1989, the Town of China received a grant from the federal government under the auspices of the DEP for $80,000 for the restoration of China Lake. This money has to be divided among the 80-90 sites indicated in the report of the Phosphorus Finding Committee. The CLA has stated that a substantial portion of this money will be channeled into farm reforms.
Several farmers feel the cost of reform is too high. Some claim that because of the weak dairy market, the prospect of retirement, or lack of aid, reform will not be practical. One farmer claims that he cannot justify putting more money into reforms. He has run the farm on the watershed for nearly 50 years and is now in semi-retirement. His operation is now scaled down to 25 beef cows and 39 sheep from a peak of 60 dairy cows and 50 heifers. Some time ago a manure storage pit was installed. The farm provided $4000 for the construction and the ASCS paid $3500. The pit now in place is sufficiently large for his herd at present, but the farmer says it would not accommodate the farm’s manure production were he ever to resume full-scale production. At present, further reforms have been suggested. It has been requested that fencing be installed around a tributary that flows through one field.

In many of its recommended reforms, the DEP notes the beneficial effects of responsible environmental management. First and foremost is the installation of concrete manure storage facilities. One interesting case that involves a farmer from outside of the watershed illustrates the benefits of this measure to the farmer. Ten years ago, Lovejoy and Dutton Ponds were undergoing a crisis similar to one facing China Lake now. A farmer owning land on both sides of the watershed line, took advantage of this program to improve his farm. In 1981 he took advantage of the government’s program and had a manure containment system installed. His system is large by China’s standards, measuring 55x 90x 8ft deep with a 1,200 gallon holding tank, which can be emptied in one minute using the large hydraulic compressor at the end of the barn.

Since installing the system, he has enjoyed what he considers to be substantial benefits, including ease of barn cleaning, extended spreader and tractor life, lowered fertilizing costs, and less time spent working outdoors in the winter. Because his bin holds up to a year’s worth of manure, there is no need to spread in the winter months. This provides multiple benefits. First, he saves the manure that would normally run off the fields and into his stream. He buys very little or no chemical fertilizer now, thanks to the supply from the winter. Second, winter-time spreading meant that his spreading equipment would experience increased wear. Now, the equipment winters under cover. The farm’s spreader has lasted over ten years, when previously a spreader would have to be replaced every two years.
A common practice to reduce erosion and phosphorus loading is to take fragile or poorly drained land out of use. For several farmers altering land use or taking land out of use presents a problem. One farmer claims that the land required to establish a buffer strip on his land is too valuable to his production to give up. He estimates that the loss of grazing land involved would threaten his farm.

For at least one farm in the watershed, aid for environmental reform is not being made available. This is a result of the farm's status as a "new" or "expanded" farm. From 1986-87, the federal government initiated a buy-out of herds in the country in order to reduce the surplus production of America's dairy farms. This meant that farmers could sell off their herds to the government with the stipulation that they agree to limit the amount of milk produced for a pre-determined number of years. Also as part of the general plan to discourage surplus, the classification, "new or expanded" was created. To discourage establishment of new farms, the government passed regulations to deny much of the funding that a farmer would normally receive. In the China Lake Watershed, however, farmers can apply for a grant from the Town of China.

At present, several farmers are waiting for word on funding their farm reforms. The general feeling among the farmers is that there has been insufficient follow-up on regarding their farm reforms, though the farmers have not attempted to contact the agencies in question on their own. At present, the CLA's Cost Sharing Committee is still in the process of determining how the grant's $80,000 should be divided.

There are farms on the watershed that have managed to avoid a great deal of problems other farmers have been faced with. One farm, owned by an older couple, says that they have always worked with the environmental agencies, in particular the ASCS. Years ago, this bureau helped to pay for erosion control in a few of their fields. More recently, the DEP claimed that the farm was polluting a nearby brook and they responded by putting in culverts to redirect water, and fences to prevent cows from wading across. At present, the owners of this farm claim to be in compliance with the standards of the town and the DEP. Another farming couple claims to have always cooperated with the DEP. In the past, they have invited DEP personnel to inspect their farm. Based on these visits, drainage ditches, pipes, and culverts
have been installed. They have also rebuilt the logging road on their land, planting ground cover and installing "water wings" to divert water-flow. The government helped pay for some bulldozer work and they paid for the remaining work. They claim to have been vigilant in correcting problems and have never been cited. Another farmer claims that he has never been contacted by the DEP or the CLA concerning his farm.

A reduction of farms in the watershed might have several effects on the health of the lake. The disappearance of farms might mean a lowering of phosphorus, says a DEP official, but it is not certain. Although according to phosphorus coefficients, non-managed farms may contribute more per acre to phosphorus loading than residential areas, managing one farm that encompasses 200 acres is much easier than managing the individual residences that would populate a comparable area. It is a much simpler task to spot check and clean up a few farms than to visiting a densely populated area to test each septic field, spot check each road, and convince each resident to make the repairs and investments needed to reduce the problem. According to phosphorus coefficients, any number of homes would not contribute as much phosphorus to the watershed as one farm, but coefficients do not account for the variables in either land use. Poorly designed roads, over-fertilized lawns, and faulty septic systems might easily raise phosphorus loading to the level of a farm. On the other hand, an especially well-managed farm might have actual levels of phosphorus discharge below a housing development. According to the DEP, well-managed farms in the China Lake watershed can become a reality with only what are in most cases very simple solutions. In terms of the lake, farms are an easily manageable land use when compared to residential areas.

The disappearance of farms on the lake would also mean a change in the character of the China Lake community. China, South China, and Vassalboro are unique communities. Residents enjoy a lake, a rural existence, and close proximity to the city of Waterville, and the state's capital, Augusta. Within the watershed and surrounding areas, there is ample open space and farms dot the landscape. The rural character of the China area as well as the lake continues to attract home buyers. Property values are high by local standards, with roadside one-acre lots selling for upwards of $25,000.
Clearly the loss of farms and an increase in suburban encroachment would change the area drastically.

One plan of action that might benefit both the environmental effort, China's farmers, and the community at large, is to implement governmental action to halt the subdivision of land. In states like Vermont, the government purchases the developing rights of farms that are in danger of being bought by developers. The government, in effect, pays the farmer the difference between the value of the property as agricultural land and what it would be worth as house lots, the stipulation being that the land could never be sold for development. If adequate funding is available for such a program, the disappearing of Maine's small farms due to any number of reasons may not result in the loss of open space and rural character.

The effective management of agriculture is necessary for the improvement of water quality in the China Lake watershed. Much work has been accomplished by the DEP and the CLA in arriving at acceptable alternatives to traditional farming practices that have contributed to the phosphorus problem. Initial difficulties in persuading farmers to implement these practices has slowed progress. Misunderstanding and lack of agreement on the effects of reform on the farmer's livelihood still exist. Both reformers and farmers seem to be working towards a common ground, however arduously. It is clear that the solution to the phosphorus problem in China Lake does not involve the elimination of any land use in general, nor does the solution lie in the extinction of any lifestyle in particular. There are many sources of phosphorus in the watershed, and the elimination of one will not solve the problem. The common ideal is to minimize phosphorus loading from all sources, and work continues on the part of the DEP, the CLA, and farmers to this end.

APPENDIX II

CHINA LAKE ROAD RECONNAISSANCE
All roads within the China Lake watershed were examined for their good points and bad points in terms of construction and maintenance. A checklist was used in order to determine quality:

1. Condition of road surface - good roads are evenly graded with no turf or dirt berms on either side to restrict water flowing off. They are also crowned to facilitate the flow to the sides.

2. Location of roads - If at all possible, they should avoid passing over open water or directly next to it to avoid direct passage of runoff into the lake or tributaries.

3. Condition of ditches - good ditches are trapezoidal in shape with a shallow gradient and vegetation throughout.

4. Frequency and quality of ditch turnoffs: Ditches should have frequent turnoffs to allow their emptying of water. These turnoffs should be directed into stable ground so as to avoid any erosion.

Each number below corresponds to the number of the photograph found after the written section of this appendix.

1. Danforth Road
   *Newly paved
   *Very narrow shoulder consists of loose gravel
   *Sides have turf
   *No ditches on either side
   *Crowned so water will spill off to either side
   *At a low point of road, it goes directly over Hunter Brook and water spills into it.

2. Danforth Road
   *Same as #1

3. Bumps Road
   *New pavement continues
   *Land goes flat off sides (no ditch)
   *Very low vegetation

4. Pleasant Ridge Road
   *Going up hill
   *There are ditches on each side, primarily east
   *There is some gravel banking on east side
*No ditch turn-off down whole hill. This is probably because the outside of the ditch slopes steeply uphill.
*Farther uphill ditch is deep and wide with vertical sides
*Continued bank build-up on sides
*Ditch ends at the top of the hill but still there is good vegetation.

5. Pleasant Ridge Road
*Same as #4

6. Route 9 & 202
*Well ditched and crowned
*Inlets and outlets of culverts are well stabilized
*Effort to improve ditching. New work being done on them.
*Hay bails are down and staked, Curlex is spread with a screen to hold it down.

7. Cross Road
*Dirt Road
*Slightly crowned
*No ditch
*Gravel bank build-up on each side
*Erosion on sides at slopes and turns
*Low point - water is 1 foot below side, water flows directly in

8. Hanson Road
*Dirt Road
*South side has a lot of runoff from chicken farm field.
*Owner is doing an excellent job!
*Hay bails along a good ditch
*As it reaches the bottom of the hill it is turned off and dispersed into thick forest.
*Vegetation in place throughout whole path

9. Hanson Road
*Dirt Road
*Graded and crowned well. No gravel banks along sides
*Problem at bend around Evans Pond. Inside part of turn is low to water with only some vegetation.

10. Hanson Road
*Dirt Road
*Newly Graded
*Clearing vegetation along sides of the road to construct new ditches
11. Bog Brook Road
   *Dirt Road over Hunter Brook
   *No shoulder or ditches
   *Little way to keep water from entering water
   *Road is slightly raised over the water so it is possible that rain or runoff
doesn't collect and it spills over into the vegetation at either side of
the bridge.

12. Route 32
   *Paved Road
   *Turn in road and at low point there is a sloped turnoff
   *Turnoff turns into a public boat access to the lake

13. Danforth Road (N. End of E. Basin)
   *Road runs along waters edge
   *Public boat access directly off road
   *Road going over tributary, runoff can only go into water
   *No ditch, well pitched

14. Danforth Road
   *Same as #13

15. Danforth Road
   *Same as #13

16. Fire Road #2
   *Dirt road
   *No pitch or ditch
   *Turf buildup on sides, no runoff escape
   *Erosion on sides

17. Small Back Road
   *Just downstream of above location
   *Paved with no ditches
   *At a low point is the crossing over of Starkey Brook
   *No place for runoff to go but spill over into trib.

18. Small Back Road
   *Same as #17

19. Small Back Road
   *Same as #17

20. Fire Road #47
*Wide dirt road
*Vegetation on one side
*New ditching on the other side with hay bails and Curlex spread
*Ditch turnoff at the bottom of the hill so water goes into the woods and not the lake.

21. Fire Road #47
*Same as #20

22. Fire Road #41
*Dirt
*Well pitched but no ditch
*Turf and vegetation build up on each side act more as a barrier than a filter.

23. Fire Road #39
*Dirt
*High in the middle and turf build-up on each side

24. Fire Road #39
*Same as #23

25. Fire Road #29
*Dirt
*Steep with erosion along the bend
*No ditches and sloped toward lake

26. Fire Road #29
*Same as #25

27. Fire Road #29
*Same as #25

28. Route 9 & 202 (N. end of E. Basin)
*Good quality state road- but this is a problem location
*Goes over tributary
*Ditches drain down into wetland or directly into the water
*Pavement on bridge is curled over edges-allows runoff from nearby hill to flow over the side and into the water.
*Large culvert under road has erosion at inlet end.

29. Route 9 & 202
*Same as #28
30. Route 9 & 202  
   *Same as #28

31. Route 9 & 202  
   *Same as #28

32. Route 9 & 202  
   *Same as #28
APPENDIX III

DETERMINATION OF SOIL RUNOFF POTENTIALS IN THE CHINA LAKE WATERSHED

Soil runoff potential plays a large role in determining the effects of land use on phosphorus loading and lake water quality. Areas that contribute large amounts of phosphorus to the land where the soil has a high runoff potential may be major contributors to phosphorus loading. Therefore, one element in determining a site’s contribution to phosphorus loading is understanding the runoff properties of the soil at and nearby the site.

Soil runoff is a function of four factors: permeability, slope, groundwater level, and cropping. Soils with high permeability help reduce the risk of runoff. A very well-drained soil - for example, one that can drain 15-50 cm per hour, would allow only minimal runoff, even during a major storm event on a very steep slope (>15°) with a high water table. A poorly drained soil - for example, one that can drain only 0.15-0.50 cm per hour - would be at much greater risk of allowing runoff under the same conditions.

Soils on flat areas also help to reduce the risk of runoff. Because the water flows at lower velocities on flat areas than on slopes, the soil has more time to absorb water. Flat areas (<3°) can allow up to four times more water absorption into the soil than if the same soil was on a very steep slope (>15°).

Groundwater levels can be grouped into three categories: high, low, and seasonably high levels (that is, during spring thaw and periods of substantial rain, e.g. November in Maine). Even though swampy areas are flat, the soils are basically impermeable, and therefore are at high risk of allowing runoff and are susceptible to flooding. Therefore swampy and peaty soils are considered high-risk soils. This runoff usually does not occur, however, due to the lack of slope, and therefore the nutrient load is allowed to slowly seep into the sediment and is available to plants and other organisms. Hence, swampy areas are important in filtering out excess nutrients from the nutrient load.
Finally, cropping, the vegetation growing in the soil, absorbs water and nutrients into plant tissue, and thus affects the amount of phosphorus available for phosphorus loading. For example, runoff from bare soil will contribute much more to phosphorus loading than runoff from forested land.

**MATERIALS AND METHODS**

A runoff index was created which shows the relationship between permeability, slope, and groundwater level:

\[
\text{runoff index} = (\text{slope} / \text{permeability}) \times a
\]

where \( a \) = groundwater level coefficient, permeability equals the average of the following:
- very slow, \(< 0.15 \text{ cm/hr (0.06 in/hr)}\) (in this case, permeability = 0.15)
- slow, \(0.15-0.50 \text{ in/hr (0.06-0.20 in/hr)}\)
- moderately slow, \(0.50-1.50 \text{ cm/hr (0.20-0.60 in/hr)}\)
- moderate, \(1.50-5.00 \text{ cm/hr (0.60-2.00 cm/hr)}\)
- moderately rapid, \(5.00-15.00 \text{ cm/hr (2.00-6.00 in/hr)}\)
- rapid, \(15.00-50.00 \text{ cm/hr (6.00-20.00 in/hr)}\)
- very rapid, \(> 50.00 \text{ cm/hr (20.00in/hr)}\) (in this case, permeability = 50.00)

and where slope is given a value of 1 for flat areas (<3°), a value of 2 for gentle slopes (3-8°), a value of 3 for steep slopes (8-15°), and a value of 4 for very steep slopes (>15°). Therefore, when the soil index is high, the risk for runoff is also high. The highest indexes occur on poorly drained soils on steep slopes. This reflects what is known about the relationship of permeability and slopes to runoff levels.

The last factor, cropping (the vegetation growing in the soil) was disregarded because we wanted to determine which areas would be most likely to lead to high runoff (and therefore P loading) if left bare.
This runoff index assumes that the groundwater level is low. When the groundwater level is seasonably high, it was decided that the runoff index should increase by a factor of two. Periods of phosphorus loading are greatest during spring melt and substantial rain, precisely when the groundwater level is high in these soils. Since the soil can absorb no more water, water runs off the surface of the soil, which accelerates the problem of phosphorus loading.

Runoff indices were plotted against permeability (Figure 12), from which three approximately equal categories were derived according to the three general slopes. Low runoff risk was assigned values less than or equal to 1.53; moderate runoff risk assigned values greater than 1.53 and less than 23.07; and high runoff risk was assigned values greater than or equal to 23.07. Referring to the Soil Survey of Kennebec County, Maine, runoff indices were calculated for each soil and placed in one of the three categories. Figure 13 lists the soils, their general properties, their runoff indices and degree of runoff risk. Figure 14 lists the soils found within each soil runoff potential category.

The maps in the Soil Survey of Kennebec County Maine that include part of the China Lake watershed were enlarged to the same scale as the topographic map used by Roland Tilton and the DEP (1:12000), and areas of low, moderate, and high runoff risk were shaded according to the location of the soils on the soils map. High risk areas were shaded in red, and moderate risk areas were shaded blue. Low risk areas were left blank.

**RESULTS**

There are five important areas shown on the map, when considering water flow characteristics, that could be having a significant impact on the lake. These are the following:

1. Hunter Brook lies on high risk soils, including a large area of swampy, high risk soils at the mouth.
2. Jones Brook, like Hunter Brook, overlies high risk, swampy soils at its mouth. Most of the other soils in this area are moderate risk soils.
3. Much of the residential East Basin shoreline includes high risk soils. This includes some of the western shore and large stretches of the eastern shore.

4. Many areas of the southwestern end of the West Basin, including some farms and the East Vassalboro boat launch, are on high risk soils.

5. A large portion of the Starky Brook sub-watershed drains over moderate risk soils, with the mouth of Starky Brook on high risk soils.

There are two major areas of low-risk soils. The northeastern area of the West Basin, near East Vassalboro, has low risk Paxton and Hollis soils. The soils in the second area, mostly Hollis soils, lie on the high ridge between Hunter and Starky Brooks.

In relation to the seven major divisions used by the DEP in their studies and described in detail by the Land Use Division of SCOALE, approximate percentages for the three soil runoff potentials were obtained. For Section 1, 25% of the area contains high runoff risk soils, 25% is moderate risk soil, and 50% is low runoff risk soil. For Section 2, 15% is contains high risk soils, 20% contains moderate risk soils, and 70% contains low risk soils. The proportions for Section 3 are 40% low risk soils, 25% moderate risk soils, and 35% high risk soils. Section 4 contains 45%, 15%, and 40% for high, moderate, and low runoff risk soils, respectively. Section 5 has predominantly high risk soils, at 50%, with moderate risk soils 30%, and low risk soils only 20%. Section 6 is more evenly distributed, with 30 % for high and moderate runoff risk soils, and 40% low risk soils. Section 7 contains 35% high risk soils, 40% moderate risk soils, and 25% low risk soils.

**DISCUSSION**

The high risk soils at the mouth of Hunter Brook and along the northern shores of the East Basin elevate the residential impact on phosphorus loading in the lake body. Phosphorus and eroded sediments directly dumped into tributaries like Jones Brook or Hunter Brook, which flow across impermeable, high risk soils, will have little or no time to be filtered out during spring thaw or heavy rain. This could help explain the high phosphorus readings of Site 1 from the lake body, and the high total phosphorus readings from Hunter Brook. Starky Brook, draining
primarily moderate risk soils, could have similar impacts as Jones and Hunter Brooks, as it drains steeper slopes. The sub-watersheds draining into the southern half of the Western Basin contain many high risk soils, and could explain the high phosphorus readings of tributary and lake samples taken from this area.

Of the seven major watershed divisions used by the Land Use Division, Section 5 draws the most concern, as approximately 50% of this area has a high runoff potential. Only about 20% of this area has a low runoff risk. The three pastures in this area lie on soils with high runoff risk, as do most of the residences. Two of the pastures, the hay and corn fields, and the roads all rely on the swampland to filter out the phosphorus they contribute to lessen their impact on phosphorus loading. Section 4 also contains a high percentage of high risk soils (45%). This area is characterized by heavy residential development and many fields used for corn, hay, and pasture. Section 7 could also be cause for concern, as only about 25% of the soils in this area have a low runoff risk. Much of the land that drains into Starky Brook is moderate risk soil, and Jones Brook drains mostly high risk soil. The Jones Brook sub-watershed also contains many hay and corn fields, and a pasture located near the Jones Brook and its mouth lies on high risk soils. Fortunately, many of the small hay and corn fields on the lake shore lie on low risk soils.

Only Sections 1, 2, 3 and 6 contain a higher percentage of low risk soils than high risk soils; and of these three, only Section 2, draining into the West Basin, contains a higher percentage of low risk soils than moderate and high risk soils combined. There are several hay and corn fields in Section 1, some of which lie on high and moderate risk soils, and drain directly off the slopes into the lake. There is very little agricultural or residential activity in Section 2. The residential areas in Section 3, along the lake shore, are predominantly located on high risk soils. Fortunately, most of the large pastures are located on low risk soil; however, one pasture near Ward Brook lies on high risk soil. Several hay and corn fields also lie on high risk soils. In Section 6, there is very little land used for pasture. There are many hay and corn fields, mostly near the shoreline, and some of these lie on high risk soils. Many of the residences lie on high risk soils, but, fortunately, there is a residential area that lies on low risk soils. Hunter Brook flows over high risk soils, and this area contains primarily high and moderate risk soils.
CONCLUSION

Runoff over impermeable soils on gentle or steep slopes has a great impact on the extent of phosphorus loading. Many roads and residences on the shores of the Eastern Basin are located on steep slopes with high risk soils, enabling water to flow off directly into the lake. Phosphorus near the mouth of Hunter Brook has little chance of being filtered out before it enters the lake during heavy rains and spring thaw, and roads, residences, and farms in this area all provide sources. Likewise, soils on or near major farms in southwestern sub-watersheds are also high risk and on steep slopes, and have little capacity to absorb the large amounts of phosphorus that these farms contribute. The areas of least concern include the northwestern watershed (the northern part of Section 2 and the western part of section 3), the ridge between the Starky and Hunter Brook sub-watersheds (the middle of Section 6), and the southwestern shore of the East Basin near Jones Brook (the southern part of Section 1). The southern end of Hunter Brook (in Section 6) is also of little concern since there is little residential or agricultural activity in this area.

Soil runoff indices in ascending order, excluding groundwater level coefficient, with permeability and slope included:

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China Lake watershed soils, soil descriptions, runoff indices, and degree of runoff risk:

Berkshire-
- BhB, BkB: gentle slope and moderate permeability, index of 0.76, fine sandy loam and very stony fine sandy loam, low runoff risk
- BkC: steep slope and moderate permeability, very stony fine sandy loam, index of 2.30, moderate runoff risk
- BkD: very steep slope, moderate permeability, very stony fine sandy loam, index of 3.07, moderate runoff risk

Biddeford-
- Bo: little or no slope and very slow permeability, high water table, mucky peat found in swampy areas, index of 16.66, high runoff risk

Buxton-
- BuB2: gentle slope and very slow permeability, silt loam, seasonably high water table, index of 33.33, high runoff risk
- BuC2: steep slope and very slow permeability, silt loam, seasonably high water table, index of 100.00, high runoff risk

Deerfield-
- DeB: gentle slope and rapid permeability, loamy fine sand, seasonably high water table, index of 0.30, low runoff risk

Hartland-
- HfC: steep slope and slow permeability, very fine sandy loam, index of 23.07, high runoff risk
- HfD: very steep slope and slow permeability, very fine sandy loam, index of 30.76, high runoff risk

Hinkley-
- HkB: gentle slope and very rapid permeability, gravelly sandy loam, index of 0.10, low runoff risk
- HkC: steep slope and very rapid permeability, gravelly sandy loam, index of 0.15, low runoff risk
- HkD: very steep slope and rapid permeability, gravelly sandy loam, index of 0.20, low runoff risk

Hollis-
- HrB: gentle slope and rapid permeability, shallow to bedrock (it was assumed that this would produce the same effect, if not greater, than a high
water table, and therefore the index was tripled), fine sandy loam, index of 0.45, low runoff risk

HrC: steep slope and rapid permeability, shallow to bedrock, fine sandy loam, index of 0.69, low runoff risk

HrD: very steep slope and rapid permeability, shallow to bedrock, fine sandy loam, index of 0.90, low runoff risk

HtB: gentle slope and rapid permeability, shallow to bedrock with 15% rock outcrop, assigned to moderate runoff risk due to presence of rock outcrops

HtC: steep slope and rapid permeability, shallow to bedrock with 15% rock outcrop, moderate runoff risk

HtD: very steep slope and rapid permeability, shallow to bedrock with 20% rock outcrop, moderate runoff risk

Monarda-

MoA, MrA: mostly little or no slope and very slow permeability, silt loam and very stony silt loam, index of 33.32, high runoff risk

Paxton-

PbB: gentle slope and moderate permeability, fine sandy loam, index of 1.53, moderate runoff risk

PbC: steep slope and moderate permeability, fine sandy loam, index of 2.30, moderate runoff risk

PcB: gentle slope and moderate permeability, very stony fine sandy loam, index of 1.53, moderate runoff risk

PcC: steep slope and moderate permeability, very stony fine sandy loam, index of 2.30, moderate runoff risk

PcD: very steep slope and moderate permeability, very stony fine sandy loam, index of 3.07, moderate runoff risk

Paxton-Charlton-

PdB, PeB: gentle slope and moderately rapid permeability, fine sandy loams, index of 0.50, low runoff risk

PdC2, PeC: steep slope and moderately rapid permeability, fine sandy loams, index of 0.75, low runoff risk

PdD2, PeD: very steep slope and moderately rapid permeability, fine sandy loams, index of 1.00, low runoff risk
Peru-
PfB, PkB: gentle slope and moderately slow permeability, fine sandy loam and very stony fine sandy loam, seasonably high water table, index of 10.00, moderate runoff risk
PkC: steep slope and moderately slow permeability, very stony fine sandy loam, seasonably high water table, index of 15.00, moderate runoff risk

Ridgebury-
RcA, RdA: little or no slope and slow permeability, fine sandy loam and very stony fine sandy loam, seasonably high water table, index of 15.38, moderate runoff risk

Rifle-
RF: little or no slope and very slow permeability, seasonably high water table, mucky peat, runoff index of 33.32, high runoff risk

Saco-
SA: little or no slope and very slow permeability, seasonably high water table, index of 33.32, high runoff risk

Scantic-
ScA: mostly little or no slope and very slow permeability, silt loam, seasonably high water table, index of 33.32, high runoff risk

Scarboro-
Sd: little or no slope and rapid permeability, seasonably high water table, index of 0.14, low runoff risk

Scio-
SkB: gentle slope and moderately slow permeability, very fine sandy loam, seasonably high water table, index of 10.00, moderate runoff risk
SkC2: steep slope and moderately slow permeability, very fine sandy loam, seasonably high water table, index of 15.00, moderate runoff risk

Suffield-
SuC2: steep slope and very slow permeability, silt loam, index of 50.00, high runoff risk
SuD2: very steep slope and very slow permeability, silt loam, index of 66.66, high runoff risk
SuE2: extremely steep slope (23-45%) and very slow permeability, silt loam, index of 83.33, high runoff risk
Togus-
   TO: little or no slope and very slow permeability, seasonably high water
table, fibrous peat, index of 33.32, high runoff risk

Vassalboro-
   VA: little or no slope, very slow permeability, seasonably high water table,
fibrous peat, index of 33.32, high runoff risk

Windsor-
   WmB: gentle slope and very rapid permeability, loamy sand, index of 0.10,
low runoff risk
   WmC: steep slope and very rapid permeability, loamy sand, index of 0.15, low
runoff risk
   WmD: very steep slope and very rapid permeability, loamy sand, index
of 0.20, low runoff risk.

Woodbridge-
   WrB, WsB: gentle slope and moderately slow permeability, seasonably
high water table, fine sandy loam and very stony fine sandy loam, index of
30.76, high runoff risk
   WrC, WsC: steep slope and moderately slow permeability, fine sandy loam
and very stony fine sandy loam, seasonably high water table, index of 46.14,
high runoff risk
Soils categorized into low, moderate, and high risk runoff potential.

LOW RISK SOILS:
- Berkshire (BhB, BkB)
- Deerfield (DeB)
- Hinkley (HkB, HkC, HkD)
- Hollis (HrB, HrC, HrD)
- Limerick (Lk)
- Paxton (PbB)
- Paxton-Charlton (PdB, PdC2, PdD2, PeB, PeC, PeD)
- Windsor (WmB, WmC, WmD)

MODERATE RISK SOILS:
- Berkshire (BkC, BkD)
- Hadley (Ha)
- Hollis (HtB, HtC, HtD)
- Lyman (LyB, LyC, LyD)
- Paxton (PbC, PcB, PcC, PcD)
- Peru (PfB, PkB, PkC)
- Ridgebury (RcA, RdA)
- Scio (SkB, SkC)

HIGH RISK SOILS:
- Biddeford (Bo)
- Buxton (BuB2, BuC2)
- Hartland (HfC, HfD)
- Monarda (MoA, MrA)
- Rifle (RF)
- Saco (SA)
- Scantic (ScA)
- Scarboro (Sd)
- Suffield (SuC2, SuD2, SuE2)
- Togus (TO)
- Vassalboro (VA)
- Winooski (Wn)
- Woodbridge (WrB, WrC, WsB, WsC)
APPENDIX IV

DETERMINATION OF THE CHINA LAKE WATERSHED AND SUB-WATERSHED BOUNDARIES

INTRODUCTION

Determination of the China Lake watershed boundary is crucial to the study of phosphorus loading in China Lake. It understanding of areas directly affecting the lake through input via small streams and major tributaries or runoff directly into the lake. Determination of sub-watersheds aids in the study of water flow patterns into the lake. This is important in elucidating the effects of different land uses in specific areas of the lake on the quality of the lake water.

A watershed is a water drainage area that is bounded on the periphery by higher elevations. The China Lake watershed can be further broken into sub-watersheds, or the watersheds of the streams running into the lake. Water will flow down a slope, and any gullies will serve to accelerate this flow. Water flows very little down ridges, but instead the ridges serve to divide the flow of water: some water flows down one side, and some on the other. In other words, gravity pulls the water toward the steepest slopes, because then it will reach the bottom fastest (in this case, the lake).

MATERIALS AND METHODS

Using a topographic map of the watershed used by Roland Tilton, and outlined on a sheet of mylar overlay in black ink the China Lake watershed boundary he and the DEP used. All streams were outlined in blue ink. The perennial streams were outlined in solid, and the ephemeral streams were outlined in dots and dashes, the convention used by the USGS in their topographic maps. The intermittent streams were outlined in dots and were not outlined on the USGS topographic map. They were inferred from the...
sharp, V-shapes in rows as one looks from high topographic contours to low topographic contours. These are the gullies that water flows into during spring runoff and storm events.

Next, the major contours were outlined—more specifically the 200, 250, 300, 350, 400, and 450 foot contours—all in different colors. This made it easier to see which direction was downhill. These contour lines were later removed to simplify the map. Since water flows downhill, I started at the high contour lines, and divided the ridges in half lengthwise, emphasising how the ridges divide the flow of water. These ridges serving as the periphery of the sub-watersheds. I use the term “ridges”, but actually some were low and broad-based, while some were what we commonly think of as ridges—high and steep. Between these ridges were valleys, which serve to collect and direct the flow of water downhill, forming the major and minor streams. These sub-watershed boundaries are also marked in black.

Finally, green arrows were drawn in to show the direction of water flow.

**RESULTS**

Three areas of the China Lake watershed boundary outlined on Roland Tilton's map were found questionable. These are the following:

1. The easternmost boundary near Hunter Brook should extend farther north.

2. The southern boundary in a swampy area to the northeast of Jones Brook and south of Starkey Brook could possibly extend farther north.

3. The northern boundary through a large area of swampland near Ward Brook and the Mud Pond watershed appears to extend farther south directly below Mud Pond. Directly to the west of Mud Pond the watershed boundary should extend farther north.

The first and third of these areas (south of Mud Pond) were corrected by the Land Use division of SCOALE, and new boundaries were used in the determination of the total China Lake watershed area.

Twenty-three sub-watersheds were outlined. They included the watersheds of the major tributaries—Hunter Brook, Starkey Brook, Jones
Brook, Muldoon Pond, the Fire Road #1 stream, and Ward Brook—as well as 17 smaller sub-watersheds. Most of these smaller sub-watersheds drain directly into the lake. Four of these (three located in the northwestern watershed and drain into the West Basin, and one located south of the Muldoon Pond sub-watershed and includes Starkey Brook) are wider than the rest, and water travels over a greater distance to reach the lake. Importantly, 13 long and narrow watersheds run along the lake shore, especially in the East Basin, where a ridge up to 350 ft in height separates many shoreline residential areas, hay and corn fields from the rest of the watershed. There are no major streams in these areas, so water runs directly off the slopes into the lake. Also included among these thirteen are three southwestern sub-watersheds, where several farms are located, where water runs off the hill into the southern end of the East Basin and into the Western Basin.

In the watersheds of Muldoon Pond, Hunter Brook, and Ward Brook, water flows more indirectly over gentler slopes and swamplands into the lake. Jones Brook also flows over gently sloped and flat areas, but does not drain through swampland. A major ridge of 450 feet in height divides the water flow into the Starkey Brook and Hunter Brook sub-watersheds. Starkey and Fire Road #1 sub-watersheds drain steeper slopes, up to 15°, and do not drain through swampland.

**DISCUSSION**

**Smaller Subwatersheds**

The seventeen small sub-watersheds that slope into the lake with no major streams to drain them, and contain both residential and agricultural areas, are at high risk of significant phosphorus loading through poor septic systems, lawn fertilizers, and manure-fertilized fields. The water has no chance to “unload” its nutrients via the filtering system of a long meandering brook. Rather, increased water velocities over steep slopes cause more sediments to be carried into the lake, and thus higher total phosphorus levels leading to persistent internal phosphorus loading in the lake. Total phosphorus values can be further increased if underlying or nearby soils are
highly erodible, which is the case for Hollis and Paxton sandy loams commonly found in the area. These flow characteristics are most likely contributing to the high total phosphorus levels obtained for the cornfield sample and mouth of Statue Brook sample collected and analyzed by the Tributaries Division of SCOALE, and for the high total phosphorus readings at Sites 1 and 11 obtained by SCOALE’s Lake Body Division.

**Major Tributaries**

There are several farms and residential areas located near the major tributaries. In the Hunter Brook sub-watershed, the largest of the sub-watersheds, part of a large hay field that also extends into the Starkey Brook sub-watershed, and hay and corn fields along the high ridge at the easternmost boundary of the watershed drain into Hunter Brook. In general, however, most of the area in the southern part of the sub-watershed is wetland and therefore limited in land use possibilities. There are more hay and corn fields, and three large pasture areas in the northernmost part of the Hunter Brook sub-watershed, as it drains into Muldoon Pond. One of these pastures boarders and drains directly into Hunter Brook.

In the Muldoon Pond sub-watershed, there are several small hay fields in the northwest and several small corn fields in the north. Three pastures drain into this sub-watershed; most importantly, the two-thirds of the large pasture mentioned above that boarders Hunter Brook drains directly into China lake without draining through the swampland first. The southern and western parts are large residential areas.

There are many small hay fields, three corn fields, and three pastures in the Jones Brook sub-watershed. One of these corn fields is located at the northernmost boundary of the sub-watershed, and two hay fields are located in the northern half of the sub-watershed, but most of the agricultural and residential activity is located in the southern half of the sub-watershed.

The Ward Brook sub-watershed, draining into the West Basin, is the least affected by human activities of all the major tributaries. There are two hay fields, two small corn fields, and a pasture on the ridge that runs along the northwestern shore of the East Basin, draining from this ridge into Ward Brook. In the western part of the sub-watershed are two large pastures and a
hay field that drain directly into the Ward Brook swampland. The Ward Brook sub-watershed is sparsely populated.

Sites along the upper branches of these tributaries will have less of an impact on phosphorus loading than if they were located at the mouth or on steep shoreline, as the nutrient load has a greater chance to sink into the sediment or to be assimilated by terrestrial organisms. Since water velocities are greatly reduced along the flat areas and swamplands of these tributaries, sediment settles out and orthophosphates are more readily extracted by plants. Moreover, internal phosphorus loading from the total phosphorus attached to sediment particles is increased in swampland, thus acting as a buffer by preventing that amount of internal phosphorus loading from occurring in the lake body. It would be expected, then, that total phosphorus levels during normal weather in these areas would be low. During substantial rain and spring runoff, however, both the discharge and water velocity are increased, allowing less time for plants to incorporate orthophosphate and internal loading to occur in swampland. Increased water velocities during spring thaw and heavy rains also stir up sediments and carry them into the lake, thus increasing the total phosphorus concentrations in the lake body. Hence spring thaw and periods of heavy rain are the times of greatest phosphorus input to the lake.

Fire Road #1 and Starkey Brooks drain steeper land, up to 15°, and empty out to the lake without passing though swampland first. This means that phosphorus will more readily enter the lake, and sites that contribute phosphorus will have a greater impact than sites that drain through swampland. In the Fire Road #1 sub-watershed, there are five corn fields, two hay fields, and half of a pasture that drain into the brook. The shoreline is heavily populated. The Starkey Brook sub-watershed is much larger than the Fire Road #1 sub-watershed, and contains many small hay fields near the mouth. There are also several corn fields, including two on the ridge that divides the Starkey and Hunter Brook sub-watersheds, and several fields in the southeastern section of the sub-watershed. There are no pastures in this area. The only densely populated area in the sub-watershed is along the shoreline, and the Town of China’s dump is located above a swampy area that drains into Starkey Brook.
CONCLUSIONS

Determination of the China Lake watershed and sub-watershed boundaries has been useful in studying the water flow patterns within the watershed. Areas along the shores of the East Basin and along the northwestern and southern shores of the Western Basin drain directly off the slopes into the lake, contributing significantly to phosphorus loading. Areas near the upper branches of major tributaries, or areas that drain through swampland before draining into the lake, such as Hunter Brook and Ward Brook, will have less of an impact. This information should aid in determining impacts of land use on lake water quality and in proposing mitigative strategies for accelerated lake eutrophication.
APPENDIX V

WORK PLAN: ANALYSIS OF THE IMPACT OF LAND USE ON THE CHINA LAKE WATERSHED

Submitted by

SCOALE
(Student-Collective Organized Against Lake Eutrophication)
INTRODUCTION

China Lake covers an area of 1558 hectares and is located on the Vassalboro/Palermo quadrangle of China, Maine. The lake is divided into two basins. The west basin provides water for the greater Waterville area, and its watershed encompasses a drainage area of 86 km². The east basin contains China Lake's major inlet, and is also the residential and recreational center.

China Lake has undergone increased eutrophication within the past decade. Elaine Tietjen described the magnitude of the problem in Avoiding the China Lake Syndrome, "Small-scale but widespread pollution from the everyday activities of residential development and agriculture has accelerated the lake's eutrophication process, causing the most dramatic decline in water clarity ever documented in Maine." Phosphorus loading, the major problem concerning the lake, is a direct result of residential overdevelopment, poor agricultural practices, and improper waste disposal.

Intensive studies have been undertaken since 1984 by the Maine Department of Environmental Protection (DEP). These studies were instigated due to complaints by residents who sighted algal blooms in late August 1983. At the time of the initial DEP investigation in 1984, total phosphorus levels read 15 ppb. Levels of above 15 ppb are likely to foster algal blooms. They will not usually occur below total phosphorus levels of 15 ppb, since phosphorus is the primary limiting nutrient. Because of the importance of phosphorus, our study will focus on phosphorus levels and their probable sources.

The China Lake Association, a group of concerned residents, convinced the town to tighten restrictions on land use in order to reduce phosphorus loading. By 1987, a new land ordinance had been drafted. One of the restrictions included a law stating that a maximum of 6% of a resident's property could be covered by structures. Another group, the Concerned Citizens of China, opposed this ordinance in favor of a new proposal including a 20% coverage law. The ordinance was repealed on June 25, 1988, causing the state to intervene with emergency restrictions. Eventually, the town approved a compromise ordinance on February 4, 1989, which included a compromise of 12% land coverage. Based on a "Phosphorus Finding
Project" carried out by volunteers from the China Lake Association, an $80,000 grant for lake restoration has been awarded by the Environmental Protection Agency. This funds a cost sharing program for landowners who are willing to correct erosion problems on their properties.

There are three major components in our proposed study.

1. Determining water quality of the lake proper. This includes testing abiotic and biotic parameters, focusing on phosphorus loading.
2. Quality of the water leading into the lake proper by means of tributaries and drainage pipes/culverts: determination of phosphorus in selected sources in order to assess potential trouble spots. In the event of a storm, these tributaries will be examined for significant changes in phosphorus levels as a result of the increased water flow.

   The purpose of testing every half hour is to measure the increased phosphorus concentrations over time as a result of increased erosion of soils containing colloidal phosphorus.
3. To determine historical and present day land use within the watershed area. This includes evaluation of the trends of historical land use patterns in relation to phosphorus levels in the lake proper. Previous land use and regulations may support changes in present day legislation to help improve water quality in China Lake.

All three of these elements will be integrated so that areas will be treated in accordance to the magnitude of their degradation. Possible mitigative techniques will be investigated. Possible techniques include inhibiting erosion within the watershed, tightening restrictions on waste disposal and development, investigating the feasibility of alum treatments reducing internal recycling of total phosphorus, and increasing public awareness.

**REVIEW OF FIELD RECONNAISSANCE**
On the seventh of September in 1989, the Student-Collective Organized Against Lake Eutrophication (SCOALE) performed a two part field reconnaissance on China Lake. Some members of SCOALE observed the tributaries and exterior watershed area in cars, while other members observed the shoreline from boats looking for factors that might have contributed to phosphorus loading of the lake. The land reconnaissance groups exploring the area on the eastern side of the lake found multiple sources of possible phosphorus loading. Deforestation, including clear cutting and selective logging, were identified in various spots on the eastern coast. Additionally, grading of the roads near Evans Pond and paving operations were witnessed on Ridge Road and other roads closer to the lake. Located in the middle section of the eastern side is the South China town dump. At the dump we located uncontained storage of waste in close proximity of a tributary leading directly to the lake. Also, insufficient containment of recyclable oil and uncontained storage of salted sand were found. Land reconnaissance of the southern watershed area revealed roads with newly paved shoulders and numerous farms sloping close to the water. In East Vasselboro and the northern edge of the western basin we discovered agricultural operations set further away from the lake. On the western edge of the east basin dense residential and agricultural concentration combined with clearings to the lake shore and steep banks were noted.

The lake proper reconnaissance found drainage pipes, lawns extending to the shoreline, driveways leading into the lake and massive shoreline erosion all in the east basin, with the highest concentration in the northern tip. Furthermore, the lake's sixteen tributaries, excluding the inlet and outlet, were identified. Many of these tributaries were found passing directly through, or close to pastures, logging operations, manure storage sites, land clearing operations, and under roads. Through both the land and lake proper reconnaissance we were able to locate the major problem areas and their sources, as well as obtain a clear view of the areas on which we will need to focus our testing and research.

TEST FOR LAKE PROPER AND TRIBUTARIES
The following tests and the accompanying parameters will be tested:

1. **Algal Biomass**: A large algal population is indicative of high nutrient levels and poor water quality.

2. **Biochemical Oxygen Demand (BOD)**: BOD measures the oxygen requirement for microorganisms to oxidize organic matter, and estimates the amount of decomposers present.

3. **Coliform (total and fecal)**: Fecal coliform is a bacteria associated with fecal matter and represents an indication of fecal pollution and water quality. It is not only associated with raw sewage, but also with manure from agricultural establishments.

4. **Dissolved Oxygen**: DO is an indication of the extent of lake eutrophication. A healthy lake and its tributaries should exhibit a relatively high level of DO. Low levels of DO may be a strong indication of phosphorus loading. Moreover, low oxygen levels parallel low fish populations.

5. **Nitrates**: Nitrates are indicators of agricultural pollution stemming from manure and synthetic fertilizers for example, and act as the second most limiting growth factor for algal populations.

6. **Phosphorus**: Two forms of phosphorus will be tested, orthophosphates, the form directly available as a nutrient, and total phosphorus, which includes the amount of phosphorus tied up in sediment and other resources not available for use.

7. **pH**: pH will measure the progress of acid rain and the buffering capacity of the lake and its tributaries.

8. **Temperature**: Temperature determines the patterns of lake overturn.

9. **Turbidity and Suspended Solids**: The determination of levels of suspended solids is important as an indicator of phosphorus loading. Much of the phosphorus enters the water in colloidal form attached to soil particles. Moreover, the increase in siltation causes a decrease in the fish population. The tributary studies will utilize the test of suspended solids to measure the amount of erosion and water flow, and the lake proper studies will use a secchi disc in order to analyze turbidity.

10. **Water Flow**: The analysis of water flow in a tributary is an important parameter in determining the amount of phosphorus loading to
the lake. A tributary with faster flow can potentially introduce a proportionally greater concentration of phosphorous into the lake proper. Measurements taken before and after a storm event will measure this flow.

Note: Initial testing may require further testing and examination should any outstanding results arise.

WATER EXAMINATION OF CHINA LAKE PROPER

The purpose of the lake proper component is to monitor and update data regarding certain organic and inorganic properties of China Lake influenced by residential and agricultural development in the watershed. The tests will measure the effect of human activity on water quality. The study will focus on phosphorus loading and will try to identify major sources and the extent of damage as a continuation of previous studies.

Based on results from the field reconnaissance studies and the alum treatment proposal, ten sites have been chosen for initial testing. The following is a list of these sites, as shown in Figure 1.

SITE 1: Represents the most heavily developed and oldest residential area and is located downstream from the major inlet. Samples from site one will be offshore and stratified, and will include tests of algal biomass, BOD, dissolved oxygen, orthophosphates, total phosphorus, pH, temperature, and turbidity.

SITE 2: Parallel sample to site 1, but represents inputs near shore. Samples from this site will be taken at the surface and will include tests of coliform (total and fecal), orthophosphates, total phosphorus, pH, and temperature.

SITE 3: Measure of recently settled residential influence downstream. Samples at site 3 will be stratified and will include the following tests: dissolved oxygen, orthophosphates, total phosphorus, pH, temperature, and turbidity.
SITE 4: Parallel sample to site 3, but represents inputs near shore. This sample will test for coliform (total and fecal), orthophosphates, total phosphorus, pH, and temperature.

SITE 5: Represents an area of reduced flow, residential development, and large algal growth population. Algal biomass, BOD, dissolved oxygen, orthophosphates, total phosphorus, pH, temperature, and turbidity will be tested in stratified form at this location.

SITE 6: This is a marshy area with reduced flow located downslope from a large agricultural area. Indications of algal growth are present as well. The tests at this location are surface samples and include coliform (total and fecal), orthophosphates, total phosphorus, pH, and temperature.

SITE 7: This area represents the major access to the west basin from the residentialized east basin, and will also act as a comparison between the east and the west basins. The testing will be stratified and include dissolved oxygen, orthophosphates, total phosphorus, pH, temperature, and turbidity.

SITE 8: Measures the amount of agricultural influence brought into the west basin from a large farming area. Coliform (total and fecal), orthophosphates, total phosphorus, pH, and temperature will be measured at the surface.

SITE 9: Remnants of a large chicken farm reside upstream from this location in the west basin. The tests at this site will be at the surface and will include coliform (total and fecal), orthophosphates, total phosphorus, pH, and temperature.

SITE 10: Represents the outlet providing the water supply for the greater Waterville area. Algal biomass, BOD, dissolved oxygen, orthophosphates, total phosphorus, pH, temperature, and turbidity will be tested in stratified sequence.

SITE 11: Measures the influence of the large farming area concurrently with site eight in the west basin. Coliform (total and fecal), orthophosphates, total phosphorus, pH, and temperature will be measured in a surface sample.

Note: Each of the stratified samples will be taken at three depths, one representing the epilimnion, one the metalimnion, and one the hypolimnion.
WATER ANALYSIS OF CHINA LAKE TRIBUTARIES

In our study of the tributaries we hope to estimate the role tributaries play in contribution to decreased water quality in the lake proper, with emphasis on phosphorous loading. Any point where water enters the lake by way of a stream, pipe, or culvert is considered a tributary. We will be testing for phosphorus, dissolved oxygen, turbidity, and pH in all samples, coliform in some areas, and nitrates at one site. Sampling will be done during a storm event (ie. increased water flow), and under average weather conditions. Through data collection at tributaries the overall evaluation lake water quality will be enhanced, and will be used in conjunction with the lake proper and water shed studies to present possible solutions for the phosphorous loading problem.

On 25 September, after a discussion with Roland Tilton, the game warden of the China lake area, the following sites were designated key sites that will be tested. All sites will be tested during storm events, and those that will be tested also under average weather conditions are noted in the site descriptions. It was advised by Mr. Tilton that the optimal testing times are during storm events--for reasons of increased water flow leading to more useful data--and therefore most sites will be tested only in storm conditions. In some tributaries the water will be sampled throughout the storm to track possibly varying phosphorus levels accurately. In other areas, ie. normally ephemeral streams, there will be only spot checks. It will be noted in the site section which test will be performed.

During the storm event, testing will start as soon as possible after the rainfall begins, and tests will be taken every half hour at each test site, until the event is over, or five hours have passed. Testing will be done under "normal" weather conditions so that we will have a comparative basis to see possible changes in phosphorus loading with a storm event. Only phosphorus testing will be performed during sustained storm events.

The numbering system for test sites will be the same system that is used by the DEP. The following is an example of coding to be used: 9COLBY3A. The first number shown is the district number that the tributary
is in; "COLBY" indicates that the testing is done by Colby students; the "3" indicates the number of the tributary (in this case it would be Statue Brook); and "A" indicates where the site is on the tributary-- lettering begins with "A" at the mouth and continues upstream. Please refer to map to see the positioning of the testing sites.

The type of tests performed are described under Test for Lake Proper and Tributaries and are coded accordingly. For example, a test for phosphorus is denoted as #6.

SITE 1. Jones Brook (7COLBY2A,B,C,D)
Jones Brook is spring fed and therefore is a good source of cold water. Upstream problems include a logging area which causes silts to wash downstream. Also, a recent four acre clearing has caused noticeable plumeage of sediment as it enters China lake. Tests will be performed during "normal" conditions at all sites and a continual storm event test at A only. (6,7,8,9,10)

SITE 2. Starky Brook (7COLBY2A,B,C,D,E)
Starky Brook runs past a dump site, and through farm fields. "Normal" condition testing will be at all sites. Site A will be the only sustained storm event testing. (3,4,5,6,7,8,9,10)

SITE 3. Statue Brook (6COLBY5A,B)
Upstream from this tributary is an old dirt road that many trucks still drive on. This has caused gullying and excessive amounts of erosion into the lake. Sediment ponds and diversions have been tried unsuccessfully.

Reports have measured that during winter months four to five inches of sediment have washed out onto the ice from this tributary. A "normal" condition test and storm event spot test will be performed at A. If heavy siltation is apparent another spot check will be performed at site B. (6,7,8,9,10)

SITE 4. Hunter Brook (5COLBY7A,B,C)
This is the major inlet to the lake. This tributary runs under a road, and further upstream is Muldoon Pond. Surrounding Muldoon Pond is wetlands, and adjacent to these wetlands is a farm. Site A will be tested during "normal" and continually during a storm event. If high levels of phosphorus are found, further spot testing will be conducted during storm event on sites B and C. (3,4,5,6,7,8,9,10)

SITE 5. Fire Road 1 Brook (4COLBY8A,B)
Behind this tributary are several agricultural fields that wash down into the stream. One "normal" check will be run at site A, and a spot check during a storm event will be performed at site B. (3,4,5,6,7,8,9,10)

SITE 6. Ward Brook (3COLBY 12A,B)
This is located below Stanley Hill Road. There has been recent development near this road, and horses are on the land adjacent to the wetlands off of the brook. Only "normal" testing will be performed on sites A and B. (3,4,5,6,7,8,9,10)

SITE 7. Williams Brook (2COLBY26 A)
This is adjacent to the lake outlet. The source of this brook is the Williams farm barnyard which has no containment facilities for slurry. Testing at site A will be performed as spot checks during the storm event only. (3,4,5,6,7,8,9,10)

SITE 8. Rowe Brook (1COLBY23A)
This tributary runs from Rowe farm which has a manure pit that leaches directly into the tributaries. Storm event spot testing only will be conducted at this site. (3,4,5,6,7,8,9,10)

Through our study, we hope to show the importance of tributaries in water quality of the lake proper. This study in conjunction with the study of the lake proper and land use evaluation will compose a complete analysis of the water shed area so that accurate and effective mitigations can be proposed.

LAND USE PRACTICES

It is evident that certain land use practices within the watershed of China Lake have had an effect upon the phosphorus content of the lake. The effects of past and present land use on phosphorus levels in China Lake will be studied. We hope to identify unsound land-use practices which have led to deterioration of lake water quality. The major focus will be on existing agricultural and forestry practices, solid waste management, road building and residential development, while paying special attention to impending development of the shore line and watershed area.
Agriculture has historically been the major contributor to phosphorus loading in China Lake. According to Soil and Water Conservation estimates, farming in the area consists of dairy and beef cattle, accounting for roughly 100 acres of pasture land each, about 100 acres of cropland. The primary agricultural contributor of phosphorus to the watershed is manure, the most commonly used fertilizer. The runoff from fertilized fields which is typically rich in nutrients and bacteria, travels through tributaries to the lake. The most notable and successful means of controlling this problem is the concrete storage facility. The practice of spreading manure over frozen ground has been a major problem because manure stays on the surface and is unable to sink into the frozen soil. With the spring thaw, runoff from melted snow flushes this manure into streams, which lead directly into the lake. Concrete containment facilities allow the farmer to store manure until the ground has thawed and is more absorbant.

Tillage patterns also affect the rate of runoff. The use of contour tilling rather than straight-row tilling can be implemented to encourage absorption into the soil. In addition, reduced-till and no-till methods can be utilized, minimizing environmental damage. Vegetative buffer zones can reduce the phosphorus content of the water entering the lake by providing a natural filter. Finally, farmers could be encouraged to grow those particular varieties of crops that have been determined to absorb more phosphorus.

Forestry practices contribute to phosphorus loading. The removal of trees destroys soil cohesion and leads to extensive erosion and runoff. Erosion comes not only from water moving across the land, but also from the use of heavy machinery. Most of the regulations concerning lake conservation are directed at shoreline development and do not include specific regulations for the watershed area. According to a study by the Land Use Regulation Commission in 1977, 75% of the cases in Maine where evidence of sedimentation persisted had parts of the eroded areas within 250 ft. of streams. Heavy machinery near streams causes most erosion by tearing up the soil and leaving ruts where water can collect and erode. Wood cutters often ford streams with their vehicles causing increased erosion of stream banks and disturbance of sediment. This results in siltation.

Erosion is caused by increased runoff due to deforestation. Runoff picks up silt particles which contain phosphorus, and carries them into the lake via streams. As a consequence of this process, the proximity of these
cleared lands to wetlands or tributaries and to the lake itself is important. We will be reviewing regulations concerning silvicultural practices, conservation techniques such as rotational and selective cutting, and the replacing of cleared land with saplings or turf. The field reconnaissance of China Lake revealed selective logging in various locations within the watershed, particularly along the northern tip of the lake and near Evans Pond.

Land use practices in residential areas will be investigated in the course of this study. The rapid decrease in water quality of China Lake has been attributed to increasing development since the 1970's. We will look at the history of development in the watershed and note the accompanying land use regulations, determining the effect of population growth on phosphorus loading. The grandfather clause has been a troublesome issue for China Lake as many residents currently take advantage of obsolete environmental policy in order to avoid the cost and time necessary to comply with recent regulations. The effects as well as the possibilities of overriding this clause will be explored. This approach should expose the land use violations and lack of regulations which have contributed to the current problem, as well as point out mitigative strategies for the near future.

Roads in the watershed also add to phosphorus loading of China Lake. The proximity of roads to water, and poor shoulder construction both contribute to the deterioration of water quality. Usually water which entered the watershed has a chance to be filtered through grass and forests as it makes its way to the lake. Roads close to the water, however, serve as conduits for runoff particularly during spring thaw and storm events. Road shoulders cause considerable damage. For example, along Route 202, the shoulder consists of two six foot strips of exposed gravel which erode frequently.

The impending development of some areas around the lake is a concern. Continuing residential development is necessitating the paving of pre-existing dirt roads. In particular, Coles Road is a dirt road receiving heavy residential traffic at present and is likely to be paved. We will research road construction regulations in order to determine if existing regulations are being followed and if these restrictions satisfy China Lake's particular needs. We will also propose a plan to manage the upgrading and construction of roads in the watershed.

With the use of the ZIDAS computer and aerial photographs we will measure the land used for residential development, agriculture, silviculture,
and roads. With area values from the ZIDAS and pre-established phosphorus coefficients we will quantify the likely amount of phosphorus contributed by each particular site. Using photographs from 1960, 80, and 85, we will be able to plot increasing phosphorus loading as a function of relative land use. In turn, a phosphorus agenda for the lake will be extrapolated.

A thorough investigation of the South China Solid Waste Disposal Sight and the private landfill, both located on Alder Park Road will be undertaken in order to assess their environmental impact. Upon a brief investigation of the public dump, we found it to be an unconfined domestic waste storage sight. Poor containment practices, insufficient containment of recyclable oil, and the existence of a salted sand pile were apparent. There is an ephemeral stream near the dump which joins with a tributary during storm events and spring thaw. The area surrounding the dump is populated by cattails, indicating wet conditions for a good portion of the year. The course of water flow occurring here will be determined.

We intend to speak with permanent and seasonal residents, including farmers, as well as contractors and developers to assess their compliance with current environmental regulations, and their support for altering current land management.

Legislation, enforcement, and education are integrally related when considering mitigation of phosphorus loading. Legislation is necessary to regulate land use practices intended to improve the water quality of China Lake, and enforcement of legislation assures compliance with regulations. Although legislation is a necessary step in mitigation of phosphorus loading, it cannot be the only step. Legislation is not only passed very slowly but grandfather clauses provide the means with which to avoid regulations. By means of education residents may voluntarily fill these loopholes. We will study the present relationship legislation, enforcement and education hold in the China Lake community and recommend necessary changes.

To complete this project we will combine first hand observation with consultation and research. We will gather as much background information as possible with the use of archival materials, publications, and reports the areas of agriculture, silviculture, development and education. The ZIDAS computer will aid in quantifying and extrapolating the overall phosphorus budget of the watershed. A culmination of these different aspects will ultimately, result in a feasible land management strategy.
SUMMARY

The integration of the three components of the study: lake proper, tributaries, and land use, allows for a complete analysis of the China Lake water system. Each component is necessarily dependent on the others. For example, clear cutting in the watershed, a topic considered by the land use study, accelerates soil erosion. This erosion ultimately increases phosphorus loading, examined by the tributary and lake proper studies. The coordinated efforts of the three groups will isolate problem areas, providing data to formulate a mitigative treatment plan that is economically feasible.

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ACKNOWLEDGEMENTS

SCOALE would like to thank the following people for their support, guidance and, most of all, their time: Roy Bouchard, Timothy Christensen, Dr. F. Russell Cole, Dr. Frank A. Fekete, Dennis Myshrall, Robert O'Connor, and Roland Tilton. We would also like to thank the China Lake Association and Lee Austin.