THE STATE OF FINDLEY LAKE

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SUMMARY

Findley Lake is a beautiful natural resource that is available for the residents of this region to enjoy. Its many uses include fishing, esthetic beauty, recreational swimming, and boating. It is a major economic driver in the western portion of Chautauqua County and serves as a major revenue source for the Town of Mina. Significant alteration of this aquatic ecosystem has the potential to cause long-term hardship.

The purposes of this project were to characterize sources of nutrients and sediment flowing to the lake that are contributing to its eutrophication and to examine the current chemical and biological conditions of the lake. By documenting this information in this report, a set of baseline data has been established to serve as a guide in identifying watershed activities that can be modified to improve lake quality. This report, coupled with the ongoing collection of summer lake quality data through the Citizen's Statewide Lake Assessment Program, serves as a benchmark to which future measurements can be compared and used to determine the effectiveness of actions implemented as part of the Findley Lake watershed management plan. The ultimate purpose of the management plan, entitled The Management of Findley Lake and Its Watershed, is to slow down the aging process of the lake and improve overall lake quality to preserve it for this generation as well as those that will follow.

Introduction

Findley Lake covers an area of about 309.5 acres, has an average depth of about 3.3 m (11 ft) and a maximum depth of 11.6 m (38 ft). The land draining to the lake consists of about 3,000 acres of mixed agricultural, forested and developed land. At the present time, only approximately 10% of lakefront is in a natural, undeveloped state. The lake as we know it now, was created by Alexander Findley in 1815 by building a dam across the outlet of two natural ponds. This dam is now controlled by the Findley Lake Property Owners, Inc. (FLPO) who see to it that summer lake levels are maintained at about 1,420 ft above mean sea level. The lake level is lowered about 3 ft between October 15 and April 15 to protect lakeshore docks from ice damage, as an aid for flood control, and as a means to control shallow aquatic weeds by exposing them to freezing temperatures.

Nuisance aquatic weeds in Findley Lake have been a problem since at least the 1930s. Recreational boating, water skiing and swimming are especially impacted. Algal blooms also tend to be a problem in late summer, often turning the lake the color of pea soup and greatly reducing water transparency. The use of chemicals for weed and algae control has provided some temporary relief in the past, but proved not to be an effective long-term solution. This supports the need to develop and implement a management plan that will improve lake quality by addressing causes of lake impairment rather than treating its symptoms. That is, formulate a plan to permanently reduce the nutrients causing excessive weed growth, rather than trying to remove the weeds every year.

Summer population around the lakeshore area ranges between 1,100 and 1,200 people. This does not include the residential area on the north side of the lake that falls outside of the watershed. About 200 year-round residents live in the lakeshore area, occupying 30% of the homes and cottages surrounding the lake.

Land Use

Twenty-one categories of land uses were mapped at scales of 1 inch = 400 ft or larger that represent the land use and land coverage conditions of the Findley Lake watershed for the year 1998. Acreages were measured and percentages were calculated for 5 stream basins and lake peripheral area. The data were collected by local volunteers familiar with the area, using recent, detailed large scale air photos and checked by automobile windshield surveys. Measured areas for the 21 categories were placed into a hierarchical scheme under 4 subheadings: forest, agriculture, residential and other. About 62% of the lake watershed occurs within 5 stream basins and 38% as land peripheral to the lakeshore. Two of the stream basins are dominantly agricultural while three are primarily forested. The periphery is heavily (27%) residential and other (mainly urban) land uses, with about half the periphery in forest and a quarter in agriculture. These findings cause one to anticipate that the various sub-basins will produce varied water quantities and qualities.

Hydrology

A water budget was developed for Findley Lake by measuring water inflows and outflows and comparing them to the change in lake storage for the period November 1, 1997 to October 31, 1998. Two climate stations were established in the watershed to measure precipitation. Gaging stations were constructed on five streams that feed the lake and on the lake outlet. Three of those stations continuously recorded stream flow, the others were monitored routinely by project volunteers, along with daily lake levels. Direct runoff from the area immediately around the lake was estimated based on land cover and runoff coefficients. Evaporation from the lake surface was estimated as was ground water flowing out of the lake through the dam. These measurements and estimations were sufficiently accurate to solve for the amount of ground water that was flowing into the lake.

Ground water flowing into the lake such as from springs accounted for 39% of total inflow, stream flow accounted for 28%, direct runoff from the peripheral area around the lake accounted for about 21% and precipitation directly on the lake surface accounted for 12% of total inflow. The majority of outflow, about 91%, exits the lake through the outlet, 8% leaves by evaporation from the lake surface and less than 1% is estimated to flow through the dam as ground water. Over 400 million cubic feet, or 3 billion gallons, of water flow into and out of Findley Lake over a one year period. The total lake volume was calculated to be about 185.2 million cubic feet or 1.4 billion gallons. Dividing the lake volume by flow into the lake gives an estimate of the lake hydraulic residence time. This is the time it takes to turnover the entire volume of water in the lake, which works out to be just under six months.

Quality of Water Flowing Into the Lake

The water quality of Findley Lake is controlled by that of the surface and ground water entering the lake and by in-lake chemical, biological and physical processes. To assess the quality of water flowing into the lake, it is necessary to understand the water quality of each of the four inflow components discussed in the water budget: stream flow, runoff from peripheral lands, precipitation on the lake surface and ground water flow.

Results from monitoring five tributaries to the lake indicate they are well oxygenated, exhibit a near neutral pH and do not suffer from thermal pollution. The relatively small size of the streams flowing to the lake makes their water quality very sensitive to land use influences. The concentration of chlorides and nutrients in stream samples is directly related to the amount of land in agriculture. For example, Harrington Hill Creek, which contains the highest percentage of farmland, exhibits the highest chloride and nutrient levels, while Walkers Creek, which is almost entirely forested, exhibits the lowest levels. Thus, if the watersheds in the future were to contain larger amounts of residential and commercial development, a similar degree of degradation of water quality would be expected. Ground water that is sustaining stream flow during dry summer months contains relatively high levels of chlorides and nitrates. While this occurs in all the streams except Walker's Creek, it is especially apparent in Buesink's Creek. The phosphorus levels in streams are correlated to storm events that flush sediment off the land and into the streams, an indication that phosphorus is hitchhiking on sediment particles. Turbidity and sediment levels in Walker's Creek are unexpectedly high as are levels of phosphorus. Wetlands located at the south end of the lake are acting as a nutrient and sediment sink (i.e., a natural filter) for Harrington Hill Creek prior to that flow entering the lake. Finally, all of the streams exhibit good bacteriological water quality.

Direct runoff from the peripheral lands immediately around the lake is estimated to contribute the same amount of nitrates and phosphorus and twice as much chlorides as all five streams combined. This is directly related to the amount of developed land in this area, most of which is residential. Ground water that is directly feeding the lake was measured to contain high levels of chlorides and nutrients. Water wells tested around the northern portion of the lake are especially high in nitrates and chlorides. Septic systems, especially seepage pits around the lake, are contributing to chemical contamination of ground water that eventually flows to the lake, however, there is very little bacterial contamination of ground water. Precipitation and atmospheric deposition directly on the lake surface contributes a relatively large amount of phosphorus to the lake. Likewise, precipitation on the watershed adds a substantial amount of nutrients that were accounted for in stream flow and direct runoff.

Water Quality of the Lake

Temperature and dissolved oxygen data collected monthly at three locations in the lake indicate the lake mixes in spring and fall and stratifies during summer. The lake most likely also stratifies during the winter, given a month or more of ice cover. Summer lake temperatures at depth are colder than other lakes in this region, due to the large quantity of ground water feeding the lake. Conductivity on the other hand is much higher in Findley Lake, another indication of ground water feeding the lake. During summer stratification, reduced oxygen levels occur at about 3 m below the surface and drop to less than 5 mg/L at 4 m. Lake transparency is 3 m or more during most of the year but drops to just 1 m from July to September due to algal blooms. Near-surface pH ranges from 7 to 8.7, which is characteristic of a hard water lake in this region.

In-lake nutrients exhibit trends typical of a productive lake. The large amount of aquatic macrophytes and algae deplete nitrogen that has accumulated in the lake during winter and spring. Between July and September, there is little nitrogen available to in-lake plants. Nitrate levels at the north end of the lake are higher than elsewhere, which correlates to the higher levels of nitrates measured in the ground water at the north end. Chloride salts on the other hand become concentrated in the lake during the summer. Contributed by ground water in summer, chlorides are not depleted by biological growth, as are nitrates. There is an unusually large amount of phosphorus present in the lake. Like nitrogen, it becomes depleted by biological growth in the summer. It is important to note that during summer stratification, a reducing environment exists at the bottom of the deeper portions of the lake, at which time phosphorus trapped in bottom sediment is released back to the water column. Fall and spring turnovers then mix this high phosphorus bottom water with the shallower water, redistributing phosphorous throughout the lake.

Lake Biology

Findley Lake is, and has been, an aquatic system that is undergoing the normal ecological process of eutrophication. Previous studies indicate that the fish populations in the lake are healthy, although sheer densities of fish appear to limit size, especially among the panfish. However, in the 1930s, the State of New York Conservation Department described the lake as "weed-choked," indicating that it has suffered from aquatic weed problems for many years. The identification of nutrient and sediment inputs to the lake, as documented in this report, and subsequent reduction of those contaminants will help reduce the effects of eutrophication.

One of the sources of nutrients to the lake is introduced via waterfowl. We estimated that approximately 9 kg of phosphorous per year could be contributed by goose feces. This represents a very small percentage of total nutrient inputs. However, bacteria contributed to the lake water from goose feces can be significant. Zebra mussels, while present in almost all surrounding lakes, are notably absent in Findley Lake.

The aquatic macrophyte Eurasian watermilfoil (*Myriophyllum spicatum)* is now the dominant plant species at Findley Lake. While the details of its introduction are not known, it was not present during the 1937 survey conducted by the State of New York Conservation Department. Milfoil abundance increases during May and starts to decline around the end of June into July.

The presence of the aquatic weevil (*Euhrychiopsis lecontei*) in Findley Lake, one of the biological controls for watermilfoil, was evaluated during this study. A survey completed in late May 1998 at two locations in the lake (the Island and Cove sites), estimated weevil densities of 1.39 weevils per milfoil apical meristem tip. In late June and early July 1999, the lake was inoculated with approximately 15,000 adult weevils, half at the Island site and half at the Cove site. Surveys later that summer revealed densities of 1 per milfoil tip or less at those same sites. Although, relatively few adult weevils were found during this study, greater abundances of larvae and eggs were found, suggesting that populations may increase given the appropriate conditions for weevil survival. These densities compare well to those obtained during a University of Wisconsin study of that state's lakes. However, Wisconsin researchers speculate that approximately 3 weevils per plant tip are required to effect macrophyte growth control and Findley Lake densities have yet to reach that level.

While many control techniques are available for in-lake management of Eurasian watermilfoil, none have been demonstrated to be very successful. Chemical treatment of water with herbicides or sun-blocking dyes carry inherent ecological risk and, in the case of herbicides, human health concerns. Long-term use of herbicides is prohibitively expensive and may impair some ecosystem functions, including fish reproduction. Dredging, while an excellent treatment, is far too expensive for the vast majority of affected lake systems and may release toxic heavy metals and organic chemicals back into the water column. The use of biological controls potentially offers cost-effective and efficacious treatment of Eurasian watermilfoil in some cases. The most promising controls at this time appear to be the aquatic moth and aquatic weevil. Physical controls, including mechanical harvesting and water draw down, have had the most demonstrable success to date. While mechanical harvesting removes nutrients from the lake that are contained in the weeds, it can further exacerbate weed problems through fragmentation and subsequent regrowth.

Of the existing options available to control Eurasian watermilfoil, more research must be done to determine their effectiveness in Findley Lake. While the presence of the aquatic moth in the lake has been confirmed, its distribution and density are unknown. In order to determine the effectiveness of the weevil, additional census data must be collected for several more years. Weed harvesting, which provides a temporary clearing of the lake, must be repeated as necessary, typically annually and possibly more frequently, and will likely impair the use of biological control agents. The permitted use of herbicides, used widely in the lake from 1956 to 1971, proved to be ineffective for weed control and, at times, detrimental to the lake and outlet ecosystems. Use of chemicals as a weed control may also impair the use of biological controls. In this research teams opinion, the best long-term solution to the macrophyte problem, would be the use of biological controls.

Since the growth of algae and aquatic macrophytes are directly attributable to the presence of excessive quantities of nutrients, measures cited in The Management of Findley Lake and Its Watershed that reduce watershed nutrients should be implemented in conjunction with an in-lake macrophyte management plan, biological control being the preferred method of control. Harvesting may need to be suspended and no chemicals applied, in order to properly evaluate the biological control.

Lake Sediment Study

Lake bottom sediment samples were analyzed for two chemical herbicides known to be widely used for aquatic weed control in the 1950s and 60s, and for phosphorus and nitrogen. Results indicate that Arsenic concentrations decrease with sediment depth, the highest concentrations being found near the sediment-water interface. However, there are indications that the arsenic levels detected in Findley Lake sediments are no greater than the natural occurring levels in this area. Levels of the herbicide 2,4 D in sediment samples were below the laboratory's detection limit. Phosphorus levels are similar to that measured in Fredonia Reservoir sediment samples, while nitrogen levels are somewhat higher than those in the reservoir.

RECOMMENDATIONS

Some general recommendations can be made based on the scientific information collected for this project. These recommendations are set forth to reduce or keep in check the current aging process (i.e. eutrophication) of the lake, or collect more information about the lake and watershed in order to understand them better. These recommendations mainly emanate from the land use, hydraulic, chemical and biological scientific findings. Other issues also affect lake management and thus many other important and insightful recommendations have been made in the companion document, The Management of Findley Lake and Its Watershed. Implementation of measures cited in the management plan that reduce watershed contributions of nutrients and sediment to the lake will likewise reduce the growth of nuisance aquatic weeds and reduce algal blooms, thus improving the overall quality of the lake. This is the only long-term solution to the eutrophication problem at Findley Lake.

The acute growth of Eurasian watermilfoil and other nuisance aquatic weeds in Findley Lake is often a problem. However, as with other lakes in the region, their growth pattern is complex. In addition to the availability of nutrients, environmental variables such as ambient seasonal temperatures, amount and extent of sunshine, duration of ice and snow cover and precipitation, can impact weed growth. It is some unknown combination of variables that cause lake weeds to grow extremely heavy one year and light another year. To help understand aquatic weed growth patterns in Findley Lake, it is important to systematically document the extent of growth and types of aquatic weeds in the lake, every year. Only by comparing long-term trends of weed growth to other environmental observations, will we begin to understand weed growth patterns.

- An aquatic weed survey should be done twice annually, in June and August. During each survey, a map identifying the extent, density and predominant weed types throughout the lake should be prepared. A written procedure on how to conduct these surveys should also be prepared and a log of results maintained for public and scientific use.

- Of the existing options available to control Eurasian watermilfoil, more research must be done to determine their effectiveness in Findley Lake. It is important that the type of weed control used be carefully selected each year, based on results of the June weed survey. There are, and will continue to be, years when no external weed control is necessary. For example, 1998 saw "extreme" growth of Eurasian watermilfoil while in 2001, milfoil was greatly reduced and the extent of aquatic weed growth was very "light."

- Participation of the Findley Lake Property Owners, Inc. in the Citizen's Statewide Lake Assessment Program is very important. Findley Lake has been involved in the program since its inception in 1986 and is fortunate to have one of the most complete data sets throughout New York State.

- Activity of the aquatic weevil should be monitored. Data collection for several more years, a minimum of biomass surveys twice annually along with at least three tip surveys annually, would allow an objective evaluation of whether the lake will support sufficient weevil populations and whether weevil populations are increasing.

- A volunteer stream monitoring program should be initiated on at least two streams feeding the lake. Monitoring of nutrients, chlorides, physicochemical parameters and bacteria should be performed at the same time of year each year. These episodes of monitoring should be done four to six times per year, and represent different seasons and stream flows.

- A few key water wells should be chosen for monitoring changes in ground water chemistry (nitrogen, phosphorus and chlorides) in the gravel aquifer around the lake and data collected three times per year. These monitoring results, along with stream monitoring results, are needed to compare watershed impacts of nutrients and other parameters to those in the lake collected through the Citizen's Statewide Lake Assessment Program.

- A new bathymetric map should be made of the lake bottom that is tied to a survey benchmark. The existing map does not accurately reflect the existing lake bottom conditions and is not sufficiently accurate to detect future (or past) sedimentation.

- It is critical to preserve the 1,700 acres of forest land, which accounts for 58% of the watershed. As forest land is changed to residential, commercial or agricultural use, nutrients, chlorides and sediment flowing to the lake can increase ten-fold. Retention of forest land also assures that ground water contamination rates will remain in check.

- Sediment is a pollutant. It must be kept out of the streams and the lake. It transports phosphorus to the lake and gradually reduces the lake volume. Activities that add sediment to the lake must either be curtailed or modified to keep the soil, grit and sand on the land where it belongs. Best management practices, such as implementing construction erosion and sedimentation control programs, should be initiated.

- Riparian buffers, a strip of vegetation growing along streambanks, should be maintained along all tributaries to the lake. These act as filters for runoff entering streams. They remove sediment and nutrients from the runoff and can provide stability to the stream bank itself, especially where the banks are comprised of sandy or gravelly soils. Buffers along the lakeshore function in a similar fashion. How wide of a buffer is needed? The wider the better. A 25-foot buffer strip provides four times more filtering ability than one 5 feet wide.

- The amount of sandy and gravelly soils in the watershed makes it particularly vulnerable to ground water contamination. Large amounts of nutrients and chloride salts have found their way to the ground water surrounding the lake. The most prevalent sources are septic systems, cropping on gravel soil, and the storage and use of road deicing agents. Alternative septic system designs and locations should be considered; careful nutrient management on cropland, lawns and gardens is needed; and prudent handling, storage and use of road deicing materials should be followed.

- Waterfowl, especially the large number of Canada geese, are contributing large quantities of bacteria to localized areas of the lake and to a lesser degree, nutrients. Not to mention the mess left on swim platforms, yards and docks. A means to control the number of geese should be investigated. Reducing grass mowing in field areas near the southern basin could provide some relief by allowing grass to grow to a length not preferred by geese.

- Biological control may offer the best long-term solution to the macrophyte problem at the lake. If other in-lake weed management techniques are used, they must be done so as not to cause irreparable harm to biological agents such as the weevil. To reduce negative effects of harvesting weevils, the authors recommend the development of no harvest zones along undeveloped areas that would serve as weevil nurseries. Likewise, if herbicides are used, application areas must be carefully planned to adequately avoid weevil inoculation, control and nursery sites.

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Without the assistance, advice, criticism and support of many people, this project could not have been successful. While it is impossible to recognize the individual contributions made by the participants, I make an attempt to list them all by name. I am sincerely grateful to all participants for the time and contribution they gave to the project. This study of Findley Lake especially benefited from recent work completed on Chautauqua Lake by SUNY at Fredonia Department of Geosciences that provided a foundation from which to start. Special thanks to Joe Kowalski, Project Manager, who donated countless hours to the project and commanded the army of volunteers, and to Vicki Boria who had a hand in just about every part of it. I did my best not to leave anyone out, but apologize for the inevitable. Bill Boria.

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Cover Photograph:

This picture was taken on July 10, 1998 in an effort to map weed beds in the lake using aerial photography. More information about this is included in Chapter 5 - Lake Biology. Jeff Messinger was the pilot and Bill Boria the photographer. The importance of forest land to the lake is readily apparent in the photograph. Also, note the large amount of farmland seen in the background, a portion of which is part of the Harrington Hill Creek watershed. At the time this photo was taken, the lake was experiencing a light algal bloom.

CHAPTER 1 - INTRODUCTION

Findley Lake is the western-most lake of New York State, located in the Chautauqua County Town of Mina. Oriented in a northwest-southeast direction, the lake covers an area of 309.5 acres. With an average depth of about 3.3 m (11 ft) and a maximum depth of 11.6 m (38 ft) (McKeown, 1989), Findley Lake can be characterized as a eutrophic system that receives significant amounts of nutrients from watershed and atmospheric sources. The land draining to the lake consists of about 3,000 acres of mixed agricultural, forested and developed land. All lakes undergo a natural eutrophication or aging process through time, which ultimately results in the conversion of an open water lake - to wetlands - to dry land. The rate at which this process proceeds is dependant on the availability and transport of nutrients, organic matter and sediment to the lake.

The purposes of this project were to characterize sources of nutrients and sediment flowing to the lake that are contributing to its eutrophication and to examine the current chemical and biological conditions of the lake. By documenting this information in this report, a set of baseline data has been established to serve as a guide in identifying watershed activities that can be modified to improve lake quality. This report, coupled with the ongoing collection of summer lake quality data through the Citizen's Statewide Lake Assessment Program, serves as a benchmark to which future measurements can be compared, and used to determine the effectiveness of actions implemented as part of the Findley Lake watershed management plan. The ultimate purpose of the management plan is to slow down the aging process of the lake and improve overall lake quality to preserve it for generations to come.

Findley Lake is classified by the New York State Department of Environmental Conservation as a Class B water body whose best usage is for recreation and fishing. McKeown (1989) characterizes the lake as having a productive fishery. However, Findley Lake is ranked by the Chautauqua County Water Quality Task Force as a high priority water body due to impaired recreational uses caused by the abundance of nuisance aquatic macrophytes (WQTF, 1996). Recreational boating, water skiing and swimming are especially impacted. One of the two permitted public bathing beaches has been closed by the Chautauqua County Health Department during portions of the 1997 and 1998 bathing seasons due to high bacteria counts in the swimming area. The high coliform bacteria levels are attributed to large numbers of waterfowl and the patchy distribution of submerged aquatic macrophytes that reduces water circulation in the beach area.

The lake lies atop the Allegheny Plateau located south of and above the Lake Erie Plain. The lake and its watershed drain northward into the West Branch of French Creek, which gradually winds west then south, flowing into French Creek at Wattsburg, Pennsylvania, tributary to the Allegheny River. French Creek is well known for its high biodiversity, boasting 86 different fish species and 26 different mussel species. Of those, twelve are considered "globally rare" and two mussels, the clubshell and northern riffleshell, are on the federal endangered species list (French Creek Watershed Management Group). While precipitation into the Findley Lake watershed eventually drains to the Gulf of Mexico, precipitation just a few miles north of the lake drains to the North Atlantic by way of the Great Lakes and St. Lawrence River.

A Brief History of Findley Lake

Considering the aboriginal settlement patterns of North America, this region was probably inhabited by ancient cultures between 10,000 and 12,000 years ago. Aside from undated artifacts scattered throughout the area, the first evidence of Native Americans in Findley Lake dates to sometime around the early 1600s, when the Eriez Indians were thought to live at a small fort on an adjacent hillside (Forker, 1997).

Arrival of European settlers around 1800 began a time of drastic change. Forker (1997) described early settlement of Findley Lake, which is briefly summarized here. In 1811, Alexander Findley purchased land at the north end of the lake from the Holland Land Company. After returning from service in the War of 1812, Mr. Findley built a dam across the outlet of two ponds, flooding a hundred or so acres of low lying land around the ponds and giving birth to Findley's Lake. Settlement of the hamlet followed. Several years later, the dam washed out, creating "sickness" within the community. The lake was a convenient place to dispose of waste generated by the estimated 500 residents of the community and, when the dam washed out, the resulting swamp became a breeding ground for mosquitoes that carried such disease as typhoid fever. Once the dam was reconstructed, the breeding area was eliminated, and the lake was able to assimilate the waste stream once again. This marks the earliest documented cultural impacts to lake quality, and the onset of activities destined to accelerate the natural eutrophication or aging process of the lake.

Findley's Lake and the surrounding region was home to mature, old growth forest that included white pine, hemlock, oak, maple, giant American Chestnuts and even sassafras trees as large as 24 to 30 inches in diameter. This, according to Luensman (1999) changed quickly. By about 1840, all of the commercial pine throughout the region had been harvested. Trees of lesser value in the area were burned and used for making pearl ash or black salt (Forker, 1997). Old growth forests soon disappeared, replaced by new growth trees and farmland. Additional information about the history and settlers of Findley Lake can be found in archives of the Findley Lake and Mina Historical Society and in Forker (1997).

The dam originally built and controlled by Alexander Findley is now controlled by the Findley Lake Property Owners, Inc. (FLPO). Lake level is regulated using a mechanical gate in the spillway at the lake outlet. FLPO owns the property where the existing dam and spillway are located on both sides of Main Street; their lot also extends a short distance out into the lake. Summer lake levels are maintained at about 1,420 ft above mean sea level. The lake level is lowered about 3 ft between October 15 and April 15 to protect lakeshore docks from ice damage, as an aid for flood control, and as a means to control shallow aquatic weeds by exposing them to freezing temperatures.

Lakeshore Population: 1998

During early spring of 1998, a group of Findley Lake volunteers conducted a survey of the lakeshore and adjacent area to determine the total number of permanent versus seasonal homes and permanent versus seasonal residents surrounding the lake. The lakeshore area was divided into four sections and each section assigned to the volunteer most familiar that area. Results of this survey are given in Table 1.1.

Table1.1: Results of the Lakeshore Residence Survey.

Type of Housing	Lake Front	Lake Periphery	Subtotal	Town of Mina*
Permanent Homes	38	58	96	420
Seasonal Homes & Cottages	145	77	222	279
Total	183	135	318	699

Population	Lake Front	Lake Periphery	Subtotal	Town of Mina*
Year Round Population	81	118	199	1,129
Seasonal Population	325	154	479	
Total	406	272	678	

* From 1990 Census

Reference to lake front includes all homes or cottages located on the lake. Reference to lake periphery includes those homes or cottages not immediately on the lake but close to it. Houses across the street from the lake on Rt. 426 or Shadyside Road are in the periphery, which also includes Ball Diamond Road and other areas close to the lake, within the watershed. Population data do not include the summer populations of Paradise Bay Park or Camp Findley United Methodist Church Camp.

The results of this survey show that as of 1998, 30% of the homes and cottages surrounding the lake were used as permanent residences for nine or more months of the year and the other 70% were used as seasonal and vacation residences. In addition, about two hundred people reside in the lakeshore area year-round, while nearly five hundred come to live part-time or vacation at private homes and cottages around the lake. Paradise Bay Park adds about 400 more vacationers to the lakeshore between mid-June and the end of August, while Camp Findley adds an average of about 75 people, mostly children, to the lakeshore population between the end of June and mid-August. All told, the summer population around the lakeshore ranges between 1,100 and 1,200 people. This does not include the residential area on the north side of the lake that falls outside of the watershed.

Aquatic Vegetation in the Lake: 1930s to 1970s

The presence of aquatic weeds in Findley Lake have been a problem since at least 1937 as documented during the first known scientific study conducted by the State of New York Conservation Department (1938). The following is an excerpt from that report.

> To form the present lake, an 8-foot dam was built across the outlet of two small ponds. The total area of the two ponds was slightly more than half the area of the new lake. As a result about one-half of Findley Lake is less than 10 feet deep. Within recent years this shallow area has become quite completely choked with vegetation. During the summer, the vegetation becomes so dense that only the tops are alive. In the lower levels where sufficient light fails to penetrate, the vegetation is dead or dying. While green plants normally aerate the water, here so little of the plant actually is green that stagnant conditions prevail on the bottom. It is not unusual for algal and rooted aquatic plant growth to become sufficiently abundant to render the recreational use of a lake at times unpleasant although these growths seldom become sufficiently abundant to affect fish life adversely. The condition in Findley Lake, however, leads one to conclude that vegetation may become so abundant as to be detrimental to fishing and fish production.

In 1948 the Findley Lake Property Owners, Inc. was formed. Coincidentally, some of the earliest records about weed control in Findley Lake on file at the Chautauqua County Health Department are dated 1949. These note that "most of the homes had flush toilets with septic tanks and tilefields, there is no sewage pollution to the lake but dumping of garbage is a problem." A decade later, a 1958 news article by the New York State Conservation Department described early attempts to control weed growth in Findley Lake.

> Over the years, a number of ineffective methods of weed control had been tried. These included lowering the lake level as much as sixty inches during the winter and, one year, spreading a chlorine compound on the exposed lake bottom. These efforts had no apparent effect on the weeds but may well have been responsible for the large number of dead fish found after the ice went out.

Arsenic was used as a weed herbicide from 1956 to 1959 but its effectiveness diminished with time, it being theorized that the aquatic weeds acquired a natural resistance to arsenic. In 1960, the FLPO applied to the State to use 2-4-D (dichlorophenoxyacetic acid) and in their application letter to the State, noted that

> "...in September 1959 weed growth had increased and spread into deep water areas extending out over 800 ft from shore, and in some areas the weed lines are meeting in the narrows from shore to shore."

Use of 2-4-D for weed control continued from 1960 to 1965. In 1965, a permit was granted to experiment with different chemicals in the lake, some of which were only allowed to be used on small plots of less than one acre in an effort to isolate an effective chemical for weed control. This included 2-4-D, ortho-diquat, paraquat, silvex, simazine, arsenic, copper sulfate and Endothall. Health Department records don't indicate exactly which of these chemicals were used, however, that year coincided with a severe fish kill in the West Branch of French Creek during both August and September. Reportedly the use of chemicals caused the release of nutrients back to the water column, which served as food for algae, creating unprecedented algae blooms. Subsequent chemical applications (1966 to 1971) combined the use of ortho-diquat as a weed killer and copper sulfate as an algicide. Documentation available in Health Department files on the use of herbicides in Findley Lake ends in 1971.

The preceding discussion leads to the conclusion that lake quality, at least in terms of nuisance aquatic weeds, has improved considerably since the late 1930's and that the use of chemicals for weed control has been ineffective and sometime detrimental to water quality. This improvement is partly due to improved sanitary waste disposal in the area surrounding the lake. Cooke and others (1986), when discussing methods of lake restoration, do not endorse the use of chemical herbicides because:

> "...there is abundant evidence that herbicidal and algicidal chemicals have been associated with major adverse impacts on lake systems, and none of them is "restorative." These adverse impacts include nutrient releases to the water following plant death (e.g., Simsiman et al., 1972; Hestand and Carter, 1978; James, 1984); dissolved oxygen depletion following plant decay (e.g., Brooker and Edwards, 1975; Anderson, 1981; Carpenter and Grelee, 1981); toxic effects on non-target aquatic organisms at recommended doses (e.g., DeMayo et al., 1982) and rapid regrowth of plants following treatment (e.g., Conyers and Cooke, 1983)."

Historical information cited above describing the use and effects of chemicals as a weed and algae control in Findley Lake certainly substantiates Cooke's statement. This supports the need to develop and implement a management plan that will improve lake quality by addressing causes of lake impairment rather than treating it's symptoms. Or as John Luesman, former Chautauqua County Planning Director put it, "We must see to it that we do not add any more nutrients to the lake or increase the siltation to the lake. It's one of those things that you and I have to be responsible for, a healthy lake."

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CHAPTER 2 - LAND USE

INTRODUCTION

The purposes of this chapter are to survey patterns of land use in the Findley Lake watershed and provide a basis for examining relationships between land uses and water quantity and quality in succeeding chapters. This chapter is organized with two major sections: a discussion of methods preceding the presentation of resulting measurements.

METHODS

The number and types of land use categories were determined, then mapped (Figure 2.1). The mapped areas were measured, then summed for each category for each basin and for the total watershed.

Land use categories were chosen based on a consideration of land uses known to occur in the Findley Lake watershed and a review of the State of New York Land Use and Natural Resource (LUNR) County summaries study (1971), Chautauqua Lake Studies (1972), and Wilson, Riforgiat and Boria (2000). This land use survey contains 21 categories (Table 2.1) grouped under 4 headings (agriculture, forest, residential and other). Sums of acreages and percentages were calculated for each of the headings (e.g. agriculture), in addition to the individual categories, making results easily comparable to other lake studies.

Land use maps were prepared by community volunteers familiar with the watershed. First, Health Department personnel defined the Findley Lake watershed boundary and boundaries of the stream sub–basins and lake periphery. These boundaries were delineated by hand from U.S. Geological Survey topographic maps and field checked. Second, large scale prints of 1995 air photos were then field checked by community volunteers for land uses within the watershed boundaries and revised by auto windshield surveys during 1998. The resulting land use map was at a scale of 1 inch equals 400 feet.

The air-photo-based land use map was not an orthophoto and thus the photo base contained distortions. To improve spatial accuracy of mapping, the land use polygons were transferred to tax maps that were at scales ranging from 1inch equals 100 feet to 1 inch equals 400 feet. Features on the tax maps such as roads and property lines acted as reference points.

Land use polygons were digitized from the tax maps using AutoCAD software. Areas were usually computed using AutoCAD with several areas checked by hand by counting grid squares on transparent graph paper. ArcView software was used to design and rescale the digital maps for various presentations.

Several steps were taken to improve data quality. Types of categories and measurement methods were used or improved that were successful in prior projects.

Figure 2.1: Findley Lake Land Use Map- 1998

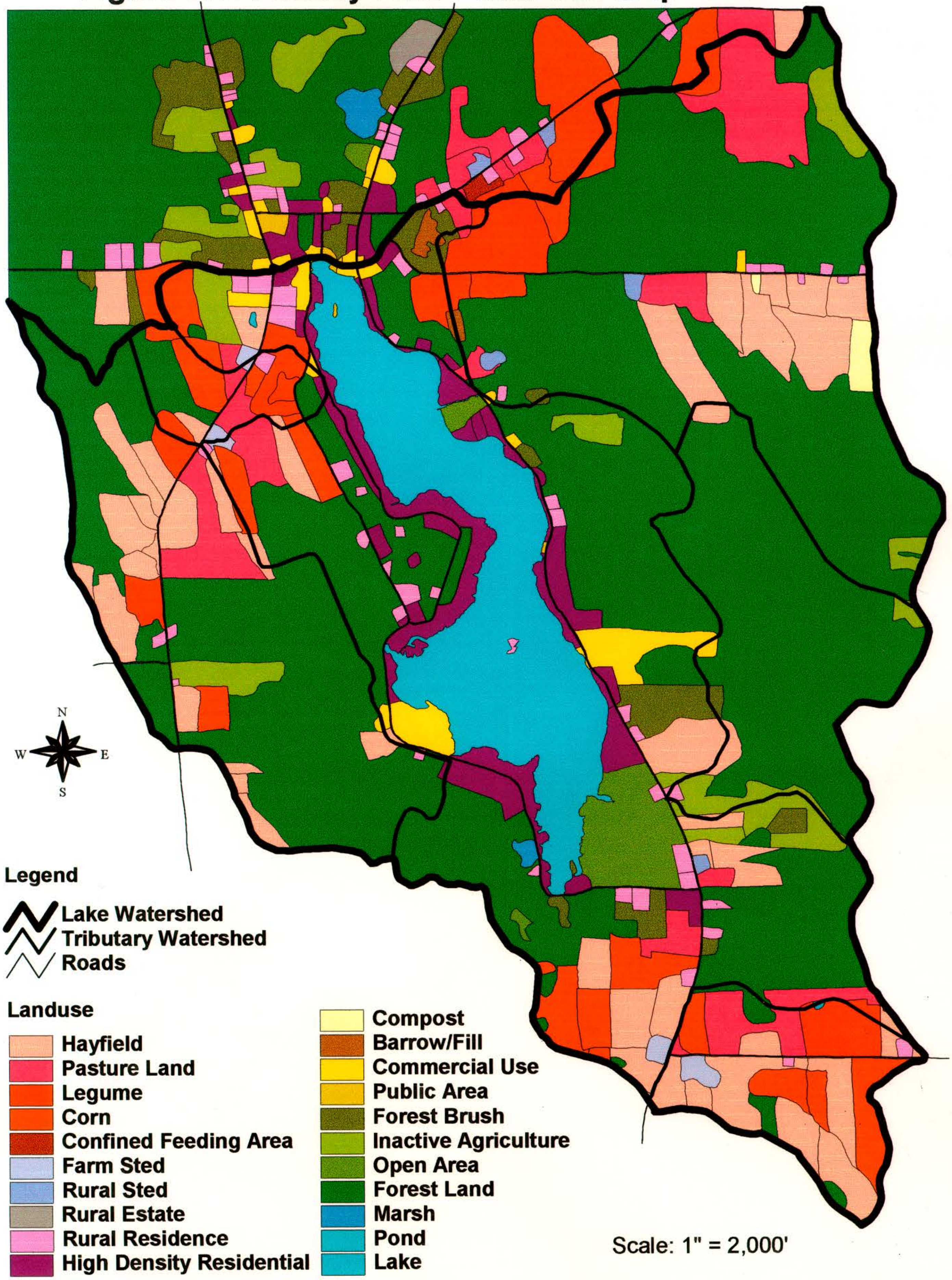

Figure 2.1 (cont.): Land Use Categories.

Agriculture

Confined Feeding Area – Feedlot or large scale dairy operation where large numbers of livestock are confined to a small area.

Corn – Areas of cropland being used to grow corn.

Farmstead – A full-fledged dairy, horse, sheep, or pig farm or combination thereof that because of size and intensity of use, may be a point source of nutrient loading.

Hayfield – Areas of cropland being used to grow hay.

Inactive Agriculture – Areas where brush and other plant growth have intruded into fields that were once crop land or pasture land, but have not yet progressed into brush land.

Legume – Areas of cropland being used to grow legumes such as oats, alfalfa, and clover.

Pasture – Areas of land used for livestock grazing.

Forest

Forest Brush – Brush land includes areas where forests are revegetating, having in excess of 10 % brush cover, up to and including stands of trees 6 inches in diameter, that are less than 30 feet in height and less than 40 - 50 years of age.

Forest Land – Forest areas with natural stands in which 50% or more of the trees are more than 50 years of age and in excess of 30 feet in height.

Residential

High Density Residential – Closely spaced cottages or homes on small lots of usually less than half an acre.

Rural Estate – A house with more than two acres of lawn or other open area.

Rural Residential – A house with less than two acres of lawn or other open area.

Ruralstead – A rural home site with up to 10 animals. Not as intensive as a farm.

Other

Borrow/Fill – Areas of gravel pits.

Commercial – Retail business, business district, and campgrounds.

Compost – Area being used for large scale composting facility of greater than 1 acre.

Marsh – Open water areas other than ponds or lakes as determined by aerial photographs.

Open Area – Mowed and maintained areas not being used for any agricultural purposes.

Pond – Open water other than the lake.

Public Areas – Parks and other areas open to the public.

Roads – Publicly maintained roads including associated drainage ditches.

Table 2.1: Summary of Acreages in 5 Tributary Basins and Periphery.

Land Use	Busink's	Castrilla's	Harrington Hill	Rothenburger's	Walker's	Periphery	Total
Total Agriculture	***236.4***	***46.1***	***162.0***	***159.7***	***26.6***	***269.7***	***900.4***
Confined Feeding Area	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn	18.6	16.9	41.6	7.2	0.0	74.8	159.0
Farmstead	0.0	1.8	4.8	0.0	0.0	5.6	12.1
Hayfield	89.2	3.9	75.6	94.9	9.0	95.2	367.8
Inactive Agriculture	19.4	0.0	0.0	15.2	17.6	45.4	97.6
Legume	42.7	16.0	20.0	14.7	0.0	15.8	109.2
Pasture	66.4	7.6	20.0	27.8	0.0	32.9	154.7
Total Forest	***523.6***	***21.3***	***15.2***	***329.8***	***289.0***	***546.7***	***1725.6***
Forest Brush	2.4	0.0	0.0	0.0	1.8	49.6	53.9
Forest Land	521.1	21.3	15.2	329.8	287.2	497.0	1671.7
Total Residential	***8.0***	***2.8***	***1.8***	***2.4***	***1.0***	***167.7***	***183.7***
High Density Residential	0.0	1.2	0.0	0.0	0.0	127.0	128.3
Rural Estate	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rural Residential	3.7	1.6	1.8	2.4	1.0	39.3	49.7
Rural Sted	4.3	0.0	0.0	0.0	0.0	1.4	5.7
Other	***21.1***	***4.0***	***4.3***	***8.0***	***1.7***	***138.1***	***177.2***
Barrow/ Fill	1.6	0.0	0.0	0.0	0.0	5.7	7.3
Commercial	1.6	0.5	0.0	1.7	1.4	46.8	52.0
Compost	10.5	0.0	0.0	0.0	0.0	0.0	10.5
Marsh	0.0	0.0	0.0	0.0	0.0	2.6	2.6
Open Area	0.0	0.0	0.0	0.0	0.0	58.4	58.4
Pond	0.0	0.3	0.0	0.0	0.0	0.0	0.3
Public Area	0.0	0.0	0.0	0.0	0.0	1.7	1.7
Roads	7.5	3.2	4.3	6.3	0.3	22.9	44.4
Total Acres	***789.0***	***74.3***	***183.3***	***499.9***	***318.3***	***1122.0***	***2986.8***
Percent of Watershed Land Area	***26.4***	***2.5***	***6.1***	***16.7***	***10.7***	***37.6***	***100.0***

Recent photos and field checks were used. The participation of community volunteers insured highly accurate parcel identifications. Rescaling and manipulation of data by use of digital maps eliminated errors.

RESULTING MEASUREMENTS

The results are presented in a set of tables, each paired with its corresponding pie chart (Tables 2.2 –2.8 and Figures 2.2 –2.8), as well as the watershed map (Figure 2.1) and summary table (Table 2.1) previously cited in this chapter. Note that all land areas and corresponding percentages shown in these tables and figures were originally calculated to the hundredth but were rounded to the nearest tenth, therefore their sums may appear off by one tenth due to rounding.

There are approximately 2,987 acres (4.67 mi^2) in the Findley Lake watershed not including the lake itself. The drainage areas of 5 streams (Table 2.1) account for 62% of the lake watershed; the lands peripheral to the lakeshore compose the remaining 38%. However, just 3 of the 5 streams account for 53% of the watershed (Buesink's, Rothenberger's and Walker's Creeks). Overall, forest (58%) and agriculture (30%) dominate land use in the watershed (Table 2.2 and Figure 2.2). The observation that 3% of the watershed is inactive agricultural land while 58% is forest fits the trends of agricultural conversion to forest known elsewhere in upstate New York (roughly a half percent per year since the early 1900s).

Looking at the details of land uses in Tables 2.3 – 2.8 and Figures 2.3 – 2.8 reveals that there are no significant confined animal feed areas, but Buesink's Creek basin contains composting areas. Corn and legumes are important components of those basins dominated by agriculture. High density residential, commercial, open and public areas are negligible outside the periphery.

While these details are interesting, it may be more important to contrast data from the major subheads between basins. Tables 2.3 – 2.8 were synthesized into Table 2.9 in order to draw attention to contrasts between basins. As Table 2.9 indicates, Buesink's and Rothenberger's Creeks basins are two-thirds forest and one-third agriculture, while Castrilla's Creek basin is two-thirds agriculture and one-third forest. Harrington Hill basin is about 88% agriculture while Walker's basin is about 91% forest. The periphery is roughly half forest, a quarter agriculture and, very significantly, a quarter residential and other urban uses.

LAND USE SUMMARY

Twenty-one categories of land uses were mapped at scales of 1 inch = 400 ft or larger that represented the land use and land coverage conditions of the Findley Lake watershed for the year 1998. Acreages were measured and percentages were calculated for 5 stream basins and the lake peripheral area. The data were collected by local volunteers familiar with the area, using recent, detailed large scale air photos and checked by automobile windshield surveys. Maps were digitized, manipulated and printed with

AutoCAD and ArcView software. Measured areas for the 21 categories were placed into a hierarchical scheme under 4 subheadings: forest, agriculture, residential and other.

About 62% of the lake watershed occurs within 5 stream basins and 38% as land peripheral to the lakeshore. Two of the stream basins are dominantly agricultural while three are primarily forested. The periphery is heavily (27%) residential and other (mainly urban) land uses, with about half the periphery in forest and a quarter in agriculture. These findings cause one to anticipate that the various sub-basins will produce varied water quantities and qualities.

Table 2.9 Summary of Major Land Uses: Basin Contrasts.

Name	Size (Acres)	Land Use %		
		Forest	Agriculture	Residential & Other
Buesink's	789	66	30	4
Castrilla's	74	29	62	9
Harrington Hill	183	8	88	3
Rothenberger's	500	66	32	2
Walker's	318	91	8	1
Periphery	1,122	49	24	27

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Table 2.2 and Figure 2.2: Entire Watershed Land Use Summary.

Entire Findley Lake Watershed

Land Use	Acres	Percent of Basin
Total Agriculture	***900.4***	***30.1***
Confined Feeding Area	0.0	0.0
Corn	159.0	5.3
Farmstead	12.1	0.4
Hayfield	367.8	12.3
Inactive Agriculture	97.6	3.3
Legume	109.2	3.7
Pasture	154.7	5.2
Total Forest	***1725.6***	***57.8***
Forest Brush	53.9	1.8
Forest Land	1671.7	56.0
Total Residential	***183.7***	***6.1***
High Density Residential	128.3	4.3
Rural Estate	0.0	0.0
Rural Residential	49.7	1.7
Rural Sted	5.7	0.2
Other	***177.2***	***5.9***
Barrow/ Fill	7.3	0.2
Commercial	52.0	1.7
Compost	10.5	0.4
Marsh	2.6	0.1
Open Area	58.4	2.0
Pond	0.3	0.0
Public Area	1.7	0.1
Roads	44.4	1.5
Total Watershed	***2986.8***	***100.0***

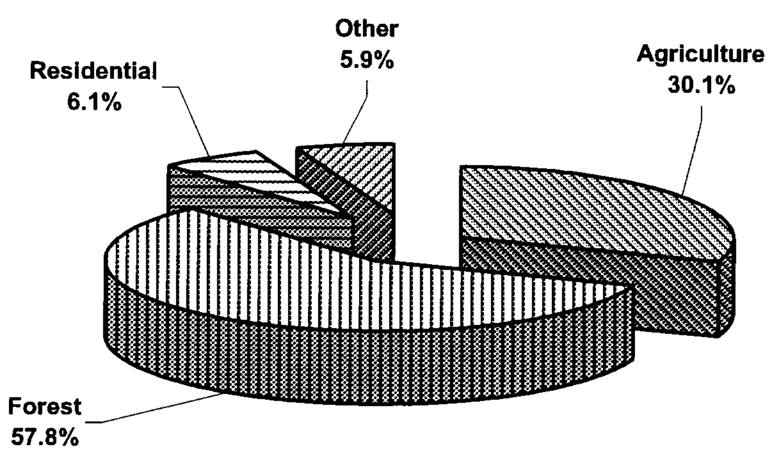


Table 2.3 and Figure 2.3: Buesink's Creek Percentages of Land Uses

Buesink's Creek Sub-Basin

Land Use	Acres	Percent of Sub-Basin
Total Agriculture	***236.4***	***30.0***
Confined Feeding Area	0.0	0.0
Corn	18.6	2.4
Farmstead	0.0	0.0
Hayfield	89.2	11.3
Inactive Agriculture	19.4	2.5
Legume	42.7	5.4
Pasture	66.4	8.4
Total Forest	***523.6***	***66.4***
Forest Brush	2.4	0.3
Forest Land	521.1	66.1
Total Residential	***8.0***	***1.0***
High Density Residential	0.0	0.0
Rural Estate	0.0	0.0
Rural Residential	3.7	0.5
Ruralstead	4.3	0.5
Other	***21.1***	***2.7***
Borrow/Fill	1.6	0.2
Commercial	1.6	0.2
Compost	10.5	1.3
Marsh	0.0	0.0
Open Area	0.0	0.0
Pond	0.0	0.0
Public Area	0.0	0.0
Roads	7.5	0.9
Total Sub-Basin	***789.0***	***100.0***

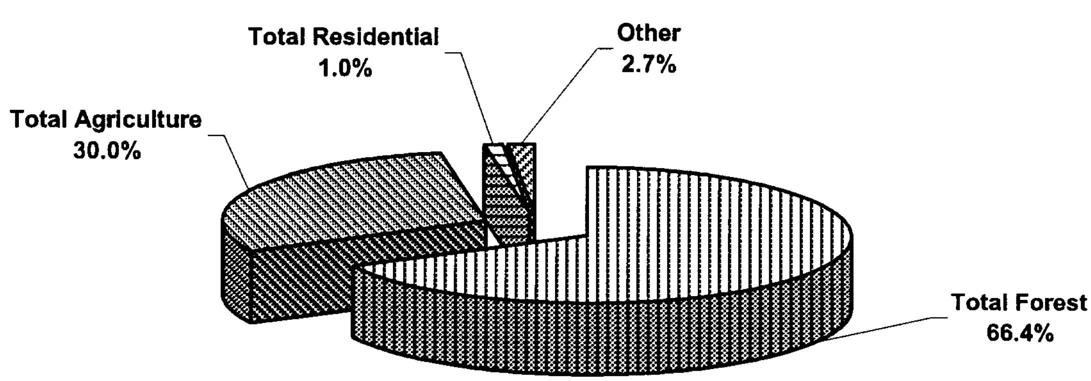


Table 2.4 and Figure 2.4: Castrilla's Creek Percentages of Land Uses.

Castrilla's Creek Sub-Basin

Land Use	Acres	Percent of Sub-Basin
Total Agriculture	***46.1***	***62.1***
Confined Feeding Area	0.0	0.0
Corn	16.9	22.7
Farmstead	1.8	2.5
Hayfield	3.9	5.2
Inactive Agriculture	0.0	0.0
Legume	16.0	21.6
Pasture	7.6	10.2
Total Forest	***21.3***	***28.7***
Forest Brush	0.0	0.0
Forest Land	21.3	28.7
Total Residential	***2.8***	***3.7***
High Density Residential	1.2	1.6
Rural Estate	0.0	0.0
Rural Residential	1.6	2.1
Ruralstead	0.0	0.0
Other	***4.0***	***5.4***
Borrow/ Fill	0.0	0.0
Commercial	0.5	0.7
Compost	0.0	0.0
Open Area	0.0	0.0
Marsh	0.0	0.0
Pond	0.3	0.4
Public Area	0.0	0.0
Roads	3.2	4.3
Total Sub-Basin	***74.3***	***100.0***

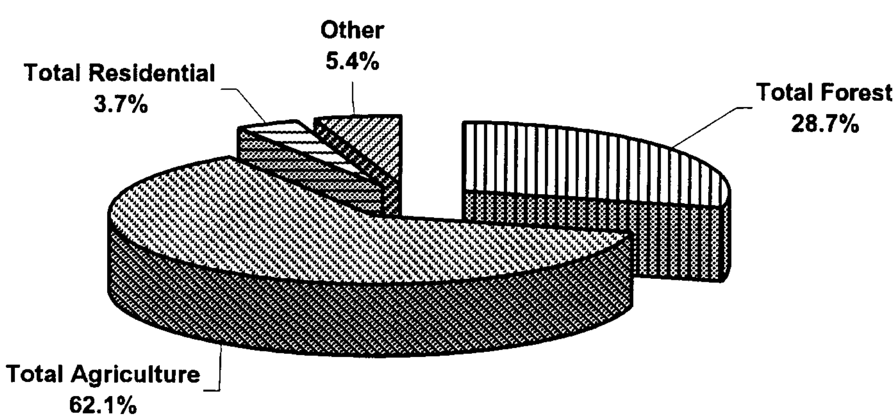


Table 2.5 and Figure 2.5: Harrington Hill Creek Percentages of Land Uses.

Harrington Hill Creek

Land Use	Acres	Percent of Sub-Basin
Total Agriculture	***162.0***	***88.4***
Confined Feeding Area	0.0	0.0
Corn	41.6	22.7
Farmstead	4.8	2.6
Hayfield	75.6	41.3
Inactive Agriculture	0.0	0.0
Legume	20.0	10.9
Pasture	20.0	10.9
Total Forest	***15.2***	***8.3***
Forest Brush	0.0	0.0
Forest Land	15.2	8.3
Total Residential	***1.8***	***1.0***
High Density Residential	0.0	0.0
Rural Estate	0.0	0.0
Rural Residential	1.8	1.0
Ruralstead	0.0	0.0
Other	***4.3***	***2.3***
Borrow/ Fill	0.0	0.0
Commercial	0.0	0.0
Compost	0.0	0.0
Open Area	0.0	0.0
Marsh	0.0	0.0
Public Area	0.0	0.0
Pond	0.0	0.0
Roads	4.3	2.3
Total Sub-Basin	***183.3***	***100.0***

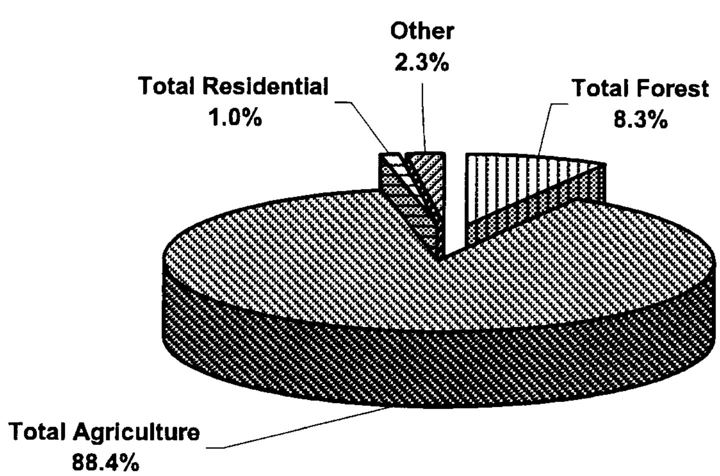


Table 2.6 and Figure 2.6: Rothenburger's Creek Percentages of Land Uses.

Rothenburger's Creek Sub-Basin

Land Use	Acres	Percent of Sub-Basin
Total Agriculture	***159.7***	***31.9***
Confined Feeding Area	0.0	0.0
Corn	7.2	1.4
Farmstead	0.0	0.0
Hayfield	94.9	19.0
Inactive Agriculture	15.2	3.0
Legume	14.7	2.9
Pasture	27.8	5.6
Total Forest	***329.8***	***66.0***
Forest Brush	0.0	0.0
Forest Land	329.8	66.0
Total Residential	***2.4***	***0.5***
High Density Residential	0.0	0.0
Rural Estate	0.0	0.0
Rural Residential	2.4	0.5
Ruralstead	0.0	0.0
Other	***8.0***	***1.6***
Borrow/ Fill	0.0	0.0
Commercial	1.7	0.3
Compost	0.0	0.0
Open Area	0.0	0.0
Marsh	0.0	0.0
Public Area	0.0	0.0
Pond	0.0	0.0
Roads	6.3	1.3
Total Sub-Basin	***499.9***	***100.0***

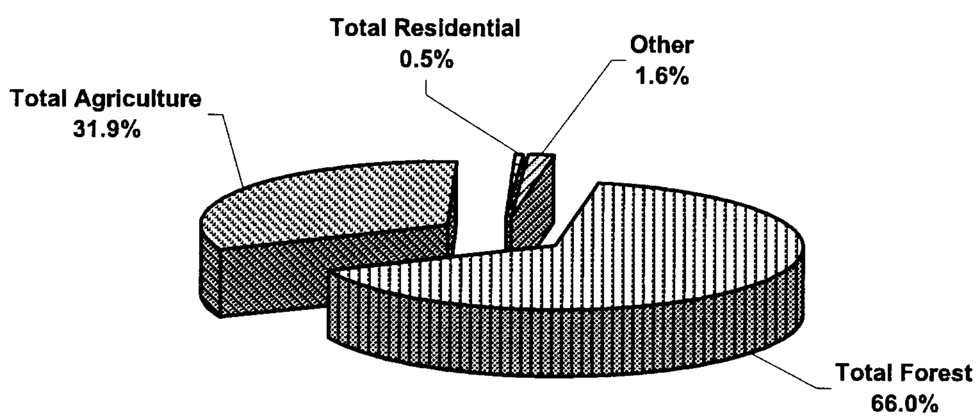


Table 2.7 and Figure 2.7: Walker's Creek Percentages of Land Uses.

Walker's Creek Sub-Basin

Land Use	Acres	Percent of Sub-Basin
Total Agriculture	***26.6***	***8.4***
Confined Feeding Area	0.0	0.0
Corn	0.0	0.0
Farmstead	0.0	0.0
Hayfield	9.0	2.8
Inactive Agriculture	17.6	5.5
Legume	0.0	0.0
Pasture	0.0	0.0
Total Forest	***289.0***	***90.8***
Forest Brush	1.8	0.6
Forest Land	287.2	90.2
Total Residential	***1.0***	***0.3***
High Density Residential	0.0	0.0
Rural Estate	0.0	0.0
Rural Residential	1.0	0.3
Ruralstead	0.0	0.0
Other	***1.7***	***0.5***
Borrow/ Fill	0.0	0.0
Commercial	1.4	0.4
Compost	0.0	0.0
Open Area	0.0	0.0
Marsh	0.0	0.0
Public Area	0.0	0.0
Pond	0.0	0.0
Roads	0.3	0.1
Total Sub-Basin	***318.3***	***100.0***

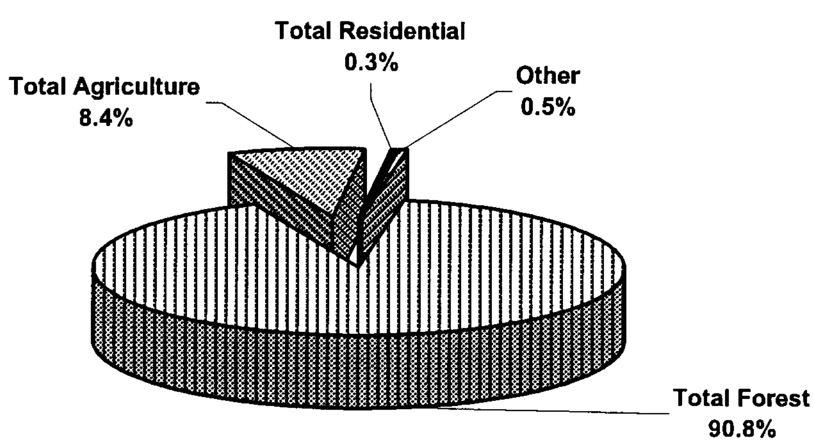
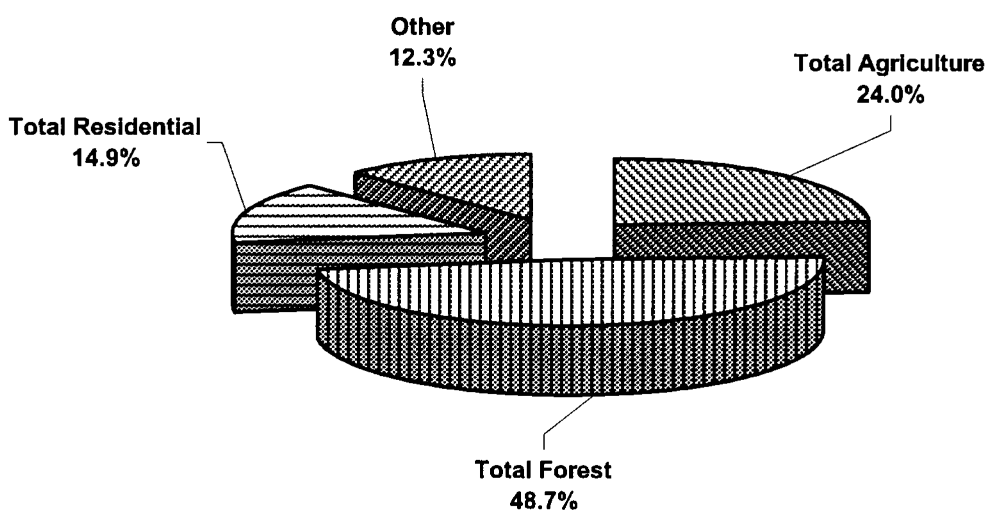


Table 2.8 and Figure 2.8: Peripheral Area Percentages of Land Uses.

Periphery

Land Use	Acres	Percent of Sub-Basin
Total Agriculture	***269.7***	***24.0***
Confined Feeding Area	0.0	0.0
Corn	74.8	6.7
Farmstead	5.6	0.5
Hayfield	95.2	8.5
Inactive Agriculture	45.4	4.0
Legume	15.8	1.4
Pasture	32.9	2.9
Total Forest	***546.7***	***48.7***
Forest Brush	49.6	4.4
Forest Land	497.0	44.3
Total Residential	***167.7***	***14.9***
High Density Residential	127.0	11.3
Rural Estate	0.0	0.0
Rural Residential	39.3	3.5
Ruralstead	1.4	0.1
Other	***138.1***	***12.3***
Borrow/ Fill	5.7	0.5
Commercial	46.8	4.2
Compost	0.0	0.0
Marsh	2.6	0.2
Open Area	58.4	5.2
Pond	0.0	0.0
Public Area	1.7	0.2
Roads	22.9	2.0
Total Sub-Basin	***1122.0***	***100.0***



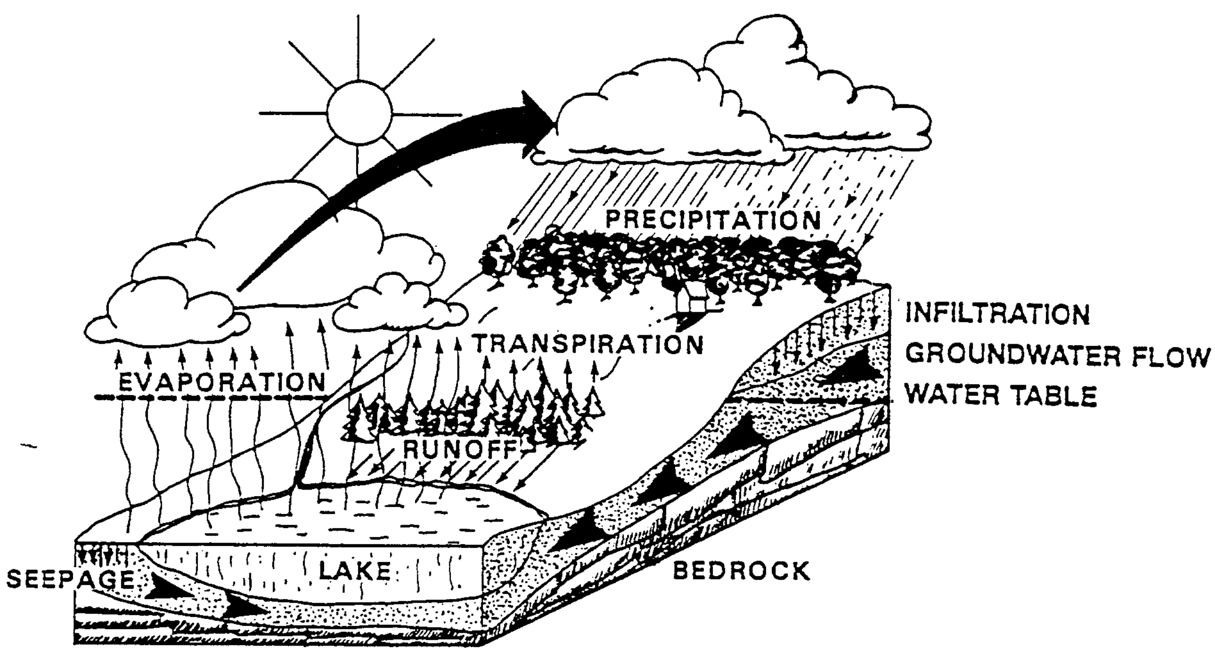
CHAPTER 3 - HYDROLOGY

INTRODUCTION

In order to make sensible lake management decisions it is necessary to have a thorough understanding of watershed dynamics and the hydrologic cycle. The hydrologic cycle, illustrated in Figure 3.1, is driven by precipitation (rain, sleet, hail and snow) that falls to the ground surface and interacts with the environment in a number of ways including: surface evaporation, plant transpiration, surface runoff, soil infiltration and ground water recharge. These interactions are controlled by watershed characteristics, the most important of which are land use or land cover, topography or land slope, soil type and geology.

The chemical, physical, and ultimately biological qualities of Findley Lake are controlled by the amount or volume of water entering the lake multiplied by the amount of materials or chemicals concentrated in that water. This concept is known as loading. In order to measure loading, both the water volumes (such as cubic feet per month or liters per month) and the chemical concentrations (such as grams per liter) need to be measured in the water entering the lake. A discussion of how water volumes are measured or estimated is covered in this section of the report.

Figure 3.1 The hydrologic cycle (from Olem and Flock, 1990).



A WATER BUDGET FOR FINDLEY LAKE

A water budget is commonly used for measuring or estimating water quantities. For a lake system we measure or estimate our gains, such as rain on the lake or stream flow into the lake, then subtract our losses, such as evaporation and outlet flow, and compare the results to changes in lake level. To develop an accurate water budget in this part of the country, it is important to collect data over a full year period that encompasses one complete winter season and one complete summer season. This requirement essentially dictates the project period, which in this case, was chosen to begin November 1, 1997 and end October 31, 1998, and is hereafter referred to as the "1998 water year." While it is preferred to develop water budgets based on more than one water year to reduce yearly climate variations, it is often difficult given funding and time restraints.

The water budget for Findley Lake was developed by measuring water inflows and outflows and comparing them to the change in lake storage. When inflows exceed outflows, the lake level rises (lake storage increases); when outflows exceed inflows, the lake level drops (lake storage decreases). If inflow and outflow can be accurately measured, then the amount of water entering the lake (inflow) should equal the amount of water leaving the lake (outflow), plus or minus the changes in lake storage. Thus the lake water budget balances.

The water budget for Findley Lake is:

(a) Inputs

1. stream flow into lake (SF_{in})
2. runoff from peripheral lands (RO)
3. rain and snow on the lake surface (Precip)
4. ground water flow into lake (GW_{in})

(b) minus Outputs

1. flow over the dam into West Branch of French Creek (SF_{out})
2. lake evaporation (Evap)
3. ground water outflow (GW_{out})

(c) equals Change in lake storage (Δ Lake Storage)

Once a water budget has been developed, it can be used in conjunction with other measurements (e.g. stream chemistry) to estimate how the lake would respond to certain watershed management strategies. It can also be used to calculate the hydraulic residence time for the lake, which is the amount of time necessary for the entire lake water volume to be replaced with fresh water via inflow and outflow. By knowing this, one can predict how long it may take to see improvements in lake quality if certain changes in the watershed or lake system were to occur.

In the paragraphs that follow, each of the water budget inputs and outputs are described. Methods and overall results from the one year study (water year 1998) are given.

INFLOW MEASUREMENTS: Methods and Results

Weather and Precipitation

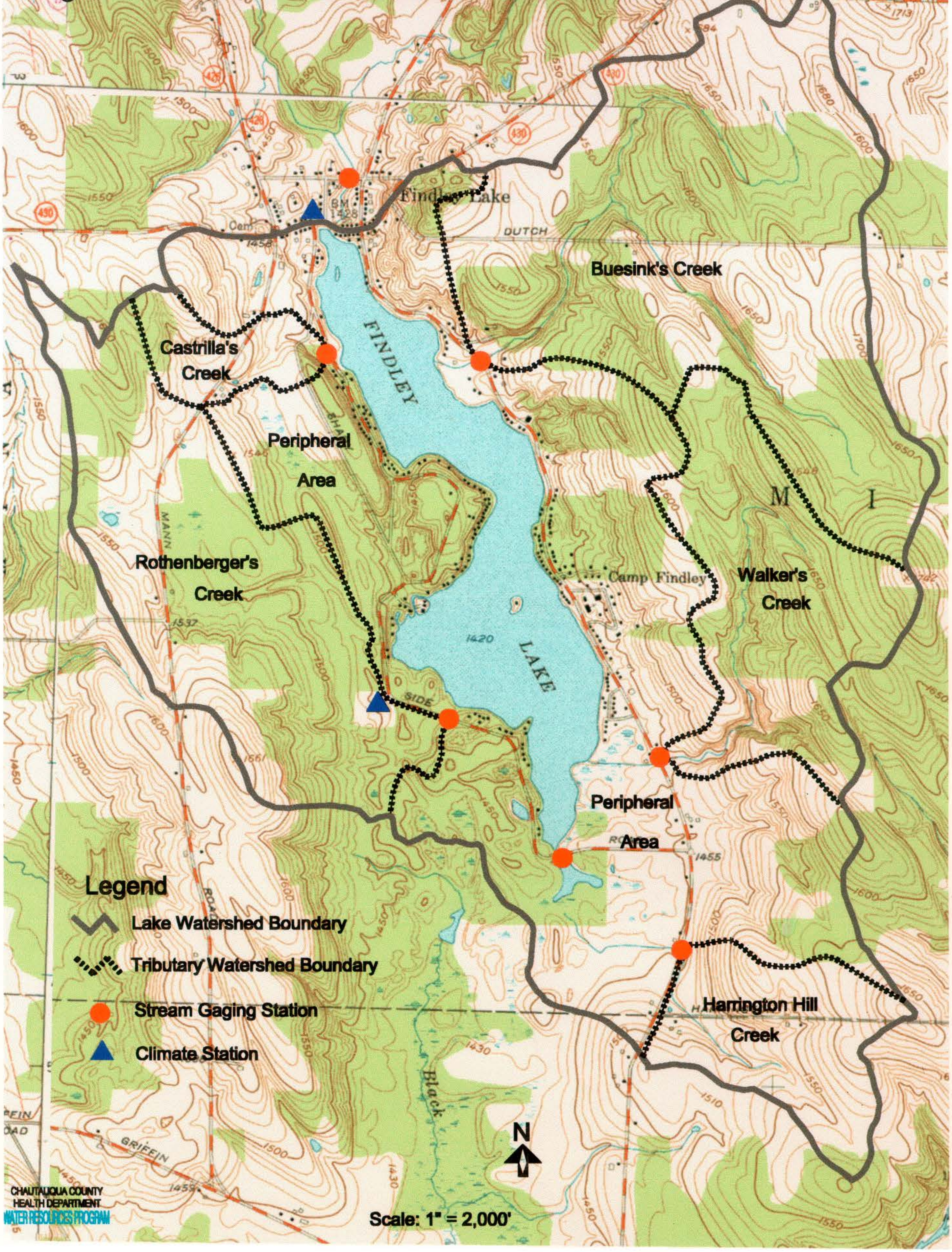
Rain and snowfall contribute water both directly to the lake surface and indirectly to the lake via stream runoff and ground water inflow. Precipitation within the Findley Lake watershed is subject to only slight variations due to its geographically small area, about 3,000 acres. Occasionally, there are isolated storms that only impact a portion of the watershed. However, they occur infrequently enough to treat the entire watershed as receiving a uniform distribution of precipitation. The proximity of the Findley Lake watershed to Lake Erie has a strong influence on precipitation as it is situated in an area subject to Lake Erie effect snowstorms. This area receives significantly more snowfall than many other parts of the region. The nearby Peek'n Peak ski resort is supported by the abundance of snowfall from these storms.

To monitor weather during the study period, a manually read climate station was installed behind the Findley Lake Post Office and an automatic recording rain gage was installed in an open field on property owned by Jim Rothenberger, near Paradise Bay Campground. These locations are shown in Figure 3.2. The manual station consisted of a U.S. Forest Service type calibrated rain gage and a high-low recording thermometer which were monitored each morning between 8:00 and 10:00 AM by project volunteers. During winter, snow collected in the gage was melted to obtain water equivalent. In addition, daily winter snowfall (snow depth) was measured and recorded each morning. The automatic station consisted of a tipping bucket rain gage connected to a computer microprocessor that recorded both the duration and intensity of rainfall. The tipping bucket was equipped with a heater that melted snow which fell in the gage recording the snow water equivalent. Electricity used to power the heater was provided by Jim Rothenberger.

Daily precipitation data from both climate stations and the Sherman, New York National Oceanographic and Atmospheric Administration (NOAA) weather station were entered into computer spreadsheets for comparative analysis. Data from the manual station near the post office and the Sherman NOAA station were quite similar, data from the automatic rain gage appears to have under-measured precipitation during winter. Total annual precipitation measured during the 1998 water year was 45.53 inches at the Post Office, 46.79 inches at Sherman, but only 26.06 inches at Rothenberger's. Examination of the daily data indicates a wide disparity for winter measurements at Rothenberger's but general agreement during non-winter seasons. Daily precipitation as recorded at the Findley Lake Post Office was reduced to reflect total monthly values and used in the water budget, while data from the automatic gage was useful to compare individual rainstorm events to stream flow.

Normal precipitation for this area, based on the average annual precipitation at Sherman for the period 1961 to 1990, is 45.13 inches. During the 1998 water year 45.53 inches were

Figure 3.2: Location of Stream and Climate Stations



measured at Findley Lake, indicating that when looking at year totals, it was close to a normal year (Table 3.1). However, the 1998 water year realized a substantial snowfall deficit, an above normal amount of rainfall during the winter months, and near-drought conditions from June through October 1998. In addition, average air temperatures in the region were above normal during at least 9 months of the 1998 water year, exacerbating the drought conditions. These conditions forced several nearby municipal public water systems to implement mandatory water conservation measures beginning in late summer of 1998.

Table 3.1: Monthly Precipitation as Measured at Findley Lake.

Month	Precip. (inches)	Normal (inches)	Departure from Norm.	Snowfall (inches)
Nov-97	4.50	4.81	-0.31	23.8
Dec-97	5.64	4.10	1.54	47.9
Jan-98	6.31	2.95	3.36	12.6
Feb-98	1.34	2.80	-1.46	0.8
Mar-98	4.03	3.03	1.00	28.3
Apr-98	5.77	3.48	2.29	0.0
May-98	1.15	1.47	-0.33	0.0
Jun-98	2.96	4.47	-1.52	0.0
Jul-98	5.39	4.27	1.12	0.0
Aug-98	2.20	4.76	-2.56	0.0
Sep-98	1.94	4.67	-2.73	0.0
Oct-98	4.31	4.32	-0.01	2.0
Total	45.53	45.13	0.39	115.35

Notes: (1) Normal monthly precipitation is based on the 30 year period of record 1961 to 1990 at Sherman, NY. (2) The average annual snowfall at Mayville, NY is 204 inches based on the 48 year period 1951 to 1999. (3) Snowfall recorded at Mayville for the 1997-98 winter was 154.4".

Stream Flow Into the Lake

Runoff to the lake constitutes the largest inflow component of the water budget. This includes stream flow from both large and small tributaries along with overland (sheet) flow that does not enter a stream but flows directly into the lake. This section of the report examines stream flow entering the lake from five small tributaries whose drainage basins range in size from 74.3 to 789 acres. Watershed boundaries for these streams are shown in Figure 3.2.

The five tributaries to the lake were chosen for monitoring both flow and water quality based on their relative size and location. Since no historical references were found for stream names, they were assigned names based on the property owner where access to each stream was made. As described in Chapter 1, soils within the lake watershed were predominantly developed from silty glacial till or glacial sand and gravel. All five streams monitored during the project generally exhibit a dendritic or branching type of pattern and their gradients are similar. Basin sizes and stream characteristics are provided in Table 3.2. Streams to the west of the lake and

Harrington Hill Creek are intermittent, typically going dry in the summer with flow resuming again in mid to late fall. These creeks all flow across unconsolidated sediment and have little or no bedrock exposed along their channels. To the contrary, streams on the east side of the lake, Buesink's Creek and Walker's Creek, exhibit substantial bedrock outcropping in their channels and flow all year round. However, they slow to little more than a trickle in late summer.

Table 3.2 Stream Characteristics and Gaging Station Locations.

Stream Name	Basin Size	Staff Gage Location	Mean Daily Discharge (cfs)			Stream	Gradient
	(acres)		min	max	mean	Order	
Buesink's Creek	789.0	50 ft upstream of Rt 426	0.0025	59.3	1.6	4th	0.019
Walker's Creek	318.3	30 ft downstream of Rt 426	0.00	24.0	0.6	3rd	0.024
Harrinton Hill Ck	183.3	30 ft downstream of Rt 426	0.00	16.3	16.5	2nd	0.021
Rothenberger's Ck	499.9	10 ft upstream of Shady Side Rd	0.00	28.8	0.7	3rd	0.015
Castrilla's Creek	74.3	Culvert inlet at Shady Side Rd	0.00	12.2	0.3	1st	0.040
Lake Outlet	3296.3	Culvert inlet at School St	0.39	80.0	11.9		

A network of stream gaging stations was established to measure stream flow into the lake. These were located where the five streams mentioned above crossed either Route 426 or Shadyside Road as shown in Figure 3.2. The stations were constructed following U.S. Geological Survey (USGS) methods (Buchanan and Somers 1978). Staff gages, used to measure stream level, also referred to as stream stage, were installed at five of the gaging stations. Stream level at the smallest creek monitored (Castrilla's) was measured using a ruler at the inlet of the culvert at Shadyside Road. Stream stages were monitored daily by project volunteers. Two continuous recording gaging stations were constructed at Buesink's Creek and Walker's Creek. A Stevens Type F mechanical water level recorder was used at Walker's Creek and a Global Water WaterLogger WL 14 pressure transducer was used at Buesink's Creek. Both were installed in stilling wells in the creek bank and provided a continuous measure of stream stage. This was especially useful for measuring storm flows.

To convert stream stage or level, measured in feet, to stream flow or volume, measured in cubic feet per second (cfs), a series of stream discharge measurements were made at each stream. Following USGS methods (Rantz et al. 1982), a set of flow measurements were made at each stream between the lowest and highest stream flow conditions. These measurements were plotted on the graphs shown in Figures 3.3 to 3.8 to establish the stage-discharge relationship unique to each stream. Each set of stream discharge measurements were collected at all streams within three to six hours. These discharge measurements coupled with the daily stream stage measurements taken by volunteers were used to develop a flow correlation between all five streams. This allowed the continuous stage data from Walker's creek, which was the most complete and accurate set of flow data, to be used for estimating the flow from the other creeks. Walker's Creek discharge and precipitation measured during water year 1998 are shown in the graph of Figure 3.9a.

Flow statistics for each stream are given in Table 3.2. Graphs showing stream discharge are provided in Figures 4.2 and 4.7 located in Chapter 4 - Water Quality. Total flow to the lake from these five streams during water year 1998 was 113.6 million cubic feet.

Figure 3.3

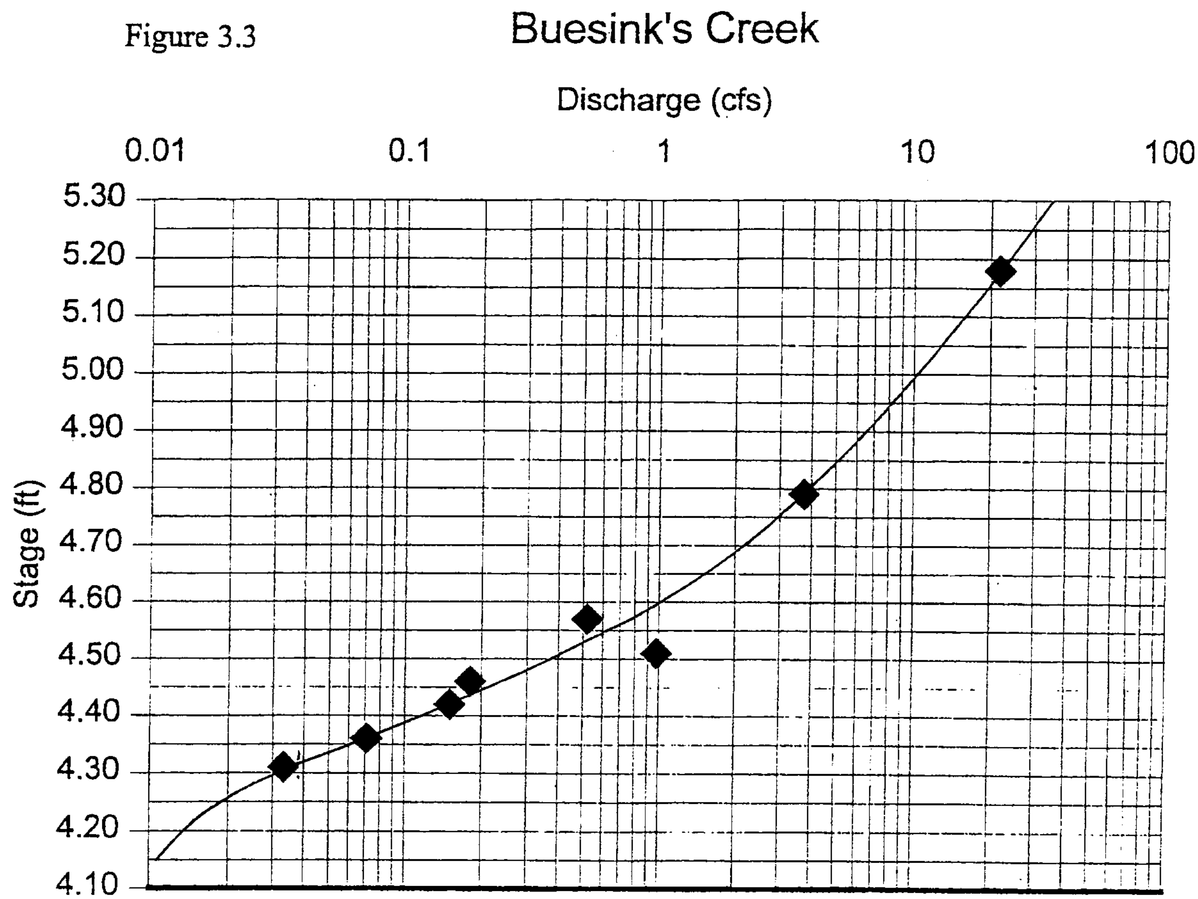


Figure 3.4

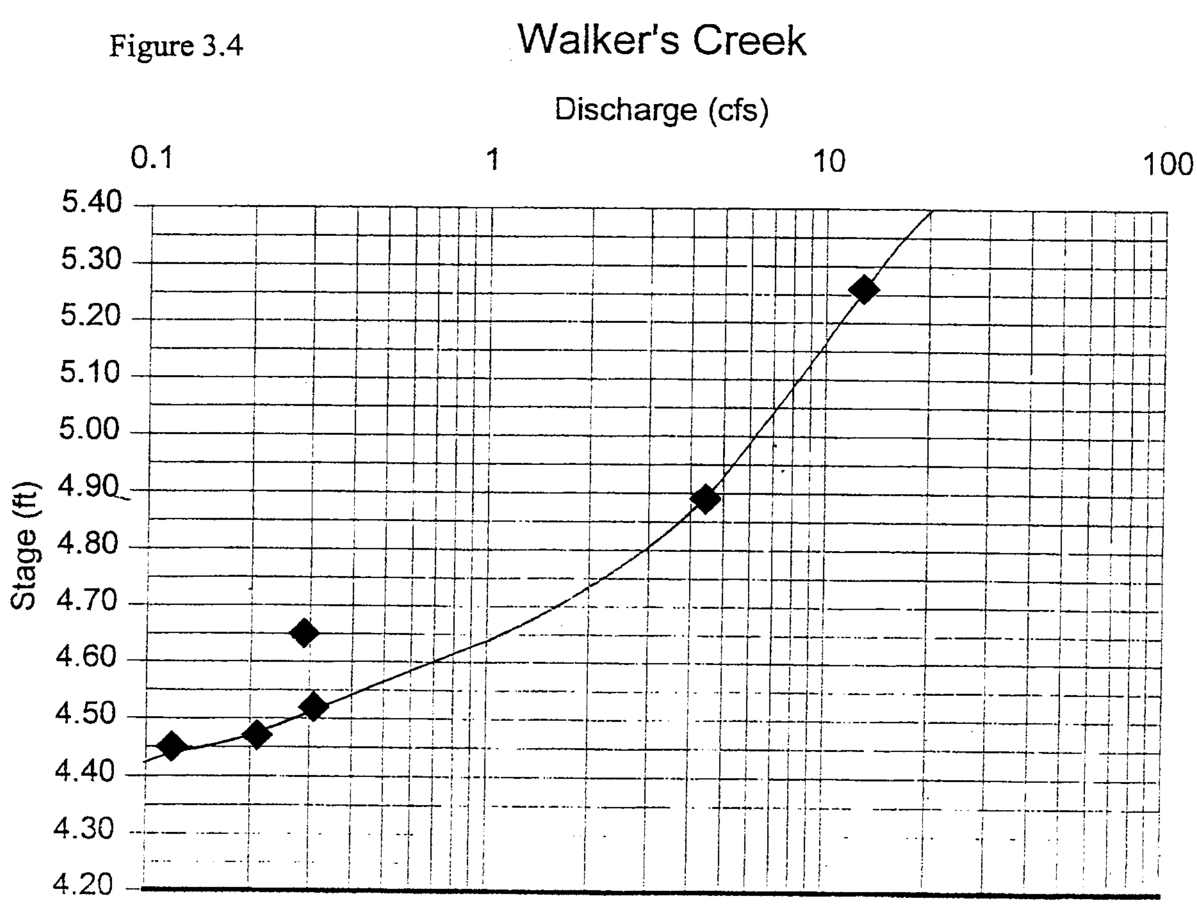


Figure 3.5

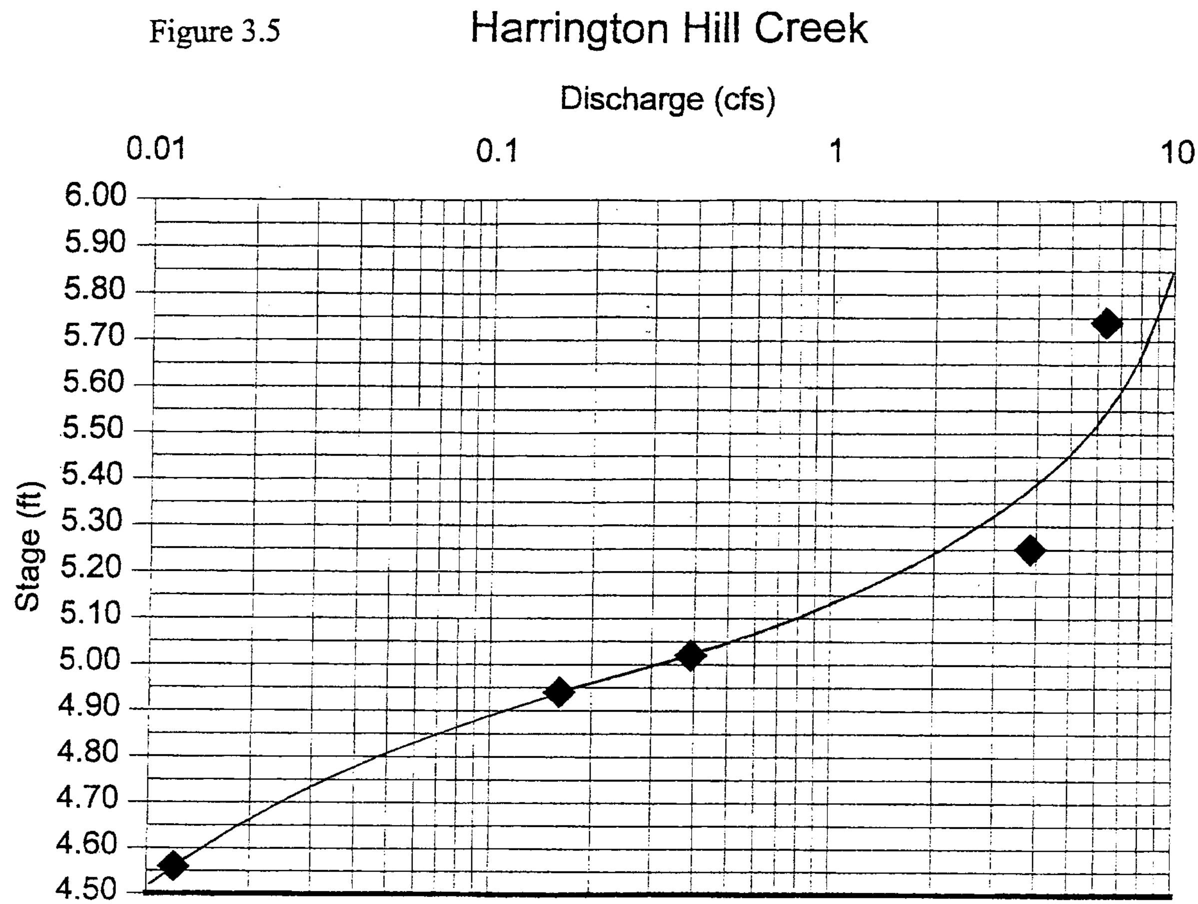


Figure 3.6

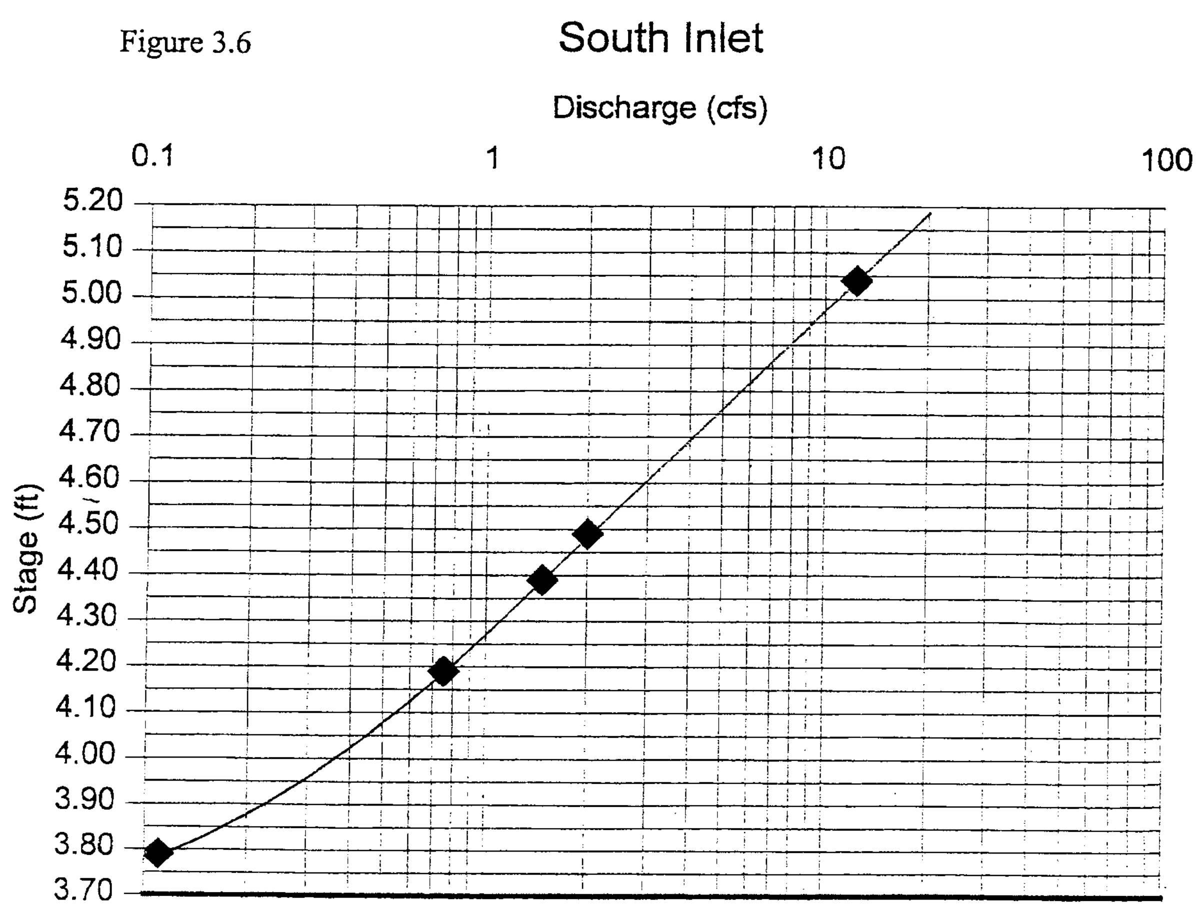


Figure 3.7

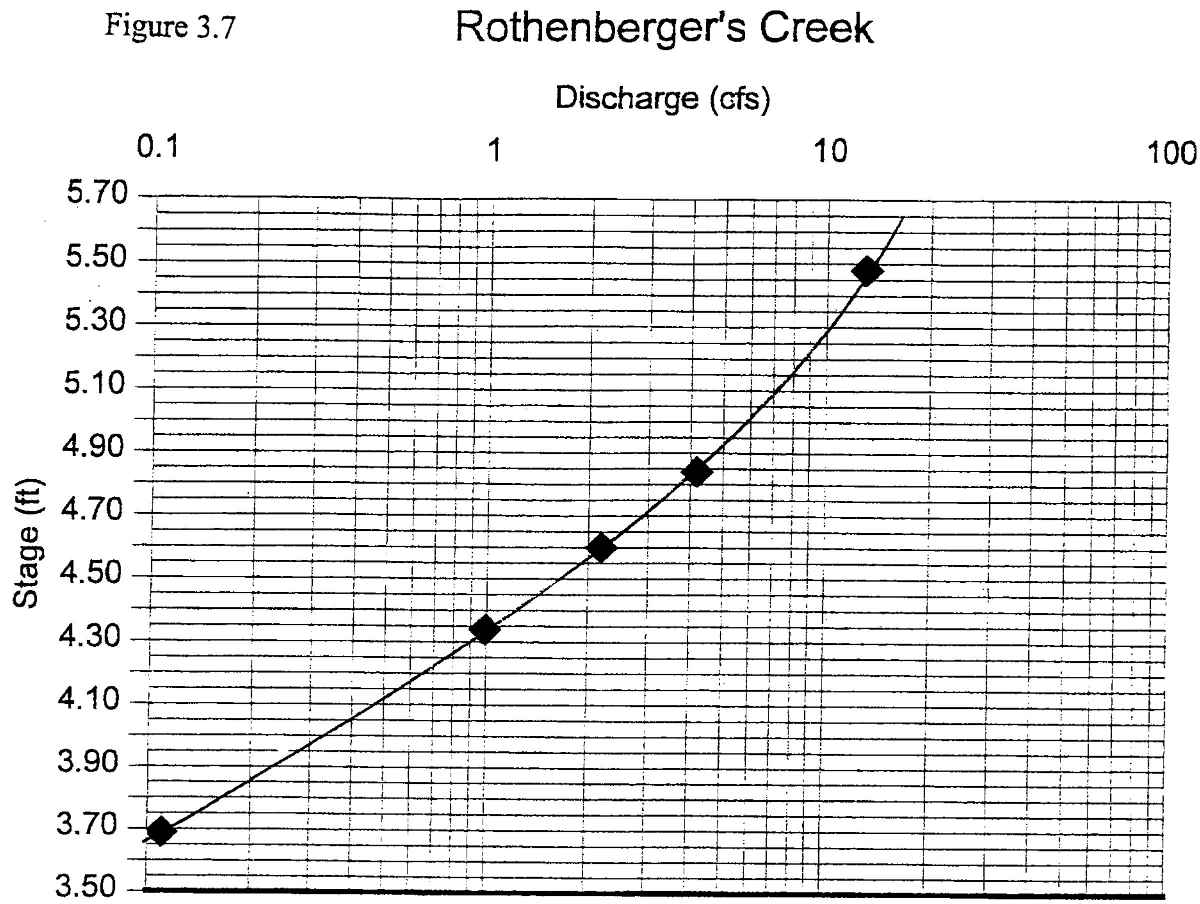


Figure 3.8

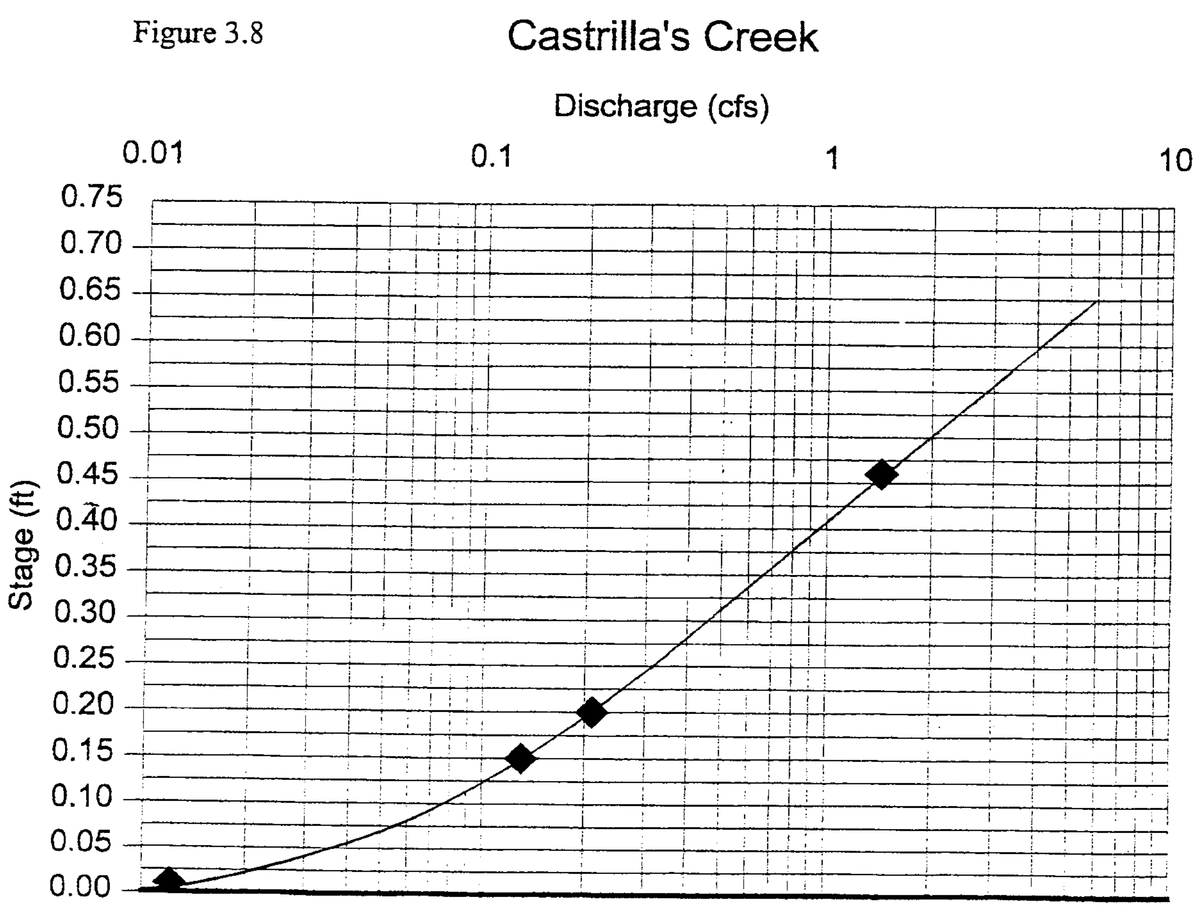


Figure 3.9a: Precipitation and Walker's Creek Discharge

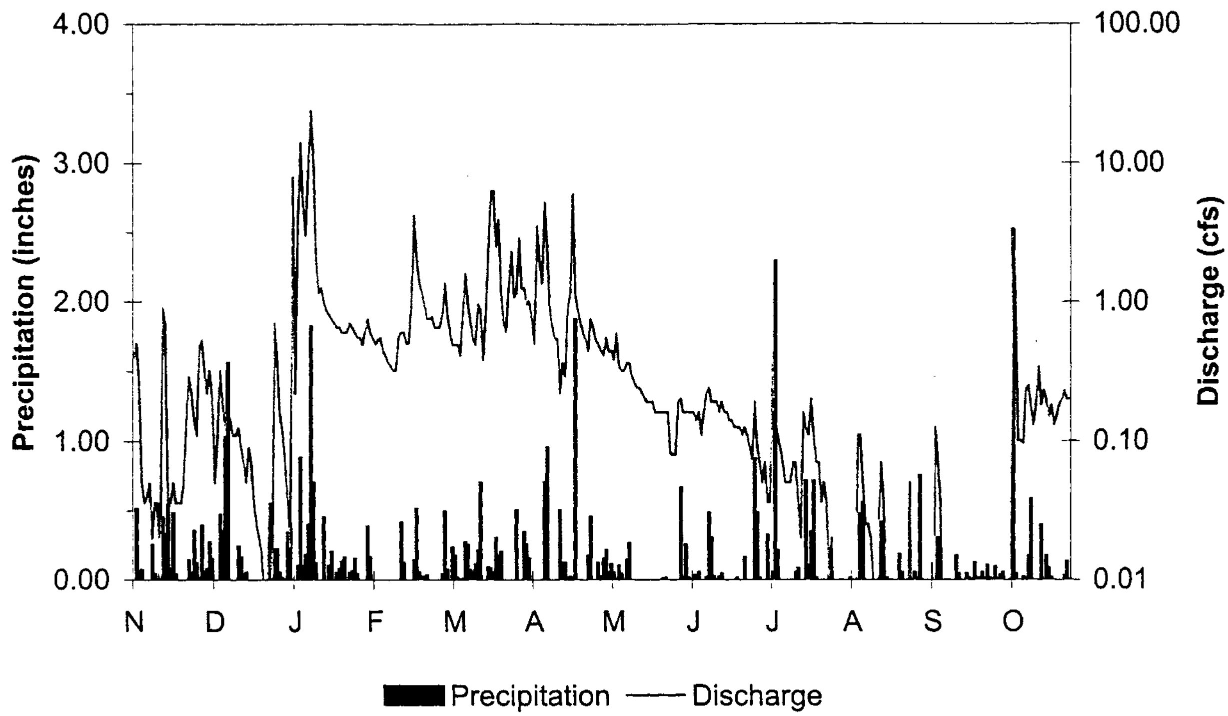
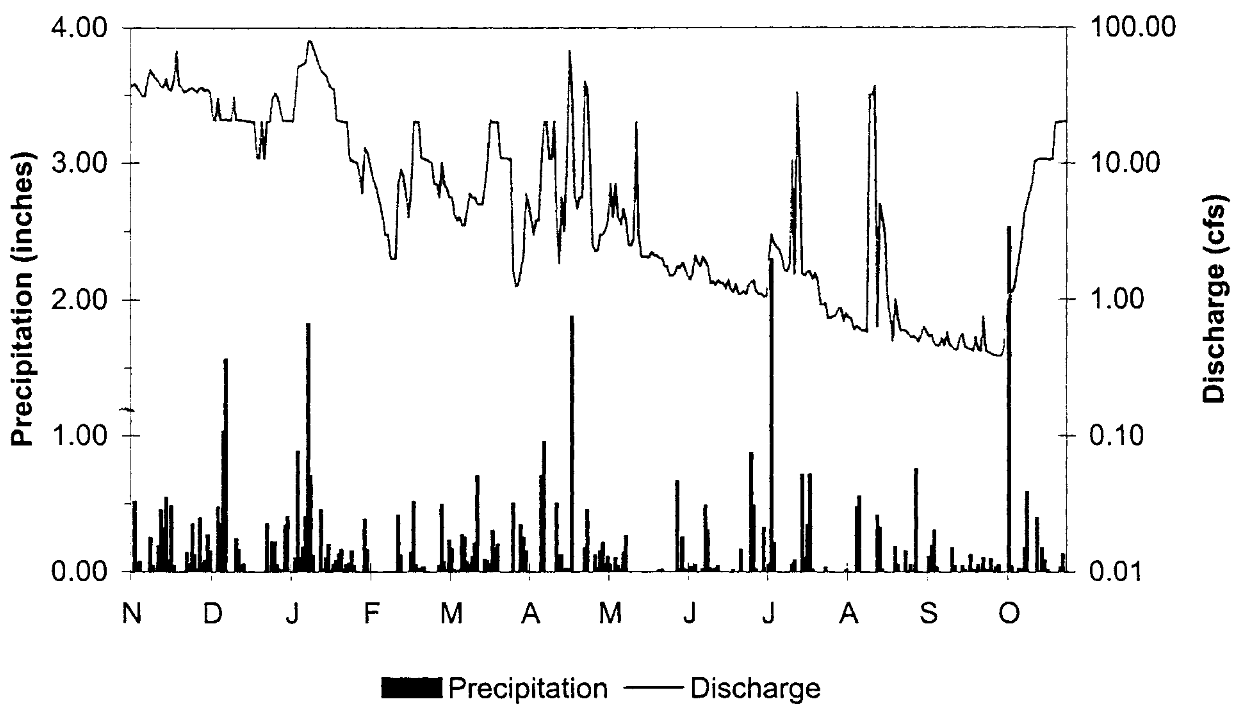


Figure 3.9b: Daily Precipitation and Lake Outlet Discharge



Runoff From Peripheral Lands

Runoff from those areas of the watershed that don't drain to one of the five tributaries described above was estimated based on precipitation, land use, and established runoff coefficients. This includes runoff that drains directly to the lake from the lakeshore and runoff that flows to smaller creeks, rivulets or roadway drainage into the lake. Since portions of this area are highly developed with homes and cottages, a greater percentage of precipitation runs off the land surface than from other less developed areas of the watershed. Using information from Chapter 2 - Land Use, the peripheral area was divided into three general land use categories: developed land, agricultural land plus open area, and forest land plus marsh (Table 3.3). Runoff contributed from each general land use was then estimated based on an established relationship between precipitation and runoff. The runoff coefficient for forest land was based on data from Walker's Creek, whose watershed is 91% forested. The runoff coefficient for agricultural land was based on data from Harrington Hill Creek, which is covered by more than 88% mixed farmland. The runoff coefficient for developed land was based on values cited by Linsley and Franzini (1964).

Table 3.3: General Land Use in the Peripheral Area and Corresponding Runoff Coefficients.

Periphery Land Use (acres)		% of Peripheral area	Runoff Coefficient
Developed	244.6	22	0.60
Agriculture	328.1	29	0.43
Forested	549.3	49	0.39

The rainfall–runoff coefficient used to estimate runoff from forest land is 38%, for agricultural land 43% and for developed land 60%. Multiplying the runoff coefficient by the total amount of precipitation which fell on each general land type, provided an estimate for runoff of 84 million cubic feet for use in the water budget. In order to use these runoff coefficients, they must be based on runoff data generated from long-term periods of record, such as a water year. These coefficients account for both high and low flow periods. Consequently, they can only be used to estimate mean annual runoff; they should not be used for estimating runoff for shorter periods of time.

Ground Water Inflow

Ground water is replenished by surface water and precipitation as it infiltrates through soils and eventually reaches the water table or saturated zone below the ground surface. Ground water recharge is therefore highly dependent on soil characteristics. While fine soils such as silt loams may contain a large amount of water in soil pores, these pores are not readily connected and are, therefore, very slow draining. Pores in coarse soils such as sand and gravel are readily interconnected and relatively fast draining and are therefore very important to ground water recharge and movement. Ground water flows through fine soils at rates of inches per week or inches per month, while it flows through coarse soils at rates of several inches to several feet per day. As streams flow across sand and gravel deposits, stream water often seeps into the ground recharging ground water supplies. This is known as a losing stream because it looses flow. Conversely, streams that are fed by ground water are called gaining streams. Ground water tends to accumulate within the hills and flow toward the valleys. As it moves, ground water can flow upward into streams and lakes due to the overlying pressure from its accumulation in the surrounding hills. Given the abundance of sand and gravel deposits throughout the Findley Lake watershed, it is no surprise that ground water plays an integral role in the lake hydrology.

Pockets of sand and gravel in the uplands act as important ground water recharge areas while the finer grained soils and shale bedrock of surrounding hills act as storage reservoirs for ground water. These fine grained soils and rock gradually release ground water to the valley bottom sediments, much of which is sand and gravel, which then transmits ground water directly to the lake. Recharge of the lake by ground water is visible in the form of spring seeps along the shore when the lake water level is lowered for winter. Miller (1988) mapped the gravel deposits surrounding Findley Lake as a "principal" unconfined aquifer which is capable of yielding more than 100 gallons of water per minute to wells. The rapid movement of ground water through the aquifer surrounding Findley Lake presents special concerns that are discussed in Chapter 4 - Water Quality.

Physically measuring the amount of ground water that is flowing to a lake, stream or wetland is very difficult and costly. One widely accepted method for estimating ground water inflow is through the use of a water budget. Since the water budget is a mass balance of inputs and outputs, and since all other inputs and outputs can be either measured or estimated, the water budget equation can be used to solve for ground water inflow. This is further discussed in the summary section of this chapter.

OUTFLOW MEASUREMENTS: Methods and Results

Outlet Flow into West Branch of French Creek

The lake outlet at Route 430 marks the beginning of the West Branch of French Creek and constitutes the single largest outflow component in the water budget. Outlet flow was measured at a continuous recording gaging station constructed where the creek flows through an 8 ft diameter culvert under School Street, approximately 750 ft downstream of the dam spillway (Figure 3.2). The gaging station included a staff gage and stilling well equipped with a Stevens Type F water level recorder, similar to that constructed on Walker's Creek. During the 1998 water year, this represented the best and most convenient location to measure lake outlet flow. A small amount of flow is contributed to the stream between the lake spillway and School Street, however, it is negligible compared to that contributed by the lake. Since mid 1999 beaver activity in the West Branch of French Creek has steadily increased. The construction of beaver dams downstream of School Street has influenced water levels at the site of this gaging station. While water level data collected during the 1998 water year was not influenced by down stream beaver dams, future researchers should use caution if considering the use of School Street for a gaging site.

Stream flow at the School Street gaging station was calculated following the same procedure discussed earlier for Walker's Creek. Mean daily flow from the lake outlet ranged from 0.4 to 80 cfs and averaged 11.9 cfs and is plotted against precipitation in Figure 3.9b. The rating curve showing the stage-discharge relationship for the outlet is given in Figure 3.10. Total outlet flow during water year 1998 was about 373.6 million cubic feet.

Evaporation from the Lake

Evaporation from the lake surface is the only other significant outflow component in the water budget. In Wilson, Riforgiat and Boria (2000), total monthly evaporation from Chautauqua Lake was calculated between January 1993 and December 1994. This research showed that monthly evaporation ranged from slightly less than 0.5 inches in the winter to about 5.5 inches during summer months. The mean annual evaporation they calculated for calendar years 1993 and 1994 was 31.2 inches. Research done by the U.S. Weather Bureau between 1946 and 1955 indicates the average lake evaporation rate in this region is about 27 inches (Fetter 1988). For the purposes of this project, evaporation rates from both sources were combined, and an estimated rate of 29 inches (2.41 ft) per year used in the water budget. Multiplying that figure times the surface area of the lake (13,482,826 ft^2) gives a total evaporation of about 32.6 million cubic feet.

Ground Water Outflow

Ground water flow out of the lake either flows in a downward direction through the lake bottom near the dam or through the dam itself. This is most likely the smallest component in the entire water budget. An estimate of ground water outflow was made by assuming: (1) that lake water is recharging ground water in an area of 6,000 ft^2 at the north end of the lake, (2) the lake bottom sediment in that area is sand and gravel with a hydraulic conductivity of 500 ft/day, and (3) the hydraulic gradient in the aquifer is 0.002. This would result in the lake losing about 2.2 million cubic feet of water as ground water outflow during water year 1998, which constitutes only 0.5% of total lake outflow.

LAKE LEVELS AND CHANGES IN LAKE STORAGE

The lake level is influenced by natural processes (lowered by drought, raised by flooding) and also by the operation of the outlet spillway. Lake level fluctuations create positive and negative changes in lake storage. These were calculated by using daily staff gage measurements taken by project volunteers at a gage installed on the concrete wall next to the spillway.

Daily lake levels are plotted against precipitation in Figure 3.11. Normally the lake level is lowered about 3 ft in mid-October and raised again in April as discussed in Chapter 1. During this project, the lake level was lowered an additional 1.5 ft in an effort to kill-off more aquatic vegetation by exposing it to freezing temperatures. In addition, the lake level was dropped earlier than normal at the request of the Borough of North East, Pennsylvania. North East pumps approximately 100 million gallons of water each year from the West Branch of French Creek into one of their drinking water reservoirs (Mallick 1997). Their pump intake is located just across the state line about 2.5 miles downstream from the spillway. They pump water from the creek

Figure 3.10

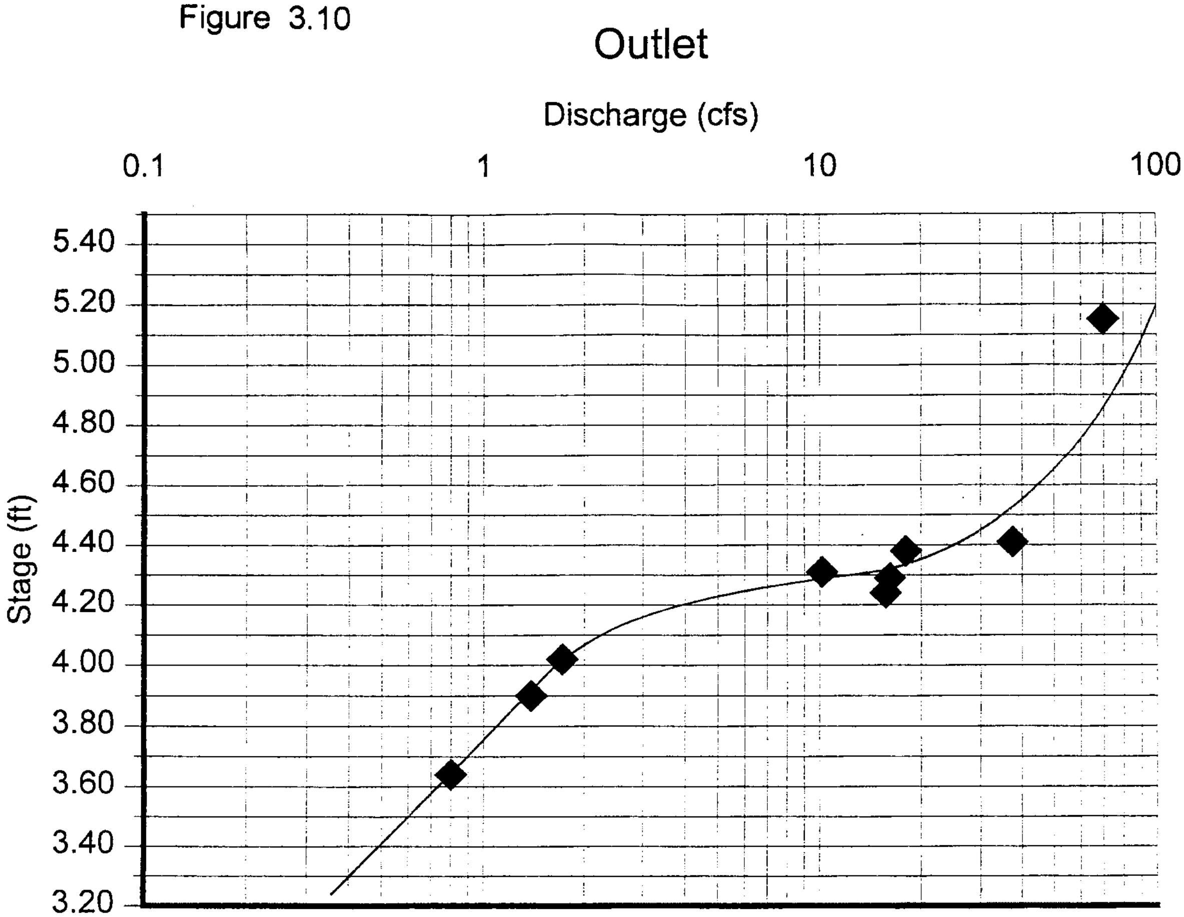
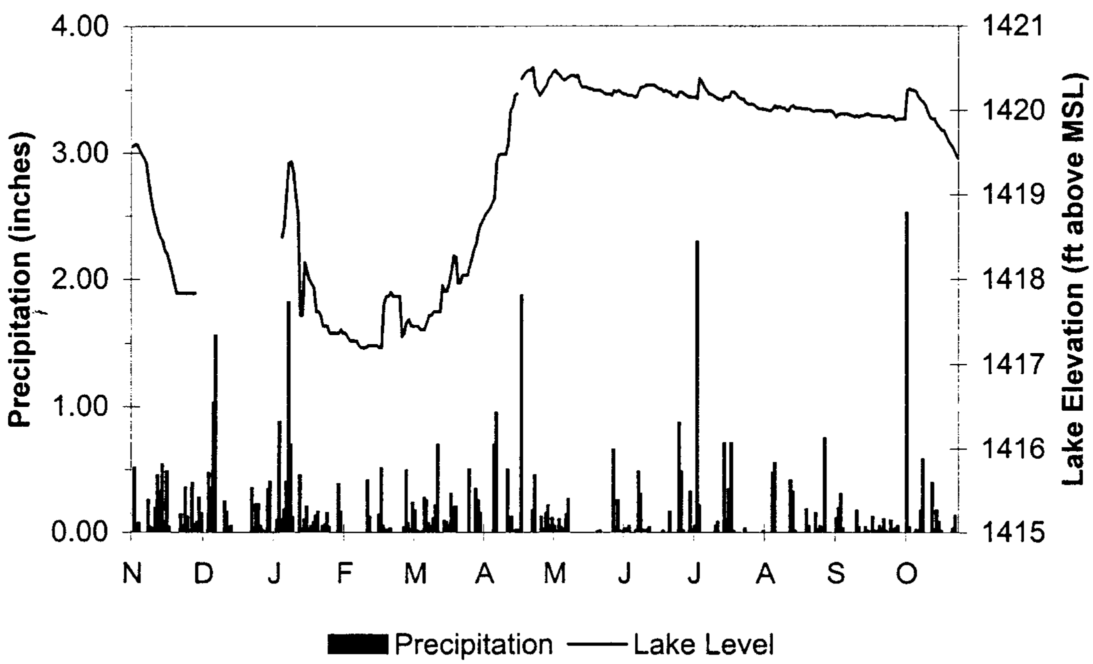


Figure 3.11: Daily Precipitation and Lake Level



when its flow is above 10 cfs at their pump station, which is typically between October and April. However, due to the drought conditions during late summer and fall of 1998, they experienced a rather severe water shortage. To help alleviate this problem, Findley Lake was lowered earlier than normal to add additional flow to the creek. This water from Findley Lake helped raise French Creek flow above minimum flow level required so the Borough could pump water from the stream to refill their reservoir.

The change in lake storage for water year 1998 is computed by comparing the lake water level measured on November 1, 1997 (1,419.58 ft MSL) to that measured on October 31, 1998 (1,419.37 ft MSL). The lake was 0.21 ft lower at the end of water year 1998 than at the beginning. Multiplying that change times the surface area of the lake (13,482,826 ft^2) gives a decrease in lake storage of about 2.8 million cubic feet.

HYDROLOGY SUMMARY

As discussed earlier in this chapter, if all components of the water budget can be accurately measured or estimated, it will balance. The only significant unknown quantity in the budget is ground water inputs, which can be solved by using the water budget equation:

$$(SF_{in} + RO + Precip + GW_{in}) - (SF_{out} + Evap + GW_{out}) = \Delta \text{ Lake Storage.}$$

Using a little algebra, the water budget equation can be rearranged as:

$$GW_{in} = \Delta \text{ Lake Storage} + (SF_{out} + Evap + GW_{out}) - SF_{in} - RO - Precip.$$

As shown in Table 3.4, ground water flow into the lake is estimated to be about 156.8 million cubic feet and, as expected, is a very substantial component of lake inflow. The water budget for the lake was also calculated monthly as given in Table 3.5.

The pie charts shown in Figures 3.12 to 3.14 summarize runoff to the lake and the inflow-outflow components of the water budget for water year 1998. As shown total runoff accounts for a majority of lake inflow (48.7%), followed by ground water inputs (38.7%) and precipitation directly on the lake surface (12.6%). The majority of outflow is from the lake outlet (91.5%) with the remainder from evaporation (8%) and a small amount from ground water outflow (0.5%).

Using data from the water budget, the hydraulic residence time can be calculated for the lake. This is determined by dividing the volume of the lake by the annual flow into it. The volume of the lake was measured using a bathymetric map prepared by Dr. Ken Mantai (1985). The original map was computer-digitized using AutoCAD (Figure 3.15) and the area of each contour measured and summed to yield a total lake volume of 185.2 million cubic feet or 1.39 billion gallons. Dividing that by the total lake inflow gives a hydraulic residence time of about 0.46 years.

As a rough check for this and the water budget, hydrologic data from the period March 15 to April 15, 1998 was evaluated. At that time, the spillway was raised to begin bringing the lake up to its normal summer level and the lake level rose 2.0 ft. This amounts to adding about 27 million cubic feet of water to the lake in one month. Since the entire lake volume is about 185 million cubic feet, under the same conditions it would take a little less than 7 months to completely fill the lake. It should be noted that precipitation during that month period was 3.51 inches, about normal. While fairly crude, this check is close to the estimate of just under 6 months noted in the preceding paragraph.

Table 3.4: Annual Water Budget for Findley Lake: Water Year 1998 (11/01/1997 to 10/31/1998).

Inflow - Outflow = Change in Lake Storage		cubic feet (in millions)	gallons (in millions)
Inflow:	Precipitation on Lake Surface	51.2	382.6
	Stream Discharge (from 5 monitored tribs)	113.6	850.0
	Peripheral Runoff	84.0	628.5
	Ground Water Inputs	156.8	1,172.7
	Total	405.6	3,033.8
Outflow:	Outlet Flow	373.6	2,794.9
	Evaporation off of Lake Surface	32.6	243.7
	Ground Water Outflow	2.2	16.4
	Evapotranspiration (from lake weeds)		
	Total	408.4	3,055.0
Change in lake storage		(2.8)	(21.2)
Total Lake Volume		185.2	1,385.5
Hydraulic Residence Time = Lake Volume/Inflow		0.46 years	

FINDLEY LAKE ANNUAL WATER BUDGET: November 1, 1997 to October 31, 1998

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Total
LAKE INFLOW													
Precipitation falling on lake surface (ft3):													
	5,056,060	6,336,928	7,089,719	1,505,582	4,522,364	6,482,992	1,286,486	3,320,146	6,056,036	2,471,851	2,179,724	4,842,582	51,150,470
Discharge from the Lake's five monitored tributaries (ft3):													
Buesink's Creek	1,299,228	777,979	20,258,821	4,883,842	9,886,126	7,917,437	1,743,543	985,945	583,671	118,015	55,273	1,687,844	50,197,723
Walker's Creek	526,003	314,971	8,201,952	1,977,264	4,002,480	3,205,440	705,888	399,168	236,304	47,779	22,378	683,338	20,322,965
Harrington Hill Creek	357,682	214,180	5,577,327	1,344,540	2,721,686	2,179,699	480,004	130,464	36,288	0	0	0	13,041,871
Rothenberger's Creek	631,204	377,965	9,842,342	2,372,717	4,802,976	3,846,528	691,200	205,632	63,936	0	0	0	22,834,500
Castrilla's Creek	199,881	119,689	3,116,742	751,360	1,520,942	1,218,067	268,237	24,538	16,784	0	0	0	7,236,241
Total	3,013,998	1,804,785	46,997,185	11,329,723	22,934,210	18,367,171	3,888,873	1,745,747	936,983	165,794	77,650	2,371,181	113,633,301
% of yearly flow	2.7	1.6	41.4	10.0	20.2	16.2	3.4	1.5	0.8	0.1	0.1	2.1	100.0
Estimated runoff from peripheral area to lake (ft3):													
developed land	669,978	401,183	10,446,942	2,518,469	5,098,015	4,082,814	864,452	388,060	208,281	36,854	17,261	527,087	25,259,395
agricultural land	618,385	370,289	9,642,456	2,324,530	4,705,433	3,768,409	797,884	358,177	192,242	34,016	15,932	486,497	23,314,249
forest land	940,378	563,099	14,663,280	3,534,912	7,155,551	5,730,619	1,213,341	544,679	292,342	51,728	24,227	739,817	35,453,972
Total	2,228,740	1,334,572	34,752,677	8,377,910	16,958,999	13,581,843	2,875,677	1,290,915	692,864	122,598	57,419	1,753,401	84,027,616
Ground water into lake (ft3):													
	13,064,680	13,064,680	13,064,680	13,064,680	13,064,680	13,064,680	13,064,680	13,064,680	13,064,680	13,064,680	13,064,680	13,064,680	156,776,155
LAKE OUTFLOW													
Outlet flow (ft3):	98,280,000	58,505,760	91,571,040	19,409,760	21,384,000	31,484,160	9,093,600	3,827,520	8,383,392	11,278,656	1,301,184	19,126,368	373,645,440
Evaporation from lake surface 29"/year (ft3):													
% of yearly flow	2.7	1.7	1.4	3.0	5.0	9.0	13.0	16.3	17.8	14.9	9.2	6.0	100.0
	879,754	553,919	456,169	977,505	1,629,175	2,932,515	4,235,854	5,311,110	5,799,862	4,854,941	2,997,682	1,955,010	32,583,496
Ground water flow out of lake (ft3):													
	182,500	182,500	182,500	182,500	182,500	182,500	182,500	182,500	182,500	182,500	182,500	182,500	2,190,000

Table 3.5

RUNOFF TO LAKE

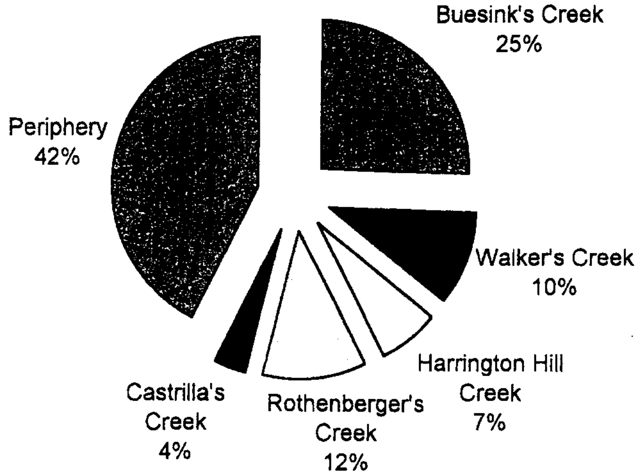


Figure 3.12

LAKE INFLOW

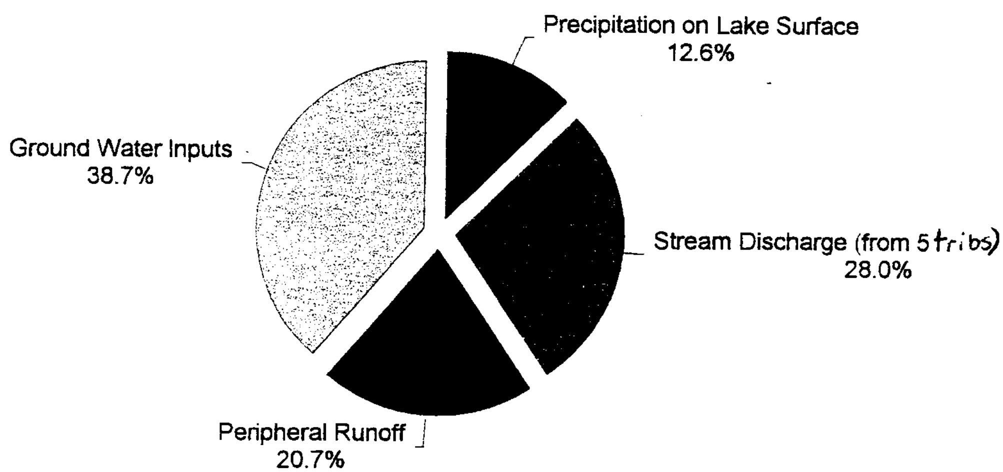


Figure 3.13

LAKE OUTFLOW

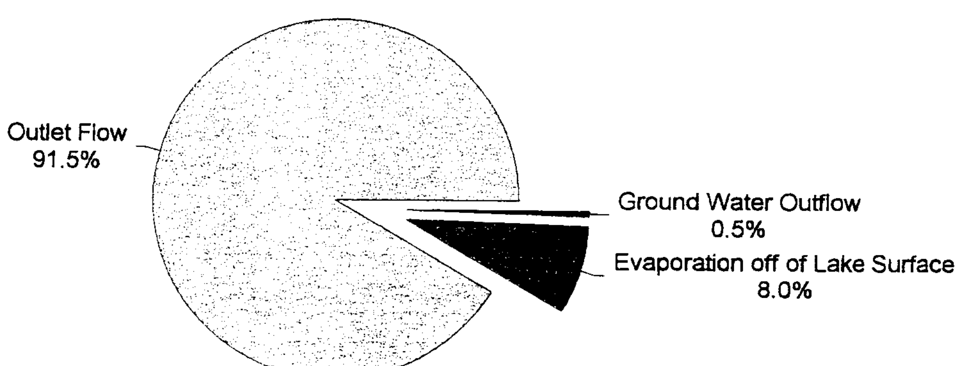


Figure 3.14

BATHYMETRIC MAP OF FINDLEY LAKE

MODIFIED FROM MANTAI, 1985, SUNY-FREDONIA

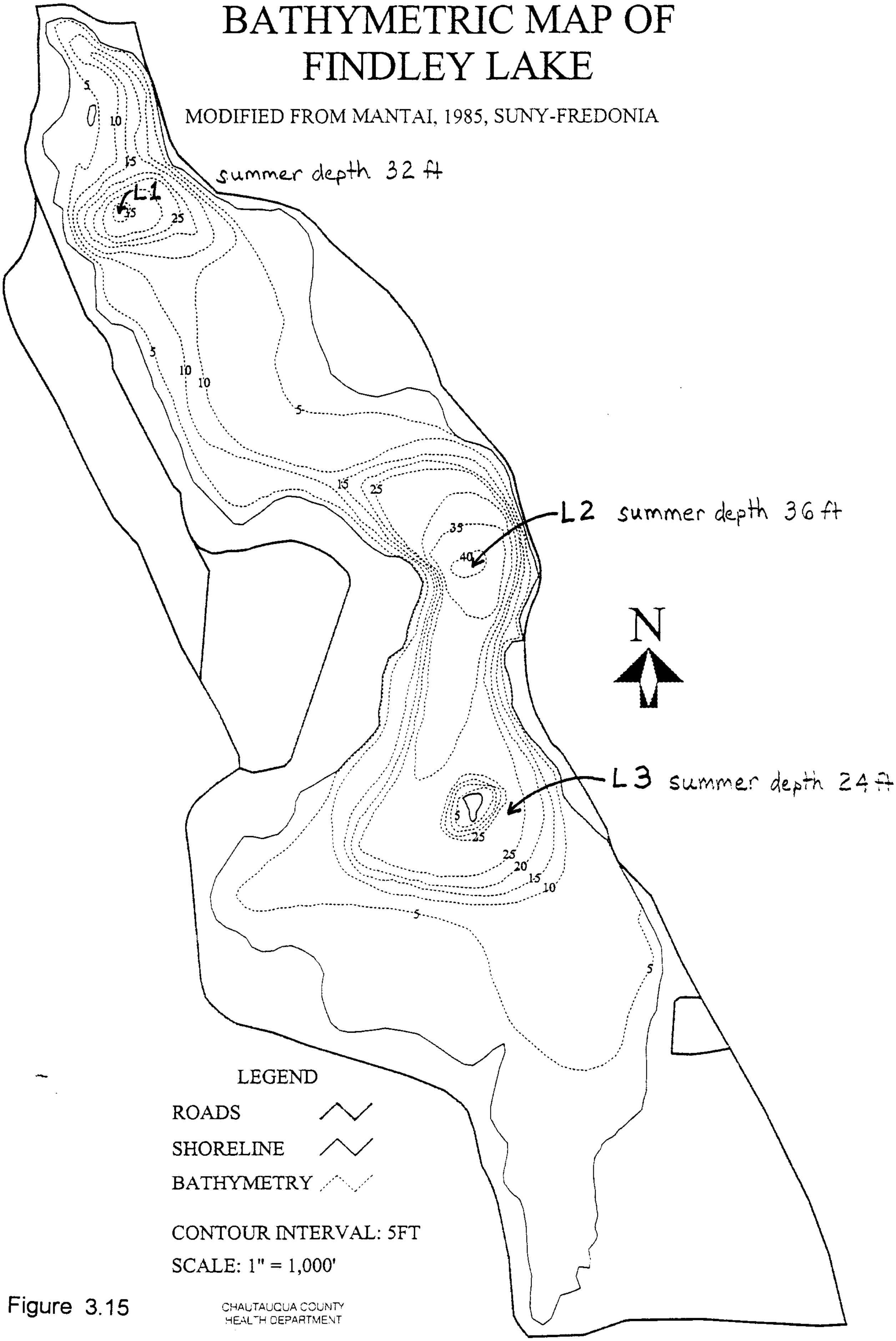


Figure 3.15

CHAUTAUQUA COUNTY HEALTH DEPARTMENT

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CHAPTER 4 - WATER QUALITY

INTRODUCTION

The water quality of Findley Lake is controlled by that of the surface and ground water entering the lake and by in-lake chemical, biological and physical processes. To assess the quality of water flowing into the lake, it is necessary to understand the water quality of each of the four inflow components discussed in the water budget: stream flow, runoff from peripheral lands, precipitation on the lake surface and ground water flow. This chapter provides an overview of the physical and chemical conditions of Findley Lake and the water flowing into it.

Water Quality Parameters Tested

During the watershed study a number of physical and chemical measurements were made to characterize water quality in the Findley Lake watershed.

Nitrogen is one of the most abundant elements in the atmosphere. It is also a very important nutrient essential to the growth of all plants. Nitrate-nitrogen is the final, stable form in the nitrogen cycle. Other forms of nitrogen include ammonia and nitrite that are eventually converted to nitrate. Excess nitrates become completely dissolved in water and "go with the flow," transported by ground and surface water until they are removed from the hydrologic cycle by plants. Nitrates are un-reactive and do not bond to soil particles. They are usually found in relatively low concentrations in surface water, but can build up in ground water. Sources of nitrates include the atmosphere (dissolved in precipitation), septic systems, manure, and commercial fertilizers used on lawns, gardens, and agricultural crops. Excess amounts of nitrates stimulate the growth of aquatic plants which, when they die and decompose, consume large quantities of oxygen. The maximum allowable level of nitrate-nitrogen in drinking water is 10 mg/L. The primary health concern associated with nitrates is that it can cause a low blood oxygen condition in infants called methemoglobinemia or blue baby syndrome. High nitrates in drinking water may also be responsible for incidents of spontaneous abortion in pregnant women (CDC, 1996).

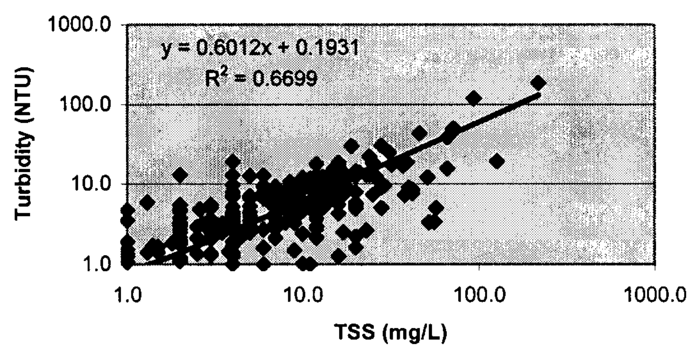
Phosphorus, like nitrogen, is an essential nutrient for the growth of plants. Unlike nitrates however phosphorus is frequently the least abundant nutrient in nature and therefore often limits plant productivity. The major concern with phosphorus is that, like nitrates, it causes nutrient enrichment of surface waters, which leads to excessive weed and algae growth. Phosphorus tends to bind to soil particles and act as a "hitch-hiker" when soil is eroded and swept downstream to a lake. Sources of phosphorus are the same as those of nitrates, along with wind blown dust particles. Phosphates use to be a common ingredient in laundry detergents but were banned in the late 1970s for environmental reasons. Most automatic dishwashing detergents still contain phosphates today. Since phosphorus can bind to soil particles, it tends to build up in the bottom sediments of lakes. There are no known adverse human health affects caused by phosphorus in drinking water. Therefore, no maximum level of phosphorus has been established for drinking water in fact, certain types of phosphorus are used in drinking water treatment processes.

Chlorides, found in all natural waters, originate from salt compounds such as sodium chloride, calcium chloride, potassium chloride, etc. In western New York, chlorides come primarily from road deicing salts, brines associated with oil and gas wells, sewage (septic or animal manure) and fertilizers. Chlorides, like nitrates, dissolve completely in water and are un-reactive or very stable in the environment and move readily with ground-water flow. Elevated levels of chlorides usually indicate human impact. For most people chlorides in drinking water are not harmful to health except at extremely high levels (>1,500 mg/L). However, persons suffering from heart or kidney disease should avoid consumption of excess chlorides. Depending on a person's taste-sensitivity, chlorides can impart a salty taste to water at levels around 200 mg/L. For this reason the recommended maximum level in drinking water is set at 250 mg/L.

Total suspended solids and turbidity are a measure of particulates in the water. These particulates can be fine sediment, algae or other matter such as small pieces of weeds. If enough particulates are present, the water appears cloudy. Turbid lake water blocks sunlight penetration, reducing plant photosynthesis and oxygen production. Large amounts of suspended particulates in water can clog fish gills and interfere with filter-feeding shellfish. Excess sediment in streams can destroy fish spawning areas and benthic macroinvertebrates by depositing layers of sediment in streambeds. For drinking water, turbidity must be less than 0.5 NTU 95% of the time and must never exceed 5 NTU.

Total suspended solids (TSS) is a measure of the total dry weight of particulates present in a sample, i.e. mg of particulates per liter of water. Turbidity is simply a measure of the cloudiness of the water. Because biological materials such as algae weigh very little, when present in large quantity, they yield a relatively high turbidity but low TSS. Therefore, lake and pond measurements of TSS and turbidity are usually not directly comparable. However, since stream turbidity is most often the result of suspended sediment rather than biological matter, a correlation between them can be made. Figure 4.1 plots the results of TSS against turbidity for 430 stream samples analyzed for both parameters during the recent study of Chautauqua Lake (Wilson, Riforgait and Boria, 2000) and this study of Findley Lake. As shown, a good correlation has been identified that provides an estimate of TSS from turbidity. This is important for future projects since the current cost for TSS analysis is about $15 per sample and requires specialized lab equipment, while measuring turbidity can be done in the field with a single instrument very inexpensively.

Figure 4.1:Turbidity vs. TSS
Chautauqua Lake and Findley Lake Data



Dissolved oxygen (DO) in water is required by fish and other aquatic organisms to survive. DO typically ranges between 0 and 15 mg/L in natural waters, the higher concentrations being most favorable to aquatic life. Many factors influence the amount of DO in fresh water.

For example colder water can hold more oxygen than warm water. Water flow, wave action and plant photosynthesis adds oxygen to water, whereas stagnant conditions and rotting vegetation consume oxygen. The United States Environmental Protection Agency (USEPA) notes that at least 5 mg/L of DO must be maintained in a clean water environment to prevent adverse affects on aquatic animals. New York State Department of Environmental Conservation (DEC) cites 3.0 mg/L as the lowest DO level allowed in class D streams. Game fish thrive at DO levels of about 8 mg/L or more.

Water temperature is very important to aquatic habitats and to the chemical characteristics of water. For example most fish species have there own optimal water temperature where they thrive. As cited by Jacobson (1991) Northern Pike will not grow in water warmer than 28°C (82°F) and will die in water warmer than 30°C (86°F); they will not spawn in temperatures above 11°C (52°F) and their embryos can't survive in water warmer than 19°C (66°F). Temperature also controls the amount of DO that can be held by water. Stream temperatures of 30°C in this region are an indication of poor water quality.

pH is a measure of free hydrogen ions in water and has a range of 0 to 14 units with 7 being neutral. Values less than 7 are acidic and values greater than 7 are basic. Precipitation in this area is extremely acidic ranging between 4.0 and 4.5. As precipitation hits the ground it begins to react with calcium minerals in the soil and becomes buffered; that is, its pH is increased. Most aquatic organisms thrive at near neutral pHs. In areas whose soils contain little calcium, such as in parts of the Adirondack Mountains, precipitation is not buffered resulting in dead lakes that are essentially devoid of aquatic life. Jacobson (1991) indicates that the "tolerable range" of pH for most fish is between 5 and 9 but prefer pHs between 6.5 and 8.2.

Specific conductance or conductivity is a measure of water's ability to conduct an electric current. Distilled water is a relatively poor conductor, and water conductivity increases as the amount of dissolve chemicals in it increases. Therefore, contaminated water is more conductive that clean water. Ground water, which dissolves minerals as it moves through soil and rock, is more conductive than surface water.

Oxidation reduction potential (ORP) is a measure of the electron activity in water. High ORP is associated with strong oxidizing conditions and low electron activity, whereas low ORP is associated with reducing conditions and higher electron activity. Therefore, ORP is a controlling factor for certain chemical reactions such as the oxidation of iron.

Secchi disk transparency is the measure of water clarity. It is determined by lowering a weighted 20 cm black and white disc into the water column until it is no longer visible. Essentially, the depth at which it disappears is the Secchi disk transparency. Factors such as the concentration of suspended solids/turbidity, and the naturally occurring color of the water will affect the Secchi disk transparency.

Coliform bacteria are used as an indicator of sewage contamination in drinking water. That is, the presence of coliforms indicates that there is a possibility of fecal contamination since this type of bacteria is found in the intestinal tract of all warm-blooded animals. The drinking water standard for total coliform is <1 coliform bacteria colony in 100 ml of water. Fecal coliform bacteria come from the feces of humans, domestic pets, livestock and wild animals including birds. New York State Department of Health (NYSDOH) standards for bathing beaches are: total coliform "shall not exceed a logarithmic mean of 2,400 colonies/100 ml for a series of five or more samples in any 30-day period, nor shall 20 percent of total samples during the period exceed 5,000 coloies/100ml." For fecal coliform, samples should not exceed a logarithmic mean of 200 colonies/100 ml from five or more samples in a 30-day period, or 1,000 colonies/100ml on any given day (NYSDOH, 1992).

Hetertotrophic bacteria are those that are free-living in nature and are primarily responsible for organic decay processes, such as rotting of wood. This group of bacteria is not considered harmful to human health, therefore, there is no standard set for heterotrophic bacteria in drinking water or in bathing beaches.

General Sampling and Testing Procedures

Water samples collected for measuring nitrate nitrogen, chlorides, total phosphorus and total suspended solids were analyzed by Microbac Laboratories in Erie, Pennsylvania, a New York State Health Department certified lab. Laboratory methods and detection limits used by Microbac are given in Table 4.1. Chemical results reported by the lab as being less than the laboratory detection limit were assigned a value of one-half the detection limit for data analysis. Samples collected for total coliform bacteria, heterotrophic bacteria and turbidity were analyzed at the Chautauqua County Health Department Lab, which is also New York State certified. Sample bottles were provided by the respective lab performing the analysis and contained all necessary preservatives. Samples were placed in coolers immediately after being collected and transported to the lab within 24 hours of collection or sooner as required.

Table 4.1: Microbac Laboratory Methods and Detection Limits.

Parameter	EPA Method Number	Method Description	Detection Limit (mg/L)
Total Suspended Solids	160.2	gravimetric	1.0
Chlorides	325.2	automated ferricyanide	0.5
Nitrate-Nitrogen	353.2	automated cadmium reduction	0.01
Total Phosphorus	365.1	persulfate digestion, automated ascorbic acid	0.01

A Hydrolab Surveyor II was used to measure on-site physicochemical parameters, which was loaned to the project by the Chautauqua Lake Association. Routine measurements collected with the Hydrolab included: dissolved oxygen, air temperature, water temperature, pH, specific conductance and ORP. The Hydrolab was sent back to the manufacturer prior to beginning this project for factory calibration and cleaning. It was field calibrated twice during the project period, requiring only minor adjustments. The Hydrolab was also field checked against separate hand held dissolved oxygen, conductivity and pH meters.

Data Quality Control

To assure that water quality data collected during this project was representative of the water being sampled and that all the data was directly comparable, careful sampling and analytical procedures were followed. The same procedures, laboratories and many of the instruments used for this project were used for a similar project on Chautauqua Lake which included a very costly and comprehensive data validation process (Wilson, Riforgait and Boria 2000). Because the Chautauqua Lake work showed that high quality results were obtained for the same parameters tested in this project, and in light of the limited resources available to the Findley Lake project, data quality assurance measures were limited. Laboratory quality assurance included the collection of duplicate chemical samples, submission of split chemical samples to different labs and the tracking of in-lab quality assurance and quality control (QA/QC) procedures and results.

Results of duplicate samples are given in Table 4.2. The relative percent difference (RPD) between each sample and its duplicate provides a measure of lab precision. USEPA (1994) recommends a control limit of ±20% for the RPD. Any result falling outside this limit should be qualified as an estimated value only. Also shown in Table 4.2 are the results of split samples analyzed by Microbac Labs and by the NYSDOH Lab. Both duplicate and split sample results generally indicate the data is of good quality and adequate for its intended purpose. Total phosphorus results show some disparity which is not surprising given the affinity of phosphorus to latch on to sediment particles and the very small quantities that occur in nature.

Table 4.2: Duplicate Sampling Results and Split Sampling Results.

Sample ID	Date Sampled	Cl (mg/L)	TP (mg/L)	NO3 (mg/L)	TSS (mg/L)
S1.5	03/03/98	5.7	0.039	1.06	--
duplicate		5.7	0.026	1.04	--
	RPD	0.0	40.0	1.9	--
S2.6	04/14/98	0.9	0.071	0.28	--
duplicate		1.0	0.067	0.30	--
	RPD	-10.5	5.8	-6.9	--
S9.7	05/12/98	14.1	0.018	0.03	--
duplicate		14.3	0.022	0.04	--
	RPD	-1.4	-20.0	-24.7	--
S1.8	06/08/98	10.7	0.050	3.37	--
duplicate		10.8	0.054	3.37	--
	RPD	-0.9	-7.7	0.0	--
S9.10	08/04/98	20.6	0.073	<0.01	15
duplicate		20.8	0.091	<0.01	14
	RPD	-1.0	-22.0	0.0	6.9
S1.11	09/17/98	15.8	0.077	2.43	--
duplicate		15.8	0.061	2.44	--
	RPD	0.0	23.2	-0.4	--
S1.12	10/27/98	8.2	0.047	0.73	
duplicate		10.2	0.035	0.72	
	RPD	-21.7	29.3	1.4	
S9.13	11/24/98	14.0	0.165	0.11	
duplicate		14.5	0.033	0.12	
	RPD	-3.5	133.3	-7.0	

Results of Split Samples Submitted to Different Labs:

Sample ID	Date Sampled	Lab	TP (mg/L)	NO3 (mg/L)
L2A.8	06/08/98	Microbac	0.033	0.01
		NYSDOH	0.025	0.01
L2A.10	08/03/98	Microbac	0.049	0.01
		NYSDOH	--	0.01
L2A.11	09/14/98	Microbac	0.117	<0.01
		NYSDOH	0.067	--

For more information on lab and field QA/QC, the reader is referred to Chautauqua Lake - Entering the 21st Century: State of the Lake Report, Chapter 4, Tributary and In-Lake Chemistry. This report is available in all Chautauqua County public libraries and includes a detailed analysis of this topic with additional results of quality control samples submitted to Microbac Laboratory, Inc.

STREAM WATER QUALITY

Methods

Stream sampling stations were established in five tributaries to the lake, at the south inlet on Shadyside Road and at the lake outlet. These are the same streams where flow was measured as described in the previous chapter. Grab water samples and in-situ measurements were all taken at the gaging sites shown in Figure 3.2, from moving water, just below the water surface, in the deepest part of the stream channel. Samples from the lake outlet were collected at the spillway outlet rather than at the gaging station. Samples at the south inlet were only collected while the lake was at low winter level, because summer lake levels cause lake water to back up into it.

Routine water samples and measurements were collected once each month during water year 1998. Due both to budget constraints and a lack of stream flow, most streams were not sampled every month except for Buesink's Creek and the lake outlet. These routine monthly samples were used to represent base line or low flow stream conditions throughout the year. Since it is widely accepted that runoff during storm events contributes substantial quantities of contaminants to receiving water bodies, storm related stream samples were also collected. Project staff and volunteers coordinated a grab sampling program that successfully captured pre-storm, storm and post-storm samples during three storms: one four day rainstorm coinciding with a massive snowmelt event in January, one three day event in May, and a summer thunderstorm in July of 1998.

Results

Twelve rounds of monthly routine samples and measurements were collected from streams that feed Findley Lake and from the lake outlet. This included a total of 48 sets of water samples and on-site measurements. An additional 54 sets of water samples were collected during the storm events. A complete table of these results is provided at the end of this chapter. All original field data collection sheets and laboratory certificates of analyses are on file at the Chautauqua County Health Department.

Combined results of both routine and storm related samples for chlorides, total phosphorus and nitrate-nitrogen are shown as bars in the graphs of Figures 4.2 to 4.7. These graphs show the chemical concentration, reported by the lab in milligrams (by weight) of each chemical contained in one liter of water (mg/L), and are read by using the left linear Y-axis. The higher the bars reach on the graph, the higher the chemical concentration. Also shown on these graphs is stream discharge, read using the scale on the right Y-axis. By comparing the discharge line on the graph to the chemical bars on the graph, we get an idea of how stream flow during different times of the year carries differing amounts of each chemical. Table 4.3 provides summary statistics for each stream. Later in this chapter, the concentration of each chemical will be multiplied by stream flow to obtain the total load, by weight, of each chemical entering the

Figure 4.2

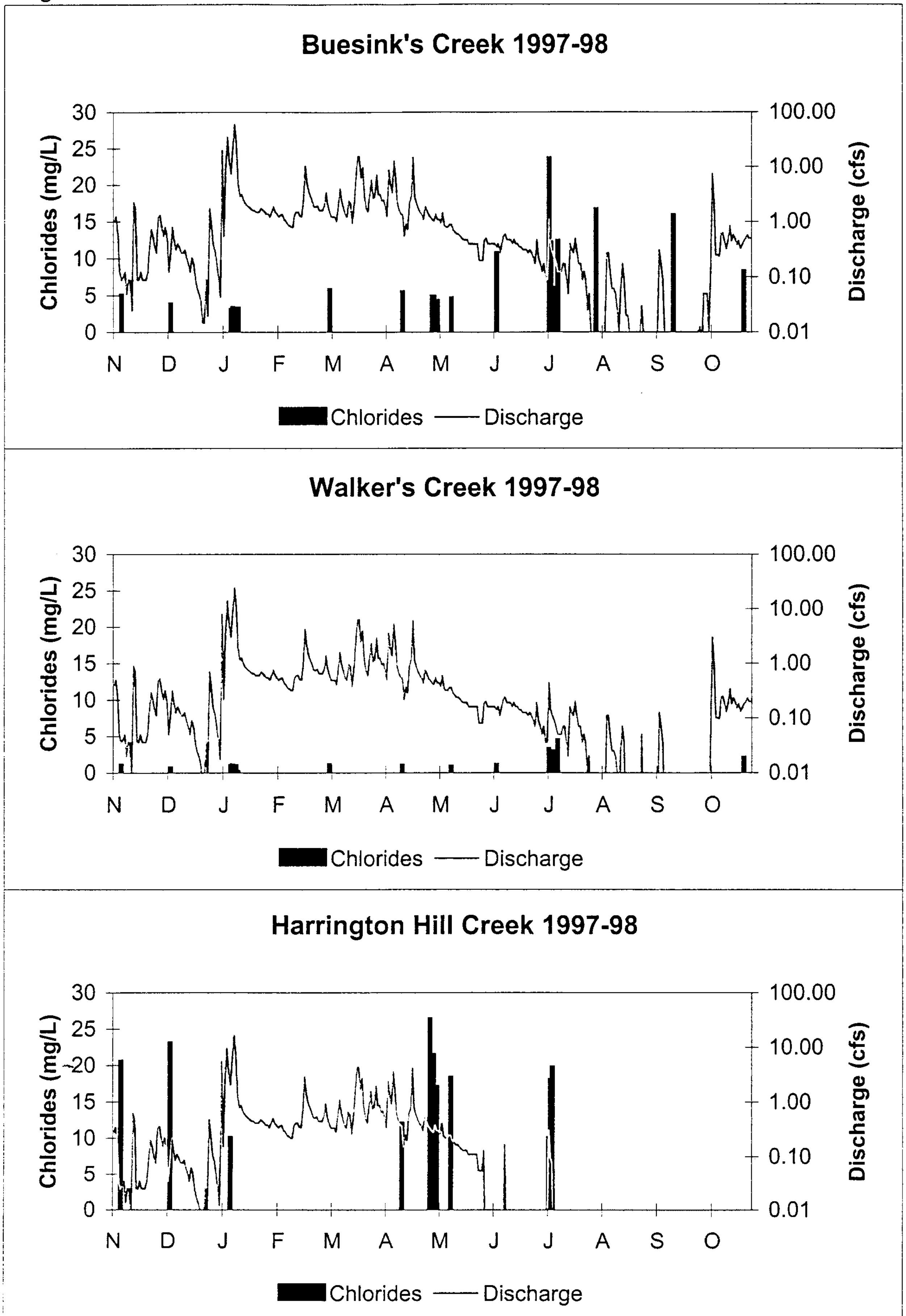

Buesink's Creek 1997-98
Chlorides (mg/L)
Discharge (cfs)
30
25
20
15
10
5
0
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Chlorides
Discharge
Walker's Creek 1997-98
Chlorides (mg/L)
Discharge (cfs)
30
25
20
15
10
5
0
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Chlorides
Discharge
Harrington Hill Creek 1997-98
Chlorides (mg/L)
Discharge (cfs)
30
25
20
15
10
5
0
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Chlorides
Discharge

Figure 4.3

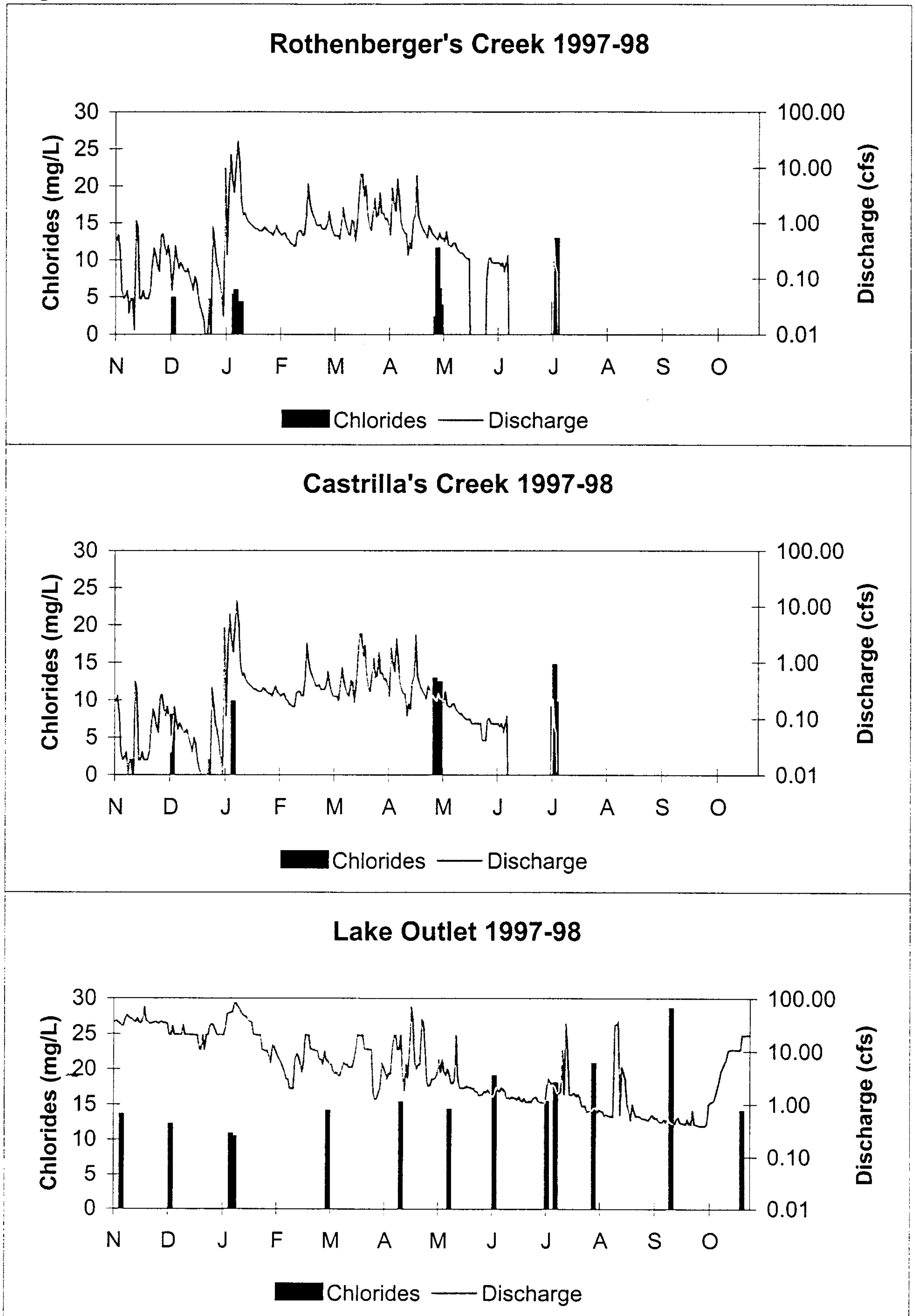

Rothenberger's Creek 1997-98
Chlorides (mg/L)
30
25
20
15
10
5
0
100.00
10.00
1.00
0.10
0.01
Discharge (cfs)
N D J F M A M J J A S O
Chlorides
Discharge
Castrilla's Creek 1997-98
Chlorides (mg/L)
30
25
20
15
10
5
0
100.00
10.00
1.00
0.10
0.01
Discharge (cfs)
N D J F M A M J J A S O
Chlorides
Discharge
Lake Outlet 1997-98
Chlorides (mg/L)
30
25
20
15
10
5
0
100.00
10.00
1.00
0.10
0.01
Discharge (cfs)
N D J F M A M J J A S O
Chlorides
Discharge

Figure 4.4

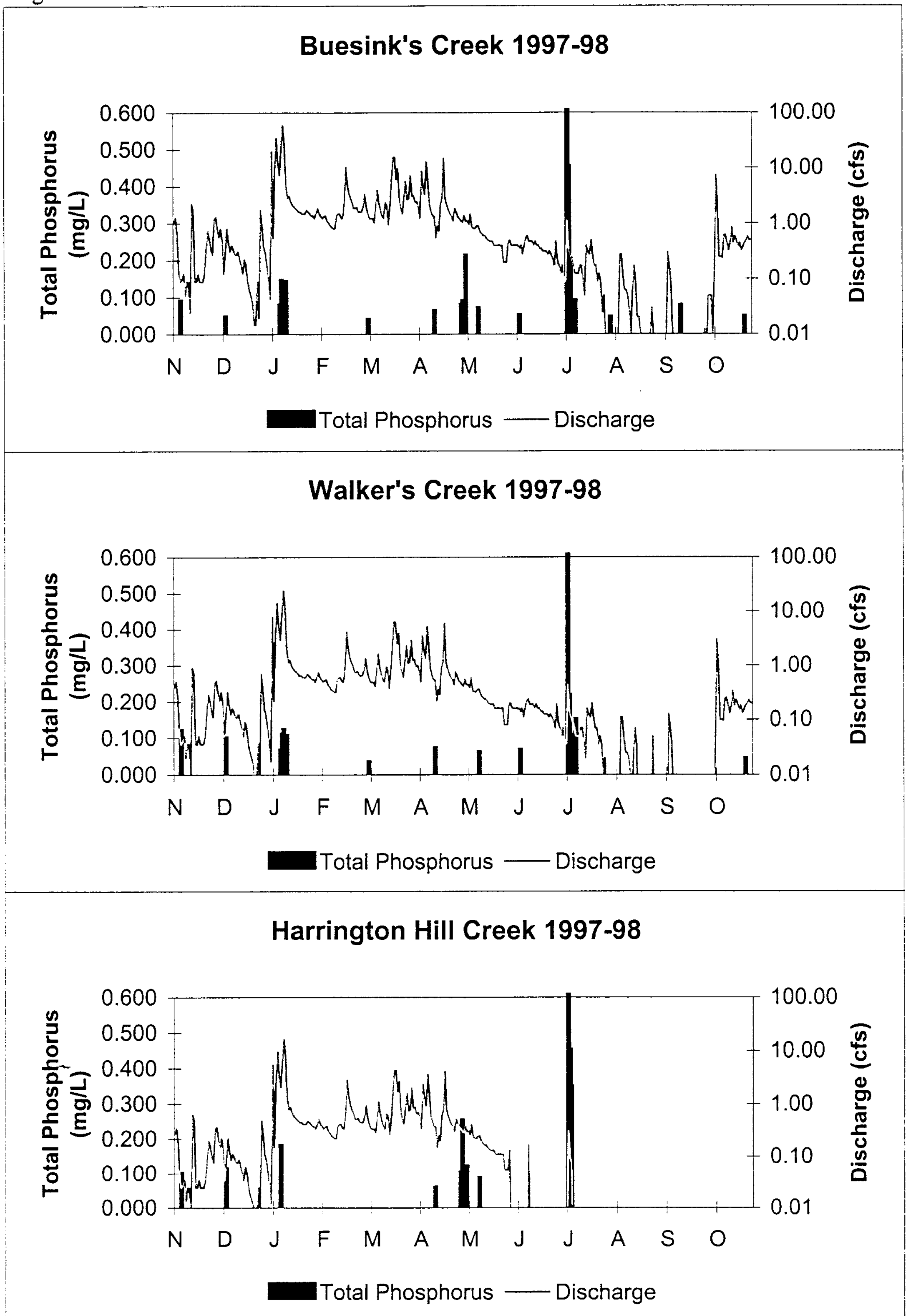
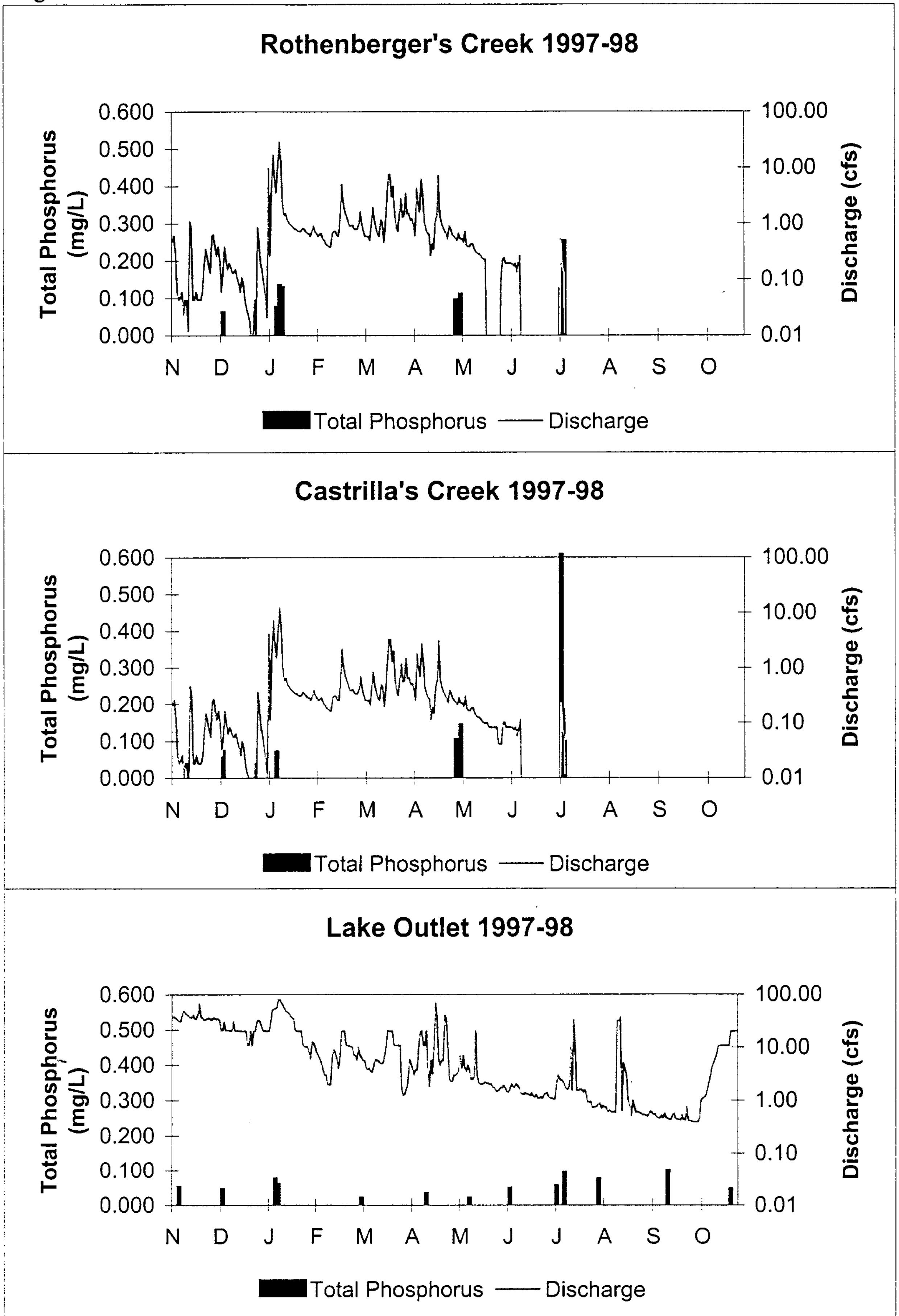
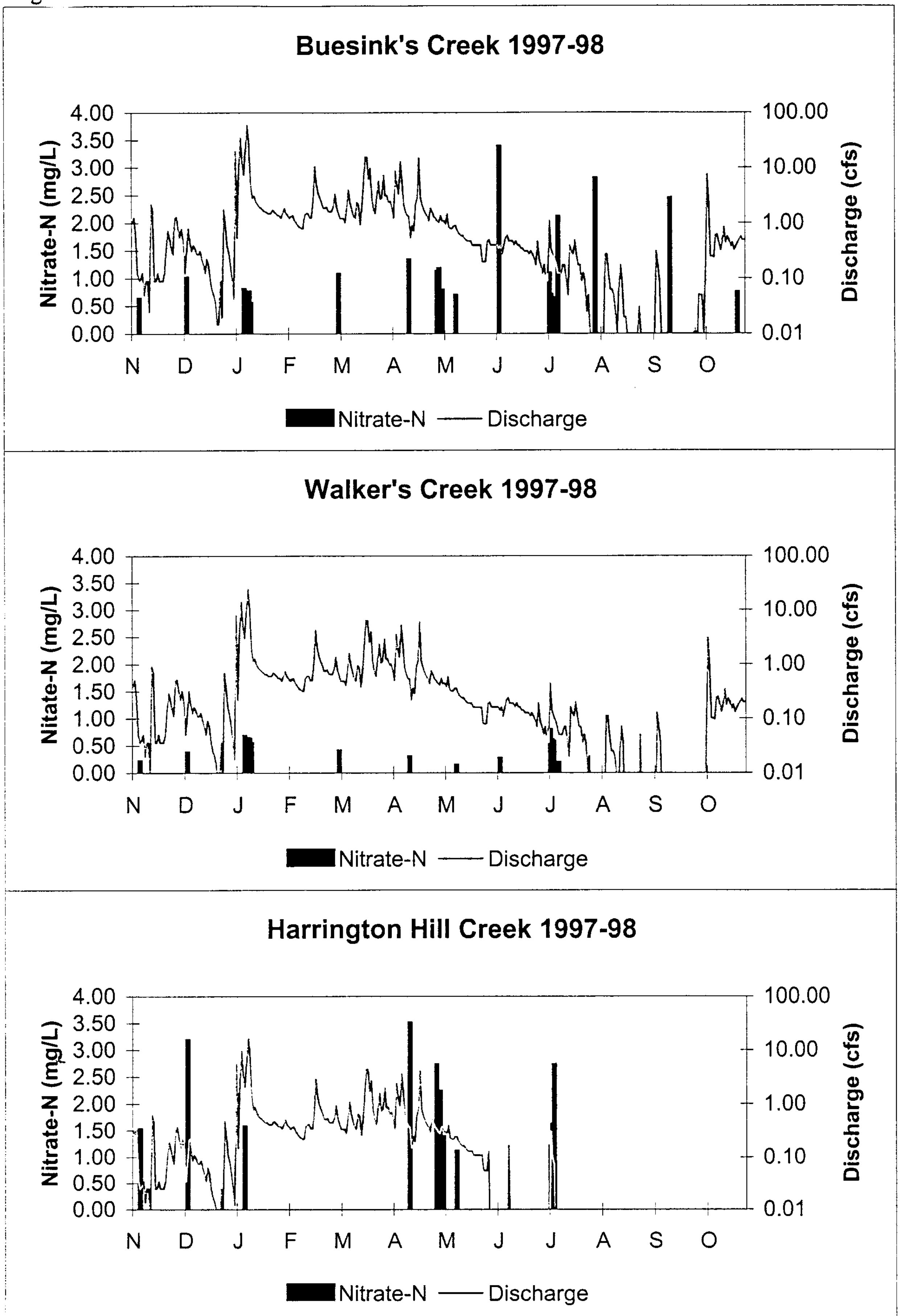

Buesink's Creek 1997-98
Total Phosphorus (mg/L)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Discharge (cfs)
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Total Phosphorus
Discharge
Walker's Creek 1997-98
Total Phosphorus (mg/L)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Discharge (cfs)
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Total Phosphorus
Discharge
Harrington Hill Creek 1997-98
Total Phosphorus (mg/L)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Discharge (cfs)
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Total Phosphorus
Discharge

Figure 4.5



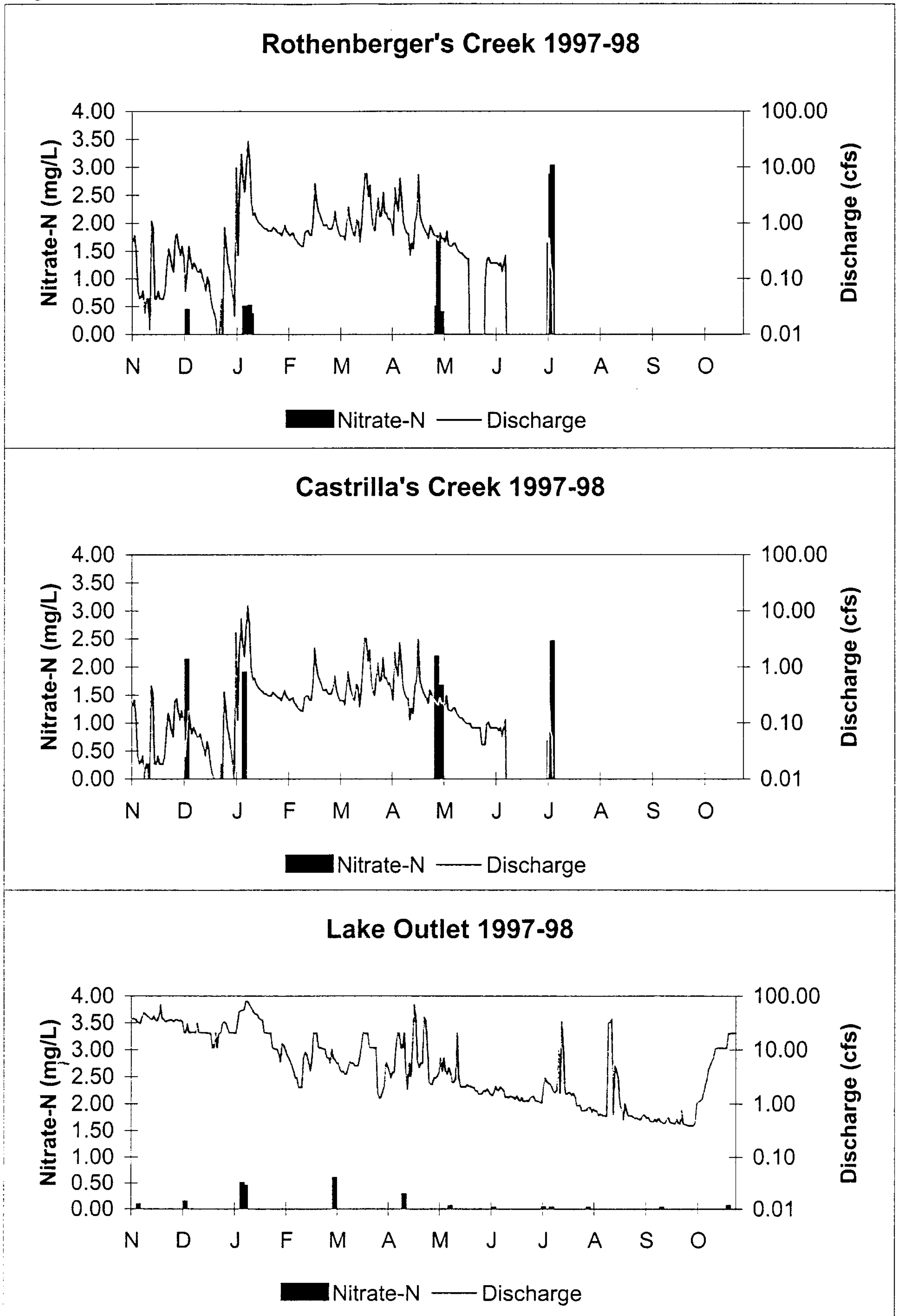
Rothenberger's Creek 1997-98
Total Phosphorus (mg/L)
Discharge (cfs)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Total Phosphorus
Discharge
Castrilla's Creek 1997-98
Total Phosphorus (mg/L)
Discharge (cfs)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Total Phosphorus
Discharge
Lake Outlet 1997-98
Total Phosphorus (mg/L)
Discharge (cfs)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Total Phosphorus
Discharge

Figure 4.6



Buesink's Creek 1997-98
Nitrate-N (mg/L)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Discharge (cfs)
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Nitrate-N
Discharge
Walker's Creek 1997-98
Nitrate-N (mg/L)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Discharge (cfs)
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Nitrate-N
Discharge
Harrington Hill Creek 1997-98
Nitrate-N (mg/L)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Discharge (cfs)
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Nitrate-N
Discharge

Figure 4.7


Rothenberger's Creek 1997-98
Nitrate-N (mg/L)
Discharge (cfs)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Nitrate-N
Discharge
Castrilla's Creek 1997-98
Nitrate-N (mg/L)
Discharge (cfs)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Nitrate-N
Discharge
Lake Outlet 1997-98
Nitrate-N (mg/L)
Discharge (cfs)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
100.00
10.00
1.00
0.10
0.01
N D J F M A M J J A S O
Nitrate-N
Discharge

lake. However, at this point in the chapter the following discussion relates directly to Figures 4.2 to 4.7.

Table 4.3: Stream chemical sampling statistics for combined routine and storm sample results.

Stream Name	Number of Samples	Chlorides (mg/L)			Total Phosphorus (mg/L)			Nitrate-Nitrogen (mg/L)		
		min	max	mean	min	max	mean	min	max	mean
Buesink's Creek	24	2.5	23.6	7.2	0.039	1.330	0.155	0.35	3.37	1.10
Walker's Creek	18	0.1	4.4	1.4	0.034	1.200	0.099	0.01	0.77	0.31
Harrington Hill Ck	15	10.0	26.3	16.1	0.058	0.851	0.192	0.87	3.49	2.27
South Inlet	5	7.3	20.7	14.5	0.077	0.427	0.169	0.56	1.26	0.84
Rothenberger's Ck	15	2.1	12.7	5.7	0.060	0.251	0.106	0.25	3.00	0.94
Castrilla's Creek	10	1.9	14.5	9.7	0.069	0.631	0.153	0.60	2.43	1.55
Lake Outlet	15	10.2	28.4	15.2	0.018	0.165	0.062	0.01	0.57	0.17

The graphs in Figures 4.2 and 4.3 show that most streams exhibit lower concentrations of chlorides during high flows and, as flow decreases, chloride concentration increase. Of particular interest are the results from Walker's Creek which are considerably lower in chloride concentration than the other creeks. Recall from Chapter 2 – Land Use, that the watershed for this creek is almost entirely forested. Also note that chlorides are rather high in Harrington Hill Creek whose watershed is almost entirely used for agriculture. Chloride concentration in the remaining creeks fall between Walker's and Harrington Hill creeks and contain a greater mix of land use. Chlorides in the lake outlet are consistently high through the year and increase as stream flow decreases.

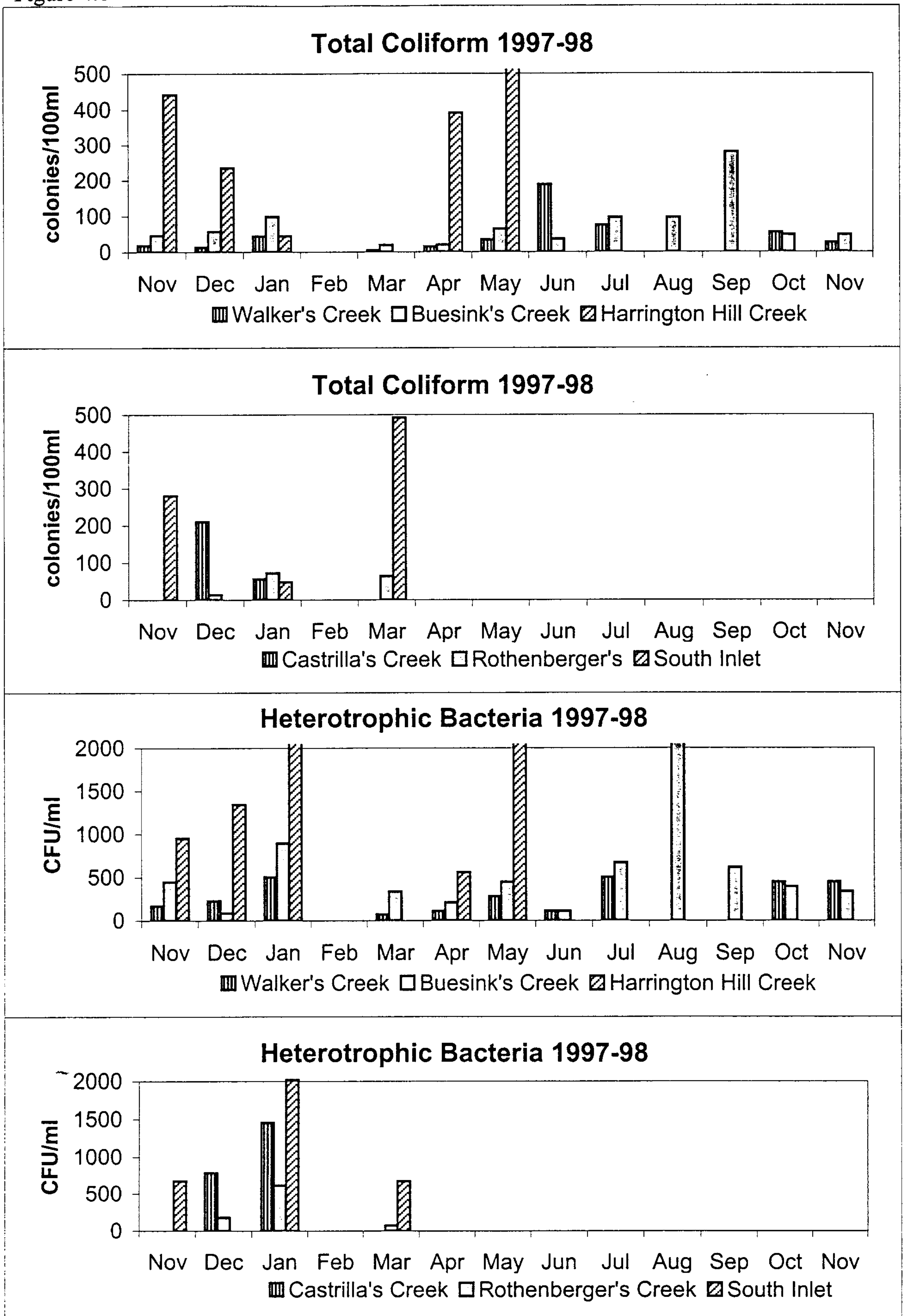
Graphs of total phosphorus in Figures 4.4 and 4.5 all indicate that a phosphorus spike occurred in July during a storm event. Phosphorus levels in the lake outlet were lower than the other streams and like chlorides, the concentration increased as outlet stream flow decreased.

The graphs of nitrate-nitrogen in Figure 4.6 and 4.7 exhibit very similar trends as those discussed for chlorides. Walker's creek is consistently low in nitrates and there is a spike in most of the creeks during the July storm. As flow in the lake outlet decreases during the summer, the concentration of nitrates also decreases.

Results of stream samples analyzed for bacteria by the Chautauqua County Health Department lab are shown in the graphs of Figure 4.8. All stream samples analyzed for total coliform bacteria contained less than 500 colonies/100ml of water except for one sample collected at Harrington Hill Creek which contained about 3,800 colonies/100ml. Recalling that the total coliform standard for bathing beaches is <2,400 coloies/100ml, the streams feeding the lake are for the most part well within that standard. Harrington Hill Creek does exhibit higher bacteria levels than the other creeks, most likely due to the large proportion of farm animal activity in that watershed. Heterotrophic bacteria (those bacteria which are free-living in nature) were low for all creeks except for Harrington Hill and one sample from Buesink's Creek.

Results from the physicochemical measurements taken in each stream are shown in the bar graphs of Figures 4.9 to 4.12. Results from the lake outlet were not graphed but are included

Figure 4.8



Total Coliform 1997-98
colonies/100ml
500
400
300
200
100
0
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Walker's Creek Buesink's Creek Harrington Hill Creek
Total Coliform 1997-98
colonies/100ml
500
400
300
200
100
0
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Castrilla's Creek Rothenberger's South Inlet
Heterotrophic Bacteria 1997-98
CFU/ml
2000
1500
1000
500
0
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Walker's Creek Buesink's Creek Harrington Hill Creek
Heterotrophic Bacteria 1997-98
CFU/ml
2000
1500
1000
500
0
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Castrilla's Creek Rothenberger's Creek South Inlet

Figure 4.9

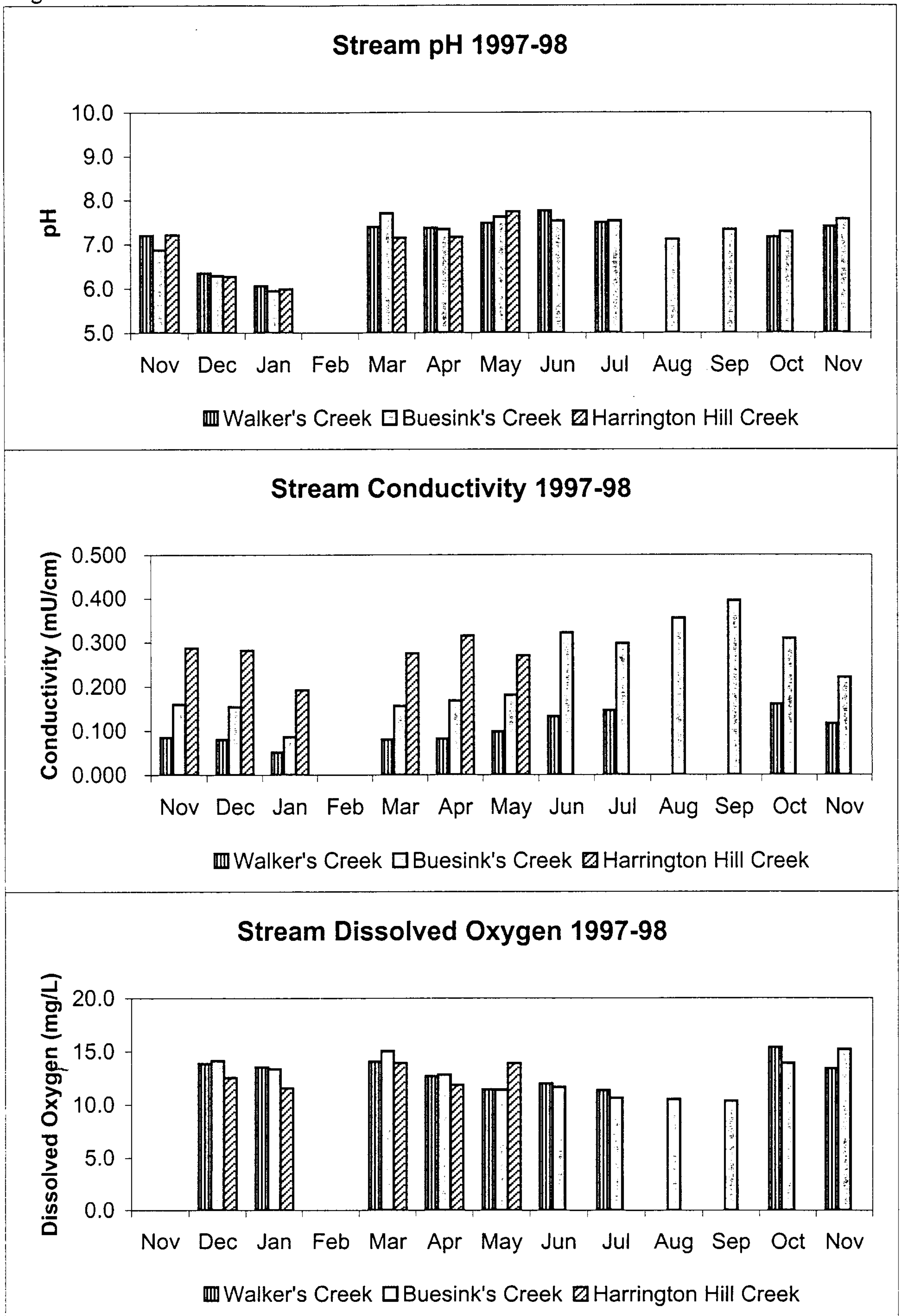

Stream pH 1997-98
10.0
9.0
8.0
7.0
6.0
5.0
pH
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Walker's Creek Buesink's Creek Harrington Hill Creek
Stream Conductivity 1997-98
0.500
0.400
0.300
0.200
0.100
0.000
Conductivity (mU/cm)
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Walker's Creek Buesink's Creek Harrington Hill Creek
Stream Dissolved Oxygen 1997-98
20.0
15.0
10.0
5.0
0.0
Dissolved Oxygen (mg/L)
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Walker's Creek Buesink's Creek Harrington Hill Creek

Figure 4.10

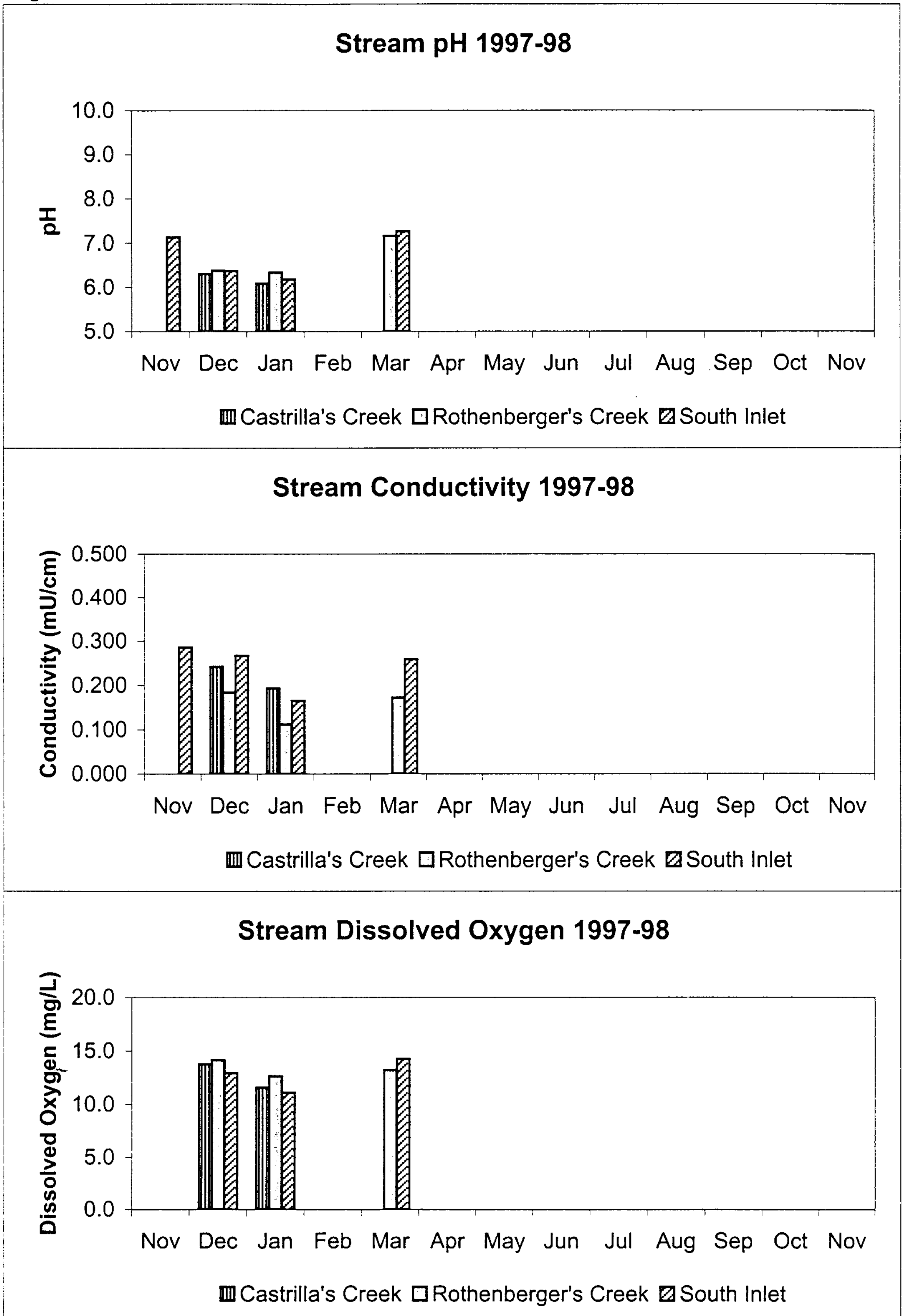
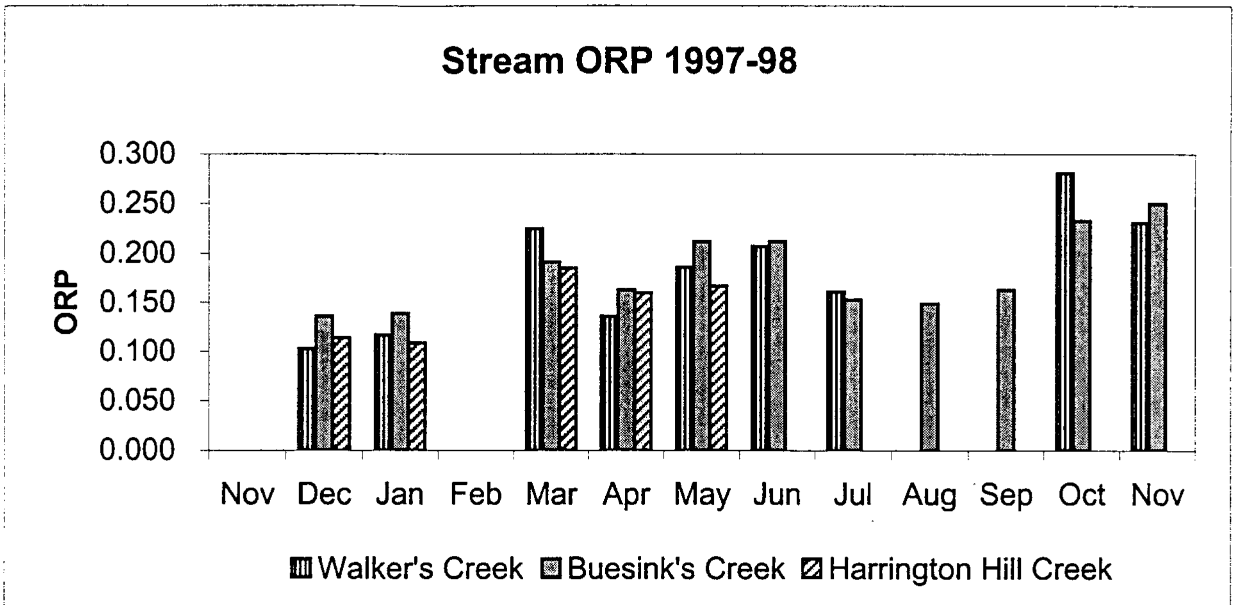
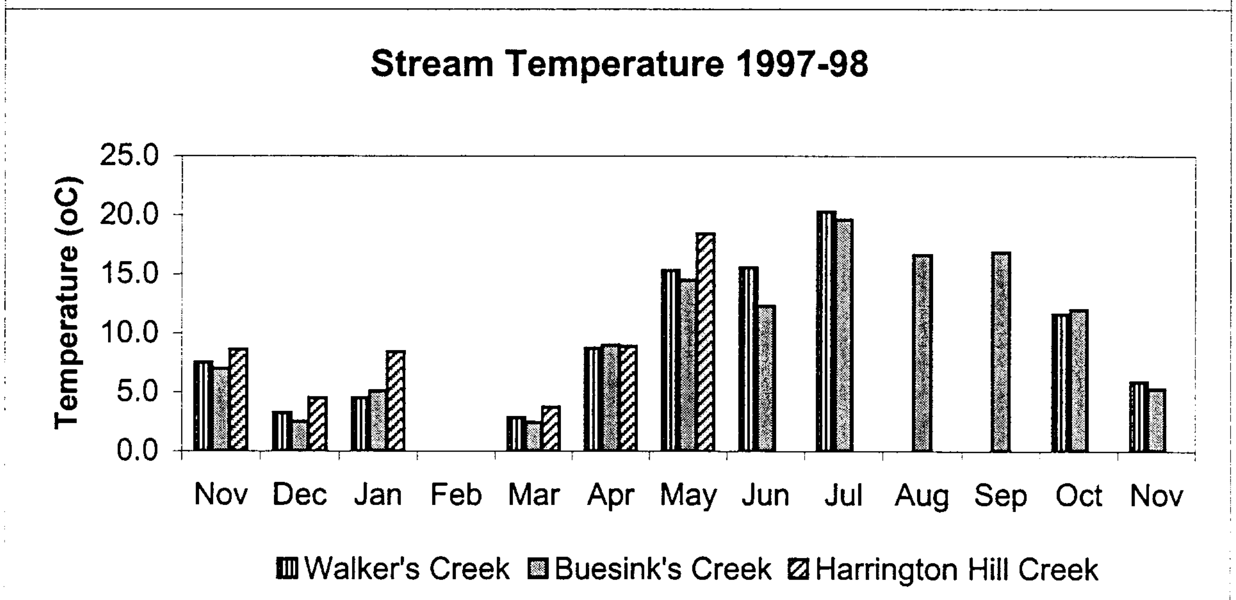

Stream pH 1997-98
pH
10.0
9.0
8.0
7.0
6.0
5.0
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Castrilla's Creek Rothenberger's Creek South Inlet
Stream Conductivity 1997-98
Conductivity (mU/cm)
0.500
0.400
0.300
0.200
0.100
0.000
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Castrilla's Creek Rothenberger's Creek South Inlet
Stream Dissolved Oxygen 1997-98
Dissolved Oxygen (mg/L)
20.0
15.0
10.0
5.0
0.0
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Castrilla's Creek Rothenberger's Creek South Inlet

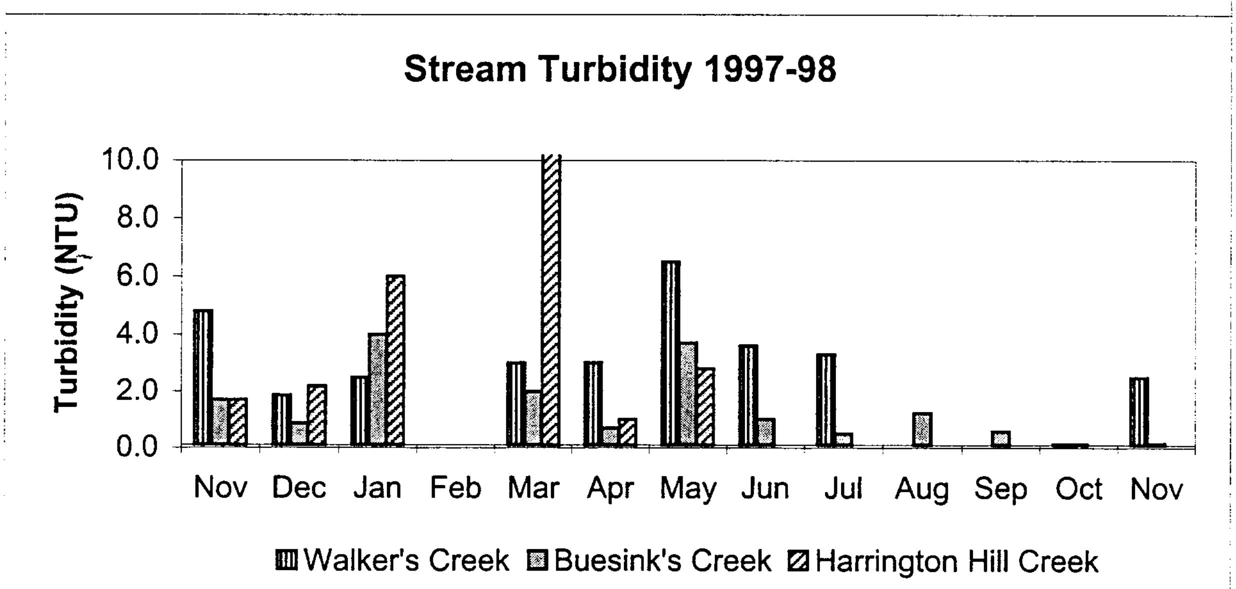
Figure 4.11



Stream ORP 1997-98
0.300
0.250
0.200
0.150
0.100
0.050
0.000
ORP
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Walker's Creek Buesink's Creek Harrington Hill Creek

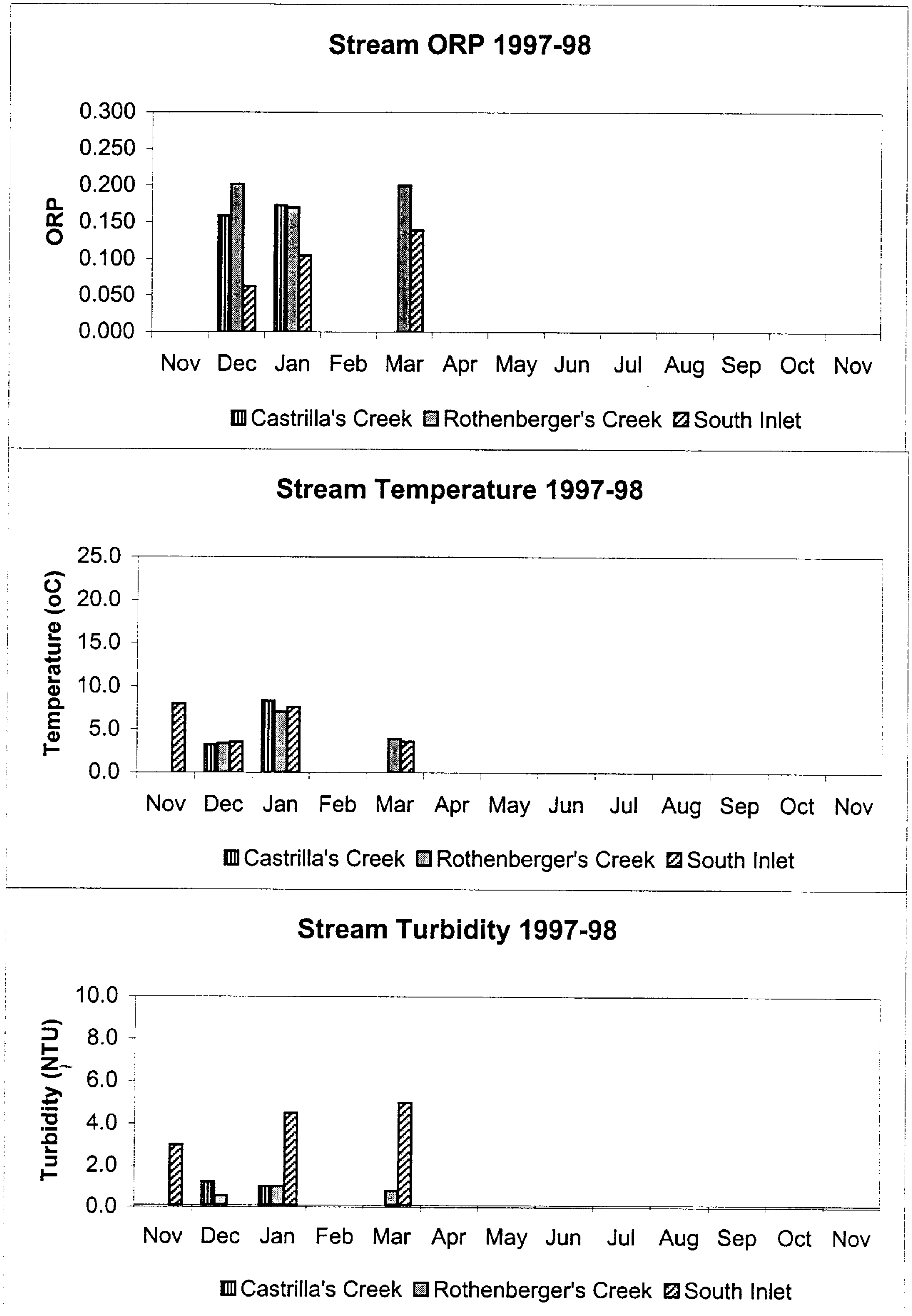


Stream Temperature 1997-98
25.0
20.0
15.0
10.0
5.0
0.0
Temperature (oC)
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Walker's Creek Buesink's Creek Harrington Hill Creek



Stream Turbidity 1997-98
10.0
8.0
6.0
4.0
2.0
0.0
Turbidity (NTU)
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Walker's Creek Buesink's Creek Harrington Hill Creek

Figure 4.12


Stream ORP 1997-98
ORP
0.300
0.250
0.200
0.150
0.100
0.050
0.000
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Castrilla's Creek
Rothenberger's Creek
South Inlet
Stream Temperature 1997-98
Temperature (oC)
25.0
20.0
15.0
10.0
5.0
0.0
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Castrilla's Creek
Rothenberger's Creek
South Inlet
Stream Turbidity 1997-98
Turbidity (NTU)
10.0
8.0
6.0
4.0
2.0
0.0
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
Castrilla's Creek
Rothenberger's Creek
South Inlet

in the summary tables at the end of this chapter. Graphs of stream pH show that all streams exhibit a healthy neutral pH of about 7 except during December and January when stream pH fell to about 6. Stream conductivity, a measure of dissolved ions in water, follows the same general pattern as that of the concentrations of chlorides and nitrates. This is not surprising since chlorides, when dissolved in water, account for most of the conductivity. The elevated summer conductivity levels in Buesink's Creek and Walker's Creek indicate these flows are being supported by ground water. This is discussed further in the summary. Dissolved oxygen is high in all the streams indicating they are capable of supporting aquatic life and are healthy. Stream temperatures show that none of the streams are suffering from thermal pollution. Summer stream temperatures in Buesink's Creek and Walker's Creek never exceeded 20 °C (68°F), while summer air temperatures reached highs of 35°C (95°F). This is additional evidence indicating that summer flow in these two streams is primarily from ground water. The temperature of ground water in this area remains pretty constant at about 10°C (50°F) throughout the year.

Total suspended solids and turbidity provide information about the sediment load carried to the lake by streams. Graphs of turbidity results from monthly routine samples show the streams carry little sediment to the lake under low to moderate flow conditions. Walker's Creek, which would be expected to carry the least sediment, exhibits relatively high turbidity during routine sampling, which usually represented low stream flow conditions. High sediment loads in Walker's Creek are also seen in the TSS samples collected only during storm flows (Table 4.4). While the source of the sediment can not be determined, recalling that phosphorus binds to sediment particles does explain the higher than expected phosphorus levels in Walker's Creek.

Table 4.4: Routine sampling turbidity results and storm flow TSS results.

Stream Name	Turbidity (NTU)				TSS (mg/L)			
	# samples	min	max	mean	# samples	min	max	mean
Buesink's Creek	17	0.1	30	5.1	16	0.5	1360	117.7
Walker's Creek	16	0.1	25	6.2	10	2.6	2960	306.8
Harrington Hill Ck	7	1.0	36	8.0	11	1.4	472	59.2
South Inlet	5	3.0	14	6.2	4	0.5	17	8.9
Rothenberger's Ck	8	0.6	22	7.6	13	2.0	126	22.7
Castrilla's Creek	3	1.0	1.2	1.1	9	2	114	17.8
Lake Outlet	16	0.8	16	3.4	7	0.5	15	5.9

WATER QUAILITY OF RUNOFF FROM PERIPHERAL AREAS

Due to the complexities and costs involved with sampling runoff from the peripheral area of the lake, it was necessary to make some estimates of peripheral water quality based on land use. In Chapter 3, the peripheral area of the lake was divided into three general land use categories, developed, agricultural and forest land. While a great deal of research has been done to model runoff water quality based on land use, it is preferred to use local data, if available, to make such estimates. Since the Harrington Hill Creek watershed is essentially all agricultural land and Walker's Creek is all forested, their water quality was used as an estimate of runoff quality from those respective land uses in the periphery. Runoff quality from developed land was based on the work of Wilson, Riforgait and Boria (2000) who studied runoff from a residential development on Chautauqua Lake. For all three land use categories, the mean annual concentration of chlorides, nitrates and phosphorus was used as an estimate of runoff quality from the periphery as shown in Table 4.5.

Table 4.5: Runoff Water Quality Based on Land Use (all values in mg/L).

Land Use	Chlorides	Nitrate-Nitrogen	Total Phosphorus
Forested	1.4	0.31	0.099
Agricultural	16.1	2.27	0.192
Developed	29.1	1.70	0.076

GROUND WATER QUALITY

Methods

All drinking water supplies in the Findley Lake area are derived from individual ground water wells or springs. The quality of the ground water that feeds the lake was determined using results from 45 private drinking water well samples collected from homes and cottages around the lake. These samples were analyzed for two suites of chemicals. Thirty-three samples were analyzed by Microbac for chlorides, nitrate-nitrogen and total phosphorus and twelve samples were tested only for nitrate-nitrogen and analyzed by the NYSDOH Wadsworth Laboratory. All samples were collected between July 14 and September 17, 1998 by County Health Department staff.

Results

The results from the well samples were plotted on a series of three maps to evaluate their spatial distribution. Figure 4.13 is a map of the chloride results and identifies an area of high chlorides located at the northwest corner of the lake. Figure 4.14 shows that the phosphorus levels exhibit no distinct pattern. Figure 4.15 shows that ground water around the north half of the lake is higher in nitrates than that around the southern half, especially on the northeast side.

The mean concentration of chlorides, nitrates and total phosphorus from the wells sampled was used to characterize the quality of ground water flowing to the lake. Table 4.6 shows summary statistics for the wells sampled and suggests that ground water could contribute large quantities of chlorides, nitrates and phosphorus to the lake. Pristine ground water in this region should contain less than 15 mg/L of chlorides, however, research cited in Wilson, Riforgait and Boria (2000) indicates that chloride levels in ground water in central Chautauqua County have increased gradually over the past 30 years from about 6 to about 30 mg/L, a rate of about 0.7 mg/L per year. Depending on local sources of chlorides and soil conditions (e.g., coarse gravel soils as in Findley Lake), it is not uncommon to see these higher chloride levels. Wetzel (1983) notes that the average concentration of phosphorus in ground water is low, about 0.020 mg/L. This is because phosphorus is quickly removed by soil adsorption and plants prior to it reaching the ground water table, leading to the conclusion that in the Findley Lake area phosphorus is originating from a widespread, nearby source such as septic systems. Nitrates on

Figure 4.13

PRIVATE WELL MONITORING RESULTS FOR CHLORIDES
SAMPLED 7/14 - 9/17/98

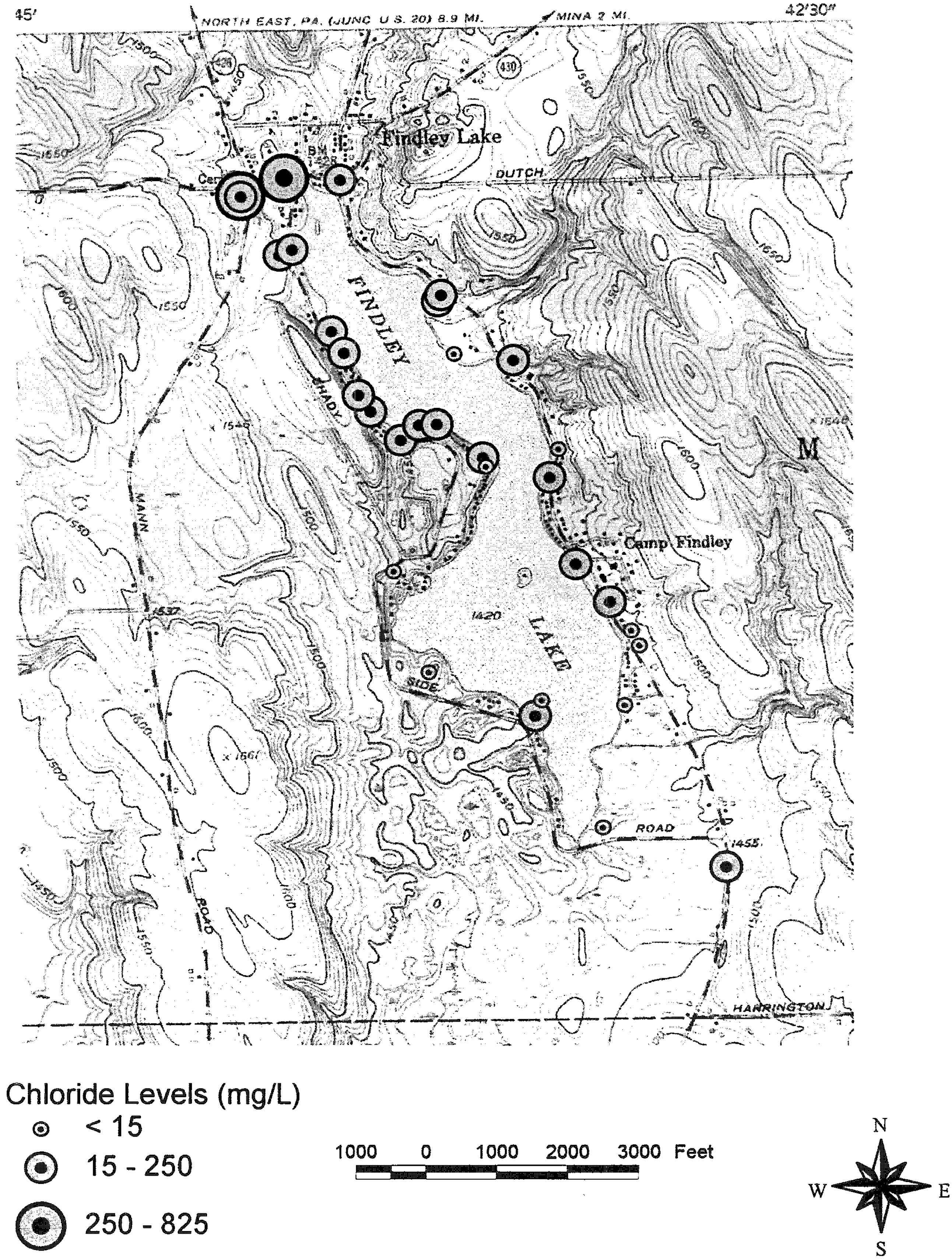


Figure 4.14

PRIVATE WELL MONITORING RESULTS FOR TOTAL PHOSPHORUS SAMPLED 7/14 - 9/17/98

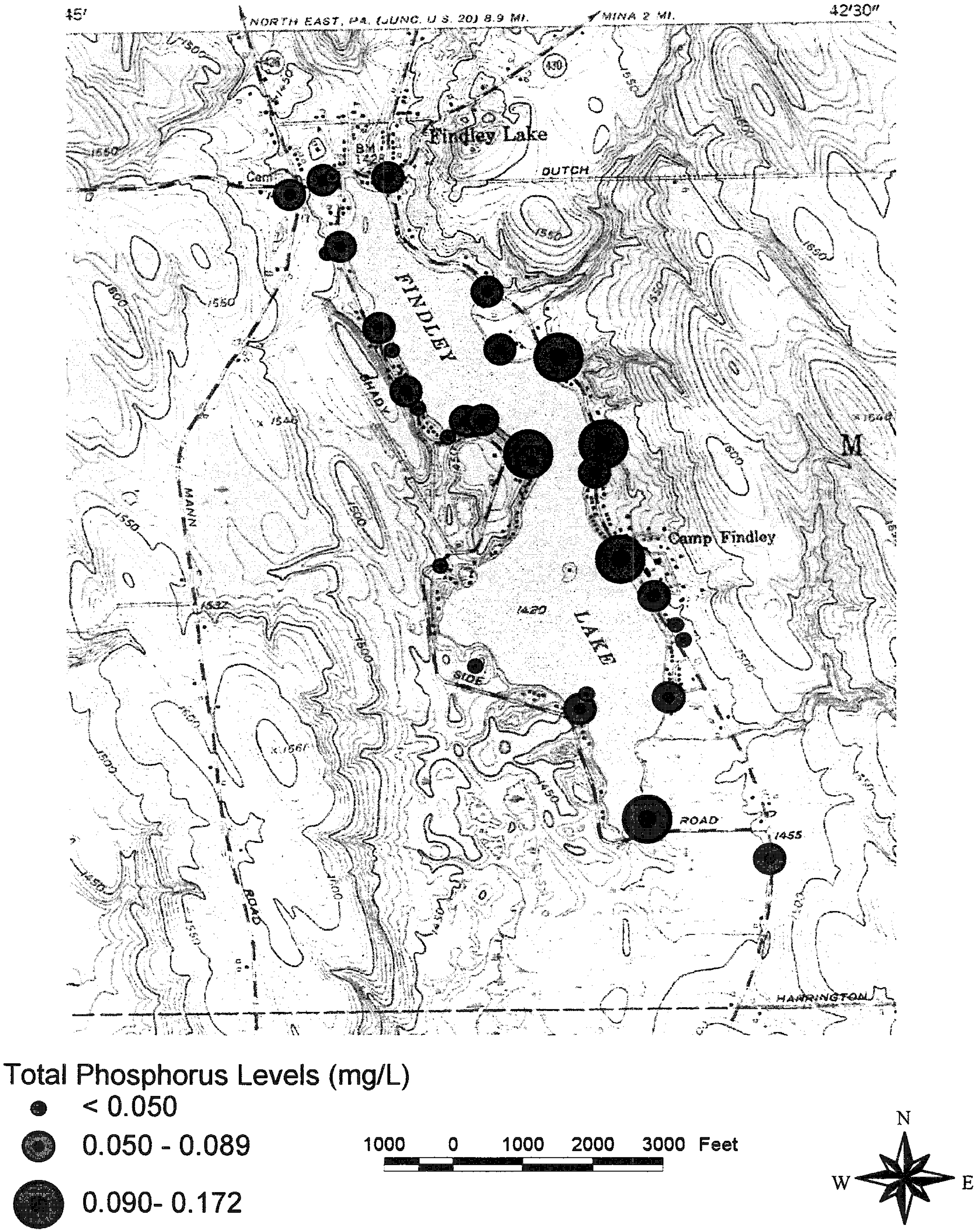
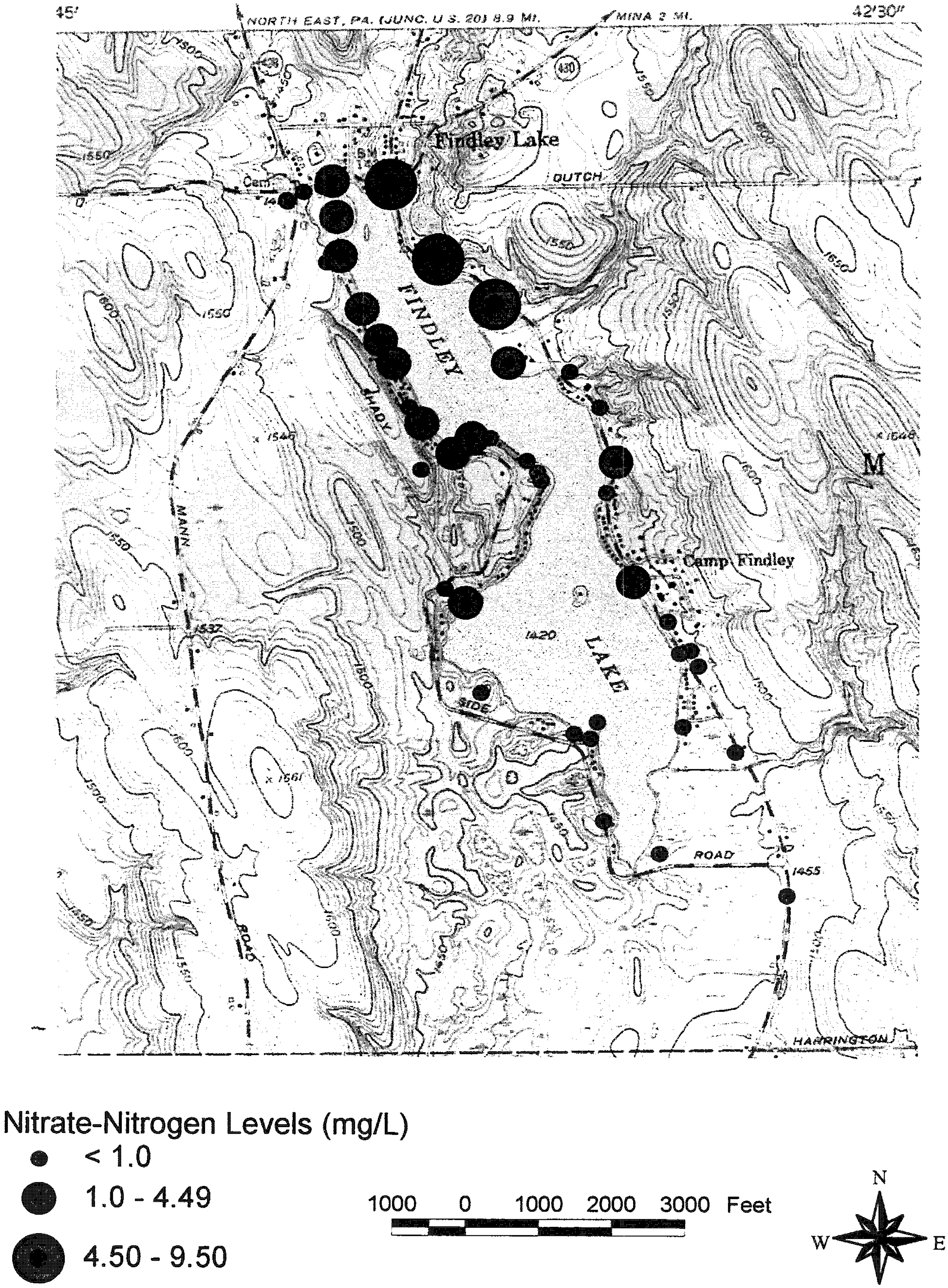


Figure 4.15

PRIVATE WELL MONITORING RESULTS FOR NITRATE - NITROGEN
SAMPLED 7/14 - 9/17/98



the other hand can migrate long distances in ground water. Their source could be from septic systems, home and garden fertilizers, agricultural activity or a combination of these. The concentration of nitrates in pristine ground water is usually 0.50 mg/L or less.

Table 4.6: Ground water monitoring results (all values in mg/L).

	Chlorides	Nitrate-Nitrogen	Total Phosphorus
Range (min– max)	0.45 – 281	<0.010 – 9.49	<0.010 – 0.172
Mean	46.3	1.44	0.063

A complete table of well sampling results is provided at the end of this chapter.

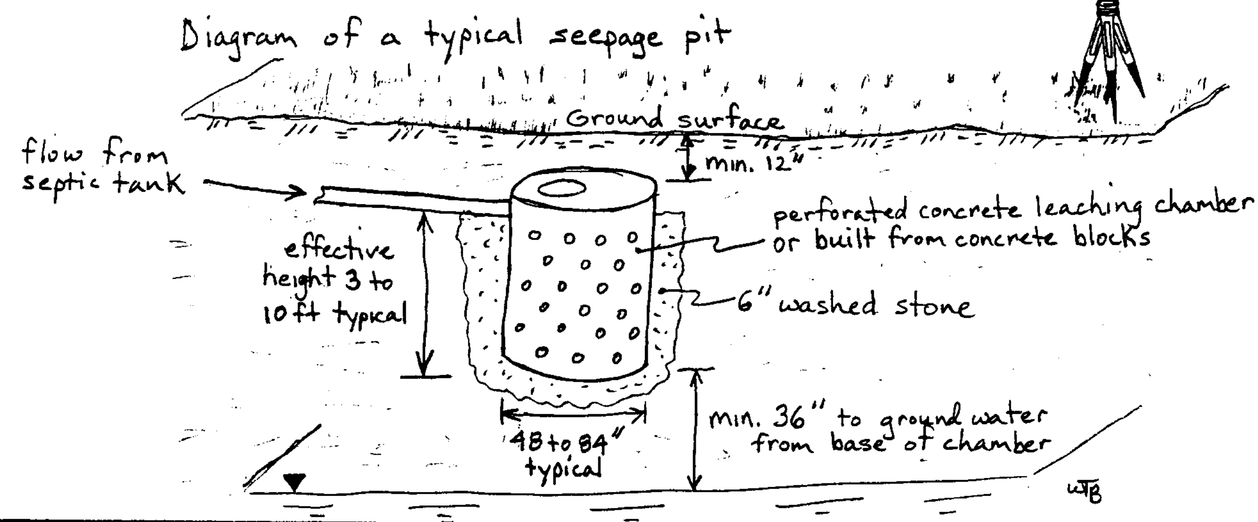
Septic Systems and Ground Water Quality

The rapid movement of ground water through the sand and gravel aquifer surrounding Findley Lake presents special concerns. Wastewater is re-circulated back to ground water via individual septic systems with leaching fields (Figure 4.16). Septic system design is governed by the percolation or infiltration rate of soil, lot size, topography and household water use.

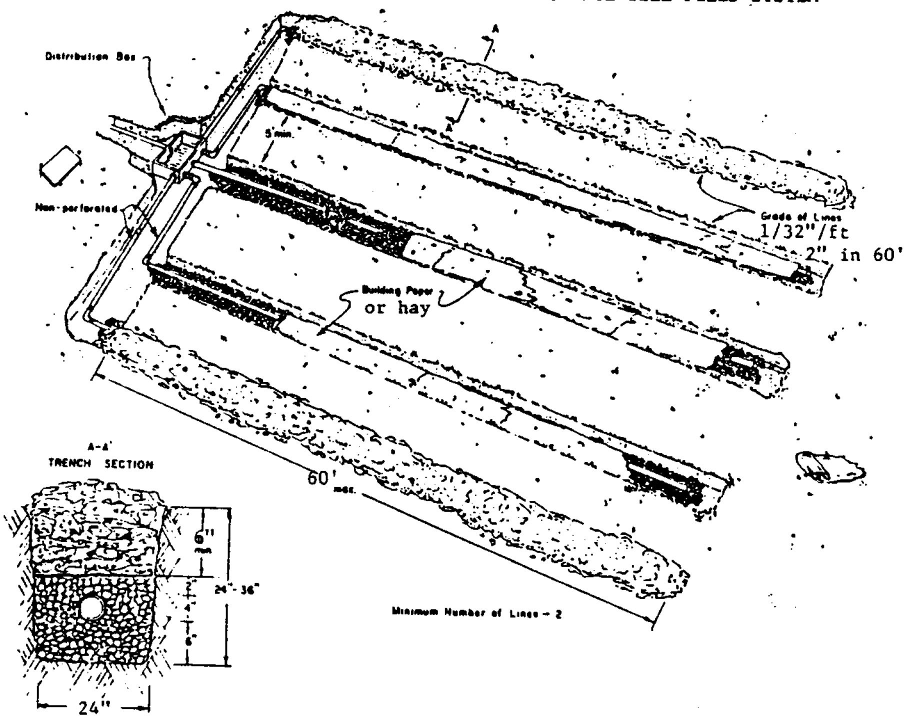
Figure 4.17 is a map of soil infiltration rates for the Findley Lake watershed. This shows that the lake is surrounded by soils that exhibit very high infiltration rates, which is typical of sandy and gravelly soils. When soil infiltration rates are high, septic system design standards allow for compact leach fields that inject wastewater to a small area beneath the ground surface. The three types of leach fields commonly used around Findley Lake are illustrated in Figure 4.16. The purpose of a leach field is to distribute the wastewater close enough to the land surface so that soil microbes and vegetation can consume nutrients and other contaminants. Once promoted by health authorities, the seepage pit is no longer allowed for any new residential construction in New York State because the wastewater is injected at depths below the soil horizon (4 to 8 ft deep), affording little biological treatment but relying instead on the physical straining ability of the sediment. Contaminants like nitrates and chlorides that are completely dissolved in water cannot be removed by sediment filtration. Research by Tofflemire, Chen and Arnold (1978) has shown that the ability of soil to adsorb phosphorus from wastewater is greatly reduced with depth. They showed that phosphate adsorption by soil in the B horizon (usually less than 3 ft deep) is 2.5 times that in the C horizon (3 to 6 ft deep) and further reduced at greater depths.

Since many parts of the lakeshore have been subdivided into very small lots, the type of leach field that can be installed is limited to one that uses the least amount of space. Pre-existing homes or cottages on small lots, whose owners are faced with replacing a leach field or entire septic system, have few options but to install a seepage pit, given appropriate soils. This is now the only situation where a new seepage pit can be constructed, i.e. the system is "grand fathered." While all types of septic leaching systems contribute contaminants to ground water (Chen 1982), seepage pits and cesspools have been shown to contribute more than other types. Currently many homes and cottages around the lake utilize a seepage pit, and given the soil conditions, it is not surprising to find above normal levels of contaminants in the ground water.

Figure 4.16: Types of Leach Fields.



STANDARD SUBSURFACE TILE FIELD SYSTEM



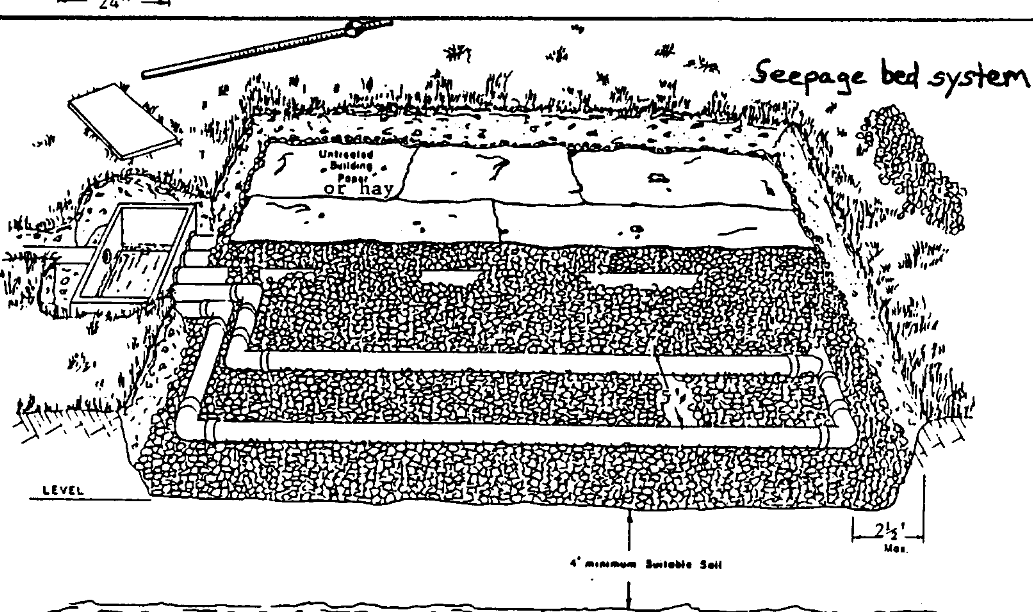
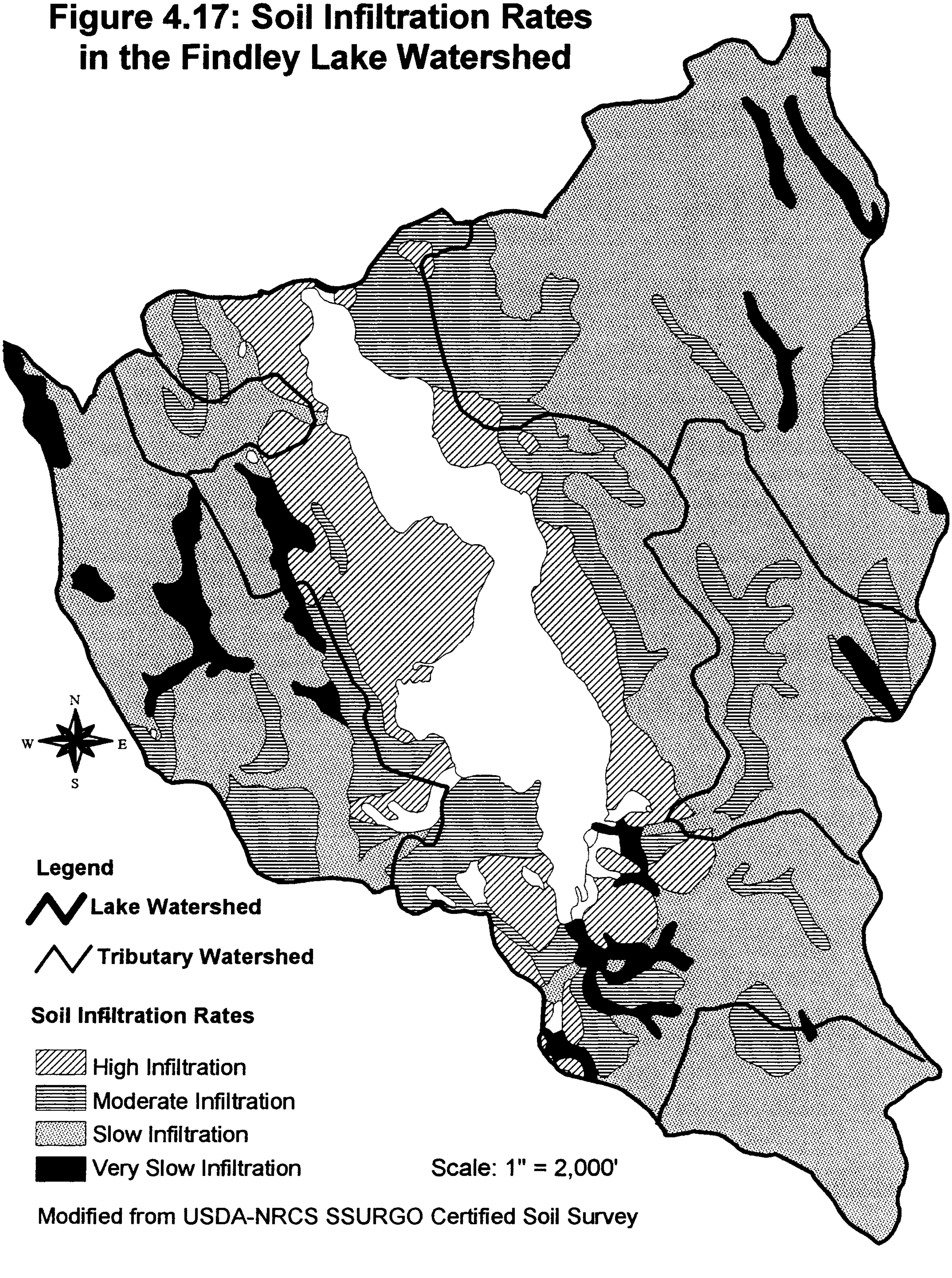


Figure 4.17: Soil Infiltration Rates in the Findley Lake Watershed



Legend

Lake Watershed

Tributary Watershed

Soil Infiltration Rates

High Infiltration
Moderate Infiltration
Slow Infiltration
Very Slow Infiltration

Scale: 1" = 2,000'

Modified from USDA-NRCS SSURGO Certified Soil Survey

Water use determines just how much wastewater flows to the septic system and is discharged into the ground. For residential septic system design purposes, water use is estimated based on the number of bedrooms the system will serve. For typical year-round homes, this practice works well, for vacation homes or cottages it may not. While vacation properties are typically only used during a very small portion of the year, they often see heavy use during that time by owners, guests and other vacationers. Therefore, large "slugs" of wastewater can be sent to a septic system during very short periods of time. This further decreases the natural ability of soil, sediment and microbes to remove contaminants from the waste stream.

While chemical contamination of ground water by septic systems appears prevalent around the lake, there is little evidence of bacterial contamination. During water-sewage surveys conducted by the Health Department during property transfers, water wells are routinely sampled for coliform bacteria, an indicator of sewage contamination. Fewer than 10% of wells sampled over the past 30 years have exhibited bacteria levels above drinking water standards. This leads to the conclusion that the soils around the lake act as good filters for bacteria and other potentially harmful microbes including parasites and viruses.

ATMOSHPERIC DEPOSITION

Inputs of nitrates, total phosphorus and chlorides to the lake from rainfall, snow and dust particles that fall directly on the lake surface were estimated using data collected at two New York State locations. Chloride and nitrate data are from a National Atmospheric Deposition Program monitoring station located in the nearby Town of Stockton, which is operated by the SUNY College at Fredonia Chemistry Department (http://nadp.sws.uiuc.edu). Total phosphorus data are from a USGS station located at Mendon Ponds near Rochester and operated by the Monroe County Health Department (Hornline et al., 1998, 1999). Data from both sources reflect actual measurements made during our project period and were reported as mean monthly concentrations. As can be seen in the summary statistics for atmospheric deposition shown in Table 4.7, precipitation could be a major source of phosphorus and to some extent nitrogen, but contributes very little chlorides to the watershed.

Table 4.7: Atmospheric Deposition Monitoring Results (all values in mg/L).

	Chlorides	Nitrate-Nitrogen	Total Phosphorus
Range (min– max)	0.05 – 0.21	0.21 – 0.99	0.015 – 0.110
Mean	0.12	0.45	0.079

LAKE WATER QUALITY

Methods

Water quality measurements and water samples were collected at three locations in the lake, once a month, beginning in late summer of 1997 until November 1998. The three sampling locations are identified as L1, L2 and L3 in Figure 3.15. These sites were chosen to represent water quality of the north, middle and south portions of the lake. Summer water depths at each site were measured to be 9.8 m (32 ft) at L1, 11.0 m (36 ft) at L2 and 7.3 m (24 ft) at L3. Any water sample designated with a "A" was taken 1 meter below the lake surface, any sample designated with a "B" was collected 1 meter above the lake bottom. Near surface samples were taken at each location throughout the year. Near-bottom samples were only taken when the lake was thermally stratified as described below. Location L2 is the same sampling site used for taking summer Citizens Statewide Lake Assessment Program (CSLAP) samples, which were also collected from 1 meter below the lake surface. Samples were collected using three Kemmerer-type samplers, one dedicated for sampling each site. Prior to sample collection, the samplers were acclimated and rinsed with water being sampled. Between sampling periods, samplers were washed with a non-phosphate detergent, rinsed and air-dried.

A Hydrolab Surveyor II was used to measure water depth, temperature, specific conductance, ORP, pH and DO at one meter intervals beginning at the lake surface and continuing to the lake bottom at each site. Lake water transparency was measured using a standard 20 cm diameter Secchi disk.

Results

Twelve sets of monthly samples and measurements were collected from each lake site from October 6, 1997 to November 25, 1998. Due to light winter ice cover, no samples were collected in January or February. In-lake water sample results are provided in a table at the end of this chapter along with depth integrated physicochemical profile data. The following is a discussion of the water quality measurements taken in Findley Lake during the watershed project, and a comparison of those measurements with other nearby lakes. Comparative data from Chautauqua Lake is from Wilson, Riforgiat and Boria, (2000).

Temperature profiles of the lake water column are shown on the graphs in Figure 4.18 and tell a lot about lake dynamics. Temperature profiles are used to assess how the lake functions during a typical year. That is, whether the lake becomes thermally stratified in the summer (warm water near the surface and cold water at depth) or winter (cold water near the surface and warmer water at depth) and also if and when the lake mixes (constant temperature throughout entire water column). As shown in these graphs, Findley Lake becomes stratified during the summer and mixes during the fall and spring. In the winter, during a period of normal ice cover (4 to 8 weeks) the lake most likely also stratifies. However, due to the lack of in-lake samples for January or February, there is no direct evidence to support winter stratification.

Surface temperatures in Findley Lake are very similar to that of Chautauqua Lake throughout the year. However during summer stratification, Findley Lake exhibits temperatures between 9 and 13°C near the lake bottom while that of Chautauqua is between 16 and 19°C. The difference is most likely due to large quantities of ground water flowing directly into Findley Lake as opposed to very little ground-water flow directly into Chautauqua.

Dissolved oxygen profiles of the lake water column are shown on the graphs of Figure 4.19. Like temperature, dissolved oxygen profiles provide insight to lake dynamics. We now know that Findley Lake undergoes thermal stratification in the summer and possibly during winter ice cover. During these times dissolved oxygen becomes depleted at depth by natural decay processes occurring in the lake bottom. From mid-July to mid-September, we begin to see

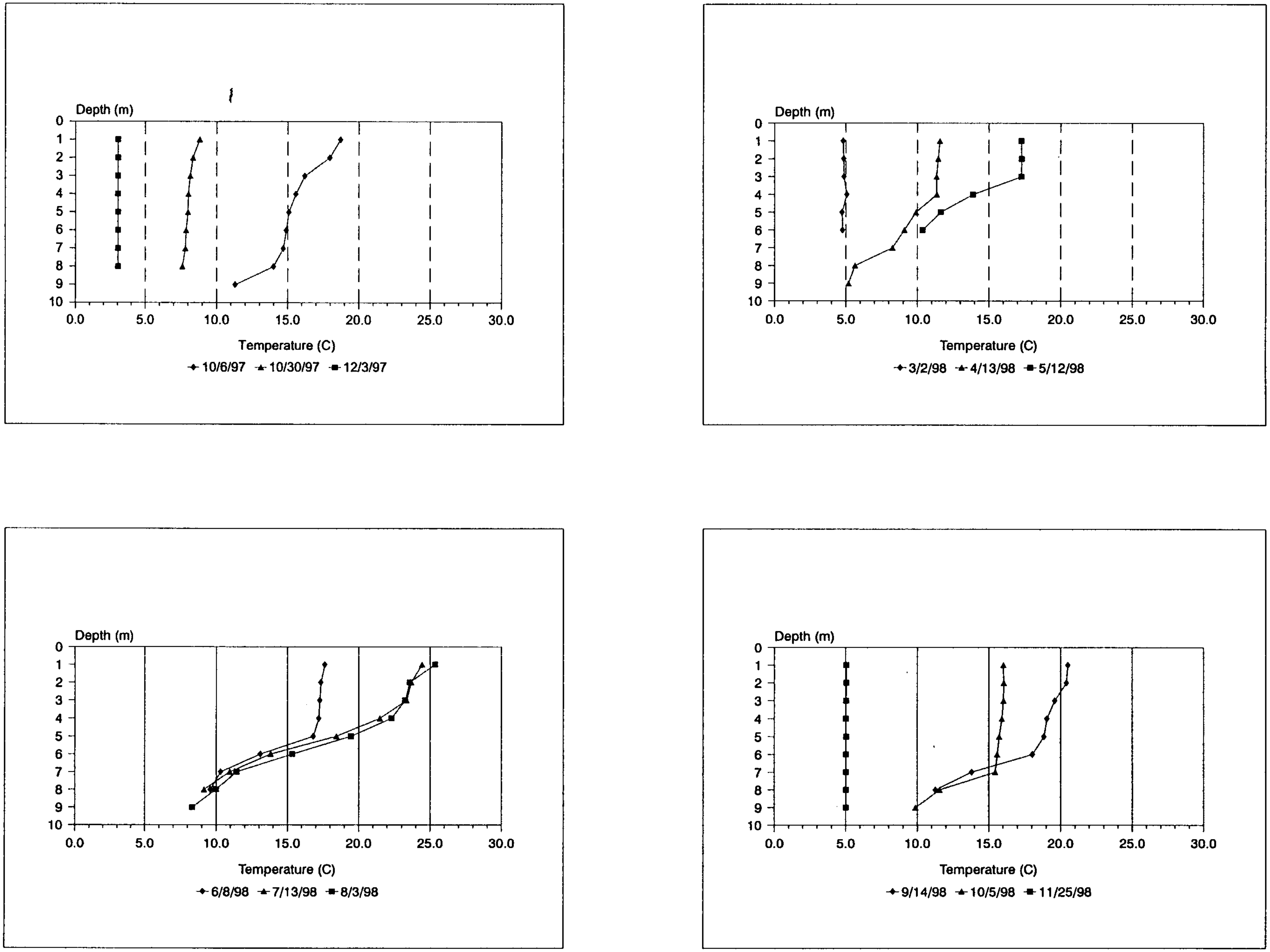


Figure 4.18 **Temperature Profiles for Station L1**

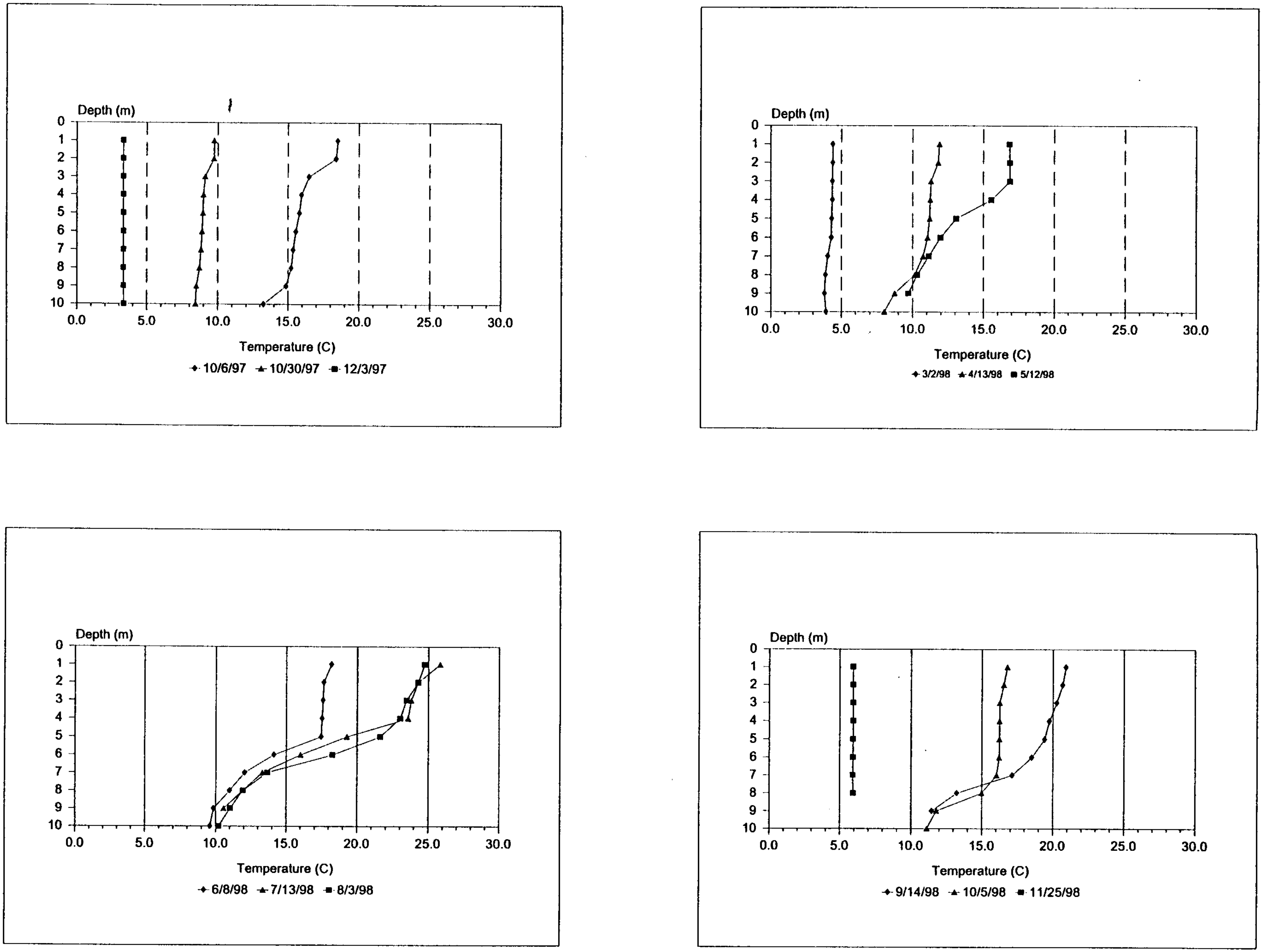


Figure 4.18 (Cont.) **Temperature Profiles for Station L2**

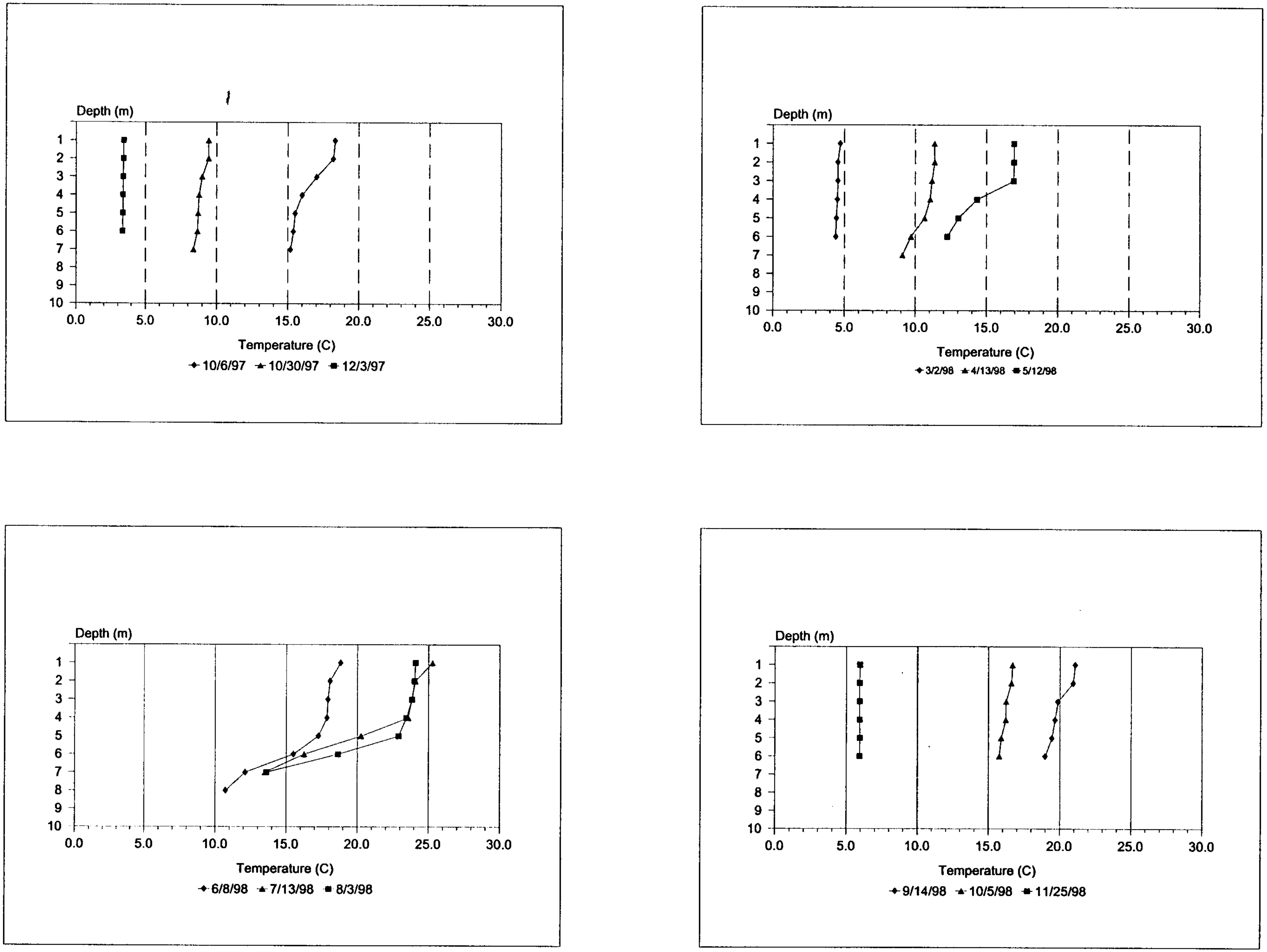


Figure 4.18 (Cont.) **Temperature Profiles for Station L3**

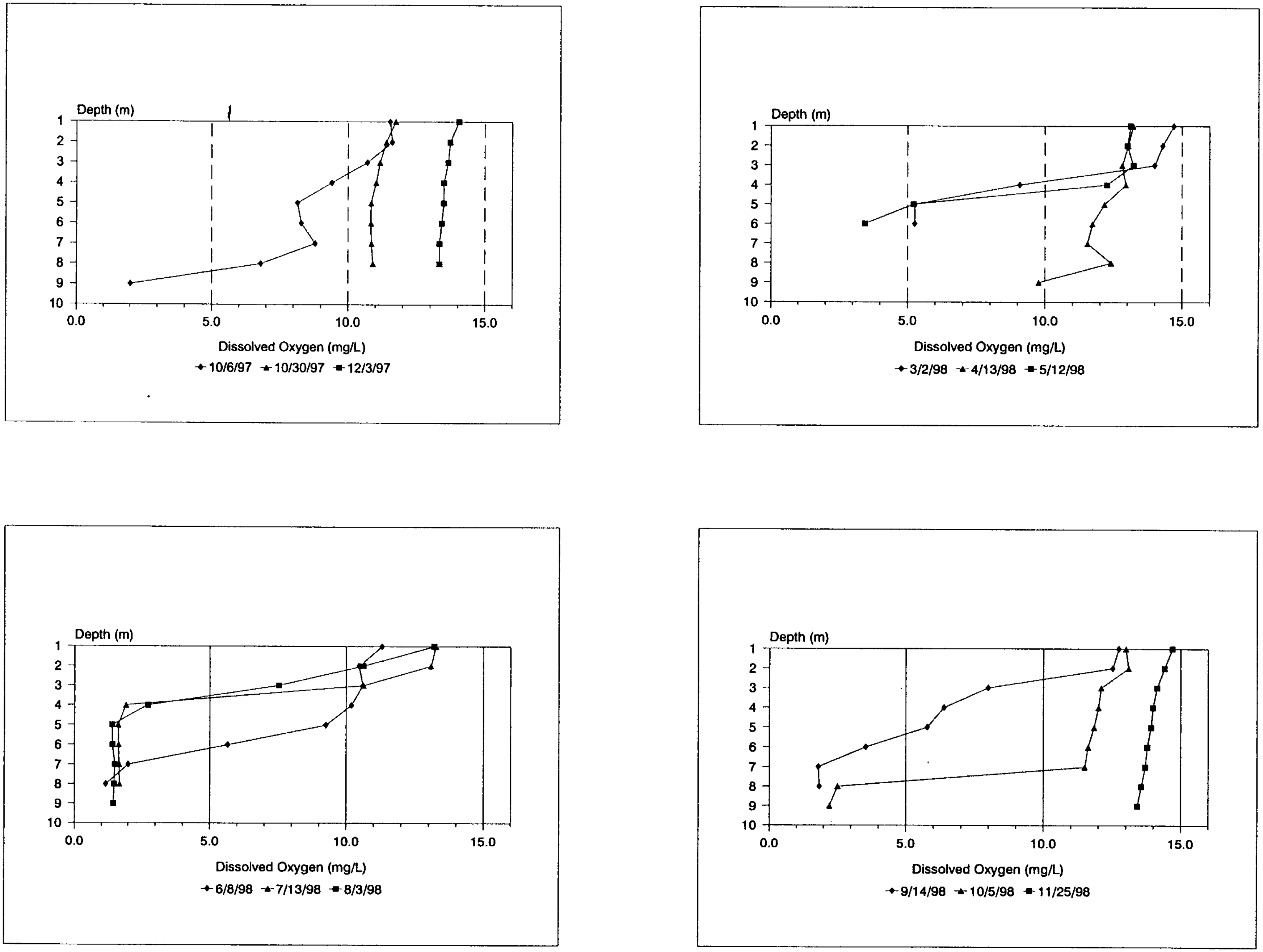


Figure 4.19 **Dissolved Oxygen Profiles for Station L1**

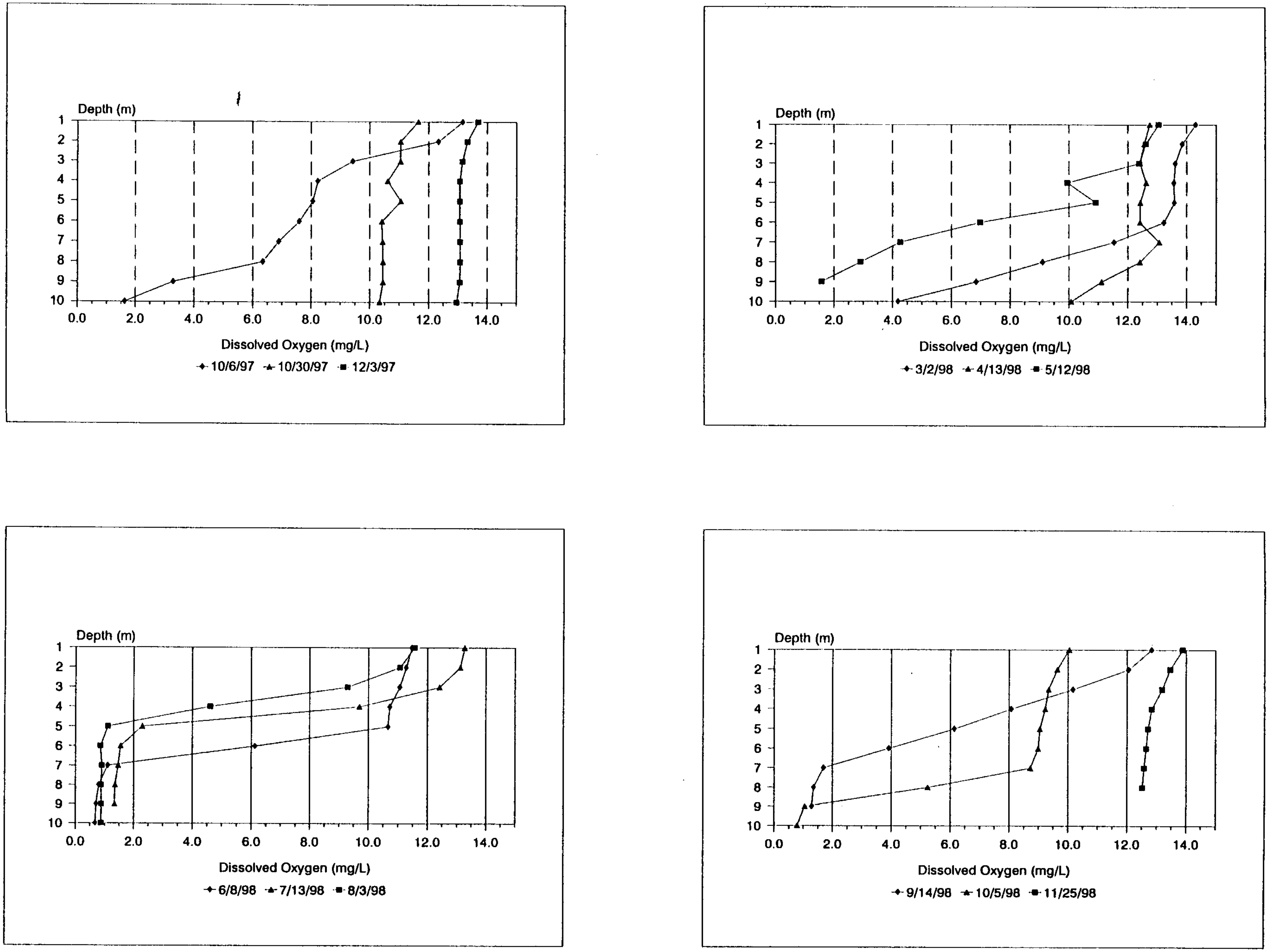
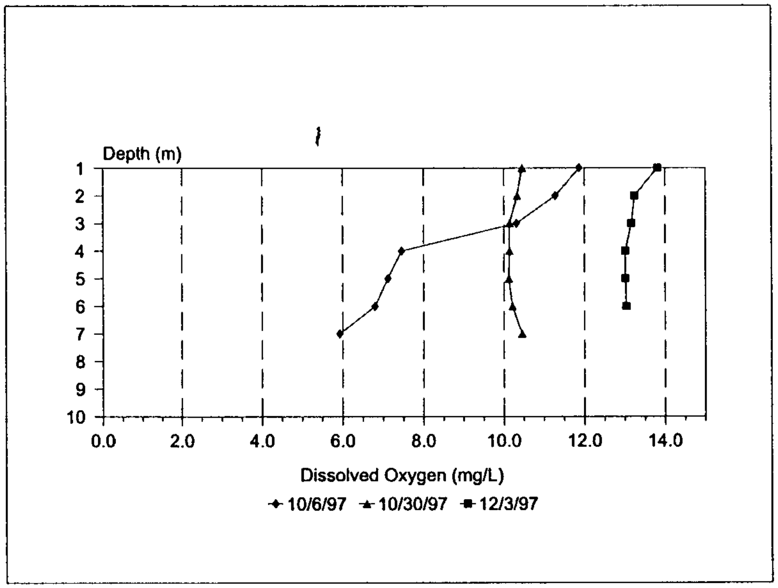
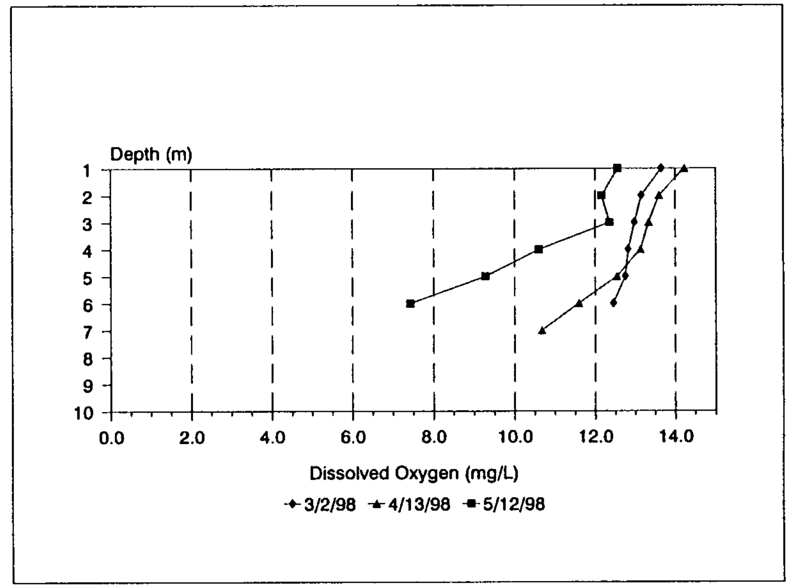
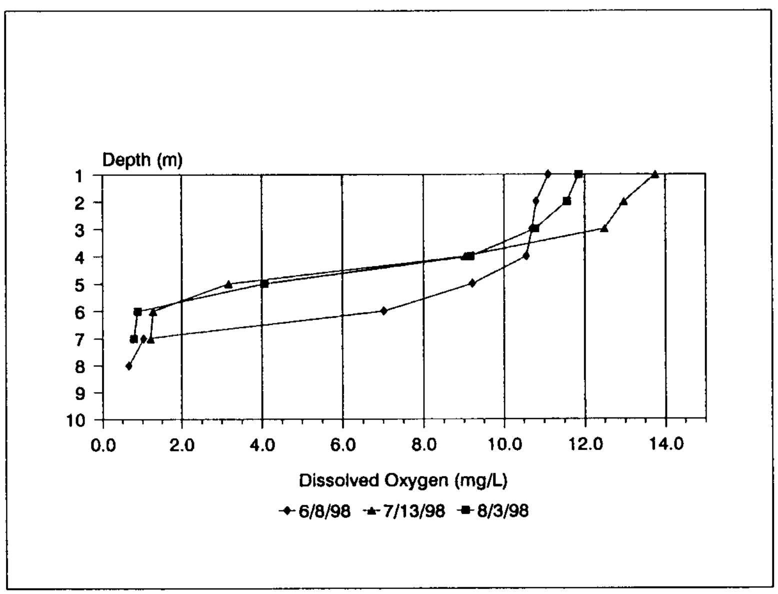


Figure 4.19 (Cont.) **Dissolved Oxygen Profiles for Station L2**







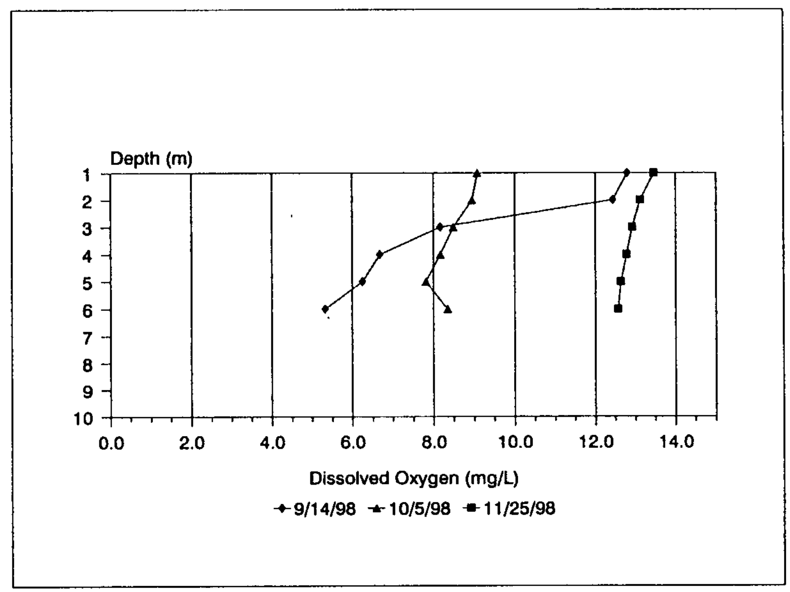


Figure 4.19 (Cont.) **Dissolved Oxygen Profiles for Station L3**

reduced oxygen levels occurring at about 3 m below the surface. At about 4 m below the surface DO levels quickly drop to less than 5 mg/L and at the lake bottom are about 1 mg/L during this period.

In the fall the lake begins to mix. That is, the thermal stratification effect is gradually eliminated allowing oxygen rich top waters to mix with oxygen depleted bottom waters. This yields a uniform DO in the entire water column of about 13 mg/l by November. Given significant ice cover, the lake probably becomes stratified again from January to March. The March 2 oxygen profiles and December 3 temperature profiles suggest winter stratification does occur. Surface DO measured throughout the year in Findley Lake (9.0 to 14.7 mg/L) is similar to that of Chautauqua Lake (7.4 to 15.0 mg/L). Summer oxygen profiles in Chautauqua Lake in July and August indicate rapid oxygen depletion occurs at about 6 m below the surface compared to about 4 m for Findley Lake. In Cassadaga Lakes oxygen is rapidly depleted between 2 and 3 m below the surface (Mantai 1998). Fish and other aquatic animals require oxygen to survive and must therefore adapt to these low bottom oxygen conditions by staying closer to the surface in the summer where they are subjected to warmer temperatures.

Results from Secchi disk measurements for transparency are plotted on the graphs in Figure 4.20. These data indicate that for most of the year, one can see 3 m or more into the lake. From July to September, transparency is reduced to about 1 m by the presence of algae and turbidity in the water column. This is similar to Cassadaga Lakes (Mantai, 1998), but less than that of Chautauqua Lake and other similar lakes in the region where transparency is typically 2 m in the summer (CSLAP, 1999).

Results for turbidity and TSS are shown in Figure 4.21 and closely follow trends for Chlorophyll _a_ discussed in the next chapter. For most of the year turbidity is about 2 NTU or less and pretty uniform throughout the lake. In August and September, turbidity increased considerably to between 15 and 22 NTU. Similar data from Chautauqua Lake (1993-94) indicate a huge variation in turbidity between sampling locations (generally less than 1 NTU in the north basin and about 3.5 NTU in the southern basin of the lake) during most of the year with a similar increase during the summer. However the summer increase at Chautauqua only reaches a maximum of about 10 NTU. These differences are due partly to the size of Chautauqua Lake compared to Findley Lake (algae blooms tend to cover only portions of Chautauqua Lake rather than the entire lake as in Findley Lake).

pH measured at the lake surface of our three sampling locations typically ranged between 7.0 and 8.7. When the lake was stratified, pH decreased with depth to the point where bottom water was slightly acidic (between 6.1 and 7.0). During summer stratification, surface pH was usually between 1 and 2 units higher than at the lake bottom. When the lake was mixing, pH was uniform throughout. Changes in oxidation-reduction potential mirrored those of pH. Noteworthy is the fact that extremely low ORP was exhibited at depth at location L2 during summer stratification.

Lake water conductivity was uniform throughout the lake in spring and fall while it was mixing, but when it was stratified, conductivity increased at depth and was higher in the northern half of the lake. The higher conductivities in the north part of Findley Lake correlate with the

Figure 4.20 SECCHI DISK TRANSPARENCY

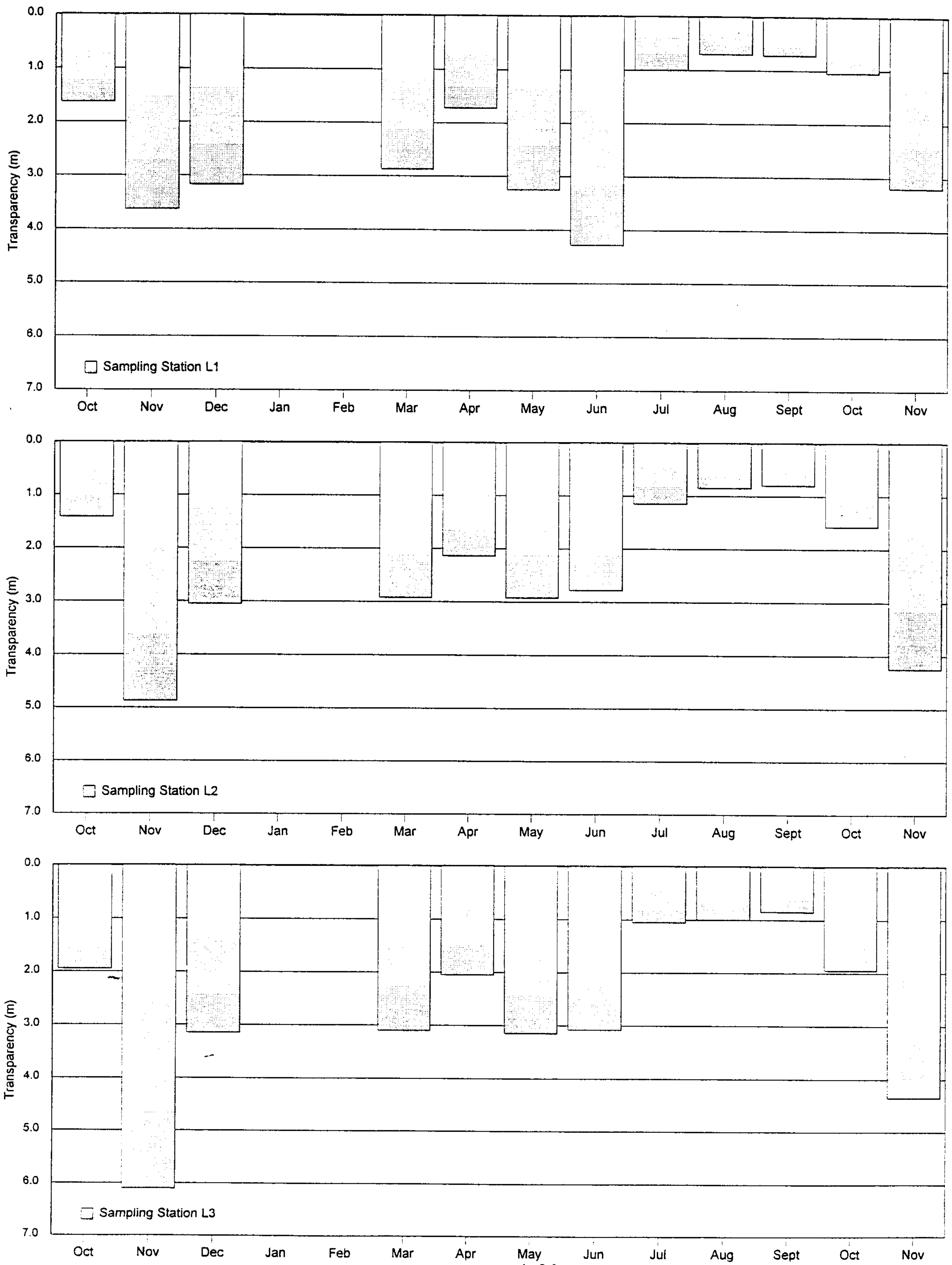
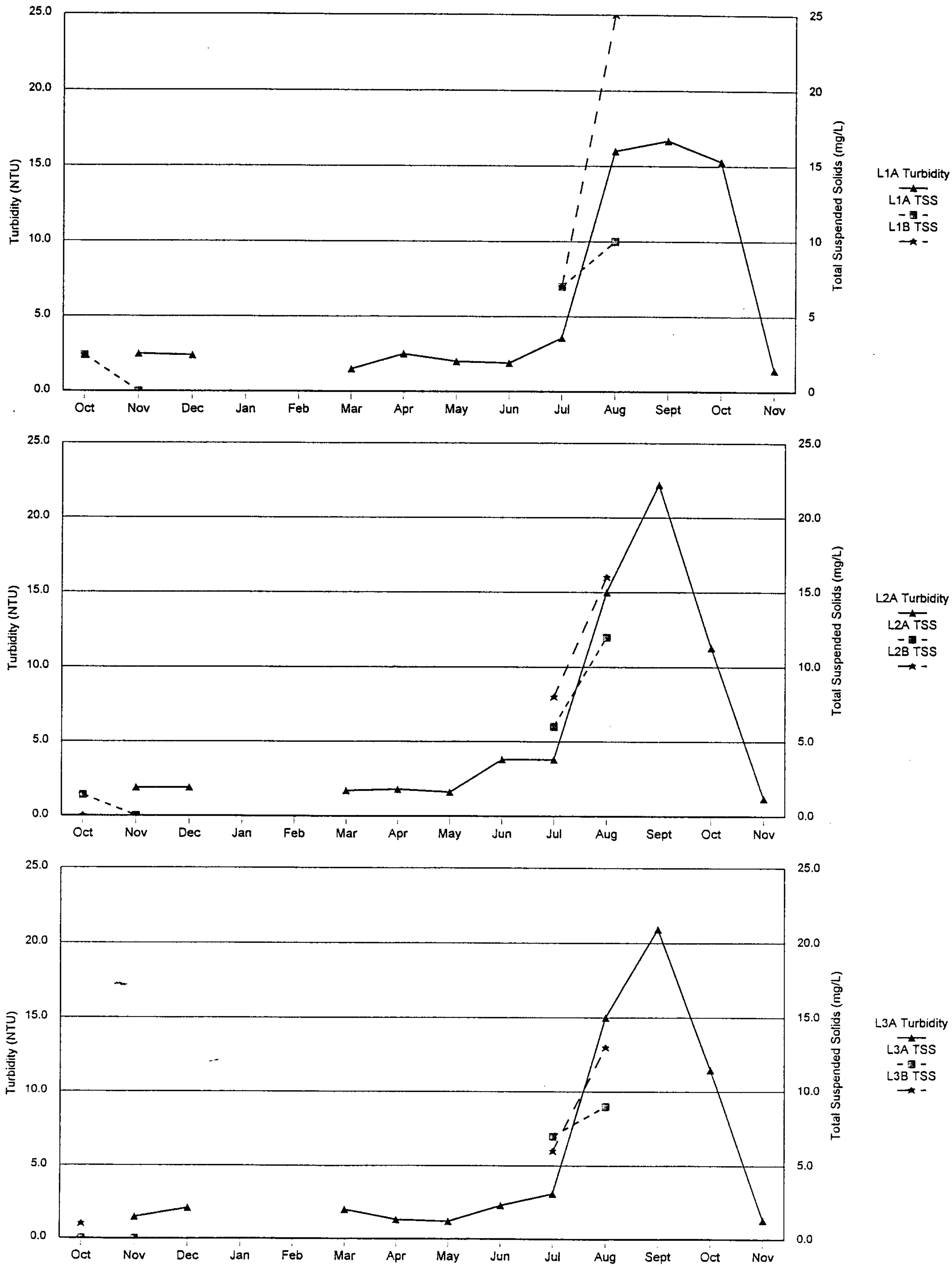


Figure 4.21 IN-LAKE TURBIDITY AND TOTAL SUSPENDED SOLIDS



elevated levels of chlorides and nitrates found in the ground water of the same area, and also with in-lake trends of those chemicals (discussed below). Conductivity at Findley Lake averaged 15 to 25 % higher than at Chautauqua Lake, likely due to the large amount of ground water feeding Findley Lake.

Chloride results from lake water samples are shown in the graphs of Figure 4.22. All of these graphs indicate chloride levels increased from March to August, peak in July, then declined through November. Recalling the earlier discussion of chlorides in ground water, and because chlorides are non-reactive within a lake (i.e. they are not consumed or generated within the lake), the increasing summer chloride levels reflect increasing summer ground water contributions to the lake. The peak from the July 13 samples might also reflect runoff from the storm event of July 7-9, when the area received 2.3 inches of rainfall in a 24 hour period. Sampling site L1 exhibits an anomalously high chloride level in October that may be related to the extremely high chloride levels detected in water wells at the northwest corner of the lake. A statistical summary of in-lake chloride results is provided in Table 4.8 and shows that results from Findley Lake are considerably higher than those from Chautauqua Lake.

Table 4.8: Summary Results for Near-Surface Samples.

Sample Location	Chlorides			Total Phosphorus			Nitrate Nitrogen		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Findley Lake L1A	11.0	23.7	14.6	0.025	0.120	0.063	<0.01	0.58	0.10
Findley Lake L2A	9.9	19.8	13.3	0.011	0.140	0.067	<0.01	0.36	0.08
Findley Lake L3A	10.5	24.7	13.6	0.030	0.228	0.072	<0.01	0.37	0.09
Chautauqua Lake L1A	5.0	11.9	10.86	0.027	0.090	0.046	<0.01	0.37	0.08
Chautauqua Lake L16A	4.3	13.7	11.4	0.026	0.171	0.058	<0.01	0.42	0.08

Results for total phosphorus are plotted in Figure 4.23. These graphs show that from March to April phosphorus increased, then declined until July and increased again through September or October. This suggests that spring and fall turnover is mixing high phosphorus bottom water (from the hypolimnion) with shallow, lower phosphorus water (from the epilimnion) and that during summer, aquatic plant growth is depleting phosphorus in the epilimnion. The July 13 near-surface sample taken at site L3 is substantially higher than the deep sample, and substantially lower than those from the other two sampling sites. This suggests that some local turnover of water occurred only at site L3 which could have been caused by the July 7-8 storm or by excessive boat traffic in that area. At site L2, phosphorus levels at depth are very high from June through August. At the same location, ORP is extremely low at depth. This is an indication that phosphorus is being released from bottom sediments back into the water column through natural water-sediment reactions. Table 4.8 provides summary statistics for in-lake total phosphorus and show that levels in Findley Lake are higher than those from Chautauqua Lake.

Graphs of in-lake nitrate-nitrogen sample results are provided in Figure 4.24. These show that nitrates built up in the lake from fall to spring, then steadily declined to very low levels in the summer as nutrients were consumed by aquatic vegetation. There is a very subtle increase in nitrates in near-surface samples from station L1 to L3 indicating that the southern part of the lake

Figure 4.22 IN-LAKE CHLORIDE LEVELS

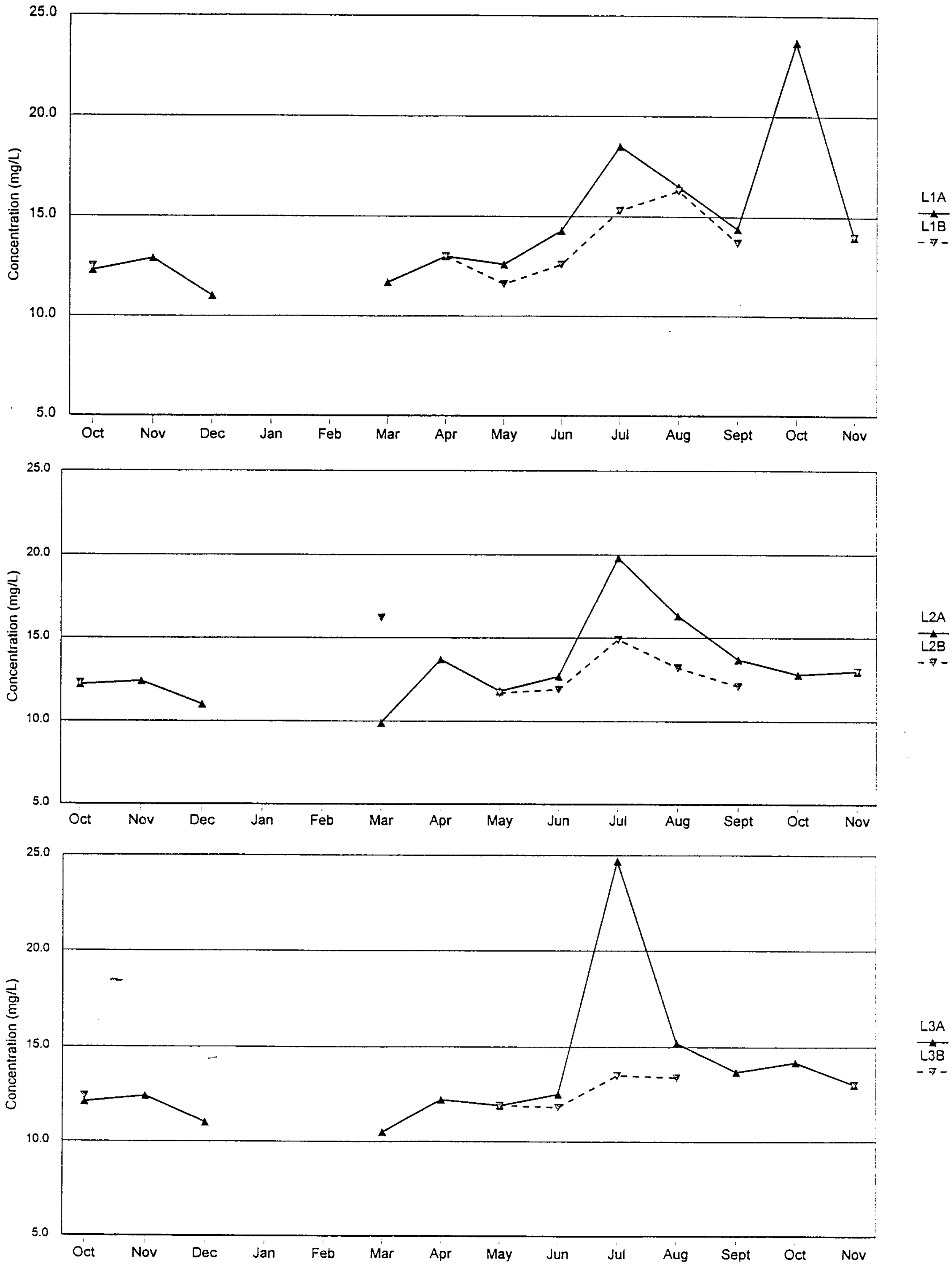
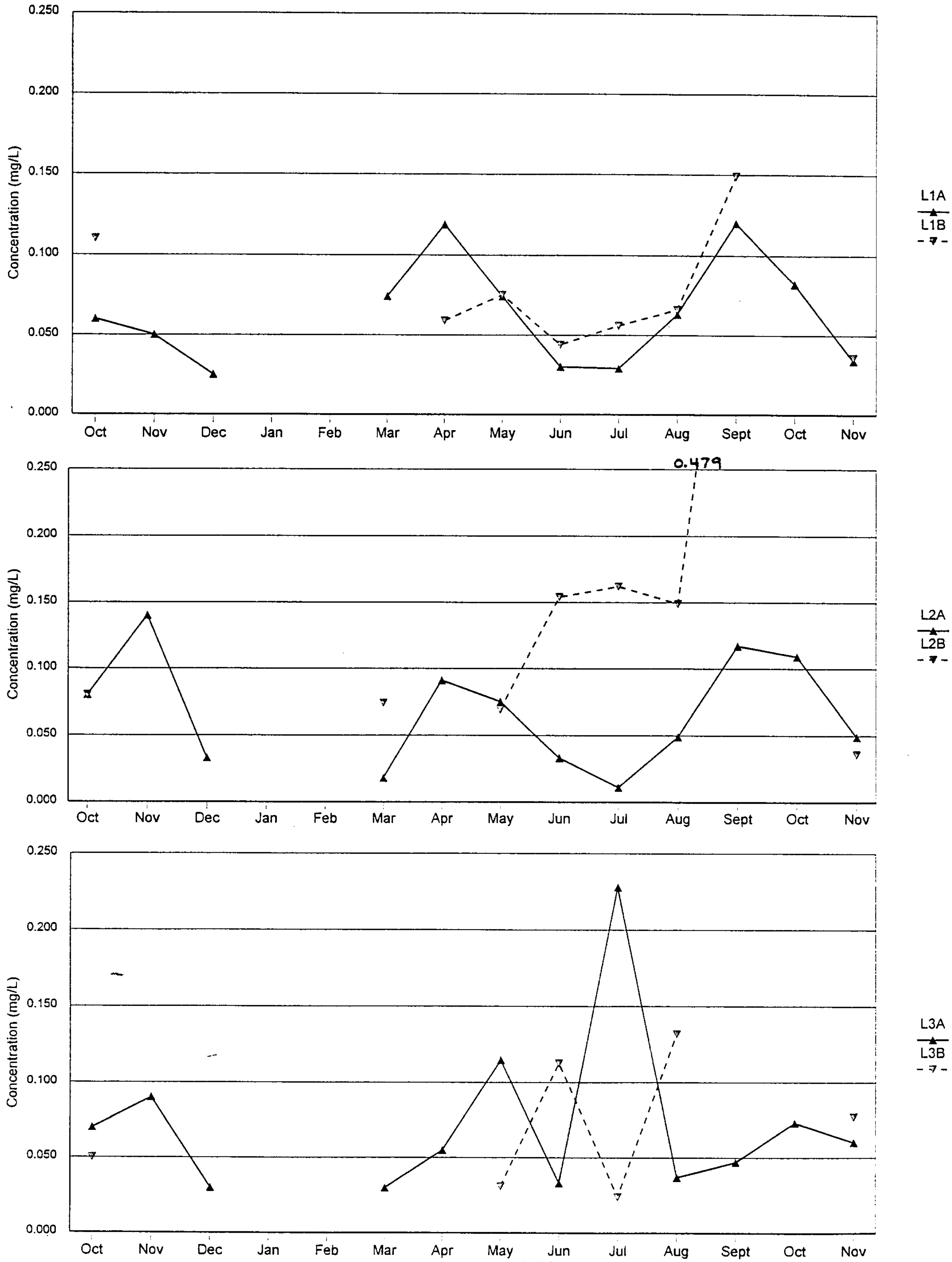


Figure 4.23 IN-LAKE TOTAL PHOSPHORUS LEVELS



may contain more nitrogen than can be consumed by plants. Summary statistics for nitrates are shown in Table 4.8 and are only slightly higher than those for Chautauqua Lake.

Bacteria results for near-surface samples collected at the three lake sampling locations are very low for total coliform, only two results are above 10 colonies/100ml (refer to tables at the end of this chapter). Heterotrophic or free-living bacteria are also low; the few instances when they are above 1,000 CFU/ml coincide with storm events. Two Health Department permitted bathing beaches, one at Camp Findley and one at Paradise Bay, are also sampled routinely for bacteria. The beach at Camp Findley has consistently met bathing beach bacteria standards, while that of Paradise Bay has had a number of recent high bacteria episodes. The likely cause is attributed to a combination of poor water circulation in the bay and feces of Canada Geese, who apparently consider the mowed grass of the beach very tasty. To test this theory, County Health Department staff performed a series of four fecal coliform extraction experiments on fresh goose feces. Results of the experiments showed that just 1 gram of feces agitated in water at room temperature can emit between 1 and 4 million fecal coliform colonies. At a feces rate of about 30 grams per day per goose (from Chapter 5), this source could easily be responsible for the high bacteria levels found in the beach water.

CHEMICAL LOADING BUDGETS FOR FINDLEY LAKE

While knowing the concentrations of chemicals in water flowing into and out of the lake is important, knowing the total weight of each chemical contributed to the lake from each individual source is of much greater importance. Combining results from the water budget with that of water quality provides the information necessary to choose appropriate lake management strategies. Similar to a water budget, a chemical budget for a lake is a mass balance of chemical inputs and outputs. Multiplying the concentration of each chemical by the appropriate inflow or outflow component of the water budget gives the loading budget for that chemical.

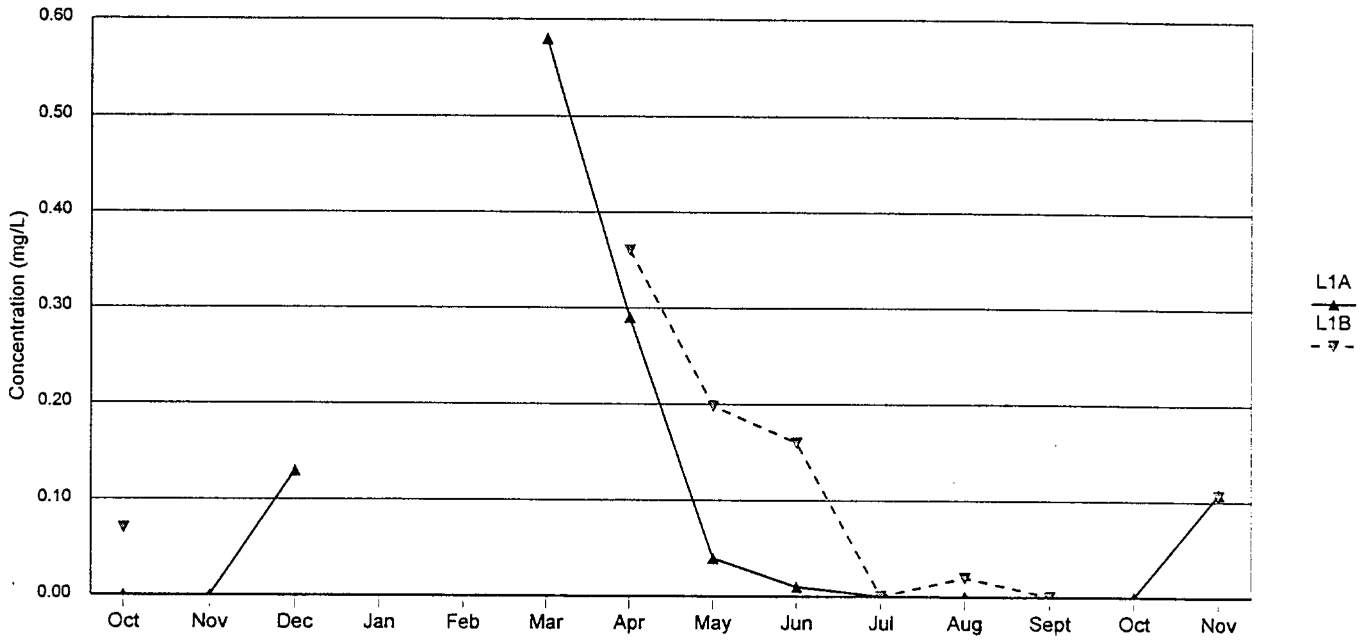
Chloride and Nutrient Inputs

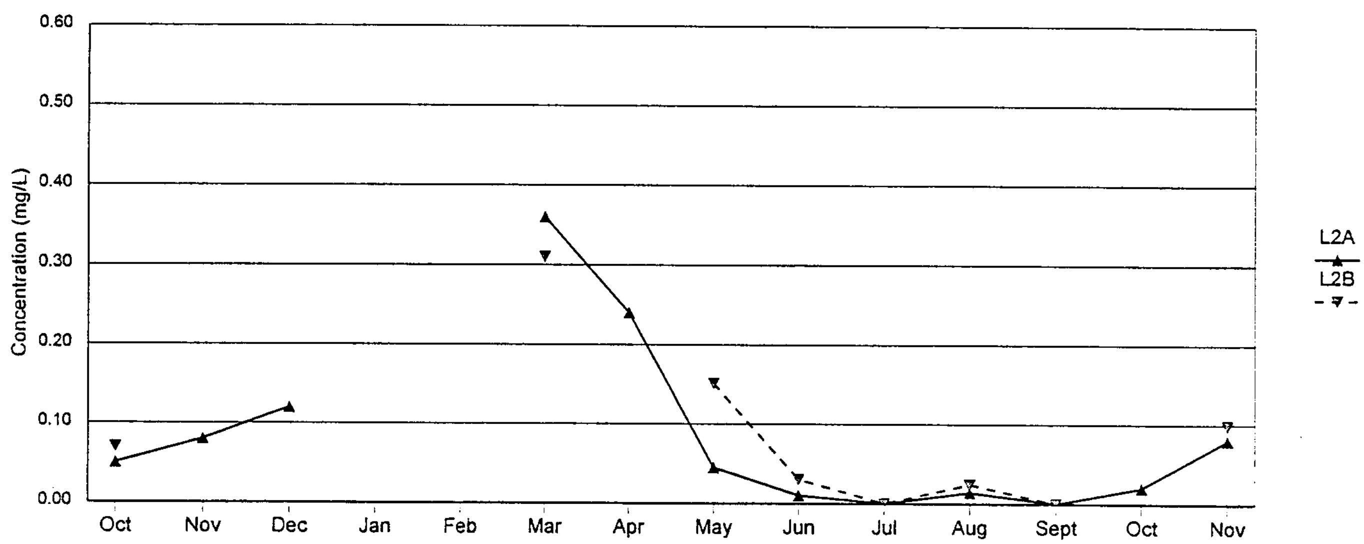
In the following discussion, chemical concentrations are based on the previous results cited in this chapter and are all in units of mg/L. Flow into and out of the lake is based on the results from Chapter 3, which were converted to units of liters prior to performing loading calculations. Table 4.9 provides the chemical loading budget for Findley Lake for water year 1998. The amount by weight of each chemical entering the lake from each source is given in kilograms (kg) and can be converted to pounds by multiplying by 2.2. A more detailed summary of how yearly loads were calculated for each inflow and outflow component is provided in a table at the end of this chapter.

Stream loading

The chemical loads carried by each stream were determined by multiplying the mean monthly concentration of chlorides, total phosphorus and nitrates (in mg/L) times the total monthly stream flow (in liters), and converting the result to kg/month. The pie diagrams in Figure 4.25 further summarize the chemical loads contributed to the lake by each stream for the entire year as a percentage of total stream inputs. As shown, Walker's Creek contributes the least load of chlorides and nitrates, while Buesink's Creek contributes the greatest load. When

Figure 4.24 IN-LAKE NITRATE-NITROGEN LEVELS





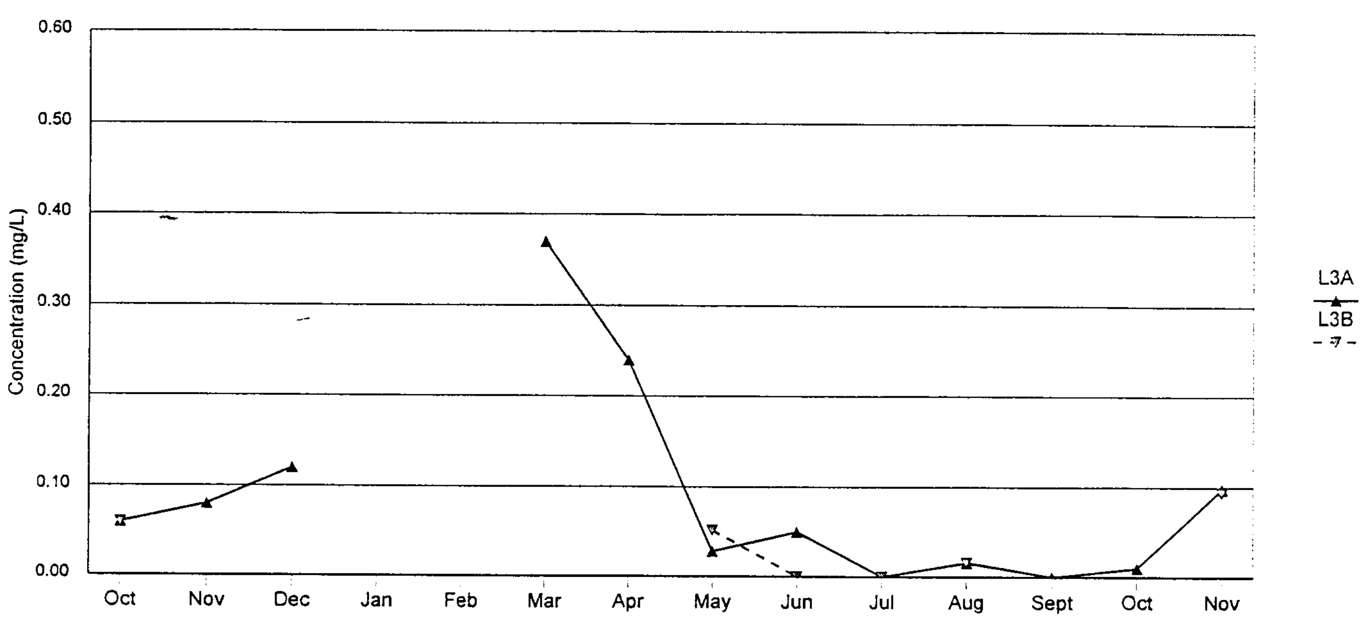


Table 4.9: Estimates of Nutrient and Chloride Loading into Findley Lake.

	Chlorides kg/year	Total Phosphorus kg/year	Nitrate-Nitrogen kg/year
Loading from 5 Monitored Tributaries:			
Buesink's Creek	6583	124	1332
Walker's Creek	532	45	248
Harrington Hill Cree	4321	51	823
Rothenberger's Creel	3105	60	328
Castrilla's Creek	1934	16	361
Sub-Total	16475	296	3092
Loading from Direct Peripheral Runoff to Lake (esitmated based on land use):			
Forested	1406	99	311
Developed	20814	54	1216
Agricultural	10629	127	1499
Sub-Total	32849	281	3026
Loading from Atmospheric Deposition (precipitation directly on lake surface):			
	167	112	625
Loading from Ground Water:			
	205546	280	6393
Grand-Total	**255037**	**968**	**13136**

Summary of Loading into Findley Lake (kg/year)

	Chlorides	Total Phosphorus	Nitrate-Nitrogen
Tributaries	16475	296	3092
Direct Runoff	32849	281	3026
Atmospheric Deposition	167	112	625
Ground Water	205546	280	6393
Total IN	**255037**	**968**	**13136**

Loading out of Findley Lake (kg/year)

Outlet	**Total OUT**	**137436**	**521**	**2418**

Net Amount Unaccounted For at the End of the Study Year (kg)

	Chlorides	Total Phophorus	Nitate-Nitrogen
	117600	448	10718
	46.1%	46.2%	81.6%

analyzing these data, it is important to put in perspective the total amount of runoff contributed to the lake by each creek and the peripheral area. Figure 3.14 shows that Buesink's Creek contributes more than two times more flow to the lake than the other streams and proportionally a greater load of chemicals.

Loading from direct runoff to lake

Chemical loads carried directly to the lake from the peripheral area by overland flow and smaller streams were determined by multiplying the chemical concentration values given in Table 4.5 times the total yearly flow calculated in Table 3.4. The pie diagrams in Figure 4.26 summarize the percentage of chemical loads flowing to the lake from each general type of land use. Recalling from Chapter 3, that forest land contributes about 1 ½ times more flow to the lake from the periphery than both developed land and agricultural land, which contribute about the same amount, it becomes clear just how important forest land is in the watershed and what would happen if that forest land were converted to another type of land use.

Loading from precipitation directly on lake surface

The chemical loads deposited on the lake surface by atmospheric deposition were determined by multiplying the mean monthly chemical concentration as measured in precipitation times the total monthly amount of precipitation that fell on the lake.

Loading from Ground Water

The chemical loads introduced to the lake by ground water were determined by multiplying the mean concentrations from sampling water wells around the lake from Table 4.6, times the total ground water flow to the lake calculated in Chapter 3.

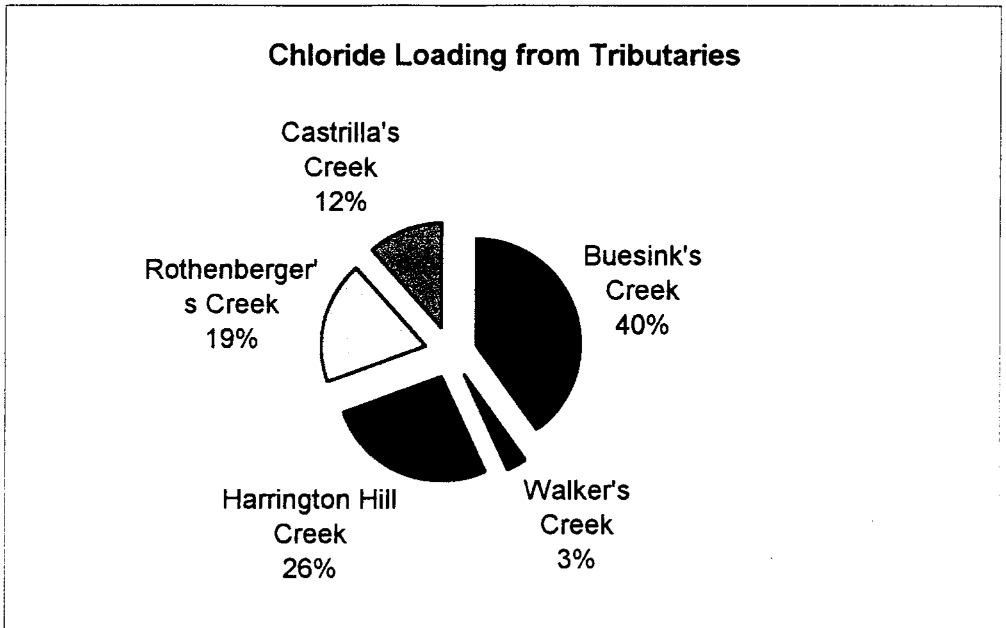
Figure 4.27 provides an excellent summary of the chemical loading into Findley Lake. Ground water contributes an enormous amount of both chlorides and nitrates to the lake and an unexpectedly large quantity of total phosphorus. Atmospheric deposition contributions directly on the lake surface are high, given the relatively small size of the lake to the entire area of the watershed.

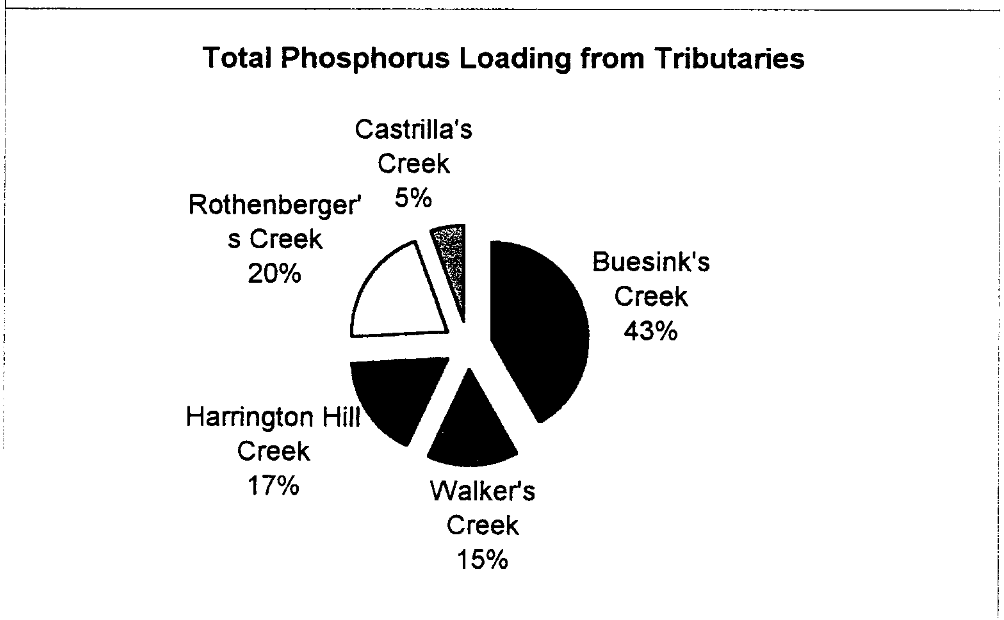
Why Don't the Chemical Budgets Balance?

Referring back to Table 4.9, shows that the total chemical loads into Findley Lake are greater than the total loads measured flowing out of the lake via the lake outlet. Assuming that the excess is retained in the lake itself, it means that 46% of the chlorides and total phosphorus and 76% of the nitrates flowing into the lake did not flow back out of the lake during water year 1998. Why don't the chemical budgets balance? Both nitrogen and phosphorus were shown to have been depleted in the lake during summer months, indicating that aquatic plants are consuming these nutrients during the growing season. Phosphorus, with its ability to become attached to sediment particles, may also be building up in the bottom sediments of the lake. More research is needed to determine why 46% of the chlorides are not accounted for.

While great care was taken to reduce potential sources of error in this project, the complexity of all the measurements needed to prepare the final chemical budgets could have introduced a certain amount of error into the results. Assuming that all the stream flow

Figure 4.25


Chloride Loading from Tributaries
Castrilla's Creek 12%
Rothenberger's Creek 19%
Buesink's Creek 40%
Harrington Hill Creek 26%
Walker's Creek 3%


Total Phosphorus Loading from Tributaries
Castrilla's Creek 5%
Rothenberger's Creek 20%
Buesink's Creek 43%
Harrington Hill Creek 17%
Walker's Creek 15%

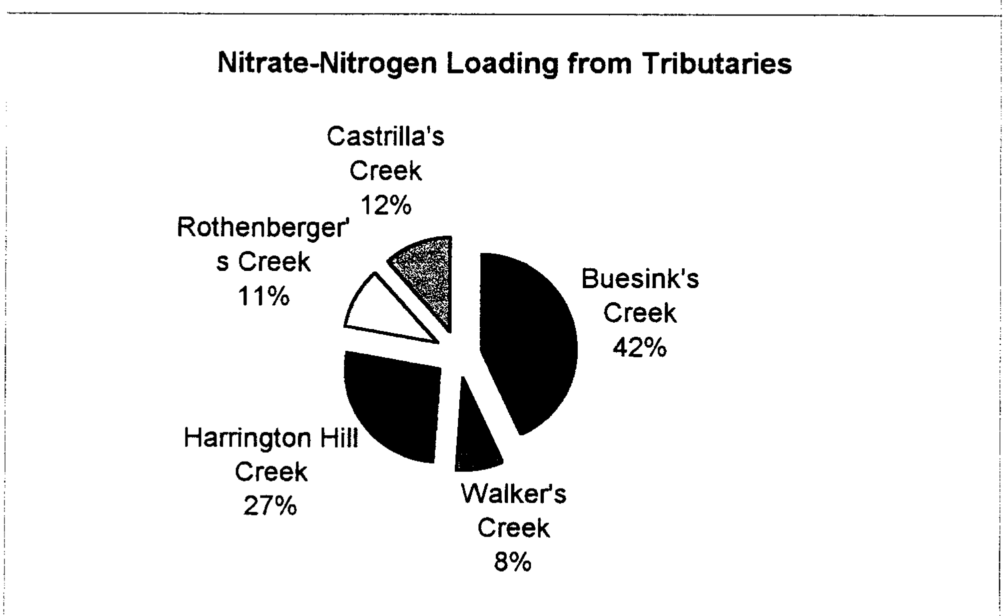
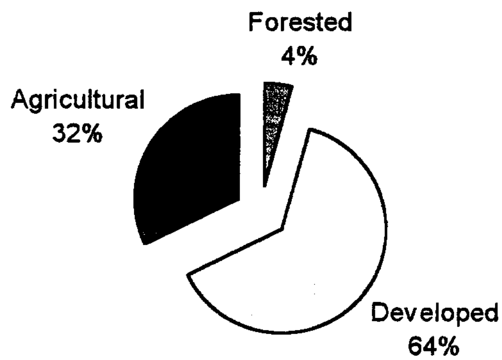
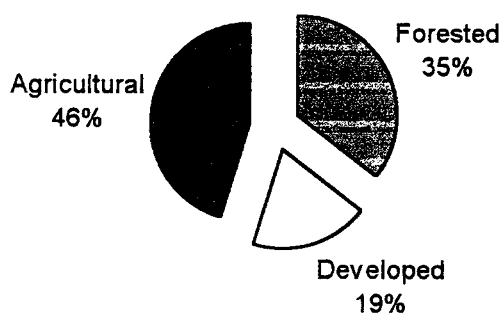

Nitrate-Nitrogen Loading from Tributaries
Castrilla's Creek 12%
Rothenberger's Creek 11%
Buesink's Creek 42%
Harrington Hill Creek 27%
Walker's Creek 8%

Figure 4.26

Chloride Loading from Direct Runoff



Total Phosphorus Loading from Direct Runoff



Nitrate-Nitrogen Loading from Direct Runoff

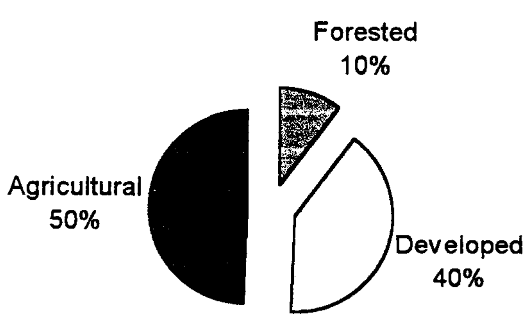
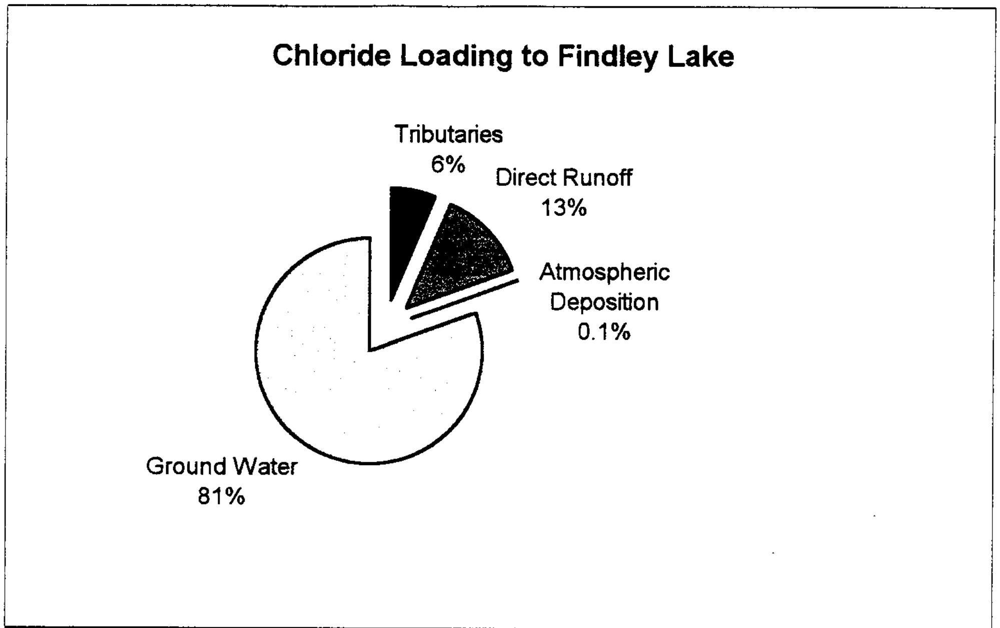
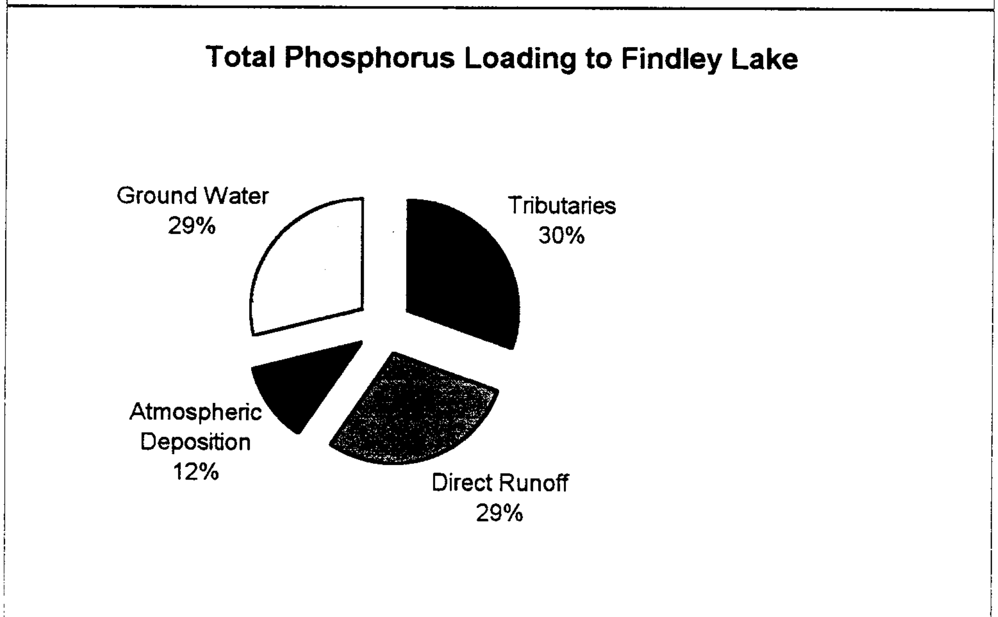
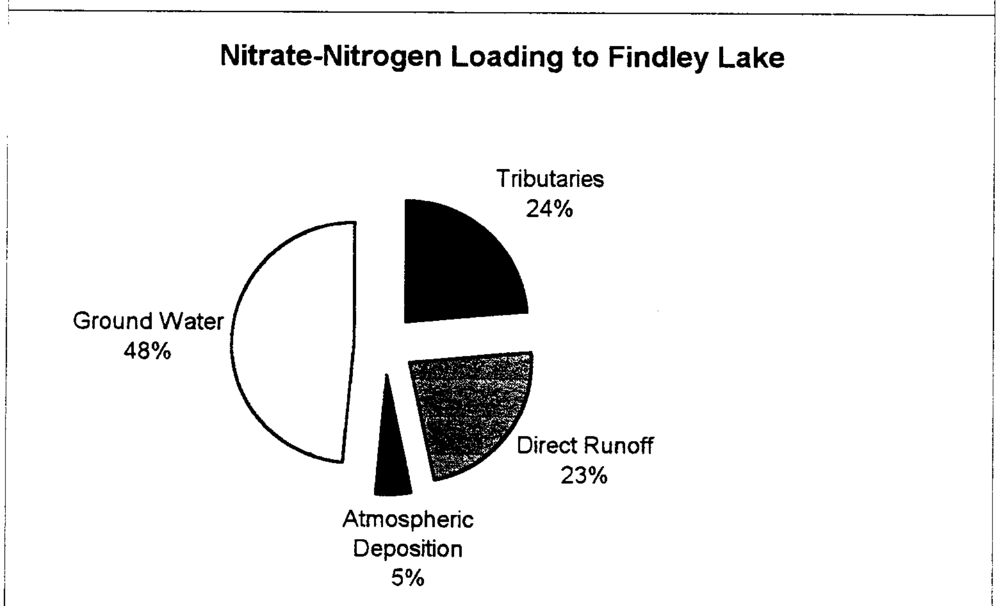


Figure 4.27


Chloride Loading to Findley Lake
Tributaries
6%
Direct Runoff
13%
Atmospheric
Deposition
0.1%
Ground Water
81%


Total Phosphorus Loading to Findley Lake
Ground Water
29%
Tributaries
30%
Atmospheric
Deposition
12%
Direct Runoff
29%


Nitrate-Nitrogen Loading to Findley Lake
Tributaries
24%
Ground Water
48%
Direct Runoff
23%
Atmospheric
Deposition
5%

measurements made were accurate to within 10% and also that all the chemical analyses were accurate to within 10%, loading calculations could be off by as much as 20%. However, it is unlikely that both sets of measurements consistently erred on either the low side or high side. They would have logically had a more random error – both high and low. Therefore, it is concluded that the in-lake accumulation of chemicals is a very real phenomena that occurred in Findley Lake during this study.

WATER QUALITY SUMMARY

An assessment was completed during this project of water quality flowing to the lake and of the lake itself. Through the course of this study, a number of important conclusions can be drawn from the information collected about the lake and its watershed.

Quality of Water Flowing Into the Lake

Results from monitoring five tributaries to the lake indicate they are well oxygenated, exhibit a near neutral pH and do not suffer from thermal pollution. The relatively small size of the streams flowing to the lake makes their water quality very sensitive to land use influences. The concentration of chlorides and nutrients in stream samples is directly related to the amount of land in agriculture. For example, Harrington Hill Creek, which contains the highest percentage of farmland, exhibits the highest chloride and nutrient levels, while Walkers Creek, which is almost entirely forested, exhibits the lowest levels. If these watersheds were to contain larger amounts of residential and commercial development, the same relationship to water quality would be observed. Ground water that is sustaining stream flow during dry summer months contains relatively high levels of chlorides and nitrates. While this occurs in all the streams except Walker's Creek, it is especially apparent in Buesink's Creek. The phosphorus levels in streams are correlated to storm events that flush sediment off the land and into the streams, an indication that phosphorus is hitchhiking on sediment particles. Turbidity and sediment levels in Walker's Creek are unexpectedly high as are levels of phosphorus. The south wetlands are acting as a nutrient and sediment sink for Harrington Hill Creek prior to that flow entering the lake. Finally, all of the streams exhibit good bacteriological water quality.

Direct runoff from the peripheral lands immediately around the lake contributes the same amount of nitrates and phosphorus and twice as much chlorides as all five streams combined. This is directly related to the amount of developed land in this area, most of which is residential.

Ground water that is directly feeding the lake contains elevated levels of chlorides and nutrients. Water wells tested around the northern portion of the lake are especially high in nitrates and chlorides. Septic systems, especially seepage pits around the lake, are contributing to chemical contamination of ground water that eventually flows to the lake, however, there is very little bacterial contamination of ground water.

Precipitation and atmospheric deposition directly on the lake surface contributes a relatively large amount of phosphorus to the lake. Likewise, precipitation on the watershed adds a substantial amount of nutrients that were accounted for in stream flow and direct runoff.

Quality of the Lake

Temperature and dissolved oxygen data collected monthly at three locations in the lake indicate the lake mixes in spring and fall and stratifies during summer. The lake most likely also stratifies during the winter, given a month or more of ice cover. Summer lake temperatures at depth are colder than other lakes, due to the large quantity of ground water feeding the lake. Conductivity on the other hand is much higher in Findley Lake, another indication of ground water feeding the lake. During summer stratification, reduced oxygen levels occur at about 3 m below the surface and drop off to less than 5 mg/L at 4 m. Lake transparency is 3 m or more during most of the year but drops off to just 1 m from July to September due to algae blooms. Near-surface pH ranges from 7 to 8.7, which is characteristic of a hard water lake in this region.

In-lake nutrients exhibit trends typical of a productive lake. The large amount of aquatic macrophytes and algae deplete nitrogen that has accumulated in the lake during winter and spring. Between July and September, there is little nitrogen available to in-lake plants. Nitrate levels at the north end of the lake are higher than elsewhere, which correlates to that of the ground water at the north end. Chloride salts on the other hand become concentrated in the lake during the summer. Contributed by ground water in summer, chlorides are not depleted by biological growth, as are nitrates. There is an unusually large amount of phosphorus present in the lake. Like nitrogen, it becomes depleted by biological growth in the summer. It is important to note that during summer stratification, a reducing environment exists at the bottom of the deeper portions of the lake, at which time phosphorus trapped in bottom sediment is released back to the water column. Fall and spring turnovers then mix this high phosphorus bottom water with the shallower water, redistributing phosphorous throughout the lake.

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Routine Stream Sampling Results

Location	Sample Number	Date Sampled	Time Sampled	Stage (ft)	Flow (cfs)	Air Temp (C)	ORP (Eh)	Cond (mU/cm)	D.O. (mg/L)	pH	Temp (C)	Turb. (NTU)	Cl (mg/L)	PO4 (mg/L)	NO3 (mg/L)	TSS (mg/L)	SPC (cfu/ml)	TC (col/ 100ml)
Buesink's	S1.2	11/05/97	02:30 PM	4.63	2.00	9.4		0.160		6.87	7.00	1.70	5.0	0.090	0.62	<1.0	448	46
Buesink's	S1.3	12/03/97	02:12 PM	4.71	3.80	0.6	0.136	0.154	14.13	6.29	2.51	0.86	3.8	0.046	1.00		88	57
Buesink's	S1.4	01/06/98	04:40 PM	5.12	19.00	16.0	0.139	0.086	13.36	5.95	5.09	4.00	3.0	0.078	0.79	4.0	896	98
Buesink's	S1.5	03/03/98	09:50 AM	4.64	2.20	0.6	0.191	0.156	15.04	7.70	2.44	2.00	5.7	0.039	1.06		336	19
Buesink's	S1.6	04/14/98	09:30 AM	4.60	1.50	13.9	0.163	0.168	12.81	7.34	9.00	0.70	5.4	0.062	1.32		210	20
Buesink's	S1.7	05/12/98	02:00 PM	4.60	1.50	16.7	0.212	0.181	11.40	7.62	14.50	3.70	4.6	0.069	0.68		448	64
Buesink's	S1.8	06/08/98	03:45 PM	4.44	0.25	15.6	0.212	0.322	11.66	7.53	12.30	1.00	10.7	0.050	3.37		112	36
Buesink's	S1.9	07/13/98	03:55 PM	4.40	0.14	27.2	0.153	0.298	10.63	7.53	19.60	0.50	12.3	0.090	2.10	2.0	672	96
Buesink's	S1.10	08/04/98	10:00 AM	4.30	0.03	22.2	0.149	0.355	10.50	7.11	16.64	1.22	16.6	0.045	2.79	2.0	4750	96
Buesink's	S1.11	09/17/98	09:45 AM	4.34	0.052	22.2	0.163	0.395	10.35	7.33	16.86	0.58	15.8	0.077	2.43		616	280
Buesink's	S1.12	10/27/98	03:15 PM	4.42	0.18	21.1	0.233	0.309	13.90	7.28	11.98	0.10	8.2	0.047	0.73		392	48
Buesink's	S1.13	11/24/98	03:00 PM	4.52	0.69	10.0	0.250	0.221	15.20	7.57	5.27	0.15	7	0.048	0.35		336	48
Castrilla's	S7.3	12/03/97	02:40 PM	0.17	0.16	0.6	0.159	0.242	13.74	6.31	3.27	1.22	7.8	0.071	2.11		784	210
Castrilla's	S7.4	01/06/98	02:45 PM	0.35	0.65	16.0	0.173	0.193	11.56	6.09	8.32	1.00	9.6	0.069	1.88	6.0	1456	56
Harrington H	S4.2	11/05/97	01:40 PM	4.86	0.02	9.4		0.287		7.21	8.60	1.70	20.5	0.100	1.51	1.4	952	442
Harrington H	S4.3	12/03/97	01:50 PM	4.91	0.08	0.6	0.114	0.282	12.53	6.27	4.51	2.19	23.0	0.112	3.17		1344	235
Harrington H	S4.4	01/06/98	04:00 PM	5.11	0.92	16.0	0.109	0.192	11.55	5.99	8.43	6.00	10.0	0.180	1.57	10.0	2240	44
Harrington H	S4.5	03/03/98	12:30 PM	4.98	0.41	0.6	0.185	0.275	13.91	7.14	3.73	36.00						
Harrington H	S4.6	04/14/98	09:10 AM	4.85	0.36	13.9	0.160	0.315	11.86	7.16	8.88	1.00	12.0	0.058	3.49		560	392
Harrington H	S4.7	05/12/98	01:30 PM	4.86	0.25	16.7	0.167	0.270	13.90	7.74	18.41	2.80	18.3	0.085	1.10		2688	3808
Outlet	S9.2	11/05/97	05:00 PM	4.47	32.00	9.4				7.12		2.00	13.4	0.050	0.06	<1.0		
Outlet	S9.3	12/03/97	02:30 PM	4.40	20.50	0.6	0.150	0.216	13.84	6.44	3.16	1.35	12.0	0.043	0.12		224	216
Outlet	S9.4	01/06/98	05:00 PM	4.80	64.00	16.0	0.165	0.184	12.70	5.89	2.40	2.50	10.6	0.074	0.47	3.0	2128	96
Outlet	S9.5	03/03/98	09:30 AM	4.25	6.00	0.6	0.164	0.221	13.59	7.53	5.10	1.30	13.9	0.018	0.57		98	2
Outlet	S9.6	04/14/98	10:15 AM	4.35	20.00	13.9	0.159	0.230	12.84	7.67	11.68	2.40	15.1	0.031	0.26		238	4
Outlet	S9.7	05/12/98	02:15 PM	4.18	3.50	16.7	0.187	0.202	12.07	8.74	18.59	2.30	14.1	0.018	0.03		165	1
Outlet	S9.8	06/08/98	04:15 PM	3.91	1.37	15.6	0.210	0.232	11.29	8.19	17.96	2.20	18.8	0.046	<0.01		224	7
Outlet	S9.9	07/13/98	03:41 PM	4.00	1.60	27.2	0.122	0.220	11.28	8.62	24.83	1.50	17.8	0.092	<0.01	9.0	560	22
Outlet	S9.10	08/04/98	10:15 AM	3.68	0.87	22.2	0.101	0.234	10.22	8.02	23.14	15.50	20.6	0.073	<0.01	15.0	784	22
Outlet	S9.11	09/17/98	09:00 AM	3.36	0.45	22.2	0.255	0.409	7.10	6.90	18.28	8.93	28.4	0.097	<0.01		1120	88
Outlet	S9.12	10/27/98	02:30 PM	4.34	10.90	21.1	0.290	0.226	13.81	7.57	13.37	0.76	13.9	0.044	0.04		336	14
Outlet	S9.13	11/24/98	02:30 PM	4.41	20.65	10.0	0.243	0.232	13.20	7.87	6.03	0.75	14	0.165	0.11		42	8
Rothenberge	S6.3	12/03/97	01:20 PM	4.24	0.73	0.6	0.202	0.184	14.13	6.38	3.43	0.55	4.7	0.060	0.42		180	14
Rothenberge	S6.4	01/06/98	03:30 PM	5.27	9.70	16.0	0.170	0.112	12.63	6.34	7.08	1.00	5.1	0.074	0.47	11.0	616	72
Rothenberge	S6.5	03/03/98	01:00 PM	4.23	0.70	0.6	0.200	0.172	13.20	7.16	3.92	0.80					74	64
South Inlet	S5.3	12/03/97	01:40 PM	4.20	0.79	0.6	0.063	0.267	12.92	6.37	3.53	no sample taken						
South Inlet	S5.4	01/06/98	03:45 PM	4.70	4.10	16.0	0.105	0.165	11.10	6.18	7.62	4.50	12.7	0.131	0.84	9.0	2016	48
South Inlet	S5.5	03/03/98	12:00 PM	4.04	0.40	0.6	0.139	0.258	14.24	7.26	3.60	5.00	20.7	0.077	1.26		672	492
South Inlet	S5.2	11/05/97	02:00 PM	4.80	5.70	9.4		0.286		7.13	8.00	3.00	18.9	0.080	0.56	<1.0	672	280
Walker's	S2.2	11/05/97	02:10 PM	4.68	0.04	9.4		0.085		7.20	7.50	4.80	1.0	0.120	0.20	2.6	168	18
Walker's	S2.3	12/03/97	02:00 PM	4.70	0.07	0.6	0.103	0.080	13.86	6.35	3.23	1.86	0.6	0.100	0.36		228	13
Walker's	S2.4	01/06/98	04:10 PM	5.03	1.40	16.0	0.117	0.051	13.52	6.06	4.50	2.50	0.9	0.067	0.66	17.0	504	44
Walker's	S2.5	03/03/98	11:30 AM	4.92	0.65	0.6	0.225	0.080	14.04	7.39	2.83	3.00	1.0	0.034	0.39		72	5
Walker's	S2.6	04/14/98	09:50 AM	4.89	0.53	13.9	0.136	0.082	12.67	7.37	8.73	3.00	0.9	0.071	0.28		112	15
Walker's	S2.12	10/27/98	02:45 PM	4.45	0.15	21.1	0.281	0.160	15.39	7.16	11.60	0.10	2	0.043	<0.01		448	54
Walker's	S2.13	11/24/98	03:30 PM	4.52	0.30	10.0	0.231	0.116	13.38	7.40	5.85	2.50	1	0.06	0.05		448	26
Walker's	S2.7	05/12/98	01:45 PM	4.84	0.36	16.7	0.186	0.098	11.43	7.48	15.30	6.50	0.8	0.061	0.13		280	34
Walker's	S2.8	06/08/98	03:30 PM	4.74	0.14	15.6	0.207	0.132	12.00	7.76	15.54	3.60	1.0	0.067	0.25		112	188
Walker's	S2.9	07/13/98	04:10 PM	4.70	0.07	27.2	0.161	0.146	11.35	7.49	20.27	3.30	4.4	0.150	0.17	52.0	504	74

Storm Sampling Results

Location	Sample Number	Date Sampled	Time Sampled	Stage (ft)	Discharge (cfs)	Turbidity (NTU)	Cl (mg/L)	PO4 (mg/L)	NO3 (mg/L)	TSS (mg/L)
Buesink's	S1.9B	07/08/98	11:00 AM		6.18		12.1	0.453	0.69	340.0
Buesink's	S1.9A	07/08/98	08:47 AM		1.85		23.6	1.330	1.07	1360.0
Buesink's	S1.9C	07/08/98	01:25 PM		8.98		6.0	0.202	0.63	56.0
Buesink's	S1.7A	05/01/98	06:14 PM	4.60	1.50		4.8	0.079	1.11	4.0
Buesink's	S1.7B	05/02/98	07:28 AM	4.60	1.50		4.8	0.088	1.16	4.5
Buesink's	S1.7D	05/03/98	12:45 PM	4.64	2.2		4.2	0.212	0.77	4.5
Buesink's	S1.7C	05/02/98	06:00 PM	4.70	3.80		3.7	0.045	0.42	9.5
Buesink's	S1.4	01/06/98	04:40 PM	5.12	19.00	4.00	3.0	0.078	0.79	4.0
Buesink's	S1.4C	01/08/98	03:30 PM	5.20	22.50	8.00	2.8	0.114	0.75	9.0
Buesink's	S1.4A	01/07/98	07:40 PM	5.30	28.00	17.00	3.3	0.145	0.53	37.0
Buesink's	S1.4D	01/09/98	08:20 AM	5.37	32.00	30.00	3.2	0.142	0.54	19.0
Buesink's	S1.4B	01/08/98	09:50 AM	5.39	34.00	11.00	2.5	0.101	0.66	27.0
Castrilla's	S7.9A	07/08/98	09:00 AM		0.38		8.9	0.631	0.65	114.0
Castrilla's	S7.9B	07/08/98	11:15 AM		1.28		14.5	0.182	0.80	8.0
Castrilla's	S7.9C	07/08/98	03:45 PM		0.15		9.5	0.096	2.43	2.0
Castrilla's	S7.7A	05/01/98	06:35 PM	0.23	0.28		12.7	0.102	2.16	2.0
Castrilla's	S7.7C	05/02/98	05:00 PM	0.27	0.37		10	0.082	1.33	3.0
Castrilla's	S7.7B	05/02/98	09:40 AM	0.27	0.37		1.9	0.082	0.60	17.0
Castrilla's	S7.7D	05/03/98	11:15 AM	0.29	0.44		12.2	0.141	1.64	2.0
Castrilla's	S7.4	01/06/98	02:45 PM	0.35	0.65	1.00	9.6	0.069	1.88	6.0
Harrington Hill	S4.9C	07/08/98	02:25 PM	-4.75	0.41		19.7	0.348	2.71	61.0
Harrington Hill	S4.9A	07/08/98	09:10 AM	-4.80	0.51		10.0	0.851	1.19	472.0
Harrington Hill	S4.7B	05/02/98	04:30 PM	-4.88	0.44		21.4	0.071	2.22	2.0
Harrington Hill	S4.7A	04/30/98	06:14 PM	-4.88	0.30		26.3	0.102	2.71	2.0
Harrington Hill	S4.7E	05/03/98	12:30 PM	-4.92	0.36		17	0.12	1.37	2.5
Harrington Hill	S4.7D	05/02/98	06:00 PM	-4.96	0.41		14.3	0.101	1.02	8.5
Harrington Hill	S4.9B	07/08/98	11:29 AM	-4.98	1.46		18.0	0.451	1.60	50.0
Harrington Hill	S4.7C	05/02/98	11:20 AM	-5.01	1.51		18.6	0.252	0.87	32.0
Harrington Hill	S4.4	01/06/98	04:00 PM	-5.11	2.04	6.00	10.0	0.180	1.57	10.0
Outlet	S9.9A	07/08/98	08:15 AM	4.44	20.90		15.2	0.053	0.01	8.0
Outlet	S9.4	01/06/98	05:00 PM	4.80	64.00	2.50	10.6	0.074	0.47	3.0
Outlet	S9.4C	01/08/98	03:00 PM	5.15	95.00	3.50	10.2	0.058	0.42	3.0
Rothenberger's	S6.9A	07/08/98	08:52 AM		0.90		4.1	0.122	1.61	36.0
Rothenberger's	S6.9B	07/08/98	11:00 AM		3.00		8.1	0.159	2.84	4.0
Rothenberger's	S6.9C	07/08/98	03:35 PM		0.46		12.7	0.251	3.00	2.0
Rothenberger's	S6.7A	05/01/98	06:25 PM	4.16	0.57		2.1	0.093	0.47	2.0
Rothenberger's	S6.7D	05/03/98	11:00 AM	4.2	0.65		3.7	0.108	0.37	8.0
Rothenberger's	S6.7B	05/02/98	09:30 AM	4.20	0.65		11.4	0.067	1.74	3.5
Rothenberger's	S6.7C	05/02/98	05:45 PM	4.29	0.87		5.9	0.063	0.25	14.0
Rothenberger's	S6.4	01/06/98	03:30 PM	5.27	9.70	1.00	5.1	0.074	0.47	11.0
Rothenberger's	S6.4C	01/08/98	04:30 PM	5.48	13.50	7.50	3.7	0.091	0.49	12.0
Rothenberger's	S6.4A	01/07/98	07:00 PM	5.84	20.00	19.50	5.7	0.065	0.28	126.0
Rothenberger's	S6.4B	01/08/98	09:10 AM	5.86	22.00	8.50	3.2	0.132	0.48	42.0
Rothenberger's	S6.4D	01/09/98	08:00 AM	5.88	22.50	22.00	4.1	0.126	0.34	24.0
South Inlet	S5.4	01/06/98	03:45 PM	4.70	4.10	4.50	12.7	0.131	0.84	9.0
South Inlet	S5.4B	01/08/98	09:30 AM	5.40	29.00	14.00	7.3	0.427	0.69	17.0
Walker's	S2.9C	07/08/98	02:15 PM	4.84	0.36		2.9	0.106	0.56	40.0
Walker's	S2.9B	07/08/98	11:20 AM	5.00	1.15		2.3	0.216	0.59	143.0
Walker's	S2.4	01/06/98	04:10 PM	5.03	1.50	2.50	0.9	0.067	0.66	17.0
Walker's	S2.4C	01/08/98	03:45 PM	5.26	7.70	14.00	0.9	0.082	0.61	21.0
Walker's	S2.4A	01/07/98	07:20 PM	5.30	11.00	9.00	1.0	0.109	0.50	40.0
Walker's	S2.4D	01/09/98	08:10 AM	5.35	15.80	25.00	0.1	0.105	0.53	31.0
Walker's	S2.9A	07/08/98	09:05 AM	5.36	17.00		3.2	1.200	0.77	2960.0
Walker's	S2.4B	01/08/98	09:40 AM	5.40	23.00	12.00	0.9	0.122	0.62	51.0

negative sign or a blank in stage indicates Q was estimated from Walker's Creek using discharge coefficients.

FINDLEY LAKE WATER QUALITY DATA

Location/ Sample ID	Date Sampled	Time	Cl (mg/L)	TP (mg/L)	NO3-N (mg/L)	TSS (mg/L)	Turb (NTU)	Secchi (m)	SPC (CFU/ML)	TC (col/ 100ml)
L1A-1	10/06/1997	01:30 PM	12.3	0.060	<0.01	2.4		1.6	2072	18
L1A-2	10/30/1997	02:40 PM	12.9	0.050	<0.01	<1	2.5	3.6		
L1A-3	12/03/1997	12:04 PM	11.0	0.025	0.13		2.4	3.2	472	11
L1A-5	03/02/1998	03:30 PM	11.7	0.074	0.58		1.5	2.9	280	4
L1A-6	04/13/1998	04:00 PM	13.0	0.119	0.29		2.5	1.7	126	1
L1A-7	05/12/1998	09:05 AM	12.6	0.074	0.04		2.0	3.3	12	3
L1A-8	06/08/1998	10:35 AM	14.3	0.030	0.01		1.9	4.3	12	1
L1A-9	07/13/1998	01:45 PM	18.5	0.029	<0.01	7.0	3.6	1.0	1792	7
L1A-10	08/03/1998	03:15 PM	16.5	0.063	<0.01	10.0	16.0	0.7	840	2
L1A-11	09/14/1998	10:30 AM	14.4	0.120	<0.01		16.7	0.7		
L1A-12	10/05/1998	02:10 PM	23.7	0.082	<0.01		15.3	1.1	840	4
L1A-13	11/25/1998	11:00 AM	14.0	0.034	0.11		1.4	3.2	36	4
Max			**23.7**	**0.120**	**0.58**	**10.0**	**16.7**	**4.3**	**2072**	**18**
Min			**11.0**	**0.025**	**<0.01**	**<1**	**1.4**	**0.7**	**12**	**1**
Mean			**14.6**	**0.063**	**0.10**	**4.9**	**6.0**	**2.3**	**648**	**6**
L1B-1	10/06/1997	02:00 PM	12.5	0.110	0.07	2.4				
L1B-6	04/13/1998	04:00 PM	13.0	0.059	0.36				56	1
L1B-7	05/12/1998	09:40 AM	11.6	0.075	0.20					
L1B-8	06/08/1998	10:35 AM	12.6	0.044	0.16					
L1B-9	07/13/1998	01:45 PM	15.3	0.056	<0.01	7.0			1680	24
L1B-10	08/03/1998	03:15 PM	16.3	0.066	0.02	25.0				
L1B-11	09/14/1998	10:30 AM	13.7	0.149	<0.01					
L1B-13	11/25/1998	11:10 AM	14.0	0.036	0.11					
Max			**16.3**	**0.149**	**0.36**	**25.0**				
Min			**11.6**	**0.036**	**<0.01**	**2.4**				
Mean			**13.6**	**0.074**	**0.11**	**11.5**				
L2A-1	10/06/1997	02:30 PM	12.2	0.080	0.05	1.4		1.4	1512	<2
L2A-2	10/30/1997	02:02 PM	12.4	0.140	0.08	<1	1.9	4.9		
L2A-3	12/03/1997	11:30 AM	11.0	0.033	0.12		1.9	3.1	91	4
L2A-5	03/02/1998	02:45 PM	9.9	0.018	0.36		1.7	2.9	224	2
L2A-6	04/13/1998	04:25 PM	13.7	0.091	0.24		1.8	2.1	84	<1
L2A-7	05/12/1998	09:50 AM	11.8	0.075	0.05		1.6	2.9	10	2
L2A-8	06/08/1998	11:10 AM	12.7	0.033	0.01		3.8	2.8	34	2
L2A-9	07/13/1998	02:30 PM	19.8	0.011	<0.01	6.0	3.8	1.2	2464	1
L2A-10	08/03/1998	03:45 PM	16.3	0.049	0.01	12.0	15.0	0.9	180	2
L2A-11	09/14/1998	10:50 AM	13.7	0.117	<0.01		22.2	0.8		
L2A-12	10/05/1998	02:35 PM	12.8	0.109	0.02		11.3	1.6	672	4
L2A-13	11/25/1998	11:45 AM	13.0	0.049	0.08		1.2	4.3	28	1
Max			**19.8**	**0.140**	**0.36**	**12.0**	**22.2**	**4.9**	**2464**	**4**
Min			**9.9**	**0.011**	**<0.01**	**<1**	**1.2**	**0.8**	**10**	**<1**
Mean			**13.3**	**0.067**	**0.08**	**4.9**	**6.0**	**2.4**	**530**	**2**
L2B-1	10/06/1997	02:35 PM	12.3	0.080	0.07	<1				
L2B-5	03/02/1998	02:45 PM	16.2	0.074	0.31					
L2B-7	05/12/1998	10:25 AM	11.7	0.069	0.15					
L2B-8	06/08/1998	11:10 AM	11.9	0.154	0.03					
L2B-9	07/13/1998	02:30 PM	14.9	0.162	<0.01	8.0			220	6
L2B-10	08/03/1998	03:45 PM	13.2	0.149	0.02	16.0				
L2B-11	09/14/1998	10:50 AM	12.1	0.479	<0.01					
L2B-13	11/25/1998	12:00 PM	13.0	0.036	0.10					
Max			**16.2**	**0.479**	**0.31**	**16.0**				
Min			**11.7**	**0.036**	**<0.01**	**<1**				
Mean			**13.2**	**0.150**	**0.09**	**8.0**				

FINDLEY LAKE WATER QUALITY DATA (continued)

Location/ Sample ID	Date Sampled	Time	Cl (mg/L)	TP (mg/L)	NO3-N (mg/L)	TSS (mg/L)	Turb (NTU)	Secchi (m)	SPC (CFU/ML)	TC (col/ 100ml)
L3A-1	10/06/1997	03:00 PM	12.1	0.070	0.06	<1		2.0	112	2
L3A-2	10/30/1997	02:35 PM	12.4	0.090	0.08	<1	1.5	6.1		
L3A-3	12/03/1997	11:00 AM	11.0	0.030	0.12		2.1	3.2	120	7
L3A-5	03/02/1998	02:10 PM	10.5	0.030	0.37		2.0	3.1	82	<1
L3A-6	04/13/1998	04:50 PM	12.2	0.055	0.24		1.3	2.1	126	2
L3A-7	05/12/1998	10:40 AM	11.9	0.115	0.03		1.2	3.2	168	6
L3A-8	06/08/1998	11:43 AM	12.5	0.033	0.05		2.3	3.1	224	1
L3A-9	07/13/1998	03:00 PM	24.7	0.228	<0.01	7.0	3.1	1.1	2352	4
L3A-10	08/03/1998	04:15 PM	15.2	0.037	0.02	9.0	15.0	1.0	3640	6
L3A-11	09/14/1998	11:25 AM	13.7	0.047	<0.01		20.9	0.9		
L3A-12	10/05/1998	03:00 PM	14.2	0.073	0.01		11.5	2.0	560	6
L3A-13	11/25/1998	12:30 PM	13.0	0.060	0.10		1.3	4.4	26	2
Max			**24.7**	**0.228**	**0.37**	**9.0**	**20.9**	**6.1**	**3640**	**7**
Min			**10.5**	**0.030**	**<0.01**	**<1**	**1.2**	**0.9**	**26**	**<1**
Mean			**13.6**	**0.072**	**0.09**	**4.0**	**5.7**	**2.6**	**741**	**4**
L3B-1	10/06/1997	03:06 PM	12.4	0.050	0.06	1.0				
L3B-7	05/12/1998	10:40 AM	11.9	0.031	0.05					
L3B-8	06/08/1998	11:43 AM	11.8	0.113	<0.01					
L3B-9	07/13/1998	03:00 PM	13.5	0.024	<0.01	6.0			616	9
L3B-10	08/03/1998	04:15 PM	13.4	0.132	0.02	13.0				
L3B-13	11/25/1998	12:45 PM	13.0	0.077	0.09					
Max			**13.5**	**0.132**	**0.09**	**13.0**				
Min			**11.8**	**0.024**	**<0.01**	**1.0**				
Mean			**12.7**	**0.071**	**0.04**	**6.7**				

Notes: Cl = chlorides
TP = total phosphorus
NO3-N = nitrate nitogen
TSS = total suspended solids
Turb = turbidity
Secchi = Secchi disk transparency
SPC = standard plate count bacteria
TC = total coliform bacteria

Station L1, 8/27/97, 1:30 pm, air temp 22.1 C, secchi depth1.5 m
Summer water depth 9.5 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	112	216	10.62	7.45	20.97
2	110	215	10.60	7.46	20.34
3	123	222	8.43	7.09	19.55
4	139	224	6.86	6.77	19.11
5	146	224	5.31	6.61	18.91
6	154	231	0.85	6.39	17.55
7	42	254	0.50	6.13	13.16
8	72	264	0.47	6.06	11.19

Station L1, 9/15/97, 1:50 pm ,air temp 24 C, Secchi depth 1.4 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	112	219	10.05	7.17	19.74
2	112	219	9.86	7.18	19.32
3	113	220	9.79	7.17	19.23
4	116	222	8.78	7.09	19.03
5	126	223	7.23	6.88	18.93
6	134	223	6.06	6.69	18.72
7	-84	259	1.74	6.31	15.00
8	-112	273	1.68	6.19	11.79

Station L1, 10/6/97, 2:00 pm, air temp 23 C, Secchi depth 1.6 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	123	209	11.53	7.07	18.71
2	122	208	11.61	7.21	17.96
3	126	213	10.70	7.12	16.21
4	139	217	9.41	6.92	15.57
5	148	218	8.15	6.72	15.07
6	152	215	8.29	6.65	14.89
7	153	216	8.80	6.58	14.68
8	159	229	6.80	6.34	13.98
9	-105	302	2.01	6.06	11.29

Station L1, 10/13/97, 1:00 pm, air temp 11.9 C, Secchi depth 2.1 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	48	211	11.16	7.69	17.35
2	51	211	10.83	7.69	17.38
3	52	211	10.68	7.69	17.35
4	54	211	10.37	7.68	17.28
5	74	220	5.76	7.05	15.92
6	97	218	3.83	6.68	14.95
7	102	218	1.71	6.52	14.48
8	104	226	1.48	6.40	13.95

Station L1, 10/30/97, 2:40 pm, air temp 9.3 C, Secchi depth 3.6 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	167	218	11.73	5.67	8.81
2	160	214	11.39	5.97	8.34
3	158	214	11.18	6.13	8.15
4	157	214	11.02	6.21	8.02
5	157	215	10.84	6.28	7.99
6	158	214	10.83	6.33	7.86
7	158	215	10.85	6.38	7.81
8	158	215	10.90	6.41	7.60

Station L1, 12/3/97. 12:04 am, air temp. 2.7 C, Secchi depth 3.2 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	204	212	14.04	6.62	3.03
2	205	212	13.72	6.63	3.03
3	205	212	13.65	6.63	3.03
4	205	212	13.49	6.64	3.02
5	205	212	13.49	6.64	3.03
6	205	212	13.41	6.64	3.03
7	205	212	13.33	6.64	3.03
8	205	212	13.33	6.64	3.03

Station L1, 3/02/98. 3:30 pm., air temp 8.8 C, Secchi depth 2.9 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	217	204	14.70	7.56	4.81
2	219	204	14.29	7.56	4.85
3	219	204	14.00	7.56	4.87
4	225	323	9.08	7.20	5.07
5	235	388	5.26	7.07	4.73
6	237	409	5.26	7.03	4.76

Station L2, 8/27/97, 2:00 pm, Secchi depth 1.6 m
Summer water depth 11.0 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	659	213	10.22	7.24	21.42
2	62	213	10.10	7.29	20.87
3	72	216	8.43	7.10	19.89
4	83	216	7.12	6.88	19.37
5	94	217	6.35	6.71	19.24
6	103	218	4.73	6.50	18.72
7	110	221	0.75	6.26	16.89
8	-48	247	0.53	6.02	13.79
9	-102	263	0.53	5.94	12.23

Station L2, 9/15/97, 2:45 pm, air temp 24 C, Secchi depth 1.8 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	154	214	10.75	7.00	20.43
2	138	213	10.11	7.14	20.30
3	133	213	9.83	7.19	19.23
4	130	214	9.44	7.19	19.50
5	133	215	7.92	7.02	19.32
6	141	215	6.52	6.80	19.28
7	25	218	1.61	6.28	17.95
8	-30	255	1.28	6.21	15.29
9	-87	271	1.28	6.13	12.79

Station L2, 10/6/97,2:30 pm, air temp 23 C, Secchi depth 1.4 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	166	209	13.16	6.98	18.51
2	150	209	12.33	7.20	18.40
3	148	213	9.43	7.12	16.48
4	162	215	8.23	6.89	15.96
5	166	215	8.06	6.80	15.80
6	167	215	7.60	6.69	15.55
7	169	215	6.89	6.61	15.36
8	169	216	6.34	6.54	15.22
9	171	222	3.29	6.43	14.85
10	-97	278	1.62	6.13	13.24

Station L2, 10/13/97, 1:00 pm, air temp 12.6 C, Secchi depth 2.7 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	123	209	10.31	7.48	17.15
2	122	209	10.26	7.48	17.12
3	121	209	10.17	7.47	17.10
4	121	209	9.81	7.43	16.99
5	124	210	9.35	7.34	16.93
6	137	212	6.07	6.88	16.17
7	151	215	4.12	6.68	15.39
8	160	222	2.17	6.46	14.87
9	-26	233	1.79	6.29	14.45
10	-104	258	1.71	6.09	13.68

Station L2, 10/30/97, 2:02 pm, air temp. 12.8 C, Secchi depth 4.9 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	162	212	11.64	6.45	9.74
2	164	213	11.04	6.45	9.73
3	166	212	11.04	6.46	9.11
4	166	212	10.60	6.47	9.00
5	166	211	11.05	6.47	8.96
6	167	212	10.40	6.48	8.90
7	167	212	10.43	6.48	8.82
8	168	212	10.44	6.48	8.71
9	168	213	10.44	6.48	8.49
10	169	212	10.33	6.47	8.42

Station L2, 12/3/97. 11:30 am, air temp. 2.6 C, Secchi depth 3.1 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	221	207	13.69	6.54	3.32
2	220	206	13.32	6.54	3.32
3	220	206	13.15	6.55	3.32
4	220	207	13.06	6.55	3.33
5	219	207	13.06	6.54	3.33
6	219	207	13.06	6.55	3.33
7	219	208	13.07	6.54	3.33
8	218	208	13.07	6.55	3.32
9	218	208	13.06	6.55	3.33
10	218	208	12.95	6.54	3.35

Station L2, 3/02/98, 2:45 pm, air temp 8.8 C, Secchi depth 2.9

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	174	185	14.31	7.61	4.39
2	177	184	13.85	7.58	4.39
3	178	184	13.61	7.56	4.36
4	179	185	13.56	7.56	4.36
5	180	186	13.58	7.54	4.32
6	181	188	13.22	7.50	4.29
7	187	208	11.53	7.36	4.04
8	191	238	9.11	7.23	3.88
9	197	250	6.84	7.14	3.81
10	200	281	4.19	7.08	3.91

Station L3, 8/27/97, 2:20 pm, Secchi depth 1.5 m
Summer water depth 7.3 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	118	213	10.40	7.25	20.88
2	108	213	10.25	7.32	20.52
3	106	213	9.61	7.28	19.89
4	111	214	8.64	7.14	19.62
5	121	217	7.07	6.84	19.33
6	129	217	6.04	6.68	19.10
7	-12	229	0.66	6.29	16.36

Station L3, 9/15/97, 3:05 pm, air temp. 24 C, Secchi depth 1.7 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	125	213	10.89	7.08	20.39
2	114	213	10.36	7.21	20.08
3	110	213	10.10	7.25	19.89
4	109	213	9.40	7.22	19.57
5	119	213	7.24	6.97	19.20
6	125	212	6.65	6.78	19.07
7	132	217	1.40	6.44	17.84

Station L3, 10/6/97, 3:00 pm, air temp 23 C, Secchi depth 2.0m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	129	205	11.87	7.21	18.32
2	122	209	11.28	7.32	18.20
3	118	207	10.31	7.33	17.02
4	127	214	7.45	6.88	16.00
5	143	215	7.11	6.74	15.51
6	145	215	6.79	6.66	15.39
7	146	215	5.92	6.58	15.18

Station L3, 10/13/97,1:00 pm, air temp 17.6 C, Secchi depth 2.5 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	127	207	10.72	7.19	17.22
2	122	205	10.48	7.31	17.21
3	120	206	10.29	7.36	17.15
4	117	206	10.30	7.41	17.10
5	119	206	9.49	7.39	17.06
6	134	213	5.81	6.92	16.14
7	148	215	3.09	6.61	15.30

Station L3, 10/30/97, 2:35 p.m., air temp. 9.75 C, Secchi depth 6.1 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	191	212	10.45	6.51	9.44
2	191	212	10.33	6.51	9.44
3	191	212	10.14	6.52	8.99
4	192	212	10.14	6.52	8.78
5	192	212	10.12	6.52	8.71
6	192	212	10.21	6.52	8.67
7	192	212	10.45	6.55	8.38

Station L3, 12/3/97, 11:00 a.m., air temp 4.74 C, Secchi depth 3.15

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	212	209	13.81	6.41	3.43
2	207	208	13.24	6.46	3.41
3	206	208	13.16	6.48	3.39
4	206	208	13.01	6.50	3.38
5	206	208	13.01	6.51	3.37
6	205	208	13.03	6.52	3.35

Station L3, 3/02/98, 2:10 pm, air temp 8.8 C, Secchi depth 3.0

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	171	192	13.65	7.80	4.70
2	182	193	13.15	7.73	4.53
3	187	196	12.98	7.61	4.54
4	190	196	12.82	7.56	4.50
5	191	197	12.75	7.52	4.43
6	194	1990	12.45	7.48	4.39

Station L1, 4/13/98, 4:00 pm, air temp 13.6 C, Secchi depth 1.7 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	164	215	13.21	8.17	11.56
2	170	215	13.03	8.08	11.45
3	172	214	12.81	8.03	11.34
4	174	215	12.94	8.01	11.35
5	180	212	12.16	7.76	9.90
6	186	213	11.72	7.59	9.08
7	190	219	11.54	7.47	8.25
8	196	220	12.40	7.41	5.63
9	200	228	9.77	7.28	5.18

Station L1, 5/12/98, 9:05 am, air temp 14.1 C, Secchi depth 3.2 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	178	195	13.12	8.78	17.26
2	180	196	13.00	8.80	17.29
3	180	196	13.22	8.79	17.27
4	216	225	12.25	7.07	13.88
5	233	220	5.22	6.88	11.63
6	248	211	3.45	6.88	10.35

Station L1, 6/8/98, 10:35 am, air temp 18.30C, Secchi depth 4.3 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	119	202	11.30	8.23	17.63
2	121	203	10.47	8.25	17.35
3	121	203	10.61	8.28	17.28
4	121	204	10.19	8.28	17.21
5	122	204	9.26	8.13	16.83
6	139	230	5.65	7.35	13.09
7	156	222	2.00	7.07	10.31
8	163	230	1.16	7.00	9.60

Station L1, 7/13/98, 1:45pm, air temp 22.5 C, Secchi depth 1.0 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	191	205	13.26	8.56	24.43
2	190	205	13.08	8.58	23.68
3	202	206	10.62	8.29	23.35
4	232	206	1.92	7.10	21.48
5	21	228	1.62	6.97	18.44
6	3	232	1.63	6.89	13.81
7	-10	229	1.66	6.85	10.94
8	-28	238	1.67	6.82	9.15

Station L1, 8/3/98, 3:15 pm, air temp 24.1 C, Secchi depth 0.7 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	183	200	13.20	8.44	25.34
2	179	202	10.62	8.29	23.58
3	189	205	7.54	7.99	23.25
4	200	211	2.74	7.25	22.30
5	-79	236	1.40	7.03	19.47
6	-104	233	1.41	6.91	15.35
7	-109	249	1.50	6.81	11.42
8	-114	252	1.47	6.78	9.98
9	-118	277	1.44	6.76	8.33

Station L1, 9/14/98, 10:30 am, air temp 18.8 C, Secchi depth 0.7 m

Depth (m)	ORP (mV)	Cond (uU/cm)	D.O. mg/L	pH	Temp (C)
1	272	209	12.74	8.34	20.50
2	278	208	12.52	8.33	20.40
3	292	213	7.99	7.72	19.60
4	313	214	6.38	7.50	19.05
5	325	214	5.77	7.40	18.85
6	333	218	3.54	7.25	18.05
7	-63	255	1.80	7.06	13.80
8	-83	266	1.84	7.00	11.26

Station L1, 10/5/98, 2:10 pm, air temp 14.7 C, Secchi depth 1.1 m

Depth (m)	ORP (mV)	Cond (uU/cm)	D.O. mg/L	pH	Temp (C)
1	180	219	13.00	7.90	16.02
2	180	219	13.10	7.88	16.05
3	182	219	12.10	7.85	16.03
4	183	219	12.00	7.77	15.92
5	184	220	11.84	7.80	15.73
6	185	220	11.62	7.74	15.59
7	187	221	11.50	7.67	15.45
8	-94	274	2.51	6.96	11.55
9	-112	294	2.21	6.88	9.87

Station L1, 11/25/98, 11:00 am, air temp 4.4 C, Secchi depth 3.2 m

Depth (m)	ORP (mV)	Cond (uU/cm)	D.O. mg/L	pH	Temp (C)
1	164	232	14.70	7.83	5.04
2	166	232	14.41	7.82	5.05
3	168	232	14.14	7.80	5.03
4	170	232	13.99	7.79	5.02
5	171	232	13.92	7.78	5.03
6	172	233	13.78	7.78	5.02
7	172	233	13.71	7.77	5.02
8	174	234	13.56	7.77	5.02
9	175	233	13.42	7.76	5.02

Station L2, 4/13/98, 4:25 pm, air temp 12.8 C, Secchi depth 2.1 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	182	213	12.74	8.39	11.88
2	211	212	12.55	8.21	11.80
3	215	211	12.41	8.13	11.29
4	216	212	12.62	8.08	11.24
5	216	212	12.42	8.05	11.20
6	216	212	12.41	8.01	11.05
7	216	213	13.06	7.91	10.73
8	219	214	12.40	7.79	10.13
9	225	213	11.10	7.49	8.74
10	232	211	10.07	7.34	8.01

Station L2, 5/12/98, 9:50 am, air temp 14.1 C, Secchi depth 2.9 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	122	201	13.04	8.65	16.84
2	124	203	12.61	8.63	16.85
3	126	204	12.38	8.61	16.87
4	147	213	9.95	7.70	15.55
5	165	209	10.91	7.67	13.06
6	175	208	6.98	7.20	11.96
7	186	209	4.26	7.00	11.13
8	190	215	2.90	7.07	10.32
9	206	218	1.57	6.96	9.70

Station L2, 6/8/98. 11:10 am, air temp 20.1C, Secchi depth 2.8 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	153	180	11.47	8.60	18.19
2	149	187	11.28	8.60	17.64
3	148	188	11.06	8.60	17.59
4	147	188	10.72	8.60	17.53
5	146	188	10.66	8.60	17.47
6	171	212	6.12	7.54	14.13
7	186	216	1.10	7.08	12.04
8	193	219	0.79	6.99	10.98
9	60	229	0.70	6.96	9.86
10	-8	236	0.67	6.95	9.60

Station L2, 7/13/98, 2:30 pm, air temp 20.5 C, Secchi depth 1.2 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	92	198	13.27	8.66	25.83
2	89	197	13.12	8.67	24.28
3	92	198	12.41	8.61	23.80
4	99	200	9.70	8.36	23.58
5	125	206	2.30	7.22	19.28
6	145	217	1.54	7.02	16.01
7	142	215	1.46	6.94	13.30
8	88	225	1.35	6.90	11.91
9	-7	239	1.33	6.88	10.55

Station L2, 8/3/98, 23:45 pm, air temp 20.0 C, Secchi depth 0.9 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	40	193	11.56	8.62	24.74
2	48	193	11.07	8.56	24.28
3	54	193	9.30	8.40	23.46
4	76	199	4.61	7.68	23.02
5	84	205	1.11	7.17	21.60
6	-26	220	0.85	6.98	18.27
7	-53	229	0.90	6.84	13.66
8	-76	242	0.87	6.83	11.92
9	-99	248	0.88	6.82	11.02
10	-113	262	0.87	6.82	10.19

Station L2, 9/14/98, 10:50 am, air temp 19.5 C, Secchi depth 0.8 m

Depth (m)	ORP (mV)	Cond (uU/cm)	D.O. mg/L	pH	Temp (C)
1	110	204	12.83	8.44	20.91
2	112	205	12.06	8.43	20.68
3	124	206	10.17	8.19	20.26
4	140	207	8.08	7.83	19.75
5	155	210	6.14	7.55	19.42
6	167	211	3.92	7.37	18.51
7	178	229	1.69	7.28	17.13
8	-79	255	1.35	7.08	13.23
9	-104	270	1.28	7.00	11.46

Station L2, 10/5/98, 2:35 pm, air temp 14.8 C, Secchi depth 1.6 m

Depth (m)	ORP (mV)	Cond (uU/cm)	D.O. mg/L	pH	Temp (C)
1	99	217	10.04	7.74	16.78
2	93	216	9.64	7.72	16.53
3	91	215	9.35	7.66	16.25
4	91	216	9.23	7.64	16.24
5	90	216	9.05	7.61	16.23
6	90	217	8.99	7.58	16.21
7	91	218	8.72	7.55	16.03
8	96	230	5.23	7.31	14.98
9	-105	282	1.04	7.05	11.79
10	-127	293	0.78	6.96	11.12

Station L2, 11/25/98, 11:45 am, air temp 4.4 C, Secchi depth 4.2 m

Depth (m)	ORP (mV)	Cond (uU/cm)	D.O. mg/L	pH	Temp (C)
1	206	225	13.88	7.64	5.94
2	207	225	13.46	7.64	5.94
3	207	225	13.19	7.64	5.94
4	208	225	12.84	7.63	5.94
5	208	226	12.71	7.63	5.93
6	208	227	12.65	7.62	5.93
7	209	227	12.58	7.62	5.92
8	209	226	12.52	7.61	5.93

Station L3, 4/13/98, 4:50 pm, air temp 12.3 C, Secchi depth 2.1 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	210	211	14.23	7.98	11.34
2	215	211	13.59	7.97	11.35
3	214	211	13.33	7.98	11.16
4	213	210	13.13	7.97	11.03
5	215	211	12.54	7.87	10.64
6	218	212	11.59	7.65	9.69
7	225	212	10.67	7.50	9.09

Station L3, 5/12/98, 10:40 am, air temp 13.0 C, Secchi depth 3.2 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	152	205	12.56	8.63	16.94
2	150	205	12.16	8.61	16.93
3	154	205	12.36	8.60	16.91
4	169	217	10.60	7.80	14.34
5	187	213	9.28	7.52	13.03
6	197	211	7.42	7.28	12.24

Station L3, 6/8/98, 11:43 am, air temp 19.8C, Secchi depth 3.1 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	110	189	11.10	8.63	18.81
2	102	187	10.80	8.63	18.07
3	100	189	10.70	8.63	17.92
4	99	188	10.56	8.61	17.86
5	100	192	9.22	8.40	17.26
6	118	208	7.01	7.75	15.50
7	135	220	1.03	7.11	12.11
8	70	223	0.66	7.02	10.72

Station L3, 7/13/98, 3:00 pm, air temp 21.4 C, Secchi depth 1.1 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	69	211	13.75	8.67	25.27
2	72	197	12.97	8.65	24.07
3	76	198	12.49	8.62	23.82
4	89	201	9.03	8.29	23.58
5	112	201	3.17	7.40	20.25
6	123	205	1.27	7.06	16.25
7	106	218	1.21	6.98	13.50

Station L3, 8/3/98, 3:00pm, air temp 18.1 C, Secchi depth 1.0 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	58	793	11.85	8.50	24.09
2	49	193	11.56	8.51	24.01
3	48	194	10.78	8.47	23.85
4	52	193	9.17	8.31	23.44
5	65	22	4.06	7.58	22.89
6	49	220	0.88	7.08	18.64
7	-85	232	0.79	6.87	13.60

Station L3, 9/14/98, 11:25 am, air temp 21.9 C, Secchi depth 0.8 m

Depth (m)	ORP (mV)	Cond (uU/cm)	D.O. mg/L	pH	Temp (C)
1	99	204	12.80	8.58	21.07
2	98	204	12.44	8.60	20.93
3	112	205	8.17	7.95	19.87
4	126	208	6.68	7.78	19.67
5	131	208	6.25	7.69	19.45
6	134	208	5.32	7.57	18.98

Station L3, 10/5/98, 3:00 pm, air temp 15.0 C, Secchi depth 2.0 m

Depth (m)	ORP (mV)	Cond (uU/cm)	D.O. mg/L	pH	Temp (C)
1	35	219	9.08	7.58	16.67
2	32	218	8.95	7.61	16.60
3	34	218	8.49	7.57	16.23
4	38	219	8.17	7.52	16.21
5	42	219	7.81	7.51	15.89
6	44	219	8.35	7.56	15.75

Station L3, 11/25/98, 12:30 pm, air temp 4.4 C, Secchi depth 4.4 m

Depth(m)	ORP(mV)	Cond(uU/cm)	DO(mg/L)	pH	Temp(C)
1	220	227	13.46	7.65	5.95
2	222	227	13.12	7.63	5.93
3	224	226	12.92	7.63	5.93
4	224	227	12.78	7.62	5.93
5	225	227	12.64	7.61	5.94
6	225	227	12.57	7.61	5.93

COMPUTATION OF NUTRIENT AND CHLORIDE LOADING TO FINDLEY LAKE

Stream Discharge (ft3):

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Total
Buesink's Creek	1,299,228	777,979	20,258,821	4,883,842	9,886,126	7,917,437	1,743,543	985,945	583,671	118,015	55,273	1,687,844	50,197,723
Walker's Creek	526,003	314,971	8,201,952	1,977,264	4,002,480	3,205,440	705,888	399,168	236,304	47,779	22,378	683,338	20,322,965
Harrington Hill Creek	357,682	214,180	5,577,327	1,344,540	2,721,686	2,179,699	480,004	130,464	36,288	0	0	0	13,041,871
Rothenberger's Creek	631,204	377,965	9,842,342	2,372,717	4,802,976	3,846,528	691,200	205,632	63,936	0	0	0	22,834,500
Castrilla's Creek	199,881	119,689	3,116,742	751,360	1,520,942	1,218,067	268,237	24,538	16,784	0	0	0	7,236,241
Outlet	98,280,000	58,505,760	91,571,040	19,409,760	21,384,000	31,484,160	9,093,600	3,827,520	8,383,392	11,278,656	1,301,184	19,126,368	373,645,440

Stream Discharge (L):

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Total
Buesink's Creek	36,790,237	22,030,027	573,669,047	138,295,756	279,945,419	224,198,058	49,371,917	27,919,003	16,527,808	3,341,820	1,565,156	47,794,675	1,421,448,924
Walker's Creek	14,894,833	8,919,039	232,254,675	55,990,185	113,338,226	90,768,444	19,988,630	11,303,240	6,691,420	1,352,964	633,666	19,350,071	575,485,394
Harrington Hill Creek	10,128,486	6,064,947	157,933,179	38,073,326	77,069,994	61,722,542	13,592,269	3,694,349	1,027,567	0	0	0	369,306,659
Rothenberger's Creek	17,873,799	10,702,847	278,705,610	67,188,222	136,005,871	108,922,133	19,572,710	5,822,881	1,810,476	0	0	0	646,604,550
Castrilla's Creek	5,660,036	3,389,235	88,256,776	21,276,270	43,068,526	34,492,009	7,595,680	694,843	475,273	0	0	0	204,908,647
Outlet	2,782,994,760	1,656,707,606	2,593,017,140	549,626,174	605,530,728	891,536,959	257,503,471	108,383,884	237,392,511	319,377,702	36,845,627	541,601,363	10,580,517,924

Average Monthly Chloride Concentration (mg/L):

values in italics were estimated by method of running averages

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Total
Buesink's Creek	5.0	3.8	3.0	*4.3*	5.7	5.4	4.4	10.7	13.5	16.6	15.8	8.2	
Walker's Creek	1.0	0.6	0.8	*0.9*	1.0	0.9	0.8	1.0	3.2	*2.1*	*2.1*	2.0	
Harrington Hill Creek	20.5	23.0	10.0	*11.0*	*11.0*	12.0	22.1	*19.0*	15.9				
Rothenberger's Creek	*4.5*	4.7	4.4	*5.1*	*5.1*	*5.1*	5.8	*7.0*	8.3				
Castrilla's Creek	*8.7*	7.8	9.6	*9.4*	*9.4*	*9.4*	9.2	*10.1*	11.0				
Outlet	13.4	12.0	10.4	*12.2*	13.9	15.1	14.1	18.8	16.5	20.6	28.4	13.9	

Total Monthly Chloride Loading (kg):

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Total
Buesink's Creek	184.0	83.7	1,698.1	598.8	1,595.7	1,210.7	218.2	298.7	223.1	55.5	24.7	391.9	6,583
Walker's Creek	14.9	5.4	176.0	49.2	113.3	81.7	16.0	11.3	21.4	2.8	1.3	38.7	532
Harrington Hill Creek	207.6	139.5	1,579.3	418.8	847.8	740.7	300.4	70.2	16.3				4,321
Rothenberger's Creek	81.0	50.3	1,215.2	340.5	693.6	555.5	113.0	41.0	15.0				3,105
Castrilla's Creek	49.2	26.4	847.3	200.0	404.8	324.2	69.9	7.0	5.2				1,934
Outlet	37,292.1	19,880.5	26,967.4	6,678.0	8,416.9	13,462.2	3,630.8	2,037.6	3,917.0	6,579.2	1,046.4	7,528.3	137,436

Average Monthly Total Phosphorus Concentration (mg/L):

values in italics were estimated by method of running averages

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Total
Buesink's Creek	0.090	0.046	0.116	*0.078*	0.039	0.062	0.099	0.050	0.519	0.045	0.077	0.047	
Walker's Creek	0.120	0.100	0.097	*0.066*	0.034	0.071	0.061	0.067	0.418	*0.055*	*0.055*	0.043	
Harrington Hill Creek	0.100	0.112	0.180	*0.119*	*0.119*	0.058	0.142	*0.346*	0.550				
Rothenberger's Creek	*0.079*	0.060	0.098	*0.090*	*0.090*	*0.090*	0.083	*0.130*	0.177				
Castrilla's Creek	*0.070*	0.071	0.069	*0.085*	*0.085*	*0.085*	0.102	*0.202*	0.303				
Outlet	0.050	0.043	0.066	*0.042*	0.018	0.031	0.018	0.046	0.073	0.073	0.097	0.044	

Total Monthly Phosphorus Loading (kg):

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Total
Buesink's Creek	3.3	1.0	66.5	10.7	10.9	13.9	4.9	1.4	8.6	0.2	0.1	2.2	124
Walker's Creek	1.8	0.9	22.5	3.7	3.9	6.4	1.2	0.8	2.8	0.1	0.0	0.8	45
Harrington Hill Creek	1.0	0.7	28.4	4.5	9.2	3.6	1.9	1.3	0.6				51
Rothenberger's Creek	1.4	0.6	27.2	6.1	12.3	9.8	1.6	0.8	0.3				60
Castrilla's Creek	0.4	0.2	6.1	1.8	3.7	2.9	0.8	0.1	0.1				16
Outlet	139.1	71.2	171.1	23.1	10.9	27.6	4.6	5.0	17.2	23.3	3.6	23.8	521

COMPUTATION OF NUTRIENT AND CHLORIDE LOADING TO FINDLEY LAKE (cont.)

Average Monthly Nitrate-Nitrogen Concentration (mg/L): *values in italics were estimated by method of running averages*

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Total
Buesink's Creek	0.62	1.00	0.65	*0.86*	1.06	1.32	0.83	3.37	1.12	2.79	2.43	0.73	
Walker's Creek	0.20	0.36	0.58	*0.49*	0.39	0.28	0.13	0.25	0.52	*0.26*	*0.26*	0.01	
Harrington Hill Creek	1.51	3.17	1.57	*2.53*	*2.53*	3.49	1.93	*1.88*	1.83				
Rothenberger's Creek	*0.41*	0.42	0.41	*0.56*	*0.56*	*0.56*	0.71	*1.60*	2.48				
Castrilla's Creek	*2.00*	2.11	1.88	*1.66*	*1.66*	*1.66*	1.43	*1.36*	1.29				
Outlet	0.06	0.12	0.45	*0.51*	0.57	0.26	0.03	0.01	0.01	0.01	0.01	0.04	

Total Monthly Nitrate-Nitrogen Loading (kg):

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Total
Buesink's Creek	22.8	22.0	374.5	118.4	296.7	295.9	40.8	94.1	18.6	9.3	3.8	34.9	1,332
Walker's Creek	3.0	3.2	135.5	27.3	44.2	25.4	2.5	2.8	3.5	0.4	0.2	0.1	248
Harrington Hill Creek	15.3	19.2	247.2	96.2	194.8	215.4	26.3	7.0	1.9				823
Rothenberger's Creek	7.4	4.5	114.2	37.5	76.0	60.8	13.8	9.3	4.5				328
Castrilla's Creek	11.3	7.2	166.0	35.2	71.4	57.1	10.9	0.9	0.6				361
Outlet	167.0	198.8	1,161.7	279.8	345.2	231.8	8.2	0.5	1.8	1.6	0.2	21.7	2,418

CHEMICAL QUALITY OF PRECIPITATION

Average Monthly Concentration (mg/L): *values in italics were estimated by method of running averages*

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Mean
Chlorides	0.15	0.13	0.14	0.11	0.05	0.09	*0.11*	0.12	0.12	0.06	0.21	0.10	0.12
Total Phosphorus	0.015	0.025	0.020	0.030	0.025	0.040	0.085	0.110	0.050	0.070	0.035	0.440	0.079
Nitrate Nitrogen	0.44	0.44	0.36	0.43	0.21	0.53	*0.47*	0.41	0.51	0.33	0.99	0.30	0.45
pH	4.35	4.43	4.32	4.37	4.60	4.52	*4.42*	4.32	4.13	4.35	4.09	4.43	4.36
condutivity (mU/cm)	0.025	0.020	0.022	0.023	0.017	0.023	*0.024*	0.026	0.039	0.026	0.054	0.020	0.027

Notes: Precipiation data is from National Atmospheric Deposition Program - Stockton, NY station except Total Phosphorus which is from USGS - Mendon Ponds, Rochester, NY station.
Concentration data is from a composite of wet fall (water) and dry fall (dust, pollen, etc.).

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Precipitation (in):	4.50	5.64	6.31	1.34	4.03	5.77	1.15	2.96	5.39	2.20	1.94	4.31
Precipitation (m):	0.114	0.143	0.160	0.034	0.102	0.147	0.029	0.075	0.137	0.056	0.049	0.109
vol precip on lake (m3)	143,175.43	179,446.54	200,763.78	42,634.46	128,221.56	183,582.72	36,589.28	94,177.62	171,492.35	69,996.88	61,724.52	137,130.25

Total Monthly Loading (kg) from Precipitation Falling Directly on Lake Surface

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Total
Chlorides	21.5	23.3	28.1	4.7	6.4	16.5	3.8	11.3	20.6	4.2	13.0	13.7	167.1
Total Phosphorus	2.1	4.5	4.0	1.3	3.2	7.3	3.1	10.4	8.6	4.9	2.2	60.3	111.9
Nitrate Nitrogen	63.0	79.0	72.3	18.3	26.9	97.3	17.2	38.6	87.5	23.1	61.1	41.1	625.4

CHEMICAL QUALITY OF GROUND WATER

Results of Well Samples Collected Between 7/14/98 and 9/17/98

	Number of Samples	Min (mg/L)	Max (mg/L)	Mean (mg/L)
Chlorides	33	0.45	281	46.3
Total Phosphorus	33	<0.010	0.172	0.063
Nitrate-Nitrogen	45	<0.010	9.49	1.44
Well Depth	24	12 ft	180 ft	67.3 ft

Ground Water Flow to Lake

(ft3/year)	(L/year)
156,776,155	4,439,430,389

Estimated Total Yearly Loading From Ground Water

	(kg/year)
Chlorides	205,546
Total Phosphorus	280
Nitrate-Nitrogen	6,393

RUNOFF DIRECTLY TO LAKE

Mean Concentration (mg/L) by Land Use

	Forested	Developed	Agricultural
Chlorides	1.4	29.1	16.1
Total Phosphorus	0.099	0.076	0.192
Nitrate-Nitrogen	0.31	1.70	2.27

Runoff as estimated in Water Budget

	Forested	Developed	Agricultural
ft3/year	35,453,972	25,259,395	23,314,249
L/year	1,003,950,113	715,270,292	660,189,593

Estimated Total Yearly Loading From Direct Runoff (kg/year)

	Forested	Developed	Agricultural	Total
Chlorides	1,406	20,814	10,629	32,849
Total-P	99	54	127	281
Nitrate-N	311	1,216	1,499	3,026

Data Sources for Runoff Calculations:
Forested Land - Mean annual concentration as measured in Walker's Creek
Developed Land - Mean concentratiuon as measured in runoff at Chautauqua Institute, 1993-1994 (from Chautauqua Lake - Entering the 21st Century: State of the Lake Report)
Agricultural Land - Mean annual concentration as measured in Harrington Hill Creek

RESULTS OF PRIVATE WELL SAMPLES - FINDLEY LAKE PROJECT

Sample ID	Latitude	Longitude	Date Sampled	Lab	Cl (mg/L)	TP (mg/L)	NO3-N (mg/L)
75	42.11008	-79.73112	19980727	MICROBAC	31.4	0.040	1.640
76	42.11073	-79.73175	19980727	MICROBAC	63.9	0.060	0.630
77	42.10893	-79.72957	19980727	MICROBAC	41.5	0.043	1.130
78	42.10866	-79.72583	19980727	NYSDOH			0.005
79	42.10790	-79.72513	19980727	MICROBAC	5.0	0.065	0.005
81	42.11645	-79.73512	19980727	MICROBAC	41.5	0.054	3.680
81	42.10951	-79.72860	19980727	MICROBAC	41.5	0.054	3.680
82	42.11625	-79.73580	19980727	MICROBAC	55.0	0.043	0.005
83	42.11927	-79.73548	19980727	MICROBAC	281.0	0.015	3.130
85	42.10954	-79.72767	19980727	MICROBAC	22.9	0.052	0.880
86	42.10384	-79.73004	19980727	MICROBAC	1.3	0.041	0.910
87	42.09987	-79.72827	19980727	MICROBAC	1.9	0.046	0.230
88	42.09871	-79.72241	19980727	MICROBAC	4.3	0.038	0.013
89	42.09372	-79.71934	19980727	MICROBAC	9.2	0.107	0.822
90	42.09849	-79.71812	19980727	MICROBAC	11.1	0.054	0.638
91	42.10079	-79.71730	19980727	MICROBAC	0.5	0.005	0.480
92	42.10129	-79.71824	19980727	NYSDOH			0.500
93	42.10138	-79.71770	19980727	MICROBAC	0.9	0.047	0.574
94	42.10741	-79.72181	19980727	MICROBAC	59.3	0.063	0.074
95	42.11459	-79.72736	19980727	MICROBAC	40.4	0.054	4.540
96	42.11915	-79.73254	19980728	MICROBAC	75.7	0.056	9.490
97	42.11435	-79.72754	19980728	MICROBAC	35.6	0.032	3.070
98	42.11232	-79.72671	19980728	MICROBAC	14.1	0.089	1.160
101	42.11199	-79.72362	19980728	MICROBAC	16.6	0.107	0.005
102	42.10398	-79.72053	19980728	MICROBAC	71.8	0.172	1.700
103	42.09207	-79.71300	19980728	MICROBAC	106.6	0.068	0.005
104	42.09498	-79.72214	19980728	NYSDOH			0.840
105	42.10837	-79.73117	19980728	NYSDOH			0.005
106	42.11445	-79.73404	19980728	NYSDOH			3.500
107	42.11791	-79.73528	19980728	NYSDOH			2.400
108	42.11891	-79.73694	19980728	NYSDOH			0.005
112	42.11854	-79.73776	19980729	MICROBAC	61.2	0.073	0.005
113	42.11238	-79.73249	19980727	MICROBAC	30.5	0.039	2.760
114	42.10326	-79.72900	19980729	NYSDOH			1.100
115	42.09828	-79.72360	19980729	NYSDOH			0.560
116	42.09752	-79.71551	19980729	NYSDOH			0.005
118	42.11063	-79.72213	19980729	NYSDOH			0.005
119	42.11908	-79.73598	19980729	MICROBAC	23.7	0.055	0.005
120	42.11631	-79.73020	19980729	NYSDOH			8.300
150	42.10854	-79.72133	19980916	MICROBAC	2.6	0.096	2.000
152	42.11323	-79.73313	19980917	MICROBAC	23.2	0.083	2.730
153	42.09808	-79.72277	19980917	MICROBAC	19.5	0.083	0.950
154	42.10821	-79.72530	19980917	MICROBAC	62.3	0.134	0.830
155	42.10249	-79.71879	19981125	MICROBAC	16.0	0.065	0.005
158	42.11860	-79.73781	19990212	MICROBAC	255.0	0.049	0.005
				MEAN	46.3	0.0631	1.445

CHAPTER 5 - LAKE BIOLOGY

INTRODUCTION

Findley Lake is a eutrophic system that receives significant amounts of nutrients from watershed sources. The lake has been characterized as a productive fishery, although panfish exhibit poor growth due to limited ecological resources (McKeown, 1989). Certain recreational uses of Findley Lake have been impaired by the abundance of nuisance aquatic macrophytes. Additionally, one of the two permitted public bathing beaches has been closed by the Chautauqua County Health Department during portions of the 1997 and 1998 bathing seasons. The increased levels of bacteria that trigger beach closure are thought to be attributed to large numbers of waterfowl and the patchy distribution of submerged aquatic macrophytes that impairs water movement around the beaches.

In May 1998, the Department of Biology of the State University of New York at Fredonia agreed to conduct a limnological survey of Findley Lake for the Findley Lake Property Owners, Inc. (FLPO). This survey would aid in developing a watershed management plan. The specific purpose of the SUNY Fredonia investigation was to biologically characterize Findley Lake. Data were collected from May 1998 to October 1998. These data were in addition to those discussed in Chapter 4. The parameters examined included physicochemical endpoints, such as temperature, pH, and dissolved oxygen; chlorophyll *a* water column concentrations; species list of phytoplankton; estimates of lake-associated waterfowl; and estimates of types, distribution, and biomass of aquatic macrophytes present in the lake. Subsequent studies from 1999 funded by the New York State Department of Environmental Conservation (NYS DEC) are also included in this report for archival purposes.

The nuisance aquatic macrophyte Eurasian watermilfoil (*Myriophyllum spicatum)*, an exotic species, eventually became an important focus of this study. Eurasian watermilfoil is the predominant aquatic macrophyte at Findley Lake and has adverse effects upon native plants, some fisheries, as well as boating and other recreational activities at the lake.

METHODS AND MATERIALS

Sampling

Sampling occurred approximately every two weeks from late May 1998 to late August 1998. Sampling was also conducted once during the months of September and October, and periodically in 1999. Data were usually collected between the hours of 09:00 and 15:00 using small boats with outboard motors.

Sample sites were selected following a preliminary examination of the lake. Seven sites were selected to ensure a representative sampling of the lake so that future studies would have a sufficient data baseline. The seven sites selected are identified in Table 5.1 and are shown in Figure 5.1. Sites L1, L2 and L3 are shown for comparison in Figure 5.1. Site L2 (Chapter 4) is similar to Table 5.1-site 4 and L3 (Chapter 4) is similar to Table 5.1-site 6.

Table 5.1. Findley Lake sampling sites and associated GPS coordinates.

Site Number	Site Name	Latitude; Longitude
1	Outlet	42^0 07' 07.47"N; 79^0 44' 04.49"W
2	Island	42^0 07' 1.77"N; 79^0 44' 00.84"W
3	Garage	42^0 06' 43.89"N; 79^0 43' 53.73"W
4	Buoy	42^0 06' 28.10"N; 79^0 43' 24.74"W
5	Inlet/ Cove	42^0 06' 12.33"N; 79^0 43' 39.29"W Cove site used during DEC study is 30 meters south of inlet site
6	Flag	42^0 06' 11.09"N; 79^0 43' 28.74"W
7	Control Marsh	Not determined

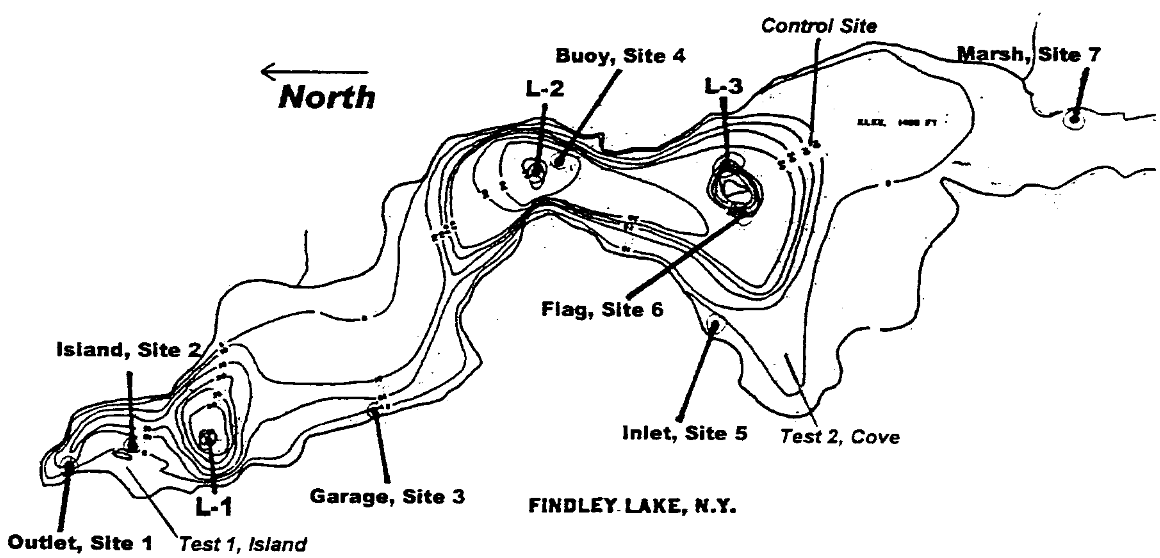
Physicochemical Parameters and Transparency

The water dissolved oxygen (DO) concentration and temperature at depth were taken at 1-meter intervals using a YSI model 85 DO meter with a 15 m cable. The DO meter was calibrated using the wet chamber technique (Standard Methods, 1995). The probe was lowered until it was just off the lake bottom and DO (mg/L) and temperature (°C) were recorded at 1 meter intervals throughout the water column and at the water surface (approximately 15 cm below surface). The pH was measured 15 cm below the water surface using a Fisher Scientific Accument Ap10 pH meter calibrated using pH 7 and pH 10 standards. The probe was rinsed with deionized water before each use. Water clarity was determined using the Secchi disk transparency method as described by Lind (1985).

Chlorophyll *a*

Chlorophyll *a* analyses followed procedures described by Lind (1985). Water samples for chlorophyll analysis were collected at approximately 0.5 meter depths between 10:00 and 15:00 hours, placed on ice, and stored in a refrigerator for no more than 72 hours prior to processing. Samples were vacuum filtered in the laboratory using Whatman 4.25 cm GF/C glass fiber filters. Approximately 1 liter of water was filtered or the sample was filtered until the filter clogged and the volume accurately recorded. Filters were stored at –20°C until extraction. Samples were extracted in methyl alcohol as it demonstrated greater extraction efficiency than alkalized acetone (data not shown). Dilutions of methanol-extracted samples were then analyzed using a Turner Model 111 fluorometer with a 5-60 primary filter and a 2-64 secondary filter. Standards were purchased from Sigma Chemical Co. and were dissolved in methyl alcohol. Values from all sites sampled were averaged to calculate a lake-wide mean at each sample interval.

Figure 5.1: Bathymetric map of Findley Lake showing sample sites and codes.



Algae

After the chlorophyll vacuum filtration, the remaining water was used for algae identification. Algae were allowed to settle to the bottom of the sampling bottle for 24 hrs at which time the supernatant was decanted until there was approximately 50 mL of liquid left in the bottle. The remaining sample was placed into 50-mL centrifuge tubes with plug seal caps and centrifuged for 15 min at 7000 rpm using a Sorvall RC-5B Superspeed centrifuge. The top 40 mL of supernatant was removed and the remaining 10 mL of concentrated sample was combined with 100 uL of Lugol's Iodine solution in a capped plastic vial. Vials were stored at 4°C until examined.

Algae species list for each sampling day were produced by examining the concentrated sample with a light microscope and comparing algae to appropriate taxonomic keys. Algae were identified to the lowest taxonomic level, usually family or genus.

Aquatic Macrophytes

Aquatic macrophytes were periodically sampled by hand and either identified in the field or preserved for identification in the laboratory. Sketches detailing the extent of macrophyte growth were also produced. Plant biomass was examined at three sites on several occasions during 1998 and 1999 using SCUBA divers. There were three samples taken at each site and all plants within a 0.25 m^2 sampling square were pulled by hand, bagged, and placed in a ice chest for transport back to the laboratory. Plant samples were dried at 105°C for approximately 24 hours or until weight was constant.

Aquatic Weevil (*Euhrychiopsis lecontei*)

Macrophyte samples for aquatic weevil enumeration were taken at periodic intervals following inoculation of weevils in 1999. Weevils were placed into Findley Lake by Cornell University researchers on two separate occasions. Approximately 7,500 weevils were added to the Island site, with 5,200 added on 22 June 1999 and 2,300 added on 2 July 1999. Approximately 7,500 weevils were added to the Cove site on 2 July 1999. Weevils arrived at the lake in glass jars that were cooled during transport from Cornell. These jars were suspended in the lake water and the weevils released near macrophyte beds at the two test sites. Weevils were observed to swim after release and no fish predation was observed during the release.

Weevil enumeration was conducted by randomly sampling 25 tips of Eurasian watermilfoil (*Myriophyllum spicatum*) within 10 meters of each large marker buoy, as it was hypothesized that the highest densities would be observed in that area and boat traffic could be effectively controlled. Care was taken not to excessively sample any given macrophyte bed and plants were selected that most closely represented the predominant conditions of the plant bed. Plants were sampled underwater either by a swimmer or from a boat. Care was taken to minimize plant handling prior to processing and no weevils were observed swimming away from collected plants. Plant samples were approximately 25 cm long. Plants were immediately placed into labeled Ziploc bags, sealed, and placed in an iced cooler prior to transport to the laboratory.

All samples were processed within 48 hours of collection. Plants were carefully examined, for weevil adults, pupae, larvae, and eggs. Any observed stem damage was dissected to look for larvae. The total number of each life stage and mean number of weevils per plant were recorded.

Fisheries

Two reports were reviewed to gather data about Findley Lake fisheries. Brooking et al. (1997) examined the stocking of walleye into the lake from 1992 to 1996. Fisheries were examined as part of their study. McKeown (1989) examined fishery stocks in Findley Lake in 1988.

Canada Geese (*Branta canadensis*)

Canada geese were counted at periodic intervals during the year. Estimates of the nutrient loading from goose feces was attempted by analyzing feces for nitrate-nitrogen and phosphate using procedures described in Standard Methods (1995) and assumptions described by Pettigrew et al. (1998). Canada geese count data were then used to estimate nutrient input to Findley Lake. Bacteria inputs to the lake from goose feces are discussed in Chapter 4.

Zebra Mussels (*Dreissena polymorpha*)

Zebra mussel traps were placed in the lake at two locations to determine if they were present. The traps, provided by the NYS DEC, were made from 6 cm diameter schedule 40 PVC pipe, approximately 60 cm long. These were attached to the chains of two buoys so that they were submerged about 1 meter below the lake surface. One of the buoys was a "no wake zone" buoy located at the north end of the lake near the public boat launch, the other was a "slow caution" buoy located near the middle of the lake at the narrows. Traps were in the lake from the summer of 1997 through the end of 1998. They were visually checked every two weeks during the boating season by project volunteers, to see if any mussels had attached themselves to any part of the trap.

RESULTS AND DISCUSSION

Data collected for dissolved oxygen, temperature, Secchi depth and pH were reduced to a series of graphs. With the exception of pH, as discussed below, these data correlate extremely well to that which was previously discussed in Chapter 4. Therefore, these graphs have been omitted from this report. They have, however, been archived in the files of the Chautauqua County Health Department for future comparative purposes.

Dissolved Oxygen and Water Temperature

The water dissolved oxygen (DO) concentration and temperature data at depth correlate nicely to that shown in Chapter 4, Figures 4.18 and 4.19. These data are typical for a stratified lake system during the summer. Maximum summer temperature at the surface was approximately

Figure 5.2: Comparison from 1937 to 1998 of water temperature and dissolved oxygen at deepest part of Findley Lake (1998 Buoy site).

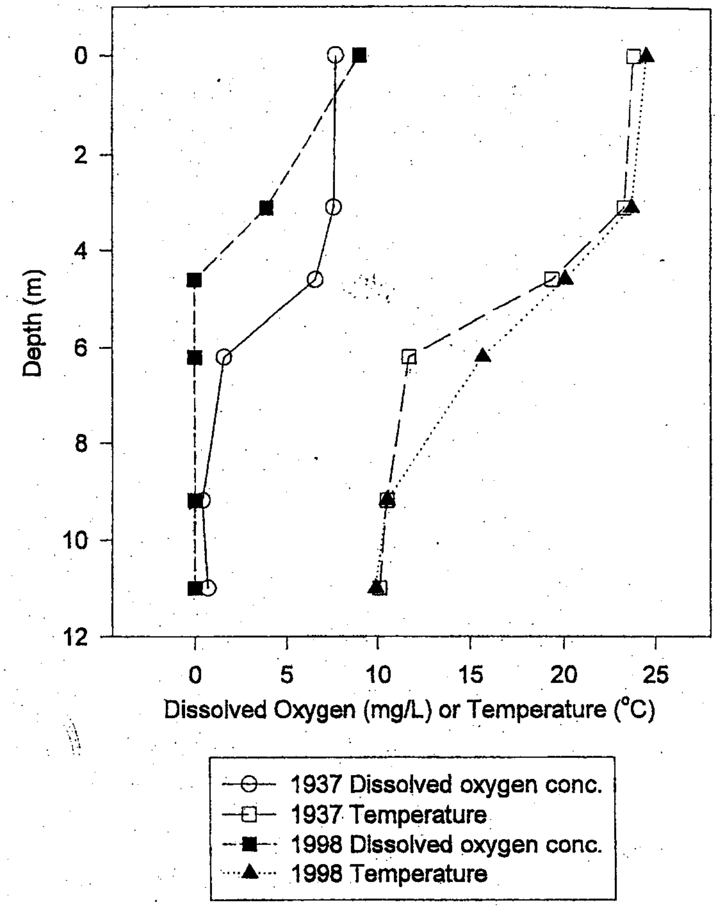
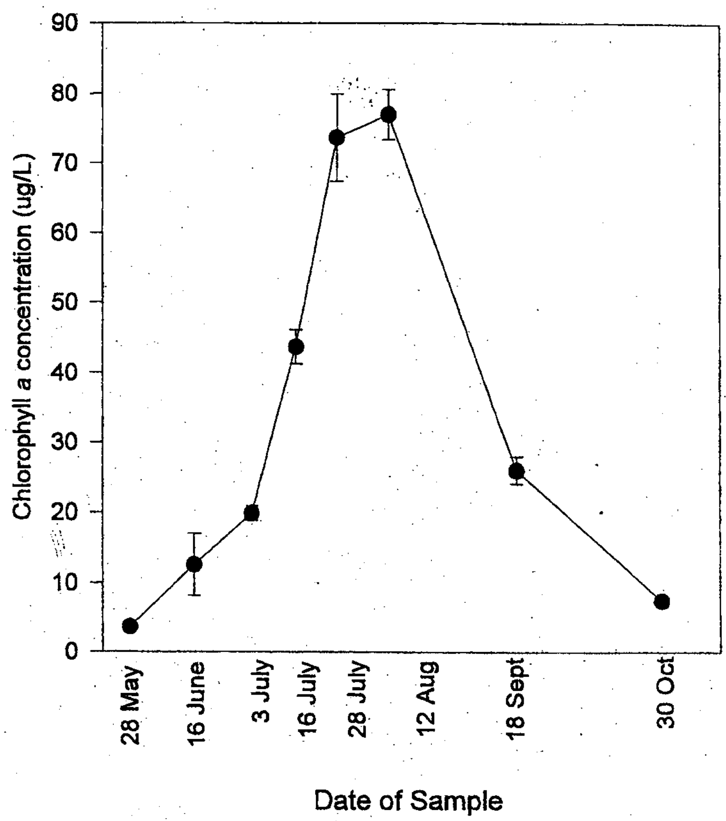


Figure 5.3: Chlorophyl a concentrations in Findley Lake, 1998. Values represent mean of six to seven sites sampled at each time. Error bars represent standard error of mean.



25 to 26°C while the hypolimnion exhibited a temperature of approximately 10°C at the height of summer. Dissolved oxygen concentration was observed to be < 1.0 mg/L at a depth of 5 meters at both the Flag and Buoy sites by 16 July 1998. By late August the depth at which the DO was depleted moved deeper in the water column as the shallower water became re-oxygenated. Data obtained during this study correlated well with those obtained in 1937 by the State of New York Conservation Department (1938). As presented in Figure 5.2, data obtained on 28 August 1937 and 12 August 1998 show very similar patterns of thermal stratification as well as similar clinograde (normal oxygen distribution curve for lakes). It should be noted that oxygen concentrations were observed to decline more rapidly in 1998 than in 1937. However, the ramifications of this, if any, are unclear.

Secchi Depth

Secchi depth decreased significantly from late-May to mid-July as shown in Chapter 4, Figure 4.20. Because of depth limitations and macrophyte growth, the Buoy data were deemed more reliable for long-term evaluation since that site was near the Citizens Statewide Lake Assessment Program (CSLAP) monitoring site. For 1999, the maximum Secchi depth at the Buoy site was 3 meters while the minimum Secchi depth was 1 meter. CSLAP data (Hohenstein et al., 1997) indicate that from 1985 to 1996, the maximum and minimum Secchi depths were 4.75 and 0.33 meters, respectively.

pH

Values typically ranged from a pH of 8 to a pH of 9.5, typical for hard water lakes of this region. However, these data taken just below the water surface, were slightly greater than those discussed in Chapter 4 and those collected during the CSLAP program (Hohenstein et al., 1997). CSLAP data for the period 1985 to 1996 yielded a maximum pH of 8.98 and a minimum of 6.92, although water samples were taken at a depth of 1.5 m, too deep for the equipment possessed by SUNY researchers. Hence, the pH values can not be correlated among the three sources of information. However, the sources all indicate that the regions soils buffer the lake against acid rain.

Chlorophyll *a*

The mean chlorophyll *a* data for all sites monitored during 1998 are presented in Figure 5.3. These data tend to corroborate data obtained during the CSLAP monitoring program. During the period from 1987 to 1995, CSLAP data had a mean of 98 ug/L with a minimum and maximum of 30.9 and 149 ug/L, respectively. The maximum value of 149 ug/L was obtained during 1991, apparently a year of significant algal blooms, as chlorophyll *a* concentrations in excess of 120 ug/L were documented into October of 1991. The CSLAP report (Hohenstein et al., 1997) noted a "fairly good" correlation between total phosphorous concentrations and chlorophyll *a*. The maximum chlorophyll *a* concentrations observed during this study occurred in late July and early August of 1998. Periods of very high chlorophyll *a* levels may correspond to years of major drought, such as in 1991, which are accompanied by periods of increased sunshine and therefore increased algae growth.

Algae

Algae identified on each of four sampling days are listed in Table 5.2. These species are typical for a eutrophic aquatic system in this geographical region.

Table 5.2. Algae identified at Findley Lake, New York, during each of four sampling periods during 1998.

June 16	July 16	August 12	September 18
Anabaena (Fbg)	*Anabaena* (Fbg)	*Anabaena* (Fbg)	*Anabaena* (Fbg)
Anacystis (Cbg)	*Anacystis* (Cbg)	*Volvox* (F)	*Volvox* (F)
Ceratium (F)	*Ceratium* (F)	*Fragilaria*(D)	*Fragilaria*(D)
Volvox (F)	*Volvox* (F)	*Ceratium* (F)	*Ceratium* (F)
Fragilaria (D)	*Fragilaria*(D)	*Eudorina* (F)	*Eudorina* (F)
Staurastrum(G)	*Staurastrum*(G)	*Staurastrum*(G)	*Staurastrum*(G)
Coelastrum(G)	*Coelastrum*(G)	*Spirogyra* (nFbg)	*Spirogyra* (nFbg)
	Ankistrodesmus (nFbg)		*Ankistrodesmus* (nFbg)
	Eudorina (F)		
	Pediastrum (nFbg)		
	Desmidium (G)		
	Spirogyra (nFbg)		

Cbg: Coccoid Blue-green algae
D: Diatoms
F: Flagellate algae
Fbg: Filamentous Blue-green algae
G: Green algae
NFbg: Nonmotile Filamentous Blue-green algae

Aquatic Macrophytes

The nuisance aquatic macrophyte Eurasian watermilfoil (*Myriophyllum spicatum)* was determined to be the dominant species at Findley Lake (> 90%). Sago pondweed (*Potamogeton pectinatus*), curley-leaf pondweed (*P. crispus*), duckweed (*Lemna minor*), coontail (*Ceratophyllum demersum*), wild celery (*Vallisneria americana*), *Nuphar variegata*, and *Nymphaea odorata* were also identified (Table 5.3).

Table 5.3. List of aquatic macrophytes collected at Findley Lake, New York.

Common Name	**Scientific Name**	**Type**	**Classification**
Eurasian milfoil	*Myriophyllum spicatum*	Submergent	Exotic
Coontail	*Ceratophyllum demersum*	Submergent	Native
Curly-leafed pondweed	*Potomogeton crispus*	Submergent	Exotic
Pondweeds	*Potomogeton spp. foliosus, pusillus, robbinsii, spirillus…*	Submergent	Native
Wild celery	*Vallisneria americana*	Submergent	Native
Duckweed	*Lemna minor*	Free Floating	Native
Spatterdock	*Nuphar variegata*	Floating Leaf	Native
White water lily	*Nymphaea odorata*	Floating Leaf	Native
Sedges	*spp.*	Emergent	Native
Rushes	*spp.*	Emergent	Native
Cattails	*spp.*	Emergent	Native

Macrophyte biomass data for 1998 and 1999 are shown in Figures 5.4 and 5.5. Although the sampling method does inherently have a significant amount of variation, variability was acceptable. Although data should be collected in future years for evaluating long-term trends, a significant decrease in biomass was observed in August at the Island site. It should be noted that the Cove site varied between 1998 (near the inlet) and 1999 (centrally located at Paradise Bay) and no conclusions should be drawn from those sites at this time. Biomass amounts tended to be greatest during late June and early July. However, the FLPO conducted a draw down during the winter of 1998-99 that was longer in duration and more extensive than draw downs conducted in previous winters. It is plausible that this draw down, in conjunction with weevil activity as subsequently discussed in this report, may have reduced macrophyte abundance. It is recommended that future sampling be conducted during the last week of June and the last week of July in future years using the three sites monitored during the 1999 NYS DEC-funded study.

Aerial photography of Findley Lake during July 1998 documented the extent of macrophyte distribution. Significant amounts of macrophyte and algae biomass in the shallow southern basin of the lake were observed where water depths were approximately one meter or less. Significant amounts of macrophytes, almost exclusively Eurasian watermilfoil, were

Figure 5.4: Comparison of 1998 and 1999 biomass data during July and August. Values are mean of three replicates and error bars represent standard error of the mean.

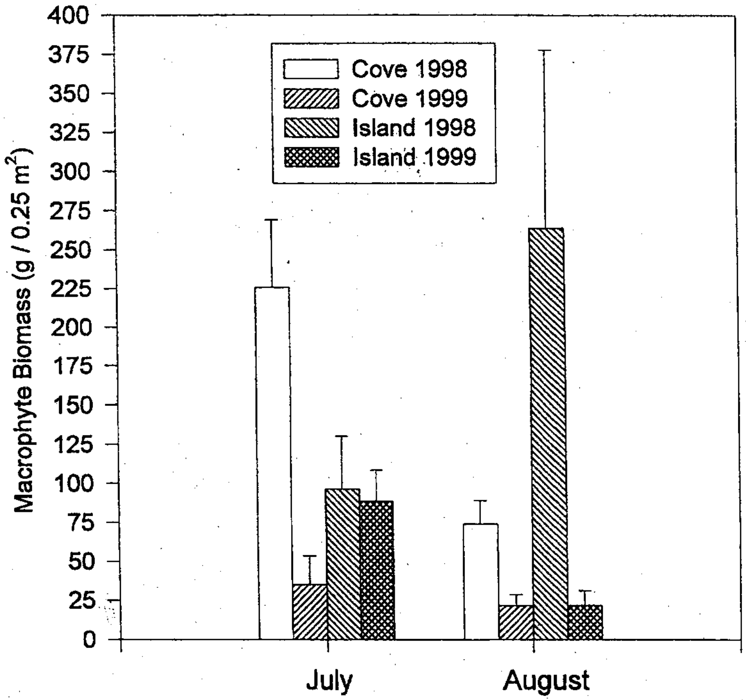
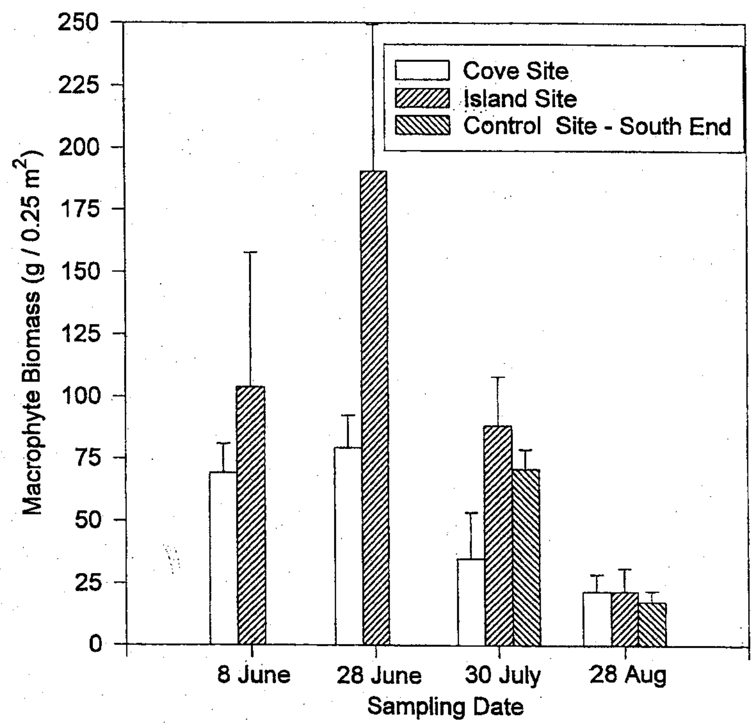


Figure 5.5: Findley Lake biomass data from Summer, 1999. Values are mean of three replicates and error bars represent standard error of the mean.



clustered around the island near the lake outlet. It should be noted that the authors of this report believed that conditions at those two locations were improved in 1999 as compared to 1998, possibly because of the lake drawdown and weevil activity.

Distribution of Eurasian watermilfoil during May and June of 1998 are shown in Figure 5.6. These drawings demonstrate the extent of macrophyte growth in late May as well as immediately following the Fourth of July holiday weekend at the lake. During the May survey, essentially all waters at depths of 10 meters or less exhibited macrophyte growth. Data obtained during 1998 compare well with similar distribution diagrams obtained by the State of New York Conservation Department (1938) that show significant macrophyte growth in nearly the identical areas found during the current study (Figure 5.7). Although *M. spicatum* was not yet present in 1937, it is obvious that other species, including several no longer found, dominated what was already a nutrient-rich aquatic system.

Aquatic Weevil (*Euhrychiopsis lecontei*) and Aquatic Moth (*Acentria ephemerella*)

The use of biological controls potentially offers cost-effective and efficacious treatment of Eurasian watermilfoil in some cases. The most promising controls at this time appear to be an aquatic moth and an aquatic weevil.

The aquatic moth *Acentria ephemerella* is small (12 mm) and lives only about 24 hours as an adult. Larvae are visible during September and October and feed on many species of native and exotic aquatic plants including Eurasian watermilfoil. *Acentria* has an upper temperature limit of approximately 22°C thus limiting its usefulness during warmer months. Reduction of milfoil in lakes has been correlated with the presence of *Acentria* and the moth has been found by others at Findley Lake (Gross and Johnson, 1997).

The aquatic weevil *Euhrychiopsis lecontei* is a small (2-4 mm) coleopteran insect that emerges during the summer months and appears to prefer Eurasian watermilfoil over other native and exotic aquatic plant species. The adults live for approximately one to two months and overwinter in detritus within one or two meters of the shoreline. Researchers working in other parts of the country have demonstrated that the weevils are likely to be effective in controlling watermilfoil in laboratory and controlled field conditions. Their research has shown that weevils reproduced at water temperatures up to 31°C, preferred Eurasian watermilfoil over other plant species, and preferred plants grown in richer sediments. Lakes exhibiting reductions in Eurasian watermilfoil , where the watermilfoil reduction appeared correlated to weevil abundance, included Fish Lake, Wisconsin, McCullom Lake, Illinois, and Cenaiko Lake, Minnesota.

In the Findley Lake study Aquatic weevil (*Euhrychiopsis lecontei*) densities were evaluated at the 2 sites where exogenous weevils were introduced and at a control site during 1999 as part of the NYS DEC grant and data are presented in Table 5.4. All three of these sites were marked with buoys to prevent weed harvesting near them. Data generated on 28 May 1999 by Cornell researcher Robert Johnson at the Island and Cove sites estimated weevil densities of 1.39 weevils per milfoil apical meristem tip prior to inoculation with exogenous weevils (data not shown). Our estimates were slightly lower than their estimates although our sampling

Figure 5.6: Spatial Distribution of Eurasian watermilfoil topping beds (*Myriophyllum spicatum*) shown in black on 27 May 1998 (top) and 7 July 1998 (bottom) in Findley Lake.

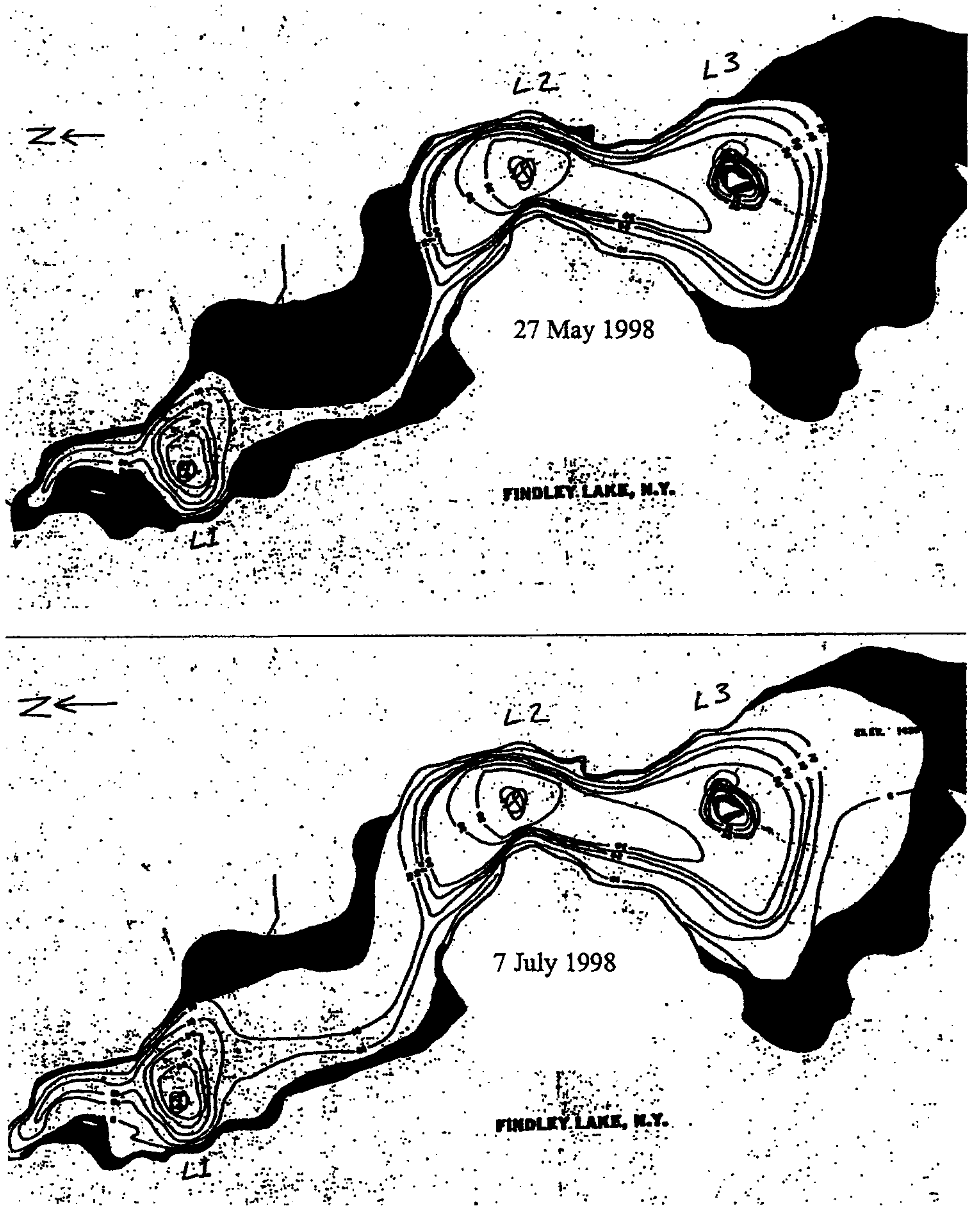
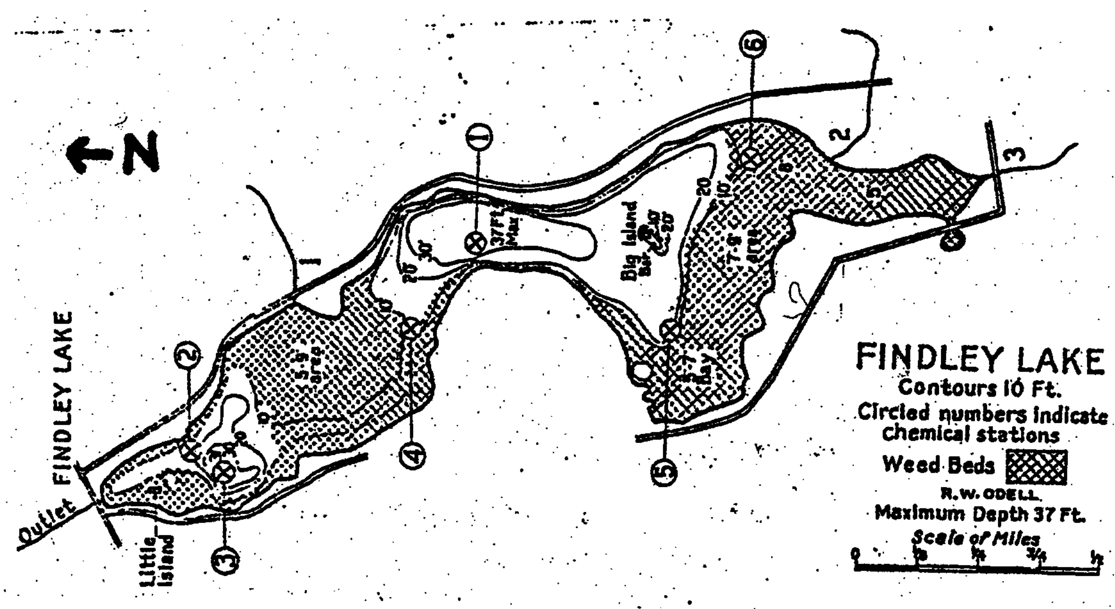


Figure 5.7: Diagram of Findley Lake in 1937 (drawn by R. Odell, State of New York Conservation Department, 1938) showing spatial distribution of macrophyte beds and lake contours.



program was not initiated until 21 June 1999. Care was taken to examine and dissect each tip under magnification and our data compared well with background weevil densities obtained during a University of Wisconsin study of that state's lakes (Jester and Bozek, 1999). During that study, 31 lakes were sampled with only two lakes exhibiting means greater than 2.0 weevils per tip and 18 lakes having a mean of less than 1.0 weevil per tip. Jester and Bozek (1999) speculate that approximately 3 weevils per plant tip are required to effect macrophyte growth control.

Surprisingly, relatively few adults were found during the Findley Lake study. However, greater abundances of larvae and eggs were found. Adults are of sufficient size that they are relatively easy to locate even without the use of a hand lens. It is unknown if such low abundances are the result of technical error, predation, or weevil migration away from inoculated sites. (Foley and Newman (1999) have concluded that fish predation may limit weevil abundance.)

Table 5.4. Weevil densities on *Myriophyllum spicatum* from Findley Lake, New York, during 1999. Counts are shown for 25 plant tips (top 25 cm).

	# of adult weevils	# of larvae	# of eggs	# of pupae	Mean weevils per tip
Island					
June 21	2	14	3	1	0.8
July 8	1	16	2	6	1.0
August 4	3	2	7	0	0.5
August 23	0	3	0	0	0.1
September 10	3	11	11	3	1.1
October 15	0	0	0	1	0.04
Cove					
July 8	0	7	3	1	0.4
August 4	0	3	1	0	0.2
August 23	1	4	6	0	0.44
September 10	2	7	7	2	0.8
October 15	3	0	0	0	0.1
Control					
July 8	1	0	11	6	0.7
August 4	0	2	2	0	0.2
August 23	0	10	10	3	0.9
September 10	0	4	6	6	0.6
October 15	0	0	0	0	0.0

While the aquatic weevil does appear to be a viable biocontrol agent in some lakes, its presence does not necessarily correlate with reductions in plant biomass (Jester and Bozek, 1999). As part of the Findley Lake biological characterization study, weevil eggs, larvae, and adults were found in Findley Lake in May of 1998, but watermilfoil biomass did not appear to be visually damaged. Jester and Bozek (1999) and others speculate that approximately 3 weevils per milfoil apical meristem tip are needed to produce significant damage. As shown in Table 5.5, Findley Lake does not have these amounts of weevils even after augmentation with exogenous weevils. Given the developed shoreline, lack of leaf pack, and phosphorous concentrations (Jester and Bozek, 1999), it may be difficult to establish the weevil as effective biological control agents at Findley Lake.

Fisheries

Brooking et al. (1997) conducted fall night electrofishing studies from 1992 to 1996. According to their data, Findley Lake has significant populations of largemouth bass, smallmouth bass, yellow perch, bluegill sunfish, and pumpkinseed as compared to the five other lakes sampled. The electrofishing catch rate is shown in Table 5.5. Brooking et al. (1997) estimated the shoreline gradient at Findley Lake to be 3.7% and also estimated watermilfoil to occupy 46% of the shoreline.

McKeown (1989) found that relative abundance of both smallmouth and largemouth bass compared favorably with other New York State waters. Panfish were found to exhibit relatively poor growth although growth rates of bluegill and pumpkinseed were deemed marginally acceptable.

The authors of this report agree that Findley Lake is an above average fishery. During the summer of 1998, we received one report of a 48-inch Northern pike being caught and witnessed many fishing successes by local fishermen.

Table 5.5. Electrofishing catch rates (number / hectare) for fish older than young of year at Findley Lake (from Brooking et al., 1997).

	1992	1993	1994	1995	1996
Walleye	0.0	0.0	1.0	4.7	7.2
Largemouth bass	33.2	18.1	14.6	12.0	13.1
Smallmouth bass	5.4	2.6	6.7	0.7	16.6
Northern pike	0.6	1.1	1.1	2.2	0.2
Bluegill	470	103		82	67
Pumpkinseed	380	202		122	195
Yellow perch	81	164		87	105

Canada Geese

Canada geese data are presented in Table 5.6. Significant Canada goose populations were identified in a field at the southern portion of the lake.

Table 5.6. Count and estimate data of Canada geese at Findley Lake, New York during 1998.

Date	Count [C] or Estimate [E]	Number of Geese
March	E	800-1000
April	C	300
June 3	C	220
June 9	C	174
June 18	C	156
June 22	C	145
June 23	C	200
June 25	C	175
September 18	E	500
October 30	E	>900
December	E	>1000

Analysis of goose excrement from Findley Lake determined an average of 0.66 mg nitrogen (as nitrate) and 1.52 mg phosphorous (as orthophosphate) per gram dry weight of feces. Assuming a population of 500 geese, an average feces weight of 1.17 grams dry weight, and 28 feces drops per day (Pettigrew et al., 1998), these 500 geese would contribute 10.7 g/day nitrogen (as nitrate) and 24.9 g/day phosphorous (as orthophosphate) to the lake. Over the course of a year, the amounts of nitrogen and phosphorous added to the lake would be 3.9 kg and 9.1 kg, respectively. However, conservatively assuming a lake volume of 1E09 liters in the southern basin of Findley Lake, this amount of nutrient input would only result in the nitrogen and phosphorous concentrations in the south lake basin increasing 3.9 ug/L and 9.1 ug/L, respectively, assuming no sorption, uptake, or other depletion of the nutrient. Dilution into the entire lake would further reduce these estimated concentrations.

Zebra Mussels (*Dreissena polymorpha*)

While zebra mussels are a problem in Lake Erie, Chautauqua Lake, and other nearby lakes, no zebra mussels were found in Findley Lake during this study.

LAKE BIOLOGY SUMMARY

Findley Lake is, and has been, an aquatic system that is undergoing the normal ecological process of eutrophication. Previous studies indicate that the fish populations in the lake are healthy, although sheer densities of fish appear to limit size, especially among the panfish. However, in the 1930s, the State of New York Conservation Department (1938) described the lake as "weed-choked," indicating that it has suffered from aquatic weed problems for many years. The identification of nutrient and sediment inputs to the lake, as documented in this report, and subsequent reduction of those pollutants will help reduce the effects of eutrophication.

One of the sources of nutrients to the lake is introduced via waterfowl. We estimated that approximately 9 kg of phosphorous could be contributed by goose feces. This represents a very small percentage of total nutrient inputs. However, bacteria contributed to the lake water from goose feces can be significant, as discussed in Chapter 4. Zebra mussels, while present in almost all surrounding lakes, are notably absent in Findley Lake.

The aquatic macrophyte Eurasian watermilfoil (*Myriophyllum spicatum)* is now the dominant plant species at Findley Lake. While the details of its introduction are not known, it was not present during the 1937 survey (State of New York Conservation Department, 1938). Milfoil abundance increases during May and starts to decline around the end of June into July.

The presence of the aquatic weevil (*Euhrychiopsis lecontei*) in Findley Lake, one of the biological controls for watermilfoil, was evaluated during this study. A survey completed in late May1998 at two locations in the lake (the Island and Cove sites), estimated weevil densities of 1.39 weevils per milfoil apical meristem tip. In late June and early July 1999, the lake was inoculated with approximately 15,000 adult weevils, half at the Island site and half at the Cove site. Following surveys that summer revealed densities of 1 per milfoil tip or less at those same sites. Although, relatively few adult weevils were found during this study, greater abundances of larvae and eggs were found, suggesting that populations may increase given the appropriate conditions for weevil survival. These densities compare well to those obtained during a University of Wisconsin study of that state's lakes (Jester and Bozek, 1999). However, as a result of that study Jester and Bozek (1999) speculate that approximately 3 weevils per plant tip are required to effect macrophyte growth control and Findley Lake densities have yet to reach that level.

While many control techniques are available for in-lake management of Eurasian milfoil, none have been demonstrated to be very successful. Chemical treatment of water with herbicides or sun-blocking dyes carry inherent ecological risk and, in the case of herbicides, human health concerns. Long-term use of herbicides is prohibitively expensive and may impair some ecosystem functions, including fish reproduction. Dredging, while an excellent treatment, is far too expensive for the vast majority of affected lake systems and may release toxic heavy metals and organic chemicals back into the water column. The use of biological controls potentially offers cost-effective and efficacious treatment of Eurasian watermilfoil in some cases. The most promising controls at this time appear to be the aquatic moth and aquatic weevil. Physical controls, including mechanical harvesting and water draw down, have had the most demonstrable success to date. However, mechanical harvesting can further exacerbate weed problems through fragmentation and subsequent regrowth.

Of the existing options available to control Eurasian watermilfoil, more research must be done to determine their effectiveness in Findley Lake. While the presence of the aquatic moth in the lake has been confirmed, its distribution and density are unknown. In order to determine the effectiveness of the weevil, additional census data must be collected for several more years. Weed harvesting, which provides a temporary clearing of the lake, must be repeated as necessary, typically annually and possibly more frequently, and will likely impair the use of biological control agents. The permitted use of herbicides, used widely in the lake from 1956 to 1971, proved to be ineffective for weed control and, at times, detrimental to the lake and outlet ecosystems. Use of chemicals as a weed control may also impair the use of biological controls.

In this research teams opinion, the best long-term solution to the macrophyte problem, would be the use of biological controls.

Since the growth of algae and aquatic macrophytes are directly attributable to the presence of excessive quantities of nutrients, it is our recommendation that a watershed nutrient reduction plan be developed in conjunction with an in-lake macrophyte management plan.

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CHAPTER 6 – LAKE SEDIMENT STUDY

INTRODUCTION

The water quality of Findley Lake is controlled by that of the surface and ground water entering the lake, and by in-lake chemical, biological and physical processes. The in-lake chemical and physical processes include chemical and physical interactions between the water and the sediment in the lake. This chapter provides a brief overview of the physical and chemical conditions of the lake sediments.

Bottom Sediment Parameters Tested

Samples of the bottom sediments were taken in December of 1998. A number of chemical measurements were made on these cores to determine the quantity of nutrients in the sediments, and the impact of herbicides that were used in the past.

Nitrogen is a very important nutrient essential to the growth of all plants. The various forms and sources of nitrogen are discussed in Chapter 4. Regardless of its original form, all nitrogen will eventually be converted to Nitrate-nitrogen, the final stable form in the nitrogen cycle. Nitrate-nitrogen is chemically un-reactive and does not bond to soil particles, it typically remains dissolved in a body of water until being taken up by plants. Therefore, although the water quality was determined by testing for nitrate, the sediment samples taken were tested for Total Kjeldahl Nitrogen. The Kjeldahl method measures nitrogen in the trinegative state, which includes nitrogen in the form of ammonia, and nitrogen that is bound to organic material. The Kjeldahl method does not measure nitrogen in the form of nitrate, nitrite, or other inorganics such as azides (APHA, 1989).

Phosphorus, though an essential nutrient for plant growth, is often the least abundant nutrient and therefore it is the limiting factor in plant growth. The sources of phosphorus are the same as those listed in Chapter 4 as sources of nitrogen. However, unlike nitrate, phosphorus does become bound to soil particles. In fact, approximately 95% of the phosphorus in streams adheres to sediment particles (Hem, 1985). This sediment, once deposited in streams or lakes, acts as a sink where phosphorus is stored and then released to the overlying water and biota (Baudo, 1990). Phosphorous can be released from the lake bottom sediments under both oxygen rich and oxygen depleted conditions. However, the rate of release is typically much greater in oxygen depleted conditions. The impact of this release of phosphorus from sediments can be significant and cause continuing eutrophication problems even after other sources have been substantially reduced (Thomann, 1987).

Arsenic in the form of sodium arsenite was commonly used as an herbicide (weed killer) both terrestrially and aquatically through the late 1960s. Records show that sodium arsenite was applied to Findley Lake for at least four years, from 1956 through 1959. In 1956 sodium arsenite was applied to approximately 70 acres of the lake, at a treatment rate of 7.5 parts per million. Subsequent water sampling indicated that it took 22 days after application for the arsenic levels in the lake to reach a "safe level" of less than one part per million. In 1957, encouraged by the success from the previous year, an application rate of 10 parts per million was used to treat 87 acres or about 30% of the lake. Sodium arsenite was also applied in 1958 and 1959, though the treatment rates and areas treated were not documented. Though applied at relatively low rates, subsequent testing of bottom sediments after application in June of 1959 indicated arsenic concentrations as high as 710 parts per million with an average of 335 parts per million. Prior to application the average concentration of arsenic in the sediment was 114 parts per million. These results indicate that arsenic was absorbed by the sediment. The mechanisms by which arsenic is absorbed by sediments and subsequently desorbed back into the water are not well understood.

2,4-Dichlorophenoxy acetic acid was used as an herbicide from 1960 through 1965. This compound will not be discussed in any detail due to the fact that it was not detected in any of the sediment cores that were taken.

General Sampling and Testing Procedures

Sediment samples were collected after the level of Findley Lake had been lowered approximately 4 feet below summer level, or to an elevation of 1416.16 feet. The lake level is lowered each fall in order to expose the vegetation to freezing conditions in an effort to inhibit weed growth. Samples were taken by using a hammer to drive a 1.2 m long, 7.5 cm diameter core sampler into the sediments as far as possible. This provided undisturbed cores of bottom sediments, which were then analyzed visually for particle size and content. Composite samples were taken of various segments of the cores for chemical analysis. See Figure 6.1 for a map of the sample locations. Core samples were also taken in the Fredonia Reservoir to be used for comparison purposes. Samples were analyzed by Microbac Laboratories in Erie, Pennsylvania, a New York State Health Department certified lab. Laboratory methods and detection limits used by Microbac are given in Table 6.1. Samples were bagged, refrigerated, and transported to the lab for analysis.

Table 6 .1: Microbac Laboratory Methods and Detection Limits

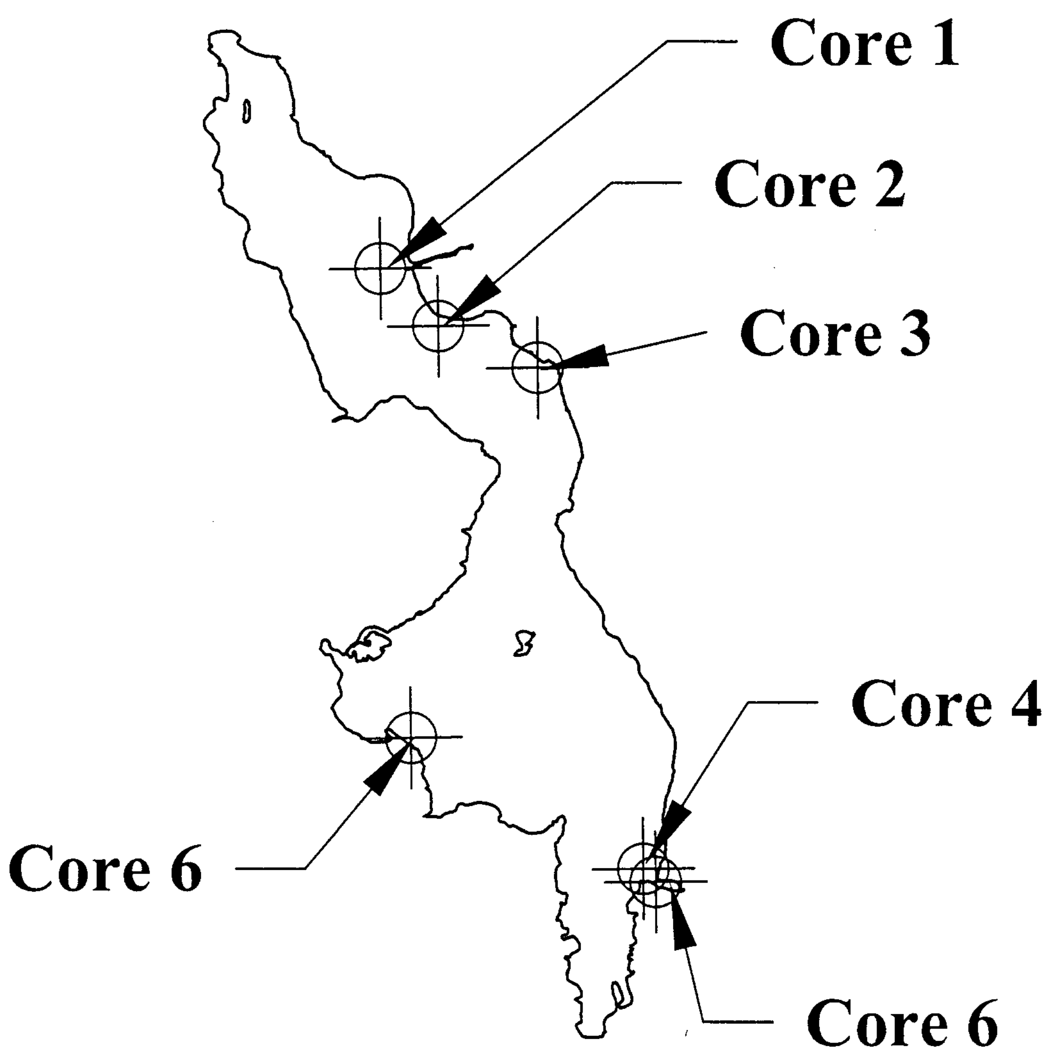
Parameter	EPA Method Number	Method Description	Detection Limit (mg/kg)
Phosphorus, Total	365.2	Colorimetric, one reagent	0.1
Nitrogen, Kjeldahl	351.3	Colorimetric	0.1
Arsenic, Total	SW846 7061	AA, Gaseous Hydride	0.5
2,4-D	SW846 8151A	GC Capillary Column with Electron Capture Detector	0.01

The following information was recorded at each sample site: the total depth that the sampler was driven, the length of material recovered in the sampler, and the position using global positioning satellites (GPS).

Data Quality Control

Laboratory quality assurance included the collection of duplicate field samples and the tracking of in-lab quality assurance and quality control (QA/QC) procedures and results. Results of duplicate field samples are given in Table 6.2. The relative percent difference (RPD) between

Figure 6.1: Locations of Sediment Core Samples Taken December 1998



Brief Description of Bottom Sediment Cores from Findley Lake
Core #1 - Washed out material from creek
Core #2 - Organic material over silt and clay
Core #3 - Organic material over sand and gravel
Core #4 - Organic material over silt and clay
Core #5 - Organic material over iron oxidized silt and clay
Core #6 - Organic material over peat.

each sample and its duplicate is a measure of laboratory precision. USEPA (1994) recommends a control limit of ± 20% for the RPD. Any results falling outside of this interval should be used only as an estimated value. All duplicate sample results fell within the control limits thus validating the use of this data.

Table 6.2: Duplicate Sampling Results

Sample ID	Sample Date	Phosphorus,Total (mg/kg)	Nitrogen,Kjeldahl (mg/kg)	Arsenic (mg/kg)	2,4-D (mg/kg)
C1-2	12/8/98	159	1025	11.1	<0.01
Duplicate		179	1060	12.5	<0.01
RPD		11.8	3.4	11.8	0
C1-3	12/8/98			11.1	
Duplicate				12.2	
RPD				9.4	

As part of their internal QA/QC Microbac analyzed a standard reference solution with each analyte as well as performing a duplicate and matrix spike analyses for each analyte. The RPD for in lab duplicates should be ± 20%. The percent recovery on the reference standard should be 100 ± 10% and the percent recovery on the spike should be 100± 20% (USEPA, 1994). The results of the internal quality control are shown in Table 6.3. Note that the arsenic samples were run in 3 different batches, which necessitated the need for three sets of quality control samples. All of the quality control results were within their respective control limits, which validates the data.

Table 6.3: Internal Quality Control Results

Parameter	%RPD	Reference % Recovery	Spike % Recovery
Phosphorus, Total	1.51	100.0	99.0
Nitrogen, Kjeldahl	2.51	101.0	
Arsenic	2.86	102.0	92.0
	1.96	100.0	101.0
	5.42	98.0	93.0

RESULTS

A total of 6 core samples were taken at Findley Lake over a period of 8 days. One core sample was taken at Fredonia Reservoir to use as a basis of comparison. Table 6.4 contains the sampling statistics for both the Findley Lake and Fredonia Reservoir samples. Note that the phosphorus and nitrogen statistics are based on 12 samples for Findley Lake and 2 samples for Fredonia Reservoir. Arsenic statistics are based on 22 samples for Findley Lake and 4 samples for Fredonia Reservoir. One arsenic result for Findley Lake was discounted because it was a factor of 10 higher than all other results, due most likely to a lab calculation or reporting error. A complete table of the results is included at the end of this chapter. All original field data collection sheets, laboratory certificates of analyses, and chain of custody forms are on file at the Chautauqua County Department of Health.

Table 6.4: Sample Statistics

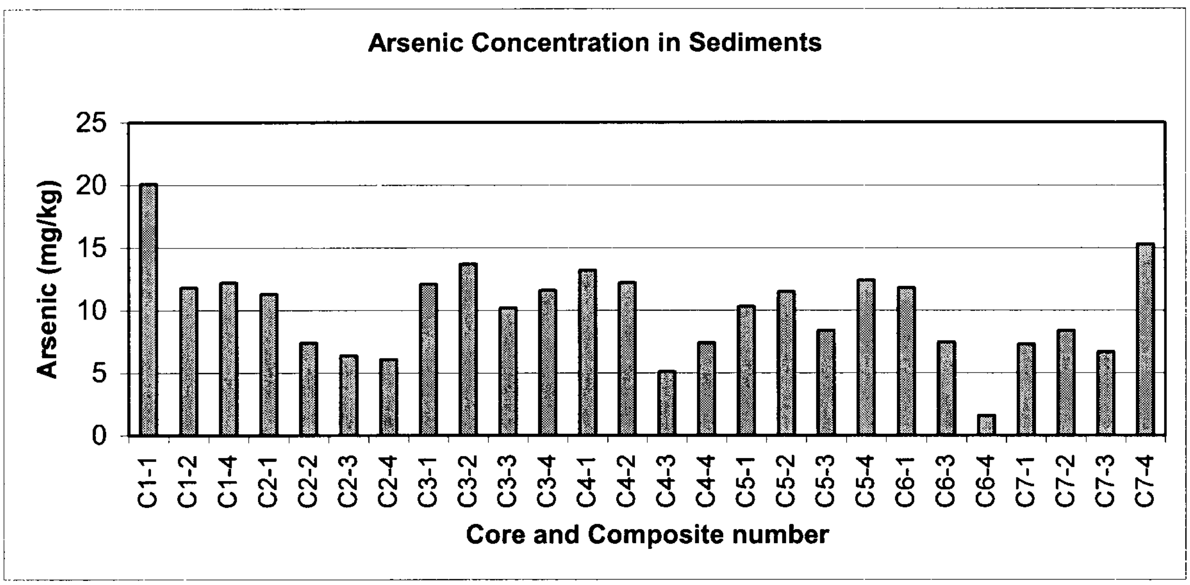
Sample Location	Total Phosphorus (mg/kg)			Kjeldahl Nitrogen (mg/kg)			Arsenic (mg/Kg)		
	min	max	mean	min	max	mean	min	max	mean
Findley Lake	26	220	131	1043	2230	1525	1.6	20.1	10.2
Fredonia Reservoir	182	196	189	885	1310	1098	6.7	15.3	9.4

The statistics indicate that the only analyte that significantly differs from typical background concentrations (Fredonia Reservoir) is Kjeldahl Nitrogen.

Cores were numbered in the order in which they were taken. Samples for chemical analysis are numbered using a combination of the core number and a composite number (example C1-2 represents core #1, composite #2). Composite number 1 samples are taken nearest the sediment water interface with successive numbers moving deeper into the sediment.

Figure 6.2 contains the results of the arsenic testing. If in fact the arsenic that was added to Findley Lake as an herbicide in the 1950s remained in the sediment, you would expect to find an area of higher concentration in each core. This is evidenced in cores 1, 2, 4, and 6 where the composite nearest the water/sediment interface contained the highest concentration of arsenic. The concentration gradient is especially marked in core #6 which is located in an area that is sure to have received repeated treatments of arsenic based herbicides.

Figure 6.2: Arsenic Concentration in Sediments



However, there are indications that the arsenic levels detected in Findley Lake sediments are no greater than the natural occurring levels in this area. The sediments in Findley Lake showed an arsenic concentration in the range of 1.6 to 20.1 mg/kg. A study completed by Malcolm Pirnie, Inc. at the Ellery Sanitary Landfill site showed natural soils having an arsenic concentration in the range of 6.4-24 mg/kg. The arsenic concentrations in core #7 taken in the Fredonia Reservoir were in the same range at 6.7 to 17.3 mg/kg. Though arsenic was detected in what would be considered "normal" levels in the lake sediment, it is quite possible that a very thin layer of sediment in the cores could contain much higher levels than these data suggest.

Figures 6.3 and 6.4 contain the results of the total phosphorus and Kjeldahl nitrogen testing. The concentration of each analyte does not appear to either consistently increase or decrease with depth. An attempt was also made to correlate the concentration of each analyte with the type of material in the composite (logs of the core samples are shown at the end of this chapter). The concentration of nitrogen and phosphorus did not correspond with the amount of organic material in the sample. There were several composites made of mostly silt and clay that had high nitrogen and phosphorus contents, and in fact samples with the highest nitrogen concentration did not necessarily have a high phosphorus concentration.

Figure 6.3: Phosphorus Concentration in Sediments

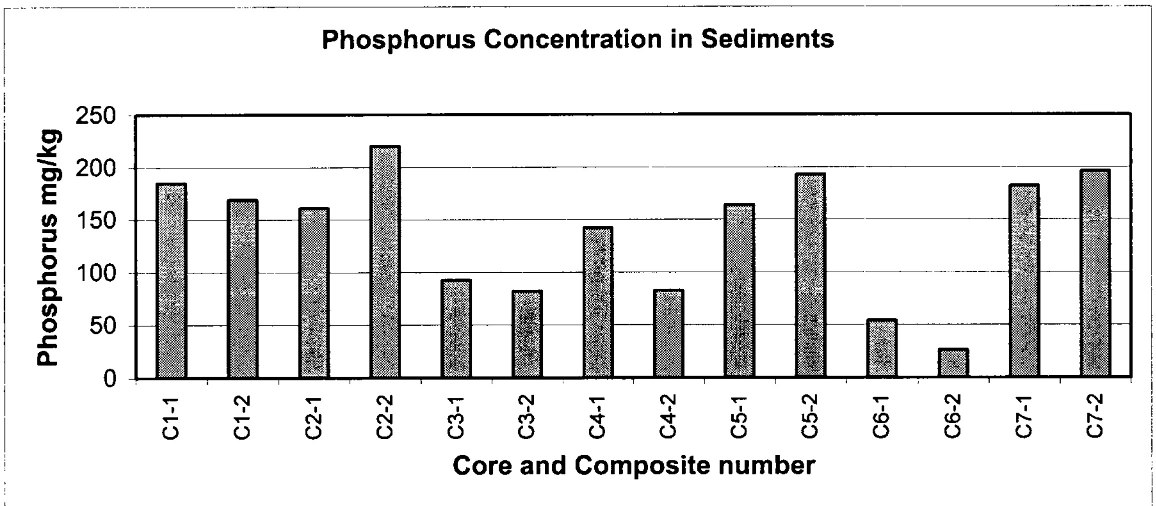
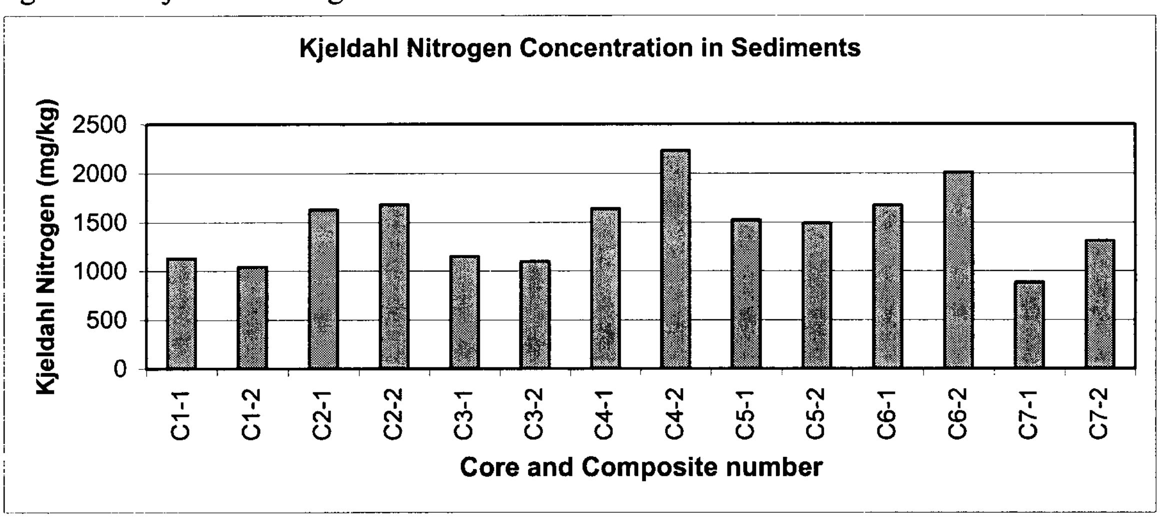


Figure 6.4: Kjeldahl Nitrogen Concentration in Sediments



Further evaluation of the core samples indicated a distinct difference between cores #1 and # 5. Both of these cores were taken in areas where creeks enter the lake. Core #1 was taken where Buesink's Creek enters the lake, and core #5 was taken where Walker's Creek enters the lake. Core #1 contained distinct layers of leaves and leaf fragments, inter-layered between sand and silts, whereas core #5 contained a layer of organic material at the water sediment interface lake. Core #1 contained distinct layers of leaves and leaf fragments, inter-layered between sand and silts, whereas core #5 contained a layer of organic material at the water sediment interface over lying silt and clay with no leaf layers. This shows that Buesink's creek is transporting large amounts of sediment (apparent by the presence of coarse silt and sand) and large quantities of deciduous leaves, at routine intervals during recent times. This has caused the formation of a substantial delta at the mouth of the Buesink's Creek, but not at Walker's Creek. Similar leaf/sediment layering was observed in cores from the Fredonia Reservoir. The presence of interbedded leaf layers in a delta may provide insight to the rates of both delta building and lake and reservoir sedimentation. More research is needed to make such a correlation.

SUMMARY

Lake bottom sediment samples were analyzed for two chemical herbicides known to be widely used for aquatic weed control in the 1950s and 60s, and for phosphorus and nitrogen. Results indicate that Arsenic concentrations decrease with sediment depth, the highest concentrations being found near the sediment-water interface. However, there are indications that the arsenic levels detected in Findley Lake sediments are no greater than the natural occurring levels in this area. Levels of the herbicide 2,4 D in sediment samples were below the laboratory's detection limit. Phosphorus levels are similar to that measured in Fredonia Reservoir sediment samples, while nitrogen levels are somewhat higher than those in the reservoir.

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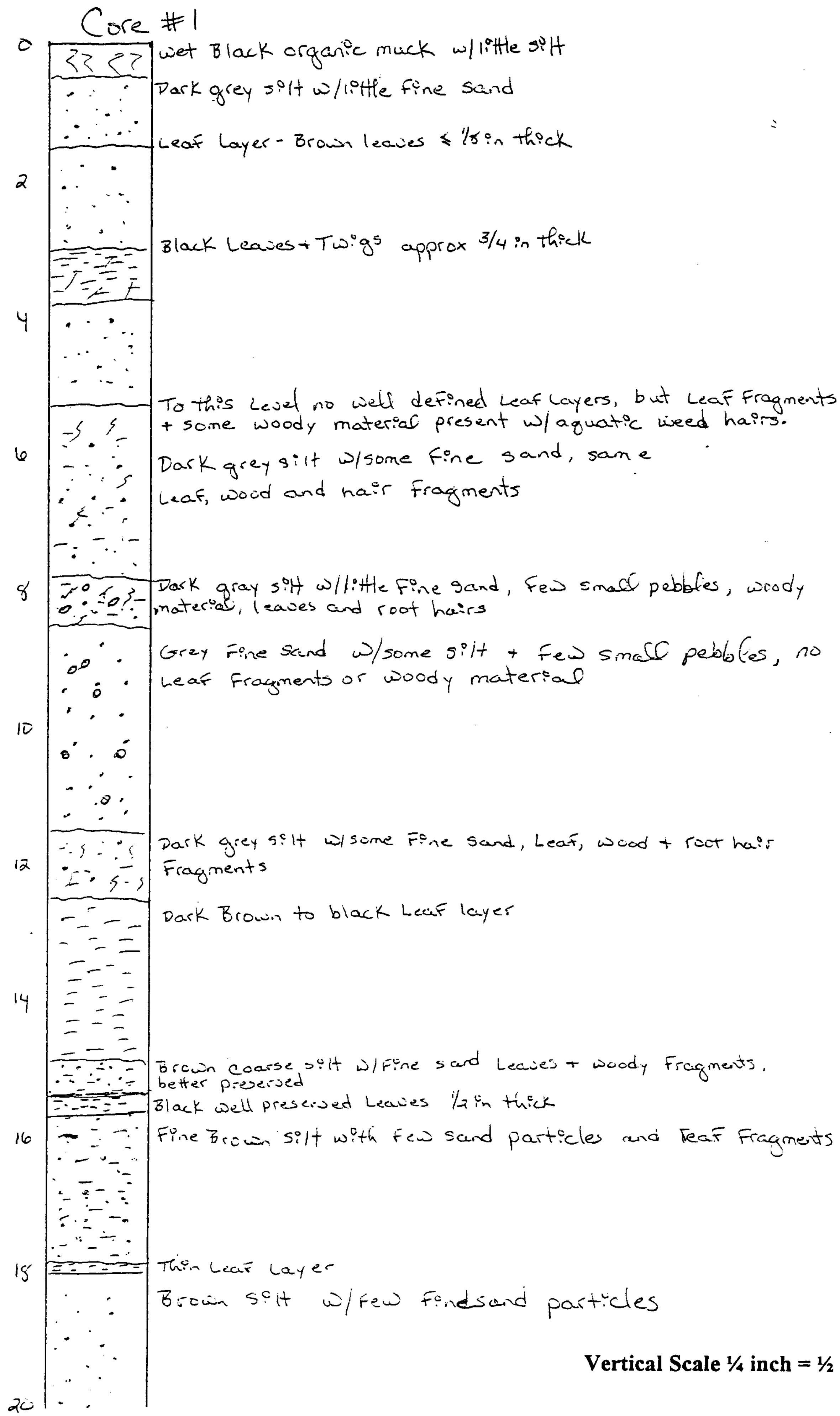
Sediment Core Data

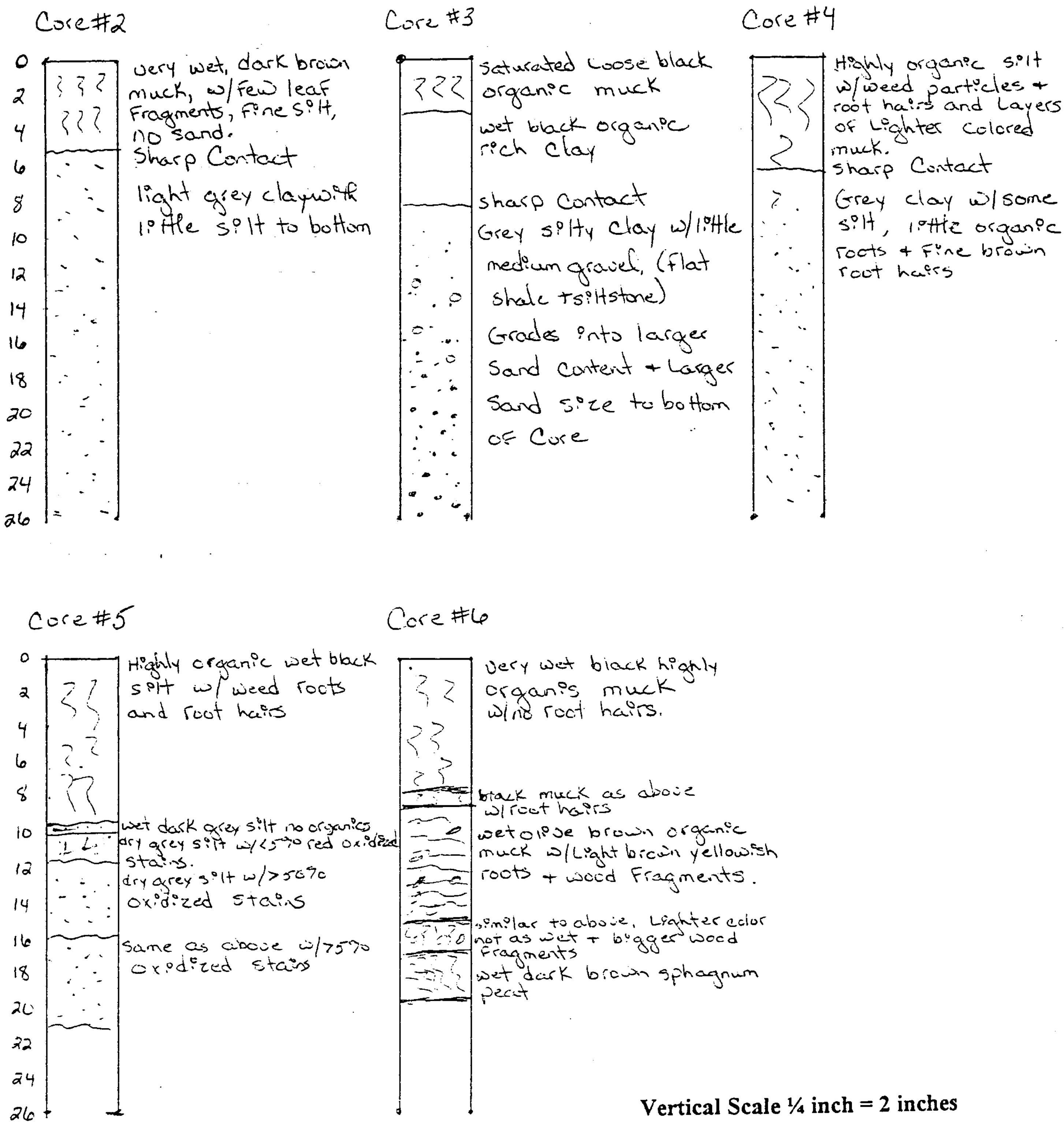
Core/Composite #	Date Sampled	Total Phosphorus as P (mg/kg)	Kjeldahl Nitrogen (mg/kg)	Arsenic (mg/kg)	2,4-D (mg/kg)
C1-1	12/08/1998	185	1130	20.1	<0.01
C1-2	12/08/1998	159	1025	11.1	<0.01
C1-4	12/08/1998			12.2	
C2-1	12/08/1998	161	1630	11.3	<0.01
C2-2	12/08/1998	220	1680	7.4	<0.01
C2-3	12/08/1998			6.4	
C2-4	12/08/1998			6.1	
C3-1	12/08/1998	92.5	1150	12.1	<0.01
C3-2	12/08/1998	81.7	1100	13.7	<0.01
C3-3	12/08/1998			10.2	
C3-4	12/08/1998			11.6	
C4-1	12/09/1998	142	1630	13.2	<0.01
C4-2	12/09/1998	82.5	2230	12.2	<0.01
C4-3	12/09/1998			5.1	
C4-4	12/09/1998			7.4	
C5-1	12/09/1998	164	1520	10.3	<0.01
C5-2	12/09/1998	193	1490	11.5	<0.01
C5-3	12/09/1998			8.4	
C5-4	12/09/1998			12.4	
C6-1	12/15/1998	54	1675	11.8	<0.01
C6-2	12/15/1998	26.3	2010	102**	<0.01
C6-3	12/15/1998			7.5	
C6-4	12/15/1998			1.6	
C7-1		182	885	7.3	<0.01
C7-2		196	1310	8.4	<0.01
C7-3				6.7	
C7-4				15.3	

** Note this result was discarded as a possible computational or reporting error.



Vertical Scale ¼ inch = ½ inch

Log of Core #1



Vertical Scale ¼ inch = 2 inches

Log of Cores 2 through 6