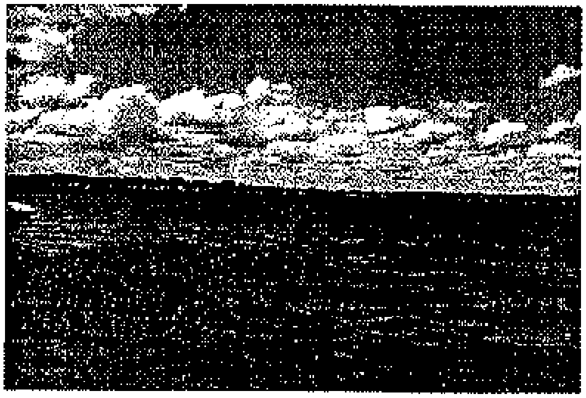
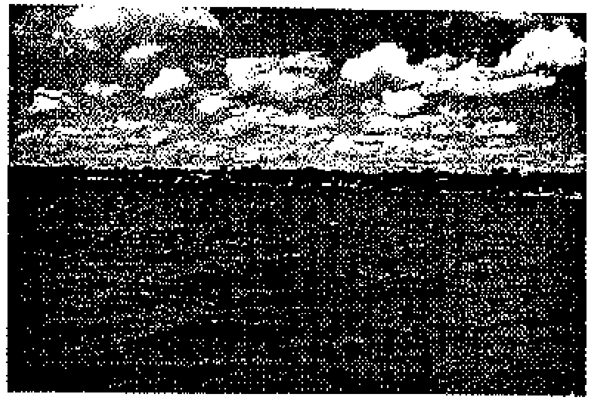
STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
FOR

WALLED LAKE


SHAWOOD LAKE


MEADOWBROOK LAKE

JCK & associates, inc.

Consulting Engineers • Architects • Land Surveyors
• Environmental Services • Planners •

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August 12, 1999

Mr. Anthony Nowicki - Director of Public Services
City of Novi
45175 W. Ten Mile Road
Novi, Michigan 48375

Re: Stormwater Sediment and Aquatic Plant Study

JCK No. N-6238

Dear Mr. Nowicki:

Based on your comments of the draft report, enclosed find the final version of the "Stormwater Sediment and Aquatic Plant Study" for Walled Lake, Shawood Lake and Meadowbrook Lake. Enclosed are five copies for your distribution. If you need additional copies please let us know.

Based on the review of the data obtained for Walled Lake, Shawood Lake and Austin Canal our findings are that hydraulic dredging of lake bottom sediments is **not** recommended at this time. In addition **no** aquatic plant removal or herbicide treatment is recommended at Walled Lake, Shawood Lake or Austin Canal at this time.

Sediments from natural streambank erosion and runoff, in addition to possible construction activities have left substantial deposits of sediments at the points where the middle branch of the Rouge River and Ingersol Creek discharge into Meadowbrook Lake. Therefore, it is recommended that the sediment which has been deposited in Meadowbrook Lake at the north end be removed by hydraulic dredging.

Estimated general project costs are approximately $18 - $20 per cubic yard of material removed.

It is recommended that if the City of Novi plans to proceed with the project recommended at this time, that this estimate does **not** include any costs associated for right-of-way , easements that may be required or disposal. An application for a Rouge Program Office (RPO) grant should be applied for in an effort to acquire funds to help defer the costs associated with the recommended lake dredging project.

If you have any questions or need additional information, please contact our offices at (248) 348-2680.

Sincerely,

JCK & Associates, Inc.
Consulting Engineers for the City of Novi

C. Benjamin Farnham

C. Benjamin Farnham
Director of Environmental Services

cc: Tonni Bartholomew, Clerk City of Novi
Dave Potter, JCK
Doug Pakkala, JCK
file

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE AND MEADOWBROOK LAKE

CITY OF NOVI
OAKLAND COUNTY, MICHIGAN

Prepared for:

City of Novi and the Stormwater Financial Review Committee
for Walled Lake, Shawood Lake and Meadowbrook Lake
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JCK & Associates, Inc. Project No.: N-6238-00

DATE: AUGUST 9, 1999

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STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

I. INTRODUCTION

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I. INTRODUCTION

A. PURPOSE OF STUDY

The purpose of this study is to present the findings of an aquatic plant survey performed on Walled Lake and a sediment study for limited areas on Walled Lake, Shawood Lake and Meadowbrook Lake. This study was prepared based upon request by the City of Novi Stormwater Financial Review Committee. See Appendix I.

Specifically, this study will review the three subject lakes with respect to water quality and sedimentation; determine the need for control measures; develop a control measure implementation plan; and prepare plans, specifications, estimates of costs, and the preparation of appropriate permit applications.

B. STUDY OBJECTIVES

A proposal for professional services was prepared by JCK and Associates, Inc., for the City of Novi. A copy of the proposal is included in Appendix II. The following items, while not all inclusive, were proposed as the basic requirements of the study:

WALLED LAKE

1. Analyze aquatic plant growth in identified areas and make recommendations for removal and control. Prepare a map which shows the locations and types of aquatic vegetation and approximate lake bottom contours using existing data. Initial aquatic plant observations to be performed in July and a follow-up in September.

2. Determine water quality in these identified areas, such as inlets and high growth areas, using the following listed parameters and recommend appropriate action to improve water quality:

    a. pH
    b. Oxygen Concentration
    c. Phosphorus Concentration
    d. Nitrogen Concentration
    e. Chlorophyll *a* Concentration
    f. Secchi Disk Transparency
    g. Theoretical Nutrient Budget

3. Evaluate lake bottom sediments and associated nutrients in high plant growth areas, evaluate their removal and appropriate disposal, if necessary.

4. Investigate alternative methods of plant control including chemical and mechanical methods, aeration, dredging, etc.

WALLED LAKE, SHAWOOD LAKE AND MEADOWBROOK LAKE

1. Identify areas adjacent to the selected stormwater outfall into the lakes that have deposited sediments into the lakes.

2. Perform a lake bottom topographic survey in the identified areas and perform a chemical analysis of the sediments to determine removal and disposal requirements, if appropriate.

3. Prepare a report detailing findings along with cost estimates and permit requirements for the sediment removal, if applicable.

C. HISTORICAL LAKE CHARACTERISTICS

Walled Lake

The Walled Lake area and the adjacent land were influenced by Glaciers approximately 12,300 years ago. At that time, the Huron-Erie Lobe of the Wisconsin glaciation (the latest in a series of many ice advances) stalled near the Walled Lake area as it was receding toward the east. Walled Lake was probably develop as a "kettle lake", meaning that it was formed because a large remnant block of glacial ice melted sometime after the majority of the glacial ice had receded. (1983, U of M - Architecture & Urban Planning and 1984, O.C.D.C. - Lake Level Control Study)

A map of the "Walled Lake Watershed Area" can be seen in Figure 1.1. The tributary area draining to Walled Lake is approximately 2,614 acres, which consist of three communities; the City of Novi, the City of Walled Lake and Commerce Township. The surface area of Walled Lake is approximately 645 acres, at a water surface elevation of approximately 932.27 (Surveyed level as of 2/2/99). The volume of water contained within Walled Lake is approximately 358 million cubic feet or 8,221 acre-feet. The Lake is approximately 50 feet deep at its deepest point, based upon the existing bottom contour map prepared for Walled Lake, dated 1984, O.C.D.C. - Lake Level Control Study. Much of the near-shore area is very shallow, thus subject to aquatic plant weed growth.

Walled Lake is currently within the jurisdiction of two communities; City of Novi and Walled Lake. The land adjacent to Walled Lake has been developed for residential and some commercial uses. As land development continued within the watershed, a system of storm drainage systems were constructed as part of those developments, which discharge directly into Walled Lake. The level of Walled Lake is controlled by a lake level control structure located at the southwest end of the lake, that discharges into the Middle Branch of the Rouge River. The outlet control works are operated and maintained by the Oakland County Drain Commissioner.

Shawood Lake

Shawood Lake was most likely created during the same period of glacial activity that created Walled Lake. Historically, Shawood Lake has been known by many names such as Mudd Lake, Pond Lake, Fish Lake and even platted as "Swamp" in 1825. All of these names have a descriptive commonality to them due to the soft bottom and shallow depths of the lake.

A map of the "Shawood Lake Watershed Area" can be seen in Figure 1.2. The tributary area draining to Shawood Lake is approximately 381.7 acres, which consists of land within the City of Novi. The surface area of Shawood Lake is approximately 34.9 acres, at a water surface elevation of approximately 932.35 (as surveyed on 2/2/99). The volume of water contained within Shawood Lake is approximately 3.67 million cubic feet or 84.3 acre-feet. The Lake is approximately 6 feet deep at its deepest point, based upon the lake bottom contour map prepared for Shawood Lake as part of this study. This lake is considered very shallow, and is thus subject to aquatic plant weed growth.

Shawood Lake is located within the sole jurisdiction of the City of Novi. The land adjacent to the east side of Shawood Lake has been developed primarily for residential uses, with limited commercial use. The land adjacent to the west side of Shawood Lake is currently owned by the City of Novi. As land development continued within the Shawood Lake watershed, a system of storm drainage systems were constructed as part of the adjacent residential and/or commercial developments. The storm water runoff within the watershed is directed to Shawood Lake and is discharged directly into Shawood Lake or Shawood Lake canal which runs from Old Novi Road to Shawood Lake. Shawood Lake discharges into Walled Lake via an existing road culvert under South Lake Drive. The level of Shawood Lake is also controlled by the Oakland County lake level control structure located at the southwest end of the Walled Lake, which discharges into the Middle Branch of the Rouge River.

Meadowbrook Lake

Meadowbrook Lake was originally a segment of the Walled Lake Middle Branch Rouge River. The land adjacent to this segment of the Rouge River was excavated and made into a "lake" as it is known today. Meadowbrook Lake is located on the southern end of the City of Novi and a large majority of the storm water runoff from the upstream reaches of the City of Novi will flow through Meadowbrook Lake, due to it's location.

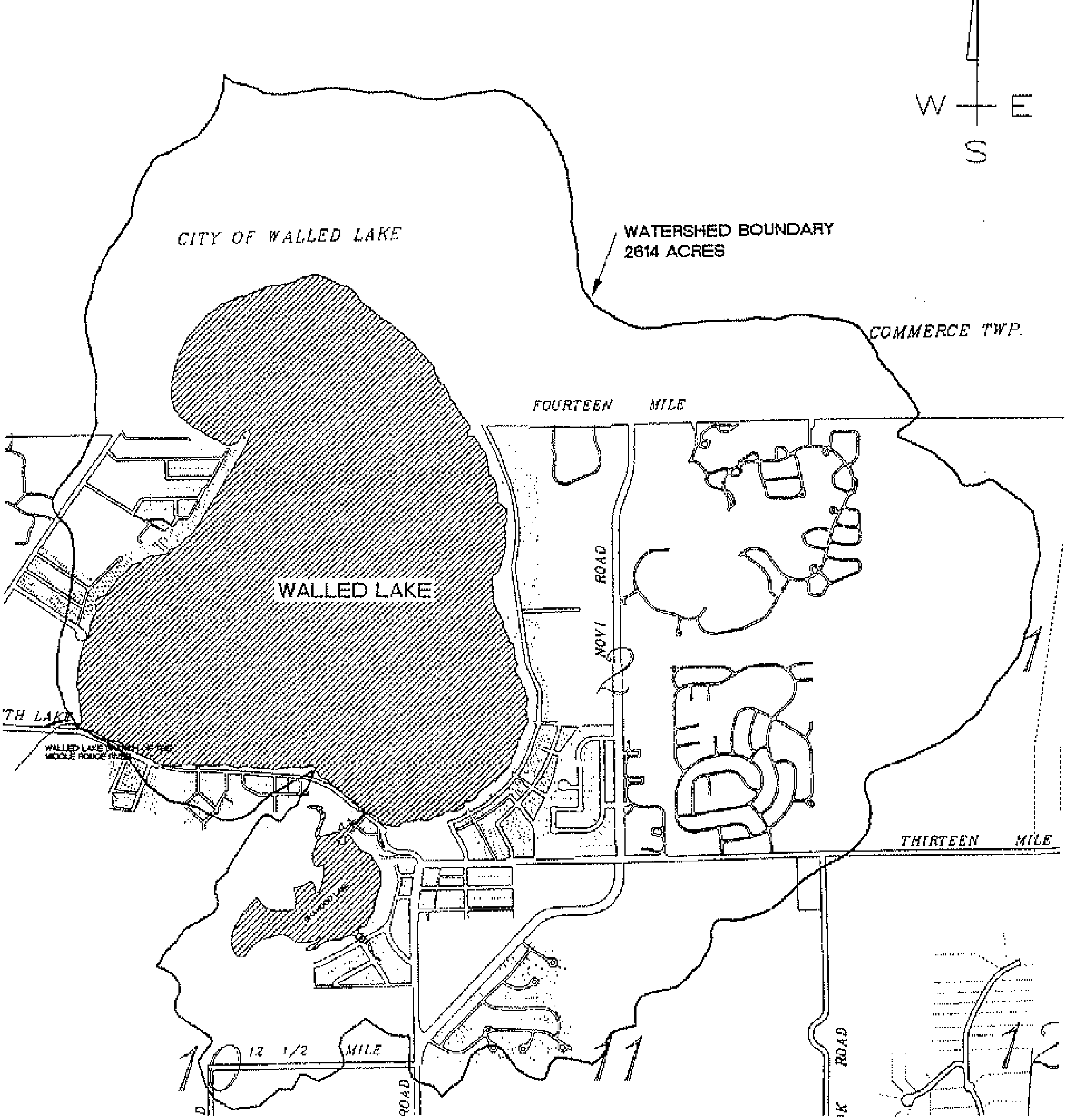
A map of the "Meadowbrook Lake Sub-Watershed Area" can be seen in Figure 1.3. The area tributary to Meadowbrook Lake within the sub-watershed area is approximately acres. The total tributary area draining to Meadowbrook Lake is approximately 12,450 acres, which consists of the majority of the City of Novi Watershed. The surface area of Meadowbrook Lake is approximately 12.9 acres, at a water surface elevation of approximately 837.00. The volume of water contained within Meadowbrook Lake is approximately 4.5 million cubic feet or 102.7 acre-feet. The Lake is approximately 11 feet deep at its deepest point, based upon the existing bottom contour map prepared for Walled Lake, dated 1983.

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

I. INTRODUCTION

FIGURES

WATERSHED AREA MAP FOR WALLED LAKE



STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
WALLED LAKE, SHAWOOD LAKE, AND MEADOWBROOK LAKE

CITY OF NOVI

JCK & associates, inc.

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CONSULTING ENGINEERS
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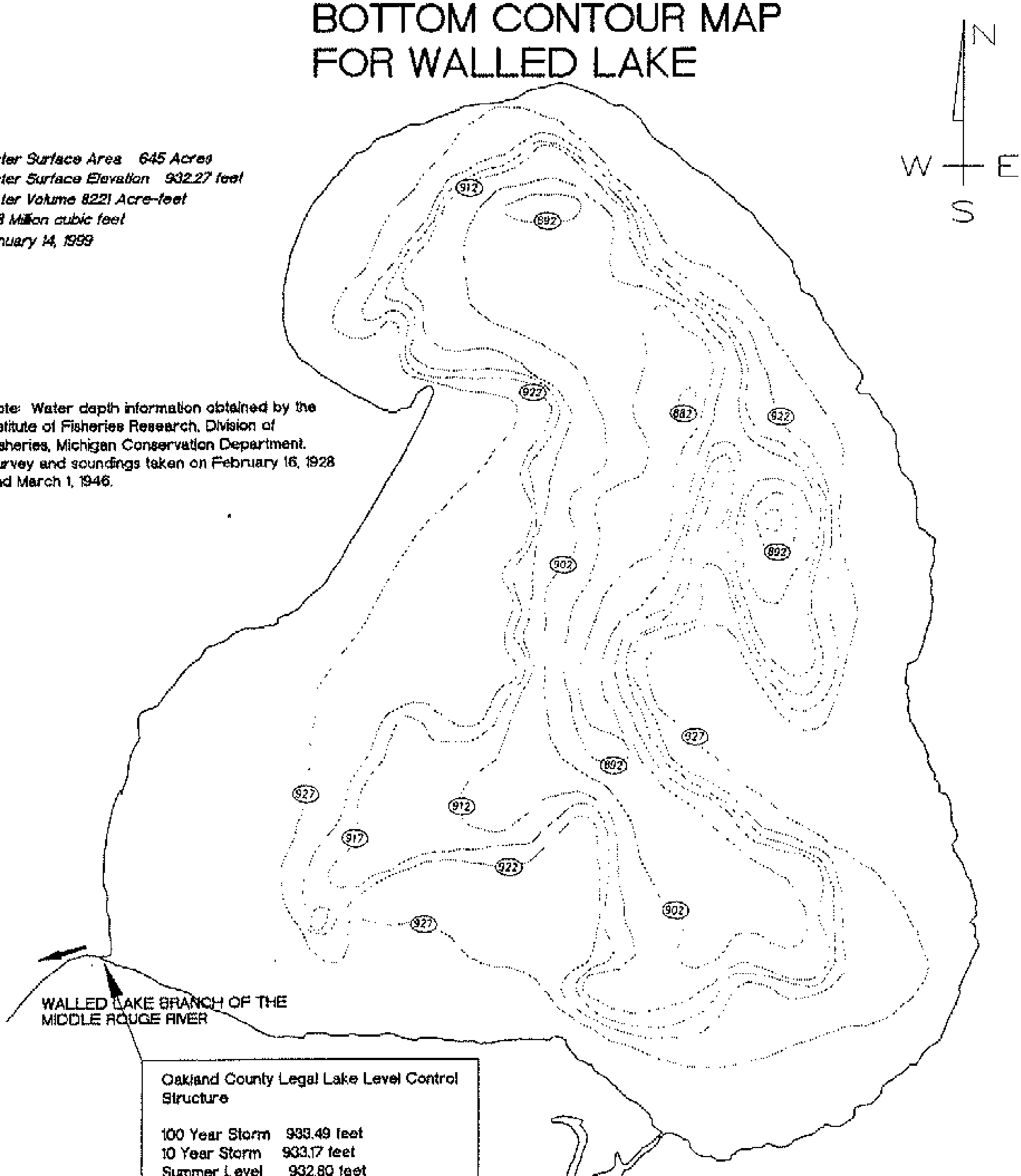
BOTTOM CONTOUR MAP FOR WALLED LAKE

Water Surface Area 645 Acres
Water Surface Elevation 932.27 feet
Water Volume 8221 Acre-feet
358 Million cubic feet
January 14, 1999

Note: Water depth information obtained by the Institute of Fisheries Research, Division of Fisheries, Michigan Conservation Department. Survey and soundings taken on February 16, 1928 and March 1, 1946.



Oakland County Legal Lake Level Control Structure

100 Year Storm 933.49 feet
10 Year Storm 933.17 feet
Summer Level 932.80 feet
Winter Level 932.10 feet

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
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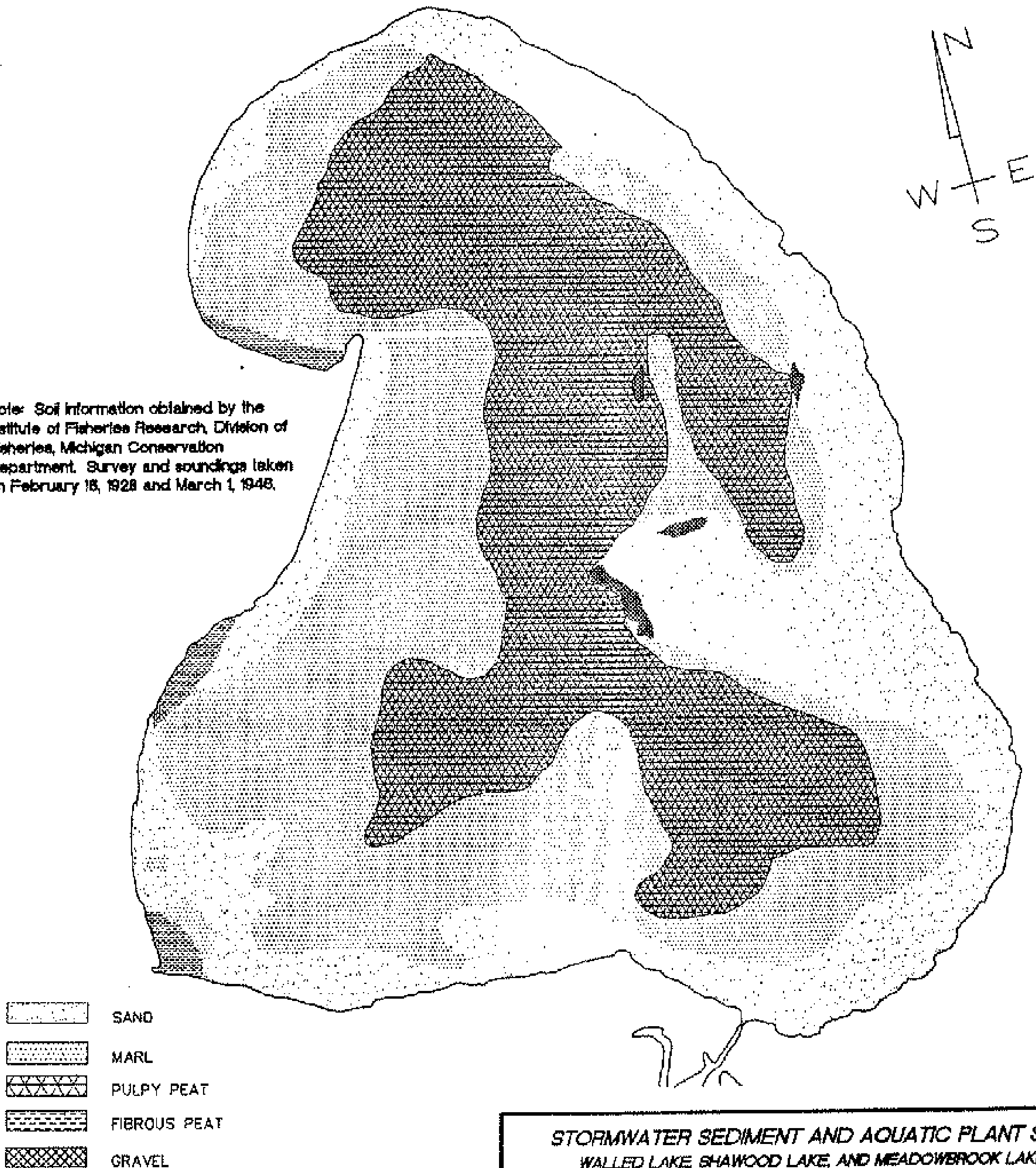
SOIL TYPES FOR WALLED LAKE



Note: Soil information obtained by the Institute of Fisheries Research, Division of Fisheries, Michigan Conservation Department. Survey and soundings taken on February 16, 1928 and March 1, 1946.

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
WALLED LAKE, SHAWOOD LAKE, AND MEADOWBROOK LAKE

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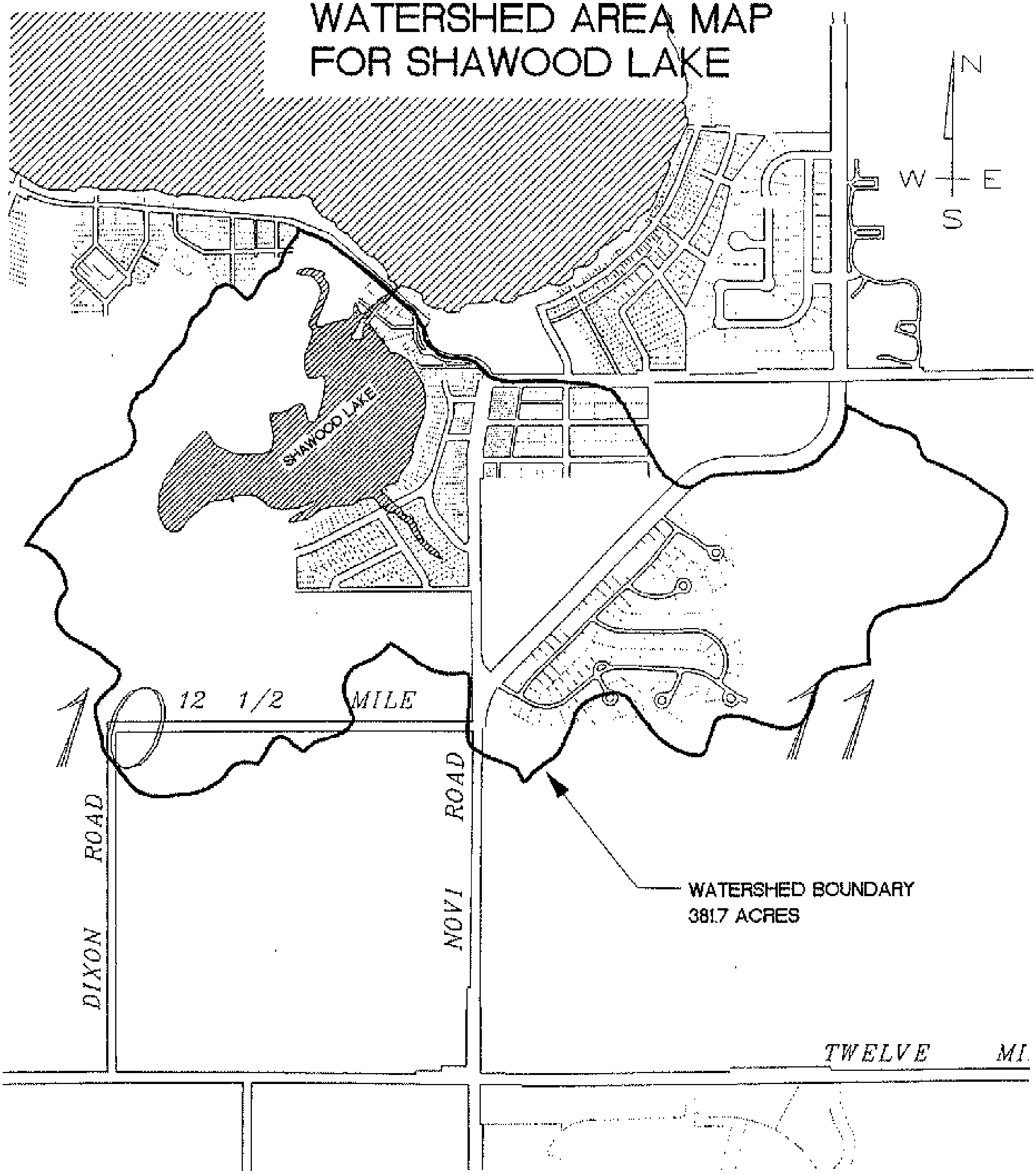
WATERSHED AREA MAP FOR SHAWOOD LAKE



STORMWATER SEDIMENT AND AQUATIC PLANT STUDY

WALLED LAKE, SHAWOOD LAKE, AND MEADOWBROOK LAKE

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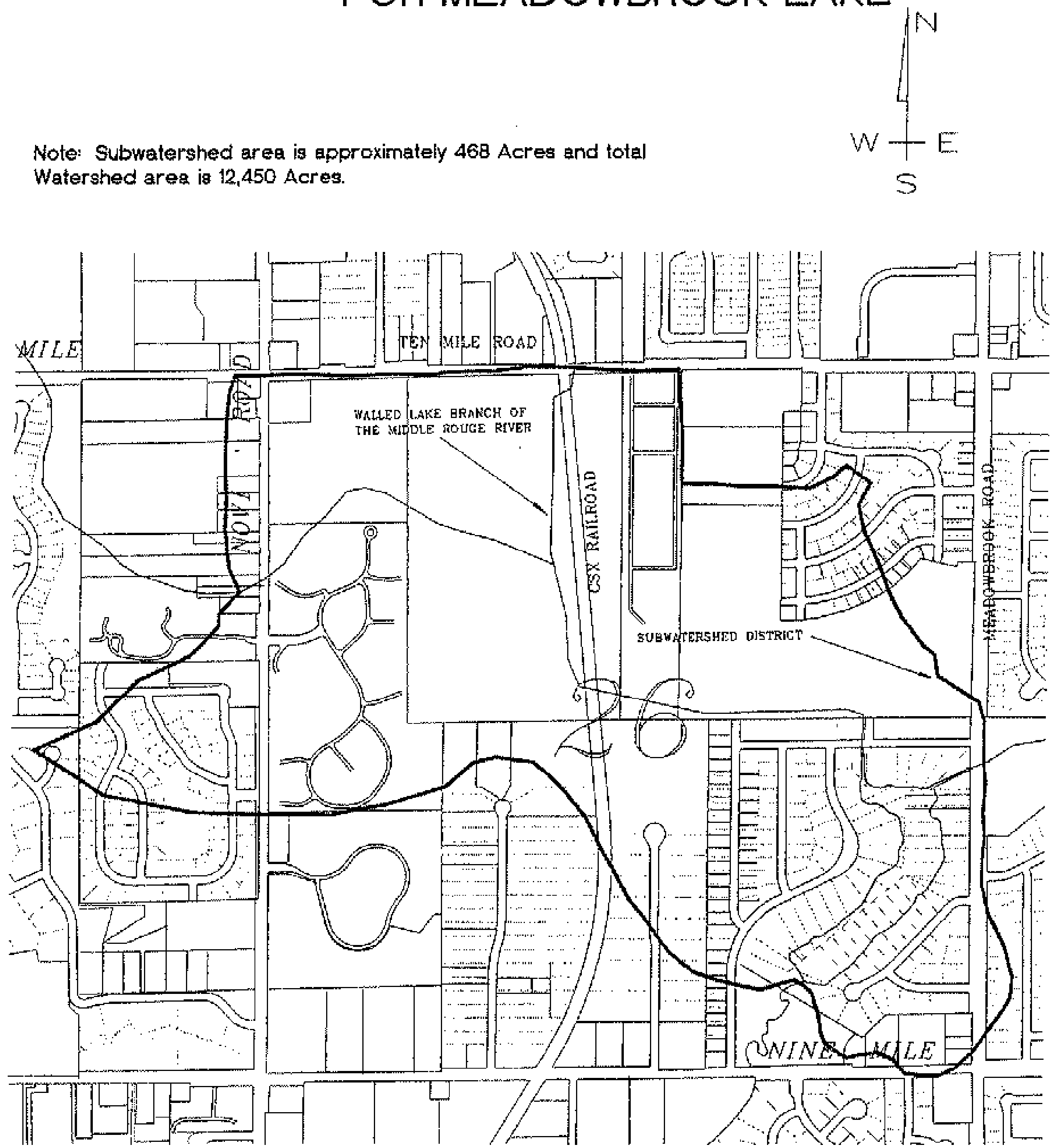
SUBWATERSHED AREA MAP FOR MEADOWBROOK LAKE

Note: Subwatershed area is approximately 468 Acres and total Watershed area is 12,450 Acres.



STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
WALLED LAKE, SHAWOOD LAKE, AND MEADOWBROOK LAKE

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STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

II. LAKE WATER QUALITY

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II. LAKE WATER QUALITY

A. INTRODUCTION

BACKGROUND

Lakes are one of the most important resources on our landscapes. Because the natural lake water quality obviously affects lake uses, an important goal for lake management is to identify and define the uses a lake could naturally support and to develop a compatible lake (and watershed) management plan support to restore a lake to this natural condition or protect and maintain it's current condition. This variability brings up a key point in lake management. Whatever the starting conditions and whatever the limitation on what can ultimately be achieved, the goal is always the same, to minimize lake water quality problems.

B. WATER QUALITY DISCUSSION

Lake water quality is not only dependent on physical parameters (physical, chemical and biological condition) of the lake, but also management of the watershed. To determine and recommend proper lake improvement action, all of these parameters must be studied to determine the standard of lake quality required while implementing a cost effective program.

Based on the visual inspection of the three lakes, it would seem that the largest concern is about the excessive plant life and algae and the sedimentation would be a close second. Below, are some critical areas which can contribute the majority of sediments and nutrients to the lakes:

- ☞ Flower and vegetable gardens contribute nutrients, sediments and pesticides, if not properly managed.
- ☞ Septic tank systems contribute nutrients and bacteria (currently only one known septic tank is in service in the immediate area of Walled Lake and Shawood Lake.
- ☞ A well manicured lawn contributes nutrients (fertilizers) and herbicides.
- ☞ Boat motors contribute nutrients from oils and grease.
- ☞ New construction contributes sediments.
- ☞ Road runoff contributes nutrients and sediments from oils and grease.
- ☞ Shoreline erosion can contribute nutrients and sediments.
- ☞ Large trees located along the shoreline can contribute nutrients to the lake.

Construction activities can be significant sources of sediment runoff. Sediment basins are man-made depressions in the ground where runoff water is collected and stored to allow suspended solids to settle out. They are used in conjunction with many other erosion control BMP's (Best Management Practices) to prevent off-site sedimentation. Their primary purpose is to trap sediment and other course material. Secondary benefits can include runoff control and preserving the capacity of downstream reservoirs, ditches, canals, diversions, waterways and streams. Sedimentation Basins along with their conjunctive measures makes them the most specified and accepted forms of sediment control. Stormwater and runoff from newer developments around the Lakes have to be routed through sedimentation basins before entering the Lake or its watershed. Two such examples of newer development are Bristol Corners and Lilley Pond Subdivisions. Both of these developments have sediment basins which take in stormwater and runoff from the entire active portion of the sites. Most of the sediment is settled out into the sump of the basin, then filtered through numerous types secondary controls. Secondary controls can be Buffer/Filter Strips, Geotextile Materials, Standpipes or Berms of Stone. After entering the "sediment basin process" stormwater should have settled out a large percentage of the sediment. The stormwater can now be released with better water quality into the Lake or watershed.

In general, the best management practices that can be implemented are these four primary, interactive processes:

- erosion control
- runoff control
- nutrient control
- pesticide or toxic controls

There are three stages to a lake's development; oligotrophic lakes, mesotrophic lakes and eutrophic lakes. Oligotrophic lakes are typically clear, with little aquatic plant and algae growth due to few nutrients. These lakes are generally deep with a sandy or marly bottom and steep slopes. Eutrophic lakes have higher nutrient levels therefore, large amounts of aquatic plant life. The water may be cloudy due to the abundance of suspended algae cells, and typically is shallow with a mucky bottom. Mesotrophic lakes fall somewhere between oligotrophic and eutrophic lakes, exhibiting some signs of eutrophication.

C. WATER QUALITY PARAMETERS

Dissolved Oxygen - Dissolved Oxygen (DO) is one of the most important water quality factors because of its effect on aquatic flora and fauna, and especially on the ability of a water body to degrade organic wastes. All regulatory agencies within the United States have a DO standard for natural waters, such as the DO shall never be less than 4 mg/L. The concentration 5 mg/L is often specified as the acceptable minimum.

DO content is a measure of the ability of surface waters to support aquatic life. Oxygen is poorly soluble in water, and the DO is dependent on three primary parameters; temperature, atmospheric pressure and dissolved solids. Generally the critical conditions for DO deficiency typically occur during the late summer months when the temperatures are high, biological processes are enhanced, and stream flow, if any, is slow. If oxygen demands exceed the rate of production of DO enough so that the DO in the water is completely depleted, anaerobic conditions can produce winter and summer fish kills and also lead to production of methane and other noxious gases. During summer months, the DO in shallow eutrophic lakes may be depleted following a rapid algae die-off. Severe DO depletions can occur from natural causes, but they can also result from unwise management; for instance, treating an algae bloom in the entire lake with herbicides can drastically reduce the DO and cause fishkill. Also, for lakes that freeze at the surface during the winter months, DO can be reduced by the end of winter to conditions that cause fishkill.

The dissolved oxygen of Walled Lake is shown to be 8.22 mg/L. This is a reasonable level to support small, warm water fish such as bass, bluegill and crappie. The morning reading of DO was significantly lower than the afternoon due to the daytime photosynthesis. *The test result for DO in Shawood Lake was 11 mg/L.* The higher amount is due to the large amount of weed growth in the lake.

Phosphorous - Phosphorous is an important component of organic matter. In many lakes, phosphorus is the limiting nutrient that prevents additional productivity (biological activity) from occurring. When this is the case, the control of phosphorus in run-off waters and non-point-source pollution is important. Critical levels of phosphorus causing excessive algae and weed growth can be as low as 0.005 to 0.01 mg/L, but concentrations are more frequently on the order of 0.05 mg/L. The origin of phosphorus in lakes is the mineralization of phosphates from the soil and rocks, or drainage containing fertilizer or other industrial products.

Walled Lake has a phosphorus concentration of approximately 0.02 mg/L. High concentrations of phosphorus whether naturally occurring or allowed to enter the lake, can stimulate algae productivity. Such high productivity, however, may result in nuisance algae blooms, noxious tastes and odors, oxygen depletion and undesirable fishkills during winter and summer. *The phosphorus concentration of Shawood Lake is approximately 0.03 mg/L.* Notice the concentrations are even higher. This does not mean that Shawood Lake has a phosphorus problem, it is just an indicator that the phosphorus levels in the Shawood Lake have higher naturally occurring levels from the mineralization of phosphates from the soil and rocks, or drainage discharges possibly containing fertilizer.

Since phosphorus is most often the nutrient that limits algae productivity, it is usually the element that is the focus of many lake management or restoration techniques. Phosphorus loading can be reduced in the watershed by using proper agricultural and land management practices, improving septic systems and applying fertilizer carefully.

Nitrogen - The nitrogen cycle (Figure 2.4) is important to water quality for several reasons. Nitrification (oxidation of ammonia and nitrite and nitrate) consumes dissolved oxygen in the lake. Ammonia and nitrate are also important nutrients for the growth of algae and other plants. Excessive nitrogen can lead to eutrophication. Nitrogen is also an important component for cell building by bacteria and other aquatic animals.

Humans influence the stream nitrogen balance in at least three related ways; (1) Nitrate fertilizers and ammonia, (2) Nitrogen oxides are released from burning fossil fuels and other industrial activities and (3) Important forms of nitrogen include organic nitrogen, ammonia and nitrate.

The principal water quality criteria for nitrogen is to focus on nitrate and ammonia. The effects of nitrite are of concern but rarely approach elevations that need to be managed in a water quality cleanup for lakes. Nitrate concentrations exceeding 10 mg/L present potentially serious public health problems. *Maximum concentration in Walled Lake was 1.1 mg/L (using the Kjeldahl Nitrogen Method) found at the 43" x 66" outlet pipe. The maximum concentration found in Shawood Lake was 1.4 mg/L at the Austin Road inlet pipe.* Ammonia concentrations in lakes are generally in the range of 0.1 to 3.0 mg/L. *Walled Lake has a concentration of approximately 0.0425 mg/L and Shawood Lake has a concentration of 0.28 mg/L.* Concentrations greater than 0.5 mg/L tend to cause significant ammonia toxicity to fish and other organisms. Ammonia concentrations in groundwater is normally low because of adsorption of the ammonia into the soil.

Nitrite concentrations in many lakes rarely exceed 0.5 mg/L, most lakes have concentrations much lower and many times not detectable. *Nitrite concentrations in both Walled Lake and Shawood Lake were not detectable (less than 0.05 mg/L).*

Both nitrogen concentration results were well within the standards for lakes. Lakes and streams fed by shallow groundwater draining agricultural areas, however, may be more heavily polluted with nitrate. Fertilizer use, especially on lawns surrounding a lake contributes high concentrations of nitrate.

There are a number of ways to measure the various forms of aquatic nitrogen. Figures 2.4 and 2.5 show the relationship between the various types of measurements and the forms of nitrogen in the water. Typical measurements of nitrogen for lake surveys include Kjeldahl nitrogen (organic nitrogen plus ammonia), nitrite and nitrate.

pH (Hydrogen Ion Concentration) - The pH is measured on a scale of 0 to 14. A pH from 0 to 7 indicates "acidic" (0 being the most acidic); and 7 to 14 indicates "basic" (14 being the most basic). The pH is the negative logarithm of the hydrogen ion concentration; therefore, each unit of pH represents a tenfold increase in acid or base. Most lakes maintain a pH level between 7.5 and 8.0, but a pH level anywhere between 6.5 and 8.8 is acceptable. At high or low pH levels (below 4.5 and 9.6), the water becomes unsuitable for most organisms. Very acidic lake can cause leaching of heavy metals into the water, which is detrimental to aquatic life.

The concentration of gases, such as oxygen and carbon dioxide, directly influence the pH. A build-up of carbon dioxide from bacterial respiration causes the lake water to become slightly more acidic in the absence of oxygen. This is because the carbon dioxide reacts with the water to form carbonic acid which increases the amount of acid, therefore lowering the pH.

The pH is also a good indicator of acid rain. About 95% of the rain events in southeast Michigan have a pH below 5.6, considering them to be acid. However, it appears that no lake in southeast Michigan is affected by the acid rain.

The pH for Walled Lake varies from 8.4 to 8.8 and Shawood Lake varies between 7.8 and 8.2. This indicates "basic" lake conditions, however, the pH is within acceptable limits.

Macrophyte Biomass - Aquatic macrophyte communities range from completely submerged stand of large algae (for example, Chara, Cladophora) to stands of rooted plants with floating leaves (waterlily). Macrophyte densities vary seasonally, between lakes in an area. Densities also vary within a lake, eutrophic lakes generally have very high quantities of aquatic plants.

During a macrophyte survey, several tasks are normally accomplished. The first is mapping the location and extent of the major community types: emergents, floating leaves and submergent plants and abundance. Then, plant density, species identification, frequency, and depth of growth can be determined. This survey is generally another indicator that a lake is in eutorphication. It was concluded that Shawood Lake had significant amounts of aquatic plant growth, combined with numerous trees around the lake that this which causes a faster rate of organic matter to be deposited on the Lake bottom. Results of the aquatic plant study can be found in Section 3, Page 3.2.

Secchi Disk Transparency - Secchi depth is probably the most frequently used parameter in lake water quality testing (limnology). The Secchi disk is a 20 cm (8 inches) plastic or metal disk that is either painted entirely white or divided into alternating black and white quadrants. The disk is lowered into the water, and the observer measures the depth at which it can no longer be seen, then raises the disk again until it comes into view and the depth is read again. The average between the two depths is called the Secchi Transparency.

The assumption is that the greater the Secchi depth, the better the water quality of the lake. The transparency is based on the transmission of light through water and is related, in part, to the natural light attenuation of the water being measured, the amount of inorganic suspended solids, and the amount of organic suspended solids (algae cells). The relationship between the Secchi Transparency and the amount of algae biomass as expressed in chlorophyll-*a* has been developed for many regions. Northern United States lakes with Secchi depth of greater than 30 feet is considered to be oligotrophic while eutrophic lakes may have a reading of 7.5 feet or less during the summer algae blooms. Most lakes in southeastern Michigan have a Secchi Transparency of less than 10 feet.

The Secchi Transparency Disk application on Walled Lake read an average of 9.0 feet. There was no reading done at Shawood Lake because the disk was visible from the surface to the bottom of the lake in all test areas.

Temperature - Temperature patterns and/or thermal stratification influence the fundamental processes occurring in a lake such as dissolved oxygen depletion (solubility of gases), nutrient release, algae growth, types of organisms, and biological activity.

Temperature variations in a lake cause it to stratify into layers because the temperature affects the density of water. Temperature measurements are useful, more so in deeper lakes rather than shallow. Shallow lakes generally mix periodically throughout the summer. Deeper lakes (greater than 17 feet) generally remain stratified throughout the summer months and as fall arrives, go through what is called "Fall Turnover". Fall turnover is when the surface waters cool, become more dense and sink to the bottom. *Walled Lake has some deep areas, but for the most part, is quite shallow. Shawood Lake is a shallow lake and will generally mix throughout the summer.*

Theoretical Nutrient Budget - Consider the relative importance and contributions of point sources and non-point sources to the lake. The watershed to lake surface area ratio is also important. The ratio can indicate whether point or non-point sources are likely to dominate water quality. This ratio is quite simple to calculate: Lake area ratio equals the watershed area divided by the lake area (computed in acres). If the watershed is small, local point sources and septic tank drainage are probably quite important. As the watershed to lake surface ratio increases, these sources might still be important, but non-point sources also must be considered.

Assessing point and domestic wastewater sources, with an existing on-lot system, the first step is to determine whether the system is operating satisfactorily. If it is, finding out how to maintain the system in good condition is all that is necessary. If the system is not working well, however, correcting the malfunction will be necessary. The local County or State Health Department can check a system and generally provide advice or referrals for further information.

Point sources which had been perceived to contribute to the majority of water quality problems, had masked non-point source pollution problems. Once point sources were subjected to corrective actions, the importance of non-point sources became apparent. Only by stepping away from the narrow viewpoint (that point sources caused nearly all water quality problems) were water quality specialists able to see the lake and watershed as an integrated system being affected by diverse sources of influences.

By approaching the management of lakes from a broader perspective, water specialists found that in many systems, non-point sources were equal to or greater than point source contributions and, in general, non-point sources were major contributors of sediment organic matter and nutrients to the lake, See Figure 2.3, "Potential Hydraulic Dredging Areas". Although, the nutrient concentration in runoff waters or the amount of nutrients absorbed in the sediments are generally not as great as the nutrient concentrations in a point source, the total load (concentration times flow) can be substantial and far exceed point source contributions. The Nutrient Budget describes the amount of nutrients which flow into the lake, generally source of origin, how much accumulates in the water or on the bottom and how much flows out. This will in part determine the excessive plant growth in a lake.

Phosphorus is the key parameter in Nutrient Budget calculations, this is because it has been identified as a major nutrient contributing to plant growth. The aquatic plants need more phosphorus than what naturally occurs in lakes. Phosphorus is also the one nutrient that man is able to control through good lake management practices. Nitrogen is generally not considered a controllable source as it occurs naturally in lakes in sufficient quantities for the aquatic plants.

Theoretical Nutrient Budget (TNB) calculations are based on a number of parameters linked to phosphorous loading of a lake within the watershed. One of the key parameters are the number of septic tanks/fields within the given water shed. Mr. Bruce Jerome with the City of Novi Department of Public Works told JCK that he believed there was only one (1) septic tank/field currently in use in the study area. The site is located at 329 Elm Court on the northwest side of Shawood Lake. Other parameters looked at are fertilizers applied to lawns and gardens (especially properties adjacent to the lake), stormwater runoff and amount of phosphorus currently in the lake. Walled Lake has a phosphorous concentration of approximately 0.02 mg/l and Shawood Lake has a phosphorus concentration of 0.03 mg/l. Acceptable levels range from 0.005 to 0.05 mg/l.

Septic tanks/fields are generally the largest contributor of phosphorus to a lake. Since there is only one septic tank/field currently in use in the study area, it is our opinion that the TNB load due to septic tanks/fields would have minimal effect on the lake water quality.

D. BEST MANAGEMENT PRACTICES

There are a number of options available to improve the water quality of the lake, they range from picking up litter around the lake to the implementation of best management practices (BMP's) in the watershed. BMP's have been developed for agricultural, silvicultural, urban and construction activities. Agricultural practices, for example, have been developed for cropland, pastures, barnyard or manure management and pesticide control. Silvicultural practices have been developed for activities such as new road and residential construction and pesticides. Urban practices have been designed to keep city streets and roadsides clean, while construction practices were developed for erosion and runoff control.

Water quality specialists for lakes focus on BMP's to control four primary, interactive processes:

- Erosion control
- Runoff control
- Nutrient control
- Pesticide or toxic controls

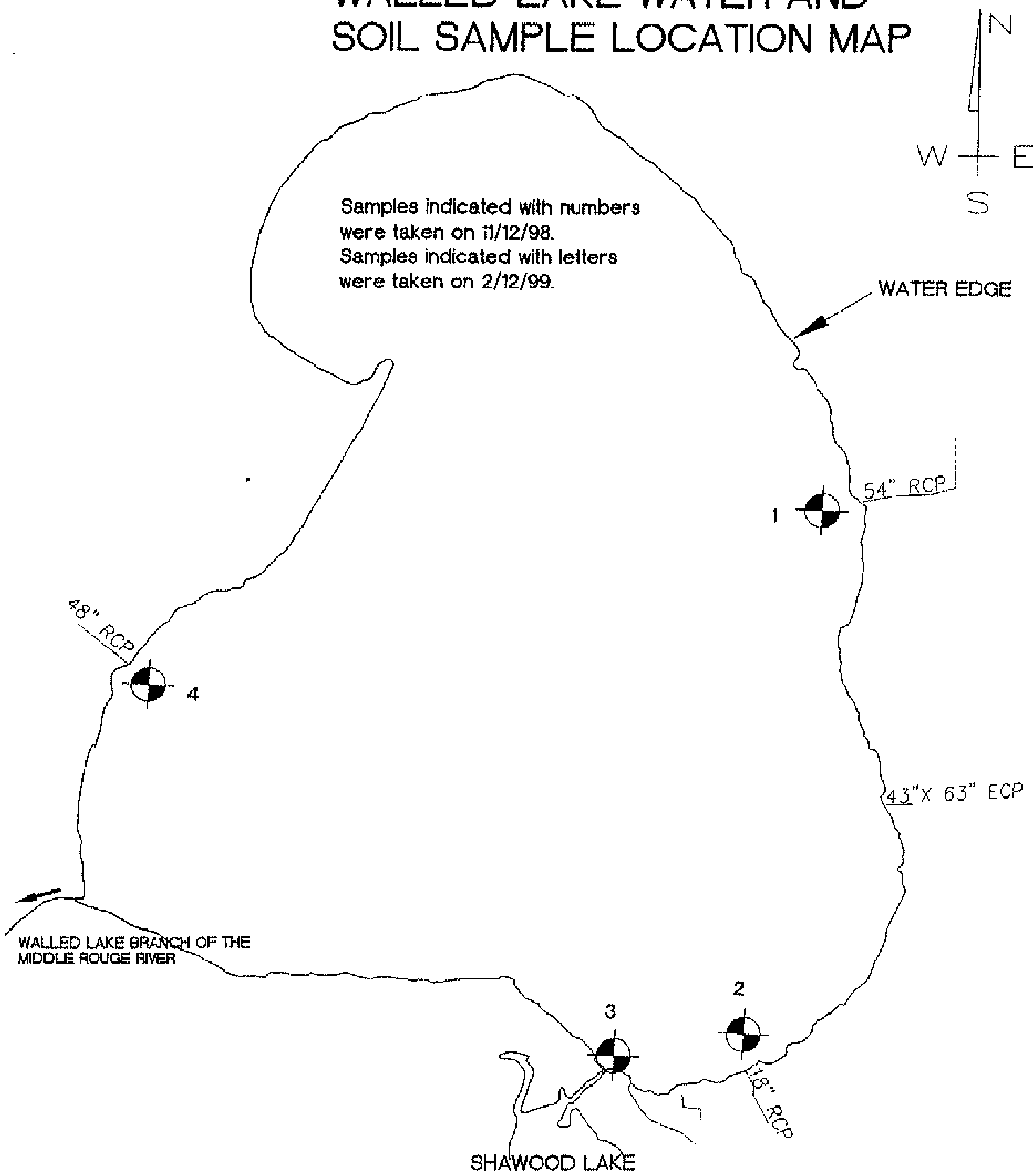
These processes are highly interactive because runoff control, for example, offers benefits for reducing sediments, nutrients and pesticide contamination in lakes. Control for other factors, however, may still be necessary.

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

II. LAKE WATER QUALITY

FIGURES

WALLED LAKE WATER AND SOIL SAMPLE LOCATION MAP



STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
WALLED LAKE, SHAWOOD LAKE, AND MEADOWBROOK LAKE

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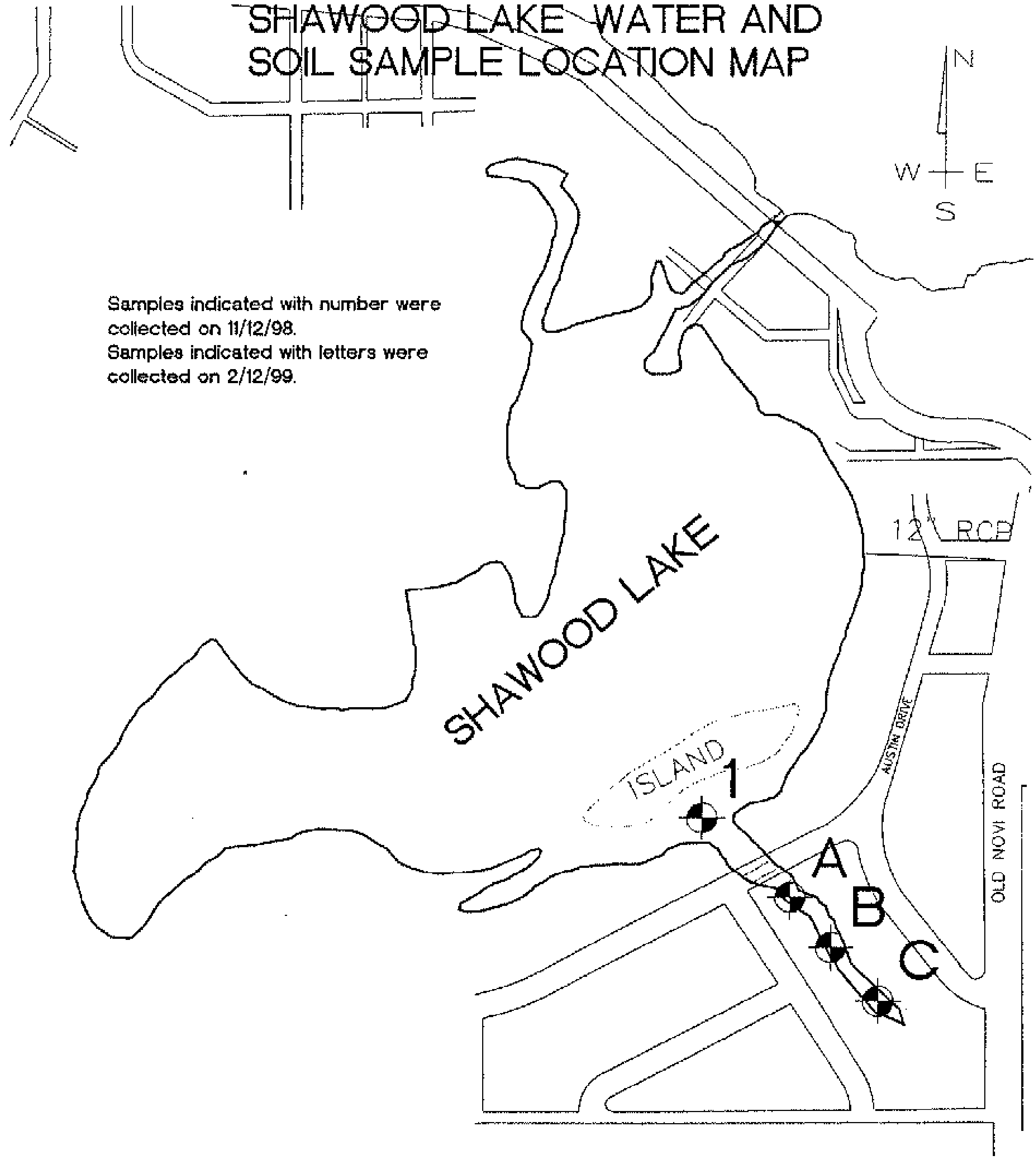
SHAWOOD LAKE WATER AND SOIL SAMPLE LOCATION MAP



Samples indicated with number were collected on 11/12/98.
Samples indicated with letters were collected on 2/12/99.

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
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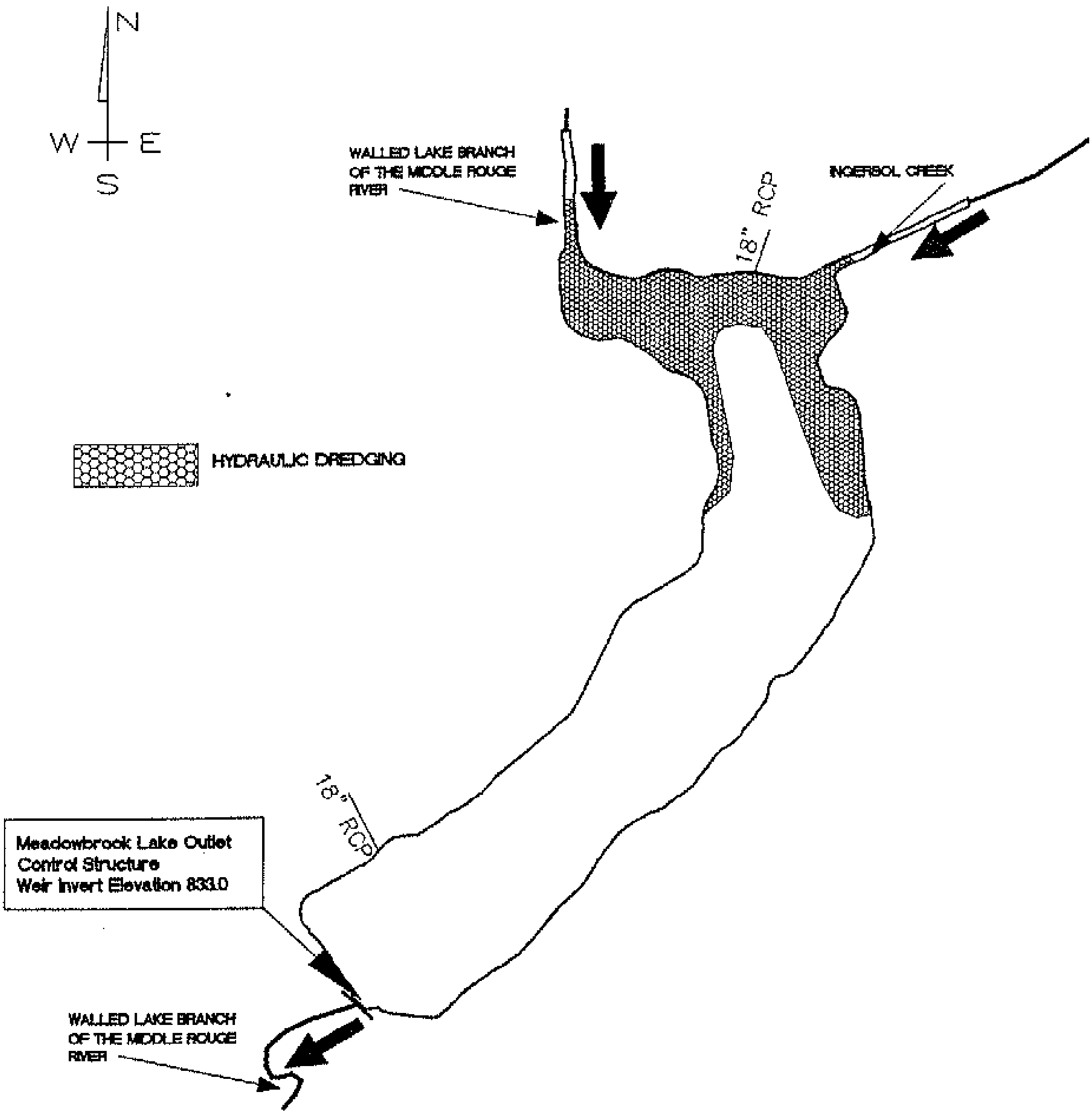
POTENTIAL HYDRAULIC DREDGING AREAS FOR MEADOWBROOK LAKE



STORMWATER SEDIMENT AND AQUATIC PLANT STUDY

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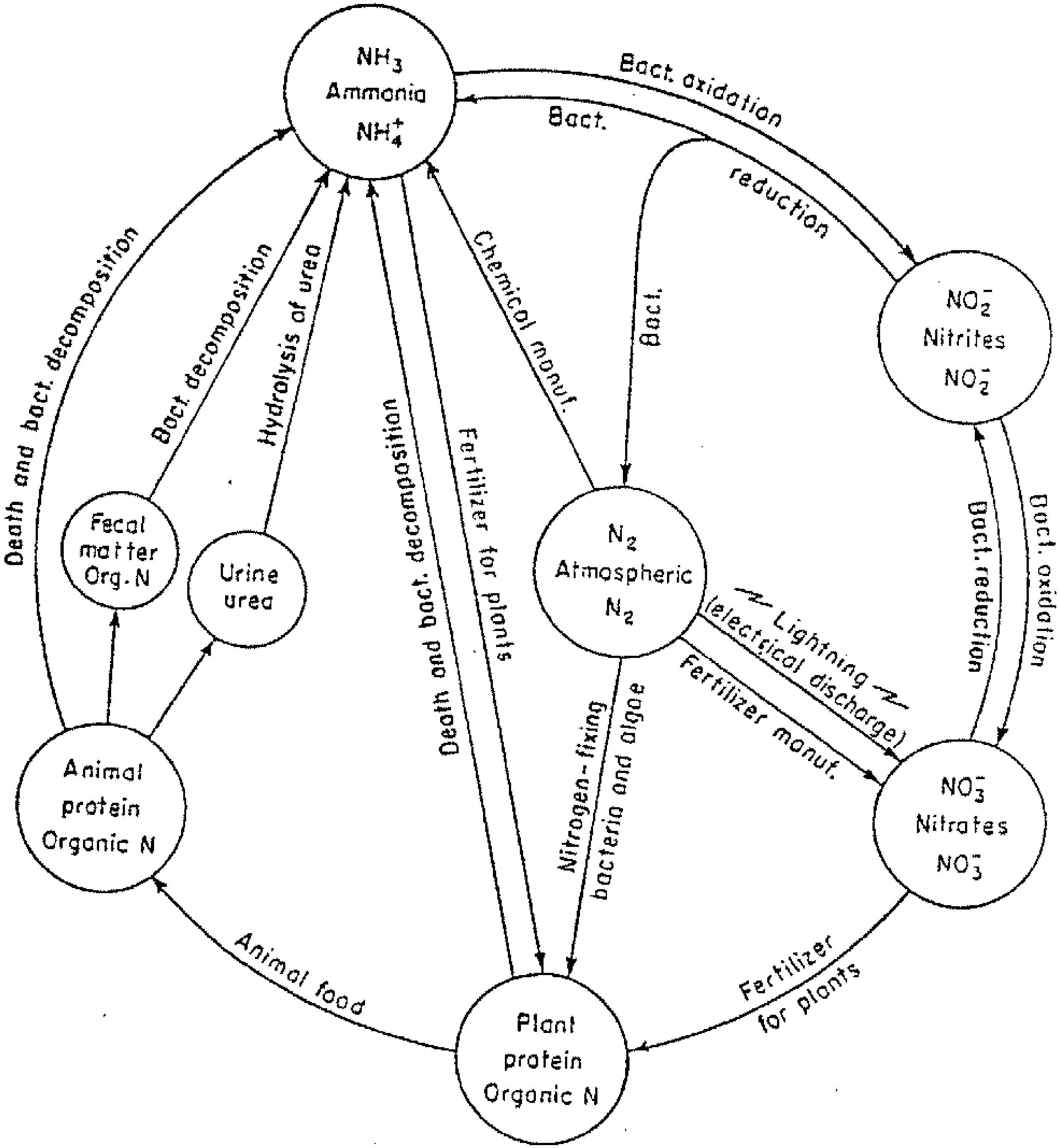
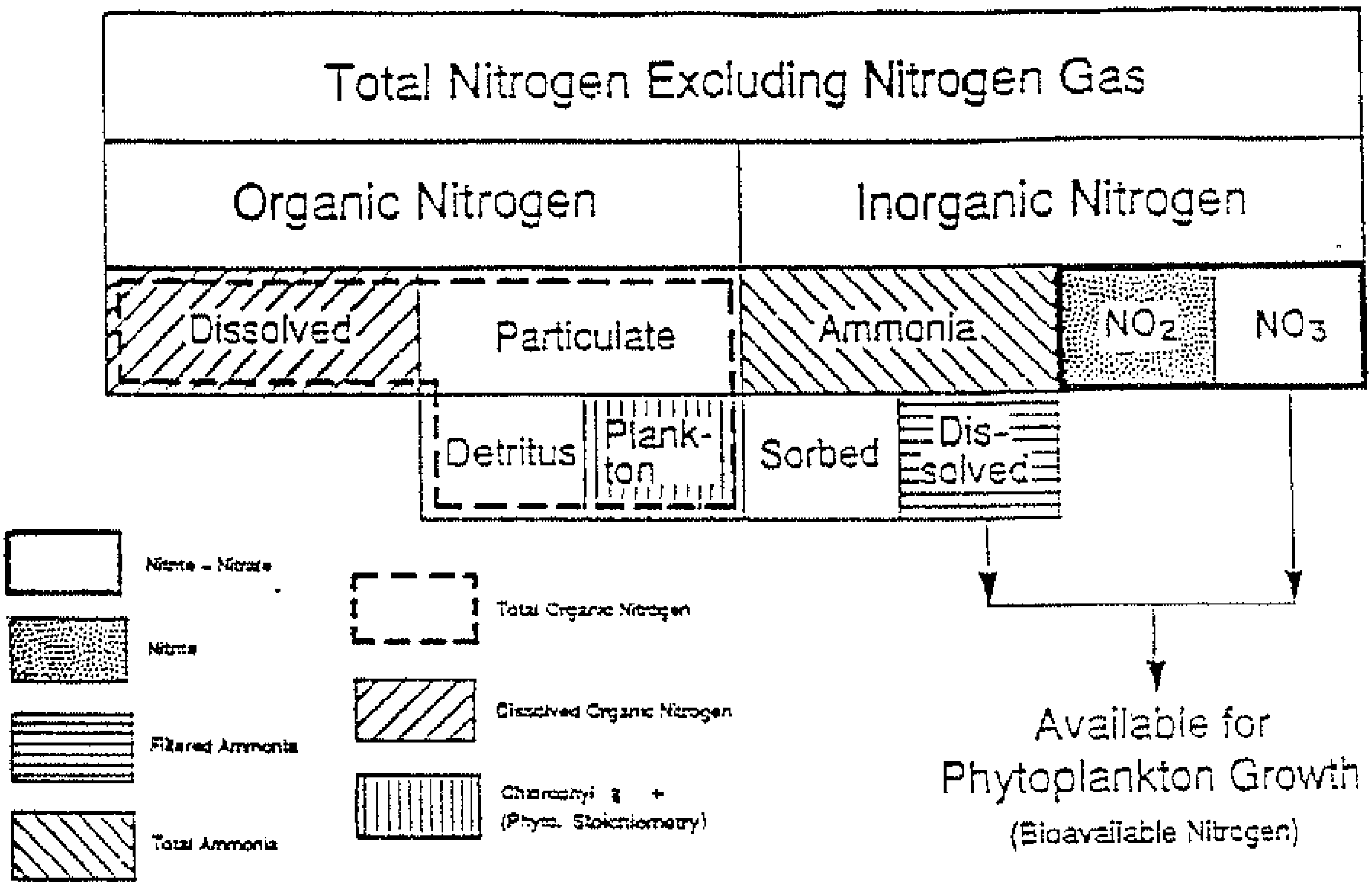


THE NITROGEN CYCLE

(Chemistry for Sanitary Engineers, McGraw-Hill 1967)



NOTE: Filtered Kjeldalh Nitrogen = dissolved organic nitrogen + dissolved ammonia
Total Kjeldalh Nitrogen = total organic nitrogen + total ammonia

Forms of nitrogen present in water and the types of measurements available.
(From McCutcheon)

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

III. AQUATIC PLANT SURVEY

PAGE NO.

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B. Observations 3.2

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Figure	3.3	Shawood Lake Vegetation Density Performed on July 7, 1998	3.5
Figure	3.4	Plant Species Observed	3.6

III. AQUATIC PLANT SURVEY

A. INTRODUCTION

It is important to note that managing aquatic plants does not mean completely removing them. The basic goal is to maintain a proper balance of plants and still maintain the lake's recreation and economic importance. Aquatic plants convert chemical elements into living plant tissue by photosynthesis. This process also replenishes the lake with oxygen. The plants are also used by bacteria and animals (zooplankton, fish, waterfowl, insects and water mammals) for food. Aquatic plants create an environment in which fish-food organisms can reside. The plants furnish protection for young animals and fish and are associated with the reproductive activities of certain fish.

Aquatic plants play an important role in lake systems. They supply oxygen and energy to the system, provide cover for larval fishes, are an important part of the food chain, and help recycle nutrients.

Aquatic plants can be divided into two major categories including both algae and macrophytes. An overabundance of algae often brings numerous complaints about film on the water surface, odor and taste problems.

The aquatic macrophyte communities can range from completely submerged stands of macro-algae to stands of rooted plants with floating leaves. Macrophytes can be divided into three types based on their growth pattern; free-floating, submergent, and emergent.

Free-floating macrophytes float freely, dependent on winds and currents to move their masses. In Michigan, duckweeds belong to this category.

Submergent macrophytes are typically rooted to the substrate (muck) with the stems and leaves floating below the surface of the water. Species commonly observed include elodea, coontail and milfoil.

Emergent macrophytes grow rooted in shallow waters with the majority of the plant being visible above the waters surface. These are typical of lake shorelines and wetlands, and include cattails, water lilies, and rushes.

While these plants are important providers of food and cover for fish, waterfowl, and other aquatic life, they can interfere with recreation and detract from aesthetic values of a lake. Significant quantities of nutrients and organic matter may be introduced to the water column by these plants. This in turn may increase the dissolved oxygen consumption and stimulate algal blooms.

As there are no native animals found to graze on these plants in sufficient amounts to control them, alternative methods of control have been utilized for many years.

B. OBSERVATIONS

The on-site aquatic plant survey was performed on Tuesday, July 7, 1998 and again on Wednesday, September 23, 1998, by physical sampling and identification by JCK staff and Mr. Howard Wandell (Michigan Department of Environmental Quality - Inland Lake Management Unit). Figures 3.1, 3.2 and 3.3 were prepared to record the "Aquatic Plant Survey" and general concentrations of the plant species that are growing in Walled Lake, Shawood Lake and Meadowbrook Lake.

Plant growth was observed in individual Aquatic Vegetation Assessment Sites (AVAS) around the lake. Vegetation density was rated from 'dense', being present in considerable quantity, to 'sparse', with one or two plants of species located in the AVAS.

Maps of the aquatic plants and their locations is illustrated in Figures 3.1, 3.2 and 3.3. A listing of plant species found throughout the lake, as well as those found to be dense or moderate is shown in Figure 3.4.

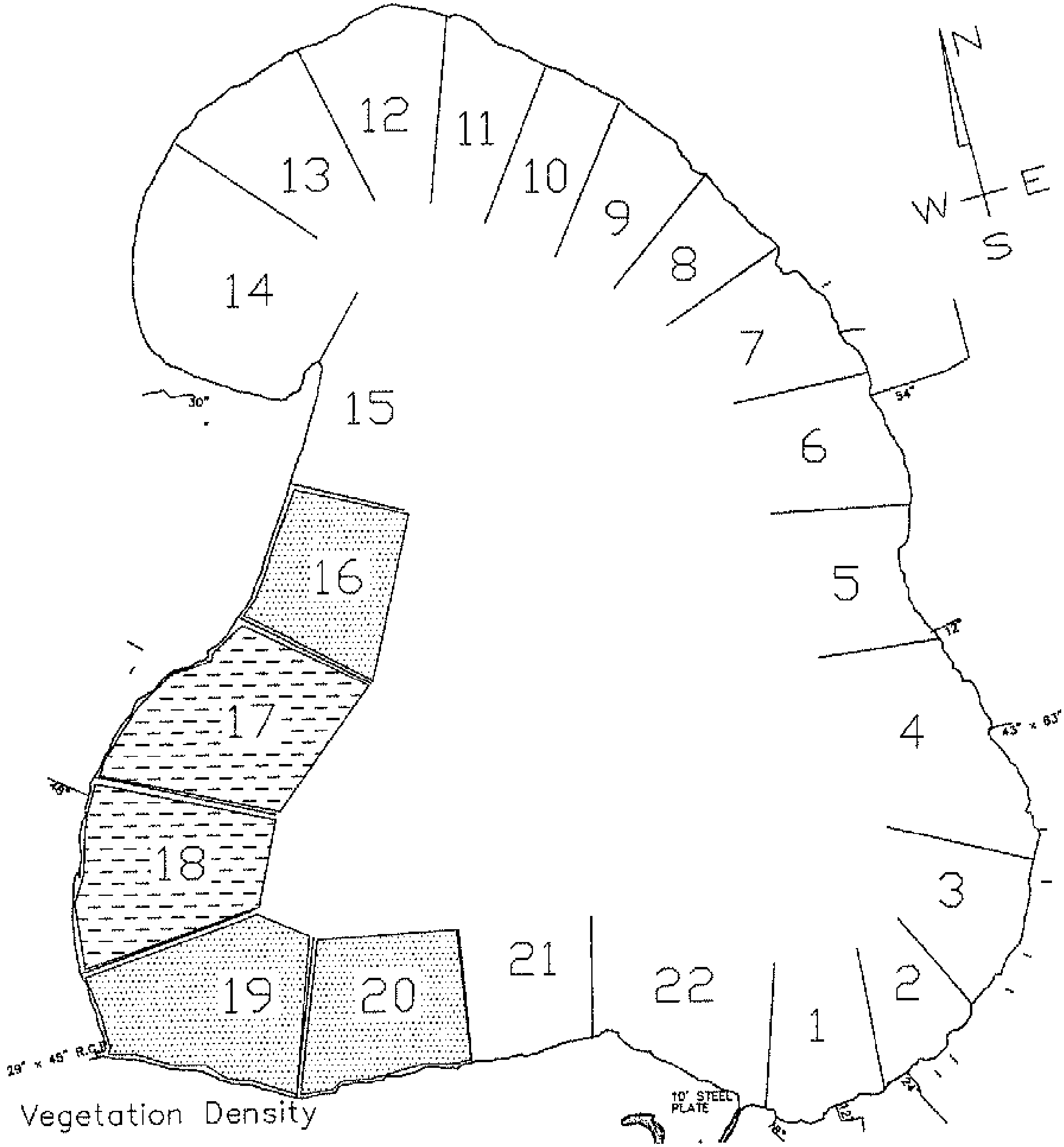
Aquatic plant growth is dependant upon numerous parameters, including sunlight, dissolved oxygen, water nutrients, and lake bottom sediment types. Areas of the lake bottom that are sandy produce little to no plant cover, while areas of the lake bottom that had organic layers of soil produced moderate to heavy plant growth. Growth of macrophytic plants in Walled Lake and Meadowbrook Lake was found sometimes in large numbers. The plants found were normally found at shallow areas around the lakes. They also did not contain many 'dense' AVAS's (especially Meadowbrook Lake). The excessive organic material on the lake bottom that is prominent throughout most of the lake is probably due to the abundance of aquatic plant growth, decomposing leaves and other vegetation and the shallowness of the lake which lets more light in and increases aquatic plant growth. Growth of macrophytic plants in Shawood Lake was similar to that of Walled Lake with areas of organic soils on lake bottom. Due to Shawood Lake's eutrophication process, the organic over-burdens on the lake bottoms has accelerated more rapidly. Therefore it is recommended that no aquatic plant removal be done on any of the lakes in this study.

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

III. AQUATIC PLANT SURVEY

FIGURES

VEGETATION DENSITY FOR WALLED LAKE 7-7-98



Vegetation Density

Legend
7-7-98 Sparse/Light
7-7-98 Moderate/Heavy
7-7-98 Dense

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
WALLED LAKE, SHAWOOD LAKE, AND MEADOWBROOK LAKE

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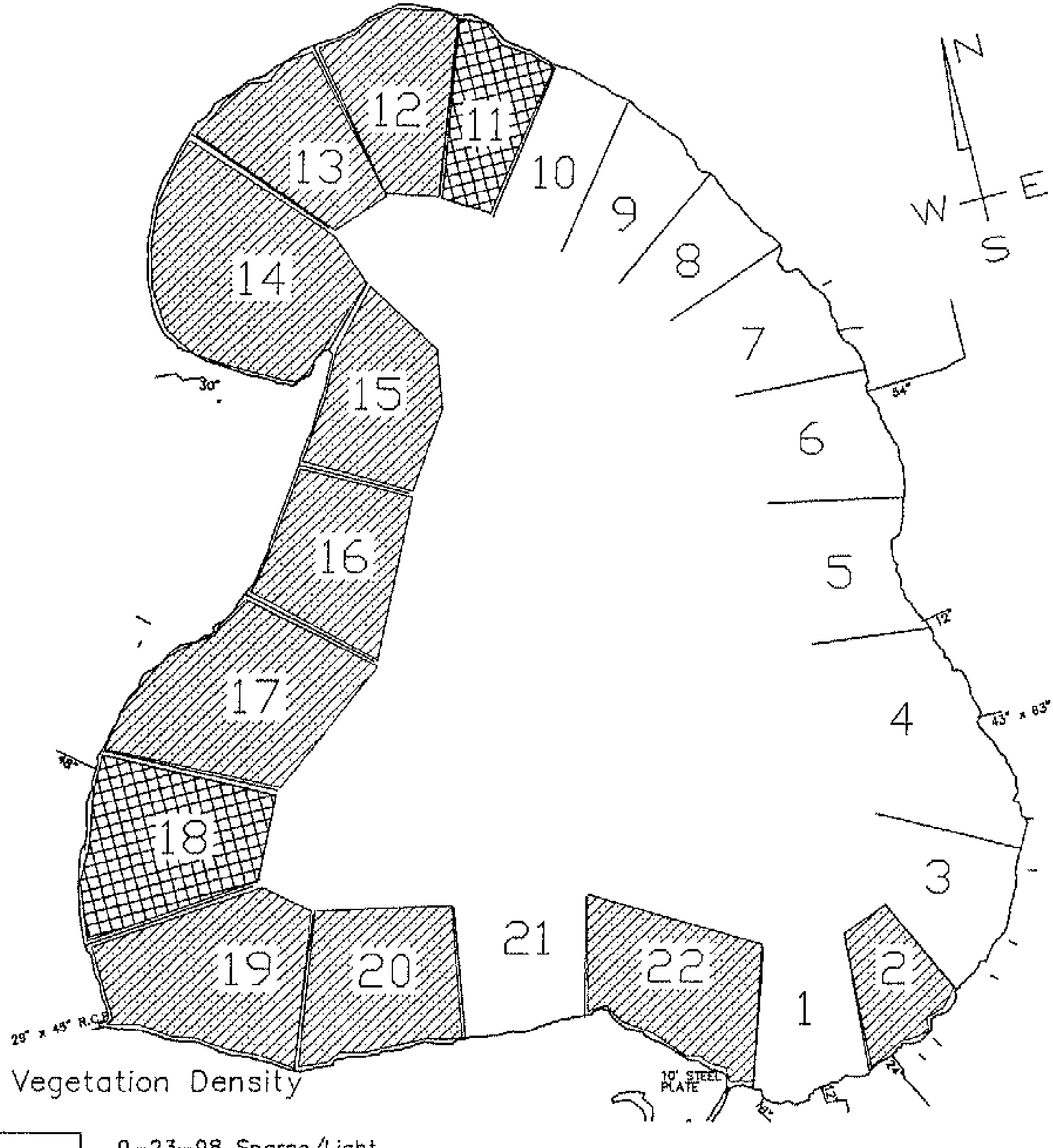
VEGETATION DENSITY FOR WALLED LAKE 9-23-98



Vegetation Density

- 9-23-98 Sparse/Light
- 9-23-98 Moderate/Heavy
- 9-23-98 Dense

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
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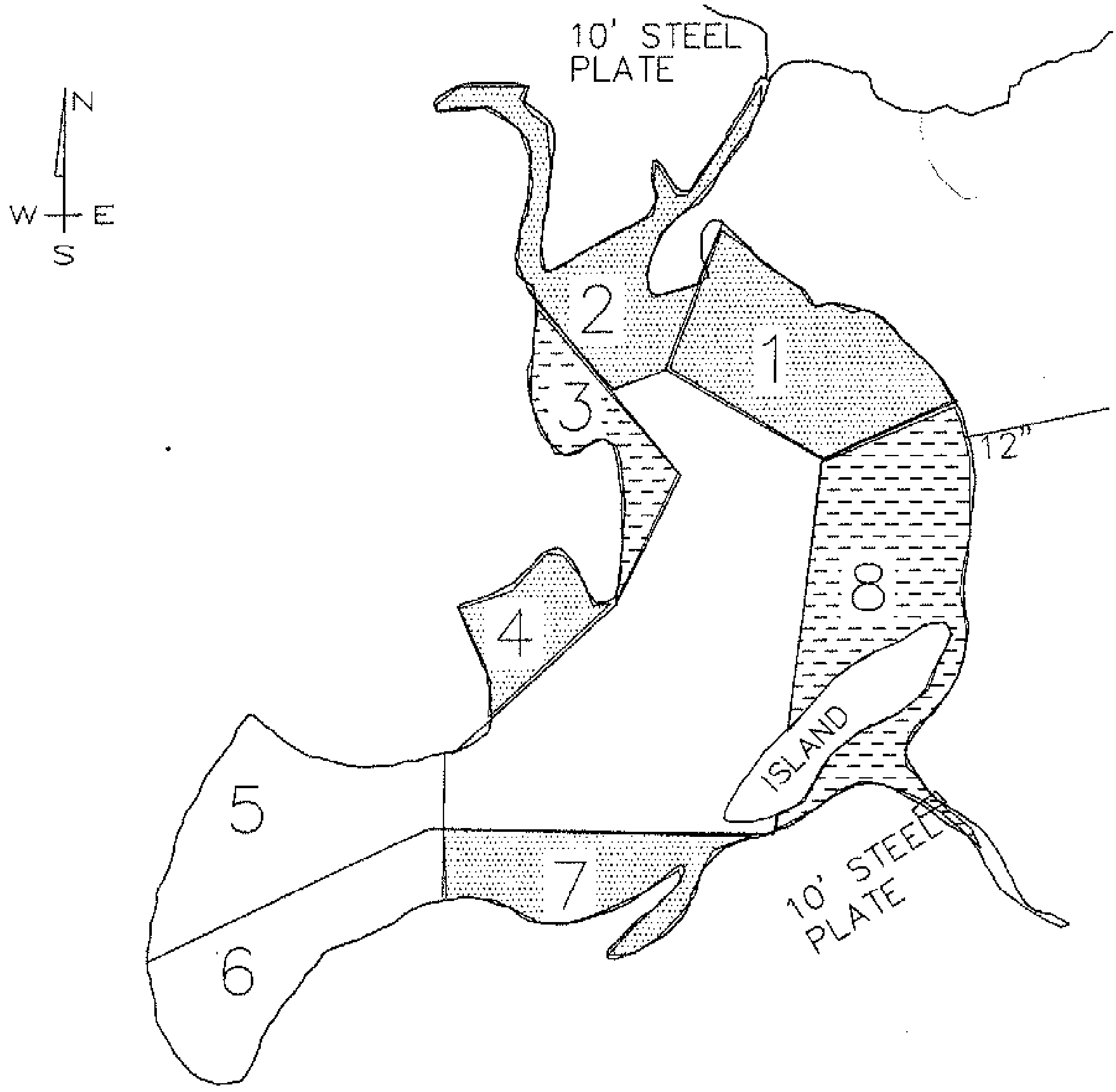
VEGETATION DENSITY MAP FOR SHAWOOD LAKE 7-7-98



Vegetation Density

7-7-98 Sparse/Light

7-7-98 Moderate/Heavy

7-7-98 Dense

STORMWATER, SEDIMENT, AND AQUATIC PLANT STUDY
WALLED LAKE, SHAWOOD LAKE, AND MEADOWBROOK LAKE

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FIGURE 3.4

Emergent and Submergent
Plant Species - Observed

Scientific Name	Common Name
Potamogeton confervoides	American Pondweed
Spirodella polyrhiza	Duckweed
Pontederia cordata	Pickerel Weed
Myriophyllum verticillatum	Northern Milfoil
Vallisneria americana	**Wild Celery**
Potamogeton filiformis	**Thin-leaf Pondweed (Sago)**
Potamogeton perfoliatus	**Clasping Leaf Pondweed**
Potamogeton amplifolius	**Big-leaf Pondweed**
Potamogeton zosteriformis	**Flat-stem Pondweed**
Potamogeton crispus	Curly-leaf Pondweed
Potamogeton praelongus	White-stem Pondweed
Potamogeton gramineus	Variable Pondweed
Potamogeton richardsonii	Richardson's Pondweed
Ceratophyllum demersum	Coontail
Potamogeton illinoesis	Illinois Pondweed
Myriophyllum spicatum	**Eurasian Milfoil**
Myriophyllum sibiricum	**Native Milfoil**
Najas guadalupensis	**Southern Water-Nymph (Naiad)**
Najas marina	Brittle Water-Nymph (Naiad)
Elodea canadensis	Common Waterweed
Nuphar microphylla	Yellow Water Lilly
Nuphar odorata	White Water Lilly
Scirpus subterminalis	**Water Bulrush**
Lythrum salicaria	Purple Loosestrife
Zosterella dubia	Water Stargrass
Typha angustifolia	Narrow-Leaved Cat-tail
Typha latifolia	Common Cat-tail
Chara validus	**Muckgrass**

Note: Plants in bold type were found in dense and moderate quantities.

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
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IV. LAKE MANAGEMENT ALTERNATIVES

PAGE NO.

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Figure 4.2 Lake Aeration System 4.10

Figure 4.3 Lake Draw-Down Effects on Plants 4.11

Figure 4.4 Mechanical Weed Harvesting 4.12

IV. LONG & SHORT TERM SEDIMENT & WATER QUALITY CONTROLS

A. INTRODUCTION

Every sediment and water quality controls program should have two phases: long-term controls and short-term controls. Long-term is the process of nutrient control; short-term involves the direct manipulation of aquatic plants.

B. LONG-TERM CONTROLS

Long-term effects concentrate on the control of the nutrients entering the lake. It is a more complicated method of control than short-term, and it takes years to develop. This method of control directs itself at what causes the aquatic plants to grow (nutrients), rather than the aquatic plants themselves. This control of nutrient sources in the long run can help reduce the rate of lake aging.

Nutrient sources are natural or cultural. Natural (non-point) nutrient sources will enter a lake, even without human influence, and usually contain small amounts of nutrients. Cultural (point) sources are usually in high volumes and concentrations and can greatly accelerate the rate of eutrophication.

Examples of natural nutrient sources include: wetland runoff; meadow land runoff; forest runoff; precipitation on the lake surface; soil erosion; aquatic bird and animal wastes; leaf, pollen and dust deposition; groundwater influxes; nitrogen fixation by plants; and sediment recycling.

Examples of cultural nutrient sources include: domestic and industrial wastewater; agricultural runoff; agricultural wetland drainage; managed forest runoff; urban storm water runoff; septic tank discharges; landfill drainage; construction activities; lake shore lawn runoff; and atmospheric fall-out of wind-borne fertilizers from land and industry.

Some of the methods of long-term controls (nutrient source management) are: proper land use; wise consumer use of commercial products; treatment of the in flowing waters that are high in nutrients; diversion of the water that is high in nutrients; and municipal and industrial wastewater treatment. A brief discussion of these methods follow.

Some of the control methods for nutrient and sediment reduction may not directly apply to Walled Lake, Shawood Lake or Meadowbrook Lake but are included for the reader's information.

Proper Land Use

Many units of government are enacting ordinances to regulate land use. The Natural Resources and Environmental Protection Act, Act 451 of the Public Acts of 1994, Part 31, Flood Plain Regulatory Authority and Part 91, Soil Erosion and Sedimentation Control. This act limits the movement of sediments into surface waters during earth-moving activities (except agricultural tillage).

The following are some examples of land use practices that can help to reduce the amount of nutrients entering a lake from the watershed:

1. Sediment control from construction activities; - Novi City Ordinance

2. Designate wetlands as "no development" areas; - Novi City Ordinance

3. Routine inspection and maintenance of catch basins in storm drains;

4. Prevent storm water drainage from directly entering the lake by subdivision designs which utilize infiltration;

5. Community collection and disposal of leaves in urban areas that are adjacent to the lake;

6. Eliminate or restrict the use or types of fertilizers on lawns adjacent to a lake or stream;

7. Green belting around the lake and stream banks; - Novi City Ordinance 25' setback from wetlands .

8. Keep a minimum distance of at least 100 feet between the shoreline and private septic systems and tile fields; - Regulated by the County Health Department

9. There should be no development in areas where the groundwater is high, or where the soils are poor nutrient traps for private sewage disposal systems - Regulated by the County Health Department.

Routine inspections of catch basins and storm drains are constantly performed by the Novi Department of Public Works. Design of new subdivisions and their roads incorporate Best Management Practices (BMP's) utilizing temporary sediment basin construction and permanent water quality basins for storm water detention and discharge therefore, reducing the amount of sediments and or contaminants discharging directly into lakes and streams.

Wise Consumer Use of Commercial Products

Some products, such as detergents and fertilizers, contribute significant amounts of nitrogen and phosphorus to the waters. Restricting or decreasing the use of these products, or substituting with the use of a product with low nitrogen and phosphorus content, will help to reduce the nutrient loading into the lake. In Michigan, high-phosphate detergents have been banned.

A County Cooperative Extension Agent can provide information on soil testing procedures to determine which chemical nutrients are needed. If the soil does not require phosphorus, a fertilizer with little or no phosphorus should be used.

Treatment of In flowing Waters High in Nutrients

An in flowing stream or drain may carry substantial amounts of nutrients from sources such as agricultural drainage or urban storm water drainage. Instead of trying to control the many nutrient sources draining into the stream, it may be more feasible to chemically or physically treat the in flowing water.

Diversion of Waters High in Nutrients

The principle of diversion involves re-routing water high in nutrients around or away from a lake. This method is most often applied to municipal wastewater, but it can also be used for any waters that have high nutrient levels from other sources. This method has shown a marked increase in water quality when implemented.

Unfortunately, diversion is not a method of proper land management. Although it works for the lake where the diversion takes place, it really just transfers the non-treated, nutrient rich waters to downstream lakes.

Municipal and Industrial Wastewater Treatment

Municipal wastewater discharge is a major source of nutrients. Even when this wastewater has been treated, it still may be high in nutrients. To completely eliminate the effects of wastewater discharge, the water would either have to be diverted or land disposal would have to be considered.

Industrial wastewater varies in its quality. Most governments require some amount of treatment for the wastewater, but the wastewater should be tested for the amount of nutrients that it is contributing to the lake.

C. SHORT-TERM CONTROLS

Short-term control techniques are implemented in lakes that have such serious plant problems that, without immediate action, recreational and economic interests in the lake cannot be maintained. There are also lakes or reservoirs in which long-term nutrient control is impractical; short-term practices must be implemented yearly. Again, it is important to note that, under no circumstances, should complete eradication of aquatic plants be considered. However, in lakes where nutrient control is possible, these short-term management techniques are only temporary measures to replace nuisance plant species with species that will conflict less with recreational and economic interests.

Some methods of short-term control include biological control, environmental control, weed harvesting and herbicides. A discussion of these methods follow.

Biological Control

Biological control involves the introduction of an organism that competes with, preys upon, inhibits the growth of, causes disease in or parasitizes a plant species.

Grass carp are an example of biological control. Triploid grass carp, an exotic species from central Asia, have been introduced into lakes in 31 states. They are sterile when introduced and, therefore, cannot reproduce. Unfortunately, grass carp are selective feeders; the weed they like to eat the least is milfoil, which is the largest weed problem in Michigan lakes.

Water Resources Commission Act, Act 245 of the Public Acts of 1929 state that the introduction and release of exotic, foreign or non-native insects, fish or other animals into Michigan without specific authorization is strictly forbidden. No specific biological control techniques are being applied in Michigan waters at this time.

Environmental Manipulation

Environmental manipulation attempts to alter one or more physical or chemical factors critical to plant reproduction and growth. These methods vary in economic and environmental practicality in every lake. If a program to reduce nutrient inputs is not implemented, the environmental manipulation methods will only achieve temporary results. Most of these activities require a permit from the Michigan Department of Environmental Quality.

Methods of environmental manipulation include dredging, aeration, nutrient inactivation, draw-down, dilution or displacement, shading, covering of bottom sediments and intensive use and periodic manual cleaning of shoreline areas. Each method will be discussed in the following paragraphs.

Dredging

Dredging removes the bottom sediments of the lake and deepens the lake. This temporarily removes the aquatic plants and reduces the growth of new plants by reducing the size of the well-lighted zone around the shore. Dredging causes a temporary increase in the silt suspended in the water, which may smother bottom-living animals when it settles.

It is important to find a suitable upland site for the deposition of the dredged material. Depositing the material too close to the lake will allow it to simply wash back into the lake in a short period of time. Permits are required for the dredging operation, as well as an approved site for the deposition of the dredged material.

Costs for dredging vary significantly from site to site. The costs depend on if the spoils must be hauled from the site or if a nearby spoil site has been set aside. The costs also vary with the accessibility of the lake for the dredging equipment. Typically, at least 20,000 cubic yards of spoil need to be removed to get a dredging company interested in bidding. A good cost estimate for dredging is approximately $15.00/cubic yard of spoil removed. See an example of hydraulic dredging equipment in Figure 4.1.

Aeration

Aeration is the introduction of air into the water to increase the dissolved oxygen concentration. This procedure is most often implemented in lakes where the deep water is devoid of oxygen. By adding oxygen to the deep water, the release of nutrients from the sediments is prevented. In many instances following aeration, a decrease in nuisance algal populations and a shift to more favorable species is observed. However, control of aquatic plants has not been observed with aeration.

There are possible detrimental effects to cold water species if the warm surface waters are mixed with cool bottom waters; however, there are methods of aerating only the deeper waters. The aerator may also increase the turbidity of the water by re-suspension of the bottom mud.

Few advantages are recognized by aeration and this procedure is very expensive. See an example of lake aeration equipment in Figure 4.2.

Nutrient Inactivation

Nutrient inactivation is the application of a chemical that will bind with and immobilize the nutrients necessary for plant growth. These immobilized nutrients settle to the lake bottom. The chemical substance used is usually a metal ion such as iron, aluminum or calcium. The process of the immobilized nutrients settling may also reduce the suspended solids and decrease the turbidity and color.

Nutrient inactivation has been useful for algae control, but has had little effect on the growth of aquatic plants. It may also have an adverse effect on small animals that live in the bottom sediments and serve as fish food. It is also fairly expensive.

Draw-Down

Draw-down is the process of lowering the water level for a period of time and exposing shallow water areas. This is usually accomplished during the winter to dry out and freeze the exposed plants to kill them. This procedure is generally only applicable to lakes formed by damming a stream, creek or river. A draw-down for approximately two months is necessary for drying and freezing.

Many submergent macrophytes such as milfoil are controlled by this procedure; but, unfortunately, some emergent macrophytes actually benefit from it. This method also does not control algae. A concern with draw-down on non stream-fed lakes is the method of refilling the lake. See, "Effects of Lake Draw-Down on Aquatic Plant Species", Figure 4.3.

Dilution or Displacement

Dilution or displacement of low quality water with high quality water helps to lessen algae problems. By replacing water high in nutrients with water low in nutrients is an acceptable means but there must be a source of low nutrient water easily accessible and a method to discharge water high in nutrients.

Shading

Shading is the process of limiting the amount of light passing through the surface to reduce plant growth. Two methods of shading have been employed: dyes and black plastic sheeting as a floating shade. The shading technique has been effective for submergent macrophytes, and limited control has been observed for emergent macrophytes. The floating plastic shade is more effective in small ponds because the wave action and currents of larger lakes move the floating shade around. The plastic sheeting should remain in place for 5 to 6 weeks. This method does not effectively control algae. Great care must be used if children are in the area, when using this technique.

Covering of Bottom Sediments

The covering of bottom sediments is accomplished with a sheeting material such as black plastic and/or a particulate material such as sand or clay. This is effective in two ways: the sheeting prevents the exchange of nutrients from the sediments to the water, and it retards the establishment of rooted plants. Sheeting is available that has pores to allow gases to escape to prevent the sheeting from floating to the surface. This technique results in good temporary control.

Disadvantages of covering are that the bottom-dwelling animals are usually killed when the sediment is covered. Also, the aquatic plants gradually re-colonize over the covering unless the sheeting is removed periodically and cleared of growth.

Intensive Use and Periodic Manual Clearing of Shoreline

This is an effective means of plant control in beach areas. This works because the rooted plants must produce food in their leaves to maintain their root systems. When the leaves are frequently cut off or destroyed by wading and swimming, the root system eventually dies. This technique is particularly effective with emergent vegetation. This care must be implemented often, similar to weeding a garden.

Mechanical Harvesting

Mechanical harvesting employs the pulling or cutting and removal of aquatic plants from selected areas of a lake. This procedure is similar to mowing a lawn. A barge-like boat with a sickle bar-type attachment is used. The weeds are cut and removed from the water by a series of conveyors. When the plants are cut, most float to the top and must be removed and taken off site. The plants make a good compost for farmers. In removing the cut material from the lake, water quality occasionally improves somewhat if the amount of nutrients removed in plant material is greater than the amount of nutrients entering the lake from the watershed.

Advantages of mechanical harvesting are that no additional chemicals are added to the lake (the process is somewhat natural). There is also no waiting period after mechanical harvesting has been implemented, so recreational areas uses can be immediately restored. A large organic load is removed when the dying cut plants are removed from the water, and the cut plants can be used by farmers as fertilizer. See an example of weed harvesting equipment in Figure 4.4.

Some disadvantages of weed harvesting are that the harvester has no specificity; it cuts everything in its path, including desirable aquatic plants. The harvester cannot be implemented in shallow areas or near docks. During the process of removing the cut vegetation, fish and other invertebrates may also be removed. The fragments of certain plants may actually promote additional growth. The cutting equipment rental and removal equipment rental is quite expensive. Also, weed harvesting is not effective for the removal of planktonic and filamentous algae.

The cost of mechanical harvesting will vary depending on the accessibility to the lake, and the type of equipment that can be put in the lake. A cost estimate for weed harvesting is approximately $200.00/acre harvested.

Herbicides

Herbicides are an effective method of removing aquatic plant and algae growth. There are a number of chemicals available which offer varying degrees of action time, persistence, cost, selectivity and safety.

Advantages of herbicides are that there is a degree of selectivity, meaning that noxious plants can be eliminated while desirable plants can still be preserved. State approved herbicides have a very low toxicity to humans or fish, if any. The application of herbicides early in the year kills the plants before they reach maximum growth; and also resulting in less vegetation to decompose on the bottom. Systemic herbicides kill plants from the root, not leaving any fragments to continue growing. Herbicides give relatively immediate results and the costs are limited to paying for the application of the herbicide.

Disadvantages of herbicides are that the chemicals are prone to wind or current action and may concentrate near a beach area. The chemicals may also affect wells near the lake. The Michigan Department of Environmental Quality (MDEQ) imposes limits on recreational activities on a lake for a period of typically 24 hours after application. The decomposition of plants settling to the bottom may deplete the dissolved oxygen level in the water, potentially causing a fish kill. An MDEQ permit must be obtained prior to application of chemical herbicides.

It is important with chemical herbicides that they are properly used in every way. Improper use can result in harm to humans or wildlife.

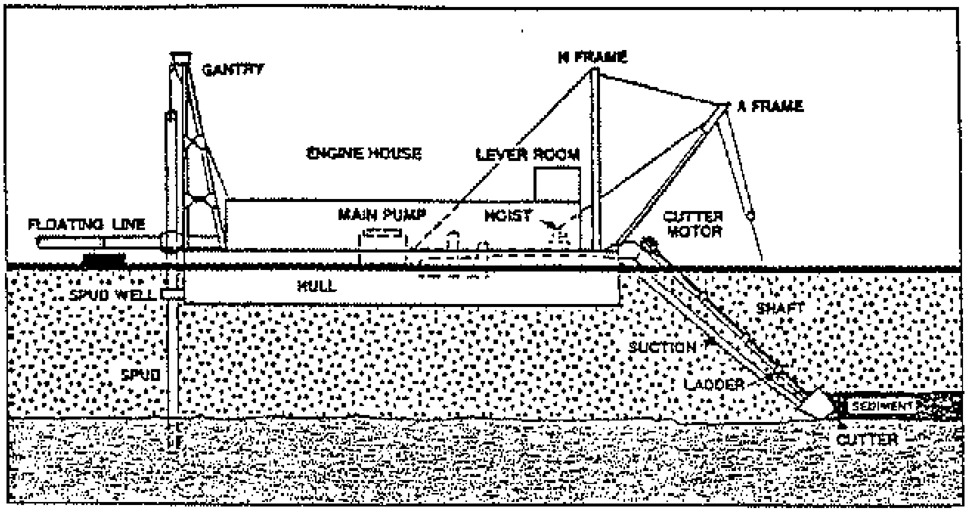
Chemical herbicide costs vary from lake to lake. The costs for chemicals alone, say 2,4-D is approximately $250.00/acre or approximately $50.00/acre for copper sulfate, which is used for algae control. There are usually additional costs for the service of the chemical application, varying with the size of the lake, and the accessibility for the applicator. Accordingly, since each lake is unique, a cost proposal shall be solicited from a qualified licensed contractor for each lake.

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

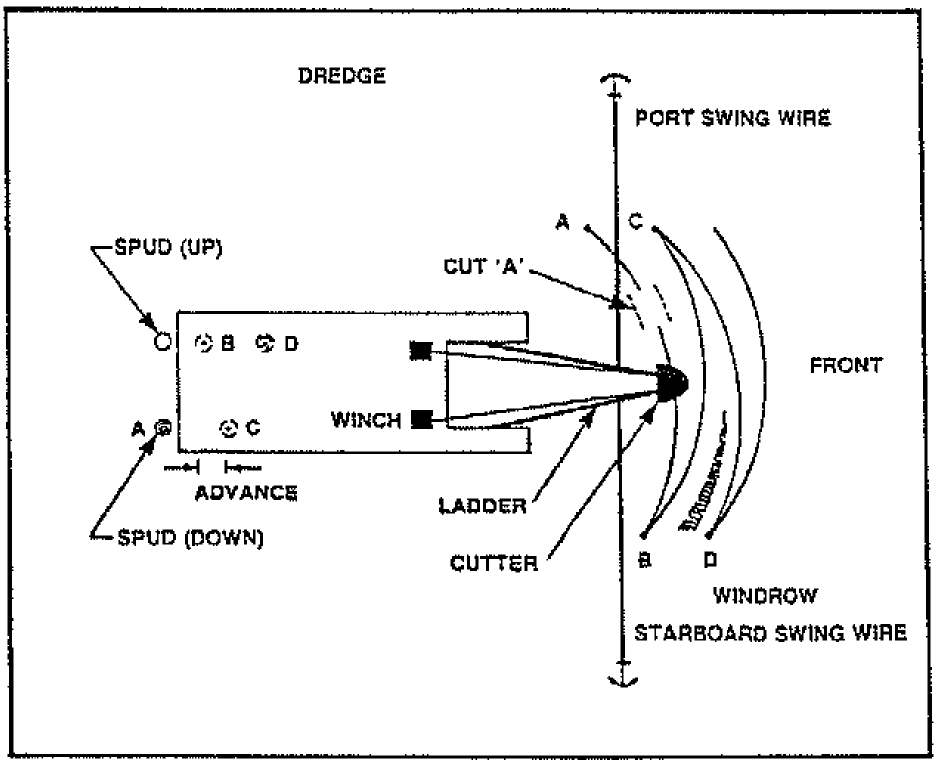
IV. LAKE MANAGEMENT ALTERNATIVES

FIGURES

FIGURE 4.1



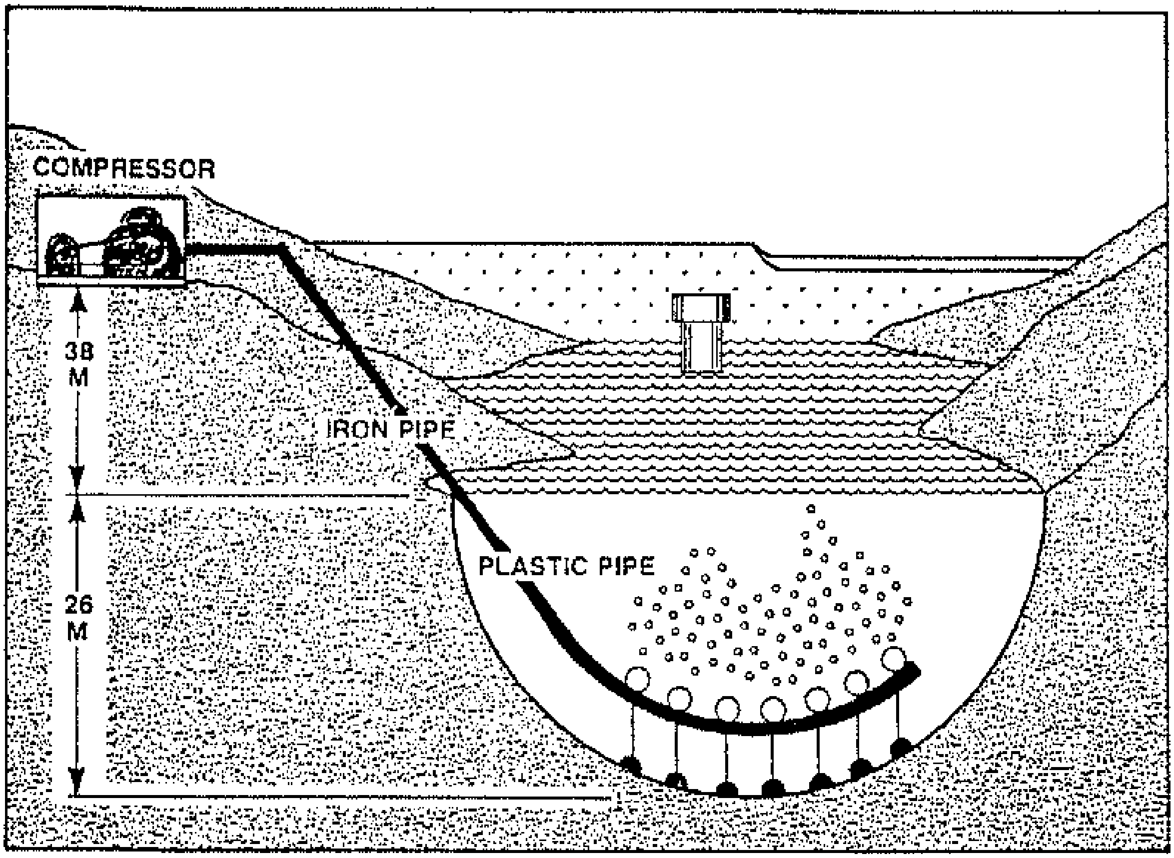
Configuration of a typical cutterhead dredge (from Barnard, 1978).



Spud-stabbing method for forward movement, and resultant patterns of the cut (from Barnard, 1978).

Hydraulic Dredging Equipment

FIGURE 4.2



Lake Aeration System

FIGURE 4.3

DECREASE

Coontail (*Ceratophyllum demersum*)
Brazilian elodea (*Elodea = Egeria densa*)
Milfoil (*Myriophyllum spp.*)
Southern naiad (*Najas guadalupensis*)
Yellow Water Lily (*Nuphar spp.*)
Water Lily (*Nymphaea odorata*)
Robbin's Pondweed (*Potamogeton robbinsii*)

INCREASE

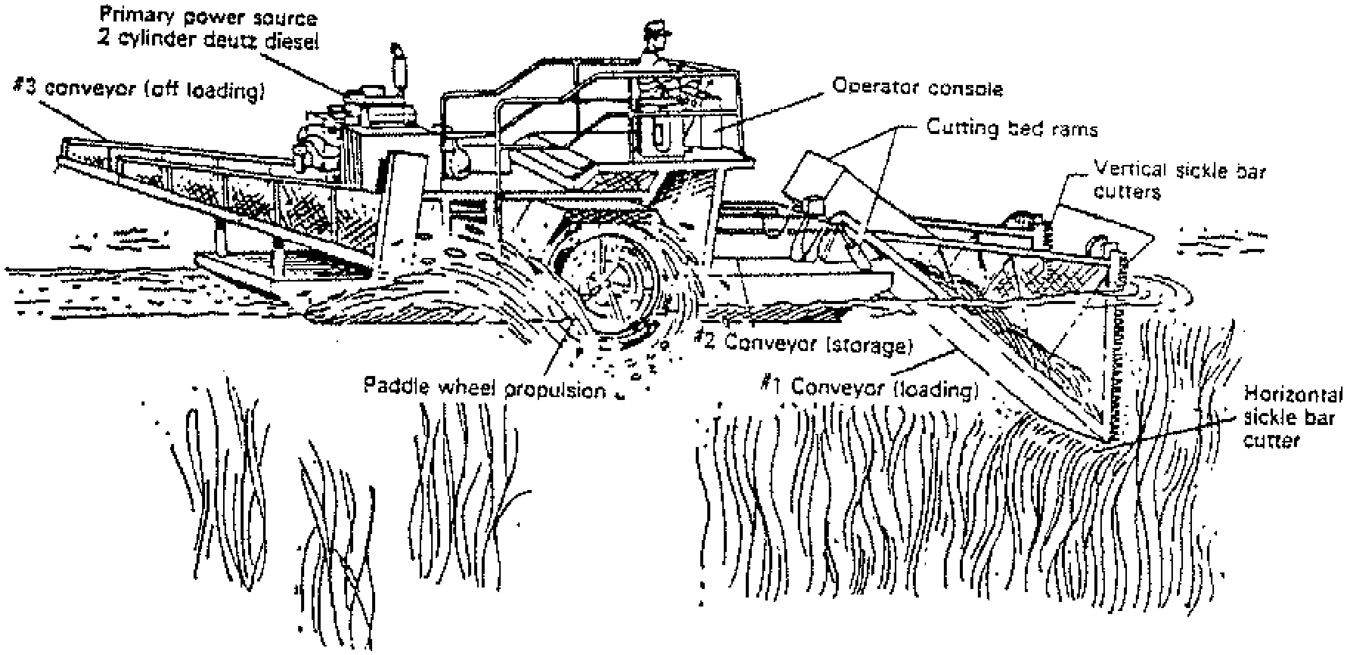
Alligator Weed (*Alternanthera philoxeroides*)
Hydrilla (*Hydrilla verticillata*)
Bushy Pondweed (*Najas flexilis*)

VARIABLE

Water Hyacinth (*Eichhornia crassipes*)
Common Elodea (*Elodea canadensis*)
Cattail (*Typha latifolia*)

Lake Draw-Down Effects on Plant Species

FIGURE 4.4



Mechanical Weed Harvesting

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

V. FINDINGS AND RECOMMENDATIONS

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V. FINDINGS AND RECOMMENDATIONS

A. WALLED LAKE

Findings - Upon review of the data collected within the scope of this report, we find that Walled Lake is in relatively good health. This statement is made based upon the water quality and sediment data collected and analyzed, as well as a review of the aquatic plant survey that was performed on Walled Lake.

Based upon the data collected, Walled Lake can be classified as an "Oligotrophic" Lake, which means that Walled Lake is low in plant nutrient, minerals and organisms and rich in oxygen at all depths, which can average from 15 to 25 feet. A summary of the data collected is listed as follows:

1.) Aquatic Plant Survey

As can be seen in Figure 5.1, the southwestern part of Walled Lake located just north of the Walled Lake - Lake Level Control Structure, shows that Walled Lake had experienced significant levels of "emergent" (above water) plant growth. The most frequent species of emergent plant growth that was identified in July and September of 1998, in this area was Common Cat-tail (*Typha latifolia*) and Eurasian Milfoil (*Myriophyllum spicatum*).

The land adjacent to the southwestern shoreline of Walled Lake, which has been observed to experience relative higher aquatic plant growth, is currently undeveloped. The recently approved Bristol Corners development proposes to conserve the wetlands contiguous and adjacent to this part of Walled Lake.

In addition, it is recommended to retain certain areas of a lake in their current plant growth cycles, in order to provide shelter for small fish and to take advantage of their oxygen producing capabilities.

Accordingly, at this time it would not be recommended to perform mechanical weed harvesting or to use the application of herbicides in this area, in order to control aquatic plant growth.

2.) Water Quality Analysis

Four water samples were taken at the areas shown in Figure 2.1 and tested for pH, dissolved oxygen, nitrogen (nitrite & nitrate), phosphorus and coliform bacteria. It should be noted that the source of coliform bacteria in a typical water body being tested is usually attributed to warm blooded animals. The coliform bacteria is analyzed in order to determine the total bacterial count that is present in the water sample. Results of these tests shows an excellent correlation to the lakes ability to support life. These samples were analyzed by Brighton Analytical, Inc., a State of Michigan certified laboratory.

After comparing the samples to the "Michigan Water Quality Standards Handbook", it was found that all parameters were within acceptable limits. For a copy of the laboratory results and Chain of Custody, see Appendix III.

Although E. coli tests were not performed as part of this study, recent water testing conducted by the Oakland County Health Department in June 1999, recorded excessive levels of E. coli present in Walled Lake at E.V. Mercer Beach (Walled Lake) and Lakeshore Park (Novi). It is recommended that the water quality testing program as implemented by the Oakland County Health Department, be continued and the results watched carefully. It should be noted that it can be difficult to determine the source(s) of E. coli, which is a organism present in all warm blooded animals. It could be speculated, that the recent high levels can be attributed to the number of nesting waterfowl (geese), pets and other animals on the lake during this time of year, coupled with a short term heat wave - immediately followed by a heavy rainfall. This combination of events can trigger bacteria blooms resulting is temporary spikes in E. coli bacteria levels, therefore requiring public beaches to be closed until acceptable levels are reached.

It is recommended that the City of Novi investigate possible sources of bacteria discharge into Walled Lake, after continued and sustained high levels of E. coli readings. If the high levels of bacteria were to continue, potential sources of bacteria such as failed septic tanks, public use of beaches and possible control of geese populations would need to be identified and addressed. Due to the sensitive nature of the public use of lake park and beach areas, it is advisable that the City of Novi conduct independent test in these areas, in an effort to periodically confirm the County Health Department's test results.

3.) **Sediment and Nutrient Analysis**

Sediment samples were collected at various locations from the lake bottom at the locations as shown in Figure 2.1. Most of the sediment sampling locations were at or near the storm water pipe discharge points into Walled Lake. All of the parameters tested for within the scope of this report, were within acceptable limits. For a detailed listing the analytical results of the lake bottom sediment samples and Chain of Custody, see Appendix IV.

The depths of sediment in the areas of the storm water pipe discharge points into Walled Lake were also measured in the field. When compared to lake bottom topographic maps of Walled Lake prepared as part of prior lake studies conducted for Walled Lake dated December 1983, no significant change in the depths of sediment could be determined near the storm water pipe discharge points into Walled Lake. It was observed that the lake bottom sediments in the areas adjacent to the storm water pipe discharge points into Walled Lake consisted primarily mainly of sand, rather than silts or clays.

Accordingly, at this time it would not be recommended to perform hydraulic dredging around the storm water pipe discharge points into Walled Lake. It has been noted that previous lake bottom contours recorded in 1983 show little to no significant change to the lake bottom contours recorded as part of this study.

B. SHAWOOD LAKE

Findings - Upon review of the data collected within the scope of this report, we find that Shawood Lake, relatively speaking, is in it's declining years as a Lake. This statement is made based upon the water quality and sediment data collected and analyzed, as well as a review of the aquatic plant survey that was performed on Shawood Lake.

Based upon the data collected, Shawood Lake can be classified as a "Eutrophic" Lake, which means that Shawood Lake is rich in plant nutrients, minerals and organisms and often deficient in oxygen, especially during the mid summer months. Shawood Lake is also considered a very shallow lake, due to depths ranging from 4 to 6 feet. The eutrophication process on Shawood Lake has been an ongoing process long before the City of Novi was been settled by earlier pioneers. It should be noted that during the early days when the City of Novi was being settled, Shawood Lake, was called and known as Mud Lake. This name can be observed on old USGS topographic maps. The name can be attributed to the thick layer of soft mucky lake bottom sediments. The extent of emergent and submergent plant growth is a clear indication of the amount of nutrients available for plant growth. There are many wetlands that are contiguous to the lake.

The natural status and relative age of a lake must be taken into consideration before any type of improvements can be considered. A summary of the data collected is listed as follows:

1.) <u>Aquatic Plant Survey</u>

As can be seen in Figure 3.3, the entire lake has significant areas of plant growth. The most frequent species of emergent and submergent plants that were observed in July of 1998, were Common Waterweed (*Elodea canadensis*) to Common Cat-tail (*Typha latifolia*). Due to the variety and abundance of other species within the lake, the removal or control of the aquatic plant species would be a very expensive and difficult operation.

It can be noted that the large amount of decaying plant material decreases the water's oxygen supply. The plant material is also rich in nitrogen and phosphate compounds which settle to the lake bottom when they die, and in-turn add to the already nutrient rich lake bottom.

Due to Shawood Lake's shallow waters and nutrient rich bottom, it would not be recommended to perform mechanical weed harvesting or to use the application of herbicides on this lake in order to control aquatic plant growth.

2.) Water Quality Analysis

A water quality sample was taken from mouth of the Austin Road Canal where it discharges into Shawood Lake in November 1998, and was analyzed by Brighton Analytical, Inc., a State of Michigan certified laboratory, and tested for pH, dissolved oxygen, nitrogen (nitrite & nitrate), phosphorus and coliform bacteria. After comparing the samples to the "Michigan Water Quality Standards Handbook", it was found that all parameters were within acceptable limits. It was determined that the water quality of Shawood Lake was suitable to support aquatic plant and animal life. For a copy of the laboratory results and Chain of Custody, see Appendix V.

3.) Sediment and Nutrient Analysis

A meeting between the City of Novi and the Lake Area Residents Association (LARA) was held with prior to the November 1998 water sampling. As a result of the meeting, the residents requested that both water quality sampling and lake bottom sediment samples be acquired and analyzed for Shawood Lake. Of particular interest, the residents were concerned about the type of water and sediment being discharged into Shawood Lake from the Austin Road Canal.

A lake bottom sediment sample was collected from the Austin Road Canal where it discharges into Shawood Lake. The sample was analyzed for Volatiles and the 10 Michigan Metals.

The Volatile's test, is a test to analyze the sample for alcohols, benzenes, propanes, ethanes and other harmful organic compounds. The results of the Volatile's test were non-detectable limits for all parameters tested, using EPA method number 8260. For a detailed listing the Volatile's results and Chain of Custody, see Appendix VI.

The 10 Michigan Metals test, is a test to analyze the sample for arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver and zinc. The results of the 10 Michigan Metals test were non-detect or below acceptable limits, except for arsenic. The arsenic analysis of the sediment sample revealed 9.8 mg/Kg. The detection limit for this test is 0.1 mg/Kg, and the acceptable limit is 6.6 mg/Kg. For a detailed listing the 10 Michigan Metals test results and Chain of Custody, see Appendix VII.

Based upon the arsenic test, three additional sediment sample were collected up gradient and analyzed for the 10 Michigan Metals. The location of the up gradient sediment samples were located; 10 feet east of Austin Road culvert, 150 east of Austin Road culvert, and 25 west of Old Novi Road. See Figure 2.2 for "Shawood Lake Water and Soil Sample Locations". The results of the 10 Michigan Metals test performed on the three additional up gradient samples were non-detect or below acceptable limits. For a detailed listing the 10 Michigan Metals test results and Chain of Custody, see Appendix VIII.

Arsenic is a naturally occurring element in soils. According to the "Background Soil Survey" report prepared April 1991, by the Michigan Department of Environmental Quality (MDEQ), formerly known as the Department of Natural Resources (MDNR) shows background mean arsenic level of topsoil in Southeast Michigan to be 11.0 mg/Kg. Other possible sources are historic orchards which quite often used a lead-arsenate based pesticide for spraying trees. Arsenic in soils does not generally migrate in solution. Possible sources of arsenic from old orchards within a one half mile radius of Shawood Lake were reviewed on historic photographs and are as follows; East side of Dixon Road between Twelve to 12½ Mile Road, north of 12½ Mile Road and ⅛ mile west of Old Novi Road, northeast corner of Thirteen Mile Road and New Novi Road (Decker Road) and numerous sites south of Thirteen Mile Road Between Novi and Meadowbrook Roads.

A topographic survey of the existing bottom and silt depths was conducted in order to estimate the depths of soft lake bottom sediments. It was found that the depths of sediment in the entire lake were very thick and rich in nutrients. When the field data was analyzed, Shawood Lake averaged 5-7 feet of soft bottom lake sediment, with less soft bottom lake sediments nearer to the shoreline ranging from 1-3 feet. The amount of sediment in Shawood Lake appears to be naturally occurring from decaying plant matter and not from sediment loading from recent storm water runoff events.

The level of eutrophication was discovered to be at a level expected, based upon the amount of weed growth and thickness of lake bottom sediments. Considering the extensive amount of weed and soft lake sediments that exists in Shawood Lake, it is <u>not</u> recommended that a lake dredging program be considered. In addition, an extensive geotechnical evaluation would have to be performed in order to determine the stability of the shoreline, subsequent to completion of dredging operations. There is a risk the existing shoreline "sluffing" off into the lake, due to the counter weight effect of the existing lake sediment being removed.

C. MEADOWBROOK LAKE

Findings - Meadowbrook Lake is considered to be an "in-line lake", meaning that it is basically a widening of the river. Meadowbrook Lake was designed and constructed in the summer of 1984. The lake discharges water to the downstream river via an outlet weir structure. The lake is fed by two water course systems one being the Walled Lake Branch of the Middle Rouge River and the other being Ingersol Creek.

There were no water quality or lake sediment samples collected or analyzed for Meadowbrook Lake, within the scope of this report. In addition an aquatic plant survey was not performed on Meadowbrook Lake, however informal observations were noted. The objective of this phase of the study was to estimate the amount of sediments that have been deposited into Meadowbrook Lake and to determine the feasibility of removing the sediments.

1.) Weed Growth Observations

The were no significant aquatic plant growth areas, either emergent or submergent, on Meadowbrook Lake that were observed during the several site visits to the Lake while investigating the sediment deposit locations . It can easily be speculated that due to the high levels of Total Suspended Solids (TSS) (very cloudy water), submergent plant-life is not able to flourish due to the lack of sunlight penetration. The shorelines appeared to be well maintained to the waters edge, allowing little opportunity for aquatic plant beds to develop.

2.) Water Quality Analysis

Water quality analysis was not requested as part of this study for Meadowbrook Lake. Water quality testing was performed on Meadowbrook Lake by the Rouge River Wet Weather Demonstration Project. Water samples were collected in 1994 and 1995 for water quality analysis. In general, according to the report prepared in July 1996, entitled "RPO-MOD-TM10.00", it was found that the water quality in Meadowbrook Lake and has not changed substantially from historical data collected in 1973. The water quality parameters tested in 1994 and 1995 were all within acceptable limits. See Report "RPO-MOD-TM10.00", in Appendix IX.

3.) Sediment and Nutrient Analysis

Field data was collected for Meadowbrook Lake, for the purpose for determining the general locations of where sediments are being deposited. Upon review of the field data collected and visual observations, it was determined that most of the sediments were being deposited at the points where the Rouge River and Ingersol Creek discharge into Meadowbrook Lake.

A visual inspection of several upstream segments of the Rouge River, revealed several areas which may have contributed to the sediment being transported in the lake over the past years. Some of the processes that were noted as occurring are; stream bank erosion, streambank slope failures, streambank erosion caused by fallen trees and root systems, and sediments that may originate from upstream construction sites.

The eroded soils generated upstream of Meadowbrook Lake are transported to the Lake via the Rouge River and Ingersol Creek. During periods of higher flows, the streams "bed load", may also move downstream into Meadowbrook Lake. During periods of high flow, higher velocities occur in the streams, and therefore the sediments generally do not settle in the stream, but are carried downstream to Meadowbrook Lake.

Once the sediment laden stream flows enter Meadowbrook Lake, the velocity of the water slows down and the result is that the sediments "settle out," into the lake bottom. Accordingly, the predominant area of sedimentation is on the north end, where the Rouge River and Ingersol Creek discharge into Meadowbrook Lake. For a general location of areas identified as having sediment deposited in the Lake, see Figure 2.3.

Recommendation: Based upon the field data collected and the visual observations of the conditions present in the north portion of Meadowbrook Lake where the Rouge River and Ingersol Creek discharge into it, it is recommended that the sediment which has been deposited in Meadowbrook Lake at the north end be removed.

Cost Estimate: It should be noted that lake dredging projects can be very expensive and time consuming projects. There are many factors that affect the construction activities associated with lake dredging projects. The cost estimate shown below represents the estimated cost to remove the sediment by hydraulic dredging methods. There may be other removal methods that will be considered if the project is authorized to continue, however the feasibility of those methods will not be known until several engineering issues are resolved during the preliminary design stage.

Since Meadowbrook Lake has limited access, a construction access site, even temporary in nature, needs to be established prior to the pursuing this activity as a project. In addition, permit acquisition from the State of Michigan Department of Environmental Quality (MDEQ), for these types of projects are notorious for taking a "very long time." An permit for a recently proposed lake dredging project in a neighboring community took three (3) years to acquire, and in addition the community had great difficulty in acquiring qualified bids.

It must be noted that a final "project" cost estimate, which consists of construction and engineering cost (hard and soft costs), will only be known after additional design survey data is collected, rights-of-way/easement conditions are determined, and permit requirements are fully known. The "project" cost estimate listed below is general and should be used for budgeting purposes only.

Hydraulic Lake Sediment Dredging Program

3 acres (43,560 sq. ft.) x 10' dredging depth / (27 cu. ft./cu. yd.)	=	48,400 cu yds
Estimated 70% solids (pay item) = 48,400 cu yds x 0.70	=	34,000 cu yds

Estimated cost to dredge @ $12.00/cu yd	=	$ 408,000
Access Site and Dewatering Site Preparation	=	$ 100,000
Sub-Total		$ 508,000
Contingency (15 %)		$ 77,000
Sub-Total		$ 585,000
Engineering/Administration (35% of Site Work)		$ 35,000
Estimated Project Cost	=	**$ 620,000**

This estimate yields a general project cost of approximately $18 - $20 per cubic yard of sediment removed. This estimate does not include any cost associated for right-of way or any easements that may be required.

It is recommended that the City of Novi apply for a Rouge Program Office (RPO) grant to help offset the cost for this lake dredging project. It is recommended that the focus of the grant request should be based upon the fact that the geographic location of Meadowbrook Lake, enables the lake to act as a community wide sedimentation basin and as such benefits the downstream communities. In addition the grant request should focus on a proposal to establish a permanent sediment removal program, which is to include the establishment of permanent sediment removal staging areas and ingress and egress for the sediment dredging operations.

4.) Lake Access

The initial use will be to allow reasonable access for hydraulic dredging equipment to gain ingress and egress from the lake, and as well as a multitude of other potential benefits from having a point of access to a lake. Without a point of access, the type of equipment used to improve the lake bottom or shoreline in the future will be extremely limited, and will be reflected in the cost of pursuing such projects.

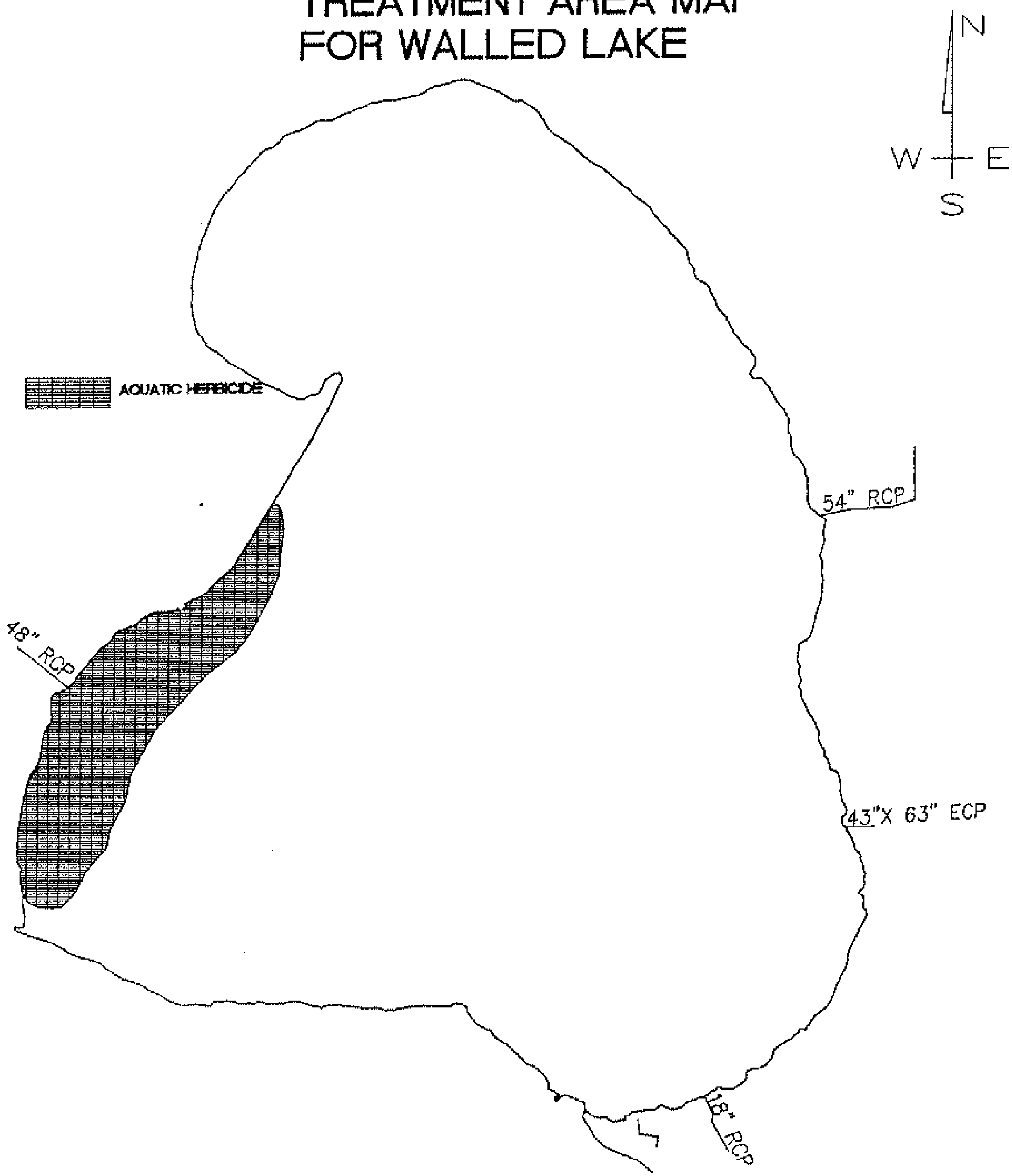
Currently, the City of Novi still owns two parcels on the north end of the lake, which was acquired for the initial dredging project back in 1984. A much larger area is owned by the Meadowbrook Lake Subdivision Association, located on the southwest end of the lake, near the outlet weir structure. Both areas may be suitable to be included in a hydraulic dredging program, however a conclusion as to the actual suitability of either site can be made until the preliminary design phase. Figure 5.5, illustrates the general location of these sites.

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

V. FINDINGS AND RECOMMENDATIONS

FIGURES

TREATMENT AREA MAP FOR WALLED LAKE



STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
WALLED LAKE, SHAWOOD LAKE, AND MEADOWBROOK LAKE

CITY OF NOVI

JCK & associates inc.

JCK & ASSOCIATES, INC.
CONSULTING ENGINEERS
NOVI, MICH. (248) 348 - 2680

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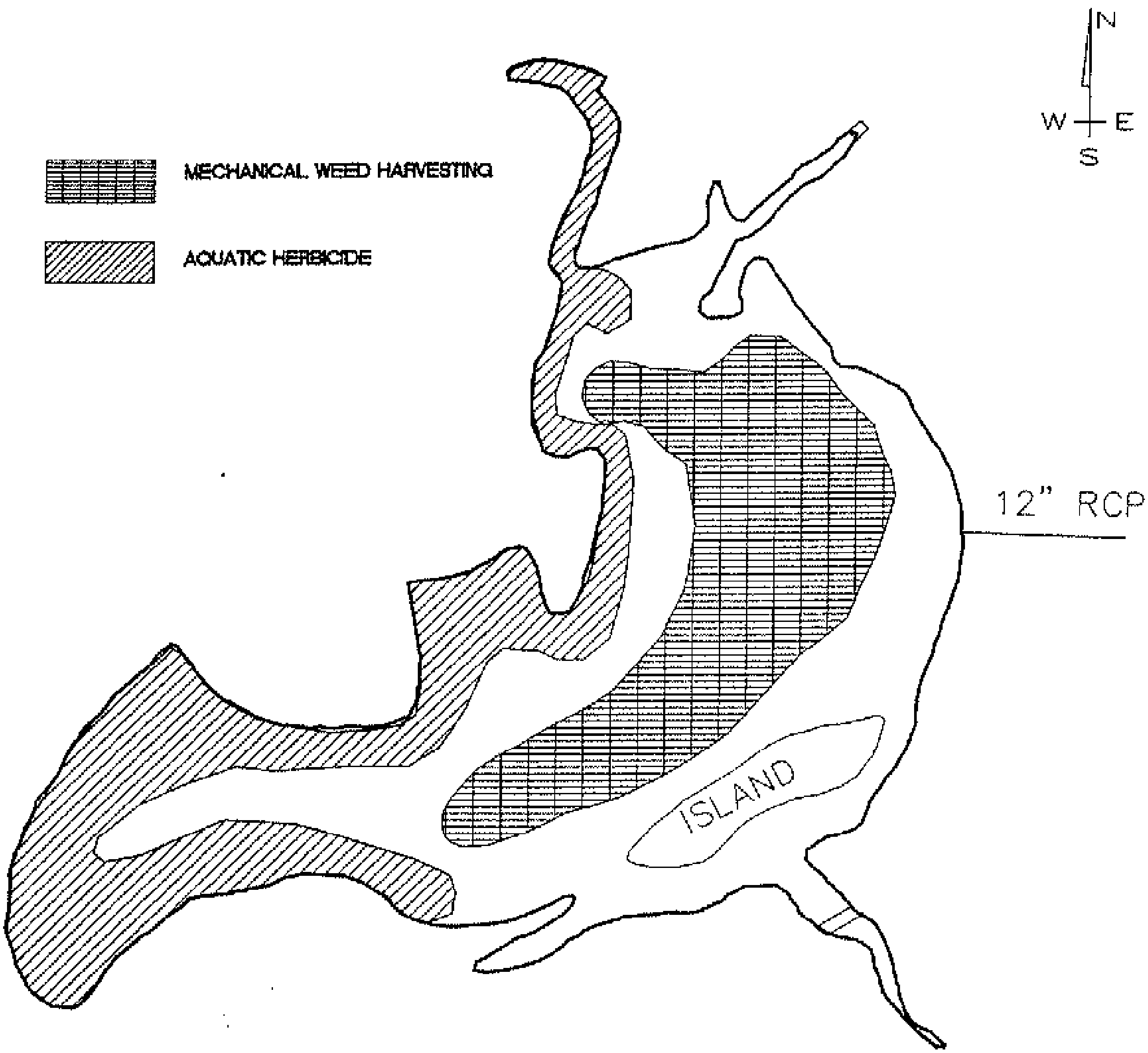
TREATMENT AREA MAP FOR SHAWOOD LAKE



STORMWATER, SEDIMENT, AND AQUATIC PLANT STUDY
WALLED LAKE, SHAWOOD LAKE, AND MEADOWBROOK LAKE

CITY OF NOVI

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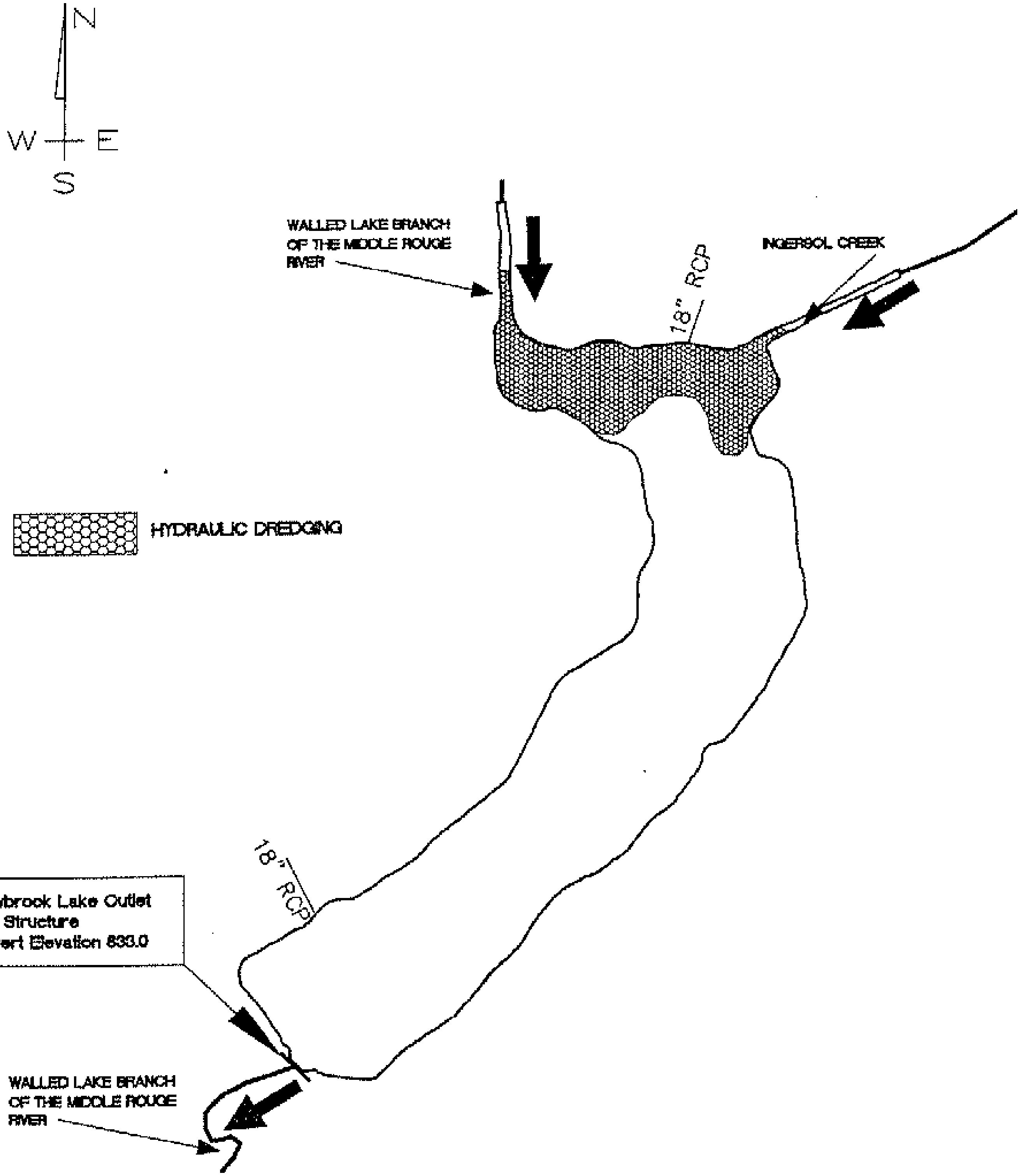
TREATMENT AREA MAP FOR MEADOWBROOK LAKE



STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
WALLED LAKE, SHAWOOD LAKE, AND MEADOWBROOK LAKE

CITY OF NOVI

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FIGURE 5.4

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

Advanced Eutrophication of a Pond.

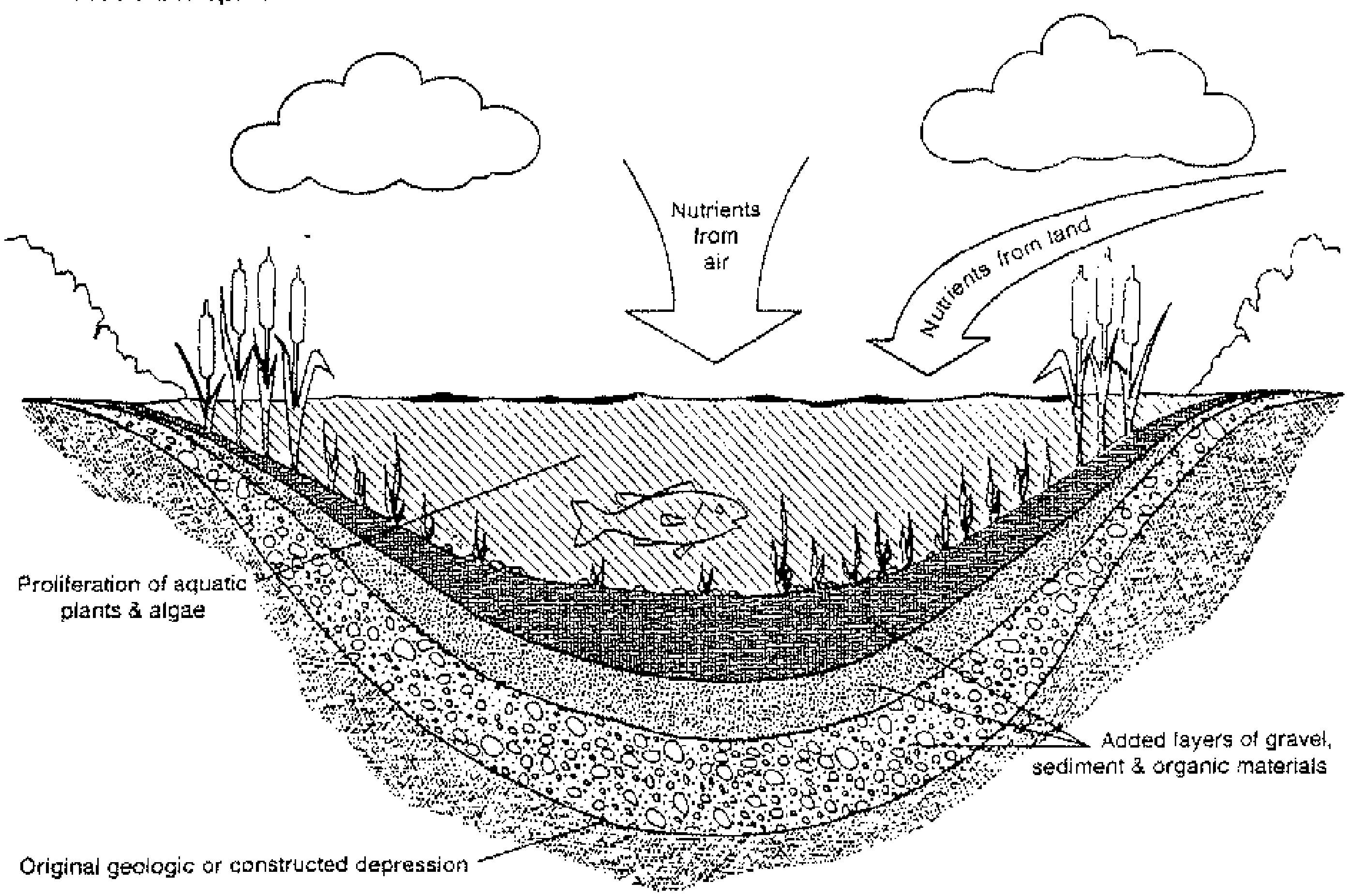
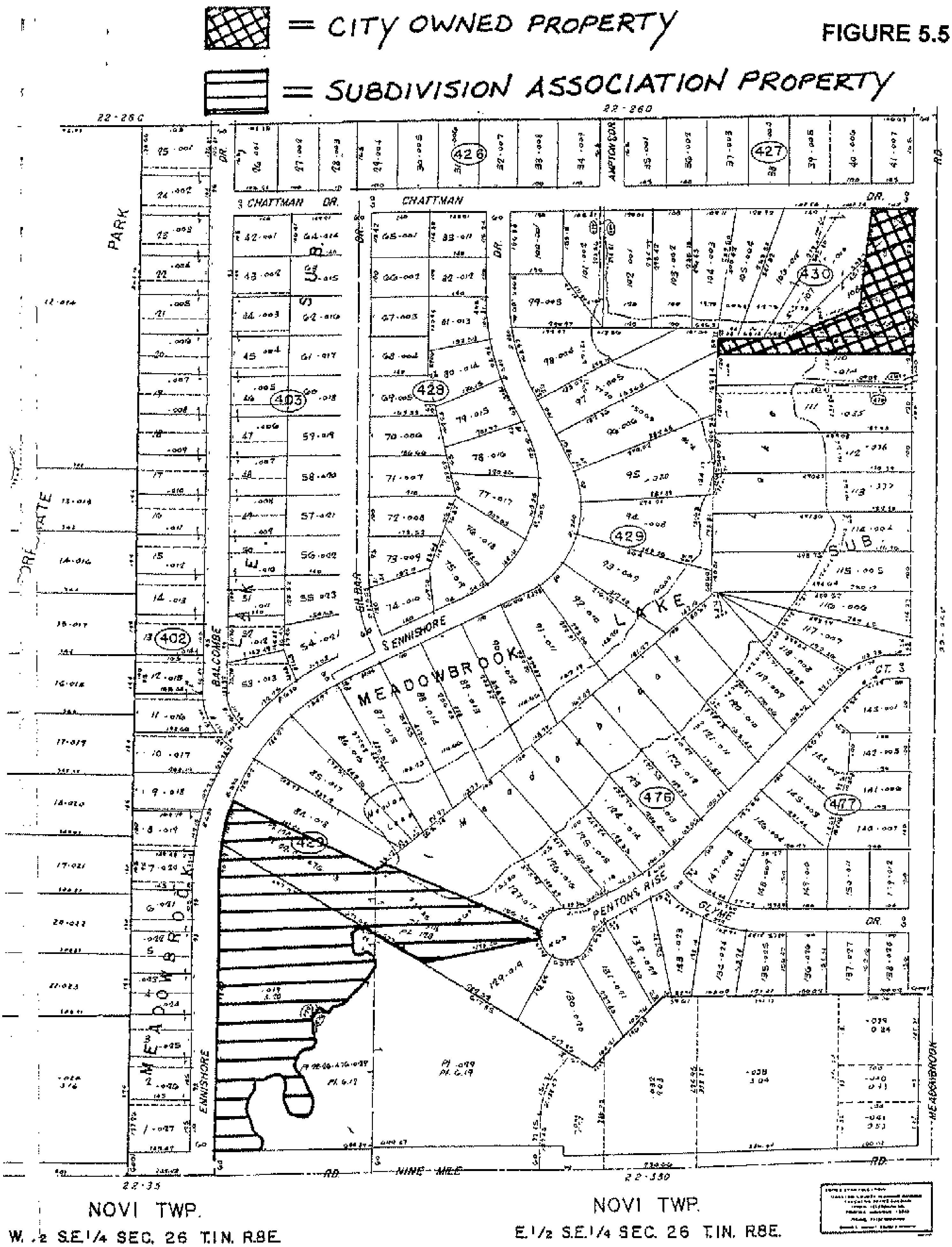


FIGURE 5.5



= CITY OWNED PROPERTY
= SUBDIVISION ASSOCIATION PROPERTY
22-260
CHATTMAN DR.
AMPTON COR.
PARK
BALCOMBE
GILBAR DR.
S. ENNISHORE
MEADOWBROOK LAKE SUB.
ENNISHORE
PENTONS RISE
GLYME DR.
CT.
MEADOWBROOK
NINE MILE RD.
22-35
22-330
NOVI TWP.
W. 1/2 S.E. 1/4 SEC. 26 T.1N. R.8E.
NOVI TWP.
E. 1/2 S.E. 1/4 SEC. 26 T.1N. R.8E.

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

APPENDICES

Appendix I	Stormwater Financial Review Committee Minutes for 1/27/97 and 10/6/97.
Appendix II	(RFP) Request for Professional Services.
Appendix III	Analytical Results for Walled Lake Water Quality.
Appendix IV	Analytical Results for Walled Lake Sediment Metals Analysis.
Appendix V	Analytical Results for Shawood Lake Water Quality.
Appendix VI	Analytical Results for Shawood Lake Volatile's Tests.
Appendix VII	Analytical Results for Shawood Lake Sediment Metals Analysis.
Appendix VIII	Additional Tests of Shawood Lake Sediments.
Appendix IX..	Rouge River National Wet Weather Demonstration Project Technical Memorandum - RPO-MOD-TM10.00. (July 96).
Appendix X..	Inland Lake Improvements - Act No. 451, Public Acts of 1994

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

APPENDIX I

Stormwater Financial Review Committee
-Minutes-

(1) January 27, 1997
(2) October 6, 1997
(3) January 13, 1998
(4) Notice of Meeting, February 9, 1998
(5) Imperviousness Study, September 24, 1997
(6) September 23, 1997
(7) Notice of Meeting, April 29, 1997
(8) April 25, 1997
(9) April 25, 1997, Sedimentation and Weed Study

Member Ross asked about water going into Walled Lake; the sediment going in the lake from development going on around there. Is there any plan to take any sediment out of Walled Lake where the drainage goes in at the outfall? This is across Decker Road. He feels if that was cleaned and restored where it goes into Walled Lake, it probably wouldn't have to be done again for a long time. We need to discuss that again to see if there is money in the budget for that.

Chairman Black said the Lakes Area Residents Association people have asked this Committee to fund a study regarding the weeds in the lake. Some sort of survey may be the starting point to determine the bad areas. The siltation by the Woods of Novi is the major spot. Member Ross pointed out that moneys have been budgeted for water testing and clarity, and he just doesn't want this dropped completely and have Walled Lake become just another basin. Where these inlets are located, there is sediment that needs to be taken care of. Member Black mentioned there is an area on the east needing attention.

Tony mentioned that one of the concerns expressed by JCK was that the Vistas of Novi would be developing, and we should wait to look at a comprehensive plan to address this entire thing. The feeling was to delay that type of a study. We can put moneys in for a preliminary study of the area and wait until the development is a little further down the road for actual finalizing of a plan. He suggested looking at Shawood Lake as well as Meadowbrook Lake, and perhaps a review of all the lakes in the area. Member Ross just wanted to bring it back up so it doesn't slip through the cracks. Packaging it like Tony had described sounded like a good plan. Tony said to set up a work program with estimated budgets, with looking for funding for some of it from the Rouge for Meadowbrook Lake. Tony will get an estimate and include it in the budget presentation to Council with weeds being put in as a separate thing. Tony suggested setting up a program, get it ready for implementation with dates. We don't want another study sitting on the shelf.

If the Committee is satisfied with what Bruce has presented in the budget contingent upon getting with the Finance Director for updated figures, Member Ross wanted to make a Motion.

It was moved by Member Ross and seconded by Chairman Black to approve the budget as presented by Bruce with moneys budgeted in to address the Mark Adams memorandum expressing LARA's concerns. Motion was unanimously approved.

Bruce explained that staffing levels and having only one piece of equipment is the problem and reason why we are so far behind in our goals for maintenance. He talked about the recent Council directive for enhanced mowing duties with additional areas to be mowed as their goal, but they did so without increasing employees and equipment to do the extra work ordered to be done.

CIP:

Tony gave a brief introduction. This CIP is something we have prepared for 6 years now, and this Committee was the front runner in developing this type of program. It deals with all the major have and mesh them with the study proposed and include all of that in the Storm Water Master Plan so the information gets to the people who need to have it. That's the whole purpose of the Storm Water Master Plan.

Michelle understood that the imperviousness study requested by the Planning Commission was made due to information they had received regarding the Davis Creek. It was stated that the Davis Creek is a true imperviousness study, not a water quality study. It's part of the Huron Watershed. Doug explained the correlation of the Middle One Study done by SEMCOG and the RPO.

Member Christoff wants to go with Tony's recommendation of doing a study on a couple of areas in more of a sampling type of thing rather than doing the whole city, and come up with the data. Chairman Black asked for some parameters to be set. It was decided that Dave and Doug will come up with a program, a scope of services, and Tony will go over that with them and get that to the Committees. The name will be changed from Imperviousness Study and retitled. Chairman Black made a few title suggestions.

Walled Lake Sedimentation and Weed Study: Chairman Black pointed out that we have two of them to consider. It was decided this can be done at a later date when this requested information from Dave and Doug on the Imperviousness Study has been digested by the Committee.

Harvest Land Development Request: Tony had another issue to throw on the table for the Committee to consider. A tentative proposal has been made by Harvest Land to remove the gravel pit from the Storm Water Master Plan. Options have been considered. Dave and Doug explained what is involved, pointing out the area in question. Harvest Land wants to use the lake as a private development and remove it from the City control. JCK has been asked to evaluate the request, and see if it can be removed from the Storm Water Master Plan. Another wrinkle is that it's also a County drain. Doug said Harvest Land's concern is water quality. They are putting in their own water quality controls for their own storm water discharges. Member Christoff asked what's the major advantage to them for doing this? Dave said their goal is to leave the lake as pristine as possible by controlling water quality and not using it as a water quality control basin. Half million dollar houses will be built around it. The question was asked as to what recreational usage would be allowed on that lake? The RUD allows only boats under sail, no motors. ?

Doug said there is a concern as to how much of the development is in the watershed. Doug said it turns out to be at least 75-80% of it is in the watershed. Joela expressed her concern that if we don't have control of the water quality in that lake, we are defeating our purpose. She cited what happened to Meadowbrook Lake as an example. There are maintenance issues, and future controls of that area that would be out of the City's hands. Tony said on the other end, there will be half-million dollar homes around that lake, and our standards may not meet their standards. Joela said if they are going to accept the maintenance over the next 100 years, and we can test their water quality to make sure it's up to par, then fine. We have to be assured of the water quality, that they are not discharging anything downstream that shouldn't be, and that they are

From: Kathy Kendra
To: Craig Smith, Dave Potter, Doug Pakkala, Tonni B...
Date: 1/13/98 1:47PM
Subject: Storm Water Financial Review Committee Meeting

Attached is the agenda for the next meeting scheduled for
Monday, February 9, 1998 at 4:30 p.m. in the Activities Room.

CC: Sue Blumer, Tony Nowicki

STORM WATER FINANCIAL REVIEW COMMITTEE
NOTICE OF MEETING

Monday, February 9, 1998
4:30 P.M.
Activities Room - Community Center Wing
45175 W. Ten Mile Rd.

AGENDA

I. Audience Participation

II. Discussion of meeting Notes taken10/6/97

III. Projects Update - JCK

IV. Discussion and Approval of 1998 Capital Improvements Program and Storm Water Budget

V. Schedule next meeting date/time

File: Agenda
(Dir)StormWtr

From: Dave Bluhm
To: Novi_GW.City_Hall.JWahl, Novi_GW.City_Hall.SCohen,...
Date: 9/24/97 8:08AM
Subject: Storm Water Financial Review Committee -Forwarded

Jim:

Tony has scheduled presentation of the previously proposed Imperviousness Study for the Stormwater Committee meeting on October 6, 1997. It is my opinion that members of the Environmental Committee and/or the Planning Commission be present and involved in the presentation along with our office.

Please call to discuss.

Dave B.

CC: DaveP

From: Kathy Kendra
To: JCK_Headquarters.JCK_PO.DaveB, JCK_Headquarters.JC...
Date: 9/23/97 5:12PM
Subject: Storm Water Financial Review Committee

The next meeting has been scheduled for October 6th at 4:30 p.m. in the Activities Room.

Dave Bluhm's Imperiousness Study will have to be presented at that meeting and the written report must be available for packet distribution.

Thanks.

CC: TNowicki

From: Kathy Kendra
To: JCK_Headquarters.JCK_PO.DougP, JCK_Headquarters.JC...
Date: 4/29/97 2:25PM
Subject: Storm Water Committee Meeting

Gentlemen:

The meeting of this committee has been canceled until further notice. The issue requested for review by Council has been resolved.

Until next time,

Kathy K.

From: Kathy Kendra
To: JCK_Headquarters.JCK_PO.DougP, JCK_Headquarters.JC...
Date: 4/25/97 5:05PM
Subject: Storm Water Review Committee Meeting

Gentlemen:

The Council has requested an immediate meeting be convened of the Storm Water Committee to discuss the imperiousness study being contemplated for funding as part of this year's budget process. Please review the study narrative prepared by your firm as well as the Storm Water Master Plan and be prepared to discuss both at the meeting on Wendesday, April 30, at 4:30 p.m. I will advise you of the room location as soon as one has been secured.

Thanks, Kathy

CC: TNowicki

From: Tony Nowicki
To: JCK_Headquarters.JCK_PO.DaveP, JCK_Headquarters.JC...
Date: 4/25/97 7:54AM
Subject: Sedimentation & Weed Control Study

Gentlemen -- At last night's budget meeting, Council had requested details and deliverables for the referenced. Please recall that the Storm Water Committee had placed this in the budget and had requested that JCK prepare a program narrative, scope of services and budget amount. To the best of my knowledge, this has not been done. If true, then please prepare such and forward to me by 1:00 pm Monday April 28, 1997. Otherwise, just forward another copy of the material. Call if you have any questions.
Thanks -- Tony.

CC: BJerome

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

APPENDIX II

(RFP) Request for Professional Services

(1) Walled, Shawood and Meadowbrook Lake Weed and Sedimentation Study RFP - Revised.
(2) Updated status for the study, September 16, 1998.
(3) Continuance Authorization, December 1, 1997.
(4) Initial Request for Professional Services.

	ESTIMATED STUDY COST		***$15,200***
SEDIMENTATION STUDY			
IDENTIFY PROBLEM AREAS		$1,500	
TOPOGRAPHIC SURVEY		$4,500	
SEDIMENT SAMPLING		$4,000	
ANALYZE DATA		$4,500	
REPORT AND COST ESTIMATE		$3,500	
	ESTIMATED STUDY COST		***$18,000***
PERMIT PREPARATION, PLANS AND SPECIFICATIONS			*$6,000*
TOTAL ESTIMATED COST			*$39,200*

The costs above do not include design of a spoils site, weed harvest site or any property acquisition costs that may be identified in the study.

It should also be noted that the above costs are preliminary estimates for budgetary purposes. A more detailed estimate of costs will be prepared once a scope of service is determined.

If you have any questions or need any additional information, please do not hesitate to call.

Very truly yours,

JCK and Associates, Inc.
Consulting Engineers for the City of Novi

Douglas A. Pakkala, P.E.
Project Manager

cc: B. Jerome, DPS
D. Potter, JCK
file

JCK & associates, inc.

Consulting Engineers • Architects • Land Surveyors
• Environmental Services • Planners •

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Branch Office
2525 E. Paris SE, Ste. 160
Grand Rapids, MI 49546
(616) 954-2770
Fax (616) 954-2777

September 16, 1998

Mr. Anthony Nowicki, Director of Public Service
City of Novi
45175 West Ten Mile Road
Novi, MI 48375

RE: Status of Walled Lake Weed and Sedimentation Study
JCK Job No. N -6238

Dear Mr. Nowicki;

In response to your request, this letter is to update you on the current status of the Walled Lake Weed and Sedimentation Study. As you may recall, this study requires a multi-phase approach to determine weed types and densities and the sediment accumulation that has occurred. The first phase of the weed study was performed in June of 1998. The weed types and densities were determined along with bottom characteristics. Water quality samples were also collected and are being analyzed. The second inspection is scheduled for September 24. This inspection will be similar to the first to determine weed types, densities and water quality parameters. Also included in the is a survey of the lake bottom in the areas of the major stormwater outfalls to determine the level of sedimentation that has occurred compared with historical data.

After all of this data has been acquired, including the laboratory analysis of the water quality samples a report will be prepared detailing the findings and recommendations for control of the weed growth and sediment removal as necessary.

It is our understanding that there is a meeting scheduled for Tuesday, September 22, 1998 with representatives of the Lake Area Residents Association to discuss the status of the investigation and report. A representative of JCK and Associates will be attending to provide a status report answer any questions from the residents.

Please do not hesitate to contact our office if you have any questions or need any additional information.

Very truly yours,

JCK and Associates, Inc.
Consulting Engineers for the City of Novi

Douglas A. Pakkala, P.E.
Director of Municipal Design Services

cc: D. Potter
C. Farnham
file

JCK & associates, inc.

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• Environmental Services • Planners •

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Fax (616) 954-2777

May 1, 1997

Mr. Anthony Nowicki
Director of Public Works
City of Novi
45175 West Ten Mile
Novi, MI 48375

RE: Walled Lake, Shawood and Meadowbrook Lake Weed and Sedimentation Study *(Revised)*
JCK Job No. 5400-13

Dear Mr. Nowicki;.

At the Stormwater Financial Review Committee meeting held on January 27, 1997, a request was presented to perform a weed study for Walled Lake and a sediment study for limited areas on Walled Lake, Shawood Lake and Meadowbrook Lake. The original scope and cost estimate prepared on February 24, 1997 has been revised to reflect the addition of permit preparation and plans and specifications for bid purposes.

WALLED LAKE WEED STUDY - OBJECTIVES AND REQUIREMENTS OF STUDY

Objective of Study - The objective of this study is to identify weed growth areas near stormwater outfalls and drainage channels, recommend solutions to control growth in the identified areas and to prepare cost estimates for the various solutions.

The following are the basic requirements of the study:

A. Analyze aquatic weed growth in identified areas and make recommendations for removal and control. Prepare a map which shows the locations and types of aquatic vegetation and approximate lake bottom contours using existing data.

B. Determine water quality in these identified areas using the following listed parameters and recommend appropriate action to improve water quality.

1. pH
2. Oxygen Concentration
3. Phosphorous Concentration
4. Nitrogen Concentration
5. Chlorophyll Concentration
6. Secchi Disk Concentration
7. Theoretical Nutrient Budget

C. Evaluate the sediments and associated nutrients in high weed growth areas, their removal and appropriate disposal if necessary.

D. Investigate alternative methods of weed control including chemical and mechanical methods, aeration, dredging, etc.

SAMPLE WORK PROGRAM

The following is a sample work program for the above mentioned project.

Coordinate and perform field survey of plant types, locations and density. The initial inspection will be performed in May-June and a follow-up inspection in August.
Perform water quality testing at inlets and high growth areas
Prepare report and cost estimate

WALLED LAKE, SHAWOOD LAKE AND MEADOWBROOK LAKE - SEDIMENTATION REMOVAL STUDY - OBJECTIVE AND REQUIREMENTS OF STUDY

Objective of Study - The objective of this study is to identify areas in the lakes that are experiencing sedimentation adjacent to stormwater outfalls and other discharge points. The sediments in these areas will then be tested and quantified to determine methods and estimated costs for removing sediments deposited by the stormwater outfalls.

The following are the basic requirements of this portion of the study:

A. Identify areas adjacent to the stormwater outfall into the lakes that have deposited sediments into the lakes

B. Perform a lake bottom topographic survey in the identified areas and preform a chemical analysis of the sediments to determine removal and disposal requirements

C. Prepare a report detailing findings along with cost estimates and permit requirements for the sediment removal.

The studies will be presented to the City for review and comment. If the City desires to proceed with the work identified in the studies, JCK and Associates, Inc. will prepare and submit permit applications for the permits identified in the study. After receipt of permits, we will prepare final plans and specifications for bid purposes.

SUMMARY OF COSTS

WEED STUDY

FIELD IDENTIFICATION	$5,200
WATER QUALITY SAMPLING AND ANALYSIS	$7,500
REPORT AND COST ESTIMATES	$2,500

City of Novi
45175 west ten mile road / novi, michigan 48375-3024 / (810) 347-0460 general information

December 1, 1997

David Potter
JCK & ASSOCIATES, INC.
45650 Grand River
Novi, Michigan 48376

RE: Walled Lake, Shawood and Meadowbrook Lake
Weed and Sedimentation Study

Dear Mr. Potter:

Regarding the referenced, you were authorized to proceed with conceptual phase of this study, as well as most other projects contained within the Capital Improvement Program, on June 10, 1997. As you had indicated, I did receive your facsimile of October 6, 1997 on this matter, however, it was a transmittal of a previous letter and only requested a telephone call if I had any questions. In any case, please get this study moving forward.

Also, as a point of clarification, this study should include everything to the point that we can solicit proposals for the work. Your budget for the study is $39,200.

Should you have any questions, contact me as needed.

Sincerely,

Anthony W. Nowicki
Director of Public Services

AWN:kk
Enclosures: DPS letter dated 6/10/97
JCK fax dated 10/6/97
cc: C. Smith

File: Tri-Lake Sty
(Dir)StormwtrStudies

JCK & associates, inc.

Consulting Engineers • Architects • Land Surveyors
• Environmental Services • Planners •

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Fax (616) 954-2777

February 24, 1997

Mr. Bruce Jerome
Superintendent of Public Service
City of Novi
26300 Delwal
Novi, MI 48375

RE: Walled Lake, Shawood and Meadowbrook Lake Weed and Sedimentation Study
JCK Job No. 5400-13

Dear Mr. Jerome:

At the Stormwater financial review Committee meeting held on January 27, 1997, a request was presented to perform a weed study for Walled Lake and a sediment study for limited areas on Walled Lake, Shawood Lake and Meadowbrook Lake. Subsequent to this meeting JCK and Associates was requested to prepare a cost estimate for this work.

WALLED LAKE WEED STUDY - REQUIREMENTS AND OBJECTIVES OF STUDY

The following are the basic requirements of the study:

A. Analyze aquatic weed growth and make recommendations for removal and control. Prepare a map which shows the locations and types of aquatic vegetation and approximate lake bottom contours using existing data.

B. Determine lake water quality using the following listed parameters and recommend appropriate action to improve water quality.

1. pH
2. Oxygen Concentration
3. Phosphorous Concentration
4. Nitrogen Concentration
5. Chlorophyll Concentration
6. Secchi Disk Concentration
7. Theoretical Nutrient Budget

C. Evaluate the lake bottom sediments and associated nutrients, their removal and appropriate disposal.

D. Investigate alternative methods of lake improvements including chemical and mechanical weed control, aeration, dredging, etc.

SAMPLE WORK PROGRAM

The following is a sample work program for the above mentioned project.

Coordinate and perform field survey of plant types, locations and density. The initial inspection will be performed in May-June and a follow-up inspection in August.
Perform water quality testing at inlets and high growth areas
Prepare report and cost estimate

WALLED LAKE, SHAWOOD LAKE AND MEADOWBROOK LAKE, SEDIMENTATION REMOVAL STUDY - REQUIREMENTS AND OBJECTIVES OF STUDY

The following are the basic requirements of this portion of the study:

A. Identify areas adjacent to the stormwater outfalls into the lakes that have deposited sediments into the lakes

B. Perform a lake bottom topographic survey and chemical analysis of the sediments to determine removal and disposal requirements

C. Prepare a report detailing findings along with cost estimates and permit requirements for the sediment removal.

SUMMARY OF COSTS

WEED STUDY	
FIELD IDENTIFICATION	$5,200
WATER QUALITY SAMPLING AND ANALYSIS	$7,500
REPORT AND COST ESTIMATES	$2,500
ESTIMATED STUDY COST	$15,200
SEDIMENTATION STUDY	
IDENTIFY PROBLEM AREAS	$1,500
TOPOGRAPHIC SURVEY	$4,500
SEDIMENT SAMPLING	$4,000
ANALYZE DATA	$4,500
REPORT AND COST ESTIMATE	$3,500
ESTIMATED STUDY COST	$18,000

It should be noted that normally studies of this nature are paid for by establishing a Lake Board and assessing the adjoining residents. It should also be noted that the above costs are preliminary estimates for budgetary purposes. A more detailed estimate of costs will be prepared once a scope of service is determined.

If you have any questions or need any additional information, please do not hesitate to call.

Very truly yours,
JCK and Associates, Inc.
Consulting Engineers for the City of Novi

Douglas A. Pakkala, P.E.
Project Manager

cc: A. Nowicki, DPS
D. Potter, JCK
file

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

APPENDIX III

Walled Lake Analytical Results For:
Water Quality

3037

Brighton Analytical, Inc.™

2105 Pless Drive
Brighton, MI 48114
Phone: (810) 229-7575
Fax: (810) 229-8650

COMPANY NAME: JCK

PROJECT NAME: LAKE STUDY

REQUESTED TURNAROUND: (circle one)
Rush: 1-3 business days (verify with lab)
Expedited: 5 business days
Standard: 10 business days

PROJECT NUMBER: N-5400-13

P. O. NUMBER/QUOTE #:

REPORT RESULTS TO: BEN FARNHAM

PHONE: 248-348-2680 x136
FAX: 248-348-2777

ABBREVIATIONS FOR MATRIX
S = Solids A = Air
U = Sludge Q = Aqueous

Analysis Requested

Brighton ID #	Sample Description	Date Sampled	Time Sampled	# of Containers	Sample Matrix	pH	Dissolved Oxygen	Nitrogen (Nitrate + Nitrite)	Phosphorous	Coliform	10 MI Metals	Ammonia - N	TKN	Comments:
1) 06981	WL-1 14 + E. Lake	7-29	10:34	3	Q	X	X	X	X	X		X	X	
2)														
3) 82	WL-2 13 + Novi	7-29	11:05	3	Q	X	X	X	X			X	X	
4)														
5) 83	WL-3 Shawood	7-29	12:47	3	Q	X	X	X	X			X	X	
6)														
7) 84	WL-4 W. Lake + Penfill	7-29	1:30	3	Q	X	X	X	X	X		X	X	
8)														
9)														
10)														
11)														

Please fill out the Chain of Custody completely and review. Incorrect or incomplete information will result in a "hold" on all analyses

(1) Relinquished by: Ben Farnham	(1) Date/Time: 7-29-98 4:30 AM	(1) Received by: [signature]	(1) Date/Time: 7/29/98 4:30 pm
(2) Relinquished by:	(2) Date/Time:	(2) Received by:	(2) Date/Time:
(3) Relinquished by:	(3) Date/Time:	(3) Received by:	(3) Date/Time:

BA Brighton Analytical Inc.

Brighton Analytical, Inc.
2105 Pless Drive
Brighton, Michigan 48116
Phone: (810)229-7575 FAX: (810)229-8650

Date: 08/06/98

Date Submitted: 07/29/98
Date Sampled: 07/29/98

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: **30137**

Project Name: **Lake Study**

Sample ID: **WL-1 14+E. Lake**

BA Sample ID: **AN06981**

Project Number: **N-5400-13**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Inorganic Analysis						
Dissolved Oxygen	**7.9**	mg/L	0.05	EPA 360.1	BC	07/30/98
Nitrate	**Not detected**	mg/L	0.05	EPA353.2/300	RM	07/30/98
Nitrite	**Not detected**	mg/L	0.05	EPA353.2/300	RM	07/30/98
Nitrogen (Ammonia)	**0.05**	mg/L	0.01	EPA 350.3	RM	08/03/98
Nitrogen (Kjeldahl)	**0.77**	mg/L	0.10	EPA 351.2	RM	07/30/98
pH	**8.7**	S.I.		EPA 150.1	LS	07/31/98
Phosphorus (total)	**Not detected**	mg/L	0.02	EPA 365.2	RM	08/05/98
Micro-Biological Analysis						
Total Coliform	**3900**	CFU/100 ml	1.0	SM 9222B	WT	07/30/98

Analytical
Inc.

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 8/6/98

Coliform performed by State of MI certified lab Water Tech, Inc.

BA Brighton Analytical Inc.

Brighton Analytical, Inc.
2105 Pless Drive
Brighton, Michigan 48116
Phone: (810)229-7575 FAX: (810)229-8650

Date: 08/06/98

Date Submitted: 07/29/98
Date Sampled: 07/29/98

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: **30137**

Project Name: **Lake Study**

Sample ID: **WL-2 13+ Novi**

BA Sample ID: **AN06982**

Project Number: **N-5400-13**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Inorganic Analysis						
Dissolved Oxygen	**7.8**	mg/L	0.05	EPA 360.1	BC	07/30/98
Nitrate	**Not detected**	mg/L	0.05	EPA353.2/300	RM	07/30/98
Nitrite	**Not detected**	mg/L	0.05	EPA353.2/300	RM	07/30/98
Nitrogen (Ammonia)	**0.04**	mg/L	0.01	EPA 350.3	RM	08/03/98
Nitrogen (Kjeldahl)	**1.1**	mg/L	0.10	EPA 351.2	RM	07/30/98
pH	**8.7**	S.I.		EPA 150.1	LS	07/31/98
Phosphorus (total)	**0.02**	mg/L	0.02	EPA 365.2	RM	08/05/98

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 8/6/98

Brighton Analytical Inc.

Brighton Analytical, Inc.
2105 Pless Drive
Brighton, Michigan 48116
Phone: (810)229-7575 FAX: (810)229-8650

Date: 08/06/98

Date Submitted: 07/29/98
Date Sampled: 07/29/98

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: **30137**

Project Name: **Lake Study**

Sample ID: **WL-3 Shawood**

BA Sample ID: **AN06983**

Project Number: **N-5400-13**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Inorganic Analysis						
Dissolved Oxygen	**8.6**	mg/L	0.05	EPA 360.1	BC	07/30/98
Nitrate	**Not detected**	mg/L	0.05	EPA353.2/300	RM	07/30/98
Nitrite	**Not detected**	mg/L	0.05	EPA353.2/300	RM	07/30/98
Nitrogen (Ammonia)	**0.04**	mg/L	0.01	EPA 350.3	RM	08/03/98
Nitrogen (Kjeldahl)	**0.92**	mg/L	0.10	EPA 351.2	RM	07/30/98
pH	**8.8**	S.I.		EPA 150.1	LS	07/31/98
Phosphorus (total)	**Not detected**	mg/L	0.02	EPA 365.2	RM	08/05/98

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 8/6/98

BA Brighton Analytical Inc.

Brighton Analytical, Inc.
2105 Pless Drive
Brighton, Michigan 48116
Phone: (810)229-7575 FAX: (810)229-8650

Date: 08/06/98

Date Submitted: 07/29/98
Date Sampled: 07/29/98

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: **30137**

Project Name: **Lake Study**

Sample ID: **WL-4 W. Lake + Penhill**

BA Sample ID: **AN06984**

Project Number: **N-5400-13**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Inorganic Analysis						
Dissolved Oxygen	**8.6**	mg/L	0.05	EPA 360.1	BC	07/30/98
Nitrate	**Not detected**	mg/L	0.05	EPA353.2/300	RM	07/30/98
Nitrite	**Not detected**	mg/L	0.05	EPA353.2/300	RM	07/30/98
Nitrogen (Ammonia)	**0.04**	mg/L	0.01	EPA 350.3	RM	08/03/98
Nitrogen (Kjeldahl)	**0.86**	mg/L	0.10	EPA 351.2	RM	07/30/98
pH	**8.4**	S.I.		EPA 150.1	LS	07/31/98
Phosphorus (total)	**Not detected**	mg/L	0.02	EPA 365.2	RM	08/05/98
Micro-Biological Analysis						
Total Coliform	**18000**	CFU/100 ml	1.0	SM 9222B	WT	07/30/98

Brighton Analytical Inc.

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 8/6/98

Coliform performed by State of MI certified lab, Water Tech, Inc.

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

APPENDIX IV

Walled Lake Analytical Results for:
Sediments (10 Michigan Metals)

3C'36

Brighton Analytical, Inc.™

2105 Pless Drive
Brighton, MI 48114
Phone: (810) 229-7575
Fax: (810) 229-8650

COMPANY NAME: JCK

PROJECT NAME: LAKE STUDY

REQUESTED TURNAROUND: (circle one)
Rush: 1-3 business days (verify with lab)
Expedited: 5 business days
Standard: 10 business days

PROJECT NUMBER: N-5400-13

P. O. NUMBER/QUOTE #:

REPORT RESULTS TO: BEN FARNHAM

PHONE: 248-348-2680
FAX: 248-348-2777

ABBREVIATIONS FOR MATRIX
S = Solids A = Air
U = Sludge Q = Aqueous

Analysis Requested

Brighton ID #	Sample Description	Date Sampled	Time Sampled	# of Containers	Sample Matrix	10 MI. METALS								Comments:
1) 06977	WL-1 14 + E LAKE	7-29	10:34	1	S	X								
2) 78	WL-2 13 + NOVI	↓	11:05	1	S	X								
3) 79	WL-3 SHAWOOD	↓	12:47	1	S	X								
4) 80	WL-4 W. LAKE + PENHILL	↓	1:30	1	S	X								
5)														
6)														
7)														
8)														
9)														
10)														
11)														

Please fill out the Chain of Custody completely and review. Incorrect or incomplete information will result in a "hold" on all analyses

(1) Relinquished by: Ben Farnham	(1) Date/Time: 7-29-98 4:30PM	(1) Received by: [signature]	(1) Date/Time: 7/29/98 4:30pm
(2) Relinquished by:	(2) Date/Time:	(2) Received by:	(2) Date/Time:
(3) Relinquished by:	(3) Date/Time:	(3) Received by:	(3) Date/Time:

Brighton Analytical Inc.

Brighton Analytical, Inc.
718 Advance Street
Brighton, Michigan 48116
Phone: (810)229-7575 FAX: (810)229-8650

Date: 08/03/98

Date Submitted: 07/29/98
Date Sampled: 07/29/98

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: **30136**

Project Name: **Lake Study**

Sample ID: **WL-1 14 + E. Lake**

BA Sample ID: **AN06977**

Project Number: **N-5400-13**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Metal Analysis						
Total Arsenic	**3.1**	mg/Kg	0.10	SW846 6020	GW	07/31/98
Total Barium	**5.2**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Total Cadmium	**Not detected**	mg/Kg	0.05	SW846 6020	GW	07/31/98
Total Chromium	**3.5**	mg/Kg	0.20	SW846 6020	GW	07/31/98
Total Copper	**3.6**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Total Lead	**3.5**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Total Mercury	**Not detected**	mg/Kg	0.10	SW846 7471	GW	08/02/98
Total Selenium	**Not detected**	mg/Kg	0.50	SW846 6020	GW	07/31/98
Total Silver	**Not detected**	mg/Kg	0.50	SW846 6020	GW	07/31/98
Total Zinc	**19**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Metal Soil (digestion)	**Digested**				LS	07/31/98
Mercury (digestion)	**Digested**				GW	08/02/98
%Solid	**79.9**	%		ASTM D-2216	GW	07/31/98

Brighton Analytical Inc.

All soil results based on dry weight.

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 8/3/98

Brighton Analytical, Inc.
718 Advance Street
Brighton, Michigan 48116
Phone: (810)229-7575 FAX: (810)229-8650

Date: 08/03/98

Date Submitted: 07/29/98
Date Sampled: 07/29/98

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: **30136**

Project Name: **Lake Study**

Sample ID: **WL-2 13 + Novi**

BA Sample ID: **AN06978**

Project Number: **N-5400-13**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Metal Analysis						
Total Arsenic	**3.9**	mg/Kg	0.10	SW846 6020	GW	07/31/98
Total Barium	**13**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Total Cadmium	**0.32**	mg/Kg	0.05	SW846 6020	GW	07/31/98
Total Chromium	**7.6**	mg/Kg	0.20	SW846 6020	GW	07/31/98
Total Copper	**17**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Total Lead	**55**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Total Mercury	**Not detected**	mg/Kg	0.10	SW846 7471	GW	08/02/98
Total Selenium	**Not detected**	mg/Kg	0.50	SW846 6020	GW	07/31/98
Total Silver	**Not detected**	mg/Kg	0.50	SW846 6020	GW	07/31/98
Total Zinc	**76**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Metal Soil (digestion)	**Digested**				LS	07/31/98
Mercury (digestion)	**Digested**				GW	08/02/98
%Solid	**75.4**	%		ASTM D-2216	GW	07/31/98

Brighton Analytical Inc.

All soil results based on dry weight.

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 8/3/98

BA Brighton Analytical Inc.

Brighton Analytical, Inc.
718 Advance Street
Brighton, Michigan 48116
Phone: (810)229-7575 FAX: (810)229-8650

Date: 08/03/98

Date Submitted: 07/29/98
Date Sampled: 07/29/98

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: **30136**

Project Name: **Lake Study**

Sample ID: **WL-3 Shawood**

BA Sample ID: **AN06979**

Project Number: **N-5400-13**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Metal Analysis						
Total Arsenic	**5.5**	mg/Kg	0.10	SW846 6020	GW	07/31/98
Total Barium	**10**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Total Cadmium	**0.07**	mg/Kg	0.05	SW846 6020	GW	07/31/98
Total Chromium	**4.3**	mg/Kg	0.20	SW846 6020	GW	07/31/98
Total Copper	**5.2**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Total Lead	**7.1**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Total Mercury	**Not detected**	mg/Kg	0.10	SW846 7471	GW	08/02/98
Total Selenium	**Not detected**	mg/Kg	0.50	SW846 6020	GW	07/31/98
Total Silver	**Not detected**	mg/Kg	0.50	SW846 6020	GW	07/31/98
Total Zinc	**27**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Metal Soil (digestion)	**Digested**				LS	07/31/98
Mercury (digestion)	**Digested**				GW	08/02/98
%Solid	**74.2**	%		ASTM D-2216	GW	07/31/98

Brighton Analytical Inc.

All soil results based on dry weight.

DL=Detection Limit as recommended by MDEQ.

Released by: J Kenyon

Date: 8/3/98

Brighton Analytical Inc.

Brighton Analytical, Inc.
718 Advance Street
Brighton, Michigan 48116
Phone: (810)229-7575 FAX: (810)229-8650

Date: 08/03/98

Date Submitted: 07/29/98
Date Sampled: 07/29/98

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: **30136**

Project Name: **Lake Study**

Sample ID: **WL-4 W. Lake + Penhill**

BA Sample ID: **AN06980**

Project Number: **N-5400-13**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Metal Analysis						
Total Arsenic	**7.1**	mg/Kg	0.10	SW846 6020	GW	07/31/98
Total Barium	**13**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Total Cadmium	**0.15**	mg/Kg	0.05	SW846 6020	GW	07/31/98
Total Chromium	**8.2**	mg/Kg	0.20	SW846 6020	GW	07/31/98
Total Copper	**15**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Total Lead	**15**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Total Mercury	**Not detected**	mg/Kg	0.10	SW846 7471	GW	08/02/98
Total Selenium	**Not detected**	mg/Kg	0.50	SW846 6020	GW	07/31/98
Total Silver	**Not detected**	mg/Kg	0.50	SW846 6020	GW	07/31/98
Total Zinc	**57**	mg/Kg	1.0	SW846 6020	GW	07/31/98
Metal Soil (digestion)	**Digested**				LS	07/31/98
Mercury (digestion)	**Digested**				GW	08/02/98
%Solid	**77.7**	%		ASTM D-2216	GW	07/31/98

Brighton Analytical Inc.

All soil results based on dry weight.

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 8/3/98

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

APPENDIX V

Shawood Lake Analytical Results for:
Water Quality

3225/

Brighton Analytical, Inc.™

2105 Pless Drive
Brighton, MI 48114

Phone: (810) 229-7575
Fax: (810) 229-8650

COMPANY NAME: JCR

PROJECT NAME: SHAWOOD LAKE STUDY

REQUESTED TURNAROUND: (circle one)
- **Rush:** 1-3 business days (verify with lab)
- **Expedited:** 5 business days
- **Standard:** 10 business days

PROJECT NUMBER: N - ~~Bate~~ 6238-00-02

P. O. NUMBER/QUOTE #:

REPORT RESULTS TO: BEN FARNHAM

PHONE: 248-348-2680 X 136

FAX: 248-348-2777

ABBREVIATIONS FOR MATRIX
S = Solids A = Air
U = Sludge Q = Aqueous

Brighton ID #	Sample Description	Date Sampled	Time Sampled	# of Containers	Sample Matrix	PH	DISSOLVED OXYGEN	NITRATE	NITRITE	PHOSPHOROUS	COLIFORM	AMMONIA - N	TKN	Comments:
1) 06232	AUSTIN ~~CHANNEL~~ ROAD DRAIN	NOV 12, 1998	1:00	11	Q	X	X	X	X	X	X	X	X	Coliform temp NO: 111298MC
2)														
3)														
4)														
5)														
6)														
7)														
8)														
9)														
10)														
11)														

Please fill out the Chain-of Custody completely and review. Incorrect or incomplete information will result in a "hold" on all analyses

(1) Relinquished by: Ben Farnham	(1) Date/Time: 11-12-98 3:50	(1) Received by: [signature]	(1) Date/Time: 11/12/98 3:50pm
(2) Relinquished by:	(2) Date/Time:	(2) Received by:	(2) Date/Time:
(3) Relinquished by:	(3) Date/Time:	(3) Received by:	(3) Date/Time:

Brighton Analytical Inc.

Brighton Analytical, Inc.
2105 Pless Drive
Brighton, Michigan 48116
Phone: (810)229-7575 FAX: (810)229-8650

Date: 11/23/98

Date Submitted: 11/12/98
Date Sampled: 11/12/98

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

Sample ID: **Austin Road Drain**

BA Report Number: **32261**
BA Sample ID: **AO06232**

Project Name: **Shawood Lake Study**
Project Number: **N-6238-00-02**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Inorganic Analysis						
Dissolved Oxygen	**11**	mg/L	0.05	EPA 360.1	RM	11/19/98
Nitrate	**Not detected**	mg/L	0.05	EPA353.2/300	RM	11/16/98
Nitrite	**Not detected**	mg/L	0.05	EPA353.2/300	RM	11/16/98
Nitrogen (Ammonia)	**0.28**	mg/L	0.01	EPA 350.3	RM	11/17/98
Nitrogen (Kjeldahl)	**1.4**	mg/L	0.10	EPA 351.2	RM	11/23/98
pH	**8.0**	S.I.		EPA 150.1	LS	11/17/98
Phosphorus (total)	**0.03**	mg/L	0.02	EPA 365.2	RM	11/19/98
Micro-Biological Analysis						
Fecal Coliform	**80**	CFU/100 ml	1.0	SM 9224D	WT	11/12/98

Brighton Analytical Inc.

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 11/23/98

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

APPENDIX VI

Shawood Lake Analytical Results for:
Sediments (Volatile's)

2213

Brighton Analytical, Inc.™

2105 Pless Drive
Brighton, MI 48114
Phone: (810) 229-7575
Fax: (810) 229-8650

COMPANY NAME: JCK

PROJECT NAME: SHAWOOD LAKE STUDY

REQUESTED TURNAROUND: (circle one)
- **Rush:** 1-3 business days (verify with lab)
- **Expedited:** 5 business days
- **Standard:** 10 business days (circled)

PROJECT NUMBER: N-6238-00-02

P. O. NUMBER/QUOTE #:

REPORT RESULTS TO: BEN FARNHAM

PHONE: 248-348-2680 X131

FAX: 248-348-2777

ABBREVIATIONS FOR MATRIX
S = Solids A = Air
U = Sludge Q = Aqueous

Analysis Requested

Brighton ID #	Sample Description	Date Sampled	Time Sampled	# of Containers	Sample Matrix	VOLATILES								Comments:
1) 6234	AUSTIN ROAD DRAIN	NOV 12, 98	1:00	2	S	X								
2)														
3)														
4)														
5)														
6)														
7)														
8)														
9)														
10)														
11)														

Please fill out the Chain of Custody completely and review. Incorrect or incomplete information will result in a "hold" on all analyses

Relinquished by	Date/Time	Received by	Date/Time
(1) Relinquished by: Ben Farnham	(1) Date/Time: 11-12-98 3:50	(1) Received by: [signature]	(1) Date/Time: 11/12/98 3:50pm
(2) Relinquished by:	(2) Date/Time:	(2) Received by:	(2) Date/Time:
(3) Relinquished by:	(3) Date/Time:	(3) Received by:	(3) Date/Time:

Brighton Analytical, Inc.
2105 Pless Drive
Brighton, Michigan 48116
Phone: (810)229-7575 FAX: (810)229-8650

Date: 11/17/98

Date Submitted: 11/12/98
Date Sampled: 11/12/98

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: 32263
BA Sample ID: AO06234

Project Name: **Shawood Lake Study**
Project Number: **N-6238-00-02**

Sample ID: **Austin Road Drain**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Volatile Analysis						
Acetone	**Not detected**	ug/Kg	100	SW846 8260	JH	11/16/98
Acrylonitrile	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Benzene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Bromochloromethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Bromodichloromethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Bromoform	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Bromomethane(Methyl Bromide)	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
2-Butanone (MEK)	**Not detected**	ug/Kg	100	SW846 8260	JH	11/16/98
Carbon disulfide	**Not detected**	ug/Kg	100	SW846 8260	JH	11/16/98
Carbon tetrachloride	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Chlorobenzene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Chloroethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Chloroform	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Chloromethane(Methyl Chloride)	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98

Brighton Analytical Inc.

BA Report Number: **32263**

Project Name: **Shawood Lake Study**

Sample ID: **Austin Road Drain**

BA Sample ID: **AO06234**

Project Number: **N-6238-00-02**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Dibromochloromethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,2-Dibromoethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,2-Dibromo-3-Chloropropane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Dibromomethane(Methylene Bromide)	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,2-Dichlorobenzene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,3-Dichlorobenzene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,4-Dichlorobenzene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Dichlorodifluoromethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,1-Dichloroethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,2-Dichloroethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,1-Dichloroethene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
cis-1,2-Dichloroethene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
trans-1,2-Dichloroethene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,2-Dichloropropane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
cis-1,3-Dichloropropene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
trans-1,3-Dichloropropene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
trans-1,4-Dichloro-2-butene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Diethyl ether	**Not detected**	ug/Kg	100	SW846 8260	JH	11/16/98
Ethyl benzene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
2-Hexanone	**Not detected**	ug/Kg	100	SW846 8260	JH	11/16/98
Hexachloroethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Isopropylbenzene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Methyl iodide	**Not detected**	ug/Kg	100	SW846 8260	JH	11/16/98
Methylene chloride	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98

Brighton Analytical Inc.

BA Report Number: **32263**

Project Name: **Shawood Lake Study**

Sample ID: **Austin Road Drain**

BA Sample ID: **AO06234**

Project Number: **N-6238-00-02**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
4-Methyl-2-pentanone(MIBK)	**Not detected**	ug/Kg	100	SW846 8260	JH	11/16/98
Methyl(tert)butyl ether(MTBE)	**Not detected**	ug/Kg	100	SW846 8260	JH	11/16/98
Naphthalene	**Not detected**	ug/Kg	330	SW846 8260	JH	11/16/98
n-Propylbenzene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Styrene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,1,1,2-Tetrachloroethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,1,2,2-Tetrachloroethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Tetrachloroethene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Toluene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,2,4-Trichlorobenzene	**Not detected**	ug/Kg	330	SW846 8260	JH	11/16/98
1,1,1-Trichloroethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,1,2-Trichloroethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Trichloroethene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Trichlorofluoromethane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,2,3-Trichloropropane	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
1,3,5-Trimethylbenzene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98

Brighton Analytical Inc.

BA Report Number: 32263

BA Sample ID: AO06234

Project Name: Shawood Lake Study

Project Number: N-6238-00-02

ample ID: Austin Road Drain

arameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
2,4-Trimethylbenzene	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
'inyl chloride	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
ı&p-Xylenes	**Not detected**	ug/Kg	20	SW846 8260	JH	11/16/98
-Xylenes	**Not detected**	ug/Kg	10	SW846 8260	JH	11/16/98
Kylenes	**Not detected**	ug/Kg	30	SW846 8260	JH	11/16/98
%Solid	**26.9**	%		ASTM D-2216	CW	11/17/98

All soil results based on dry weight.

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 11/17/98

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

APPENDIX VII

Shawood Lake Analytical Results for:
Sediments (10 Michigan Metals)

52..2

Brighton Analytical, Inc.™

2105 Pless Drive
Brighton, MI 48114
Phone: (810) 229-7575
Fax: (810) 229-8650

COMPANY NAME: JCK

PROJECT NAME: SHAWOOD LAKE STUDY

REQUESTED TURNAROUND: (circle one)
Rush: 1-3 business days (verify with lab)
Expedited: 5 business days
Standard: 10 business days (circled)

PROJECT NUMBER: N-6238-00-02

P. O. NUMBER/QUOTE #:

REPORT RESULTS TO: BEN FARNHAM

PHONE: 248-348-2680 X136

FAX: 248-348-2777

ABBREVIATIONS FOR MATRIX
S = Solids A = Air
U = Sludge Q = Aqueous

Analysis Requested

Brighton ID #	Sample Description	Date Sampled	Time Sampled	# of Containers	Sample Matrix	10 MI METALS								Comments:
1) 06233	AUSTEN ROAD DRAIN	11-12-98	1:00	1	S	X								
2)														
3)														
4)														
5)														
6)														
7)														
8)														
9)														
10)														
11)														

Please fill out the Chain of Custody completely and review. Incorrect or incomplete information will result in a "hold" on all analyses

(1) Relinquished by: Ben Farnham	(1) Date/Time: 11-12-98 3:50	(1) Received by: [signature]	(1) Date/Time: 11/12/98 3:50pm
(2) Relinquished by:	(2) Date/Time:	(2) Received by:	(2) Date/Time:
(3) Relinquished by:	(3) Date/Time:	(3) Received by:	(3) Date/Time:

Brighton Analytical Inc.

Brighton Analytical, Inc.
2105 Pless Drive
Brighton, Michigan 48116
Phone: (810)229-7575 FAX: (810)229-8650

Date: 11/18/98

Date Submitted: 11/12/98
Date Sampled: 11/12/98

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: **32262**

Project Name: **Shawood Lake Study**

Sample ID: **Austin Road Drain**

BA Sample ID: **AO06233**

Project Number: **N-6238-00-02**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Metal Analysis						
Total Arsenic	**9.8**	mg/Kg	0.10	SW846 6020	BC	11/17/98
Total Barium	**93**	mg/Kg	1.0	SW846 6020	BC	11/17/98
Total Cadmium	**0.70**	mg/Kg	0.05	SW846 6020	BC	11/17/98
Total Chromium	**14**	mg/Kg	0.20	SW846 6020	BC	11/17/98
Total Copper	**32**	mg/Kg	1.0	SW846 6020	BC	11/17/98
Total Lead	**80**	mg/Kg	1.0	SW846 6020	BC	11/17/98
Total Mercury	**Not detected**	mg/Kg	0.10	SW846 7471	GW	11/13/98
Total Selenium	**1.6**	mg/Kg	0.50	SW846 6020	BC	11/17/98
Total Silver	**Not detected**	mg/Kg	0.50	SW846 6020	BC	11/17/98
Total Zinc	**170**	mg/Kg	1.0	SW846 6020	BC	11/17/98
Metal Soil (digestion)	**Digested**				LS	11/13/98
Mercury (digestion)	**Digested**				GW	11/13/98
%Solid	**29.6**	%		ASTM D-2216	CW	11/16/98

Brighton Analytical Inc.

All soil results based on dry weight.

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 11/18/98

APPENDIX VIII

Shawood Lake Analytical Results for:
Additional Sediment Testing (10 Michigan Metals)

23984

Brighton Analytical, Inc.™

2105 Pless Drive
Brighton, MI 48114

Phone: (810) 229-7575
Fax: (810) 229-8650

COMPANY NAME: JCK

REQUESTED TURNAROUND: (circle one)
Rush: 1-3 business days (verify with lab)
~~Expedited:~~ 5 business days
Standard: 10 business days (circled)

PROJECT NAME: ~~[illegible]~~ Austin Rd. Drain

PROJECT NUMBER: N-6238-00-05

P. O. NUMBER/QUOTE #:

REPORT RESULTS TO: Ben Farnham

PHONE: 248-348-2680 X136

FAX: 248-348-2777

ABBREVIATIONS FOR MATRIX
S = Solids A = Air
U = Sludge Q = Aqueous

Comments:

Analysis Requested

Brighton ID #	Sample Description	Date Sampled	Time Sampled	# of Containers	Sample Matrix	10 MI. Metals							
1) 3092	10' E. of Austin Rd	2-12-99	11:00	1	S	X							
2) 3093	150' E of Austin Rd	↓	11:05	1	S	X							
3) 3094	West of Novi Rd	↓	11:15	1	S	X							
4)													
5)													
6)													
7)													
8)													
9)													
10)													
11)													

Please fill out the Chain of Custody completely and review. Incorrect or incomplete information will result in a "hold" on all analyses

Relinquished by	Date/Time	Received by	Date/Time
(1) Relinquished by: Ben Farnham	(1) Date/Time: 2-12-99 3:45	(1) Received by: [signature]	(1) Date/Time: 2/12/99 3:50p
(2) Relinquished by:	(2) Date/Time:	(2) Received by:	(2) Date/Time:
(3) Relinquished by:	(3) Date/Time:	(3) Received by:	(3) Date/Time:

Brighton Analytical Inc.

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Date: 02/18/99

Date Submitted: 02/12/99
Date Sampled: 02/12/99

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: **33984**

Project Name: **Austin Rd. Drain**

Sample ID: **10' E. of Austin Rd.**

BA Sample ID: **AP03092**

Project Number: **N-6238-00-05**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Metal Analysis						
Total Arsenic	**5.8**	mg/Kg	0.10	SW846 6020	BC	02/16/99
Total Barium	**34**	mg/Kg	1.0	SW846 6020	BC	02/16/99
Total Cadmium	**0.47**	mg/Kg	0.05	SW846 6020	BC	02/16/99
Total Chromium	**12**	mg/Kg	0.20	SW846 6020	BC	02/16/99
Total Copper	**20**	mg/Kg	1.0	SW846 6020	BC	02/16/99
Total Lead	**44**	mg/Kg	1.0	SW846 6020	BC	02/16/99
Total Mercury	**Not detected**	mg/Kg	0.10	SW846 7471	GW	02/18/99
Total Selenium	**0.70**	mg/Kg	0.50	SW846 6020	BC	02/16/99
Total Silver	**Not detected**	mg/Kg	0.50	SW846 6020	BC	02/16/99
Total Zinc	**86**	mg/Kg	1.0	SW846 6020	BC	02/16/99
Metal Soil (digestion)	Digested				LS	02/16/99
Mercury (digestion)	Digested				BC	02/17/99
%Solid	**62.5**	%		ASTM D-2216	GW	02/15/99

Brighton Analytical Inc.

All soil results based on dry weight.

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 2/18/99

Brighton Analytical Inc.

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Brighton, Michigan 48116
Phone: (810)229-7575 FAX: (810)229-8650

Date: 02/18/99

Date Submitted: 02/12/99
Date Sampled: 02/12/99

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: **33984**

Project Name: **Austin Rd. Drain**

Sample ID: **150' E. of Austin Rd.**

BA Sample ID: **AP03093**

Project Number: **N-6238-00-05**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Metal Analysis						
Total Arsenic	**2.7**	mg/Kg	0.10	SW846 6020	BC	02/16/99
Total Barium	**30**	mg/Kg	1.0	SW846 6020	BC	02/16/99
Total Cadmium	**0.39**	mg/Kg	0.05	SW846 6020	BC	02/16/99
Total Chromium	**5.9**	mg/Kg	0.20	SW846 6020	BC	02/16/99
Total Copper	**15**	mg/Kg	1.0	SW846 6020	BC	02/16/99
Total Lead	**26**	mg/Kg	1.0	SW846 6020	BC	02/16/99
Total Mercury	**Not detected**	mg/Kg	0.10	SW846 7471	GW	02/18/99
Total Selenium	**Not detected**	mg/Kg	0.50	SW846 6020	BC	02/16/99
Total Silver	**Not detected**	mg/Kg	0.50	SW846 6020	BC	02/16/99
Total Zinc	**75**	mg/Kg	1.0	SW846 6020	BC	02/16/99
Metal Soil (digestion)	**Digested**				LS	02/16/99
Mercury (digestion)	**Digested**				BC	02/17/99
%Solid	**54.5**	%		ASTM D-2216	GW	02/15/99

Brighton Analytical Inc.

All soil results based on dry weight.

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 2/18/99

BA Brighton Analytical Inc.

Brighton Analytical, Inc.
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Phone: (810)229-7575 FAX: (810)229-8650

Date: 02/18/99

Date Submitted: 02/12/99
Date Sampled: 02/12/99

To: J.C.K. & Associates, Inc.
45650 Grand River Avenue
P.O. Box 759
Novi, MI 48374

BA Report Number: **33984**

Project Name: **Austin Rd. Drain**

Sample ID: **West of Novi Rd.**

BA Sample ID: **AP03094**

Project Number: **N-6238-00-05**

Parameters	Results	Units	DL	Method Reference	Analyst	Analysis Date
Metal Analysis						
Total Arsenic	**4.0**	mg/Kg	0.10	SW846 6020	BC	02/16/99
Total Barium	**35**	mg/Kg	1.0	SW846 6020	BC	02/16/99
Total Cadmium	**0.38**	mg/Kg	0.05	SW846 6020	BC	02/16/99
Total Chromium	**27**	mg/Kg	0.20	SW846 6020	BC	02/16/99
Total Copper	**22**	mg/Kg	1.0	SW846 6020	BC	02/16/99
Total Lead	**85**	mg/Kg	1.0	SW846 6020	BC	02/16/99
Total Mercury	**Not detected**	mg/Kg	0.10	SW846 7471	GW	02/18/99
Total Selenium	**Not detected**	mg/Kg	0.50	SW846 6020	BC	02/16/99
Total Silver	**Not detected**	mg/Kg	0.50	SW846 6020	BC	02/16/99
Total Zinc	**74**	mg/Kg	1.0	SW846 6020	BC	02/16/99
Metal Soil (digestion)	**Digested**				LS	02/16/99
Mercury (digestion)	**Digested**				BC	02/17/99
%Solid	**71.4**	%		ASTM D-2216	GW	02/15/99

Brighton Analytical Inc.

All soil results based on dry weight.

DL=Detection Limit as recommended by MDEQ.

Released by: [signature]

Date: 2/18/99

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

APPENDIX IX

Rouge River National Wet Weather Demonstration Project

Technical Memorandum - RPO-MOD-TM10.00

THE ROUGE RIVER PROJECT
A WORLD CLASS EFFORT

BRINGING OUR RIVER BACK TO LIFE

Rouge River National Wet Weather Demonstration Project

Wayne County, Michigan

TECHNICAL MEMORANDUM
Modeling Special Studies 1994-1995: Impoundment Limnological Report

RPO-MOD-TM10.00

July 1996

Rouge River National Wet Weather Demonstration Project

Wayne County, Michigan

TECHNICAL MEMORANDUM
Modeling Special Studies 1994-1995:
Impoundment Limnological Report

Authors: Joseph E. Rathbun, Sarina G. Aryan, Gary W. Mercer

ACKNOWLEDGMENTS

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Rouge River National Wet Weather Demonstration Program

MISSION STATEMENT

The mission of the Rouge River National Wet Weather Demonstration Project is to restore the water quality in the Rouge River as necessary to:

- provide a safe and healthy environment for ourselves and future generations,
- protect downriver water resources such as the Detroit River and Lake Erie, and
- re-establish a healthy and diverse ecosystem within the Rouge River Watershed.

This will be accomplished through the development, implementation, and financial integration of a technical, social, and institutional framework leading to cost efficient, and innovative, watershed based solutions to control the wet weather problems in the Rouge River Watershed.

PREFACE

The Rouge River and its watershed are a primary source of pollution to the Great Lakes. The Clean Water Act of 1972 intended to make waterways "fishable and swimmable" by 1972. Although that goal has not been reached, great progress has been made in improving water quality in most waterways. The Rouge River Remedial Action Plan (RAP) provided a basis for which The Rouge River National Wet Weather Demonstration Project (Rouge Project) efforts were created: it identified the major sources of pollution and measured the relative contributions of each. The RAP is the continuing foundation for the Rouge Project and presents a framework for addressing the problems within the Rouge River by looking beyond treatment and focusing instead on prevention methods.

The Rouge Project was established under the initial Rouge Grant 1 from the United States Environment Protection Agency, Region 5, and enabled Wayne County to initiate a comprehensive watershed-wide pollution-control approach that addresses combined sewer overflow (CSO), storm water management, and other nonpoint source controls through the application of innovative technologies, progressive financial and institutional arrangements, and creative public involvement and education programs.

Rouge Grant 2 provides the framework for the progression and implementation of Project goals as Wayne County continues its mission to develop potential solutions and implement projects which will lead to the restoration of water quality in the Rouge River. The Project will address both conventional and toxic pollutants to:

- provide a safe and healthy recreational river resource for present and future generations;
- re-establish a healthy and diverse ecosystem within the Rouge River Watershed;
- protect downstream water resources such as the Detroit River and Lake Erie; and
- help ensure compliance with federal, state, and local environmental laws which protect human health and environment.

This will be accomplished through the development, implementation, and financial integration of technical, social, and institutional frameworks leading to cost-efficient and innovative watershed-based solutions to wet weather problems. This watershed-based national demonstration project will provide other municipalities across the nation facing similar problems with guidance and potentially effective solutions.

Under Rouge Grant 2, the Rouge Project will build on lessons learned from Grant 1 efforts and focus on further integration of the goals of the overall Mission. To this end, Rouge Grant 2 concentrates on the following key Project areas:

- **Watershed Management** will continue under Rouge Grant 2 with the development and evaluation of wet weather and storm water alternatives, the planning of long-term monitoring programs, and the ongoing efforts to enhance instream water quality, monitor rain and flow levels, interpret data analysis, and present recommendations.

- **Nonpoint Source Pollution Control** will provide for the storm water management, permit applications, and development of financial and institutional alternatives for wet-weather watershed management in concert with enhanced efforts to establish institutional partnerships. Toward the goal of institutional partnering, several community projects will be undertaken with watershed communities. Additional efforts include the inventory of wetlands and measurement of pollutant loads from abandoned dumps and air deposition with possible remediation of some sites.

- **CSO Construction Coordination** will continue to monitor the construction of CSO demonstration projects established under Grant 1. Additional planning and assistance will allow project coordinators to make additional recommendations on the design criteria of future CSO abatement facilities.

- **Public Involvement and Information** will reach and interact with more stakeholders, institutions, and regulatory agencies, thus fostering a renewed understanding and continued commitment to reducing pollution, and continuing the transfer of watershed management approaches way beyond the project. It will be the central mechanism for transmittal of the Project's Decision Support System tools, processes, and information necessary for sustaining a watershed management support system directly to varied audiences both within and outside the Rouge watershed.

Additional information on the Rouge River Project is available from many sources, including the Wayne County Department of Environment (WCDOE) and the Rouge Program Office (RPO).

This document has been generated under the Modeling Program Element. Its purpose is to provide an overview of existing water quality and environmental conditions in Walled Lake, Meadowbrook Lake, Phoenix Lake, and Newburgh Lake along the Middle Branch of the Rouge River in 1994-1995.

ABSTRACT

Limnological analyses (nutrients, dissolved oxygen, water clarity, total suspended solids, algae communities) and macrophyte distribution and abundance measurements were performed at four lakes (Walled Lake, Meadowbrook Lake, Phoenix Lake, and Newburgh Lake) along the Middle Branch of the Rouge River, between September/October 1994, and August 1995. Most of the data indicated that all four lakes are moderately to highly eutrophic, especially when judged by secchi depth, total phosphorous, total nitrogen, chlorophyll *a*, and algae community composition. Overall, Walled Lake was the least eutrophic and Meadowbrook Lake the most, with Phoenix Lake and Newburgh Lake being intermediate. Nitrate and total phosphorous concentrations increased sharply between Walled Lake and Meadowbrook Lake, partly due to the Walled Lake wastewater treatment plant discharge. All four lakes were strongly stratified during the summer of 1995, with epilimnetic dissolved oxygen concentrations near or exceeding saturation, and hypolimnetic concentrations less than 2 mg/L. The presence of an anoxic hypolimnion influenced the concentrations of nitrate, ammonia, and total phosphorous, through various microbially-mediated and sediment-associated physicochemical phenomena. Algae characteristic of eutrophic conditions were common in all lakes, especially Meadowbrook Lake, Phoenix Lake and Newburgh Lake. The macrophyte community in Walled Lake was diverse and abundant in shallow waters along the shore, while the Newburgh Lake community was dominated by the macroalgae *Chara*, along with lily pads in the western quarter of the lake. Macrophytes were missing from Meadowbrook Lake and Phoenix Lake, for unknown reasons. Based on limited historic data, algae communities and most nutrient concentrations have not changed substantially in the last 20 years. It is recommended that limnological conditions in these lakes (and perhaps others along the Middle Branch) be reexamined in three to five years, to assess the impacts of land use changes in the Middle Branch watershed. It is also recommended that Newburgh Lake be reexamined in 1997 and perhaps yearly thereafter for several years, to assess the impact of the 1996 sediment remediation project.

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1.0 INTRODUCTION.

A unique feature of the Middle Branch of the Rouge River is the presence of a lake and several impoundments along its length. All are or have the potential to be valuable ecological and recreational resources for the Rouge River Watershed. Previous studies (SEG, 1974; SEMCOG, 1978; various, cited in RPO, 1996b) have indicated that these lakes and the river waters flowing into them share a number of problems to varying degrees, including nutrient enrichment, low water transparency, high primary productivity, and seasonally low dissolved oxygen concentrations.

Limnological features of four of the lakes; one natural lake and three impoundments; were studied in the fall of 1994 and the spring/summer of 1995. Walled Lake is a natural lake, and makes up the headwaters of the Middle Branch of the Rouge River (*Figure 1-1*). Meadowbrook Lake, Phoenix Lake, and Newburgh Lake are artificial impoundments located in the middle of the Middle Branch. All four lakes were sampled once a month, in September/October 1994 and May, June, July, and August 1995, for a variety of chemical and biological parameters.

The objectives of this project were to:

Collect water samples from the lakes on the Middle Branch and analyze them for temperature, nutrients, dissolved oxygen (DO), in-situ transparency, total suspended solids (TSS), and algae taxa;

- Measure diurnal changes in DO in vertical profiles in each of the lakes;
- Measure macrophyte productivity once in each of the four lakes.

Data from the 1994-1995 Impoundment Limnological Special Studies will be used in the Rouge River National Wet Weather National Demonstration Project (Rouge Project) for the following purposes:

- Nutrient concentrations and algae communities were assessed to evaluate the trophic status of the lakes.
- Algae were identified to provide taxa-specific photosynthesis and respiration rate data for the water quality model.
- Diurnal DO measurements were made to investigate the daily fluctuations of oxygen within the lakes.
- Macrophyte community productivity was measured to assess the trophic status of the lakes.
- Total nitrogen and total phosphorous data were used to assess the limiting nutrient in each lake.
- Nutrient data were used to determine rates and processes for the water quality modeling.

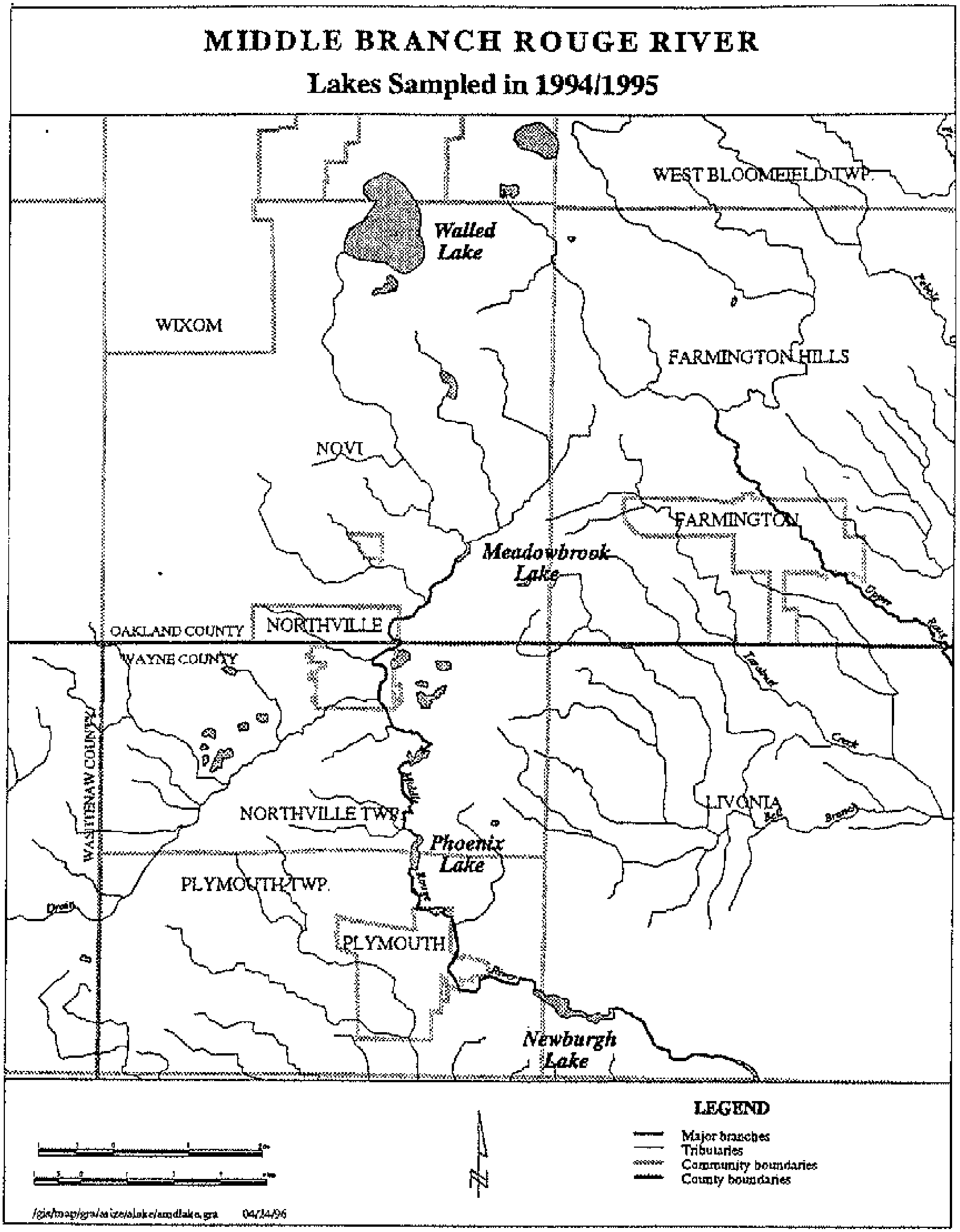


Figure 1-1: Middle Branch of the Rouge River

2.0 INVESTIGATIVE APPROACH.

2.1 STATION SELECTION. A brief account of the issues considered in establishing sampling stations is provided below. Further detail is contained in the Impoundment Limnological Studies Field Sampling Plan (FSP) (RPO, 1994a).

2.1.1 Impoundment Limnological Studies. Three issues influenced sampling site selection in the impoundment limnological studies: water column depth; potential spatial heterogeneity in the distribution of nutrients, algae, and DO within each impoundment; and the question of whether each impoundment may act as a source or sink of nutrients to the river as a whole. Based on these considerations, samples for the limnological analyses were collected from four sites in or near each lake (*Figures 2-1* through *2-4*):

- One station in the Rouge River, immediately upstream of the impoundment and downstream of the closest known point source (e.g., combined sewer overflow or industrial outfall), at which a subsurface (~ 6" below the surface) grab sample was collected.

- Two stations within the impoundment, at which subsurface grab samples were collected:

  - at mid-water column, if there was no thermal/DO stratification;
  - at both above and below the thermocline, if present.

- One station in the Rouge River, immediately downstream of the impoundment dam or lake outlet (Walled Lake) and upstream of the closest known point source, at which a single subsurface (~ 6" below the surface) grab sample was collected.

2.1.2 Diurnal Dissolved Oxygen Profiles. Diurnal DO profile data were collected from the deepest known part of each lake, because this is the location most likely to exhibit temperature stratification and maximum DO concentration heterogeneity.

2.1.3 Macrophyte Biomass Measurements. A preliminary survey of each lake established macrophyte distribution, and this information was used to select representative stations at which species composition and biomass measurements were made.

2.2 SAMPLING SCHEDULE.

2.2.1 Impoundment Limnological Studies. Water samples were collected from each lake once per month in September and October, 1994, and May through August, 1995. A single grab sample from each lake was also collected in February, 1995. This schedule provided information from all seasons, with emphasis on the spring, summer, and fall period of maximum productivity, temperature variability, precipitation variability, etc.

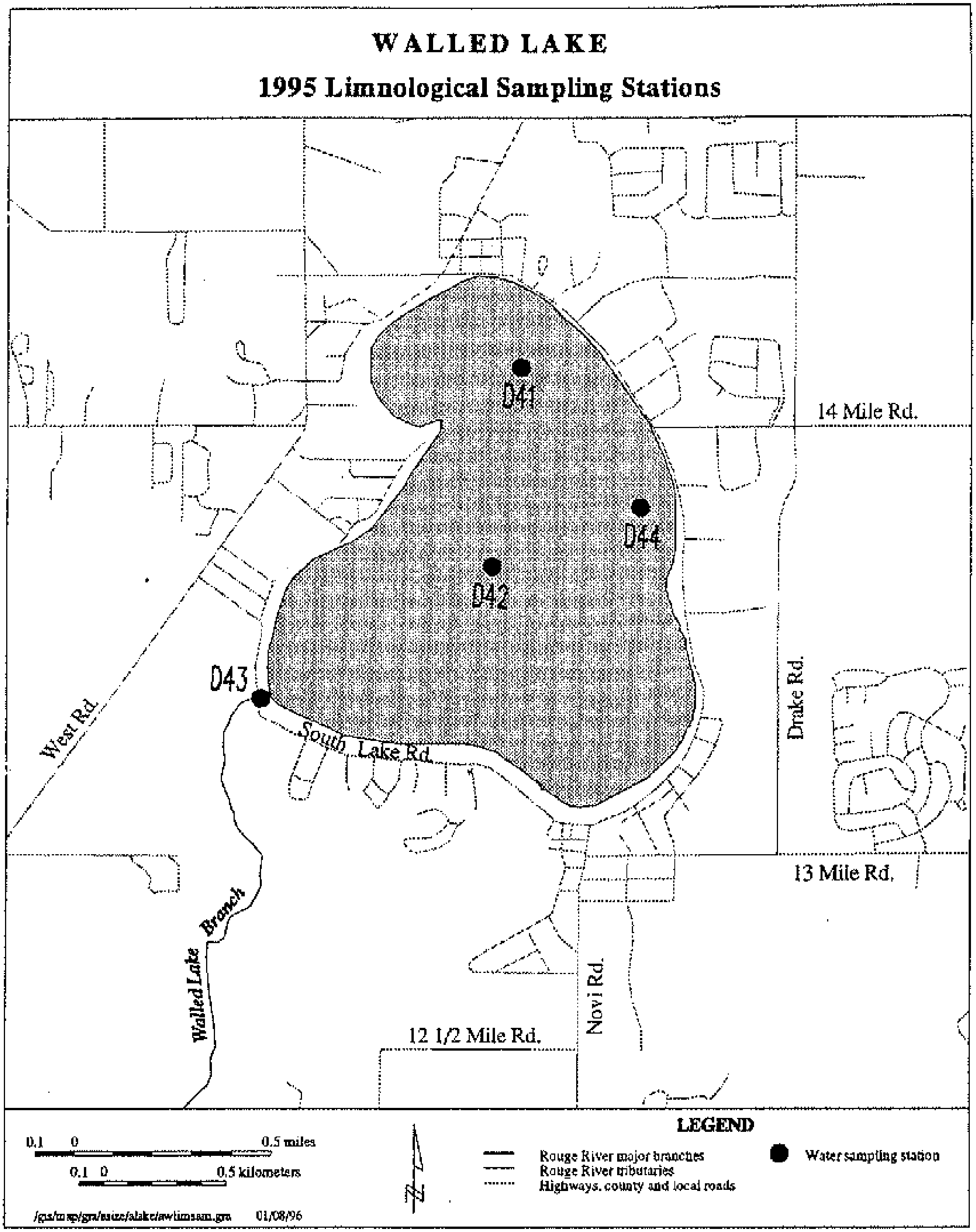


Figure 2-1: 1995 Limnological Sampling Stations - Walled Lake

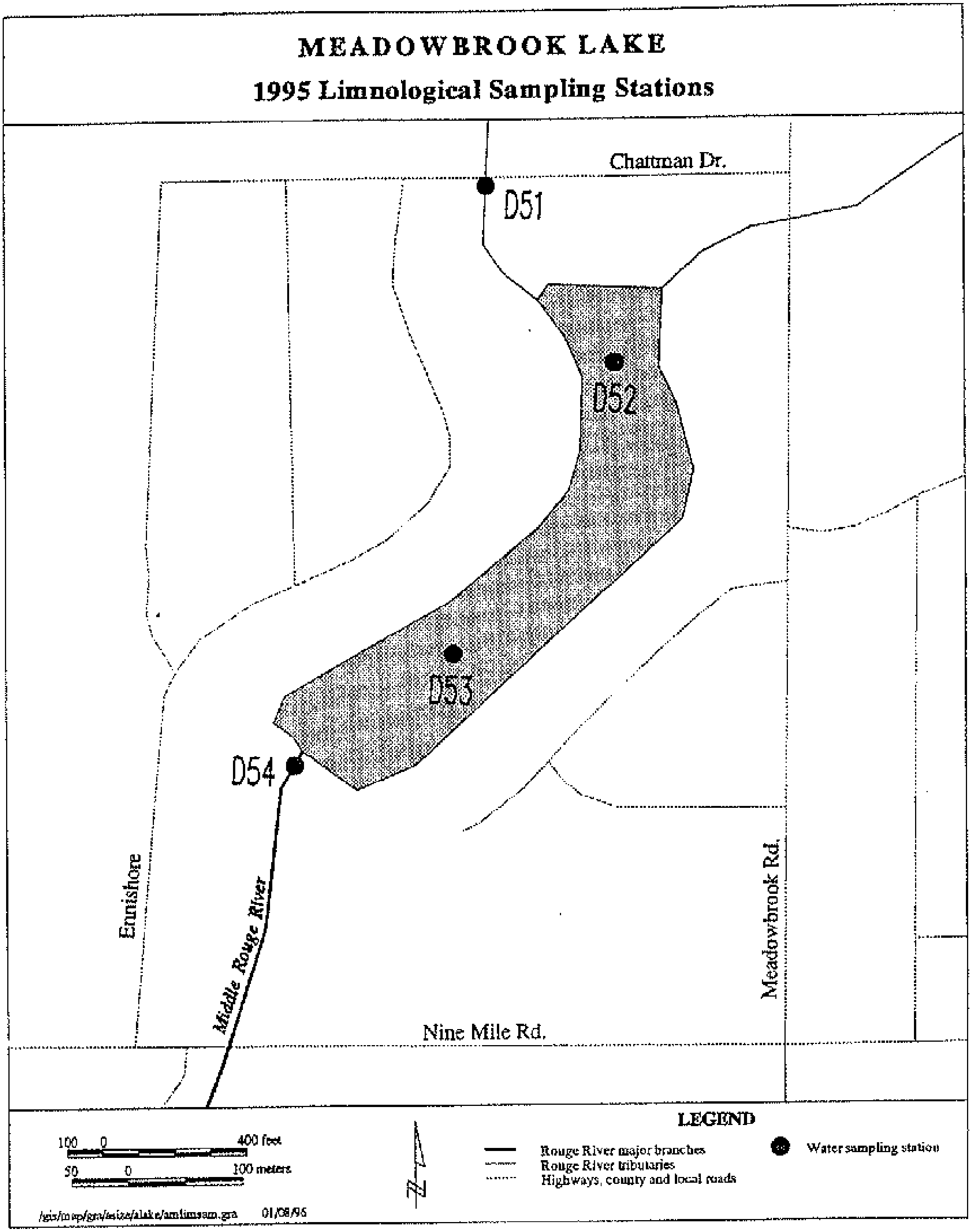


Figure 2-2: 1995 Limnological Sampling Stations - Meadowbrook Lake

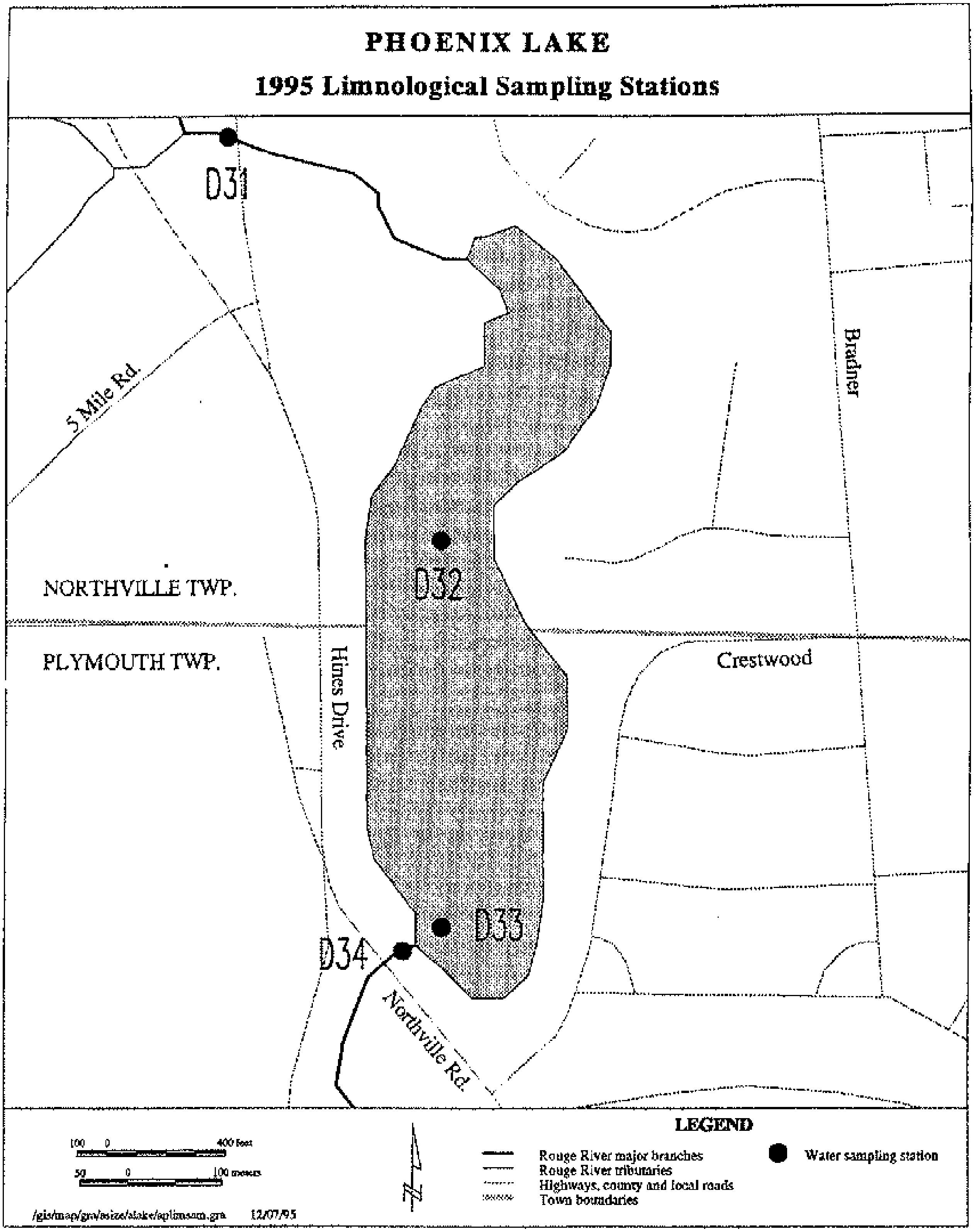


Figure 2-3: 1995 Limnological Sampling Stations - Phoenix Lake

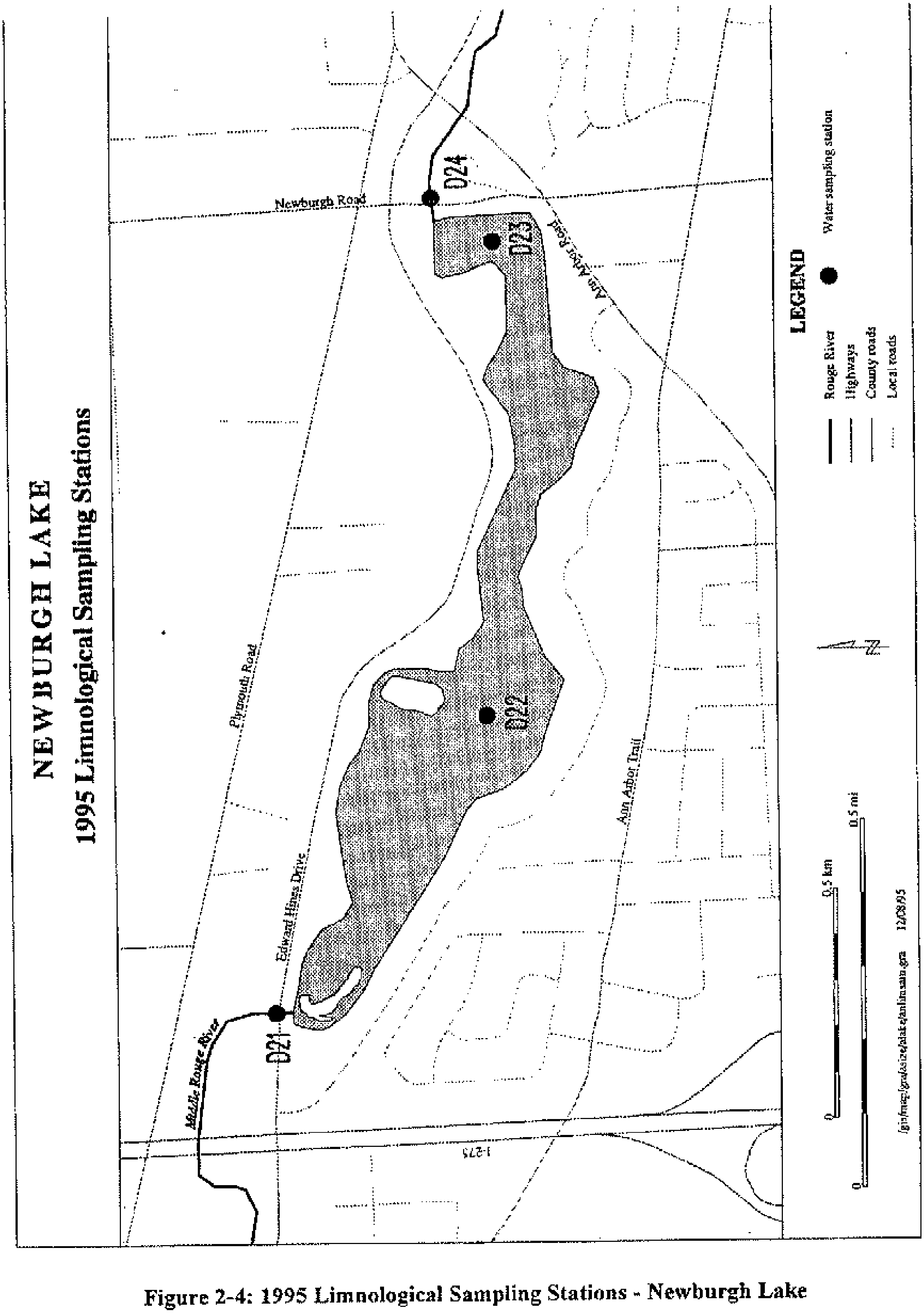


Figure 2-4: 1995 Limnological Sampling Stations - Newburgh Lake

2.2.2 **Diurnal Dissolved Oxygen Profiles.** Diurnal DO profile measurements were taken at times of minimum and maximum photosynthetic DO production (sunrise and early afternoon). Samples were generally collected on the same days as the impoundment limnological samples were collected in May through August, 1995.

2.2.3 **Macrophyte Biomass Measurements.** Macrophyte species composition and biomass measurements were made in August 1995, the time of maximum macrophyte productivity in the Great Lakes region (Herdendorff, 1987).

3.0 METHODS. A brief account of the methods used in this study is provided below. Further detail is contained in the Impoundment Limnological Studies FSP (RPO, 1994a).

3.1 IMPOUNDMENT LIMNOLOGICAL STUDIES. Grab water samples were collected at the depths and stations described in Section 2.1.1, and analyzed for the parameters listed in *Table 3.1*. Details of the analytical methods are in the Field Sampling Plan (RPO, 1994a).

Plankton were quantified only to phylum: Cyanophyta (bluegreen algae; more properly termed Cyanobacteria under current taxonomic schemes); Chlorophyta (green algae); Chrysophyta (diatoms and their allies); Pyrrhophyta (dinoflagellates); Euglenophyta (euglenoids); and Cryptophyta (cyrptophytes). Prominent genera were identified using the following taxonomic references: Greeson, 1982; Prescott, 1978; and Taft and Taft, 1971.

3.2 DIURNAL DISSOLVED OXYGEN PROFILES. DO and temperature measurements were taken at one foot intervals at Meadowbrook Lake, Phoenix Lake, and Newburgh Lake, and at five foot intervals in Walled Lake, along a vertical transect at the deepest part of each lake. A membrane electrode was used to measure DO at times of maximum and minimum photosynthetic oxygen production (i.e., mid-day and just before sunrise).

3.3 MACROPHYTE BIOMASS MEASUREMENTS. Macrophyte species composition and wet and dry biomass was measured at three representative locations in Walled Lake and Newburgh Lake in August, 1995. Significant macrophyte populations were not present in Meadowbrook Lake and Phoenix Lake. Representative stations were selected based on preliminary surveys of macrophyte distribution performed prior to the collection surveys. Plants were collected from 1.0 m^2 quadrates, using a rake (Newburgh Lake) or by snorkeling (Walled Lake). Wet and dry biomass was measured, and prominent macrophyte species identified using the following taxonomic references: Fassett, 1957; Hotchkiss, 1972; Voss, 1972; and Voss, 1985.

It should be noted that Wayne County operated a mechanical "weed harvester" on Newburgh Lake near the fishing dock on the northwest shore of the lake during the summer of 1995, to provide open water for recreational paddle boat operation. This greatly reduced the plant populations in certain parts of the lake, and these areas were not sampled in this survey.

Table 3.1
Analytical Parameters for the Impoundment Special Studies

Study	Parameter
Impoundment Limnological Studies	Total phosphorous Orthophosphorous Total Kjeldahl nitrogen Nitrate-N Nitrite-N Ammonia-N Algae taxa Chlorophyll *a* Secchi disk transparency Dissolved oxygen Total suspended solids Water temperature
Diurnal Dissolved Oxygen Profiles	Dissolved oxygen Water temperature Water depth
Macrophyte Biomass Measurements	Wet weight/square meter Dry weight/square meter Water depth

4.0 RESULTS AND DISCUSSION.

4.1 PHYSICAL LIMNOLOGICAL PARAMETERS. Data for two physical limnological parameters were collected in this study: water temperature and secchi disk transparency.

4.1.1 Water Temperature. Water temperature in the four lakes fluctuated seasonally, being lowest in February 1995 and highest in July or August 1995 (note: not all months of the year were monitored). Water temperatures in Walled Lake and its outlet were fairly uniform in any specific month, but in most months there was a noticeable increase in water temperature as the water passed through any of the three impoundments (*Table 4.1*). When the lakes were stratified, epilimnetic water temperatures were always higher than hypolimnetic temperatures, by 2 to 13 °C, even when only a few feet separated the measurements.

4.1.2 Secchi Disk Transparency. Secchi disk transparency was measured at two stations in each lake (*Table 4.2*). It was not measured at the lake inlets and outlets, because these waters were either inaccessible (deep and beneath tall bridges) or so clear that the bottom was visible. Secchi depth was also not measured during the winter sampling survey (February 1995) because ice prevented transmission of light into the lake.

Water transparency varied considerably both between lakes and within a lake over time. Walled Lake secchi depths were generally greatest, averaging 9.3 feet (range = 4.7' to 14.5'), and Phoenix Lake was usually the most turbid, with secchi depths averaging 2.0 feet (range = 0.6' to 3.5'). Newburgh Lake (average = 4.1'; range = 0.8' to 6.5') and Meadowbrook Lake (average = 3.1'; range = 0.6' to 5.5') were intermediate. For comparison, the United States Environmental Protection Agency (EPA) (1985) considered mean secchi depths of greater than 9.9 ' to be indicative of oligotrophic conditions, and less than 2.4' to indicate eutrophic conditions.

Some lake-specific observations are as follows:

- A rainfall event immediately prior to sample collection often decreased the water transparency in the three impoundments, as did algae blooms in Walled Lake. This is further discussed in Section 4.2.1.
- The shallow western end of Newburgh Lake (station D22), nearer the river inlet, was consistently more turbid than the deeper eastern station (D23).
- Increasing macrophyte growths generally increased secchi depths in Newburgh Lake, by slowing the water flow and causing suspended particles to settle out. Macrophytes were absent from Meadowbrook Lake and Phoenix Lake (see Section 4-4), and did not influence water transparency at the Walled Lake stations because of its great depths (35' to 50').

Table 4.1
Water Temperature (°C) in the Four Lakes: 1994-1995
(Stations refer to figures 2-1 to 2-4)

Walled Lake

Date	Inlet	D41	D42	Outlet
10/12/94	Walled Lake does not have an inlet	14.8	14.9	13.2
5/17/95		13.7	16.1† 9.3	16.9
6/19/95		22.0 14.1	21.2 13.3	Outlet not flowing
7/26/95		25.6 15.5	25.1 15.6	25.1
8/16/95		27.9 17.9	28.1 15.2	26.8

Phoenix Lake

Date	Inlet	D32	D33	Outlet
10/4/94*	11.4	11.6	12.3	12.3
5/23/95	13.8	17.0	15.2	16.0
6/20/95	21.0	22.5	20.8	24.8
7/27/95*	19.5	22.0	22.0 20.3	22.4
8/17/95*	22.5	24.3	24.3 21.0	25.3

Meadowbrook Lake

Date	Inlet	D52	D53	Outlet
10/19/94*	15.4	15.6	12.2	14.4
5/25/95	13.0	13.4	14.5	14.5
6/22/95	19.4	22.4	23.7 14.1	24.7
7/31/95	20.1	24.2 19.1	24.2 15.8	24.4
8/29/95	20.1	21.6	22.4 18.3	22.2

Newburgh Lake

Date	Inlet	D22	D23	Outlet
9/27/94*	16.0	16.4	19.5	19.6
5/22/95	16.2	17.3	18.4	20.1
6/23/95	21.5	24.6	25.5	25.1
7/25/95*	22.0	22.5	25.1	24.9
8/15/95*	25.3	25.7	27.7 25.4	26.7

* Recent rainfall event
† Upper value = epilimnion; lower value = hypolimnion

Table 4.2
Secchi Disk Transparency (Feet) at the Four Lakes: 1994-1995
(Stations refer to Figures 2-1 to 2-4)

Walled Lake					
	10/12/94	5/17/95	6/19/95	7/26/95*	8/16/95
D41	9.0	6.0	13.0	5.0	12.0
D42	10.0	6.5	14.5	4.7	12.2
Meadowbrook Lake					
	10/19/94**	5/25/95	6/22/95	7/31/95	8/29/95
D52	0.6	1.1	4.0	3.2	5.2
D53	0.9	1.5	5.0	3.5	5.5
Phoenix Lake					
	10/4/94**	5/23/95	6/20/95	7/27/95**	8/17/95**
D32	0.8	2.0	3.5	1.5	2.0
D33	0.6	5.0	1.2	1.5	1.7
Newburgh Lake					
	9/27/94**	5/22/95	6/23/95	7/25/95**	8/15/95**
D22	2.3	3.0	[Weeds]	0.8	4.0
D23	6.3	3.3	6.5	[Weeds]	6.5

* Algae bloom present.
** Recent rainfall event.
[Weeds] = Secchi disk obscured by macrophytes.

Comparison of the 1994-1995 Secchi Depth Data to Other Studies. The secchi depths measured during the 1994-1995 study were generally comparable to data for Phoenix Lake and Newburgh Lake collected in 1973-1974 (SEG, 1974), where the average secchi depth was 2.5' (range = 1' to 5'). Apparently, water transparency in these two lakes has not changed substantially in the last 20 years.

4.2 **CHEMICAL LIMNOLOGICAL PARAMETERS.** A principal issue in this study was whether the four lakes are sources or sinks for the chemical parameters measured, especially nutrients or TSSs. (i.e. Are the concentrations of nutrients and TSS at the lake inlet higher, lower, or comparable to the concentrations in the lake outlet water ?) For example, a lake could be a source or sink of TSS to the river, depending on the balance of solids in the water entering the lake versus the settling of solids and the algae productivity within the lake. It should be noted that Walled Lake is part of the headwaters of the Middle Branch, and has no inlet. Therefore, it can only act as a source of nutrients and solids to the river when its water level is sufficiently high for the water to flow out of the lake. Graphs of the chemical limnological parameter data collected during the study are included in Appendix A. These graphs illustrate the spatial distribution of each parameter by month, starting at the upstream end of the study reach (Walled Lake) and proceeding to the downstream end (Newburgh Lake Outlet).

4.2.1 **Total Suspended Solids.** Concentrations of TSS varied considerably between lakes, within a lake over time, and between the inlet and outlet. Mean in-lake TSS concentrations (excluding inlet and outlet river samples) were highest in Phoenix Lake, intermediate in Meadowbrook Lake, and lowest in Walled Lake and Newburgh Lake (*Table 4.3* and Appendix *Figure A-1*). In-lake TSS concentrations in Walled Lake, Meadowbrook Lake, and Phoenix Lake on a specific date were fairly consistent, while in Newburgh Lake, TSS concentrations at the lake station closest to the inlet were always higher than those at the lake station nearest the outlet. This is consistent with the secchi depth data (Section 4.1.2).

Mean lake inlet TSS concentrations were comparably high at Phoenix Lake (36 mg/L) and Newburgh Lake (33 mg/L), and lower at Meadowbrook Lake (16 mg/L). Walled Lake does not have an inlet. Mean outlet TSS concentrations were lowest at Walled Lake (5.6 mg/L),

Table 4.3
Concentrations of Total Suspended Solids (mg/L) in the Four Lakes: 1994-1995
(Stations refer to Figures 2-1 to 2-4)

Walled Lake

Date	Inlet	D41	D42	Outlet
10/12/94	Walled Lake does not have an inlet	10	12	4.0
5/17/95		5.4	7.4	5.5
6/19/95		10† 10	8.7 6.0	Outlet not flowing
7/26/95		15 19	6.8 10	8.8
8/16/95		3.6 10	6.0 8.6	4.0

Phoenix Lake

Date	Inlet	D32	D33	Outlet
10/4/94*	64	55	50 60	55
5/23/95	12	23	17	16
6/20/95	20	9.1	(Sample lost)	12
7/27/95*	44	47	36 40	20
8/17/95*	38	34	31 36	21

Meadowbrook Lake

Date	Inlet	D52	D53	Outlet
10/19/94 *	12	96	30	25
5/25/95	23	23	20	36
6/22/95	27	5.5	6.0 19	16
7/31/95	9.0	11 44	13 16	15
8/29/95	8.9	1.8	4.0 31	6.0

Newburgh Lake

Date	Inlet	D22	D23	Outlet
9/27/94*	40	10	8.0	12
5/22/95	11	9.2	5.1	13
6/23/95	7.1	9.1	3.6	16
7/25/95*	67	35	4	1.8
8/15/95*	41	11	7.2 7.1	7.5

* Recent rainfall event
† Upper value = epilimnion; lower value = hypolimnion

higher at Meadowbrook Lake (20 mg/L) and Phoenix Lake (25 mg/L), and lower again at Newburgh Lake (10 mg/L). Given the orientation of the lakes (Walled Lake – Meadowbrook Lake – Phoenix Lake – Newburgh Lake), these data indicate that:

- There is a substantial increase in TSS between Walled Lake and Meadowbrook Lake;
- Another substantial increase between Meadowbrook Lake and Phoenix Lake;
- A smaller increase between Phoenix Lake and Newburgh Lake, and;
- TSS concentrations at the Newburgh Lake outlet are comparable to those in Walled Lake and its outlet, in the headwaters of the Middle Branch.

Where there was a thermocline, TSS concentrations were higher in the hypolimnion (i.e., below the thermocline) than in the epilimnion (above the thermocline) in 10 of 13 cases (77 %), by an average of 10.7 mg/L (range = 2.6 to 33.1 mg/L). This may be due to nocturnal settling of plankton into deeper water, since almost all of the TSS samples were collected near sunrise.

Rainfall events seemed to have a greater impact on TSS concentrations than on other parameters. According to the field logs, rainfall events within 48 hours of sample collection correspond to the highest in-lake TSS concentration in Meadowbrook Lake; the three highest inlet and in-lake TSS values in Phoenix Lake; and the three highest inlet TSS values at Newburgh Lake.

The contribution of the four lakes to the TSS load in the river was also variable (*Table 4.4*). Meadowbrook Lake was alternately a source or sink, depending on the month, and overall may be a small source of solids to the Middle Branch; over the five months monitored, Meadowbrook Lake outlet water solids concentrations were higher than inlet concentrations by an average of 5.0 mg/L. Phoenix Lake and Newburgh Lake, in contrast, were usually TSS sinks, with outlet TSS concentrations at Phoenix Lake lower than inlet concentrations by an average of 10.9 mg/L, and at Newburgh Lake by an average of 23.1 mg/L. Apparently particle settling rates exceeded particle "production" by phyto and zooplankton productivity in these highly eutrophic lakes. Walled Lake is a headwater for the Middle Branch of the river, and therefore can only be a source of TSS, and only when its water level is high enough to produce an outflow (four of five months sampled). Its outlet TSS concentrations of 4.0 to 8.8 mg/L were rather low compared to the inlet and outlet samples from the other lakes, and this combined with the small discharge from the lake indicates that Walled Lake is not a major source of solids to the Middle Branch.

Table 4.4
Lake Inlet and Outlet Total Suspended Solids Concentrations (mg/L): 1994-1995

Date	Meadowbrook Lake			Phoenix Lake			Newburgh Lake		
	Inlet	Outlet	Δ	Inlet	Outlet	Δ	Inlet	Outlet	Δ
9 or 10/94	12.0	25.0	+ 13.0	64.0	55.0	- 9.0	40.0	12.0	- 28.0
5/95	22.5	36.0	+ 13.5	11.9	16.0	+ 4.1	11.1	12.5	+ 1.4
6/95	27.0	9.2	- 17.8	20.0	12.0	- 8.0	7.1	16.2	+ 9.1
7/95	9.0	15.4	+ 6.4	43.7	19.7	- 24.0	66.7	1.8	- 64.9
8/95	8.9	6.0	-2.9	38.1	20.5	- 17.6	40.8	7.5	- 33.3

Comparison of the 1994-1995 TSS Data to Other Studies. 1994-1995 TSS concentrations were comparable to those reported by RPO (1996b) for the Middle Rouge River waters under dry conditions in 1993-1994; < 1 to 25 mg/L. TSS concentrations were much more variable at all 10 stations sampled by RPO in 1993-1994 under wet weather conditions (station averages = 2 to 1,102 mg/L) and in CSO discharges to the Middle Branch (15 to 1,060 mg/L). Average wet weather TSS concentrations at selected RPO river stations in 1993-1994 were comparable to the 1994-1995 lake data; for example, stations nearest the Meadowbrook Lake inlet (32 mg/L), the Phoenix Lake inlet (98 mg/L), and the Newburgh Lake inlet (48 mg/L) and outlet (9 mg/L); but these values are averages of extremely variable data sets. For example, the TSS concentration at RPO station D02, downstream of the Meadowbrook Lake outlet, averaged 83 mg/L but ranged from 2 to 396 mg/L.

4.2.2 Dissolved Oxygen. DO concentrations were generally high in all of the lakes at all times of the year, except for the anoxic hypolimnia in the summer (*Table 4.5*). Excluding the hypolimnion values, 69 of 73 DO values (95 %) were greater than 5 mg/L.

On 11 occasions, an oxycline (a zone of rapid change in DO concentration between an aerobic epilimnion and an anaerobic hypolimnion) was observed, sometimes at both in-lake stations on the same day, and always in the summer months (June, July, and August 1995). Walled Lake, the deepest of the four lakes studied (maximum depth ≈ 50'), was most frequently stratified (both stations in each of the three summer months). In each of the 11 cases of stratification, epilimnetic DO concentrations exceeded 6 mg/L, while the hypolimnetic DOs were less than 1 mg/L . These data indicate that during the summer months the consumption of oxygen by bacterial decompostition of organic matter in all four lakes was

Table 4.5
Dissolved Oxygen Concentrations (mg/L) in the Four Lakes: 1994-1995
(Stations refer to Figures 2-1 to 2-4)

Walled Lake

Date	Inlet	D41	D42	Outlet
10/12/94	Walled Lake does not have an inlet	10.9	11.3	8.1
5/17/95		8.6	10.3	9.3
6/19/95		10.7† 0.1	11.0 0.03	Outlet not flowing
7/26/95		8.5 0.2	8.4 0.2	5.8
8/16/95		8.4 0.9	8.2 0.1	2.0

Phoenix Lake

Date	Inlet	D32	D33	Outlet
10/4/94*	10.1	8.9	8.7	9.7
5/23/95	9.1	11.0	6.7	9.4
6/20/95	Not measured	**	**	**
7/27/95*	9.4	7.0	6.2	9.3
8/17/95*	9.0	6.8	6.1 0.1	9.0

Meadowbrook Lake

Date	Inlet	D52	D53	Outlet
10/19/94 *	8.5	8.3	9.7	10.6
5/25/95	8.9	7.4	7.3	8.6
6/22/95	7.2	7.7	**	8.6
7/31/95	7.3	10.4 0.1	10.0 0.1	9.7
8/29/95	7.5	7.8	8.3 0.1	8.8

Newburgh Lake

Date	Inlet	D22	D23	Outlet
9/27/94*	8.5	5.7	6.8	7.9
5/22/95	8.8	6.0	9.9	8.9
6/23/95	6.3	3.9	13.7	9.0
7/25/95*	7.8	8.3	4.2	6.0
8/15/95*	7.0	2.5	8.5 0.5	7.8

* Recent rainfall event
** Supersaturated (> 20 mg/L)
† Upper value = epilimnion; lower value = hypolimnion

sufficient to deplete the DO in the thermally-stratified hypolimnion. In the three smaller lakes (Meadowbrook, Phoenix, and Newburgh) it was observed that storms or perhaps just strong winds could temporarily eliminate the anoxic hypolimnion, presumably by causing a turnover of the stratified water layers. This was especially evident at Newburgh Lake, whose maximum fetch lies in the direction of the typically dominant winds (east-west).

The hypolimnion in Walled Lake may be anaerobic for most of the year, although evidence for this is limited and contradictory:

- Near-bottom DO was not accurately measured in Walled Lake in February 1995 during investigation of winter-time total phosphorous concentrations due to sample collection problems (Section 4.2.7). However, what was assumed to be an anomalously low reading (~ 0.2 mg/L) at about 30' at station D41, attributed to DO meter malfunction, is now believed to have been an accurate measurement of anoxic conditions at this depth.

- DO was 10.9 mg/L near the bottom (~ 40') at station D41 in October 1994, a month when no stratification was observed at either D41 or D42.

It is possible that a zone of anoxic water exists in Walled Lake for most of the year, perhaps especially in the deepest part of the lake, near station D42, and that it disappears briefly in some or most springs and autumns.

Supersaturated DO concentrations, sometimes > 20 mg/L (the maximum reading of the DO meter used), were observed in four cases; at station D53 on Meadowbrook Lake in June 1995, and at both lake stations and the lake outlet on Phoenix Lake in June 1995. These supersaturated concentrations were due to photosynthetic DO production by the dense algae populations present in these lakes (see the chlorophyll *a* data in Section 4.2.9) during these months. Supersaturated DO was also observed during the diurnal DO profile studies (Section 4.2.10) and the dam reaeration studies (RPO, 1996a).

In the three lakes with both an inlet and an outlet, outlet DO concentrations were similar to (within 0.4 mg/L) the inlet DO concentrations in 12 of 15 cases (80%). Outlet DO concentrations were usually high; ≥ 5.8 mg/L in 18 of 19 cases (95%), one exception was Walled Lake (August 1995). The Walled Lake outlet is actually two small streams which drain the lake, and station D43 is the larger of the two (the western-most stream). In August 1995, the DO at this station was 2.0 mg/L, while the DO in the smaller eastern-most outlet stream was 6.4 mg/L. The western-most outlet stream is more circuitous and drains through more wetland than does the smaller eastern-most outlet, and there may have been a source of unusually high oxygen demand in the wetland on the sampling date (8/16/95). In any event, the inlet/outlet data indicate that reaeration processes at the three dams (Walled Lake does not have a dam) were sufficient to maintain high DO concentrations at the lake outlets regardless of the DOs within the lake. Any DO problems downstream of the lakes, then, are due to instream conditions (e.g., high SODs, low reaeration, etc.) and not to the release of low DO water from the lakes. See the Stream and Dam Reaeration Report (RPO, 1996a) and the Sediment Oxygen Demand (SOD) Report (RPO, 1996c) for a more thorough discussion of these issues.

Comparison of 1994-1995 Dissolved Oxygen Data to Other Studies. DO concentrations in the epilimnion of these four lakes, or under unstratified conditions, in 1994-1995 were comparable to the DO concentrations reported by SEG (1974) for Phoenix Lake (7.3 to 13.0 mg/L) and Newburgh Lake (6.5 to 12.4 mg/L) in June and October 1973, and February and May 1994. SEG did not sample in midsummer, however, and so probably missed the period of maximum temperature/maximum productivity/minimum DO. RPO (1996b) also reported comparable DO concentrations in river waters of the Middle Branch under dry weather conditions (8.0 to 8.6 mg/L), although their sampling was limited (n = 3).

4.2.3 **Nitrate-Nitrogen.** Nitrate-N concentrations exhibited a strong spatial pattern: all values in Walled Lake and at the Walled Lake outlet were less than the method detection limit (0.05 mg/L in 1994 and 0.10 mg/L in 1995); increased dramatically by the Meadowbrook Lake inlet in all months, to 2.4 to 9.7 mg/L, and remained elevated within Meadowbrook Lake and at the Meadowbrook Lake outlet; and then declined to ≤ 1 mg/L throughout Phoenix Lake and Newburgh Lake in all months (*Table 4.6* and Appendix *Figure A-2*). The substantial increase in nitrate concentration between Walled Lake and Meadowbrook Lake is apparently due to the Walled Lake wastewater treatment plant discharge. The decline in nitrate within Meadowbrook Lake and between Meadowbrook Lake and Phoenix Lake is probably due to a combination of algal uptake and bacterial denitrification within Meadowbrook Lake, and dilution between Meadowbrook Lake and Phoenix Lake.

In six of eight cases (75 %) where an oxycline was present and nitrate concentrations were measurable, epilimnetic nitrate concentrations were higher than hypolimnetic concentrations. This is probably due to increased denitrification in the anaerobic hypolimnion, in which nitrate is reduced to ammonia.

The stretch of the Middle Branch between Walled Lake and Newburgh Lake is apparently a small source of nitrate to the rest of the Rouge River, with Newburgh Lake outlet concentrations of 0.1 to 0.3 mg/L.

Comparison of 1994-1995 Nitrate-Nitrogen Concentrations to Other Studies. Nitrate concentrations in these lakes in 1994-1995 were comparable to combined nitrite/nitrate concentrations in Middle Branch river water under dry and wet weather conditions in 1993 and 1994 (0.07 to 3.60 mg/L), and in Middle Branch CSO discharges in 1994 (0.05 to 1.80 mg/L), reported by RPO (1996b). The RPOs' Middle Branch river water monitoring also found elevated nitrate concentrations between Walled Lake and Meadowbrook Lake, at Nine Mile Road under dry weather conditions and at 9 Mile Road and 10 Mile Road under wet weather conditions. Nitrate concentrations in Phoenix Lake and Newburgh Lake in 1994-1995 were comparable to those reported by SEG (1974) for these lakes in 1973-1974;

Table 4.6
Nitrate-Nitrogen Concentrations (mg N/L) in the Four Lakes: 1994-1995
(Stations refer to Figures 2-1 to 2-4)

Walled Lake

Date	Inlet	D41	D42	Outlet
10/12/94	Walled Lake does not have an inlet	ND	ND	ND
5/17/95		ND	ND	ND
6/19/95		ND ND	ND ND	Outlet not flowing
7/26/95		ND ND	ND ND	ND
8/16/95		ND ND	ND ND	ND

Phoenix Lake

Date	Inlet	D32	D33	Outlet
10/4/94*	0.68	0.83	0.89 0.76	0.93
5/23/95	0.83	0.66	0.67	0.68
6/20/95	0.73	0.52	0.37	0.41
7/27/95*	0.61	0.66	0.59 0.98	0.61
8/17/95*	0.48	0.44	0.44 ND	0.43

Meadowbrook Lake

Date	Inlet	D52	D53	Outlet
10/19/94 *	2.40	1.12	2.25	2.70
5/25/95	3.41	1.60	1.94	1.74
6/22/95	9.71	5.80	5.02 2.10	5.22
7/31/95	7.58	5.04 4.41	4.52 0.22	4.15
8/29/95	9.70	6.20	4.50 0.49	4.20

Newburgh Lake

Date	Inlet	D22	D23	Outlet
9/27/94*	0.88	0.62	0.15	0.14
5/22/95	0.63	0.32	0.26	0.26
6/23/95	0.26	0.12	ND	ND
7/25/95*	0.76	0.62	0.40	0.32
8/15/95*	0.53	0.50	0.26 0.27	0.30

ND = Below method detection limit (0.05 mg/L in 1994 and 0.10 mg/L in 1995)
* Recent rainfall event
† Upper value = epilimnion; lower value = hypolimnion

0.16 to 1.0 mg/L for Phoenix Lake and 0.01 to 0.88 mg/L for Newburgh Lake. Apparently nitrate concentrations in these lakes have not changed substantially in 20 years.

4.2.4 **Nitrite-Nitrogen.** Nitrite-N concentrations were very low; 77 of 88 values (88%) were less than the method detection limit (0.05 mg/L in 1994 and 0.10 mg/L in 1995; *Table 4.7* and Appendix *Figure A-3*). Eight of 11 detectable nitrite concentrations were found in Meadowbrook Lake, where the highest nitrate and ammonia concentrations were also found.

None of the available historic reports (SEG, 1974; SEMCOG, 1978; RPO, 1996b) report nitrite concentrations.

4.2.5 **Ammonia-Nitrogen.** Ammonia-N concentrations were fairly low, usually ranging from nondetectable to 0.6 mg/L. Thirty-six of the 88 values (41%) were less than the method detection limit (0.10 mg/L). The measurable ammonia concentrations did not exhibit strong seasonal or spatial patterns (*Table 4.8* and Appendix *Figure A-4*), although the late summer 1995 (July and August) concentrations in the lower part of the study reach (downstream of Meadowbrook Lake) were higher than concentrations found elsewhere in the study area in the rest of the year.

In 12 of 14 situations (86%) where an oxycline was present, hypolimnetic ammonia concentrations were higher than epilimnetic concentrations. This was probably due to bacterial denitrification in the anaerobic hypolimnion (nitrate and nitrite → ammonia), or to anaerobic bacterial decomposition of settling algae cells (organic nitrogen → ammonia). The highest individual ammonia concentrations observed, 1.45 and 1.67 mg/L, were in the hypolimnion at station D53 in Meadowbrook Lake in July and August, 1995. Ammonia concentrations in the impoundments were usually lower in the outlet samples than in the lake samples. This may have been due to volatilization and/or oxidation of ammonia as the water passed over the dam (the outlet stations at the three impoundments were downstream of the dams).

The stretch of the Middle Branch between Walled Lake and Newburgh Lake is apparently not a significant source of ammonia to the rest of the Rouge River; in four of five months monitored, the ammonia concentrations in the Newburgh Lake outlet samples were less than the method detection limit.

Comparison of 1994-1995 Ammonia Nitrogen Concentrations to Other Studies. Ammonia concentrations in these lakes in 1994-1995 were comparable to ammonia concentrations in Middle Branch river water samples under wet conditions (station averages = 0.10 to 0.25 mg/L) and dry conditions (< 0.10 to 0.12 mg/L) in 1993-1994, and less than the variable, but generally higher concentrations in CSO discharges in 1994 (0.1 to 12.0 mg/L), reported by RPO (1996b). Ammonia concentrations in these lakes in 1994-1995 were also comparable to those reported by SEG (1974) for Phoenix Lake (0.05 to 1.0 mg/L) and Newburgh Lake (0.01 to 0.61 mg/L) in 1973-1974. Apparently, ammonia concentrations in these lakes have not changed substantially in 20 years.

Table 4.7
Nitrite-Nitrogen Concentrations (mg N/L) in the Four Lakes: 1994-1995
(Stations refer to Figures 2-1 to 2-4)

Walled Lake

Date	Inlet	D41	D42	Outlet
10/12/94	Walled Lake does not have an inlet	ND	ND	ND
5/17/95		ND	ND	ND
6/19/95		ND ND	ND ND	Outlet not flowing
7/26/95		ND ND	ND ND	ND
8/16/95		ND ND	ND ND	ND

Phoenix Lake

Date	Inlet	D32	D33	Outlet
10/4/94	ND	ND	ND	ND
5/23/95	ND	ND	ND	ND
6/20/95	ND	ND	ND	ND
7/27/95	ND	ND	ND ND	ND
8/17/95	ND	ND	ND ND	ND

Meadowbrook Lake

Date	Inlet	D52	D53	Outlet
10/19/94 *	ND	0.079	0.051	ND
5/25/95	ND	ND	ND	ND
6/22/95	0.11	ND	ND ND	ND
7/31/95	0.13	0.12 0.11	0.13 ND	0.12
8/29/95	ND	ND	ND ND	ND

Newburgh Lake

Date	Inlet	D22	D23	Outlet
9/27/94	0.060	0.057	ND	ND
5/22/95	ND	ND	ND	ND
6/23/95	ND	ND	ND	ND
7/25/95	ND	0.12	ND	ND
8/15/95	ND	ND	ND ND	ND

ND = Below method detection limit (0.05 mg/L in 1994 and 0.10 mg/L in 1995)
* Recent rainfall event
† Upper value = epilimnion; lower value = hypolimnion

Table 4.8
Ammonia-Nitrogen Concentrations (mg N/L) in the Four Lakes: 1994-1995
(Stations refer to Figures 2-1 to 2-4)

Walled Lake

Date	Inlet	D41	D42	Outlet
10/12/94	Walled Lake does not have an inlet	0.37	0.30	ND
5/17/95		0.52	0.16	ND
6/19/95		0.34 0.50	0.37 0.10	Outlet not flowing
7/26/95		ND 0.23	ND 0.14	0.53
8/16/95		ND 0.22	0.13 0.49	0.20

Phoenix Lake

Date	Inlet	D32	D33	Outlet
10/4/94*	0.20	ND	0.21 0.11	ND
5/23/95	ND	ND	ND	ND
6/20/95	0.27	ND	ND	ND
7/27/95*	0.24	0.13	0.11 0.44	0.10
8/17/95*	0.35	0.46	0.49 0.57	ND

Meadowbrook Lake

Date	Inlet	D52	D53	Outlet
10/19/94 *	0.33	0.98	ND	ND
5/25/95	0.34	0.29	0.11	0.13
6/22/95	0.80	0.30	ND 0.22	0.13
7/31/95	0.29	ND 0.57	0.29 1.45	ND
8/29/95	0.14	ND	ND 1.67	ND

Newburgh Lake

Date	Inlet	D22	D23	Outlet
9/27/94*	ND	ND	0.13	ND
5/22/95	ND	ND	ND	ND
6/23/95	ND	0.22	ND	ND
7/25/95*	0.15	0.16	ND	0.20
8/15/95*	0.11	0.20	ND 0.13	ND

ND = Below method detection limit (0.1 mg/L)
* Recent rainfall event
† Upper value = epilimnion; lower value = hypolimnion

4.2.6 **Total Kjeldahl Nitrogen.** Total Kjeldahl nitrogen (TKN) concentrations did not exhibit either seasonal or spatial distribution patterns (*Table 4.9* and Appendix *Figure A-5*). TKN concentrations were generally uniform, between 1 and 3 mg/L, throughout the study area in almost every month sampled. Exceptions were:

- Walled Lake and its outlet in October 1994 (5.1 - 7.4 mg/L);
- Meadowbrook Lake in June 1995 (5.6 - 20.6 mg/L);
- Newburgh Lake in June 1995 (21.3 - 30.8 mg/L).

Field notes indicate a lack of recent rain immediately prior to sample collection in all three cases, so the cause of these elevated TKN concentrations is not immediately apparent. Where an oxycline was present, hypolimnetic TKN concentrations were generally higher than epilimnetic concentrations.

The stretch of the Middle Branch between Walled Lake and Newburgh Lake is apparently a source of TKN to the rest of the Rouge River; TKN concentrations were no higher at the Newburgh Lake outlet than in the Branch headwaters at Walled Lake, but the larger stream discharge at Newburgh Lake results in a greater mass of TKN exiting Newburgh Lake.

Comparison of the 1994-1995 TKN Data to Other Studies. TKN concentrations in these lakes in 1994 and 1995 were within the wide concentration range reported by RPO (1996b) for Middle Branch river waters under dry weather conditions (0.2 - 17 mg/L) and the more uniform wet weather concentrations (0.7 - 4 mg/L) in 1993 and 1994, and less than most of the concentrations in Middle Branch CSO discharges sampled in 1994 (1.2 - 15 mg/L; 15 of 25 [60%] values > 5 mg/L). TKN was not measured in the two earlier studies (SEG, 1974 and SEMCOG, 1978).

4.2.7 **Orthophosphorous.** Orthophosphorous concentrations (as P) were very low; 66 of 92 values (72%) were less than the method detection limit (0.01 mg/L in 1994 and 0.02 mg/L in 1995; *Table 4-10* and *Appendix Figure A-6*). Twelve of 26 measurable orthophosphorous concentrations (46 %) were found in Meadowbrook Lake, and another nine (35%) were found in Newburgh Lake. Orthophosphorous is the only significant form of inorganic phosphorous in most freshwaters (Wetzel, 1975), and is apparently absorbed rapidly by algae and macrophytes in these four lakes.

Comparison of the 1994-1995 Orthophosphorous Data to Other Studies. These 1994-1995 lake concentrations are comparable to those reported by RPO (1996b) for Middle Branch river waters under dry weather conditions (< 0.01 - 0.06 mg/L) and under wet weather conditions (0.01 - 0.06 mg/L) in 1993 and 1994. They are lower than those reported for Middle Branch CSO discharges in 1994 (0.02 - 1.4 mg/L). They are also comparable to the concentrations reported for Phoenix Lake (0.02 to 0.05 mg/L) and Newburgh Lake (< 0.01 to 0.06 mg/L) in 1973-1974 by SEG (1974).

Table 4.9
Total Kjeldahl Nitrogen Concentrations (mg/L) in the Four Lakes: 1994-1995
(Stations refer to Figures 2-1 to 2-4)

Walled Lake

Date	Inlet	D41	D42	Outlet
10/12/94	Walled Lake does not have an inlet	7.4	0.75	5.1
5/17/95		2.7	1.6	1.8
6/19/95		ND† 6.51	ND ND	Outlet not flowing
7/26/95		0.98 0.90	0.79 0.99	2.51
8/16/95		1.15 1.53	1.33 1.69	1.14

Phoenix Lake

Date	Inlet	D32	D33	Outlet
10/4/94	0.45	0.69	8.1 0.6	0.59
5/23/95	0.46	1.2	2.5	1.7
6/20/95	3.25	2.85	3.66	3.00
7/27/95	1.22	1.13	0.93 1.21	1.42
8/17/95	2.54	1.35	1.74 1.87	2.30

Meadowbrook Lake

Date	Inlet	D52	D53	Outlet
10/19/94 *	1.7	3.0	0.74	1.3
5/25/95	2.4	1.9	1.6	1.7
6/22/95	2.93	20.6	5.62 6.02	4.97
7/31/95	2.49	2.09 2.88	1.73 3.92	1.95
8/29/95	1.89	1.78	1.82 3.67	2.22

Newburgh Lake

Date	Inlet	D22	D23	Outlet
9/27/94	0.35	0.33	0.46	0.51
5/22/95	2.8	2.9	1.7	2.6
6/23/95	2.16	21.3	30.8	3.89
7/25/95	1.33	1.23	2.25	0.90
8/15/95	1.41	1.19	1.21 1.86	1.19

ND = Below method detection limit (0.1 mg/L)
* Recent rainfall event
† Upper value = epilimnion; lower value = hypolimnion

Table 4.10
Orthophosphorous Concentrations (mg P/L) in the Four Lakes: 1994-1995
(Station refer to Figures 2-1 to 2-4)

Walled Lake

Date	Inlet	D41	D42	Outlet
10/12/94	Walled Lake does not have an inlet	ND	ND	ND
2/24/95		ND	Not sampled	Not sampled
5/17/95		ND	ND	ND
6/19/95		ND† ND	ND ND	Outlet not flowing
7/26/95		ND ND	ND 0.092	ND
8/16/95		ND ND	ND ND	ND

Phoenix Lake

Date	Inlet	D32	D33	Outlet
10/4/94*	ND	ND	ND ND	ND
2/22/95	Not sampled	Not sampled	ND	Not sampled
5/23/95	ND	ND	ND	ND
6/20/95	ND	ND	ND	ND
7/27/95*	ND	ND	ND ND	ND
8/17/95*	0.050	0.024	0.039 ND	0.022

Meadowbrook Lake

Date	Inlet	D52	D53	Outlet
10/19/94 *	0.067	0.084	0.012	ND
2/24/95	Not sampled	Not sampled	ND	Not sampled
5/25/95	0. 18	ND	ND	ND
6/22/95	0.055	ND	ND ND	ND
7/31/95	0.067	ND ND	ND ND	0.069
8/29/95	0.070	0.045	0.028 0.040	0.025

Newburgh Lake

Date	Inlet	D22	D23	Outlet
9/27/94*	ND	0.023	0.023	0.023
2/22/95	Not sampled	Not sampled	ND	Not sampled
5/22/95	ND	ND	ND	0.26
6/23/95	ND	ND	ND	ND
7/25/95*	0.87	0.23	ND	ND
8/15/95*	0.024	0.020	ND ND	0.028

ND = Less than method detection limit (0.01 mg/L in 1994 and 0.02 mg/L in 1995)
* Recent rainfall event
† Upper value = epilimnion; lower value = hypolimnion

Apparently, orthophosphorous concentrations in these two lakes have not changed substantially in the last 20 years.

4.2.8 **Total Phosphorous.** Total phosphorous (total P) concentrations exhibited strong spatial and seasonal patterns (*Table 4.11* and Appendix *Figure A-7*). Total P increased dramatically between the Walled Lake outlet and the Meadowbrook Lake inlet in all months sampled; were relatively consistent downstream to the Newburgh Lake inlet in four of five months sampled; and remained uniform or declined within Newburgh Lake such that the total P concentrations at the lake outlet were comparable to those at the headwaters area below Walled Lake. The dramatic increase in total P between Walled Lake and Meadowbrook Lake is apparently due to the Walled Lake wastewater treatment plant discharge. Total P concentrations were highest in June, July, and August 1995 (0.02 to 0.16 mg/L), and lower in October 1994 and May 1995 (< 0.02 mg/L). A number of factors may account for this summer maximum of total P concentration, including storm runoff, fertilizer use, input from growing macrophytes, and desorbtion from anaerobic sediments (see below).

Twenty-six of 92 total P values (28 %) exceeded the guideline value indicative of eutrophic conditions; 0.084 mg/L (U.S. EPA, 1985).

In six of 13 cases where an oxycline was present (46 %), hypolimnetic total P concentrations were higher than epilimnetic concentrations. This may have been due to release of phosphorous from the lake sediments under anaerobic conditions. Phosphorous concentrations in sediments can exceed those in water by several orders of magnitude (Wetzel, 1975), and anaerobic conditions decrease or eliminate the oxidized microzone normally present in aerobic sediments. Elimination of this layer reduces the ferric oxides and hydroxides that bind phosphorous in sediments under aerobic conditions, releasing the absorbed phosphorous to the water column.

The stretch of the Middle Branch between Walled Lake and Newburgh Lake is apparently a source of total phosphorous to the rest of the Rouge River; total P concentrations were no higher at the Newburgh Lake outlet than in the Branch headwaters at Walled Lake, but the larger stream discharge at Newburgh Lake results in a greater mass of total P exiting Newburgh Lake.

Investigation of Phosphorous Release from Lake Sediments in the Winter. In a related study, samples were collected in February 1995, to evaluate whether phosphorous concentrations in the winter, under the ice, were different from the other seasons. It was hypothesized that oxygen reaeration would be minimal in lakes covered by ice, and although the lakes would not be thermally stratified, the near-bottom waters would become anaerobic. This would eliminate the oxidized microzone, resulting in a release of absorbed phosphorous from the sediment. Ice covered 100 % of the lake surface on the sampling date at Walled Lake and Meadowbrook Lake, and all but small areas near the inlets at Phoenix Lake and Newburgh Lake.

Table 4.11
Total Phosphorous Concentrations (mg P/L) in the Four Lakes: 1994-1995
(Station numbers refer to Figures 2-1 to 2-4)

Walled Lake

Date	Inlet	D41	D42	Outlet
10/12/94	Walled Lake does not have an inlet	ND	ND	ND
2/24/95		0.027	Not sampled	Not sampled
5/17/95		0.06	ND	ND
6/19/95		0.046† 0.032	0.035 0.039	Outlet not flowing
7/26/95		ND ND	ND 0.030	0.030
8/16/95		ND ND	ND ND	ND

Phoenix Lake

Date	Inlet	D32	D33	Outlet
10/4/94*	ND	ND	ND ND	ND
2/22/95	Not sampled	Not sampled	0.088	Not sampled
5/23/95	ND	ND	ND	ND
6/20/95	0.053	0.030	0.028	0.042
7/27/95*	0.10	0.12	0.089 0.14	0.094
8/17/95*	0.16	0.12	0.18 0.17	0.12

Meadowbrook Lake

Date	Inlet	D52	D53	Outlet
10/19/94 *	0.13	0.14	ND	ND
2/24/95	Not sampled	Not sampled	0.04	Not sampled
5/25/95	ND	0.028	0.21	0.035
6/22/95	0.11	0.039	ND 0.028	0.039
7/31/95	0.13	0.11 0.27	0.079 0.015	0.075
8/29/95	0.15	0.12	0.10 0.14	0.12

Newburgh Lake

Date	Inlet	D22	D23	Outlet
9/27/94*	ND	ND	ND	ND
2/22/95	Not sampled	Not sampled	0.037	Not sampled
5/22/95	0.029	0.034	0.027	0.032
6/23/95	0.035	0.048	0.026	0.035
7/25/95*	0.14	0.10	ND	0.021
8/15/95*	0.10	0.084	0.023 0.051	0.031

ND = Less than method detection limit (0.01 mg/L in 1994 and 0.02 mg/L in 1995)
* Recent rainfall event
† Upper value = epilimnion; lower value = hypolimnion

Results were mixed (*Table 4.11*). Total phosphorous concentrations were higher in February than in the other months at Phoenix Lake and Newburgh Lake, but not substantially different in Walled Lake or Meadowbrook Lake. This does not correspond to the February 1995 DO values (*Table 4.12*); Phoenix Lake and Newburgh Lake were aerobic throughout the water column, while Meadowbrook Lake and Walled Lake exhibited signs of depressed DOs in deeper waters. Note that the DO data for Phoenix Lake and Walled Lake were incomplete, as explained in *Table 4.12*. Further sampling is required to fully investigate the magnitude of phosphorous release from sediments in these lakes under the winter ice.

Table 4-12
Winter DO Concentrations in the Four Lakes; February 1995

Lake	Depth (Ft)	DO (mg/L)	Temp. (°C)	Comments
Walled Lake (TP sampled @ 20')	5 10 15	14.4 13.6 10.9	3.2 3.1 3.0	Station depth ≈ 40'. DO meter cable insufficient to measure DO deeper.
Meadowbrook Lake (TP sampled @ 6')	3 6 9	11.0 5.4 4.9	3.3 3.6 3.7	Station depth = 11.5'.
Phoenix Lake (TP sampled @ 2')	1	10.1	1.0	Ice unsafe; could not sample deeper area.
Newburgh Lake (TP sampled @ 4')	0.5 2 4 6	12.8 12.8 14.8 14.7	1.9 3.8 3.2 3.0	Station depth = 8.5'.

Comparison of 1994-1995 Total Phosphorous Data to Other Studies. Total P values observed in these lakes in 1994-1995 were comparable to those reported by RPO (1996b) for Middle Branch river waters under dry weather conditions (< 0.01 to 0.13 mg/L), and the higher total P values observed in the lakes (> 0.10 mg/L) were comparable to the average concentrations observed in the river under wet weather conditions (0.10 - 0.19 mg/L). Total P concentrations in CSO discharges in 1994 were substantially higher than any of the lake or river concentrations (0.40 to 5.3 mg/L). The 1994-1995 lake total P concentrations were also generally comparable to the concentrations in Phoenix Lake (0.05 to 0.36 mg/L) and Newburgh Lake (0.03 to 0.14 mg/L) in 1973-1974 (SEG, 1974). Apparently the concentrations of total P in these lakes has not changed substantially in 20 years.

4.2.9 Nitrogen\Phosphorous Ratios and Total Nitrogen. Nitrogen and phosphorous are both "macronutrients" in aquatic systems; both are plant nutrients present in μg/L (ppb) or mg/L (ppm) concentrations in most natural waters. Either may act as a "limiting nutrient"; that is, the ambient concentrations of one element may be so low as to limit the amount of primary productivity a waterbody can support, even though concentrations of the other element could support higher productivity. A procedure for determining which element is the limiting nutrient is to calculate the ratio of total nitrogen (nitrate + nitrite + total Kjeldahl nitrogen) to total phosphorous (N:P). In theory, an N:P ratio of greater than 7.2 would indicate phosphorous is limiting potential photosynthetic productivity, while an N:P ratio of less than 7.2 would indicate that nitrogen is limiting. In practice, an N:P ratio of less than five is considered nitrogen limiting; greater than 10, phosphorous limiting; and between five and 10, both N and P are limiting (U.S. EPA, 1985).

Overall (*Table 4.13*), the N:P ratios indicate that phosphorous was the primary limiting nutrient in each lake at almost every sampling date in 1994-1995. In all four lakes combined, the N:P ratio was greater than 10 in 85 of 87 samples (98 %). Nitrogen was the limiting nutrient only once, in the hypolimnion at station D42 in Walled Lake on 6/19/95, and both N and P were limiting in one sample, also from Walled Lake, on 5/17/95. *Figure 4-7* indicates that there was a substantial input of phosphorous between the Walled Lake outlet and the Meadowbrook Lake inlet in four of the five months sampled, apparently due to the Walled Lake wastewater treatment plant discharge. This may the major source of phosphorous to the Middle Branch (Section 4.2.7).

Most of the 1994-1995 total nitrogen concentrations in the Middle Branch lakes equaled or exceeded the guideline for eutrophic waters (1.9 mg/L total nitrogen) recommended by the U.S. EPA (1985): five of 20 values in Walled Lake (25 %), 24 of 24 values in Meadowbrook Lake (100 %), 17 of 23 values in Phoenix Lake (74 %), 14 of 21 values in Newburgh Lake (67 %), and 62 of 88 values overall (70 %). This generally corresponds to the other nutrient data, wherein all four lakes are eutrophic, but Walled Lake is less eutrophic than Phoenix Lake and Newburgh Lake, and all three are less eutrophic than Meadowbrook Lake.

4.2.10 Chlorophyll *a*. As would be expected from the nutrient data, the chlorophyll *a* data indicated that all four lakes are highly eutrophic. Sixty-eight of 88 samples (77 %) contained chlorophyll *a* concentrations exceeding the eutrophic guideline value of 14 μg/L (U.S. EPA, 1985). Nineteen of 88 sample concentrations (22 %) were greater than 100 μg/L, and the highest value observed was 1,084 μg/L (Meadowbrook Lake on 6/22/95). Both seasonal and spatial patterns were apparent. Chlorophyll *a* concentrations were relatively low (<20 μg/L) in all lakes in September/October 1994 and May 1995, while during the summer months of 1995 Meadowbrook Lake exhibited substantially higher chlorophyll *a* concentrations than any of the other three lakes (*Table 4.14* and Appendix *Figure A-8*). Both Meadowbrook Lake and Phoenix Lake were sources of chlorophyll during the summer of 1995; i.e., inlet sample concentrations were less than outlet concentrations; while Newburgh Lake was usually neither a source nor a sink.

Table 4.13
Nitrogen\Phosphorous Ratios from the Four Lakes: 1994-1995
(Station numbers refer to Figures 2-1 to 2-4)

Walled Lake

Date	Inlet	D41	D42	Outlet
10/12/94	Walled Lake does not have an inlet	**	**	**
5/17/95		53.7	**	**
6/19/95		7.4† 219.1	10.6 2.6	Outlet not flowing
7/26/95		** **	** 37.7	101.3
8/16/95		** **	** **	**

Phoenix Lake

Date	Inlet	D32	D33	Outlet
10/4/94*	**	**	** **	**
5/23/95	**	**	**	**
6/20/95	80.2	119.3	143.9	81.2
7/27/95*	20.7	15.6	18.3 18.8	22.7
8/17/95*	21.1	19.1	14.8 14.4	22.8

Meadowbrook Lake

Date	Inlet	D52	D53	Outlet
10/19/94*	34.1	37.0	**	**
5/25/95	**	135.4	17.4	102.0
6/22/95	123.2	684.6	** 297.9	264.6
7/31/95	80.7	65.9 29.5	84.4 372.7	82.9
8/29/95	78.2	66.5	63.2 41.6	53.5

Newburgh Lake

Date	Inlet	D22	D23	Outlet
9/27/94*	**	**	**	**
5/22/95	118.3	94.7	72.6	89.4
6/23/95	69.1	450.8	1184.6	111.1
7/25/95*	16.0	21.3	**	67.6
8/15/95*	20.5	22.5	63.9 44.3	48.1

* Recent rainfall event
** Total phosphorous concentration less than method detection limit; N:P ratio = ∞
† Upper value = epilimnion; lower value = hypolimnion

Table 4.14
Chlorophyll a Concentrations ($\mu g/L$) in the Four Lakes: 1994-1995
(Station numbers refer to Figures 2-1 to 2-4)

Walled Lake

Date	Inlet	D41	D42	Outlet
10/12/94	Walled Lake does not have an inlet	13.4	13.7	4.9
5/17/95		20.5	14.8	16.8
6/19/95		39.4† 134.1	43.8 141.8	Outlet not flowing
7/26/95		73.9 ND	56.3 56.3	43.9
8/16/95		20.9 25.1	25.1 ND	14.8

Phoenix Lake

Date	Inlet	D32	D33	Outlet
10/4/94*	2.7	3.3	3.6 3.2	3.4
5/23/95	11.4	10.9	16.9	22.4
6/20/95	87.5	171.5	171.5	133.4
7/27/95*	54.5	48.5	47.9 48.4	80.4
8/17/95*	35.2	61.6	70.4 105.7	102.1

Meadowbrook Lake

Date	Inlet	D52	D53	Outlet
10/19/94*	4.2	12.4	13.9	21.1
5/25/95	20.3	22.0	20.3	23.5
6/22/95	104.2	120.9	150.8 1084.2	175.1
7/31/95	15.3	405.4 304.1	198.7 211.1	393.9
8/29/95	24.4	44.0	59.9 72.9	277.1

Newburgh Lake

Date	Inlet	D22	D23	Outlet
9/27/94*	5.1	2.9	9.9	10.5
5/22/95	33.5	12.9	25.0	18.0
6/23/95	58.4	80.0	36.9	58.4
7/25/95*	54.5	54.5	81.7	52.1
8/15/95*	79.2	66.0	44.5 79.2	114.5

ND = Less than method detection limit
* Recent rainfall event
† Upper value = epilimnion; lower value = hypolimnion

As with the nutrient data, chlorophyll *a* concentrations in the Walled Lake outlet samples were similar to those of the Newburgh Lake outlet, so that overall, this stretch of the Middle Branch is a source of chlorophyll to the rest of the river, given the larger discharge at the Newburgh Lake outlet.

Comparison of the 1994-1995 Chlorophyll a Data to Other Studies. Aside from the extremely high values in Meadowbrook Lake (> 1,000 μg/L in June 1995), the 1994-1995 lake chlorophyll *a* concentrations were generally comparable to those reported by SEG (1974) for Phoenix Lake (0 to 50.6 μg/L) and Newburgh Lake (2.9 to 59.3 μg/L) in 1973-1974. Apparently the chlorophyll *a* concentrations, like many of the nutrients, have not changed substantially in these lakes in the last 20 years.

4.2.11 **Diurnal Dissolved Oxygen Profiles.** DO concentrations were measured at sunup and at midday at the deepest location in each lake in May, June, July and August, 1995 (but not the fall of 1994), as described in Section 3.2. Data for the diurnal DO profiles are in *Tables 4.16* through *4.19*. General conclusions are below.

Most of the lakes exhibited strong DO stratification (e.g., *Figure 4-1*) for much of the 1995 field season. DO concentrations in the epilimnion were near or above saturation, and very low (< 2 mg/L) in the hypolimnion. This condition occurred in two of the four sampling months at Newburgh Lake, and in all four months at Walled Lake, Meadowbrook Lake, and Phoenix Lake (*Table 4.15*). In 1995, the extent of hypolimnetic anoxia appeared to increase as the summer progressed.

Table 4-15
Extent of Hypolimnetic Anoxia (DO < 2 mg/L) in Rouge River Lakes; 1995
(Date and Extent of Low-DO Layer)

Walled Lake	Meadowbrook Lake	Phoenix Lake	Newburgh Lake
May = lower 5' June = lower 25' July = lower 20' + August = lower 20' +	May = lower 2' June = lower 3' July = lower 3' August = lower 5'	May = lower 1' Early July = lower 1' Late July = lower 2-3' August = lower 3-4'	July = lower 1' August = lower 3-4'

Afternoon DO concentrations at a particular depth in a particular lake were usually higher than morning readings (Walled Lake = June, July, and August; Meadowbrook Lake = July and August; Phoenix Lake = early July and August; Newburgh Lake = May, July, and August), typically by 1 or 2 mg/L though sometimes by as much as 5 mg/L. This daily fluctuation is probably due to a buildup of DO from increased primary productivity later in the day, and its effects were greatest in the upper water column. This daily fluctuation

Table 4.16
Diurnal DO Profile Data for Walled Lake (Station D42): 1995

5/31/95			6/19/95			7/26/95			8/16/95		
Depth (Feet)	DO (mg/L)	Temp. (°C)	Depth (Feet)	DO (mg/L)	Temp. (°C)	Depth (Feet)	DO (mg/L)	Temp. (°C)	Depth (Feet)	DO (mg/L)	Temp (°C)
[Sunrise]			[Sunrise]			[Sunrise]			[Sunrise]		
5	8.8	18.7	5	9.9	24.4	5	9.3	26.1	5	8.4	28.4
10	8.8	18.7	10	11.0	21.2	10	8.4	25.1	10	8.2	28.1
15	8.4	17.1	15	9.0	19.3	15	6.6	23.9	15	6.1	25.3
20	7.9	16.8	20	3.2	16.7	20	1.5	21.0	20	1.0	22.5
25	6.4	16.1	25	0.1	14.6	25	0.8	18.1	25	1.1	18.3
27.5	5.3	15.5	30	0.03	13.3	30	0.2	15.6	30	0.1	15.8
30	0.5	12.3	35	0.01	12.6	35	0.1	15.0	35	0.1	15.2
35	0.2	9.9				40	0.2	14.2	40	0.1	14.7
40	0.3	9.7				45	0.2	14.1	45	0.04	14.7
45	0.1	9.5									
[Mid-day]			[Mid-day]			[Mid-day]			[Mid-day]		
10	9.9	17.5	5	11.1	25.3	5	10.5	26.7	5	8.7	28.8
20	8.2	16.5	10	12.0	21.6	10	9.7	25.6	10	8.8	28.0
30	5.7	15.5	15	11.5	20.1	15	7.7	24.1	15	6.6	25.5
32	3.4	14.6	20	6.8	17.9	20	1.7	21.0	20	1.3	22.7
33	1.2	14.1	25	1.6	16.1	25	0.4	17.5	25	1.0	18.7
			30	0.03	13.8	30	0.3	15.6	30	0.1	16.1
			35	0.00	12.9	35	0.3	15.2	35	0.1	15.1
						40	0.2	15.3	40	0.01	14.5
						45	0.1	15.2			

Table 4.17
Diurnal DO Profile Data for Meadowbrook Lake (Station D53): 1995

5/25/95			6/22/95			7/31/95			8/29/95		
Depth (Feet)	DO (mg/L)	Temp. (°C)	Depth (Feet)	DO (mg/L)	Temp. (°C)	Depth (Feet)	DO (mg/L)	Temp. (°C)	Depth (Feet)	DO (mg/L)	Temp. (°C)
[Sunrise]			[Sunrise]			[Sunrise]			[Sunrise]		
1	7.1	14.8	1	10.3	24.9	1	15.4	24.8	1	9.5	22.4
2	7.1	14.7	2	10.1	24.9	2	14.7	24.8	2	8.3	22.4
3	7.1	14.7	3	*	23.7	3	10.0	24.2	3	7.1	21.8
4	7.1	14.5	4	*	**	4	9.5	23.5	4	5.6	21.5
5	7.1	14.3	5	*	20.7	5	6.3	22.8	5	3.2	21.0
6	7.3	14.2	6	*	**	6	1.4	21.5	6	1.2	20.6
7	7.3	14.0	7	*	17.0	7	5.5	18.6	7	0.1	20.2
8	0.9	13.7	8	2.9	15.5	8	0.1	17.2	8	0.1	19.4
9	0.0	12.4	9	1.1	14.1	9	0.1	15.8	9	0.1	18.3
			10	0.1	12.9	10	0.2	14.0	10	0.1	16.7
			11	0.1	12.6				11	0.04	14.7
[Mid-day]			[Mid-day]			[Mid-day]			[Mid-day]		
1	7.0	14.7	1	*	25.8	1	17.0	25.6	1	~ 11.0	23.4
2	6.9	14.8	2	*	25.6	2	13.3	24.7	2	12.2	22.8
3	7.0	14.8	3	*	24.5	3	12.6	24.2	3	~ 10.5	22.1
4	6.9	14.7	4	*	22.9	4	11.5	23.7	4	~ 6.7	21.6
5	7.4	14.6	5	*	21.2	5	8.3	23.0	5	2.3	21.1
6	7.3	14.5	6	*	18.7	6	2.0	21.6	6	1.8	20.7
7	7.0	14.4	7	*	16.9	7	5.7	19.2	7	0.6	19.9
8	1.5	14.3	8	2.9	15.3	8	0.1	17.1	8	0.1	19.2
9	0.0	12.2	9	1.4	14.3	9	0.1	15.2	9	0.03	18.6
			10	0.3	13.1	10	0.05	13.8	10	0.02	16.1
			11	0.1	11.9				11	0.02	14.5

* Supersaturated; DO readings fluctuated between 10 to > 20 mg/L.
** Data not recorded.

Table 4.18
Diurnal DO Profile Data for Phoenix Lake (Station D33): 1995

5/23/95			7/3/95			7/27/95			8/17/95		
Depth (Feet)	DO (mg/L)	Temp. (°C)	Depth (Feet)	DO (mg/L)	Temp. (°C)	Depth (Feet)	DO (mg/L)	Temp (°C)	Depth (Feet)	DO (mg/L)	Temp. (°C)
[Sunrise]			[Sunrise]			[Sunrise]			[Sunrise]		
1	10.6	16.9	1	7.3	20.0	1	7.6	22.6	1	9.6	25.6
2	10.7	17.3	2	7.2	20.0	2	7.5	22.6	2	7.0	24.8
3	8.8	16.6	3	7.2	20.0	3	6.2	22.0	3	6.1	24.3
4	7.4	15.9	4	5.3	19.1	4	6.1	21.5	4	4.6	23.8
5	6.7	15.2	5	4.2	18.8	5	4.8	21.1	5	1.6	23.3
6	5.7	14.5	6	5.0	18.6	6	2.4	20.6	6	0.1	22.2
7	4.2	14.1	7	4.7	18.3	7	1.0	20.3	7	0.1	21.0
8	3.0	13.7	8	2.4	18.1	8	0.1	19.7	8	0.03	20.7
			9	0.8	18.0						
[Mid-day]			[Mid-day]			[Mid-day]			[Mid-day]		
1	9.5	17.6	1	6.4	20.7	1	6.4	22.9	1	8.1	25.4
2	9.5	17.4	2	7.4	20.0	2	6.2	21.9	2	7.7	25.1
3	9.7	16.1	3	7.5	19.5	3	5.4	21.6	3	7.3	24.8
4	**	15.6	4	5.4	18.7	4	5.2	21.2	4	5.7	23.5
5	6.1	14.8	5	5.2	18.6	5	5.6	20.8	5	3.2	23.1
6	5.8	14.5	6	5.1	18.3	6	1.5	20.4	6	0.1	22.3
7	4.6	14.1	7	5.5	17.9	7	0.1	19.8	7	0.04	21.3
8	3.0	13.5	8	5.4	17.7	8	0.01	19.0	8	0.02	20.3
9	0.5	13.1	9	5.1	17.6						

** Data not recorded.

Table 4.19
Diurnal DO Profile Data for Newburgh Lake (Station D23): 1995

5/24/95			6/23/95			7/25/95			8/15/95		
Depth (Feet)	DO (mg/L)	Temp. (°C)	Depth (Feet)	DO (mg/L)	Temp. (°C)	Depth (Feet)	DO (mg/L)	Temp. (°C)	Depth (Feet)	DO (mg/L)	Temp. (°C)
[Sunrise]			[Sunrise]			[Sunrise]			[Sunrise]		
1	11.0	19.4	1	13.7	25.6	1	8.9	25.4	1	8.6	27.7
2	11.0	19.4	2	13.7	25.5	2	8.8	25.4	2	8.5	27.7
3	11.0	19.4	3	13.7	25.5	3	8.8	25.3	3	4.1	26.6
4	11.0	19.4	4	13.7	25.5	4	8.1	25.3	4	3.2	26.4
5	10.7	19.4	5	*	25.0	5	8.2	25.3	5	1.3	25.9
6	11.1	18.5	6	*	23.6	6	5.3	25.0	6	0.5	25.4
7	9.9	18.1	7	*	22.5	7	4.2	24.7	7	0.1	24.8
8	~ 4.0	17.8				8	1.7	24.1	8	0.1	23.5
[Mid-day]			[Mid-day]			[Mid-day]			[Mid-day]		
1	10.2	18.8	1	12.6	26.6	1	*	26.5	1	10.6	29.7
2	10.2	18.9	2	13.0	26.3	2	12.7	26.1	2	9.6	28.3
3	10.3	18.9	3	13.4	25.9	3	~ 11.2	25.4	3	9.3	27.8
4	10.2	18.9	4	*	25.6	4	11.1	25.2	4	6.0	26.7
5	10.3	18.9	5	*	25.0	5	~ 9.2	25.1	5	3.3	26.0
6	10.1	18.9	6	*	23.4	6	7.1	24.9	6	1.7	25.4
7	8.5	18.2	7	*	22.5	7	~ 6.2	24.8	7	1.1	25.0
8	7.6	18.0				8	4.9	24.7	8	0.7	23.8

* Supersaturated; DO readings fluctuated between 8 to > 20 mg/L.

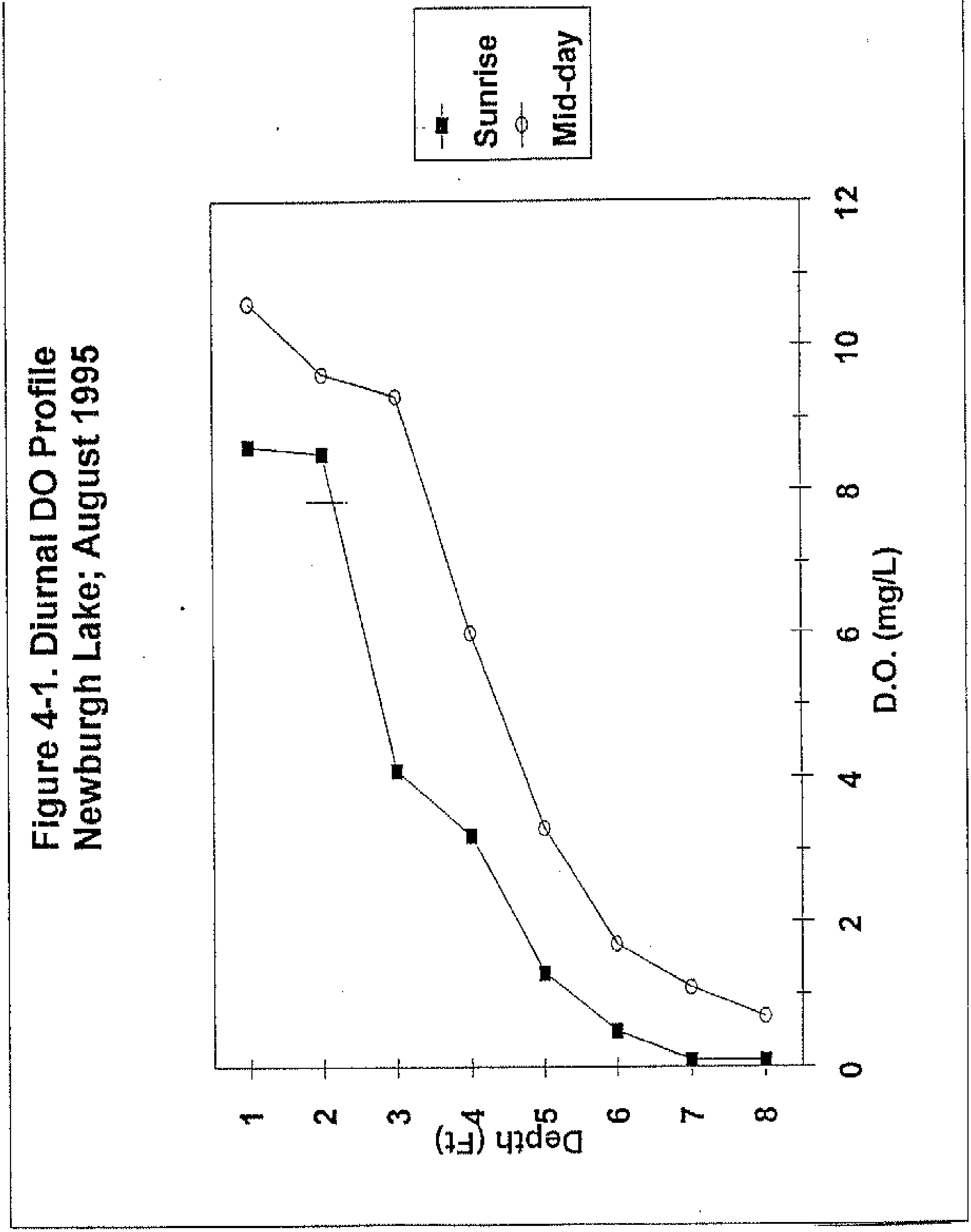


Figure 4-1: Diurnal DO Profile Newburgh Lake; August 1995

sometimes reduced the extent of hypolimnetic anoxia in the afternoon compared to the early morning, but it never completely eliminated the low-DO layer nearest the bottom.

Supersaturated DO concentrations were often observed during the summer of 1995, sometimes throughout most of the water column. Concentrations of over 20 mg/L (the maximum DO meter reading), equal to over 200% saturation at ambient temperatures, were sometimes observed. These extremely high readings were the result of photosynthetic DO production by phytoplankton and/or macrophytes. Lake water can become supersaturated with DO, up to several hundred percent saturation, particularly at depth (≥ 1 meter) where hydrostatic pressure inhibits bubble formation and DO escape (Wetzel, 1975). DO measurements in this study were sometimes highest at depths of greater than 3'. The extent of epilimnetic DO supersaturation in all of the lakes appeared to decrease as the summer progressed (*Table 4.20*). This corresponded to the increase in hypolimnetic anoxia during the same time period.

Table 4.20
Extent of Epilimnetic DO Supersaturation in Rouge River Lakes: 1995
(Date and Extent of Supersaturated DO Layer)

Walled Lake	Meadowbrook Lake	Phoenix Lake	Newburgh Lake
May = upper 10' June = upper 10-15' July = upper 10' August = upper 5-10'	June = upper 7' July = upper 4' August = upper 3'	May = upper 2' August = upper 1'	May = upper 6-7' June = upper 7' July = upper 3-5' August = upper 2-3'

Supersaturated DO concentrations sometimes decreased significantly as the water passed over the impoundment dam; see the Stream and Dam Reaeration Studies Report (RPO, 1996a) for details. Obtaining a steady DO measurement when the concentration was supersaturated was often difficult, apparently due to oxygen degassing caused by the movement of the DO probe in the water.

In one instance, at Meadowbrook Lake on 7/31/95, zooplankton respiration might have substantially lowered the DO at a particular depth. DO at the 6' depth at station D53 was 1.4 mg/L at sunrise and 2.0 mg/L in the early afternoon, while DO concentrations at the 5' depth ranged from 6.3 to 8.3 mg/L over the day, and at the 7' depth from 5.5 to 5.7 mg/L. This situation was not encountered at any other time, although zooplankton are moderately common in all of the lakes (Section 4-3).

Comparison of the 1994-1995 Diurnal DO Profile Data to Other Studies. SEMCOG (1978) sampled Phoenix Lake and Newburgh Lake (and other lakes, but not Walled Lake or Meadowbrook Lake) periodically from July 1976 to September 1977 and found little or no thermal or DO stratification. They sampled only in the historic stream channel where water circulation would be greatest, however, and so may have missed the quiescent areas where stratification is most likely to occur. SEG (1974) collected DO profile data from Phoenix Lake and Newburgh Lake in February and May, 1974, and also failed to find DO stratification. Their early season sampling dates, however, missed the period of maximum water temperature, maximum algal productivity, and maximum bacterial respiration that typically results in hypolimnetic anoxia.

4.3 **PHYTOPLANKTON COMMUNITIES.** *Tables 4.21* through *4.24* list the composition of the 1994-1995 lake phytoplankton communities by phyla. Qualitative observations of the zooplankton community are also below. Algae habitat and trophic preference information are taken from Greeson (1982) and Palmer (1977).

Plankton population counts were not performed. The chlorophyll *a* data (Section 4.2.9), however, indicated very high plankton densities were present in most of the lakes throughout the summer of 1995.

Walled Lake exhibited a fairly diverse phytoplankton community (*Figure 4-2* and *Table 4.21*). Bluegreens, greens, diatoms and dinoflagellates were prominent in all five months sampled; with blooms of the pennate diatom *Centronella* in May 1995 and the green algae *Pleodorina* in August 1995. Algae indicative of eutrophic conditions were less common in Walled Lake than in the other lakes, reflecting this lake's generally lower nutrient concentrations. Prominent zooplankton in Walled Lake included daphnids, rotifers, copepods, and nauplii larvae.

Meadowbrook Lake phytoplankton were less diverse than those in Walled Lake, with one algae group or another accounting for 60 % or more of the total community in each month sampled (*Figure 4-3* and *Table 4.22*). Cryptomonads dominated the phytoplankton in October 1994 and May 1995 (the only times these algae were observed in any of the lakes); the June 1995 sample was a near-monoculture of the pennate diatom *Asterionella*; and green algae (*Pandorina, Chlorella, Chroococcus*) dominated in July 1995 and August 1995. *Asterionella*, *Pandorina*, *Chlorella*, and *Chroococcus* are either indicators of eutrophic conditions and/or known to cause taste and odor problems in water. The presence of these eutrophic algae corresponds to the extremely elevated nutrient concentrations also found in Meadowbrook Lake. Prominent zooplankton in Meadowbrook Lake included cladocerans, ciliates, rotifers, copepods, nauplii larvae, and loricas from the amoeboid protozoan family Difflugiidae.

Phoenix Lake exhibited an even less diverse phytoplankton community than Meadowbrook Lake in four of the five months sampled (*Figure 4-4* and *Table 4.23*). The October 1994 sample was fairly diverse, but the May 1995, June 1995 and July 1995 samples were dominated by the chrysophyte *Dinobryon* while the August 1995 community was dominated by green

Table 4.21
Percent Composition of Phytoplankton Communities in Walled Lake: 1994-1995

Date	Cyn	Chl	Chr	Eug	Pyr	Prominent Genera
10/12/94	20.5	41.9	19.5	0.9	17.2	*Dinobryon, Asterionella, Fragilaria, Anabaena, Lyngbya, Pleodorina, Ceratium*
5/17/95	0.5	9.0	88.6	0	2.0	*Centronella* (> 90 % of chrysophytes), *Tabellaria, Staurastrum, Chlorella, Pediastrum*
6/19/95	31.3	37.9	17.1	0	13.7	*Chroococcus, Anabaena, Dinobryon, Staurastrum, Pediastrum, Ceratium*
7/26/95	44.0	51.0	0	0	4.9	*Pleodorina, Lyngbya, Chroococcus, Merismopedia*
8/16/95	16.9	77.6	0	0	5.5	*Lyngbya, Merismopedia, Anabaena*; Most greens = *Pleodorina*

Cyn = Cyanophyta; Chl = Chlorophyta; Chr = Chrysophyta; Eug = Euglenophyta; Pyr = Pyrrhophyta

Table 4.22
Percent Composition of Phytoplankton Communities in Meadowbrook Lake: 1994-1995

Date	Cyn	Chl	Chr	Eug	Pyr	Cry	Prominent Genera
10/19/94	0.4	1.5	15.0	0	0.4	82.7	*Chroomonas, Cryptomonas, Rhodomonas, Dinobryon*
5/25/95	0	3.2	21.5	0	0	75.3	*Chroomonas, Cryptomonas, Rhodomonas, Dinobryon*
6/22/95	0	2.8	97.1	0	0	0	Virtually a monoculture of *Asterionella*
7/31/95	27.5	60.6	11.9	0	0	0	*Chlorella, Chroococcus*
8/29/95	1.0	96.2	1.9	0	1.0	0	*Pandorina, Chlorella*

Cyn = Cyanophyta; Chl = Chlorophyta; Chr = Chrysophyta; Eug = Euglenophyta; Pyr = Pyrrhophyta; Cry = Cryptophyta

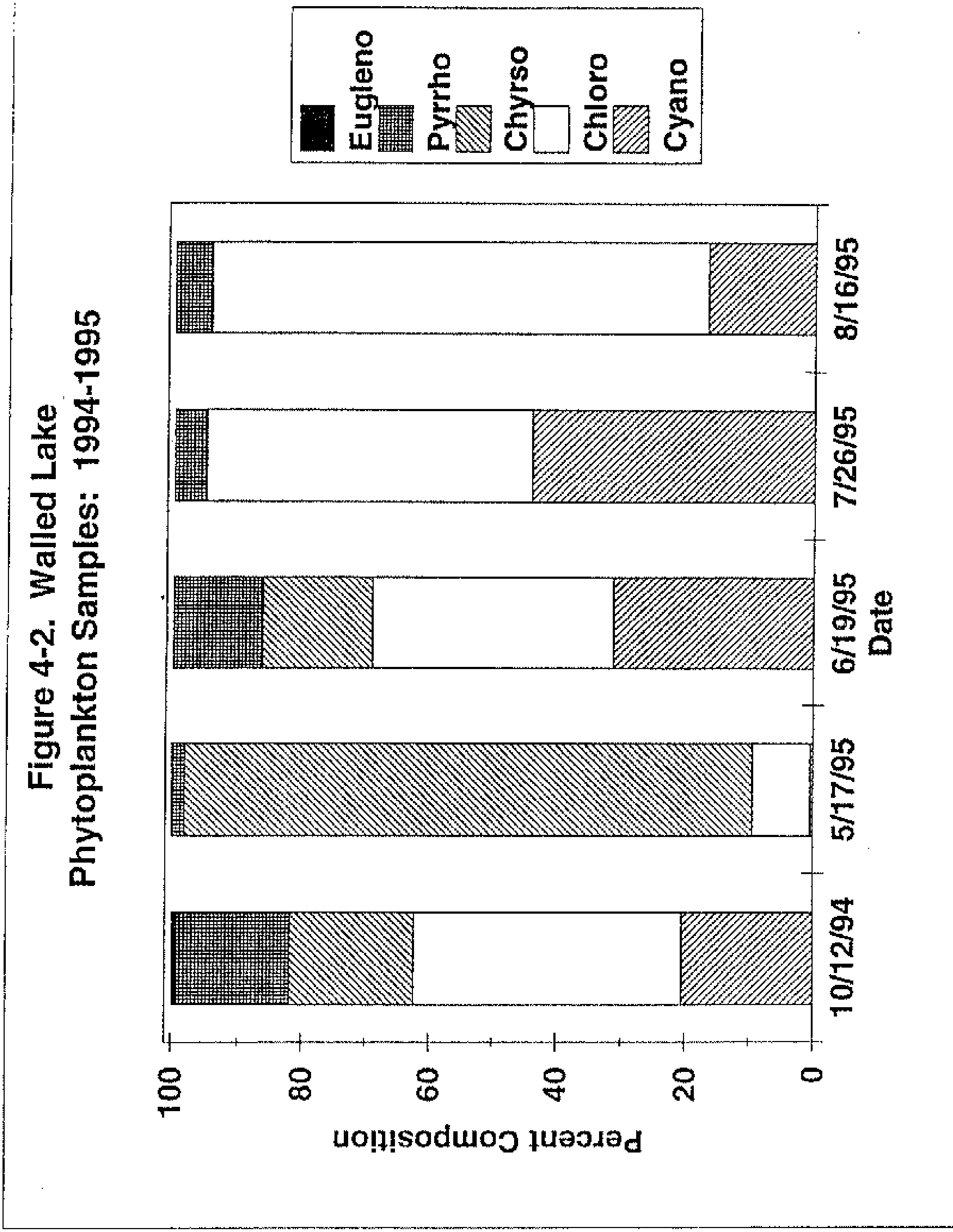


Figure 4-2: Walled Lake Phytoplankton Samples 1994-1995

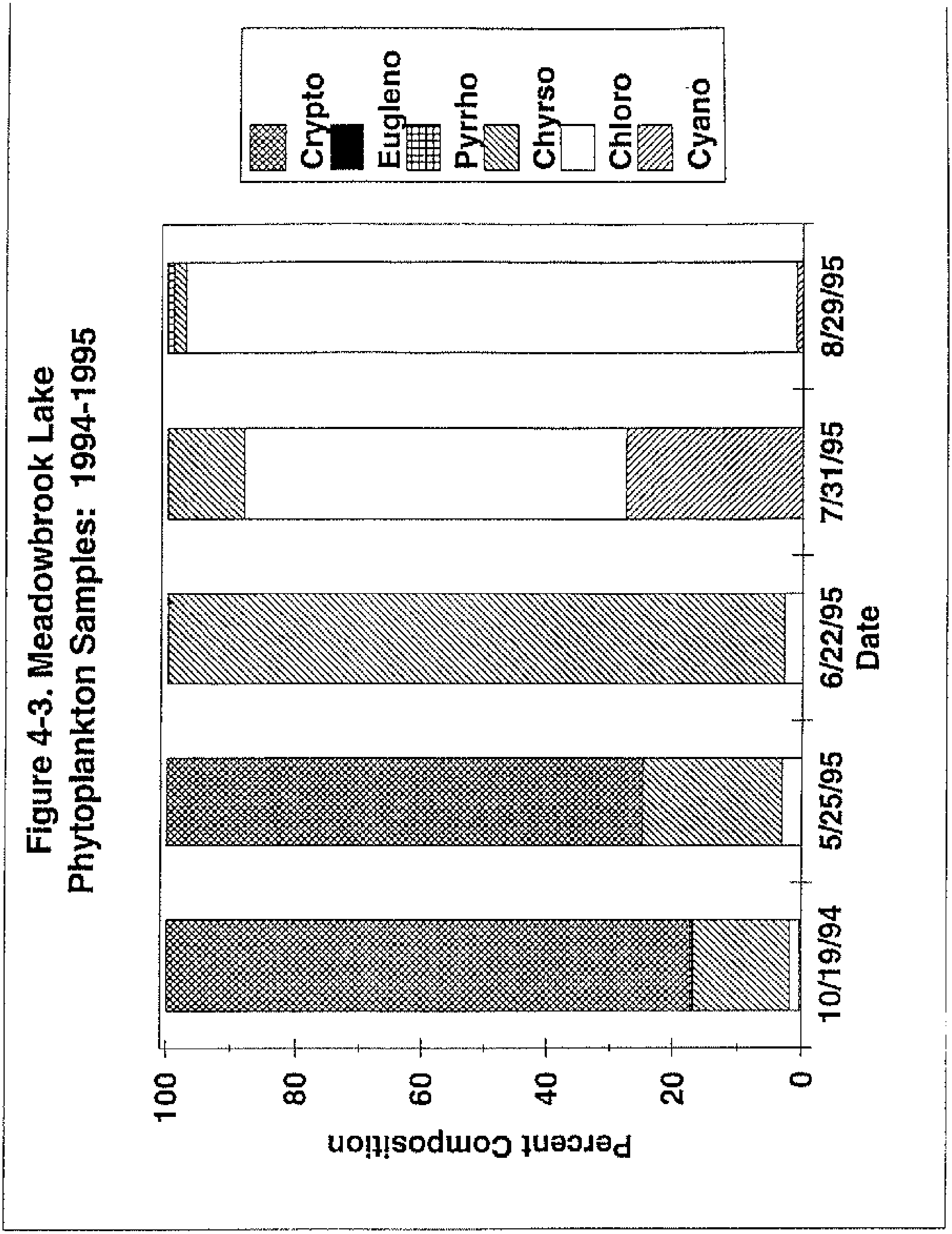


Figure 4-3: Meadowbrook Lake Phytoplankton Samples 1994-1995

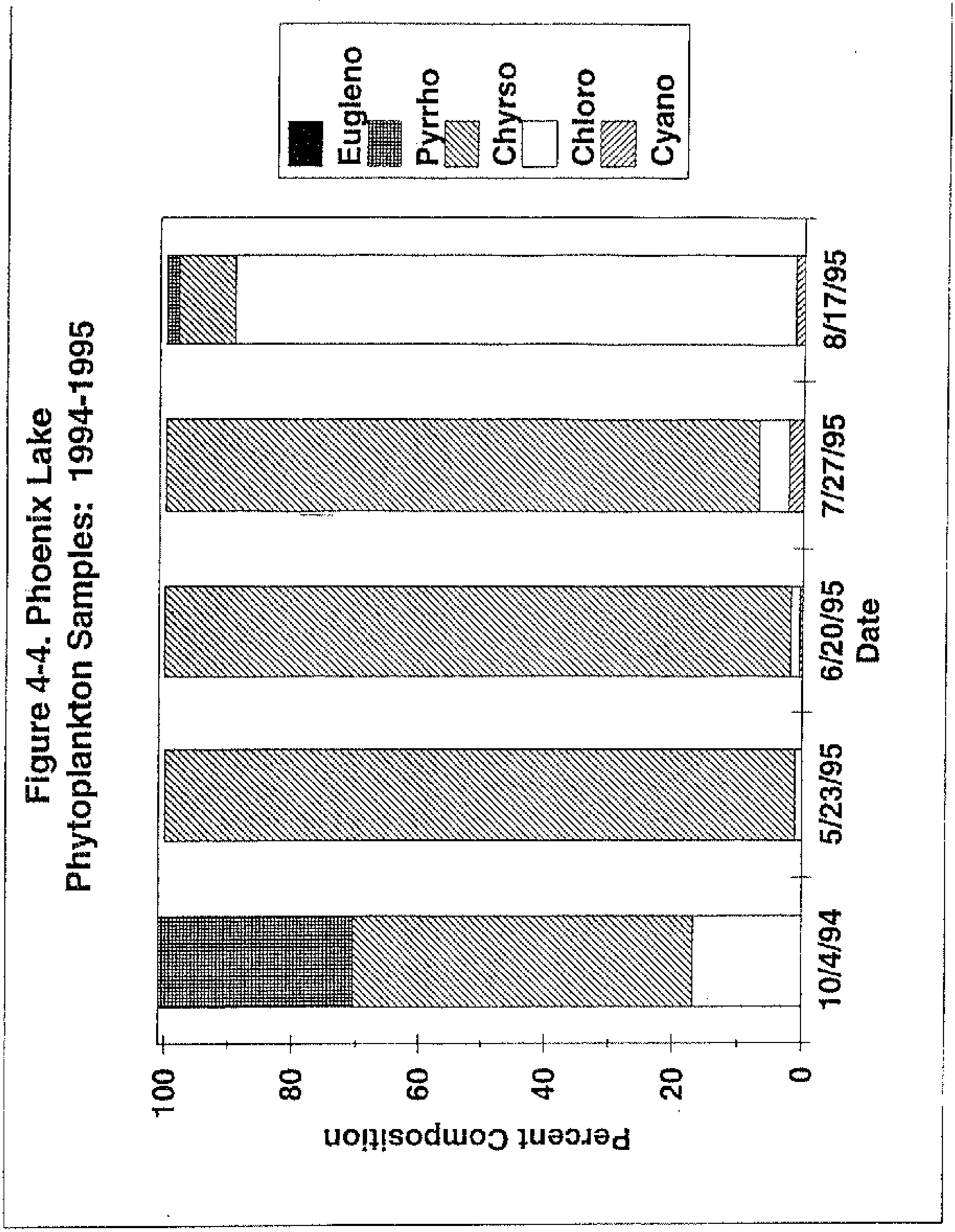


Figure 4-4: Phoenix Lake Phytoplankton Samples 1994-1995

Table 4-23
Percent Composition of Phytoplankton Communities in Phoenix Lake: 1994-1995

Date	Cyn	Chl	Chr	Eug	Pyr	Prominent Genera
10/4/94	0	16.9	53.7	0	30.8	*Asterionella, Ceratium*
5/23/95	0	1.0	99.0	0	0	Virtually a monoculture of *Dinobryon*
6/20/95	0.5	1.4	98.2	0	0	Virtually a monoculture of *Dinobryon*
7/27/95	2.3	4.6	93.1	0	0	*Dinobryon*
8/17/95	1.4	87.7	9.0	0	1.9	*Coelastrum, Closteriopsis*

Cyn = Cyanophyta; Chl = Chlorophyta; Chr = Chrysophyta; Eug = Euglenophyta; Pyr = Pyrrhophyta

algae like *Coelastrum* and *Closteriopsis*. *Dinobryon* is know to cause taste and odor problems in potable water, and *Coelastrum* is indicative of eutrophic conditions. The presence of these eutrophic algae coincides with the elevated nutrient concentrations also found in Phoenix Lake. Prominent zooplankton in Phoenix Lake included cladocerans, rotifers, copepods, ostracods, nauplii larvae, and loricas from the amoeboid protozoan family Difflugiidae.

Newburgh Lake phytoplankton were fairly diverse in May 1995 and June 1995 (*Figure 4-5* and *Table 4.24*), but were dominated by the pennate diatom *Fragilaria* in July 1995 and by green algae like *Pandorina* and *Pediastrum* in August 1995. *Fragilaria* is common in hard waters, and *Pandorina* is associated with both eutrophic conditions and taste and odor problems. *Asterionella*, *Oscillatoria*, and *Spirulina*, observed in May 1995 and June 1995, are also indicative of eutrophic conditions. The presence of these eutrophic algae correspond to the elevated nutrient concentrations also found in Newburgh Lake. Prominent zooplankton in Newburgh Lake included cladocerans, rotifers, copepods, nauplii larvae, and loricas from the amoeboid protozoan family Difflugiidae.

Comparison of the 1994-1995 Phytoplankton Data to Other Studies. SEG (1974) sampled Phoenix Lake and Newburgh Lake (and Wilcox Lake, but not Walled Lake or Meadowbrook Lake) for phytoplankton periodically between June 20, 1973 and May 30, 1974. They found a mix of eutrophic and oligotrophic diatom and flagellate green algae species in both lakes, and green and bluegreen species characteristic of highly eutrophic waters on only one occasion (6/20/73). They state that these samples may give a false indication of water quality because they were not collected during the late summer, and that the lakes may be more eutrophic than indicated. MDNR (1975, quoted in RPO, 1996b) found high numbers of diatoms and euglenoids in the river waters of the Middle Branch, and concluded that water quality was fair in the headwater area and poor in the lower part of the Branch.

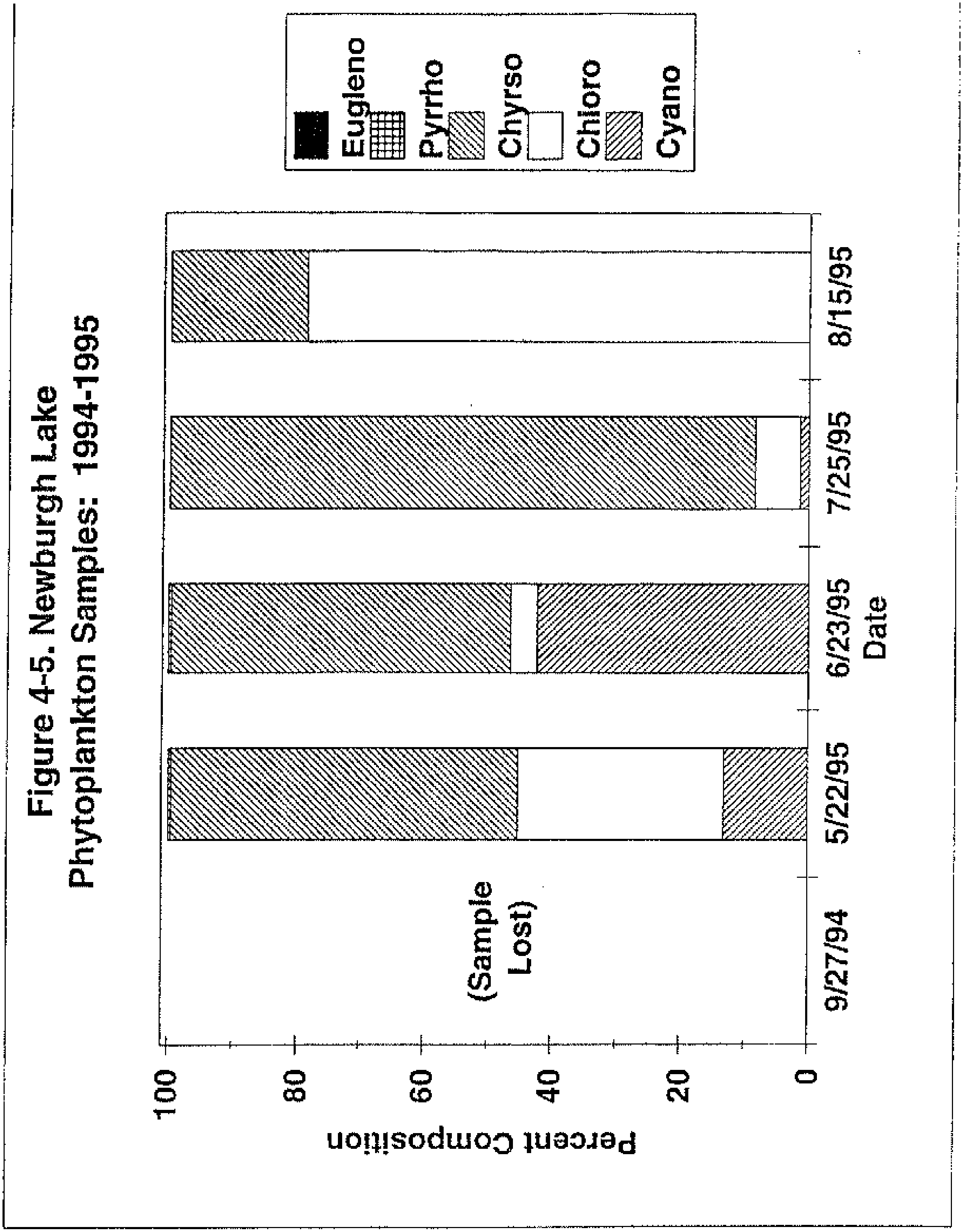


Figure 4-5: Newburgh Lake Phytoplankton Samples 1994-1995

Table 4.24
Percent Composition of Phytoplankton Communities in Newburgh Lake: 1994-1995

Date	Cyn	Chl	Chr	Eug	Pyr	Prominent Genera
9/27/94	--	--	--	--	--	Sample lost; poor preservation
5/22/95	13.2	32.1	54.2	0	0.5	*Asterionella, Closteriopsis, Oscillatoria*
6/23/95	42.2	4.3	53.1	0	0.5	*Spirulina, Dinobryon, Asterionella*
7/25/95	1.5	6.9	91.6	0	0	*Fragilaria*, different Volvocaceae
8/15/95	0	78.7	21.3	0	0	*Fragilaria, Pandorina, Pediastrum*

Cyn = Cyanophyta; Chl = Chlorophyta; Chr = Chrysophyta; Eug = Euglenophyta; Pyr = Pyrrhophyta

4.4 **MACROPHYTE DISTRIBUTION AND ABUNDANCE.** *Table 4.25* lists the common and scientific names of the macrophytes collected from or observed in Newburgh Lake and Walled Lake in 1995; *Table 4.26* lists the species composition of the macrophyte communities in both lakes; *Table 4.27* lists the wet and dry macrophyte biomass in both lakes; and *Figures 4-6* and *4-7* show the approximate distribution of macrophytes in each lake, and the biomass sampling stations.

Table 4-25
Scientific and Common Names of Macrophytes Collected from or Observed in Newburgh Lake and Walled Lake (August 1995)

Scientific Name	Common Name(s)*
Anacharis canadensis	Waterweed (formerly *Elodea*)
Ceratophyllum demersum	Coontail
Chara sp.	Muskgrass; stonewort
Lemna sp.	Duckweed
Myriophyllum spicatum	Eurasian water milfoil
Najas flexilis	Bushy pondweed
Nymphaea odorata	White water lily
Potamogeton amplifolius	Pondweed
Potamogeton crispus	Crisp pondweed
Potamogeton illionensis	Pondweed
Potamogeton pectinatus	Pondweed
Potamogeton zosteriformis	Pondweed
Vallisneria americana	Eel grass; wild celery

*Taken from Fassett, 1957.

Table 4-26
Species Composition of Macrophyte Communities Collected from Newburgh Lake and Walled Lake (August 1995)

Station (Depth; Sediment)	Species	Percent Composition* (Wet weight)
Newburgh Lake		
D20 (7'; oily silt)	*Chara* sp.	100 %
D28 (5.5'; oily silt)	*Chara* sp.	100 %
D29 (1.5'; oily silt)	*Nymphaea odorata* *Chara* sp.	68 % 32 %
Walled Lake		
D45 (5'; silt)	*Anacharis canadensis* *Myriophyllum spicatum* *Potamogeton zosteriformis* *Chara* sp. *Najas flexilis*	59 % 28 % 8 % 5 % < 1 %
D46 (8'; silty sand)	*Najas flexilis* *Myriophyllum spicatum* *Vallisneria americana* *Chara* sp. *Potamogeton pectinatus*	71 % 22 % 5 % 3 % < 1 %
D47 (8'; silty sand)	*Potamogeton pectinatus* *Vallisneria americana* *Chara* sp. *Potamogeton illionensis* *Anacharis canadensis* *Myriophyllum spicatum* *Najas flexilis* *Ceratophyllum demersum*	31 % 28 % 26 % 8 % 3 % 3 % 2 % < 1 %

* May not sum to 100 %, due to rounding.

Table 4-27
Wet and Dry Biomass of Macrophyte Communities Collected from Newburgh Lake and Walled Lake (August 1995)

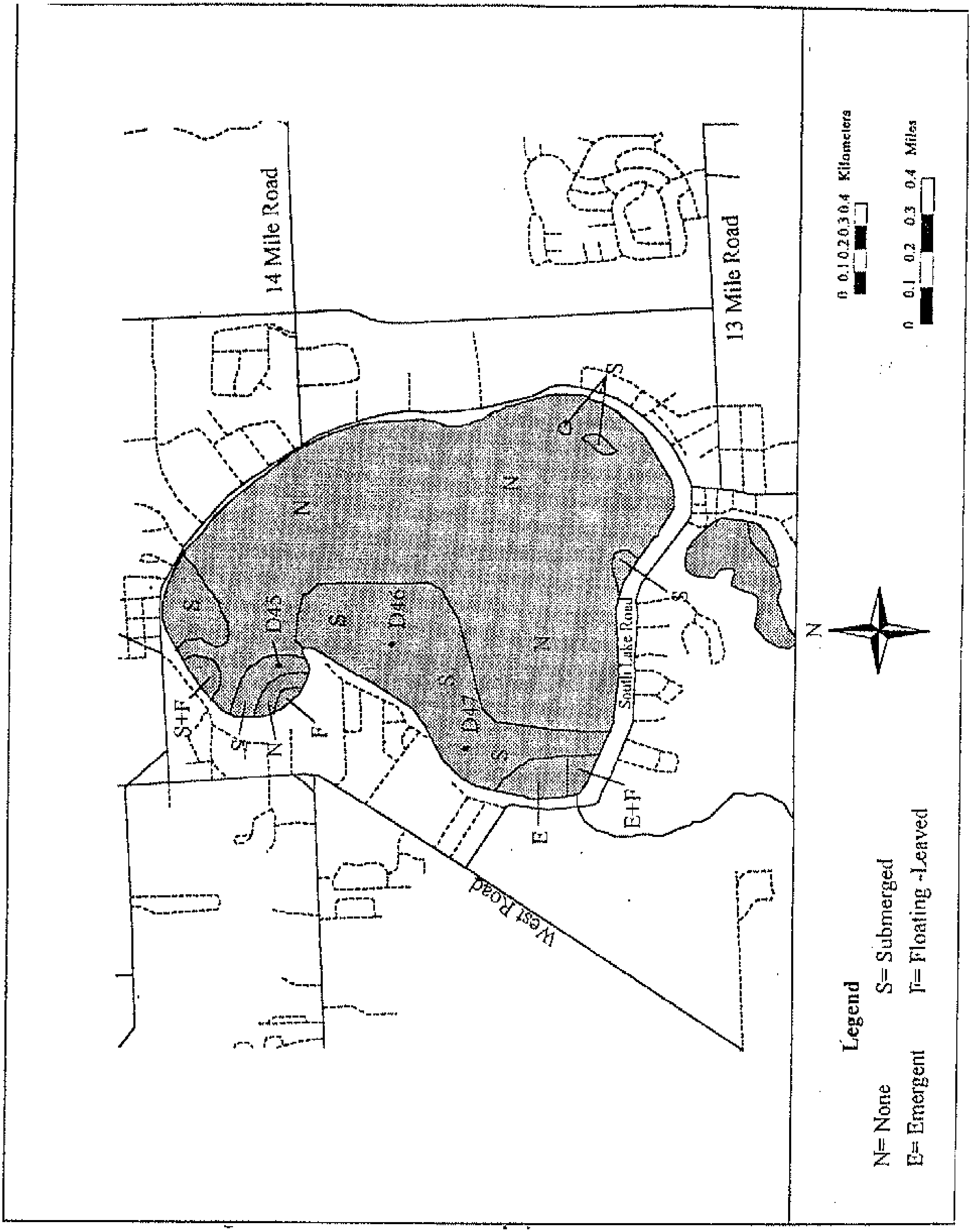
Station	Wet Weight (g/m^2)	Dry Weight (g/m^2)
Newburgh Lake		
D20	2957	366
D28	5621	885
D29	1408	111
Walled Lake		
D45	1236	178
D46	1801	261
D47	1737	268

Meadowbrook Lake and Phoenix Lake lacked significant growths of macrophytes in both 1994 and 1995. A few scattered plants of *Potamogeton amplifolius* were present in Meadowbrook Lake in both years, along the margin of the lake. The general absence of macrophytes from Meadowbrook Lake may be due to the application of aquatic herbicides by local residents, although this has not been substantiated. The reason for their absence from Phoenix Lake is unknown.

Macrophytes in Walled Lake occurred primarily along the northern and western shores, in water less than 20' deep (*Figure 4-6*). Macrophyte diversity was much higher in Walled Lake than in Newburgh Lake, with up to eight species at a single station. Unlike Newburgh Lake, no single species dominated any of the three Walled Lake stations, and the prevalence of certain species varied considerably between stations. For example, *Najas flexilis* accounted for 71 % of the total macrophyte wet weight collected at station D46, but only 2 % and < 1 % at the other two stations.

Macrophytes in Newburgh Lake were distributed throughout the lake (*Figure 4-7*), with only small areas of open water, primarily where the "weed harvester" had been operating. Macrophyte diversity was extremely low, with near-monocultures of the macroalgae *Chara* dominating much of the lake. A mix of water lilies and *Chara* occurred in the shallow western third of the lake (*Figure 4-7*). Scattered plants of *Anacharis* sp., *Potamogeton amplifolius*, *Potamogeton crispus*, and *Lemna* sp. were also observed, as was a thick floating mat of filamentous algae in limited locations. Emergent aquatic vegetation (e.g., rushes, cattails) was uncommon in Newburgh Lake in both years, except for isolated areas.

Walled Lake



14 Mile Road
13 Mile Road
West Road
South Lake Road
D45
D46
D47
S+F
E+F
0 0.1 0.2 0.3 0.4 Kilometers
0 0.1 0.2 0.3 0.4 Miles
Legend
N= None
E= Emergent
S= Submerged
F= Floating -Leaved

Newburgh Lake

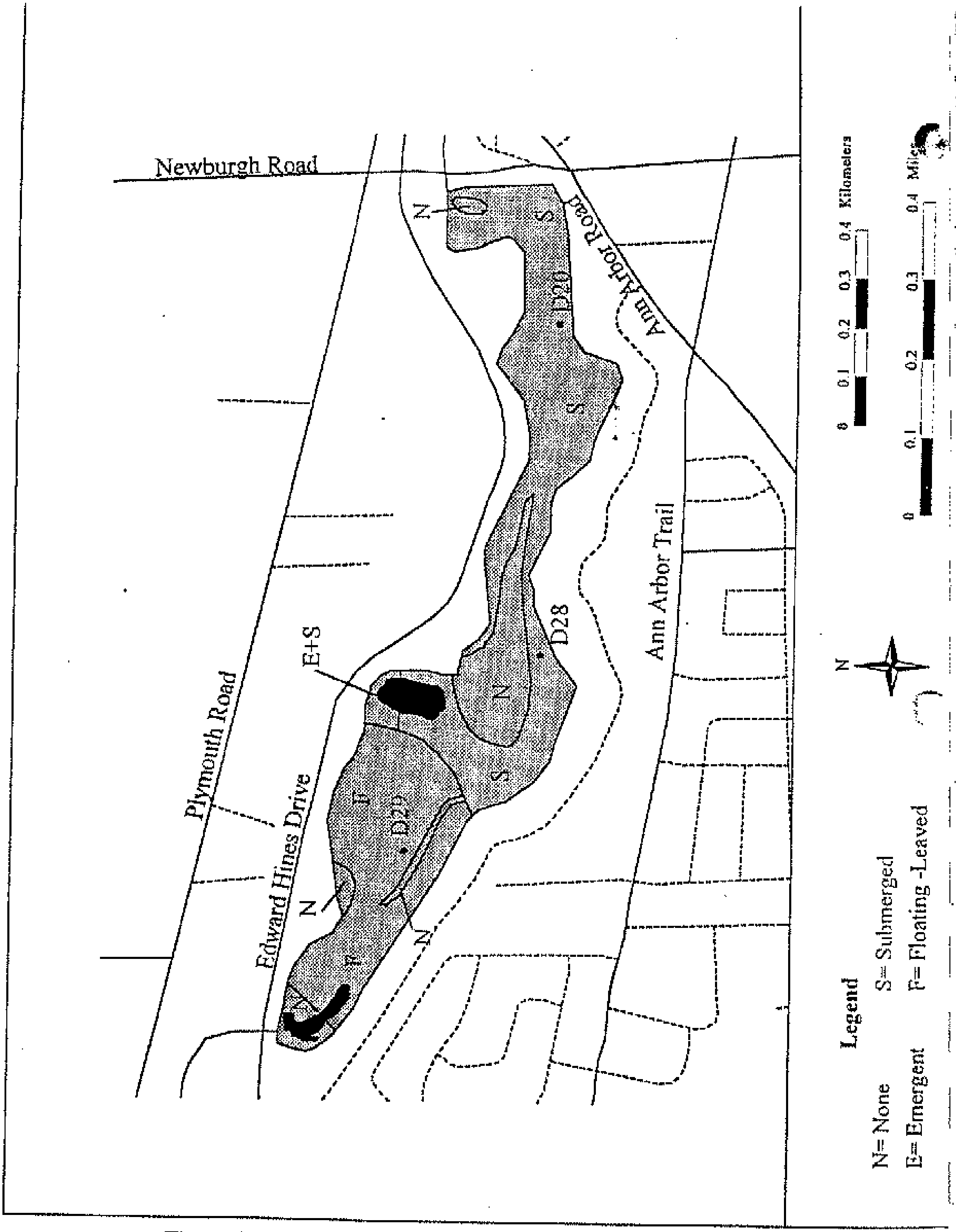


Figure 4-7: Newburgh Lake Macrophyte Distribution

The lower parts of some macrophytes collected from Newburgh Lake (i.e., those stems and leaves nearest the sediment) were often discolored (darker than normal) and felt stiffer than plants from higher in the water column. This was especially noticeable at stations D28 and D29, and was also observed in macrophytes from the eastern end of the lake. This may be attributable to toxic effects from the thick (1'-2') layer of oily, metal- and PCB-contaminated silt that covers much of the bottom of Newburgh Lake (RPO, 1994b).

Macrophyte biomass was generally higher in Newburgh Lake than in Walled Lake. The biomass at station D29 in Newburgh Lake would have been substantially higher if it had been possible to collect all of the water lily roots (see below). Five of the six dry biomass values in the two lakes fall within the range of 100 to 500 g/m^2 reported by Wetzel (1975) for macrophyte productivity in representative hardwater lakes.

It should be noted that collection of macrophyte roots was incomplete, and that the biomass values in *Table 4.27* therefore underestimate the true productivity of these macrophyte populations. Roots of most submerged macrophyte species account for less than 10 % of their total biomass, while the roots of water lilies can account for 50 to 80 % of their total biomass (Wetzel, 1975). Consequently, failure to completely collect all the plant roots should significantly affect the biomass value for only station D29 in Newburgh Lake, where water lilies were dominant.

It should also be noted that the seasonal senescence of the dense macrophyte populations found in Walled Lake and Newburgh Lake could be a significant, short-term source of phosphorous to the lakes. Leaching of phosphorous from dead macrophytes is rapid, with 20 to 50 % of the tissue phosphorous content released within a few hours (Wetzel, 1975). Macrophyte senescence in these lakes occurs in late October to early November in most years. The use of a "weed harvester" in Newburgh Lake to maintain open water near the paddle boat concession in the western half of the lake (observed during the summer of 1995) may also cause release of phosphorous from the plants into the water column, both from destruction of the plants and resuspension/oxidation of the sediments.

Comparison of 1994-1995 Macrophyte Data to Other Studies. SEMCOG (1978) did not evaluate macrophyte populations in their studies of southeast Michigan lakes and impoundments, but SEG (1974) sampled Phoenix Lake and Newburgh Lake. They reported that both lakes had been sprayed with the herbicide 2, 4-D in early May 1973, and that only 10 to 15 % of the lake surface area was covered with macrophytes on June 1, 1973. This suggests smaller macrophyte populations than were found in this study, although the early sampling time and/or herbicide application probably account for the difference. The presence of macrophytes in Phoenix Lake in 1973 contrasts with their absence during this study. MDNR (cited in RPO, 1996b) found limited numbers of macrophytes in the Middle Branch above Newburgh Lake in the 1950s, and higher numbers in the early 1960s.

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5.0 CONCLUSIONS AND RECOMMENDATIONS.

Water samples were collected from four lakes along the Middle Branch of the Rouge River (Walled Lake, Meadowbrook Lake, Phoenix Lake, and Newburgh Lake) once a month in September/October 1994 and May, June, July, and August 1995, and analyzed for a variety of limnological parameters. Most of the data indicate that all four lakes are somewhat to highly eutrophic. Secchi depths, algae communities, and nutrient concentrations were generally indicative of eutrophic conditions, especially concentrations of chlorophyll *a*, total phosphorous and the sum of the measured nitrogen compounds (total nitrogen; nitrate + nitrite + total Kjeldahl nitrogen). Concentrations of nitrate and total phosphorous increased sharply between Walled Lake and Meadowbrook Lake, probably reflecting nutrient inputs from the Walled Lake wastewater treatment plant. Highest concentrations of chlorophyll *a* and many of the nutrients occurred in Meadowbrook Lake, while Walled Lake was generally the least eutrophic.

Diurnal DO profiles indicated strong stratification in all four lakes in May through August 1995. Epilimnetic DO concentrations were typically at or above saturation, while hypolimnetic concentrations were less than 2 mg/L. As the summer progressed, the size of the hypolimnetic anoxic zone increased, and the depth of supersaturated DO concentrations decreased, as the summer progressed. Midday DO concentrations at all depths were routinely higher than those at sunrise, due to photosynthetic activity, although the near-sediment anoxic zone never completely disappeared. Rainfall events and strong winds, however, may have temporarily disrupted stratification in the three shallower impoundments (Meadowbrook Lake, Phoenix Lake, and Newburgh Lake).

When the lakes were stratified, nitrate concentrations were routinely lower in the hypolimnion than the epilimnion, and ammonia was higher in the hypolimnion, probably due to reduction of nitrate to ammonia. Hypolimnetic total phosphorous concentrations were also higher than those in the epilimnion, probably due to release of phosphorous from the anoxic sediments. Release of phosphorous in winter from sediment in ice-covered lakes was investigated, but remains an open question. Any actions taken to remediate water quality that minimize hypolimnetic anoxia should also reduce phosphorous concentrations in the water, by preventing its desorbtion from the lake sediments. Nitrate and orthophosphorous concentrations were usually below their method detection limits. Orthophosphorous is probably absorbed very quickly by the aquatic plants in these lakes.

Algae communities varied seasonally and between lakes, but in general were indicative of eutrophic conditions, especially in Meadowbrook Lake, Phoenix Lake, and Newburgh Lake. Green, bluegreen, and golden-brown algae known to cause taste and odor problems in potable water were also common in all four lakes. These conditions correspond to the elevated nutrient concentrations observed in these lakes, and were similar to conditions reported for Phoenix Lake and Newburgh Lake in 1973-1974.

Macrophytes in Walled Lake were diverse and abundant in shallow waters along the north and west shores, with up to eight species in a single 1 m^2 quadrate. The macrophyte community in much of Newburgh Lake was essentially a monoculture of the macroalgae *Chara*, with a mix of *Chara* and water lilies in the western quarter of the lake. The lower portions of some of the *Chara* plants were discolored and unusually stiff, probably due to the high amounts of oil and other contaminants in the sediments. Macrophyte productivity (g dry mass/m^2) was slightly higher in Newburgh Lake than in Walled Lake. Macrophytes were missing from Meadowbrook Lake and Phoenix Lake, for unknown reasons.

Although concentrations of most parameters at the Walled Lake outlet in the headwaters of the Middle Branch were comparable to those at the Newburgh Lake outlet (the downstream boundary of the study area), the Middle Branch between Walled Lake and Meadowbrook Lake was apparently a source of nitrate, TKN, total p, and chlorophyll *a* to the rest of the river because the stream discharge at the Newburgh Lake outlet is greater than at the Walled Lake outlet. This stretch of the Middle Branch is not a measurable source of ammonia or orthophosphorous; concentrations of these nutrients at the Newburgh Lake outlet were always less than the method detection limit.

Based on limited historic data, phytoplankton communities and concentrations of nitrate, ammonia, orthophosphorous, total p, and chlorophyll *a* in these lakes have not changed substantially between 1973-1974 and 1994-1995.

This and previous studies indicate that water quality in these four lakes, especially in the three impoundments, substantially decreases their value as ecological and recreational resources. For the most part the current water problems in the three impoundments are more a reflection of water quality in the Middle Branch as a whole, rather than due to site-specific conditions (point sources, etc.). Consequently, improved water quality in the impoundments will only follow water quality improvements in the upper Middle Branch. General steps which would improve water quality throughout the Middle Branch include reducing nutrients and solids inputs; controlling storm water inputs; controlling streambank erosion; preventing further destruction of riparian habitat, especially streamside wetlands and forests; and possibly deepening selected areas of one or more impoundments to improve fish habitat.

It is recommended that the limnological conditions in these lakes (and perhaps others along the Middle Branch) be investigated again in another three to five years, to assess the impact of land use changes in the Middle Branch watershed. It is also recommended that Newburgh Lake be resampled in 1997, and perhaps every year thereafter for three to five years, to investigate the impact of the 1996 sediment remediation project (RPO, 1995). Since the remediation project will seriously disrupt the fish and macrobenthos in the lake, an evaluation of these communities should be added to the suite of limnological parameters examined in this study.

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APPENDIX A

GRAPHS OF MONTHLY CONCENTRATIONS OF LIMNOLOGICAL PARAMETERS IN THE MIDDLE BRANCH LAKES: 1994-1995

APPENDIX A
Graphs of Monthly Concentrations of Limnological Parameters in the Middle Branch Lakes: 1994-1995

Notes:

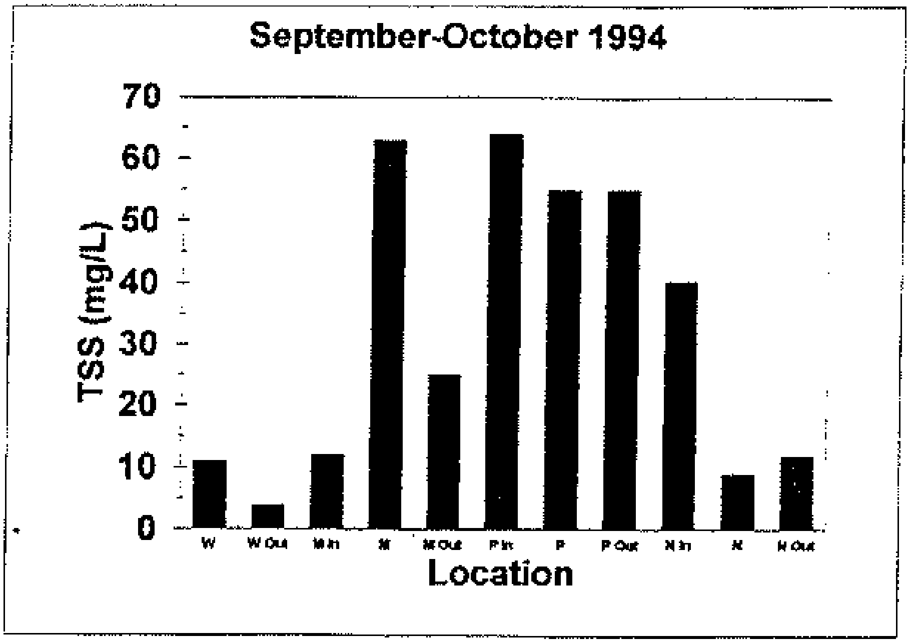
- In Appendix Figures A-1 through A-8, the plotted data for the lake inlet and outlet stations are discrete values, while the data points for the lakes are averages of all the data from the two lake stations for that month. This could be as few as two data points or as many as four data points, depending on whether the lake was stratified.

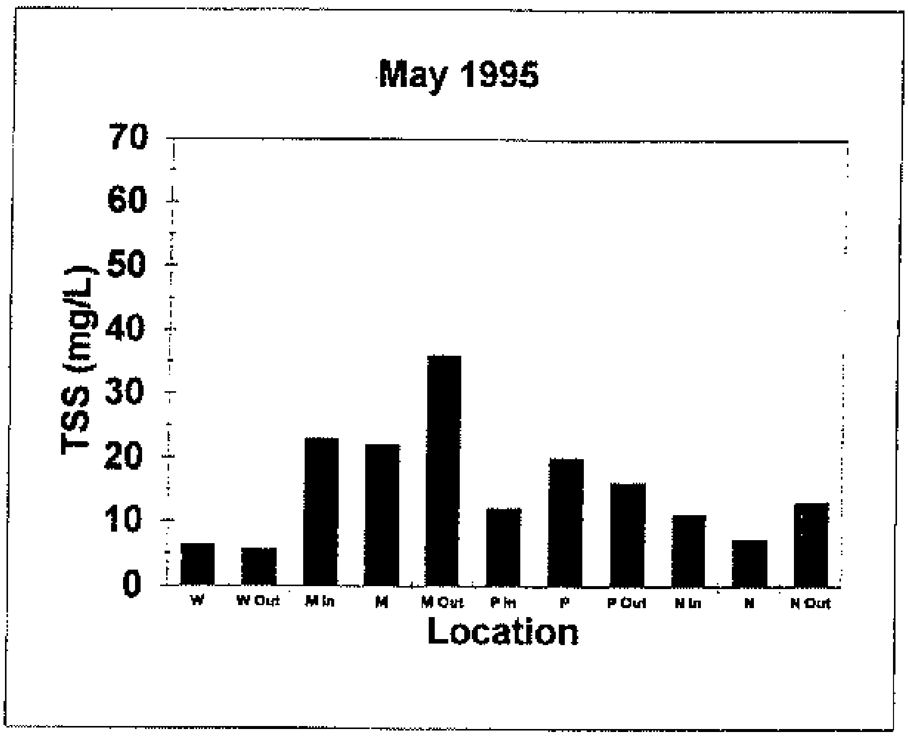
- Sampling locations not showing a bar represent parameter concentrations which were less than the method detection, not a lack of data, unless otherwise noted.

- The x-axis is not to scale; refer to Figure 1-1 for an illustration of the distances between the lakes.

- The Walled Lake outlet was not flowing in June 1995.

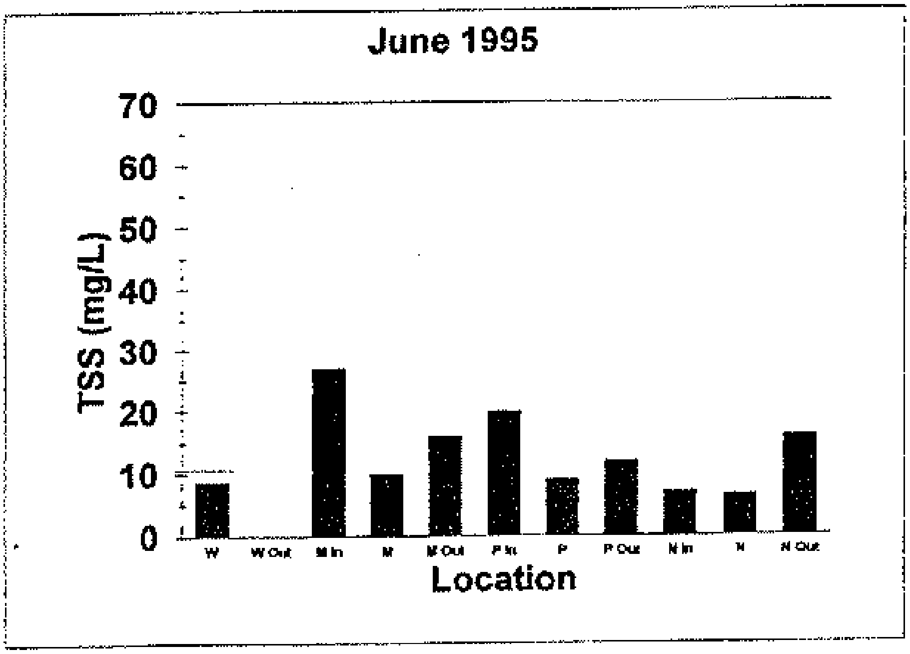
Figure A-1. Monthly Total Suspended Solids Concentrations in the Middle Branch Lakes: 1994-1995.

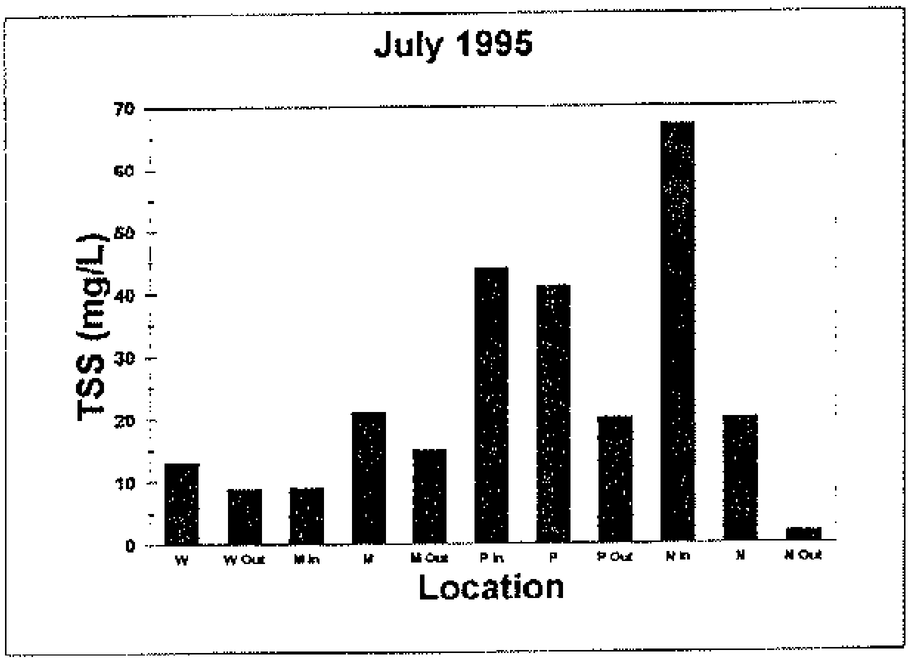




(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

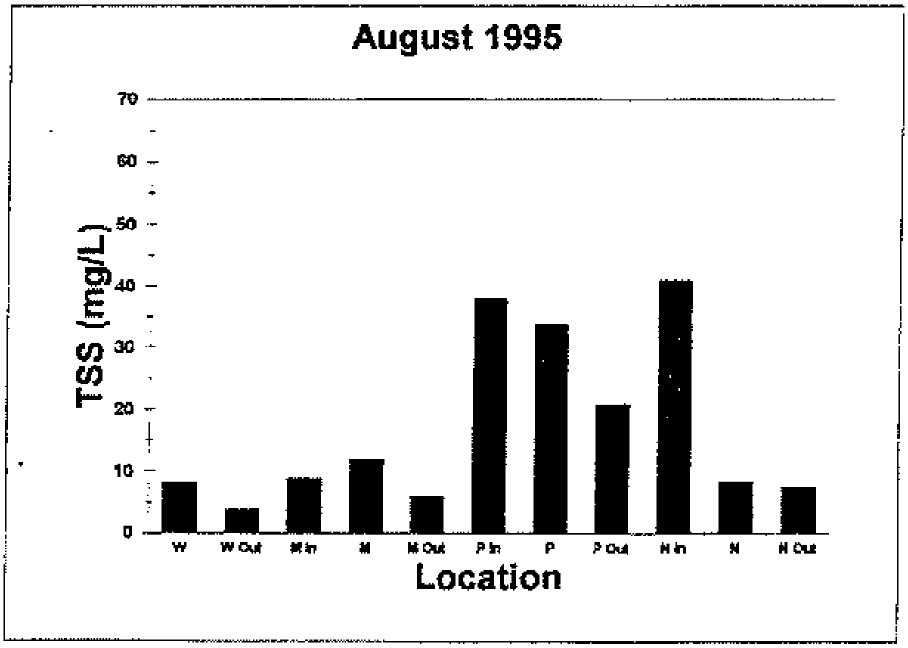
Figure A-1. Monthly Total Suspended Solids Concentrations in the Middle Branch Lakes: 1994-1995. (Continued)





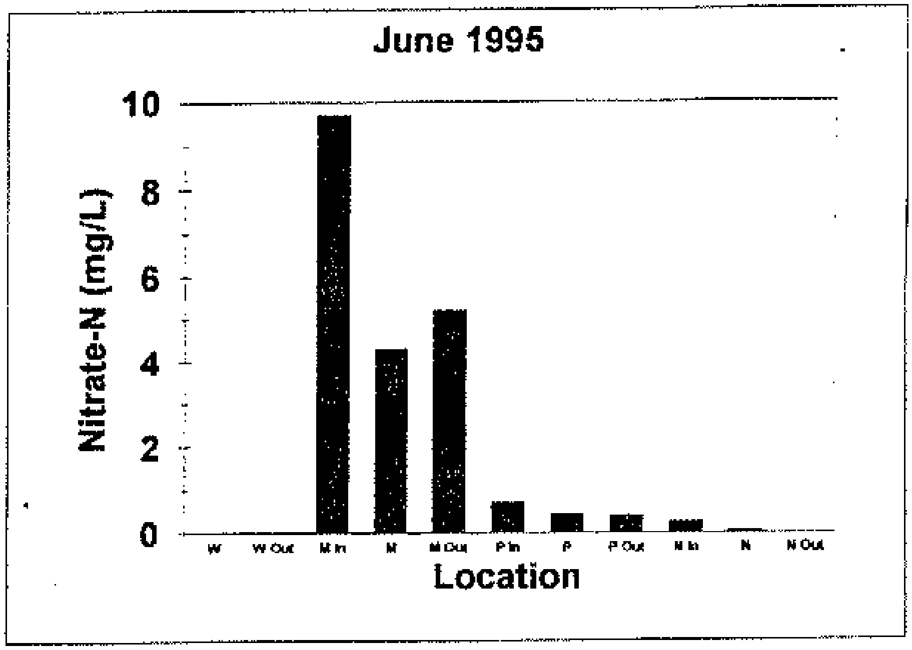
(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

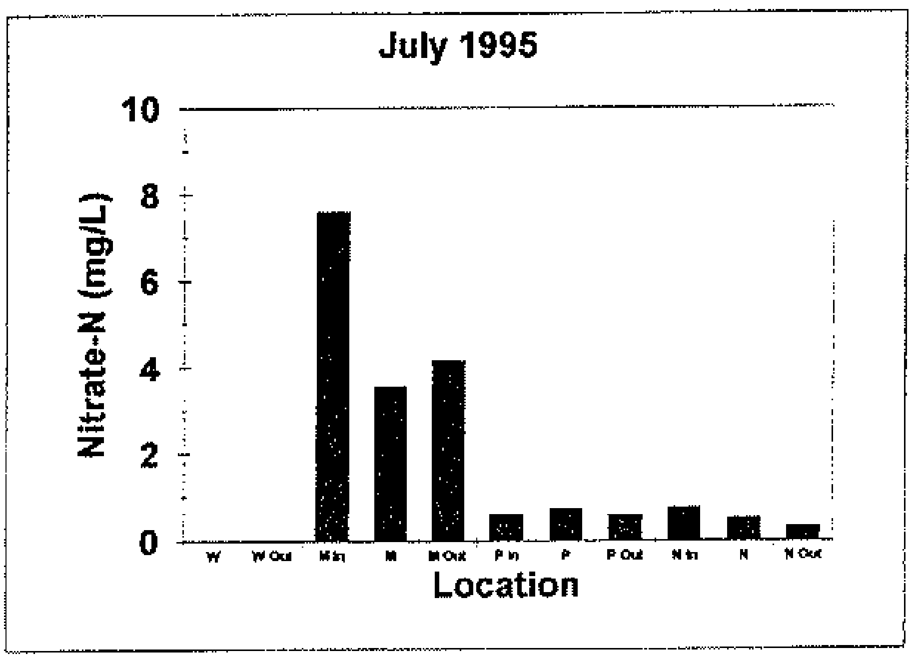
Figure A-1. Monthly Total Suspended Solids Concentrations in the Middle Branch Lakes: 1994-1995. (Concluded)



(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

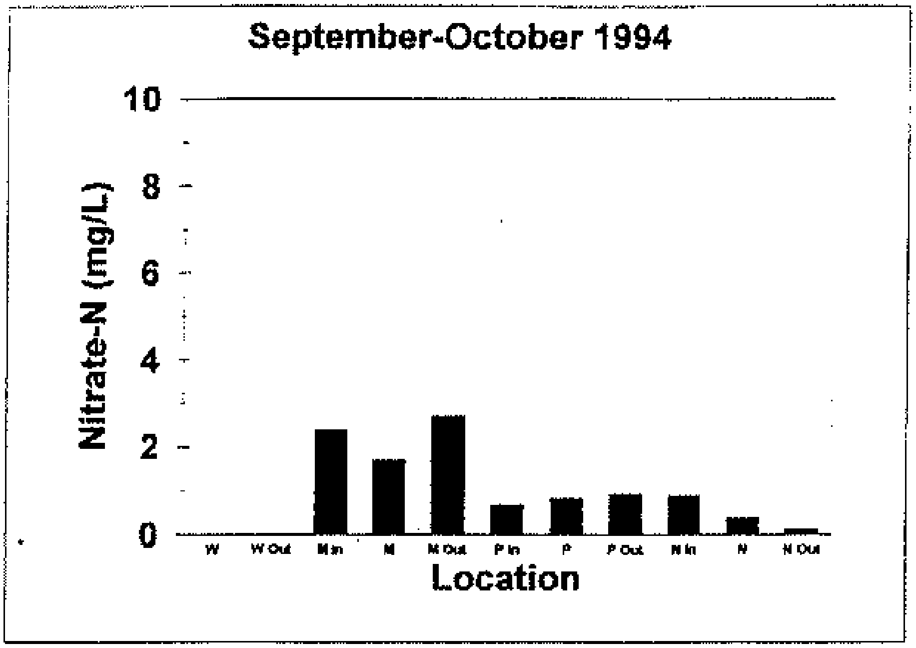
Figure A-2. Monthly Nitrate Concentrations in the Middle Branch Lakes: 1994-1995. (Continued)

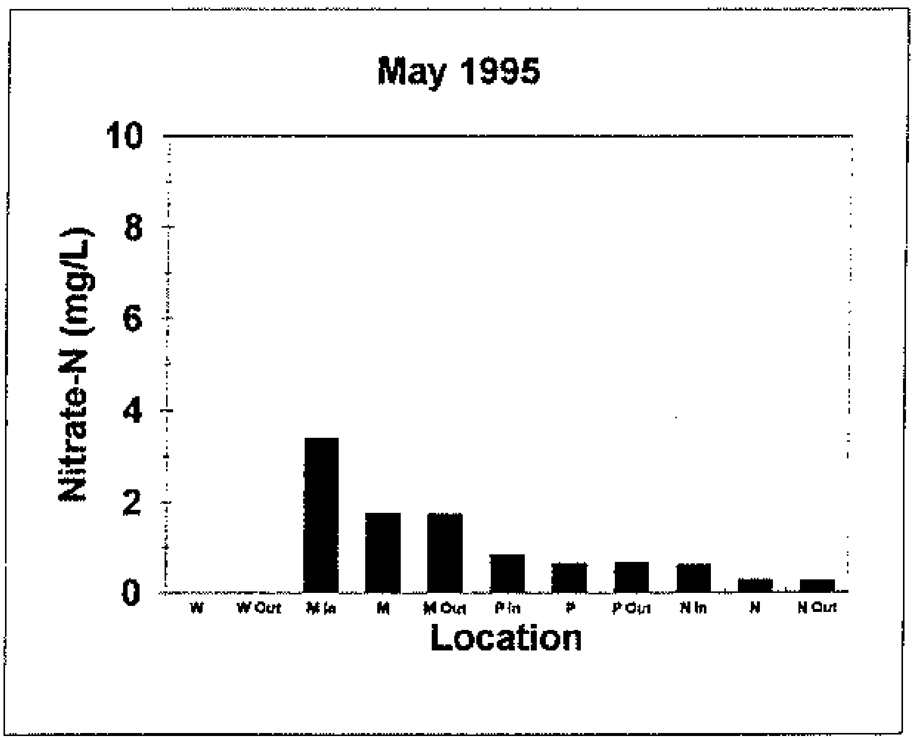




(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

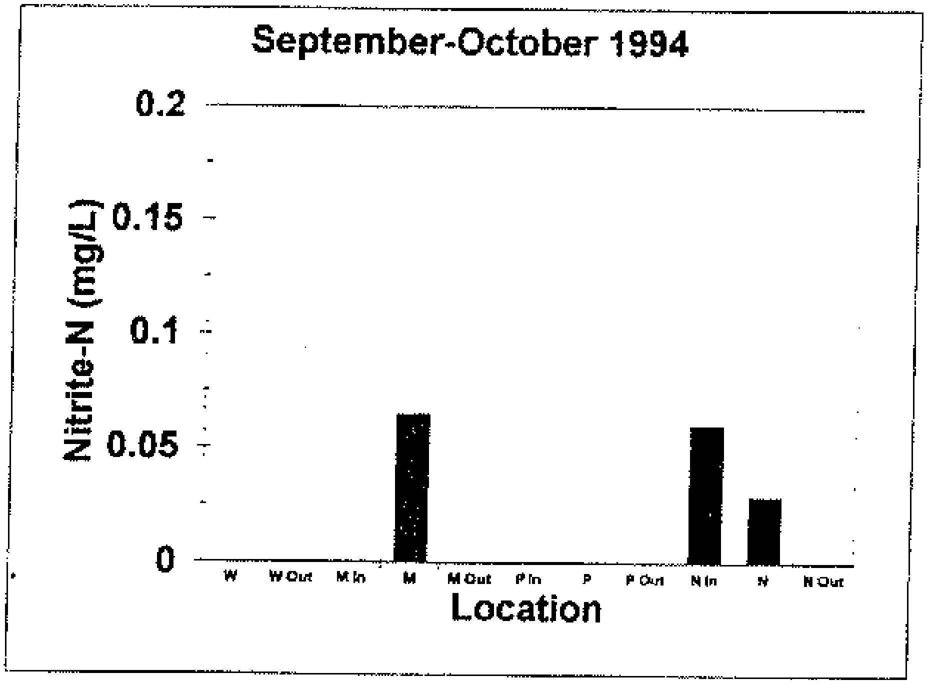
Figure A-2. Monthly Nitrate Concentrations in the Middle Branch Lakes: 1994-1995.

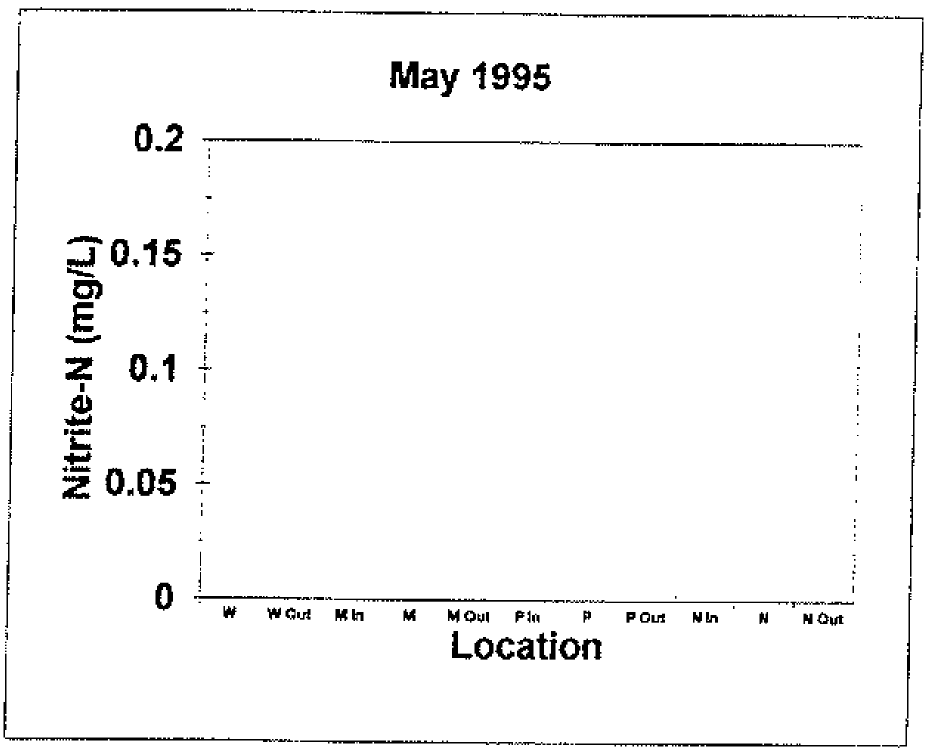




(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

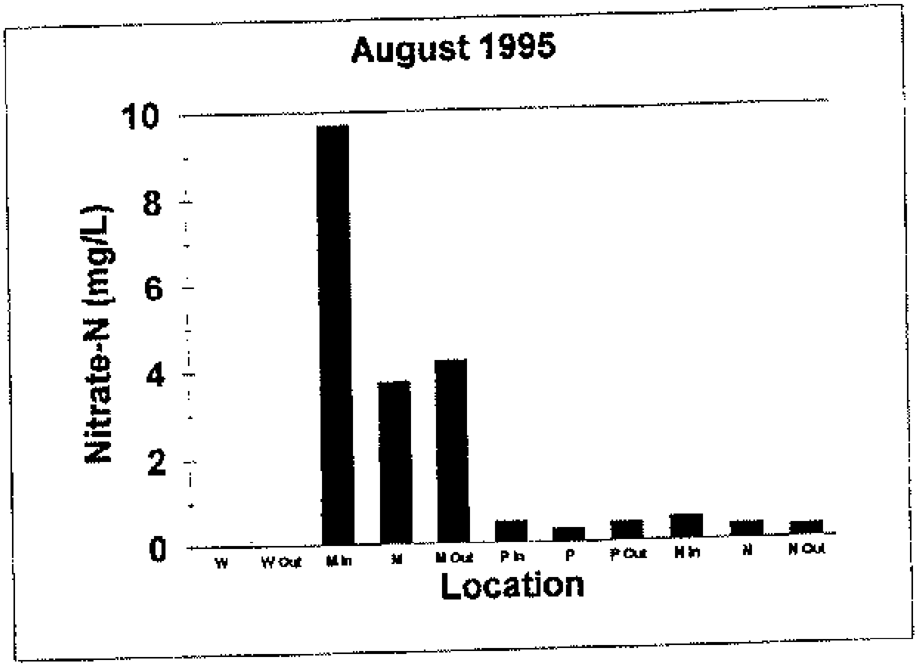
Figure A-3. Monthly Nitrite Concentrations in the Middle Branch Lakes: 1994-1995





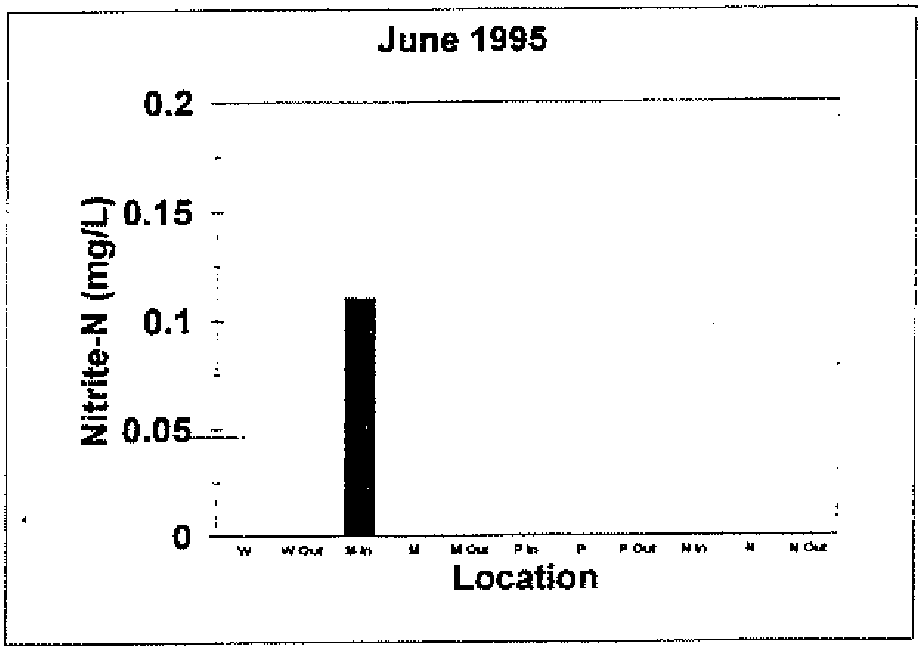
(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

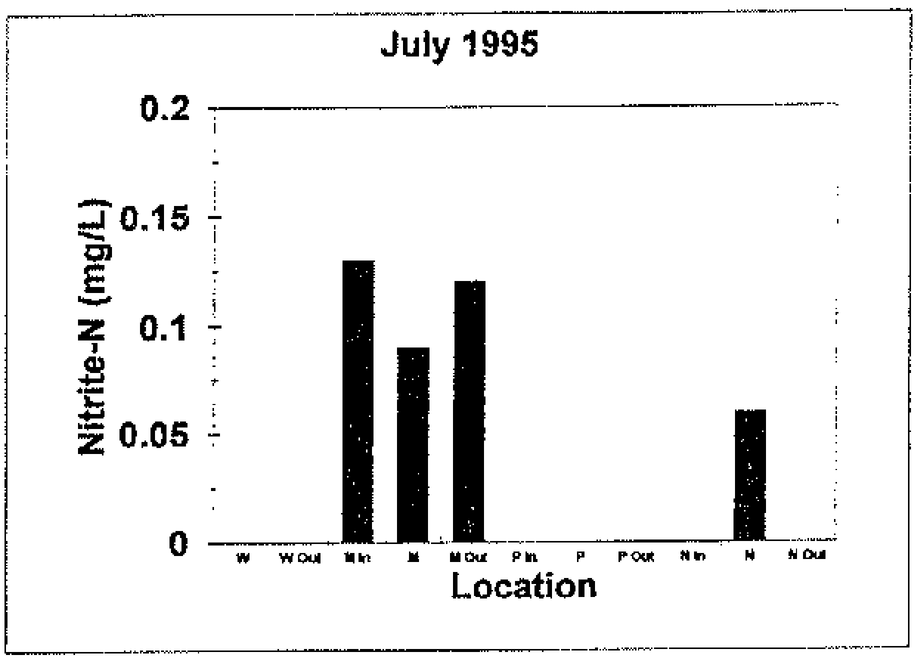
Figure A-2. Monthly Nitrate Concentrations in the Middle Branch Lakes: 1994-1995. (Concluded)



(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

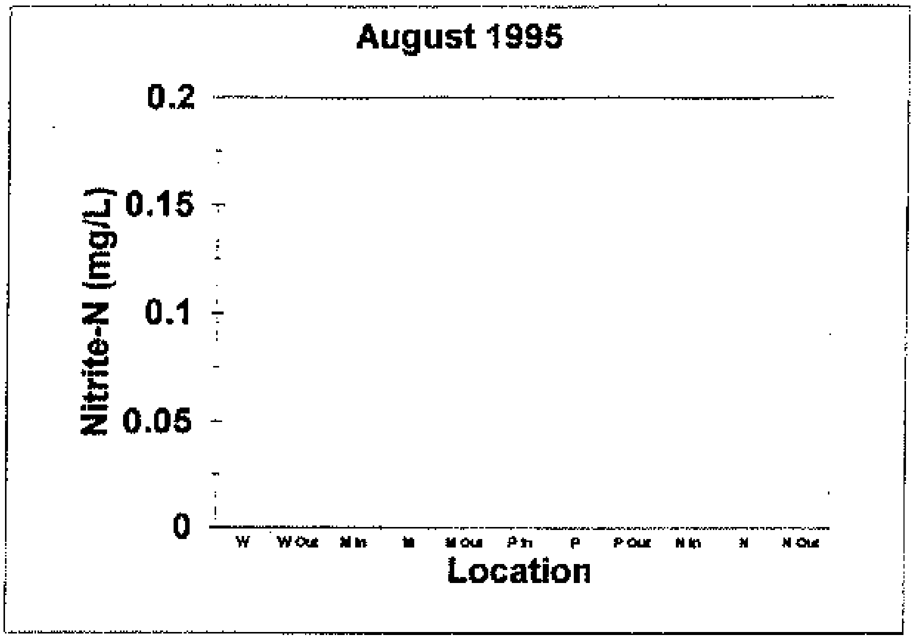
Figure A-3. Monthly Nitrite Concentrations in the Middle Branch Lakes: 1994-1995. (Continued)





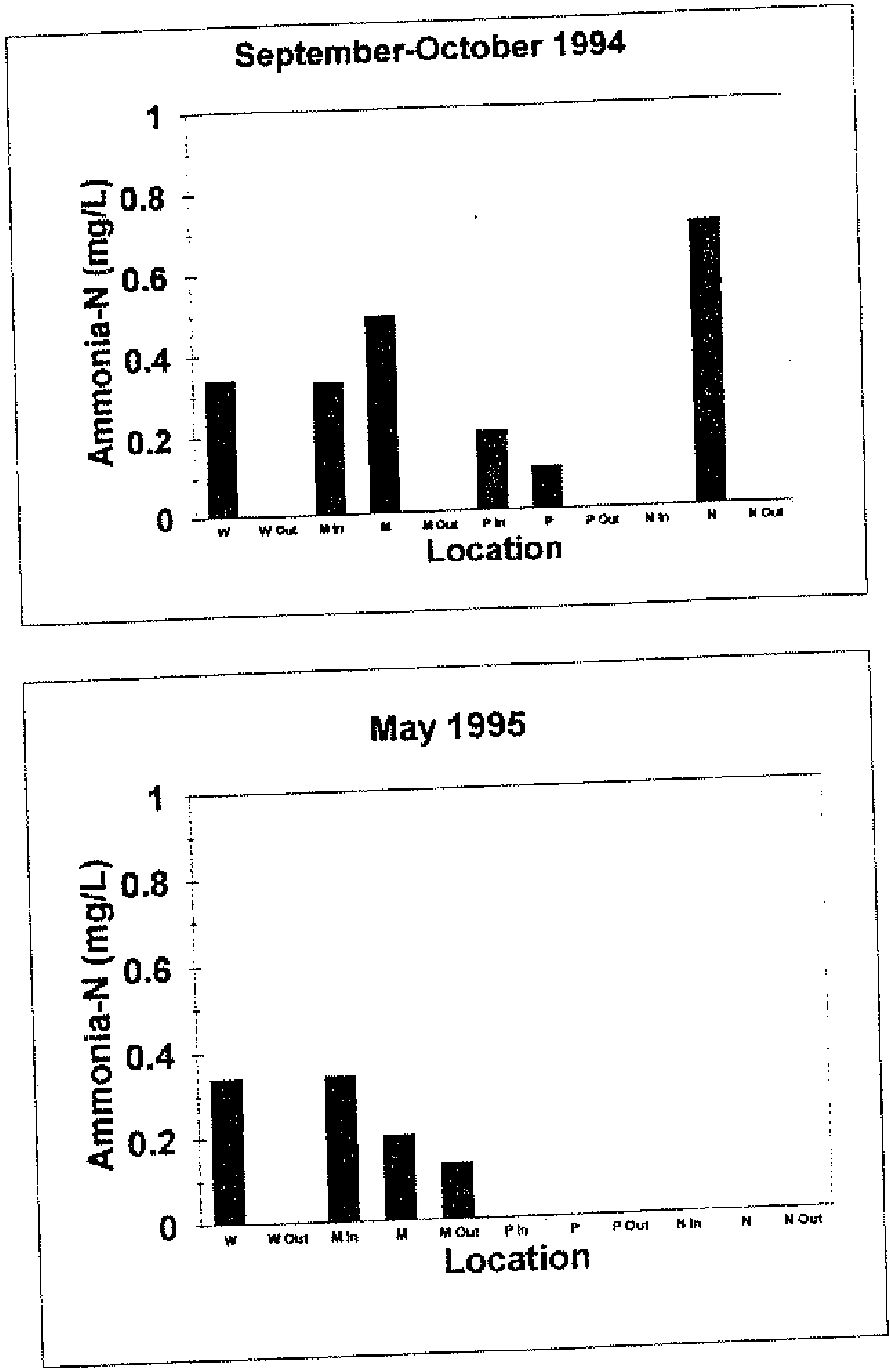
(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

Figure A-3. Monthly Nitrite Concentrations in the Middle Branch Lakes: 1994-1995. (Concluded)



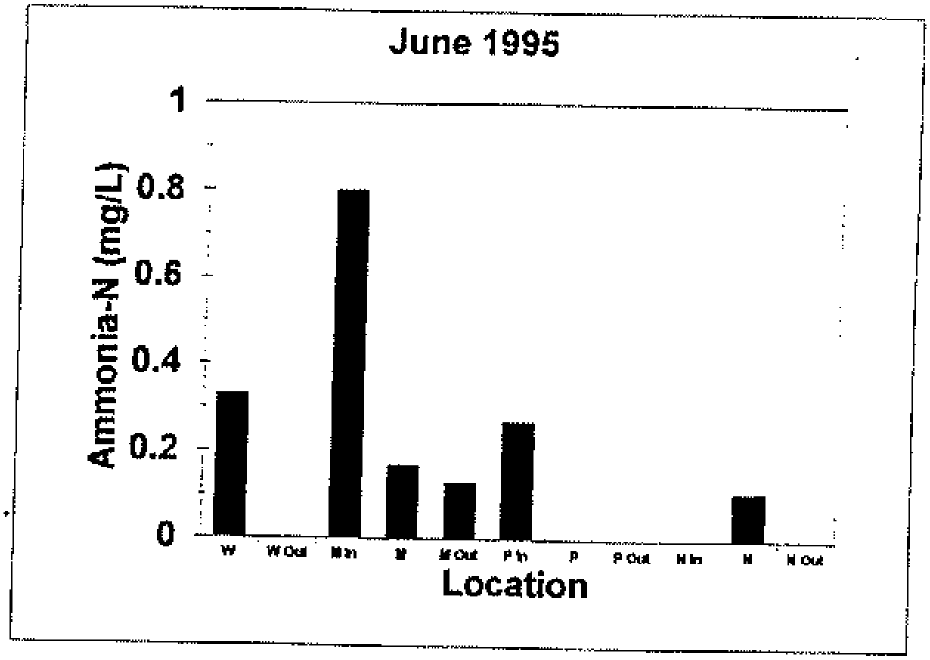
(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

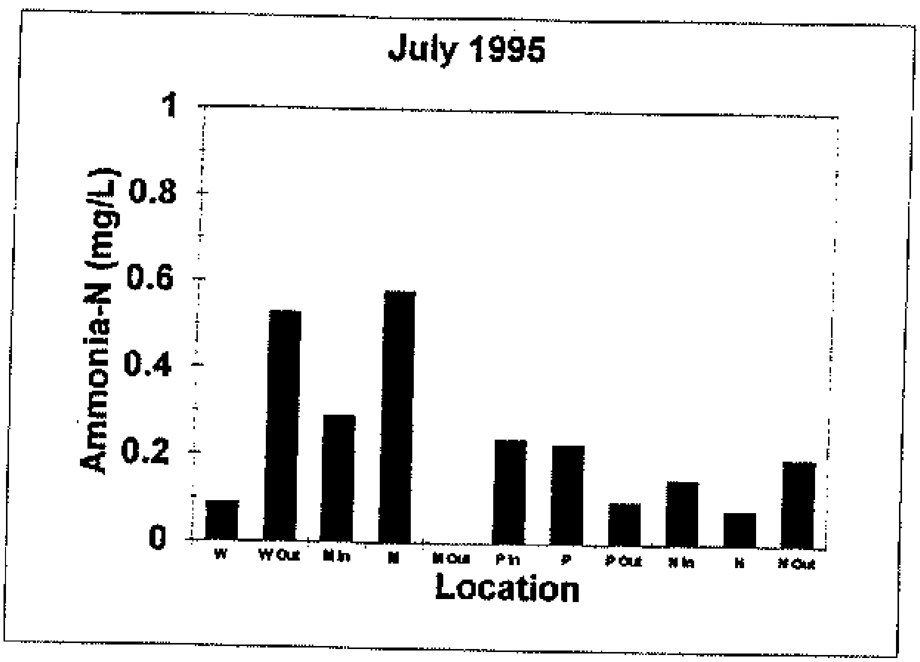
Figure A-4. Monthly Ammonia-Nitrogen Concentrations in the Middle Branch Lakes: 1994-1995.



(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

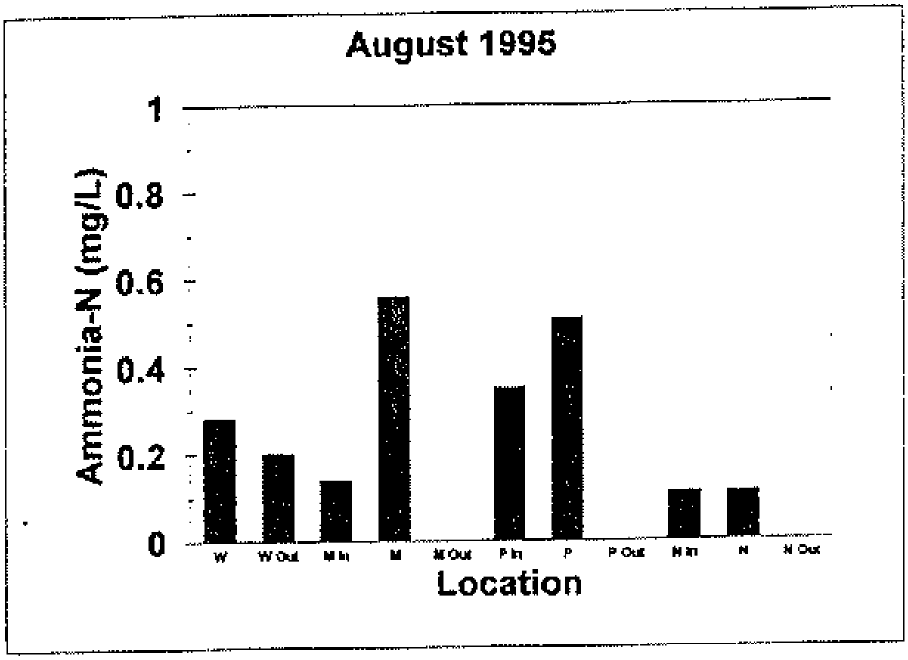
Figure A-4. Monthly Ammonia-Nitrogen Concentrations in the Middle Branch Lakes: 1994-1995. (Continued)





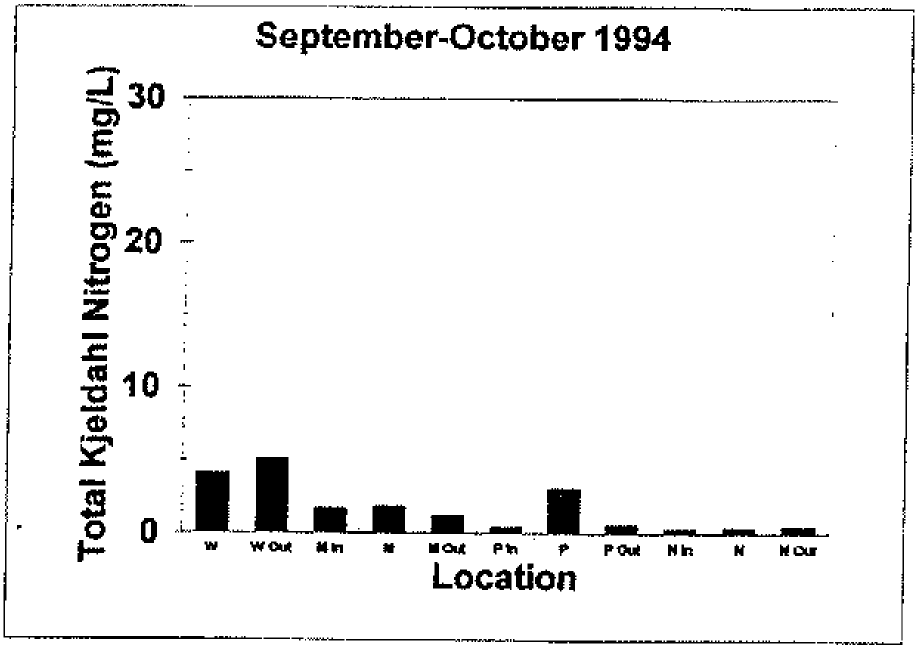
(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

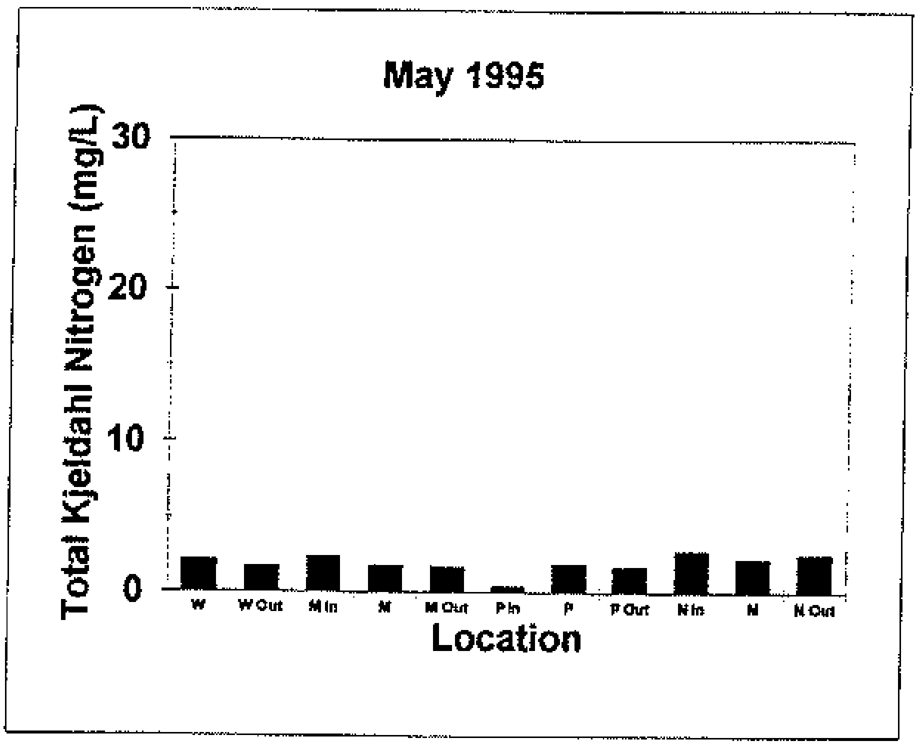
Figure A-4. Monthly Ammonia-Nitrogen Concentrations in the Middle Branch Lakes: 1994-1995. (Concluded)



(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

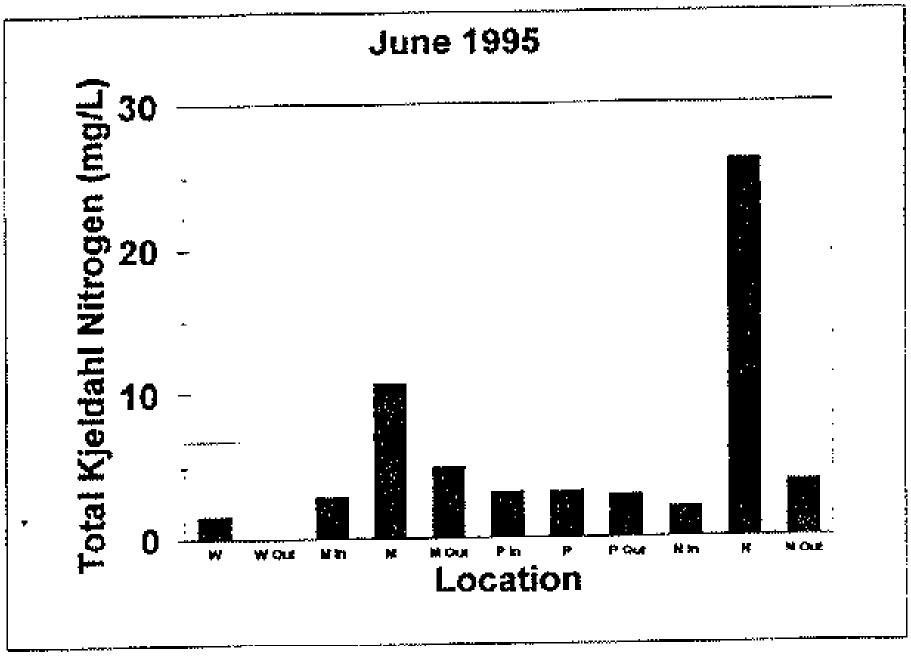
Figure A-5. Monthly Total Kjeldahl Nitrogen Concentrations in the Middle Branch Lakes: 1994-1995.

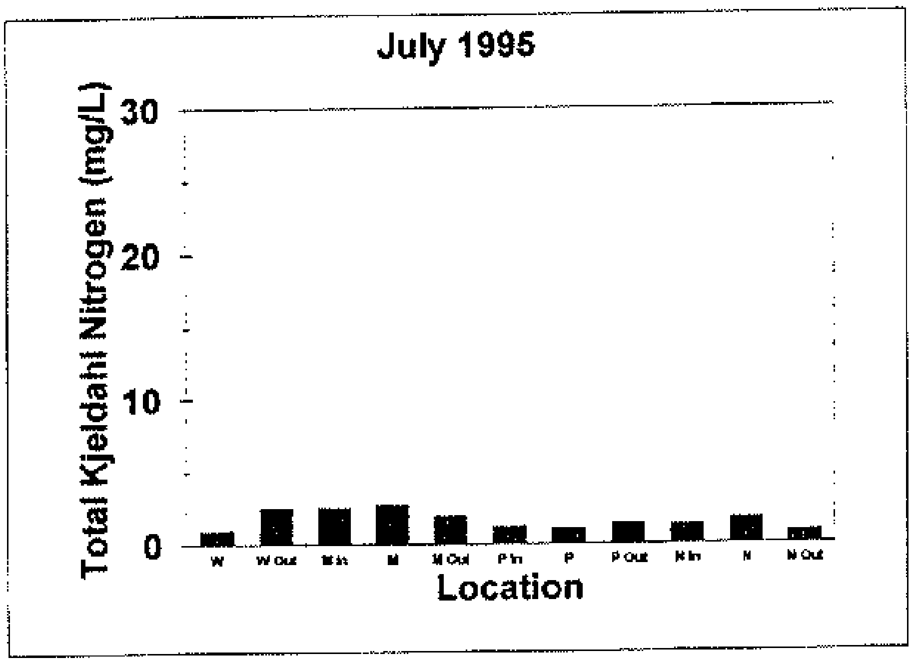




(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

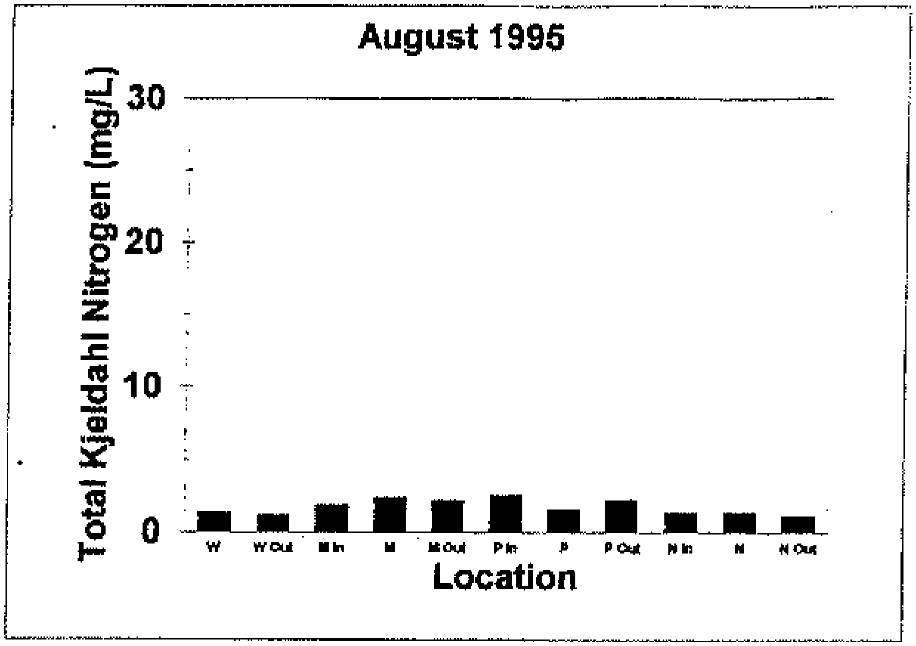
Figure A-5. Monthly Total Kjeldahl Nitrogen Concentrations in the Middle Branch Lakes: 1994-1995. (Continued)





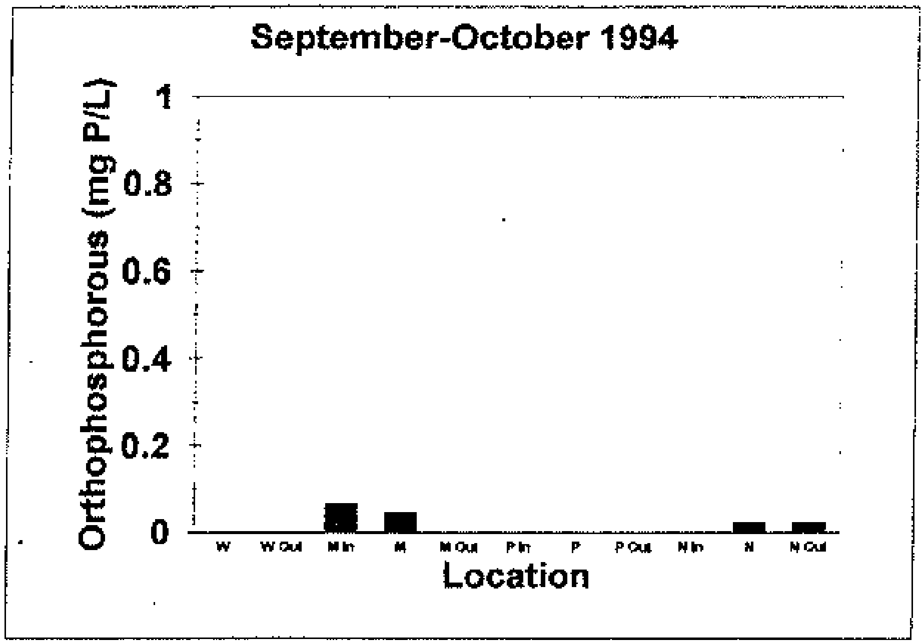
(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

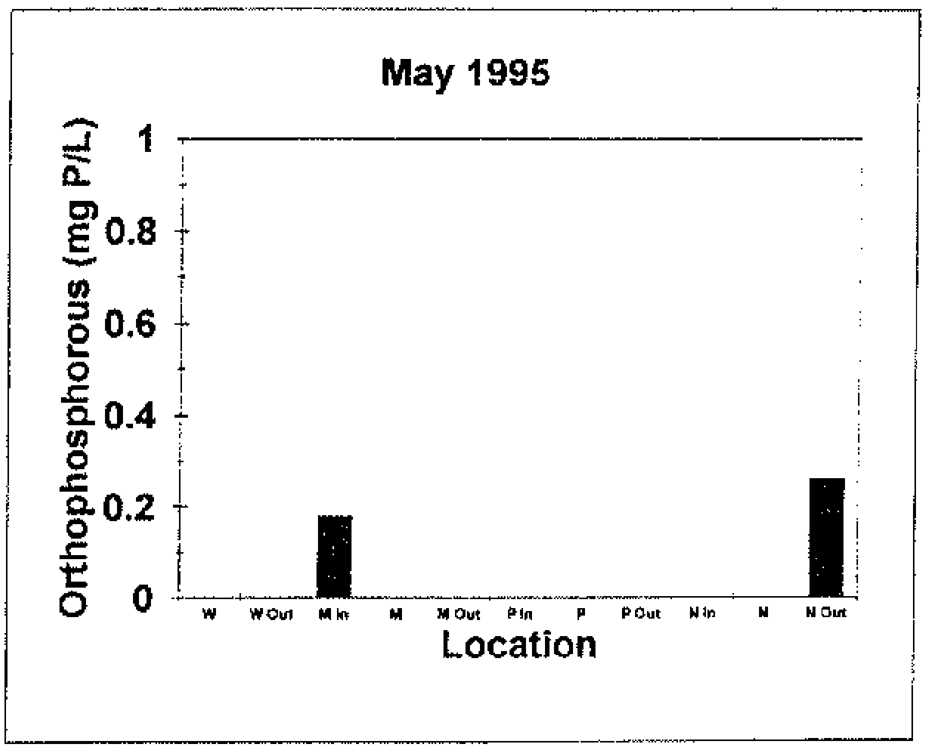
Figure A-5. Monthly Total Kjeldahl Nitrogen Concentrations in the Middle Branch Lakes: 1994-1995. (Concluded)



(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

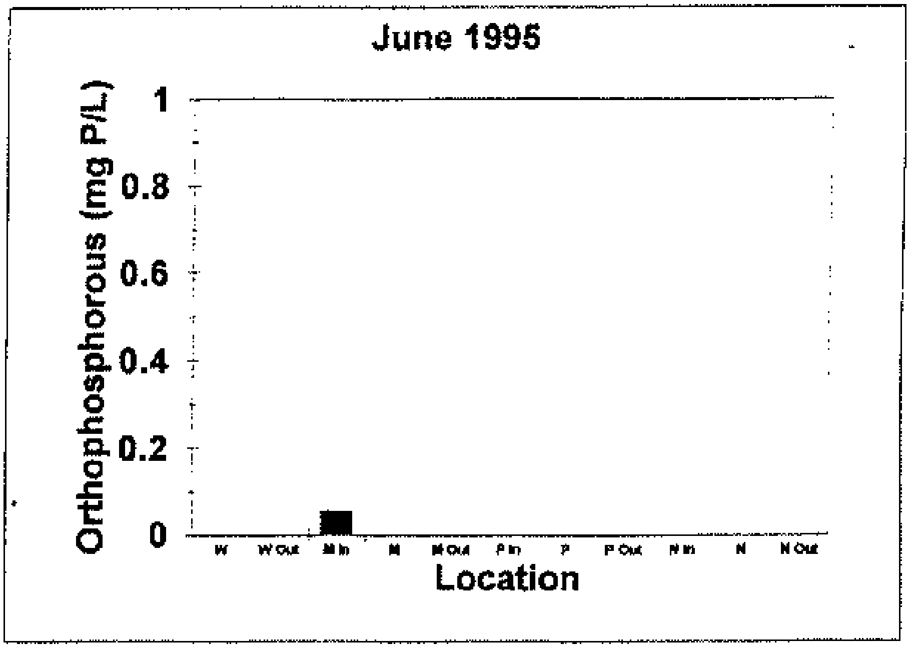
Figure A-6. Monthly Orthophosphorous Concentrations in the Middle Branch Lakes: 1994-1995.

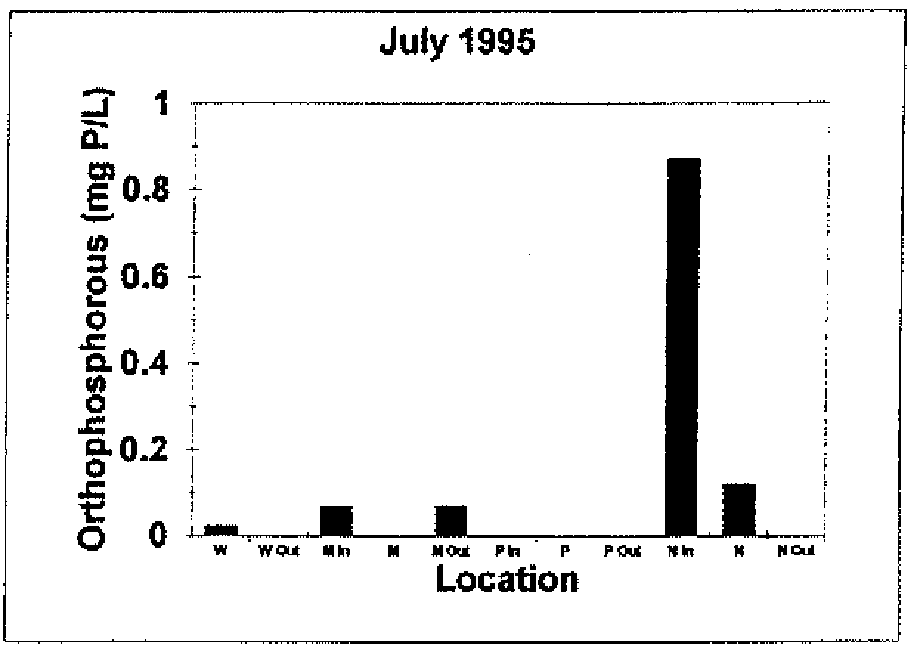




(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

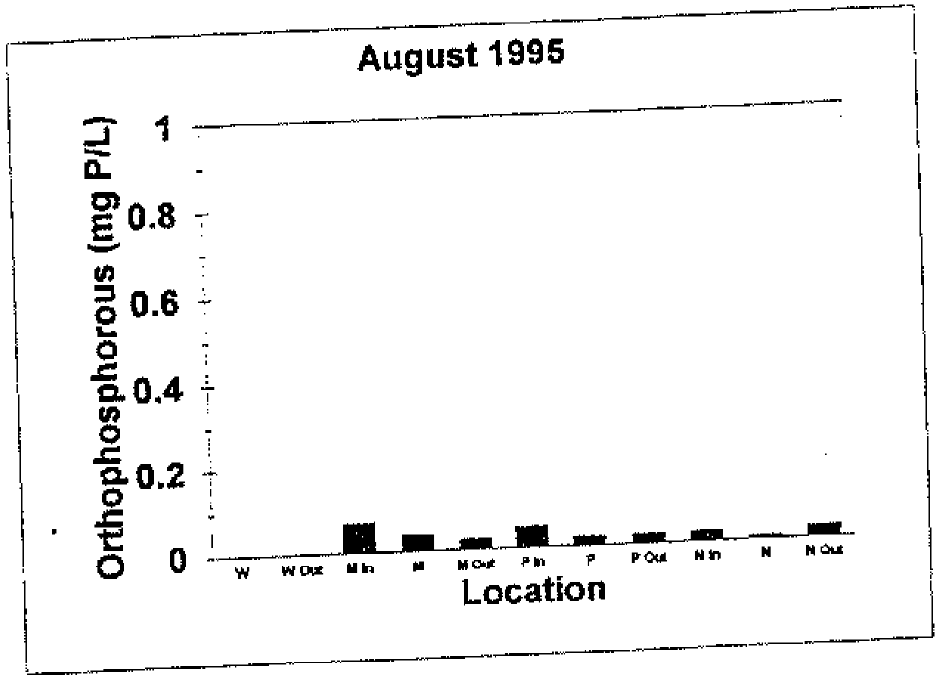
Figure A-6. Monthly Orthophosphorous Concentrations in the Middle Branch Lakes: 1994-1995. (Continued)





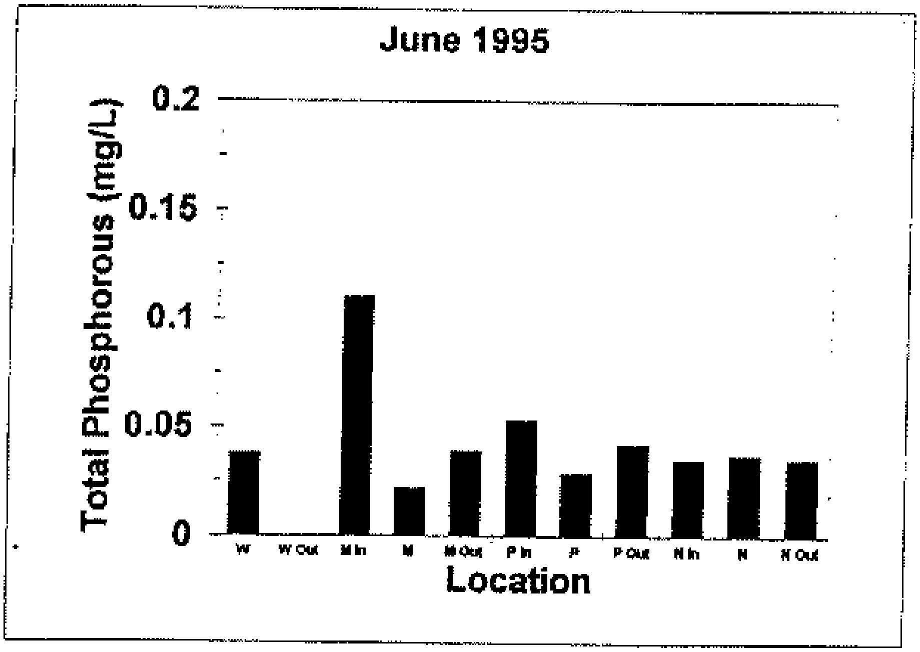
(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

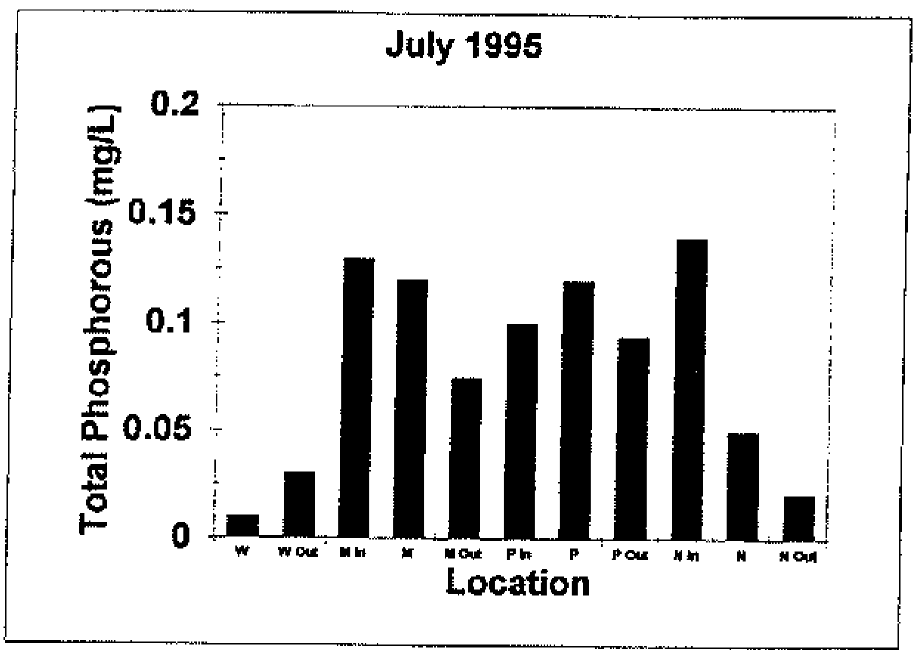
Figure A-6. Monthly Orthophosphorous Concentrations in the Middle Branch Lakes: 1994-1995. (Concluded)



(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

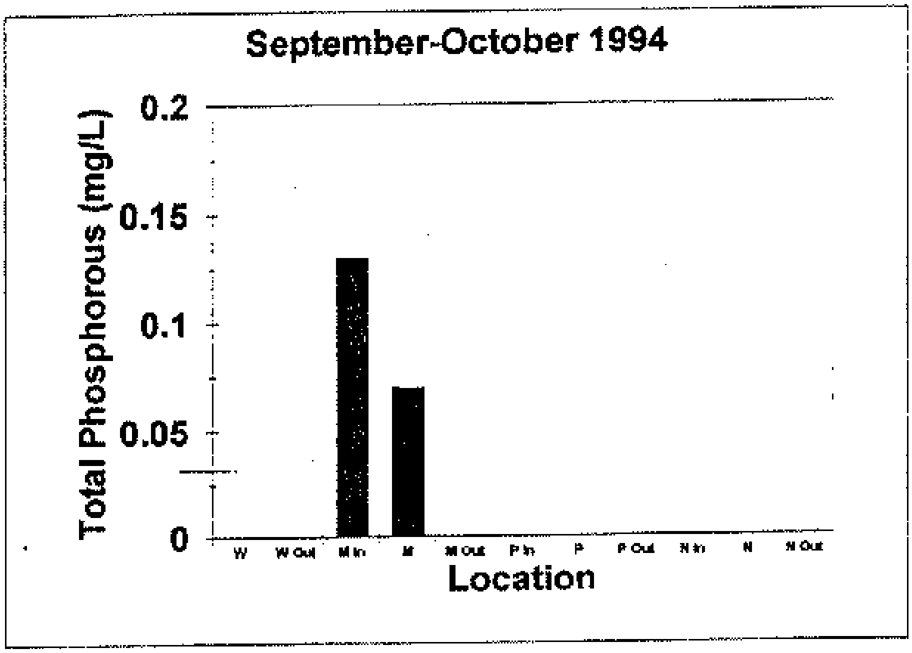
Figure A-7. Monthly Total Phosphorous Concentrations in the Middle Branch Lakes: 1994-1995. (Continued)

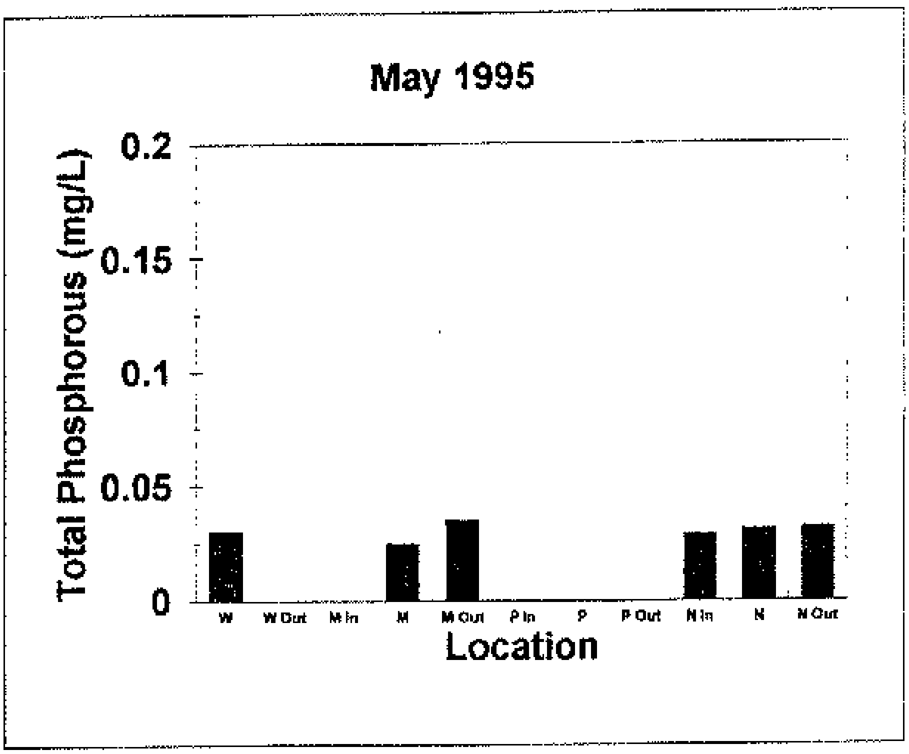




(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

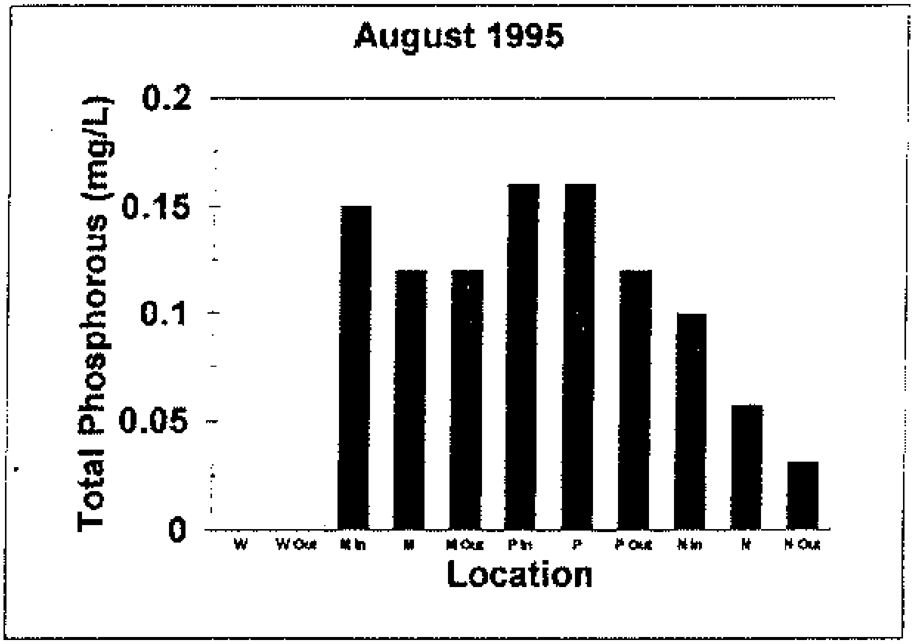
Figure A-7. Monthly Total Phosphorous Concentrations in the Middle Branch Lakes: 1994-1995.





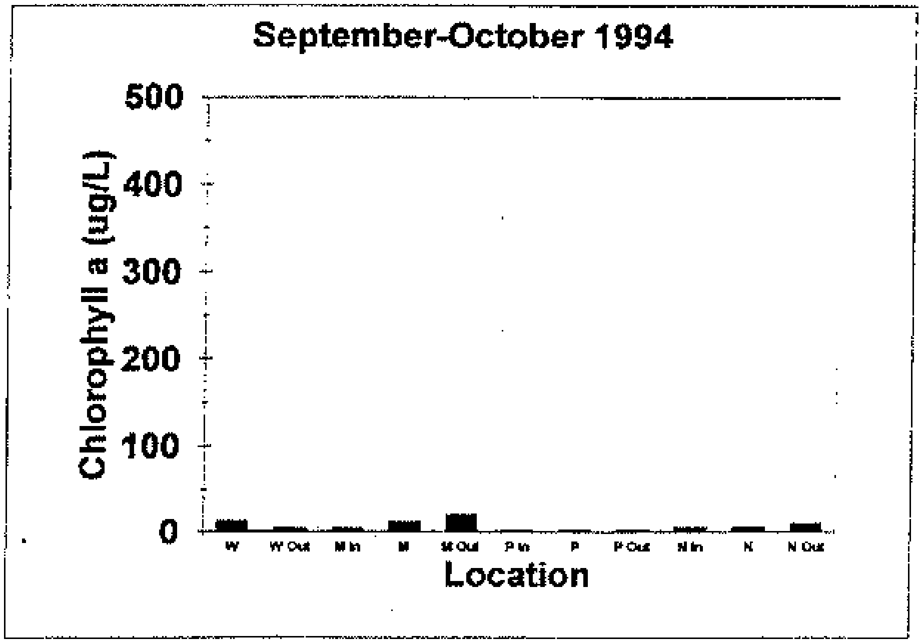
(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

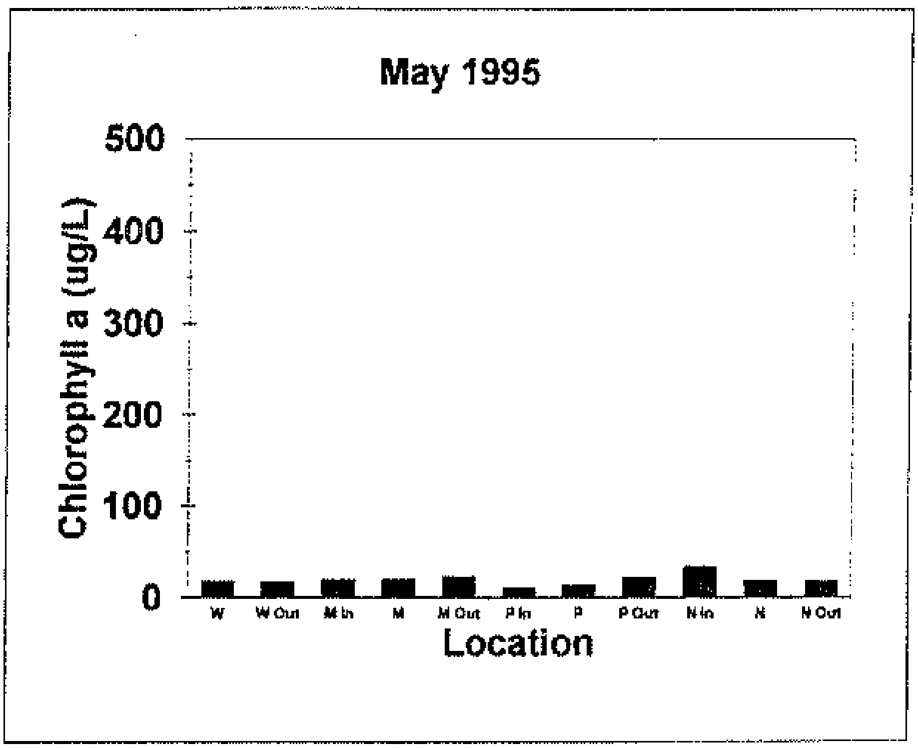
Figure A-7. Monthly Total Phosphorous Concentrations in the Middle Branch Lakes: 1994-1995. (Concluded)



(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

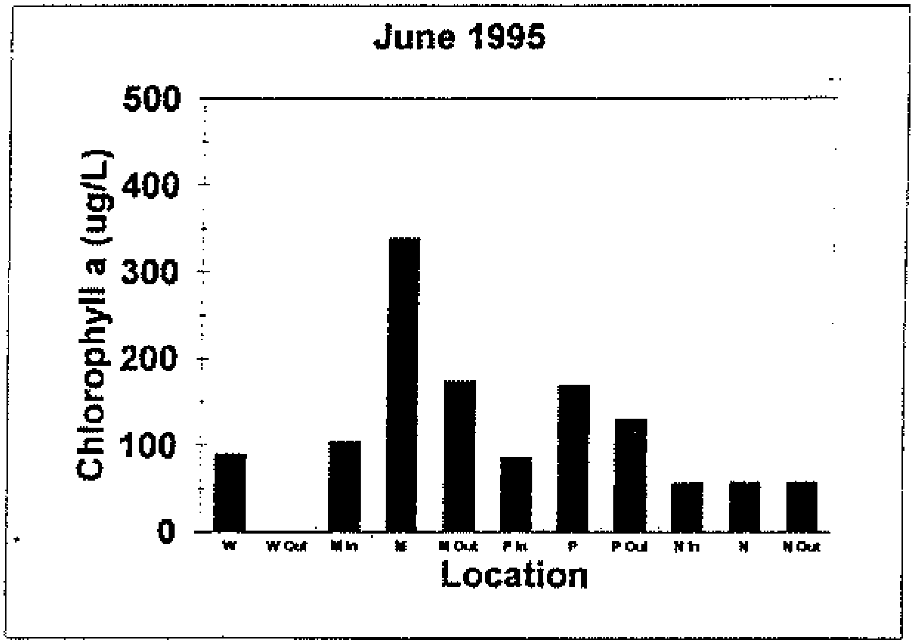
Figure A-8. Monthly Chlorophyll a Concentrations in the Middle Branch Lakes: 1994-1995.

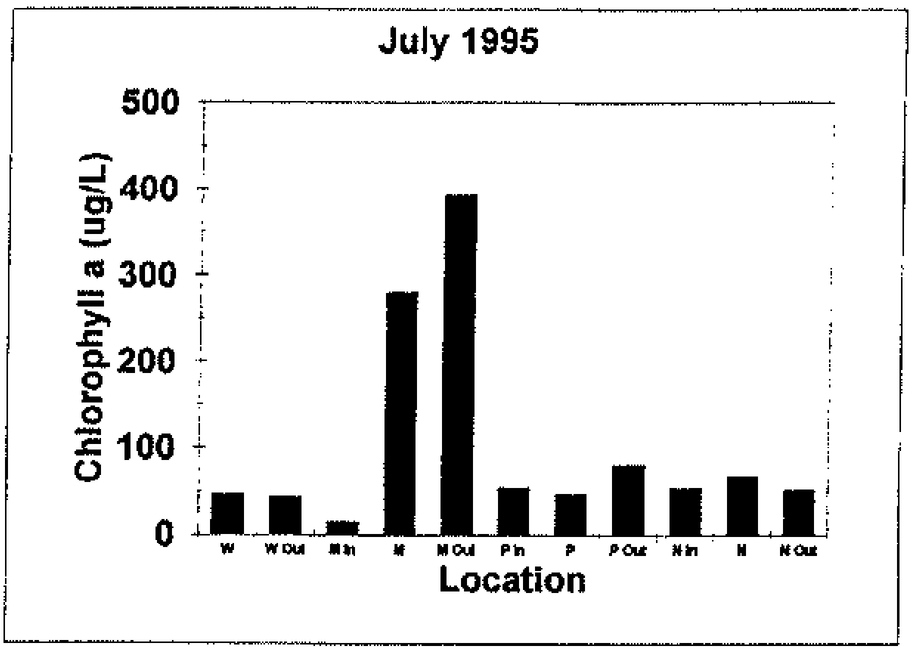




(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

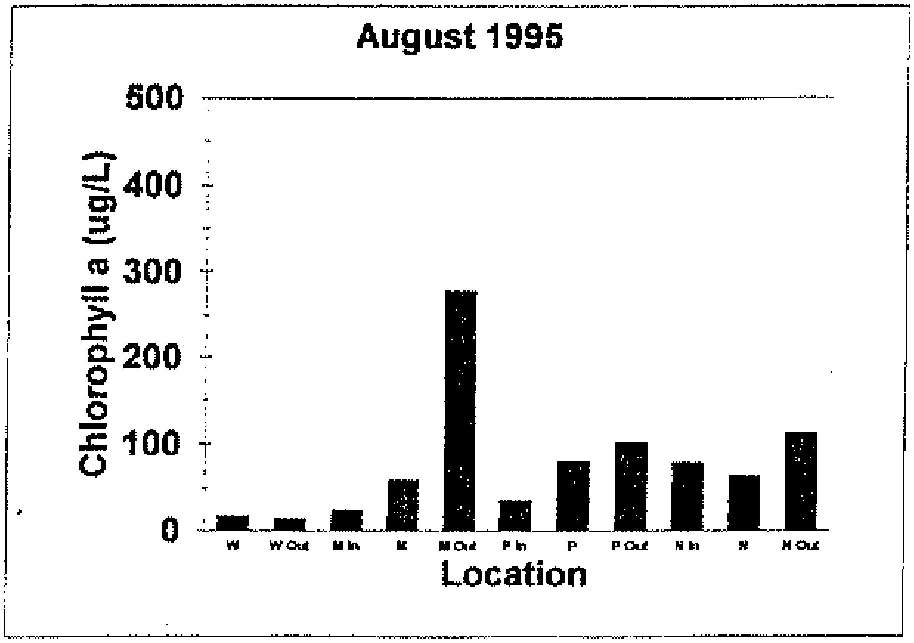
Figure A-8. Monthly Chlorophyll a Concentrations in the Middle Branch Lakes: 1994-1995. (Continued)





(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

Figure A-8. Monthly Chlorophyll a Concentrations in the Middle Branch Lakes: 1994-1995. (Concluded)



(W = Walled Lake; M = Meadowbrook Lake; P = Phoenix Lake; N = Newburgh Lake)

STORMWATER SEDIMENT AND AQUATIC PLANT STUDY
for
WALLED LAKE, SHAWOOD LAKE, MEADOWBROOK LAKE

APPENDIX X

Inland Lake Improvement Act No. 451, Public Acts of 1994

Act No. 451
Public Acts of 1994

PART 309 INLAND LAKE IMPROVEMENTS

Sec. 30901. As used in this part:

(a) "Benefit" or "benefits" means advantages resulting from a project to public corporations, the inhabitants of public corporations, the inhabitants of this state, and property within public corporations. Benefit includes benefits that result from elimination of pollution and elimination of flood damage, elimination of water conditions that jeopardize the public health or safety; increase of the value or use of lands and property arising from improving a lake or lakes as a result of the lake project and the improvement or development of a lake for conservation of fish and wildlife and the use, improvement, or development of a lake for fishing, wildlife, boating, swimming, or any other recreational, agricultural, or conservation uses.

(b) "Inland lake" means a public inland lake or a private inland lake.

(c) "Interested person" means a person who has a record interest in the title to, right of ingress to, or reversionary right to a piece or parcel of land that would be affected by a permanent change in the bottomland of a natural or artificial, public or private inland lake, or adjacent wetland. In all cases, whether having such an interest or not, the department is an interested person.

(d) "Local governing body" means the legislative body of a local unit of government.

(e) "Preliminary costs" includes costs of the engineering feasibility report, economic study, estimate of total cost, and cost of setting up the assessment district.

(f) "Private inland lake" means an inland lake other than a public inland lake.

(g) "Public inland lake" means a lake that is accessible to the public by publicly owned lands or highways contiguous to publicly owned lands or by the bed of a stream, except the Great Lakes and connecting waters.

Sec. 30902. (1) The local governing body of any local unit of government in which the whole or any part of the waters of any public inland lake is situated, upon its own motion or by petition of 2/3 of the freeholders owning lands abutting the lake, for the protection of the public health, welfare, and safety and the conservation of the natural resources of this state, or to preserve property values around a lake, may provide for the improvement of a lake, or adjacent wetland, and may take steps necessary to remove and properly dispose of undesirable accumulated materials from the bottom of the lake or wetland by dredging, ditching, digging, or other related work.

(2) Upon receipt of the petition or upon its own motion, the local governing body within 60 days shall set up a lake board as provided in section 30903 that shall proceed with the necessary steps for improving the lake or to void the proposed project.

Sec. 30903. (1) The lake board shall consist of all of the following:

(a) A member of the county board of commissioners appointed by the chairperson of the county board of commissioners of each county affected by the lake improvement project; a representative of each local unit of government appointed by the legislative body of each local unit of government, other than a county, affected by the project; the county drain commissioner, or a member of the county road commission in counties not having a drain commissioner; and a representative of the department.

(b) A member elected by the members of the lake board serving pursuant to subdivision (a) at the first meeting of the board or at any time a vacancy exists under this subdivision. Only a person who has an interest in a land contract or a record interest in the title to a piece or parcel of land that abuts the lake to be improved is eligible to be elected and to serve under this subdivision. An organization composed of and representing the majority of lakefront property owners on the affected lake may submit up to 3 names to the board, from which the board shall make its selection. The terms served by this member shall be 4 years in length.

(2) The lake board shall elect a chairperson and a secretary. A majority of the members of the lake board constitutes a quorum. The concurrence of a majority in any matter within the duties of the board shall be required for the determination of a matter.

(3) The department, upon request of the lake board, shall provide whatever technical data it has available and make recommendations in the interests of conservation.

Sec. 30904. Action may be initiated under section 30902 relating to any private inland lake only upon petition of 2/3 of the freeholders owning lands abutting the lake.

Sec. 30905. The county board of commissioners may provide for a revolving fund to pay for the preliminary costs of improvement projects within the county. The preliminary costs shall be assessed to the property owners in the assessment district by the lake board after notice of the hearing is given pursuant to Act No. 162 of the Public Acts of 1962, being sections 211.741 to 211.746 of the Michigan Compiled Laws, and shall be repaid to the fund where the project is not finally constructed.

Sec. 30906. (1) Whenever a local governing body, in accordance with section 30902, considers it expedient to have a lake improved, it, by resolution, shall direct the lake board to institute proceedings as prescribed in this part.

(2) When the waters of any inland lake are situated in 2 or more local units of government, the improvement of the lake may be determined jointly in the same manner as provided in this part, if the local governing bodies of all local units of government involved determine it to be expedient in accordance with section 30902 and, by resolution, direct the lake board to institute proceedings as prescribed in this part. Where local ordinances and charters conflict, this part shall govern.

Sec. 30907. If the department considers it expedient, in accordance with section 30902, to have a lake dredged or improved, the department may petition the local governing body or governing bodies in which the lake is located for an improvement of the lake. The department may also join with the local governing body of any local unit of government in instituting proceedings for improvements as set forth in this part.

Sec. 30908. The lake board, when instructed by resolution of the local governing body, shall determine the scope of the project and shall establish a special assessment district, including within the special assessment district all parcels of land and local units which will be benefited by the improvement of the lake. The local governing body may delegate to the lake board other ministerial duties including preparation, assembling, and computation of statistical data for use by the board and the superintending, construction, and maintenance of any project under this part, as the local governing body considers necessary.

Sec. 30909. (1) The lake board shall retain a licensed professional engineer to prepare an engineering feasibility report, an economic study report, and an estimate of cost. The report shall include, when applicable, recommendations for normal lake levels and the methods for maintaining those levels.

(2) The engineering feasibility report shall include the methods proposed to implement the recommended improvements, such as dredging, removal, disposal, and disposal areas for undesirable materials from the lake. The report shall include an investigation of the groundwater conditions and possible effects on lake levels from removal of bottom materials. A study of existing nutrients and an estimate of possible future conditions shall be included. Estimate of costs of right-of-way shall be included.

(3) The estimate of cost prepared under subsection (1) shall show probable assessments for the project. The economic report shall analyze the existing local tax structure and the effects of the proposed assessments on the local units of government involved. A copy of the report shall be furnished to each member of the lake board.

Sec. 30910. Within 60 days after his or her receipt of the reports, the chairperson shall hold a meeting of the lake board to review the reports required under section 30909 and to determine the practicability of the project. The hearing shall be public, and notice of the hearing shall be published twice in a newspaper of general circulation in each local unit of government to be affected. The first publication shall be not less than 20 days prior to the time of the hearing. The board shall determine the practicability of the project within 10 days after the hearing unless it is determined at the hearing that more information is needed before the determination can be made. Immediately upon receipt of the additional information, the board shall make its determination.

Sec. 30911. The county board of commissioners may provide up to 25% of the cost of a lake improvement project on any public inland lake.

Sec. 30912. If the lake board passes a resolution in which it determines the project to be practicable, the lake board shall determine to proceed with the project, shall approve the plans and estimate of costs as originally presented or as revised, corrected, amended, or changed, and shall determine the sufficiency of the petition for the improvement. The resolution shall be published once in a newspaper of general circulation in each local unit of government to be affected. After the resolution has been published, the sufficiency of the petition shall not be subject to attack except in an action brought in a court of competent jurisdiction within 30 days after publication. The lake board, after finally accepting the special assessment district, shall prepare an assessment roll based upon the benefits to be derived from the proposed lake improvement, and the lake board shall direct the assessing official of each local unit of government to be affected to join in making an assessment roll in which shall be entered and described all the parcels of land to be assessed, with the names of the respective owners of the parcels of land, if known, and the total amount to be assessed against each parcel of land and against each local unit of government to be affected, which amount shall be such relative portion of the whole sum to be levied against all parcels of land and local units of government in the special assessment district as the benefit to such parcel of land and local unit of government bears to the total benefit to all parcels of land and local units of government in the special assessment district. When the assessment roll has been completed, each assessing official shall affix to the assessment roll his or her certificate stating that it was made pursuant to a resolution of the lake board adopted on a specified date, and that in making the assessment roll he or she has, according to his or her best judgment, conformed in all respects to the directions contained in the resolution and the statutes of the state.

Sec. 30913. The assessment roll shall be reported to the lake board by the assessing official of the local unit or units of government initiating the proceeding and filed in the office of the clerk of each local unit of government to be affected. Before confirming the assessment roll, the lake board shall appoint a time and place when it will meet and review the assessment roll and hear any objections to the assessment roll, and shall publish notice of the hearing and the filing of the assessment roll twice prior to the hearing in a newspaper of general circulation in each local unit of government to be affected, the first publication to be at least 10 days before the hearing. Notice of the hearing shall also be given in accordance with Act No. 162 of the Public Acts of 1962, being sections 211.741 to 211.746 of the Michigan Compiled Laws. The hearing may be adjourned from time to time without further notice. Any person or local unit of government objecting to the assessment roll shall file his or her objection in writing with the chairperson before the close of the hearing or within such further time period as the lake board may grant. After the hearing, the lake board may confirm the special assessment roll as reported to it or as amended or corrected by it, may refer it back to the assessing officials for revision, or may annul it and direct a new roll to be made. When a special assessment roll has been confirmed, the clerk of each local unit of government shall endorse on the assessment roll the date of the confirmation. After confirmation, the special assessment roll and all assessments on the assessment roll shall be final and conclusive unless attacked in a court of competent jurisdiction within 30 days after notice of confirmation has been published in the same manner as the notice of hearing.

Sec. 30914. Upon the confirmation of the assessment roll, the lake board may provide that the assessments be payable in 1 or more approximately equal annual installments, not exceeding 30. The amount of each installment, if more than 1, need not be extended upon the special assessment roll until after confirmation. The first installment of a special assessment shall be due on or before such time after confirmation as the board shall establish, and the several subsequent installments shall be due at intervals of 12 months from the due date of the first installment or from such other date as the board shall establish. All unpaid installments, prior to their transfer to the tax roll of each local unit of government involved, shall bear interest, payable annually on each installment due date, at a rate to be set by the board, not exceeding 6% per annum, from such date as established by the board. Future due installments of an assessment against a parcel of land may be paid to the treasurer of each local unit of government at any time in full, with interest accrued to the due date of the next installment. If any installment of a special assessment is not paid when due, then it shall be considered to be delinquent and there shall be collected on the installment, in addition to interest as above provided, a penalty at the rate of 1/2 of 1% for each month or fraction of a month that it remains unpaid before being reported to the township board for reassessment upon the tax roll.

Sec. 30915. All special assessments contained in any special assessment roll, including any part of the special assessment payment that is deferred, constitute a lien, from the date of confirmation of the roll, upon the respective parcels of land assessed. The lien shall be of the same character and effect as the lien created for taxes in each local unit of government and shall include accrued interest and penalties. A judgment, decree, or any act of the board vacating a special assessment does not destroy or impair the lien upon the premises assessed for the amount of the assessment as may be equitably charged against the premises, or as by a regular mode of proceeding might be lawfully assessed on the premises.

Sec. 30916. When any special assessment roll is confirmed, the lake board shall direct the assessments made in the roll to be collected. The clerk of each local unit of government involved shall then deliver to the treasurer of each local unit of government the special assessment roll, to which he or she shall attach his or her warrant commanding the treasurer to collect the assessments in the roll in accordance with the directions of the lake board. The warrant shall further require the treasurer, on September 1 following the date when any assessments or any part of an assessment have become due, to submit to the lake board a sworn statement setting forth the names of delinquent persons, if known, a description of the parcels of land upon which there are delinquent assessments, and the amount of the delinquency, including accrued interest and penalties computed to September 1 of the year. Upon receiving the special assessment roll and warrant, the treasurer shall collect the amounts assessed as they become due.

Sec. 30917. If the treasurer reports as delinquent any assessment or part of an assessment, the lake board shall certify the delinquency to the assessing official of each local unit of government, who shall reassess, on the annual tax roll of the local unit of government of that year, in a column headed "special assessments", the delinquent sum, with interest and penalties to September 1 of that year, and an additional penalty of 6% of the total amount. Thereafter, the statutes relating to taxes shall be applicable to the reassessments in each local unit of government.

Sec. 30918. If any parcel of land is divided after a special assessment on the land has been confirmed and before the collection of the assessment, the lake board may require the assessment official to apportion the uncollected amounts between the divisions of the parcel of land, and the report of the apportionment when confirmed by the lake board shall be conclusive upon all parties. If the interested parties do not agree in writing to the apportionment, then, before confirmation, notice of hearing shall be given to all the interested parties, either by personal service or by publication as provided in the case of an original assessment roll.

Sec. 30919. If the assessments in any special assessment roll prove insufficient for any reason, including the noncollection of the assessment, to pay for the improvement for which they were made or to pay the principal and interest on the bonds issued in anticipation of the collection of the assessment, then the lake board shall make additional pro rata assessments to supply the deficiency, but the total amount assessed against any parcel of land shall not exceed the value of the benefits received from the improvement.

Sec. 30920. Whenever, in the opinion of the lake board, any special assessment is invalid by reason of irregularities or informalities in the proceedings, or if any court of competent jurisdiction adjudges such assessment illegal, the lake board, whether the improvement has been made or not and whether any part of the assessment has been paid or not, may proceed from the last step at which the proceedings were legal and cause a new assessment to be made for the same purpose for which the former assessment was made. All proceedings on that reassessment and for the collection of the assessment shall be conducted in the same manner as provided for the original assessment. Whenever an assessment or any part of an assessment levied upon any premises has been set aside, if the assessment or part of an assessment has been paid and not refunded, the payment shall be applied upon the reassessment.

Sec. 30921. The governing body of any department of the state or any of its political subdivisions, municipalities, school districts, townships, or counties, whose lands are exempt by law, may by resolution agree to pay the special assessments against the lands, in which case the assessment, including all the installments of the assessment, shall be a valid claim against the local unit of government.

Sec. 30922. The lake board may borrow money and issue lake level orders or the bonds of the special assessment district therefor in anticipation of the collection of special assessments to defray the cost of any improvement made under this part after the special assesament roll has been confirmed. The bonds or lake level orders shall not exceed the amount of the special assessments in anticipation of the collection of which they are issued and shall bear interest at a rate not exceeding 5% per annum. Collections on special assessments to the extent pledged for the payment of bonds or lake level orders shall be set aside in a special fund for the payment of the bonds or lake level orders. The issuance of special assessments bonds or lake level orders shall be governed by the general laws of the state applicable to the issuance of special assessments bonds or lake level orders and in accordance with the municipal finance act, Act No. 202 of the Public Acts of 1943, being sections 131.1 to 139.3 of the Michigan Compiled Laws. Bonds or lake level orders may be issued in anticipation of the collection of special assessments levied in respect to 2 or more public improvements, but no special assessment district shall be compelled to pay the obligation of any other special assessment district. The local governing body may pledge the full faith and credit of a local unit of government for the prompt payment of the principal of and interest on the bonds or lake level orders as they become due. The pledge of full faith and credit of the local unit of government shall be included within the total limitation prescribed by section 5 of chapter 5 of Act No. 202 of the Public Acts of 1943, being section 135.5 of the Michigan Compiled Laws. Bonds and lake level orders issued under this part shall be executed by the chairperson and secretary of the lake board, and the interest coupons to be attached to the bonds and orders shall be executed by the officials causing their facsimile signatures to be affixed thereto.

Sec. 30923. Whenever the lake board determines by proper resolution that it is necessary to condemn private property for the purpose of this part, the condemnation proceedings shall be commenced and conducted in accordance with Act No. 149 of the Public Acts of 1911, being sections 213.21 to 213.25 of the Michigan Compiled Laws.

Sec. 30924. (1) The lake board may receive and accept gifts or grants-in-aid for the purpose of implementing this part.

(2) The lake board may contract or make agreement with the federal government or any agency of the federal government whereby the federal government will pay the whole or any part of the costs of a project or will perform all or any part of the work connected with the project. The contract or agreement may include any specific terms required by act of congress or federal regulation as a condition for the participation of the federal government.

Sec. 30925. The department in carrying out the purposes of this part may receive and accept, on behalf of the state, gifts and grants-in-aid.

Sec. 30926. (1) Except as provided in subsection (2), the chairperson of the lake board shall advertise for bids. A contract shall be let to the lowest bidder giving adequate security for the performance of the contract, but the lake board shall reserve the right to reject any and all bids.

(2) The lake board may let a contract with a local, incorporated, nonprofit homeowner association, the membership of which is open on a nondiscriminatory basis to all residents within the geographic area to be assessed or serviced, without advertising for public bids. The homeowner association shall give adequate security for the performance of the contract.

(3) The local governing body may improve a lake as a work relief project pursuant to applicable provisions of law.

Sec. 30927. (1) Within 10 days after the letting of contracts or, in case of an appeal, then immediately after the appeal has been decided, the lake board shall make a computation of the entire cost of a project under this part that includes all preliminary costs and engineering and inspection costs incurred and all of the following:

(a) The fees and expenses of special commissioners.

(b) The compensation to be paid the board.

(c) The contracts for dredging or other work to be done on the project.

(d) The estimated cost of an appeal if the apportionment made by the lake board is not sustained.

(e) The estimated cost of inspection.

(f) The cost of publishing all notices required.

(g) All costs of the circuit court.

(h) Attorney fees for legal services in connection with the project.

(i) Interest on bonds for the first year, if bonds are to be issued.

(2) In addition to the amounts computed under subsection (1), the lake board may add not less than 10% or more than 15% of the gross sum to cover contingent expenses, including additional necessary hydrological studies by the department, and the entire sum so ascertained shall be considered to be the cost of the lake improvement project.

Sec. 30928. Whenever a public inland lake is to be improved, the department may intervene for the protection and conservation of the natural resources of the state.

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