HALF MOON LAKE
POLK COUNTY
FEASIBILITY STUDY RESULTS;
MANAGEMENT ALTERNATIVES

DRAFT

By

Office of Inland Lake Renewal

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HALF MOON LAKE
POLK COUNTY

INTRODUCTION

Many lakes throughout Wisconsin are undergoing accelerated aging (eutrophication) owing to cultural activities in the watershed. The resultant problems--prolific weed growth, nuisance algal blooms, deteriorating fisheries, impaired water quality and sediment infilling--pose a serious threat to the utilization of these lakes. International concern has stimulated considerable research on the nature and causes of the lake aging process, including the development of various control techniques. Although lake degradation and its causes have received substantial attention, and some lake rehabilitation approaches have been described, the field of lake management is still as much of a state-of-the-art as it is a science.

Approaches to lake restoration fall into two general categories: (1) methods to limit fertility and/or sedimentation in lakes, and (2) procedures to manage the consequences of lake aging. Nutrient or sediment limitation techniques treat underlying causes of lake problems. In contrast, techniques for managing the consequences of lake aging are cosmetic in nature. They enhance the usability of lakes without controlling the source of degradation. Many techniques used in lake restoration do not readily fall into a single category, as for example, biotic harvesting, which affects both species population directly (managing a consequence) and nutrient content within a lake. But there are major differences in the practical and theoretical considerations inherent in maximizing one effect over the other.

There are many difficulties associated with remedial efforts. Lakes are complicated ecosystems and the ability to predict the response of lake systems to various treatments is as yet limited. Moreover, each lake has its own "unique personality," which frustrates attempts to transfer results from one lake to another that appears to have similar problems. There are alos time constraints associated with lake renewal programs. The public wants prompt action and immediate results. This is seldom possible. A certain amount of pre-treatment information is required to formulate a well-founded remedial program.

In 1974, the State of Wisconsin passed a law (Chapter 33 of the State Statutes) that enabled lake communities to approach lake restoration in a positive way by creating a special purpose unit of government called lake districts. Once formed, a lake district can enlist the technical and financial assistance of the Department of Natural Resources in an effort to improve or protect lake water quality.

Half Moon Lake formed a lake district in 1975 and applied for both technical and financial assistance from the Department. As a result of their application a study of Half Moon Lake and respective watershed was undertaken. The study was started in 1976.

OBJECTIVES

The immediate objective of the one-year "feasibility study" at Half Moon Lake was to define:

1. a nutrient budget,
2. a water budget,
3. a characterization of inlake chemistries and biological processes,
4. a set of lake management alternatives, and to predict lake response to each alternative.

Essentially, the management plans for Half Moon Lake are under the categories of aeration and bilogical manipulation.

The management alternatives were drafted following an analysis of the data collected by by the lake district through their consulting firm.

RESULTS OF FEASIBILITY STUDY

The physical characteristics of Half Moon Lake and associated watershed are presented in Table 1.

TABLE 1. PHYSICAL CHARACTERISTICS OF HALF MOON LAKE (POLK COUNTY)

Watershed Size	5,100 acres
Lake Area (A)	579 acres
Ratio of Watershed Area to Lake Area	8.8
Average Annual Outflow	5 cfs
Lake Volume (V)	14,750 acre-feet
Maximum Depth	60 feet
Mean Depth (V/A)	25 feet

Watershed

The surface watershed draining towards Half Moon Lake is approximately 5,100 acres (Figure 1). The land-use within the watershed has been estimated to be 3,160 acres of agricultural lands, 1,160 acres of wetlands and 780 acres of forest.

The regional groundwater flow pattern is generally from the northwest towards the southeast. The local groundwater pattern about Half Moon Lake was determined by installation of observation wells about the lake. In general, the groundwater is flowing into the lake along the northwest shore of the lake and out of the lake along the southern 2/3 of the lake basin (see Figure 2). The groundwater inflow to the lake was estimated at 0.4 cfs (cubic feet per second) and the outflow at 3.4 cfs.

Generally, lakes are considered a product of their watershed, i.e., the nutrients that contribute to the growth of aquatic plants are mainly derived from runoff and erosion in the watershed. In an attempt to understand many of the processes occur-

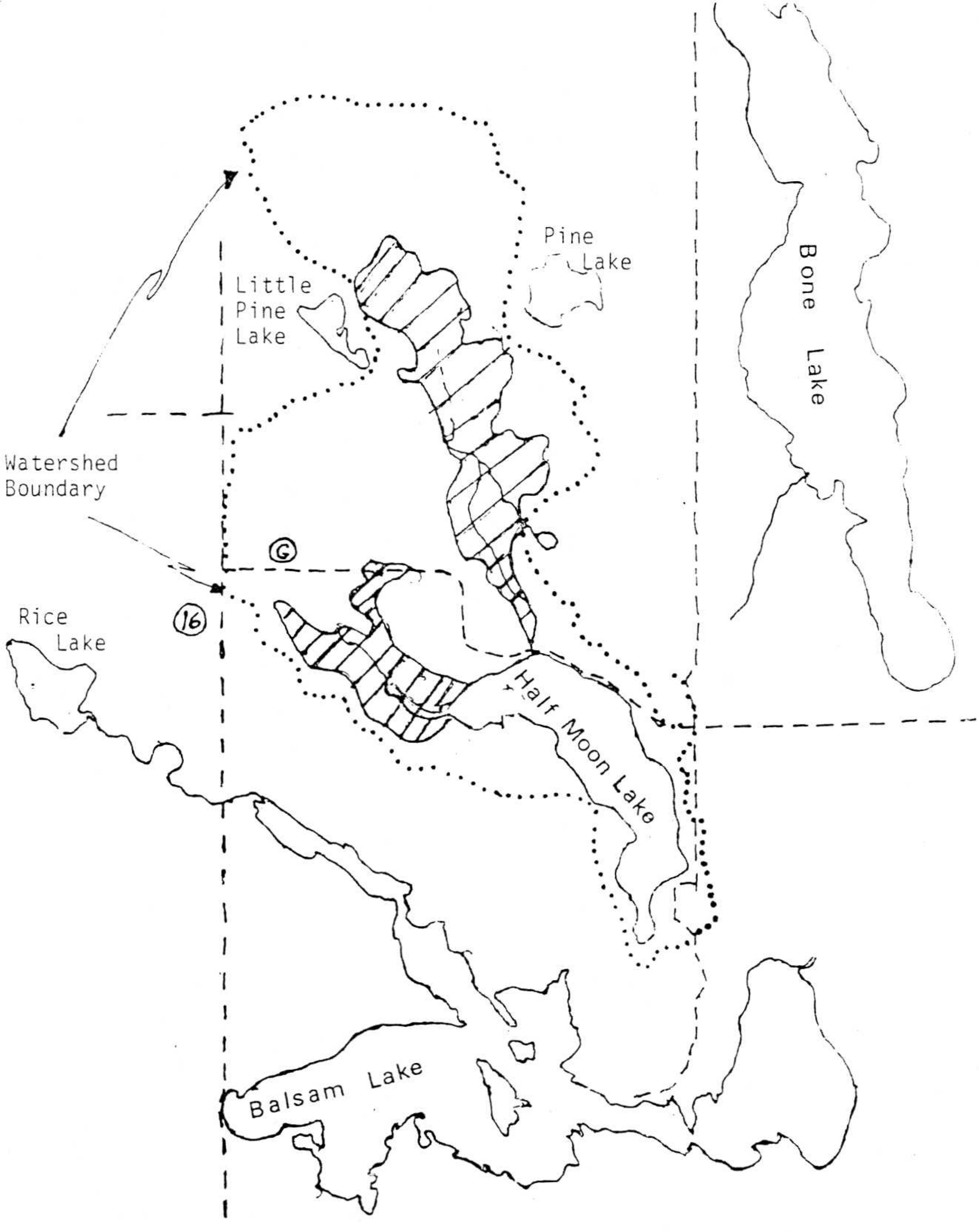


FIGURE: 1

Half Moon Lake Watershed Boundary

Watershed Wetlands

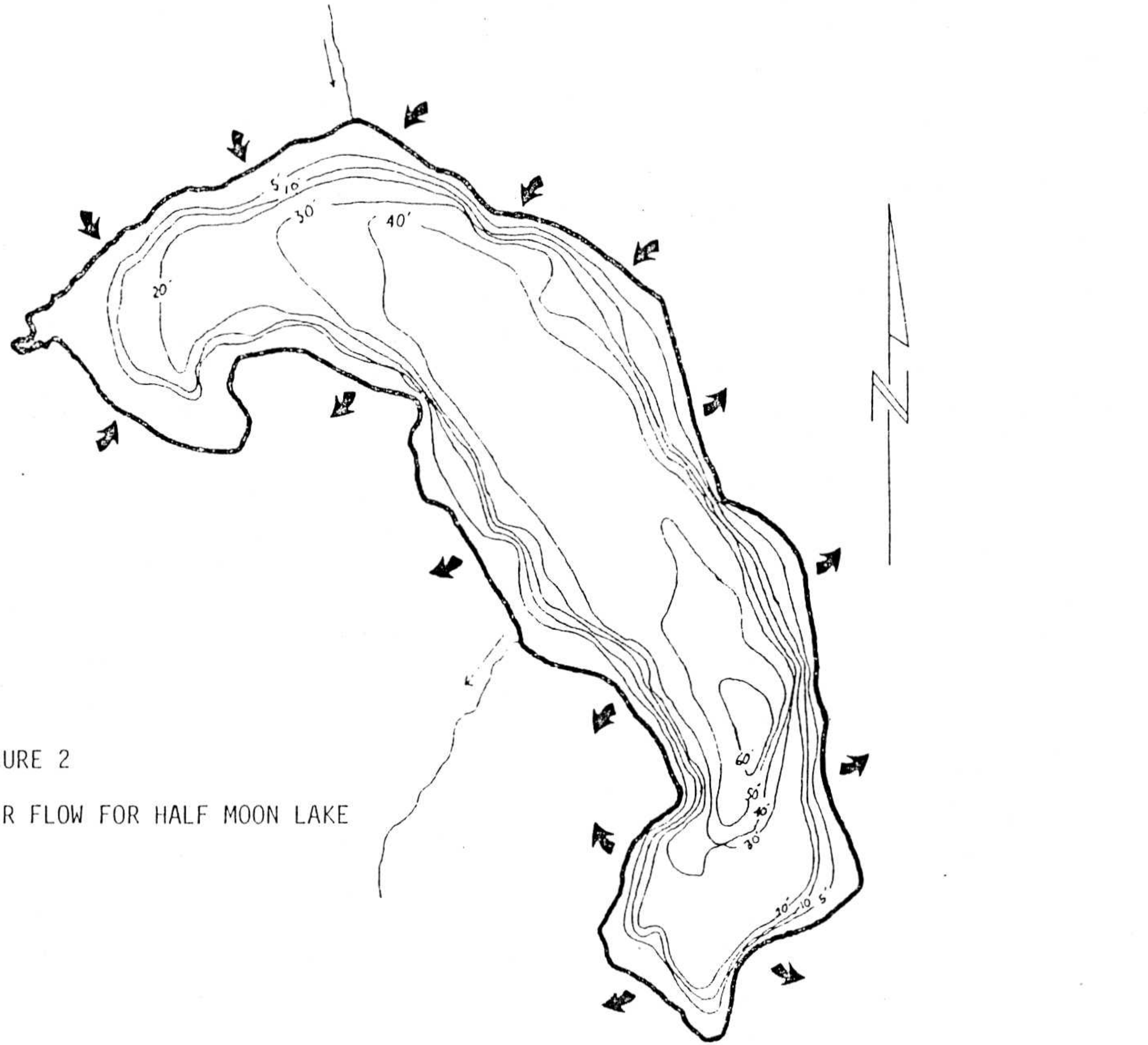


FIGURE 2

DIRECTION OF GROUNDWATER FLOW FOR HALF MOON LAKE ring in Half Moon Lake, a nutrient budget was estimated to describe the amount of phosphorus reaching the lake over the course of a year. From a nutrient control and management perspective, phosphorus is the key element of concern. Nitrogen influx to lakes can occur from a variety of uncontrollable sources, i.e., fixation of atmospheric nitrogen by some algae and direct atmospheric input. Phosphorus, however, is not a volatile element and is usually transported to lakes via surface runoff (Harder Creek), and through the groundwater (including septic tank leachate). Phosphorus is the more easily controlled element, therefore, further discussions about nutrients will only discuss phosphorus.

TABLE 2. PHOSPHORUS CONTRIBUTIONS TO HALF MOON LAKE, POLK COUNTY

SOURCE		lbs/yr. (kg/yr.)	Percent
1. Estimated budget using worst case for septic systems			
Watershed, surface runoff		1,012 (460	78
Groundwater		59 (27)	5
Septic Systems, worst case		62 (28)	5
Atmospheric		158 (72)	12
	TOTAL	1,291 (587)	100
2. Estimated budget using phosphorus contributions from septic systems in the groundwater inflow area only.			
Watershed, surface runoff		1,012 (460)	82
Groundwater		59 (27)	5
Septic Systems		11 (5)	1
Atmospheric		158 (72)	13
	TOTAL	1,240 (564)	101

The following data sources, extrapolations and assumptions were used in the process of constructing the phosphorus budget:

1. The amount of phosphorus contributed by surface runoff was determined using literature values for each type of land-use category.

2. Groundwater flow into and out of the lake were measured by the use of a series of observation wells installed and monitored during the course of the study. An average phosphorus concentration in the groundwater was 0.03 mg/l.

3. The septic system contributions assumed a worst case and an average situation.

   A. The worst case situation assumed 144 homes about the lake contributing phosphorus. There are 14 permanent homes and 130 seasonal homes. A phosphorus sorption of 80 percent was used for the soils. An average number of people occupying each home was 4 with each person contributing 2.2 gP/day for permanent occupancy and 1.8 P/day for seasonal occupancy. The length of occupancy for permanent residences was 365 days and 100 days for seasonal residences. Although the assumptions made for the septic systems are probably an overestimate, no consideration was given for phosphorus contributions from systems that experience periodic flooding. Therefore, the phosphorus desorption, flushing, and overland flow were not calculated. This may occur in some of the installations close to the lake.

   B. The septic system contributions from the groundwater <u>inflow</u> areas <u>only</u> were calculated using the above assumptions with the exception of the number of sites. The number of permanent dwellings were 3 and there were 17 seasonal dwellings.

The phosphorus loading from the watershed to Half Moon Lake has been plotted on a graph in Figure 3 that illustrates the trophic position of the lake relative to the degree of eutrophy. The three major trophic classification represented in Figure 3 are: Oligotrophic (very little nutrients in the lake--no algae problems), Mesotrophic (moderate amount of nutrients in the lake water--very seldom an algae problem) and Eutrophic (a nutrient rich lake with expected algae problems). The classification is a continuum and the higher a position plot on the scale, the more symptoms of lake eutrophy will be apparent. There are two plots on Figure 3. Positon 1 represents the nutrient loadings under worst case septic leachate conditions and position 2 represents the reasonable septic leachate conditions. The nutrient impact from the septic system leachate appears to be minimal in relation to the entire phosphorus budget to the lake, however, estimated nutrient loadings from septic systems since 1950 illustrate the change that may have occurred (Table 3).

"WORST CASE"

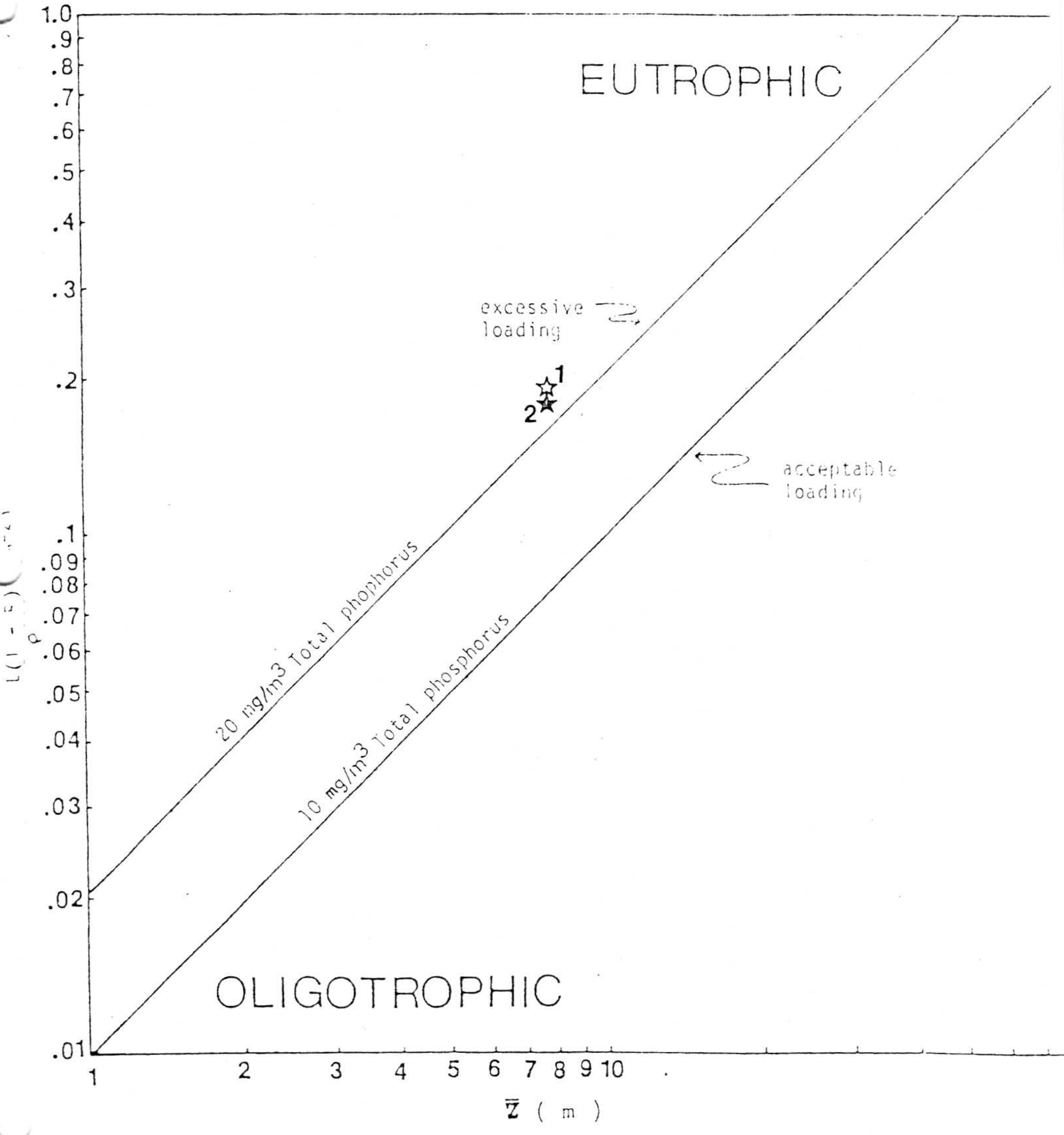
TABLE 3. ESTIMATED PHOSPHORUS LOADING TO HALF MOON LAKE FROM SEPTIC SYSTEM LEACHATE, 1950-1978
(Soil phosphorus retention = 80 percent, R_S=0.8)

Year	Number of Permanent	Lake Shore Homes Seasonal	Total Phosphorus Contribution (kg/yr)
1950	6	59	12.3
1968	11	107	22.5
1978	14	130	27.7

The assumptions for "worst case" may not reflect the actual loadings because of the extent of groundwater outflow moving away from the lake. However, increased development about the lake has potentially doubled the septic system leachate phosphorus loading to Half Moon Lake,

~~TABLE~~ 3

THE POSITION OF HALF MOON LAKE IN THE TROPHIC CONTINUUM
(AFTER DILLON AND RIGLER, 1975)
PLOT 1 INCLUDES "WORST CASE" SEPTIC SYSTEMS AND
PLOT 2 IS THE POSITION WITH PRESENT PHOSPHORUS LOADINGS.
UNDER THE PRESENT CONDITIONS, THE LAKE IS CONSIDERED ONLY SLIGHTLY EUTROPHIC.



Based on the estimated phosphorus loading to Half Moon Lake, the condition of the lake is considered slightly eutrophic. There are benefits to be derived from such a trophic classification. One such benefit is an expected increase in the amount of fish a lake will support. This rationale generally holds to a point. When a lake begins to be subjected to continuous nuisance algae blooms, there is a possibility of massive algae die-offs that may deplete much of the dissolved oxygen in the lake and cause summer fish kills or, more likely, a lake may experience winter fish kills. At this point the lake no longer becomes useful from a fisheries standpoint. In its present condition, Half Moon Lake does support an excellent sport fisheries without the problems of summer of winter fish kills because of low dissolved oxygen.

Water Quality

The water quality of Half Moon Lake appears to be reasonably good. There are several inlake parameters that are indicators of lake water quality.

Nutrients - The amounts of nutrients present in a lake is often indicative of lake fertility. There is generally a good correlation between phosphorus and nitrogen in solution and the productivity of a lake. The nitrogen compounds that are present may be in the form of organic nitrogen (a result of biological processes), and the inorganic forms of nitrate (NO_3-N) and ammonium (NH_4-N). There are also several forms of phosphorus in solution; organic phosphorus (a result of biological processes), and inorganic phosphorus. Nitrogen is essential for building new biological material (proteins) and phosphorus plays a major role in the production of essential sugars and is closely associated with biological energy transformations.

Phosphorus has become the element of most concern in studies of lake eutrophication. Phosphorus is usually the limiting element in the growth of aquatic plants, i.e., algae, and therefore has become the target for study. There exists a good correlation between phosphorus in solution and the amount of algae in a lake; the more available phosphorus in the lake the more the more algae that will be present. The phosphorus concentrations in Half Moon Lake during the spring for 1976, 1977 and 1978 were 20 parts per billion (μg/l). At this concentration of phosphorus in a lake, there should be no serious prolonged algae problems. Occassional algae accumulations may be noticed, however, the severity and duration should not interfer with the use of the lake.

Dissolved Oxygen

Dissolved oxygen is the most fundamental and important consideration in lakes. Dissolved oxygen is essential to the metabolism of all aquatic organisms. Hence the dynamics of oxygen distribution in lakes is paramount in understanding the distribution and physiological growth of aquatic organisms.

The distribution of dissolved oxygen also affects the solubility of many nutrients in the lake system. When the bottom waters overlying the sediments become anoxic (without oxygen), chemical changes can occur in the surface sediments which may allow essential nutrients such as phosphorus to be released into the water column. These changes in distribution of nutrients may result in rapid growth of many organisms capable of taking advantage of the change in nutrient concentrations. Population responses may only be transient, however, if long-term changes in oxygen regulated nutrient availability are sustained, the productivity of the entire lake can be severely altered.

The solubility of dissolved oxygen is affected by temperature, with solubility being greatest at colder temperatures. For example, at a temperature of 0^{o}C, pure water at saturation will contain approximately 14 parts per million (mg/l) of dissolved oxygen, while at 20^{o}C, pure water at saturation only contains approximately 8.8

parts per million (mg/l) of oxygen. Other factors affect the amount of oxygen in lakes, i.e., suspended solids, dissolved solids, oxygen production owing to plant photosynthesis.

Figure 4 illustrates the amount of dissolved oxygen present in Half Moon Lake during two critical time periods for two successive years. The dissolved oxygen profiles for the month of February indicates a substantial amount of oxygen is available in the entire lake and a conclusion can be made that there is little, if any, stress upon the aquatic organisms in Half Moon Lake during the winter months. During the summer months, dissolved oxygen was depleted to zero in the bottom waters (hypolimnion) of the lake. During the summer of 1977, aquatic organisms such as fish, zooplankton and bottom insects could not survive below a depth of 20-25 feet. Organisms that require oxygen, were limited to a habitat that was reduced in size.

The rate at which dissoved oxygen was being depleted in the bottom waters of Half Moon Lake was calculated to 0.05 mg/l/day on a weighted mean average for the entire hypolimnion. Figure 5 represents lines of equal dissolved oxygen concentrations with time and depth. During the end of April, the dissolved oxygen profile with depth suggests the lake did not mix shortly after ice out. Normally lakes mix to the bottom during this time and dissolved oxygen is distributed throughout the entire lake at or near saturated concentrations. The mixing process also occurs during late fall and the dissolved oxygen concentrations during October (Figure 5) are indicative of complete mixing with oxygen distribution completely to the bottom of the lake. The mixing process during the spirng and fall are dependent upon the lake water temperature and thereby water density being equal throughout the entire water column. Wind action at the surface of the lake will create lake currents that easily distribute surface water saturated with dissolved oxygen throughout the lake. The morphometry of Half Moon Lake basin and the semi-sheltered setting contribute to prevent the lake from mixing during the spring before the surface water

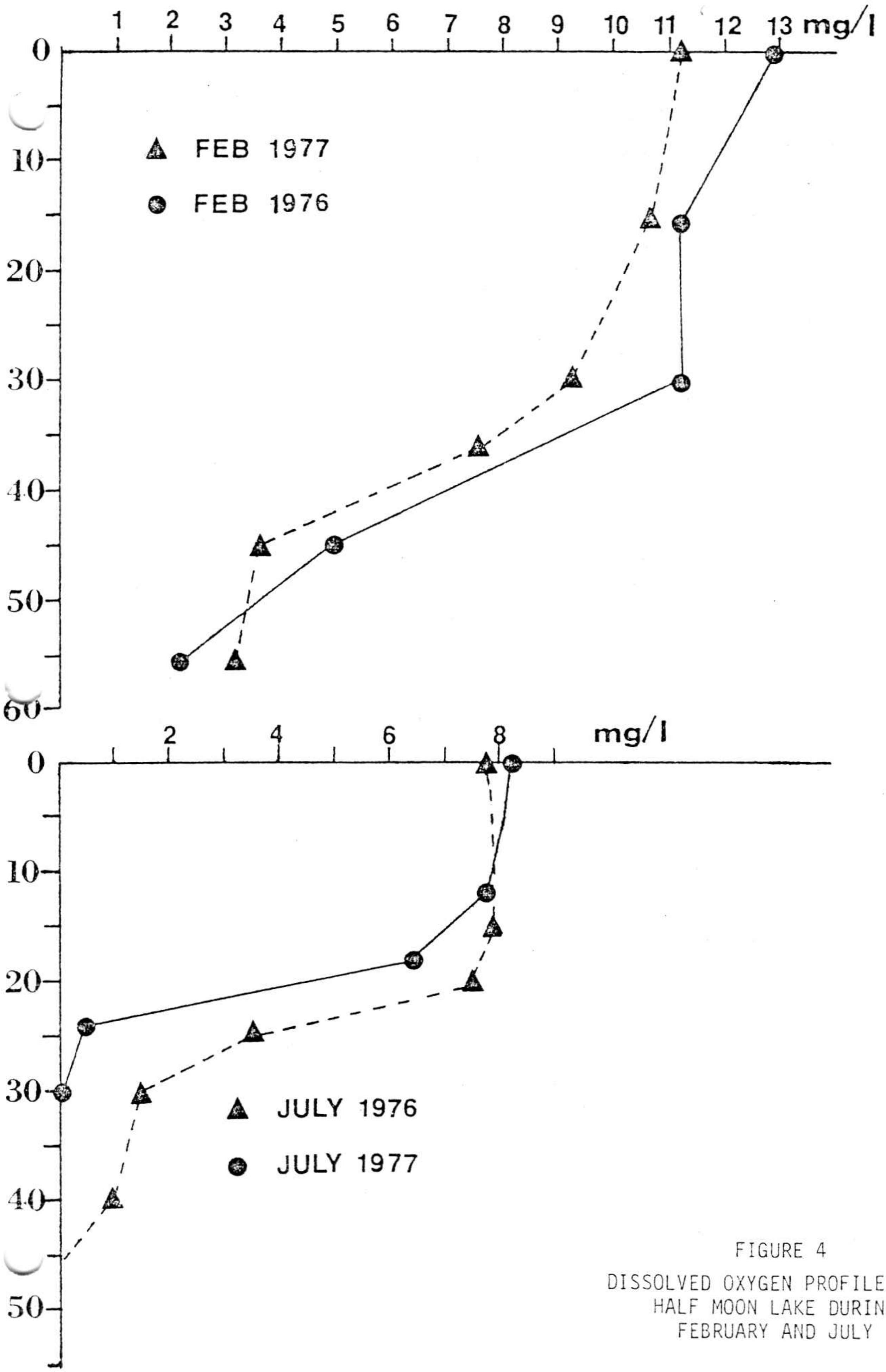


FIGURE 4

DISSOLVED OXYGEN PROFILES FOR HALF MOON LAKE DURING FEBRUARY AND JULY

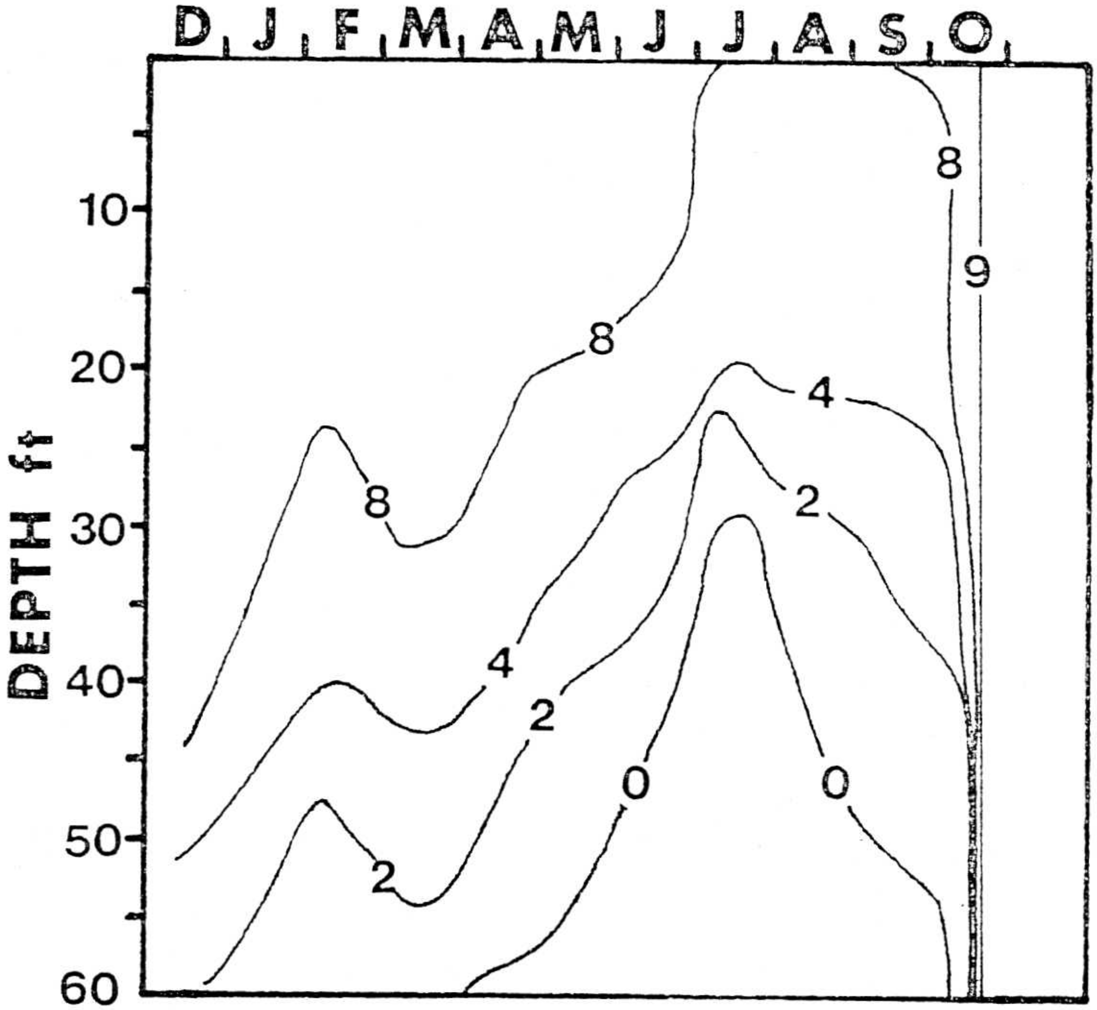


FIGURE 5

DISSOLVED OXYGEN ISOPLETHS (mg/l) FOR HALF MOON LAKE are warmed by solar radiation. Once the surface waters are warmed to temperatures above the bottom waters, a density gradient prevents the lake from further mixing to the deeper zones. If warm weather and calm conditions occurs shortly after ice out on the lake, a temperature, and therefore density gradient, will rapidly set up in the lake and inhibit complete mixing.

BIOLOGICAL CHARACTERISTICS - Phytoplankton

Phytoplankton are microscopic plants (algae) that occur throughout all lakes. Together with the larger attached aquatic plants (macrophytes), algae are the primary foundation of the aquatic food chain that ultimately culminates in predator fish populations. Phytoplankton have the ability to combine light energy from the sun and inorganic nutrients of carbon, phosphorus, nitrogen plus minor elements to construct new biological material (sugars, proteins, etc.). The process by which this occurs is called photosynthesis and the process can be summarized in the universally known equation:

$$6\ CO_2 + 12\ H_2O \xrightarrow{\text{light}} \underset{\text{(Sugar)}}{C_2H_{12}O_6} + 6\ O_2$$

The equation is an oversimplification of a complex metabolic pathway. However, the expression describes the initial reactions. From the process of photosynthesis, organic material is formed to be utilized by the small animals in lakes called zooplankton. These herbivorous animals are preyed upon by larger animals such as fish.

Algae are classified, in part, according to their respective pigmentation. All algae contain the basic photosynthetic pigment chlorophyll _a_. This pigment imparts a green color to the algae. The major taxonomic grouping consists of:

The blue-green algae which are so named because the cells contain, in addition to chlorophyll, a pigment called phycocyanin which gives them a dark green to blue tinge. When blue-green algae become abundant, some species will float on the surface of the lake and cause unsightly mats that wash up on the beaches.

The green algae contains only one significant pigment, the chlorophylls. If they become too numerous (algae blooms) in the lake, they might display a green cast to the water.

The diatoms are characterized by the presence of silica in their cell walls and by the color of various pigments giving a yellow, green or brown coloration to lake waters.

The cryptomonods are a flagellated algae that make some mobility possible. Not much is known about this group, however, they usually dominate during the late winter and early spring. Their mobility may be helpful in maintaining an optimal depth under ice.

Algal Composition

The section of the consultant's report dealing with algal composition and biomass had several problems which allows for only a cursory interpretation.

There are several statements that can be made. (1) Diatoms are present in Half Moon Lake throughout the entire summer season. The dominance by diatoms usually indicates reasonable water quality. Diatoms require silica for the formation of cells and it is not unusual for the diatom population to expand during the spring providing there is enough phosphorus and nitrogen, until the available silica has been utilized and the diatom population usually "crashes" by late spring. The presence of diatoms during the summer in Half Moon Lake suggests that silica is in sufficient supply for diatom growth and/or another nutrient, i.e. phosphorus may be limiting. There is a hypothesis expressed that suggests if enough phosphorus is supplied to such a lake as Half Moon, the diatoms will use all the available silica in the spring and the population will collapse, followed by green and blue-green algae which will fill the niche previously occupied by the diatoms. If the diatom population dominates during July and August as the data indicates, then Half Moon Lake water quality should be considered good. (2) Blue-green algae, i.e., Anabaena, appeared to dominate the algae assemblage during May and early June. The dominance by blue-green algae is usually an indication that a lake is relatively fertile. The degree of fertility is often expressed by the level of biomass of the algae present. The dominance by the blue-green algae during the spring and not during the summer months suggests the lake is showing signs of increased fertility, however, water transparency measurement during that time indicate the biomass is not considered excessive.

BIOLOGICAL CHARACTERISTICS - MACROPHYTES (ATTACHED AQUATIC PLANTS)

Attached aquatic plants (macrophytes) play a very important role in lake ecosystems. A zone of macrophytes extending about the near-shore areas offer habitat for fish and wildlife. There are many aquatic insects that inhabit beds of macrophyte and are an important source of fish food. The root systems are helpful in stabilizing the near-shore sediments from erosion. Excessive abundance of macrophytes can become a detriment to the developmant of a good sport fishery, interfere with swimming, boating, etc. The macrophyte survey completed in 1977 for Half Moon Lake indicated very few problems with over abundance. In general, the macrophyte development in Half Moon Lake is limited to a narrow width of shoreline less than 10 feet deep with eel grass (Vallesnaria americana) the most abundant and dominant species being observed at 73 percent of the sampling locations. A map describing the area of macrophyte growth is presented in Figure 6. A species list of aquatic plants identified from Half Moon Lake is presented in Table 4.

AQUATIC MACROPHYTE MAP

FIGURE 6

TABLE 4. A LIST OF THE DOMINANT MACROPHYTES IDENTIFIED IN HALF MOON LAKE, 1977 .

SPECIES	COMMON NAME
Anacharis canadensis	waterweed
Ceratophyllum demersum	coontail
Chara sp.	muskgrass
Myriophyllum sp.	water milfoil
Najas flexilis	spiny naid
Potamogeton sp.	narrow pondweed
Potamogeton Robbinsii	Robins pondweed
Potamogeton zosteriformes	flat stem pondweed
Vallisnario americana	eel gras

BIOLOGICAL - FISH

The fish assemblage in Half Moon Lake conssits of walleye, northern pike, largemouth bass, perch and panfish. The walleye was the dominant game fish observed in a fish survey undertaken by the Department, with perch being the second most common fish. The size range in the walleye population suggest good natural reproduction is occurring in Half Moon Lake.

MANAGEMENT ALTERNATIVES

Watershed

Half Moon Lake presently has a reasonable water quality, however, there are watershed practices that should be dealt with as the need may arise in order to protect an already good quality lake.

1. Control of Soil Erosion for Construction Sites About Lake

The most effective method of controlling erosion and sedimentation is careful site planning. Well established and well maintained vegetation is a major deterrent to soil erosion because it shields the soil from raindrop impact and increases flow friction (resistance). Root systems may increase soil porosity, permitting greater water infiltration and reinforcing the soil mass. Stems, stalks, leaves, and roots break up flow patterns, increase flow friction, and cause deposition of some soil particles. Plants also remove water from the soil by transpiration, so the soil can absorb more water, potentially decreasing the amount of runoff. It is important to recognize that planting and maintenance of vegetation is practical only on slopes flatter than three horizontal to one vertical. Mature sod cover will almost completely prevent water erosion in many circumstances. Mature forests reduce water erosion to as little as one-thousandth of the rate on unprotected disturbed soils. Accordingly, every effort should be made to disturb as little existing vegetation as possible, and to reestablish good cover as soon as possible after grading.

Temporary measures to minimize soil loss typically should be used if the soil is to remain exposed for more than 30 days. Permanent structural measures must be installed prior to or during active construction, not after.

Fast-growing annual and perennial grasses may be used on partially completed construction projects to protect them from erosion for short periods of time. Completion of final grading during seasons unfavorable for permanent vegetative stabilization may necessitate temporary structural surface stabilization. Certain areas such as drainageways, cut and fill slopes, borrow pit areas, excavations and soil stockpiles often require immediate structural surface stabilization, although this need may be temporary.

The need for temporary stabilization generally should be avoided, as it is costly and rarely can be salvaged or incorporated into final protective measures.

Permanent vegetative stabilization should be long-lived and require minimal care or maintenance. Grasses and legumes are generally superior to shrubs and ground covers, because of their more complex root systems. The selection of plant material should be based upon specific site growth expectancies, the purpose of the planting, and foreseeable assured level of maintenance activities. Any representation that a particular plant material is proper for a given slope, soil condition, and maintenance expectancy should be viewed skeptically unless the performance of comparable installations in the general area provides certainty.

The more fertile surface layer of the soil, if present, is usually removed and stockpiled during grading activities. Typically, exposed subsurface layers are less fertile, have lower organic matter content, and are more susceptible to erosion than surface soil horizons. For this reason, the physical and chemical properties of newly exposed soils should be considered. The principal chemical factors are nutritive elements such as nitrogen, phosphorus, magnesium, potassium, and occasionally certain trace elements. Systematic soil analyses of various horizons performed during the site investigation can be helpful in estimating the plant requirements and the proper application of fertilizers and other conditioning materials. For plant growth, factors such as soil texture, soil drainage, porosity, degree of aeration, structure, degree of compaction, soil temperature, slope gradient, available nutrients, and exposure to the sun and wind must be carefully considered.

Prior to establishment of permanent vegetation a protective layer of mulching is an important erosion control measure even when no vegetation is used, because: 1) it protects the soil against erosion, 2) it is also important when establishing vegetation, particularly grasses and legumes, as it prevents seeds, fertilizer, and other soil additives from washing away, 3) improves capacity for rainfall infiltration into the soil, 4) prevents wide variations in soil temperature, 5) encourages retention of moisture by reducing surface evaporation, and 6) shields delicate young plants. The most common mulch materials are hay, small grain straw, wood chips, jute matting, glass fiber netting, plastic and asphalt emulsions, and various paper products. Most fiber mulches require immediate anchoring to prevent dispersal. Using plastic sheeting as mulch is unwise because direct sunlight may cause it to kill seeds and plants.

2. Control of Nutrients/Sediments in Overland Flow During Storm Events

Where the property has already been extensively developed, the sculptured, manicured lawns right down to the water's edge should be modified by the reintroduction of locally common vegetation. It is recommended that a strip of land paralleling the shoreline and extending inland from the water be allowed to develop with vegetation. This can be accomplished by the selective planting of terrestrial species observed growing in this zone at other sites around the lake where development has not yet occurred. In surveying the surrounding habitats for selection of the species to be incorporated, attention should be paid to the comparison and contrast of the two areas with respect to soil type, moisture content, depth of water table, and slope.

In selecting species for incorporation in the buffer zone, a combination of deep-rooted and shallow-rooted plants should be considered for optimal drainage interception as well as inclusion of a suitable mixture of ground species. This will, ideally, result in a three-storied complex of tall trees, shorter trees and shrubs, and ground level vegetation, such as ferns, creepers, and grasses. When selecting the species to be used, their relative compatibility to one another must be considered.

While much of the nutrient uptake by the vegetative buffer strip may be expected to return in leaf fall at the onset of winter, any interruption of the flow of nutrients to algae and weeds during the spring and summer growing season helps. Raking of the fallen leaves for decomposition in a compost pile set well back from the shore will further help reduce the nutrient loading to the lake.

Home owners appear to take considerable pride in their lawns. This same pride, when applied to the lake property setting, however, must be redirected towards the more environmentally beneficial ramifications of vegetative buffer strip landscaping.

3. Lawn Fertilization

Lawn fertilizaters should only be judicously applied. As phosphates from lawn fertilizers migrate through soils as a result of over fertilization, available sites for soil attachment are occupied. When this occurs in the zone of septic system leachate, the effluent phosphates from domestic wastes are transported into the groundwater and increases the possiblity of transport to the lake. The soil retention capacity for phosphate is a finite function and once the phosphate sites are occupied, their value is negated as a sorption area for phosphorus. Care must be exercised in lawn fertilization.

INLAKE

The most conspicuous inlake problem associated with Half Moon Lake is related to dissolved oxygen. The data indicates the lake does not mix completely during the spring and this results in low dissolved oxygen throughout the bottom waters. During the summer, the lake water below 20 feet was completely devoid of oxygen. There are several solutions to this problem:

1. Total aeration/circulation of the lake during the spring and fall to completely mix and ensure good dissolved oxygen throughout the entire body of water. This can be accomplished by placing an air compressor on shore and placing a distribution conduit from the compressor to the deepest part of the lake. The end of the conduit is capped and small holes are drilled at the distill (farthest from the compressor) end to allow the compressed air to escape. The rising bubbles will entrain lake water and eventually circulate the entire water mass. The complete mixing of the water mass allows the entire system to come in contact with the atmosphere where reaeration occurs. The size and number of compressors and distribution systems are determined by the area and depth of the lake. There is no defined method other than past experiences to define the type of system necessary for a given lake. Half Moon Lake would probably require a compressor capable of 250 cfm and distribution systems, located at the deep basin, 60 feet, and placed parallel to the shore to the 40-foot depth in the western end of the lake.

   The objective of a spring and fall aeration/circulation system is to maintain dissolved oxygen at saturated conditions throughout the entire lake for some period of time, i.e., 2-3 weeks. Because dissolved oxygen saturation is dependent upon water temperatures, the system is best operated at lower temperatures, i.e., as soon as the ice is off the lake. When the system is shut down, the entire lake should be at the highest dissolved oxygen level possible. Under these conditions, the whole lake becomes a habitat for fish and other aquatic animals. As the summer progresses, the dissolved oxygen in the deeper waters will gradually decline. The relatively low dissolved oxygen depletion rates for Half Moon Lake suggest the deeper water should maintain some level of dissolved oxygen up to 90 days.

   The cost of such an aeration system is estimated to be $15,000-$20,000.

2. <u>Hypolimnetic aeration</u> of the deeper waters during the summer could be accomplished while maintaining thermal stratification. There are several systems available to accomplish this task. Based on a German design, a compressor would be required that could produce an airflow of at least 40 cubic feet per minute (cfm) at a pressure of 25 pounds per square inch (psi). The design and fabrication of such a unit in addition to a compressor could approach a cost of $50,000-$75,000.

   The advantage of such an aeration is that the bottom waters can be completely oxygenated throughout the summer without increasing the water temperatures. By maintaining low temperatures, the decomposition processes are slower and dissolved oxygen depletion processes are less. Also, phosphorus release from sediments can be controlled, providing enough dissolved iron is present. Additional fish and animal habitat can be a major benefit from such a system. A cold water fishery could be established.

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Any management alternative selected by the lake district that requires Department of Natural Resources permits and/or more than $25,000 of state funds will be evaluated by completion of an Environmental Impact Assessment (EIA). The EIA will provide an opportunity for public review and comment on its findings and will determine the need for an Environmental Impact Statement (EIS). If the EIA demonstrates that the selected management alternative will significantly affect the quality of the human environment, the Department will prepare an EIS prior to project approval.

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