

Water-Supply Bulletin 42, Part 3

# DATA ON SELECTED LAKES IN WASHINGTON

## Part 3

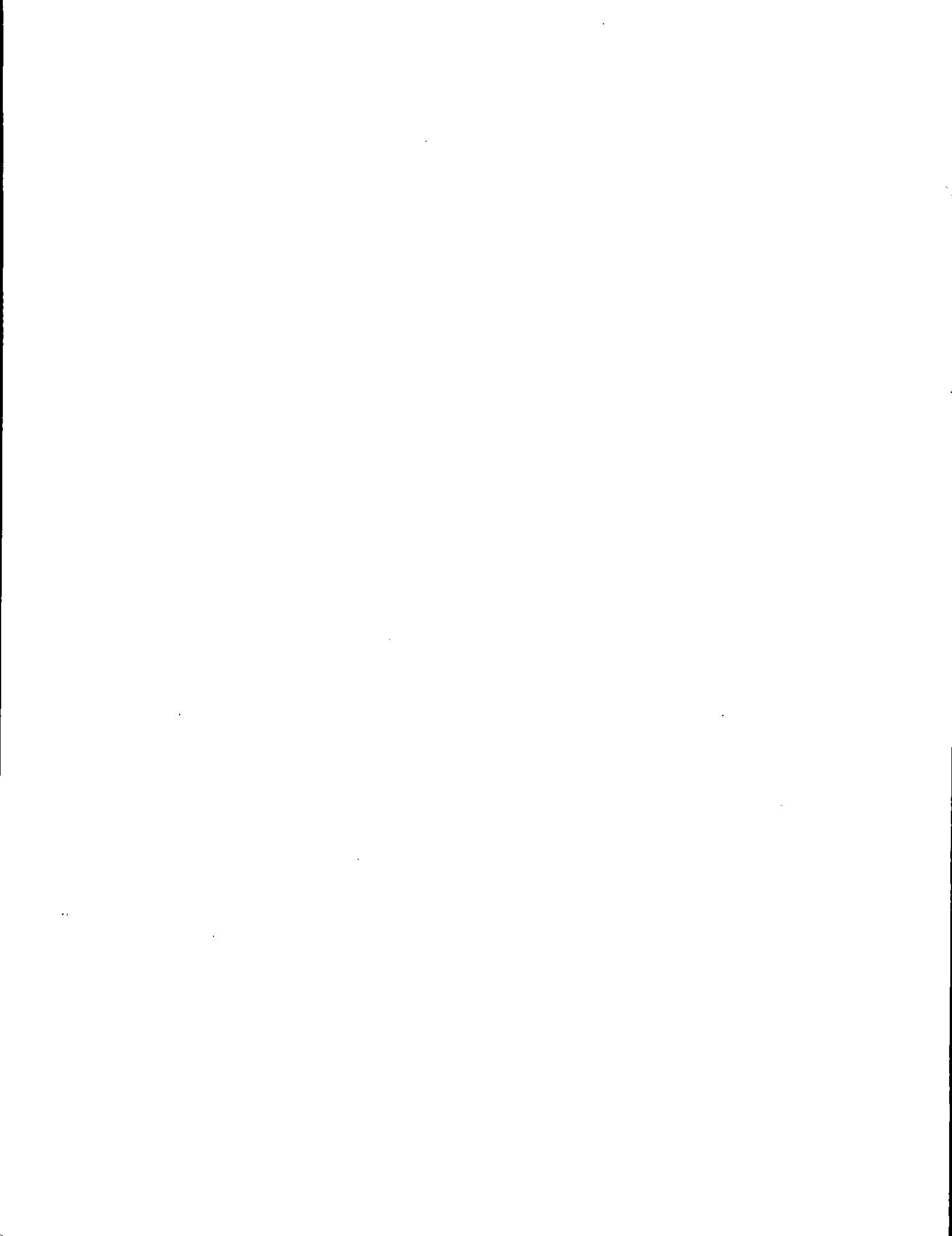


WASHINGTON STATE DEPARTMENT OF ECOLOGY

1976

Prepared cooperatively by the  
United States Department of the Interior  
Geological Survey





STATE OF WASHINGTON  
Daniel J. Evans, Governor

DEPARTMENT OF ECOLOGY  
John A. Biggs, Director

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PART 3

By

G. C. Bortleson, G. T. Higgins, J. B. McConnell,  
and J. K. Innes

of the  
United States Geological Survey

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## ILLUSTRATION

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FIGURE 1. Map showing locations of lakes studied-----

3

The following factors are provided for conversion of English values to metric values:

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<u>Multiply</u>	<u>By</u>	<u>To obtain</u>
Feet (ft)	0.3048	metres (m)
Acres	.4047	hectares (ha)
	.004047	square kilometres (km <sup>2</sup> )
Square miles (sq mi)	2.590	square kilometres (km <sup>2</sup> )
Acre-feet (acre-ft)	.001233	cubic hectometres (hm <sup>3</sup> )
Cubic feet (ft <sup>3</sup> )	.02832	cubic metres (m <sup>3</sup> )
Cubic feet per second (ft <sup>3</sup> /s)	.02832	cubic metres per second (m <sup>3</sup> /s)
Pounds (lbs)	.4536	kilograms (kg)

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### ABSTRACT

Chemical, biological, and physical data from 28 lakes in Washington are included in the report. For each lake there is a description of the physical setting, a general discussion of water quality, a bathymetric map, and an aerial photograph. The basic data include depth profiles of dissolved-oxygen concentration and temperature. Each lake was sampled four times, from winter to late summer.

### INTRODUCTION

Washington has more than 7,800 lakes, ponds, and reservoirs (Wolcott, 1964 and 1965), many of which provide exceptional recreational opportunities and supply water for agricultural, municipal, and industrial purposes. In addition, the lake shorelines attract ever-increasing home construction and recreational development. As more demands are placed on these lakes and their basins, potential problems of nutrient enrichment and water-quality deterioration may develop. In order to detect any present or potential conditions of water-quality impairment, it is essential that existing conditions in Washington's lakes be investigated and defined.

### Purpose and Scope

Although both the importance and value of the Washington lakes are widely recognized, the quantity and type of information currently available for most of the lakes are not adequate to provide the understanding needed for wise management of the lakes. Thus, the need to obtain additional information about lakes resulted in the initiation in 1970 of a cooperative program between the Washington Department of Ecology and the U.S. Geological Survey, whereby selected lakes in Washington would be investigated.

In general, the study consists of a data-collection program designed to (1) document the present water quality and the overall status of the lakes, and (2) provide basic data pertaining to the physical, cultural, and water-quality characteristics of lakes in order to establish a base of reference that will allow periodic appraisals of future lake conditions.

This is the third in a series of reports on selected lakes in Washington. The first and second reports (Collings, 1973; Bortleson and others, 1974) discuss 32 lakes throughout the State, and this report discusses an additional 28 lakes in western and northeastern Washington (fig. 1). Two of the 28 lakes have arms separated by narrow channels and each arm is discussed as an individual lake.

### Acknowledgments

The authors gratefully acknowledge the assistance of the State of Washington Department of Game for permission to reproduce many of the lake bathymetric maps. Many other bathymetric maps were reproduced from reports by Wolcott (1964, 1965). Special appreciation is expressed to several lakeside residents for their diligence in reading staff gages for determining lake levels.



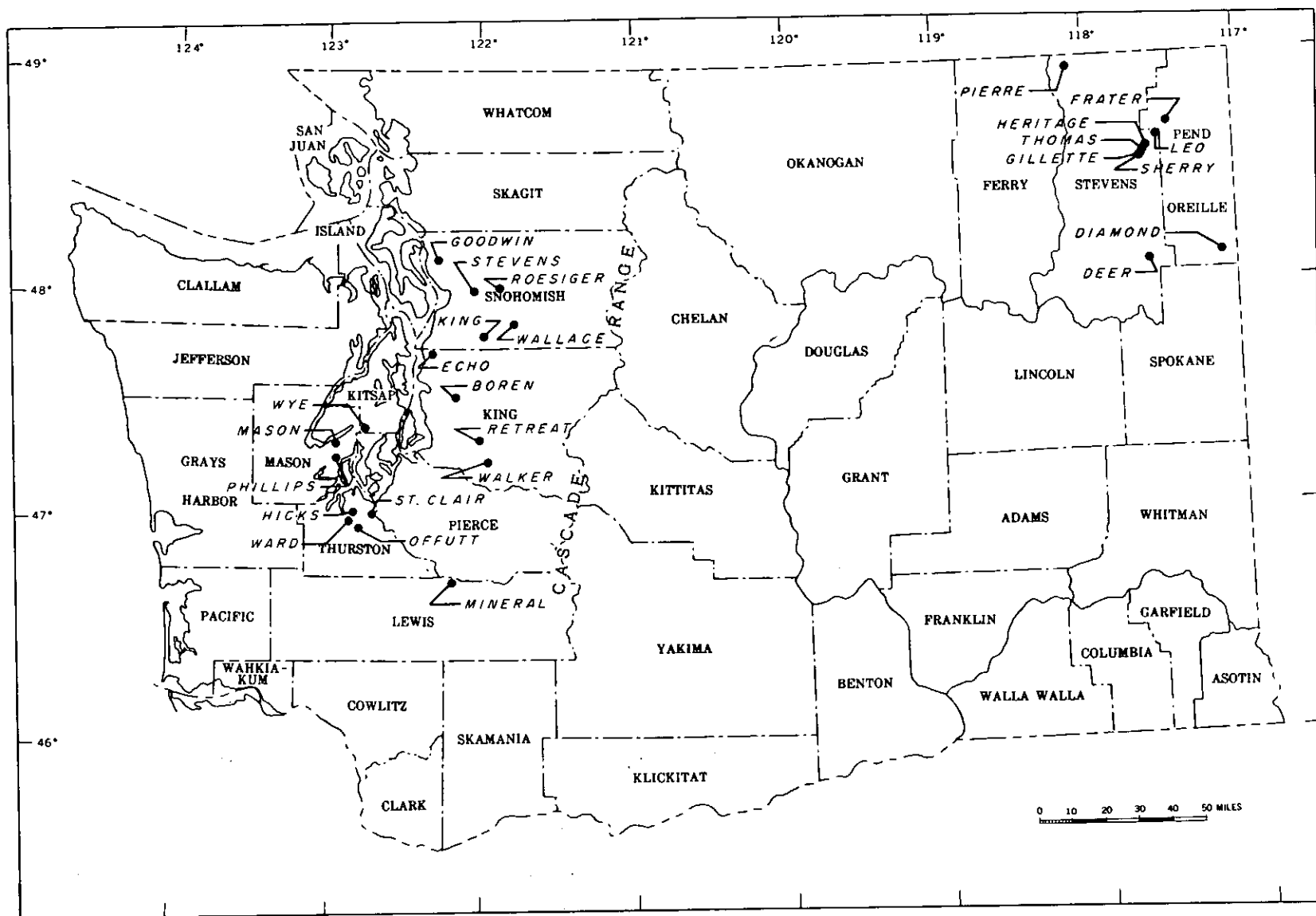


FIGURE 1.--Locations of lakes studied in 1972.

### Data Collected and Definitions

In this report, the data collected provide a basis for evaluating future changes. Most of the field data were collected during (1) the winter water-mixing period; (2) spring, shortly after thermal stratification begins; (3) summer, during advanced thermal stratification; and (4) late summer, at maximum thermal stratification. The sample sites were generally near the deepest part of the lake and are considered to be reasonably representative of the physical and chemical characteristics of the entire lake. Data to define variations in temperature and dissolved oxygen (DO) concentration at different depths were collected in the field with portable instruments. Water samples for mineral, nutrient, pH, and color analyses were collected at depths of 3 feet below the water surface and 4 to 5 feet above the lake bottom. The mineral and nutrient analyses were performed by U.S. Geological Survey laboratories using procedures described by Brown, Skougstad, and Fishman (1970). Analyses for chlorophyll a and fecal-coliform bacteria were performed using procedures described by Slack and others (1973).

Before presenting the results of each lake survey, an explanation of terms used in describing individual lakes is given below. The definitions of additional limnological and hydrological terms, used throughout the report, are found in the glossary (p.11). The parameters are discussed in the sequence they appear on the data sheets.

Identification number. The lakes are listed in this report in accordance with a numbering system used nationwide by the U.S. Geological Survey to designate data-collection stations in stream basins. Each lake has a unique number which, like the lake name, is a means of identification.

Location. Latitude, longitude, township, range, and section were determined from U.S. Geological Survey topographic maps. The location given is at the lake outlet. For lakes without outlets, the southernmost shoreline point is used. Directions and distance from prominent landmarks, such as towns, roads, and rivers, are included to aid in rapid, easy location. The major drainage system of each lake is indicated.

Physical characteristics of lake. From topographic and bathymetric maps of the lake, the following physical parameters were determined:

Drainage area.--The surface-drainage area, in square miles (sq mi), is the area that contributes water to the lake. These areas were delineated on U.S. Geological Survey topographic maps and measured by planimeter.

Surface altitude.--A single altitude in feet (ft) above mean sea level (msl), obtained from topographic maps, is given for each of the lakes.

Surface area (A).--The surface area of the lake, in acres, was obtained from planimetry of the lake outline.

Volume (V).--Lake volume, in acre-feet, was obtained by computing and then summing the volumes of each stratum of water between successive contours on the bathymetric map. Because lake volume can vary between seasons and from year to year, the volume figures reported (as well as other morphometric data) are intended only to describe the general size of the lake.

Mean depth ( $\bar{Z}$ ).--The mean depth, in feet, for a specified lake stage, is obtained by dividing the volume of the lake by its area.

Maximum depth ( $Z_m$ ).--The difference in elevation, in feet, between the bottom and the surface of the lake.

Length of shoreline (L).--The distance around, or perimeter, in feet, of the water surface touching the shore at a specified lake stage.

Shoreline configuration ( $D_L$ ).--A dimensionless ratio of length of shoreline to the circumference of a circle having an area equal to that of the lake, given as

$$D_L = \frac{L}{2\sqrt{\pi A}}$$

This quantity may be regarded as an index of the geological and littoral processes affecting the shape of the lake.  $D_L$  is always greater than unity.

Nearly circular lakes have values near unity, subcircular lakes have slightly greater  $D_L$  values and elongate lakes have the highest  $D_L$  values. High  $D_L$  values are common to lakes formed along old drainages or by the damming of streams to form a lake in the valley behind the dam.

High values for shoreline configuration suggest the presence of shallow water and protected bays--areas suitable for plant growth--and also indicate an increase in contact between land and water. Therefore, shoreline configuration is often an indirect indicator of plant growth capacity and enrichment potential from nearshore development and runoff.

Development of volume ( $D_V$ ).--The development of volume is defined as the ratio of the mean depth ( $\bar{Z}$ ) to maximum depth ( $Z_m$ ). Thus, lakes with a low  $D_V$  ratio are usually conical-shaped depressions, whereas lakes with a high  $D_V$  ratio are steep-sided and have flat bottoms. Shallow lakes which have large values for development of volume ( $D_V$ ) tend to provide greater opportunity for exposure of bottom sediments to overlying water and for circulation of bottom nutrients.

Bottom slope ( $Z_r$ ).--The slope profile of a lake bottom, expressed as a percentage ratio of the maximum depth to the mean lake diameter, referred to by Hutchinson (1957, p. 167) as relative depth, given as

$$Z_r = \frac{Z_m \times 50 \times \sqrt{\pi}}{\sqrt{A}} .$$

Basin geology and soils. Information on basin geology and soils was obtained from existing geologic maps and reports.

Land use. The drainage basins of the lakes were partitioned into various generalized land-use categories. Values given reflect the percentages of the basin used primarily for forests or for residential urban, residential suburban or agricultural development. The lake surface is also given as a percentage of the total drainage basin. A general description of the land-use categories is as follows:

- a. Residential urban.--Predominant use is for single-family residences on small lots, where apartment complexes and commercial or industrial activities also may be present.
- b. Residential suburban.--Predominant use is single-family residences.
- c. Agricultural.--Pasture or cropland.
- d. Forest or unproductive.--Public and private forest lands and tree farms. Lands may include cleared or fallow unproductive land, meadows, wetlands, and seasonal recreational areas.
- e. Lake surfaces.--Includes surface areas of the lake and upstream tributary lakes.

Nearshore residential development. The percentage of the shoreline occupied by residential development was determined from aerial photographs.

Number of nearshore homes. The number of nearshore dwellings, and whether the homes were mostly seasonal or permanent residences, were determined from field observations.

Surface-water inflow and outflow. Locations of inflow and outflow streams are shown on the bathymetric maps. Miscellaneous measurements of outflow, reported in cubic feet per second ( $\text{ft}^3/\text{s}$ ), are given for lakes in which the outflow is controlled by natural conditions. All discharge measurements made at inflow and outflow sites during the 1972 water year were published by the U.S. Geological Survey (1973).

Lake stage. The maximum variation in lake stage, in feet, is given for the period of observation. The frequency of readings was at least once weekly unless otherwise noted.

Macrophytes. These are large plants that can be seen without magnification. The rooted aquatic-plant growth was assessed according to the percentage of the lakeshore and water-surface area covered by emerged and (or) floating plants and the percentage of the lake bottom covered by submersed plants. Examples of emerged plants include cattails and sedges in which the leaves or other structures extend above the water surface. In this report, rooted aquatic plants with floating leaves, such as waterlilies and watershield, are considered emerged. Submersed plants, such as hornwort and pondweeds, complete their life cycle and live entirely under the surface of the water. The plants were identified according to the definitions of Steward, Dennis, and Gilkey (1963) or Fassett (1969).

Bathymetric map. Depth contours on the map were made from soundings taken by the State of Washington Department of Game on the survey date given. The water-quality sampling site (symbol  $\blacktriangledown$ ) and fecal-coliform sampling sites (symbol  $\bullet$ ) are shown on the bathymetric map of each lake.

Aerial photograph. A vertical-view, black-and-white aerial photograph is shown for each lake. The approximate scale and the date of aerial photography is indicated.

Water-quality data. The water-quality variables measured are reviewed briefly for each parameter.

Major chemical constituents.--In freshwater, the major anions are bicarbonate, carbonate, sulfate, chloride, fluoride, and, to a lesser extent, nitrate nitrogen and orthophosphate phosphorus. These anions are associated with the principal cations--calcium, sodium, magnesium, and potassium, and, to a lesser extent, iron and aluminum. Silicon, too, is abundant in water but almost always occurs as the compound silicon dioxide (silica).

**Nutrients.**--A nutrient is any chemical element, ion, or compound that is required by an organism for the continuation of growth, reproduction, and other life processes. Many elements and compounds act as nutrients to supply the food for aquatic plants and algae. However, nitrogen and phosphorus usually are considered the limiting nutrients for plant growth and as such received the most emphasis in this study. Whatever nutrient is limiting algal growth, the concentrations of nitrogen and phosphorus are useful in evaluating the trophic conditions of a lake (Lee, 1970). The nutrient concentrations that were determined at top and bottom sampling depths included nitrate, nitrite, ammonia and organic nitrogen, total phosphorus, and orthophosphate phosphorus. Samples collected for orthophosphate, nitrite, and nitrate analyses were filtered immediately through a 0.45- $\mu$ m (micrometre) Millipore<sup>1</sup> filter. The nutrient samples were iced in the field and later refrigerated at 4 °C (Celsius).

**Suspended solids.**--Suspended solids are those retained on a 0.45- $\mu$ m filter.

**Hardness.**--Water hardness is defined as the sum of the polyvalent cations expressed as the equivalent quantity of calcium carbonate ( $\text{CaCO}_3$ ). As a general rule, hard-water lakes are more productive of plants and animals than soft-water lakes, but there are many exceptions.

**Specific conductance.**--Specific conductance is a measure of the water's ability to conduct an electric current and is used as an approximation of dissolved-solids concentration in the water.

**pH.**--pH is the negative logarithm of the effective hydrogen-ion concentration, expressed as a number from 0 to 14. A pH of 7 is neutral, a pH of less than 7 is acidic, and a pH of greater than 7 is basic.

**Color.**--Color is one control of light transmission through water. High color values in many lakes result from the decomposition of vegetation, which gives the water a brown, tea-like color. Color is determined by a comparison of the water with standardized colored-glass discs and is reported in platinum-cobalt (Pt-Co) units.

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<sup>1</sup>Use of proprietary names is for identification only and does not imply endorsement by the U.S. Geological Survey.

Chlorophyll a.--Chlorophyll a is a green photosynthetic pigment present in plant cells, including algae. The concentration of chlorophyll a in a water sample is a commonly accepted indicator of algal biomass (Lee, 1970). Samples for chlorophyll a (0.5-2 litres) were filtered immediately in the field using a 0.45- $\mu$ m Millipore filter. The filters containing the pigment were stored immediately in a dessicator and iced in the field and later stored in a dessicator at  $-20^{\circ}\text{C}$ . Analyses were performed on samples from 1 to 20 days after collection.

Fecal-coliform bacteria.--Fecal coliforms are that part of the total coliform group derived from feces of warmblooded animals, including man; their presence in water generally is accepted as an indicator of recent fecal-waste contamination. Samples were collected approximately 100 feet offshore at a depth of 1 foot or two to five stations at each lake. The sample locations and number of sample sites are shown on the bathymetric map. The reporting unit is the number of colonies per 100 millilitres of water.

Water-temperature profiles.--Water temperature, which varies in lakes with depth and time of year, is an important controlling factor for life processes and chemical-reaction rates as well as many physical events that occur in the aquatic environment.

Generally, the water-temperature profiles of the lakes studied show total mixing during the winter--nearly uniform temperatures from top to bottom--and thermal stratification during the summer. Temperature profiles in lakes during midsummer, when thermal stratification is marked, generally follow one of two common patterns. In shallow lakes, well exposed to the wind, temperatures will be found to be practically constant from top to bottom. This uniformity of temperature indicates that the waters are well mixed throughout. The other common pattern occurs in deeper lakes, where three characteristic thermal layers are present: (1) an upper zone (epilimnion) of generally warmer water in which temperature is more or less uniform throughout; (2) an intermediate zone (metalimnion) in which temperature declines rapidly with depth; and (3) a lower zone (hypolimnion) of colder water in which temperature is again more or less uniform throughout.

Of special significance is the temperature of the deep-water layer (hypolimnion) during midsummer because (1) temperature stratification and water circulation affect the vertical distribution of nutrients, and (2) water temperatures affect the potential of cold-water fisheries resources.

Secchi-disc visibility.--Secchi-disc visibility is the depth at which a white-and-black disc (8 inches in diameter) disappears from view when lowered into the water. Secchi-disc visibility depth is a measure of water transparency or clarity. Because changes in biological production can cause changes in the color and turbidity of a lake, Secchi-disc visibility often is used as a gross measure of the plankton in the water. The depth of visibility of the Secchi disc is shown by the base of the triangle on the water-temperature-profile graphs.

Dissolved-oxygen profiles.--The concentration of DO (dissolved oxygen) in a lake varies with time of year and depth of water and is a function of many factors including the water temperature, atmospheric pressure, and salinity of the water. Oxygen in water is continually being altered by life processes, such as photosynthesis and respiration, and by complex chemical reactions. Of special biological significance is the amount of DO in the deep water during midsummer. The organisms in the lighted upper layers of water produce organic matter which settles to the bottom where bacteria consume oxygen to degrade the organic materials, thereby reducing the DO concentration in the hypolimnion. The hypolimnetic-oxygen deficit frequently is related to the biomass or plant growth in the upper waters (Hutchinson, 1957). For good growth and general health of trout, salmon, and other species of cold-water biota, the DO concentrations should not be less than 6.0 mg/l (milligrams per litre) according to the Federal Water Pollution Control Administration (1968).



## GLOSSARY OF LIMNOLOGICAL AND HYDROLOGICAL TERMS

Acre-foot. Volume of water required to cover 1 acre to a depth of 1 foot, and equal to 43,560 ft<sup>3</sup>.

Algae. Simple plants, many microscopic; contain chlorophyll and lack roots, stems, and leaves. Most algae are aquatic and may become a nuisance when environmental conditions are suitable for prolific growth.

Algal bloom. A large number--often 0.5 to 1 million cells per litre--of a particular algal species which may form objectionable scums and odors upon decomposition.

Cultural eutrophication. The acceleration of the natural process of nutrient enrichment in a lake as a result of man's activities.

Ephemeral stream. Flows only in direct response to precipitation, and has a channel that is above the water table at all times.

Eutrophication, eutrophic. The enrichment of water, a natural process that may be accelerated by the activities of man; pertains to waters in which primary productivity is generally high as a consequence of a large supply of available nutrients.

Fall overturn. A natural mixing of thermally stratified waters that commonly occurs during the early autumn. The sequence of events leading to fall overturn includes (1) cooling of surface waters, (2) density change in surface waters that produces convection currents from top to bottom, and (3) circulation of the total water volume by wind action. The overturn generally results in a uniformity of the physical and chemical properties of the water.

Genus, genera. The taxonomic category below family, consisting of one to many species.

Glacial drift. Rock debris that has been transported by glaciers and deposited either directly from the ice or from the melt water. The debris may or may not be heterogeneous.

Glaciofluvial deposits. Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and may occur in the form of outwash plains, deltas, kames, eskers, and kame terraces.

Intermittent or seasonal stream. Flows at certain times of the year when it receives water from springs or from some surface source, such as melting snow in mountainous areas.

Littoral. The shoreward region of a body of water.

Loam. Soil material that contains 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand.

Marsh. Periodically wet or continually flooded areas where the surface is not deeply submerged, covered dominantly with sedges, cattails, rushes, or other plants that require marshy areas to grow.

Morphometry. Definition of physical shape and size, as of a water body.

Muck. A mixture containing highly decomposed organic material in which the original plant parts are not recognizable. Contains more mineral matter, and is usually darker, than peat.

Plankton. Suspended microscopic organisms that drift with the water currents.

Production. The total amount of living matter produced in an area per unit time regardless of the fate of the living matter.

Runoff. That part of the precipitation that appears in surface streams.

Spring overturn. A natural mixing of thermally stratified water that commonly occurs during the early spring. The sequence of events leading to spring overturn includes (1) melting of ice cover, if present, (2) warming of surface water, (3) temperature change in surface waters that produces convection currents from top to bottom, and (4) circulation of the total water volume by wind action. The overturn results in a uniformity of the physical and chemical properties of the water.

Till. Unstratified glacial drift deposited directly by the ice and consisting of clay, sand, gravel, and boulders intermixed in any proportion.

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## LAKE DATA

Boren Lake near Renton (12119400)Location.

Lat 47°31'52", long 122°09'45", in NW $\frac{1}{4}$ NW $\frac{1}{4}$  sec.34, T.24 N., R.5 E., King County, 4.0 miles northeast of Renton; Lake Washington basin. Mercer Island quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	1.07 sq mi	Maximum depth	34 ft
Altitude	300 ft	Length of shoreline	3,700 ft
Surface area	18 acres	Shoreline configuration	1.2
Lake volume	330 acre-ft	Development of volume	0.53
Mean depth	18 ft	Bottom slope	3.4 percent

The beach and littoral zone is composed mainly of muck and silt.

Basin geology.

Glacial drift, sandstone, and volcanic rock (Liesch and others, 1963).

Soils.

Loam, gravelly fine sandy loam, and shallow, stony soils (Poulson and others, 1952).

Land use (percentage of drainage basin). Urban 0, suburban 24, agricultural 5, forest or unproductive 68, and lake surface 3.

Nearshore residential development. 70 percent.

Number of nearshore homes. 22 (mostly permanent).

Surface-water inflow and outflow.

The inflow is via two unnamed tributaries. The stream entering the lake from the north contributed minor inflow during the summer and fall. The outflow, via an unnamed outflow channel, is controlled by a concrete weir.

Lake stage.

The observed gage height from May 8 to December 2, 1972, varied 0.9 ft. Records incomplete in early part of year.

Macrophytes.

Shoreline covered by emersed plants 26-50 percent.  
 Lake surface covered by emersed plants 1 percent.  
 Lake bottom covered by submersed plants 29 percent.  
 Rooted aquatic plants observed were yellow lily (Nuphar sp.),\* water milfoil (Myriophyllum sp.),\* cattail (Typha sp.), white lily

Macrophytes.--continued

(Nymphaea sp.), waterweed (Elodea sp.), and wildcelery (Vallisneria sp.).

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Asterisk (\*) indicates dominant aquatic plants.

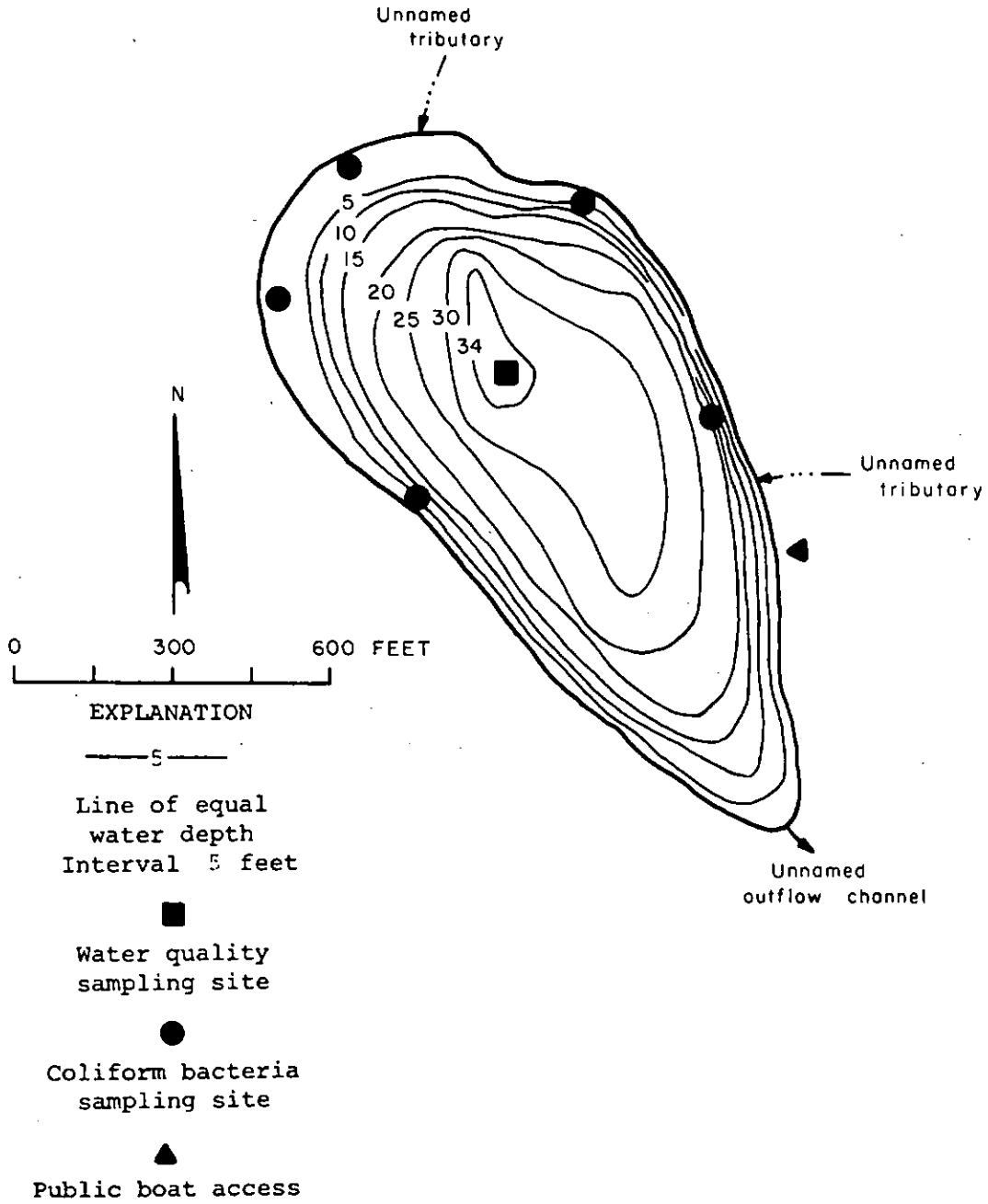
Remarks.

Because of the large drainage basin (1.07 sq mi) and small lake volume (330 acre-ft), lake stage increases rapidly during periods of high runoff.

Conclusions.

Boren Lake has a medium to high biological productivity based on water clarity, chlorophyll a concentrations, and abundance of submerged rooted aquatic plants. Winter concentrations of nitrogen were observed to be quite high. The specific conductance is slightly higher than many of the other local lakes in this vicinity. The fecal-coliform colonies ranged from 2 to 48 colonies per 100 ml. Runoff from grazing land in the lake basin may be partly responsible for the fecal-coliform colonies detected.

The surface area and volume of the lake are small compared to the size of the drainage area; therefore, the potential nutrient loading of the lake could be high if the lake basin were developed or used without proper management.



Boren Lake, King County. From Washington Department of Game, October 4, 1946.



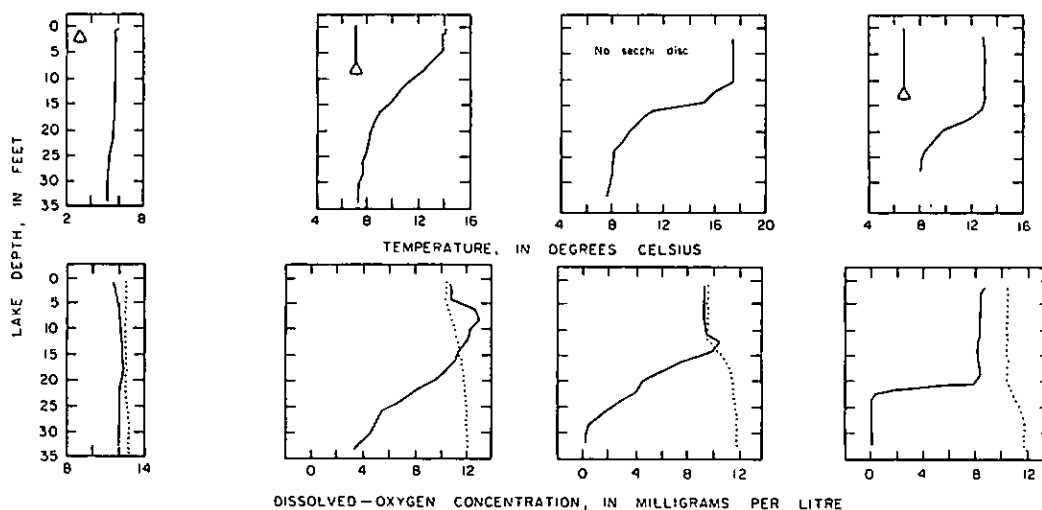
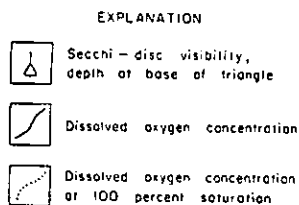


Boren Lake, King County. August 9, 1972. Approx. scale 1:3600.

## Water-quality data for Boren Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	February 28		May 8		June 23		October 6	
	3	31	3	30	3	27	3	29
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	13	13	6.9	12	5.9	12	9.0	13
Dissolved iron (Fe) -----	.02	.04	.14	.21	.22	.14	.25	1.5
Dissolved manganese (Mn) ----	.058	--	.040	.090	.040	.040	.032	.89
Calcium (Ca) -----	10	--	--	--	--	--	12	--
Magnesium (Mg) -----	3.0	--	--	--	--	--	3.5	--
Sodium (Na) -----	4.1	--	--	--	--	--	4.5	--
Potassium (K) -----	1.0	--	--	--	--	--	1.0	--
Bicarbonate (HCO <sub>3</sub> ) -----	32	35	40	35	44	38	44	48
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	.0
Sulfate (SO <sub>4</sub> ) -----	15	--	--	--	--	--	13	--
Chloride (Cl) -----	2.7	--	--	--	--	--	2.9	--
Nitrate nitrogen (as N) ----	1.5	1.6	.56	.82	.17	.69	.04	.02
Nitrite nitrogen (as N) ----	.02	.02	.02	.01	.01	.00	.01	.00
Ammonia nitrogen (as N) ----	.11	.08	.05	.06	.09	.02	.08	.40
Organic nitrogen (as N) ----	.39	.37	.30	.16	.38	.31	.31	.20
Total phosphorus (as P) ----	.042	.009	.015	.021	.020	.010	.012	.035
Orthophosphate (as P) -----	.009	.009	.002	.002	.000	.000	.002	.021
Suspended solids (110°C) ----	23	--	--	--	--	--	19	--
Hardness (Ca, Mg) -----	37	--	--	--	--	--	44	--
Specific conductance ----- (micromhos at 25°C)	103	103	100	98	106	106	110	140
pH (pH units) -----	7.5	7.5	8.1	7.8	7.8	7.2	7.4	7.1
Color (Pt-Co units) -----	35	35	30	35	30	30	20	40
Chlorophyll <i>a</i> (µg/l) -----	6.4	--	6.3	--	4.5	--	3.0	--
Pecal coliform	Range --	--	--	--	8-48	27	2-12	5
(col. per 100 ml)	Mean ---	--	--	--				



Deer Lake near Loon Lake (12406000)Location.

Lat 48°06'28", long 117°36'18", in SW $\frac{1}{4}$ SW $\frac{1}{4}$  sec.11, T.30 N., R.41 E., Stevens County, 3.3 miles northeast of town of Loon Lake; Colville River basin. Deer Lake and Nelson Peak quadrangles, 1:24,000.

Physical characteristics of lake.

Drainage area	18.2 sq mi	Maximum depth	75 ft
Altitude	2,474 ft	Length of shoreline	45,000 ft
Surface area	1,100 acres	Shoreline configuration	1.9
Lake volume	57,000 acre-ft	Development of volume	0.69
Mean depth	52 ft	Bottom slope	0.96 percent

The beach and littoral zone consists primarily of cobbles, gravel, and coarse sand.

Basin geology.

Glacial drift to northeast and southwest. Sedimentary granitic, and volcanic rock in remainder of basin (Huntting and others, 1961).

Soils.

Loam, silt loam, sandy loam, much, and shallow stony soils (Van Duyne and Ashton, 1915).

Land use (percentage of drainage basin). Urban 0, suburban 4, agricultural 4, forest or unproductive 83, and lake surface 9.

Nearshore residential development. 82 percent.

Number of nearshore homes. 358.

Surface-water inflow and outflow.

The inflow is from several intermittent and ephemeral streams originating in the surrounding mountainous terrain. The outflow channel, controlled by a low weir with flashboards, was dry during the summer visits.

Lake stage. The maximum variation in gage height from September 30, 1971 to October 1, 1972 was 1.92 ft (U.S. Geological Survey, 1973). A continuous recorder monitored lake stage in 1972. Datum of the gage is 2,473.9 ft above mean sea level, unadjusted.

Macrophytes.

Shoreline covered by emersed plants 26-50 percent.

Lake surface covered by emersed plants 3 percent.

Lake bottom covered by submersed plants 18 percent.

Rooted aquatic plants observed were watershield (Brasenia sp.),\* muskgrass (Chara sp.),\* five varieties of pondweed (Potamogeton, spp.)\* cattail (Typha sp.), sedge (Cyperaceae), waterweed (Elodea sp.), quillwort (Isoetes sp.), and watermilfoil (Myriophyllum sp.).

Asterisk (\*) indicates dominant aquatic plants.

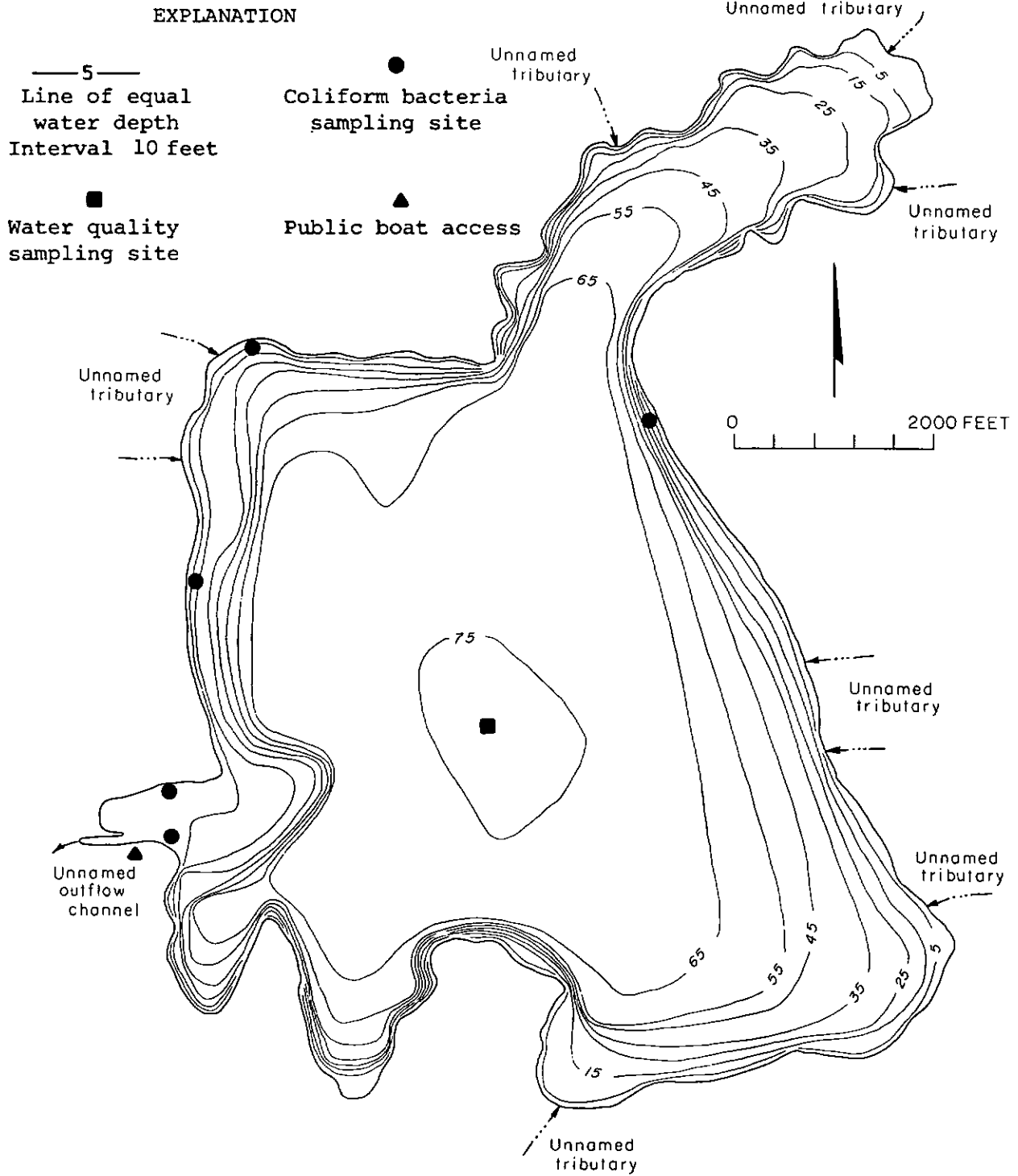
Remarks.

A continuous record of water stage is collected by the U.S. Geological Survey at Deer Lake.

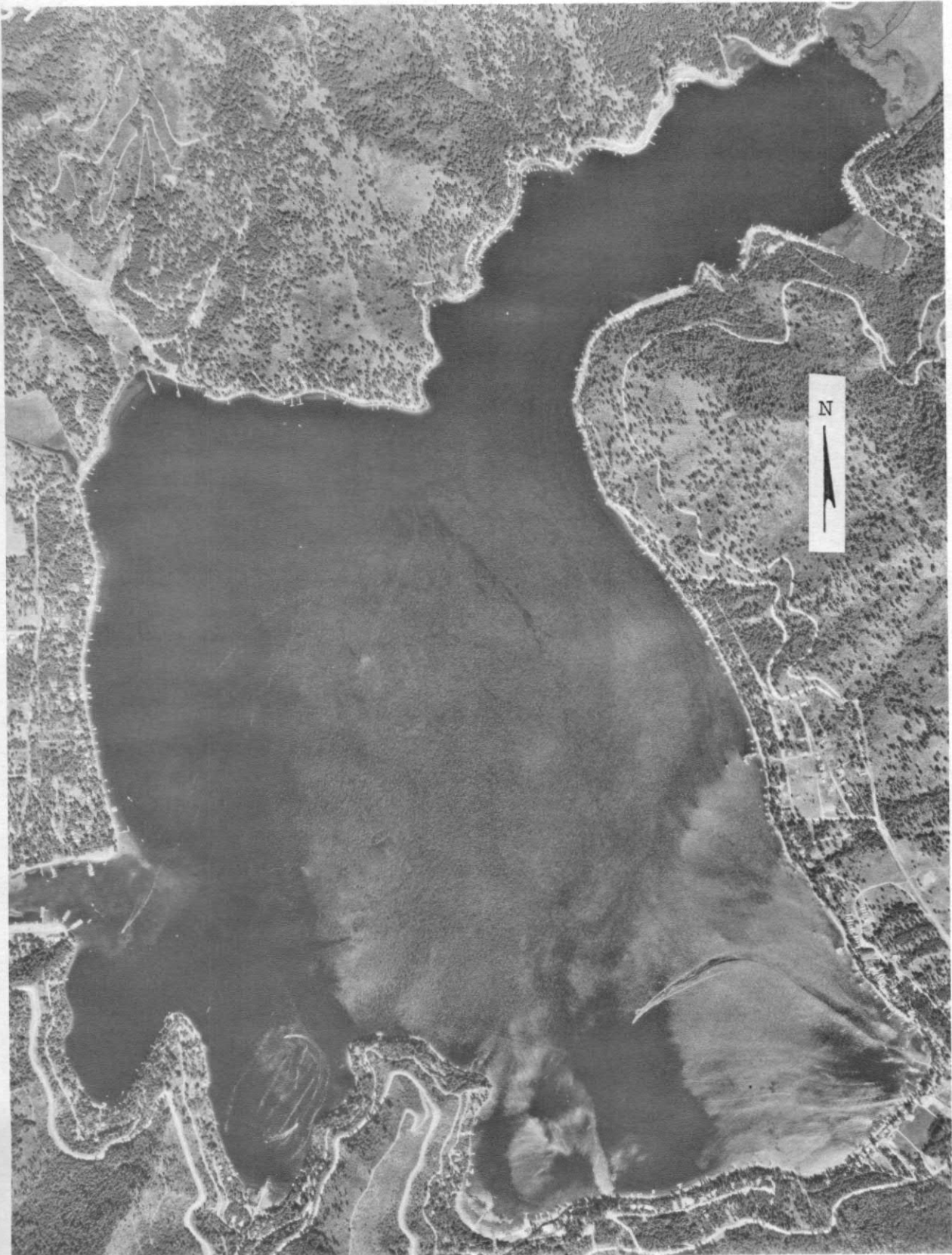
Conclusions.

Because of the favorable size and depth of the lake, dissolved-oxygen conditions, water clarity, lack of abundant algae, and moderate dissolved-solids content, Deer Lake could be considered low to medium in biological productivity. The lake water was saturated with DO to a depth of 50 feet for most of the summer and only in the bottom few feet of the hypolimnion did the DO concentration approach zero. The lake water was also very clear; the mean Secchi-disc-visibility depth of 22 feet was the deepest mean light penetration recorded for any of the lakes studied in 1972.

Because of continued development of the uplands and an increased recreational use of the large natural lake, Deer Lake should be closely observed for signs of accelerated nutrient enrichment.



Deer Lake, Stevens County. From Washington Department of Game, February 22, 1955.






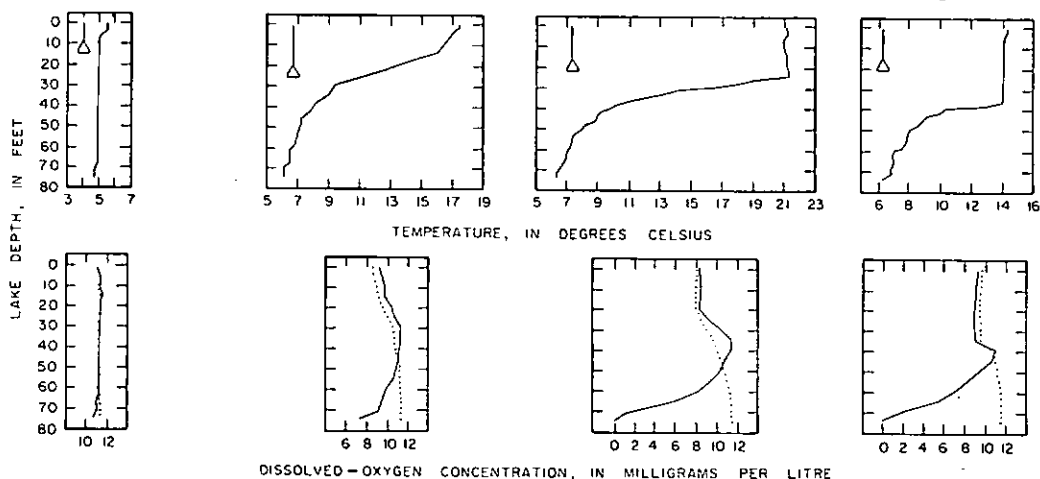
Deer Lake, Stevens County. August 10, 1972. Approx. scale 1:16,000.

Water-quality data for Deer Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	April 18		June 6		August 15		September 25	
	3	72	3	72	3	70	3	70
Silica (SiO <sub>2</sub> ) -----	11	11	10	11	9.1	12	9.1	11
Dissolved iron (Fe) -----	.02	.06	.09	.15	.04	.30	.04	.09
Dissolved manganese (Mn) ----	.000	.000	.010	.000	.000	.017	.010	.020
Calcium (Ca) -----	8.0	--	--	--	--	--	8.3	--
Magnesium (Mg) -----	2.0	--	--	--	--	--	2.3	--
Sodium (Na) -----	4.4	--	--	--	--	--	4.2	--
Potassium (K) -----	1.6	--	--	--	--	--	1.4	--
Bicarbonate (HCO <sub>3</sub> ) -----	43	42	42	43	43	43	44	44
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	.0
Sulfate (SO <sub>4</sub> ) -----	3.4	--	--	--	--	--	4.1	--
Chloride (Cl) -----	1.8	--	--	--	--	--	.1	--
Nitrate nitrogen (as N) ----	.01	.01	.01	.03	.05	.04	.02	.02
Nitrite nitrogen (as N) ----	.00	.00	.00	.00	.00	.01	.00	.00
Ammonia nitrogen (as N) ----	.25	.24	.19	.04	.02	.06	.01	.01
Organic nitrogen (as N) ----	.16	.11	.24	.19	.34	.78	.28	.28
Total phosphorus (as P) ----	.070	.042	.012	.009	.010	.012	.027	.022
Orthophosphate (as P) -----	.002	.002	.000	.002	.004	.002	.000	.002
Suspended solids (110°C) ----	29	--	--	--	--	--	8	--
Hardness (Ca, Mg) -----	28	--	--	--	--	--	30	--
Specific conductance ----- (micromhos at 25°C)	76	78	72	76	78	84	78	78
pH (pH units) -----	7.8	7.9	8.2	8.0	8.2	7.2	8.3	7.5
Color (Pt-Co units) -----	10	10	0	0	0	0	0	0
Chlorophyll a (µg/l) -----	3.1	--	.7	--	1.7	--	2.8	--
Fecal coliform	Range ---	--	2	2	<1-1	<1	<1	<1
(col. per 100 ml)	Mean ---	--	2	2	<1	<1	<1	<1

- EXPLANATION
-  Secchi - disc visibility, depth at base of triangle
  -  Dissolved oxygen concentration
  -  Dissolved oxygen concentration at 100 percent saturation



DISSOLVED-OXYGEN CONCENTRATION, IN MILLIGRAMS PER LITRE

Diamond Lake near Newport (12427500)Location.

Lat 48°07'08", long 117°13'05", in SE $\frac{1}{4}$ SE $\frac{1}{4}$  sec 3, T.30 N., R.44 E., Pend Oreille County, 8.0 miles southwest of Newport; Spokane River basin. Diamond Lake and Camden quadrangles, 1:24,000.

Physical characteristics of lake.

Drainage area	17.4 sq mi	Maximum depth	58 ft
Altitude	2,340 ft	Length of shoreline	37,000 ft
Surface area	800 acres	Shoreline configuration	1.8
Lake volume	22,000 acre-ft	Development of volume	0.47
Mean depth	27 ft	Bottom slope	0.87 percent

The beach and littoral zone is composed of cobbles, gravel, sand, and large areas of muck.

Basin geology.

Glacial drift with some sedimentary rock (Hunting and others, 1961).

Soils.

Silt loam and sandy loam (U.S. Soil Conservation Service, 1968).

Land use (percentage of drainage basin). Urban 0, suburban 2, agricultural 13, forest or unproductive 78, and lake surface 7.

Nearshore residential development. 78 percent.

Number of nearshore homes. 355.

Surface-water inflow and outflow.

Minor inflow from two unnamed tributaries was observed during the April 17 visit. No inflow was observed during the summer. The outflow channel was dry during four visits.

Lake stage.

The observed gage height from March 27 to September 29, 1972, varied 0.7 ft.

Macrophytes.

Shoreline covered by emerged plants 11-25 percent.

Lake surface covered by emerged plants 1 percent.

Lake bottom covered by submersed plants 30 percent.

Rooted aquatic plants observed were sedge (*Cyperaceae*),\* three varieties of pondweed (*Potamogeton* spp.),\* cattail (*Typha* sp.), yellow lily (*Nuphar* sp.), watershield (*Brasenia* sp.), bushy



Macrophytes.--continued

pondweed (Najas sp.), and muskgrass (Chara sp.).

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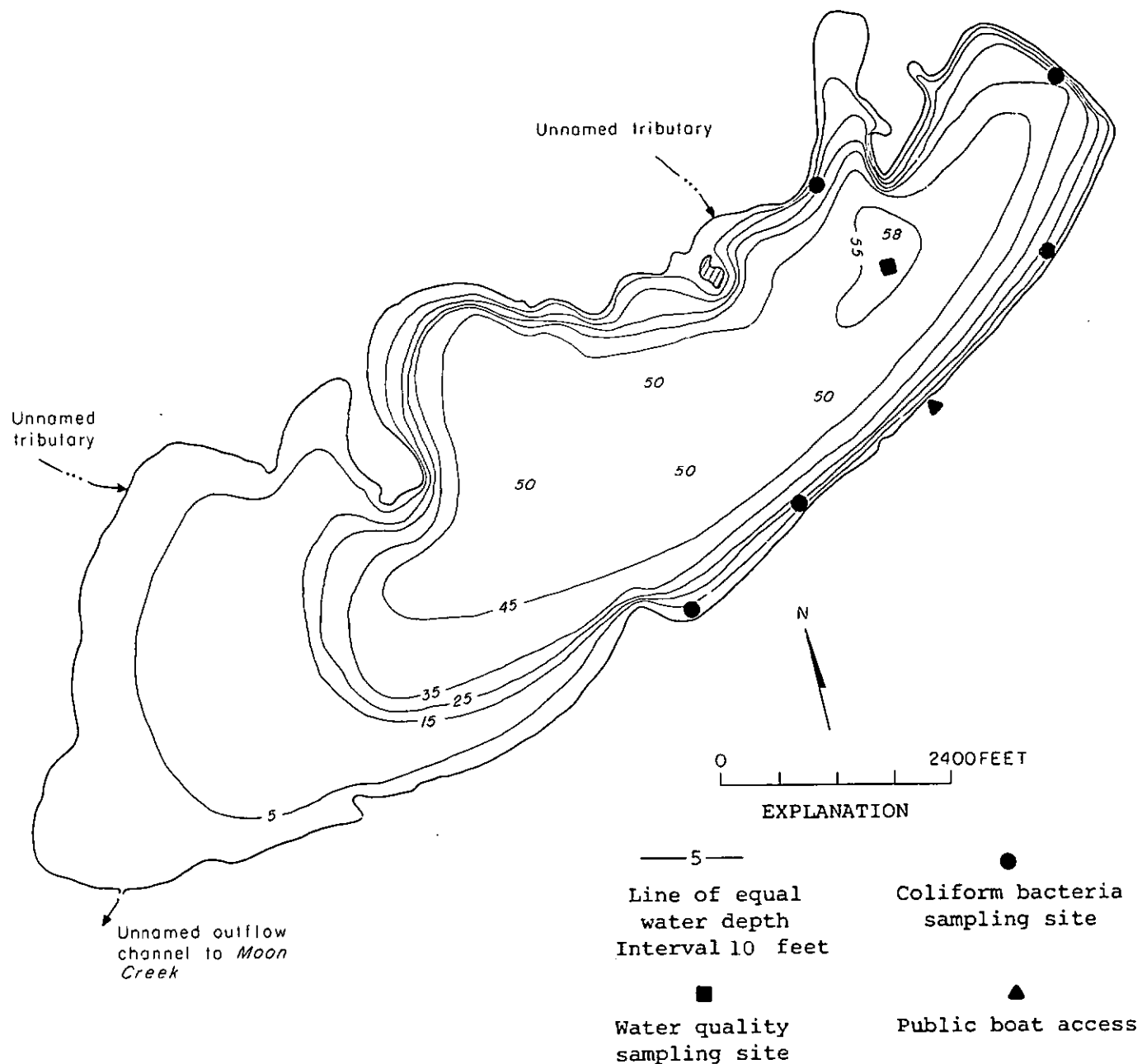
Asterisk (\*) indicates dominant aquatic plant.

Conclusions.

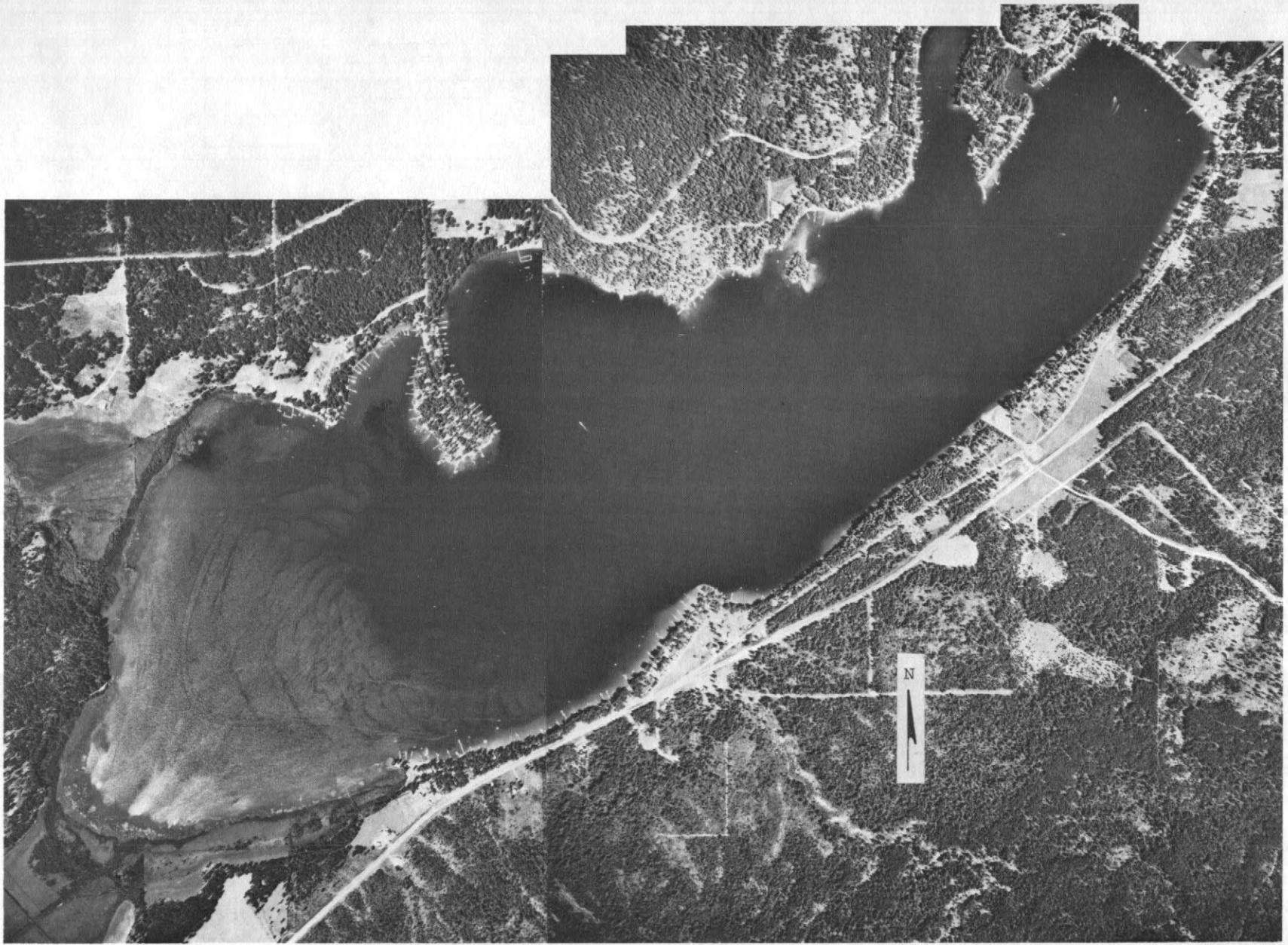
The biological productivity of the lake is probably about medium.

About 30 percent of the lake bottom is covered with submersed plants. DO depletion to near zero occurred only in the lower hypolimnion. The Secchi-disc-visibility depth varied from 14 to 27 feet indicating the water clarity was good. Concentrations of total phosphorus were medium. Mean chlorophyll a concentrations were lower than the average for the lakes studied.

Because of possible continued residential development of the surrounding uplands and an increased recreational use of this fairly large natural lake, the lake should be observed closely for signs of accelerated nutrient enrichment.



Diamond Lake, Pend Oreille County. From Washington Department of Game, January 27, 1955.




Diamond Lake, Pend Oreille County. July 29, 1967. Approx. scale 1:16,800.


Water-quality data for Diamond Lake.


[Milligrams per litre unless otherwise indicated]

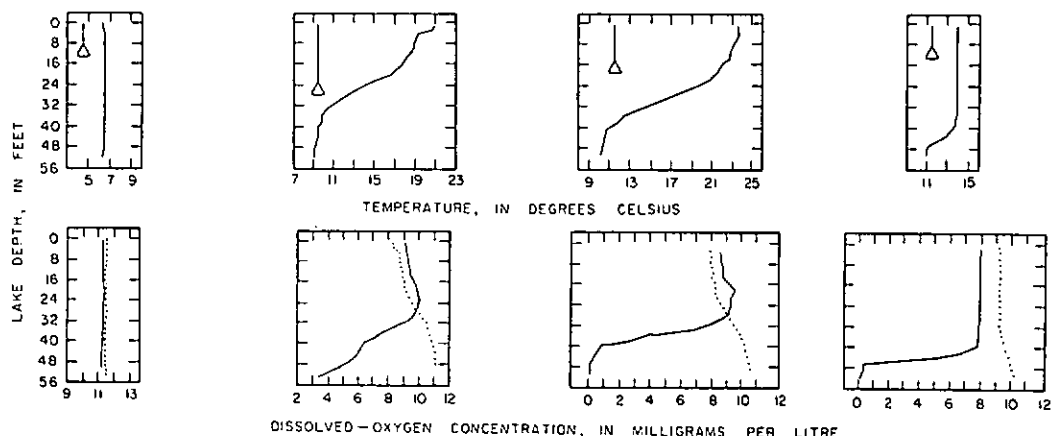
Date of collection (1972) ---	April 17		June 5		August 14		September 25	
	3	51	3	51	3	49	3	50
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	0.6	0.6	0.4	0.9	0.4	0.4	0.5	1.2
Dissolved iron (Fe) -----	.02	.07	.04	.07	.05	.05	.09	1.7
Dissolved manganese (Mn) ----	.000	.020	.000	.020	.000	.000	.010	.23
Calcium (Ca) -----	6.7	--	--	--	--	--	7.1	--
Magnesium (Mg) -----	1.7	--	--	--	--	--	1.9	--
Sodium (Na) -----	3.6	--	--	--	--	--	3.6	--
Potassium (K) -----	1.4	--	--	--	--	--	1.4	--
Bicarbonate (HCO <sub>3</sub> ) -----	37	37	38	36	38	37	38	42
Sulfide (as H <sub>2</sub> S) -----	--	.0	--	--	--	--	--	--
Sulfate (SO <sub>4</sub> ) -----	1.0	--	--	--	--	--	2.9	--
Chloride (Cl) -----	1.1	--	--	--	--	--	.1	--
Nitrate nitrogen (as N) -----	.06	.05	.02	.04	.04	.06	.02	.02
Nitrite nitrogen (as N) -----	.01	.00	.00	.00	.01	.00	.00	.00
Ammonia nitrogen (as N) -----	.14	.10	.08	.15	.14	.04	.02	.19
Organic nitrogen (as N) -----	.50	.57	.42	.31	.61	.56	.33	.44
Total phosphorus (as P) -----	.35	.060	.013	.016	.010	.006	.022	.034
Orthophosphate (as P) -----	.003	.002	.002	.001	.003	.002	.001	.001
Suspended solids (110°C) ----	32	--	--	--	--	--	8	--
Hardness (Ca, Mg) -----	24	--	--	--	--	--	26	--
Specific conductance ----- (micromhos at 25°C)	65	65	64	66	66	71	67	80
pH (pH units) -----	8.0	8.1	8.2	7.8	8.2	7.8	8.3	7.7
Color (Pt-Co units) -----	5	5	0	0	10	25	0	25
Chlorophyll <i>a</i> (µg/l) -----	6.3	--	1.0	--	1.3	--	3.7	--
Fecal coliform Range -- (col. per 100 ml) Mean ---	--	--	<1	<1	<1-2	1	<1-13	5

EXPLANATION

 Secchi - disc visibility, depth at base of triangle

 Dissolved oxygen concentration

 Dissolved oxygen concentration at 100 percent saturation



DISSOLVED-OXYGEN CONCENTRATION, IN MILLIGRAMS PER LITRE

Echo Lake near Richmond Heights (12127395)Location.

Lat 47°46'23", long 122°20'25", in SW $\frac{1}{4}$ NE $\frac{1}{4}$  sec.6, T.26 N., R.4 E., King County, 0.8 mile north of Richmond Heights; Lake Washington basin. Edmonds East quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	0.45 sq mi	Maximum depth	30 ft
Altitude	393 ft	Length of shoreline	3,400 ft
Surface area	13 acres	Shoreline configuration	1.3
Lake volume	220 acre-ft	Development of volume	0.46
Mean depth	14 ft	Bottom slope	3.6 percent

The beach and littoral zone is composed of muck, sand, and gravel.

Basin geology.

Glacial drift (Liesch and others, 1963).

Soils.

Gravelly sand loam (Poulson and others, 1952).

Land use (percentage of drainage basin). Urban 96, suburban 0, agricultural 0, forest or unproductive 0, and lake surface 4.

Nearshore residential development. 100 percent.

Number of nearshore homes. 30 (mostly permanent).

Surface-water inflow and outflow.

Minor inflow was observed from an unnamed tributary on the south end of the lake. The outflow, via an unnamed channel, was intermittent.

Lake stage.

The observed gage height from March 10 to September 29, 1972, varied 0.9 ft.

Macrophytes.

Shoreline covered by emerged plants 11-25 percent.

Lake surface covered by emerged plants 1 percent.

Lake bottom covered by submersed plants 5 percent.

Rooted aquatic plants observed were white lily (Nymphaea sp.),\* cattail (Typha sp.), yellow lily (Nuphar sp.), and waterweed (Elodea sp.).

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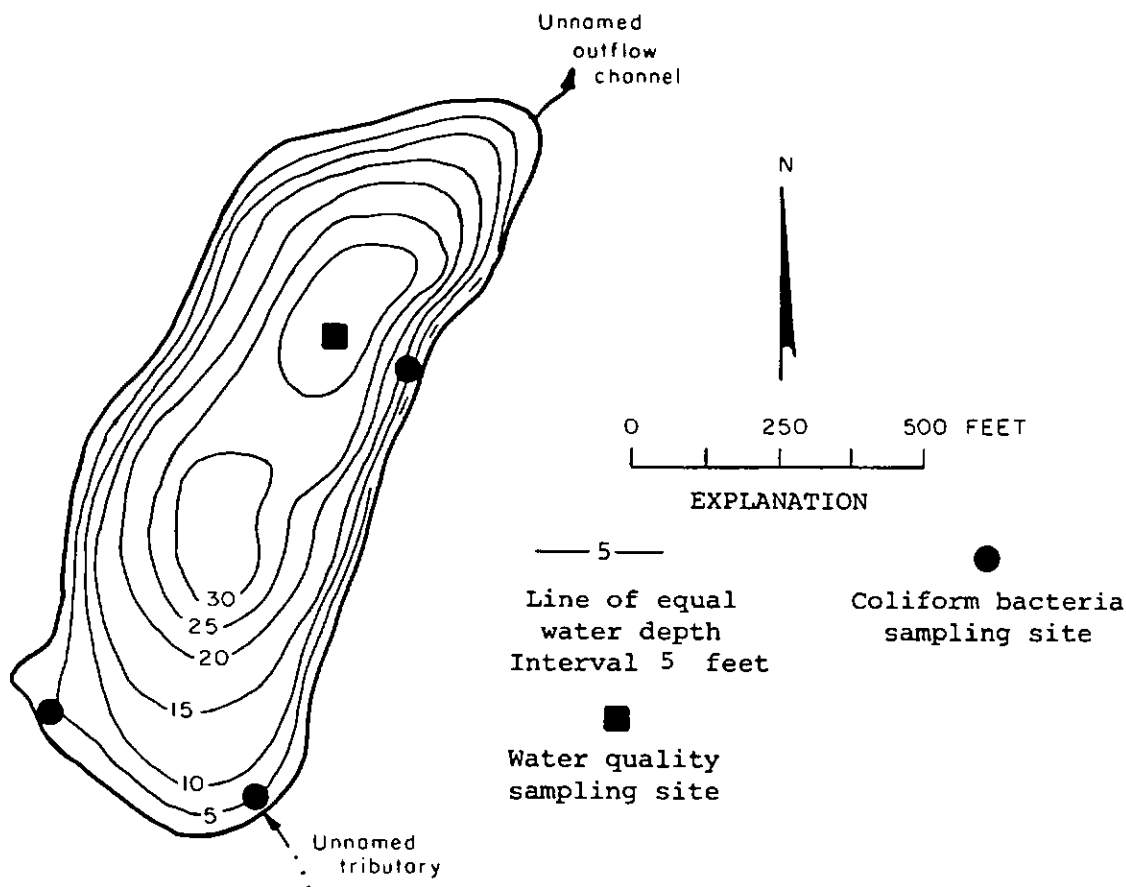
Asterisk (\*) indicates dominant aquatic plant.

Remarks.

Scheffer (1933) obtained chemical and biological data on Echo Lake in 1931. As a comparison, in 1931 the Secchi-disc-visibility depth ranged from about 9 to 20 feet with a mean for the year of 14 feet. In 1972, from March to October, the Secchi-disc-visibility depth ranged from 4 to 11 feet with a mean of four measurements being 8 feet.

Conclusions.

The small size and urban-environment setting of Echo Lake probably is the major cause of its medium biological productivity. The trophic condition of the lake is evidenced by moderate chlorophyll a concentrations, oxygen depletion in the bottom waters during the summer, and sparse growth of rooted aquatic plants. The fecal-coliform test showed bacteria counts ranging from 26 to 640 colonies per 100 ml, with a median of 80 for seven samples collected during the four sampling periods; these were the highest counts recorded for any lake studied in 1972.



Echo (26N-4E-6) Lake, King County. From Washington Department of Game, June 6, 1946.

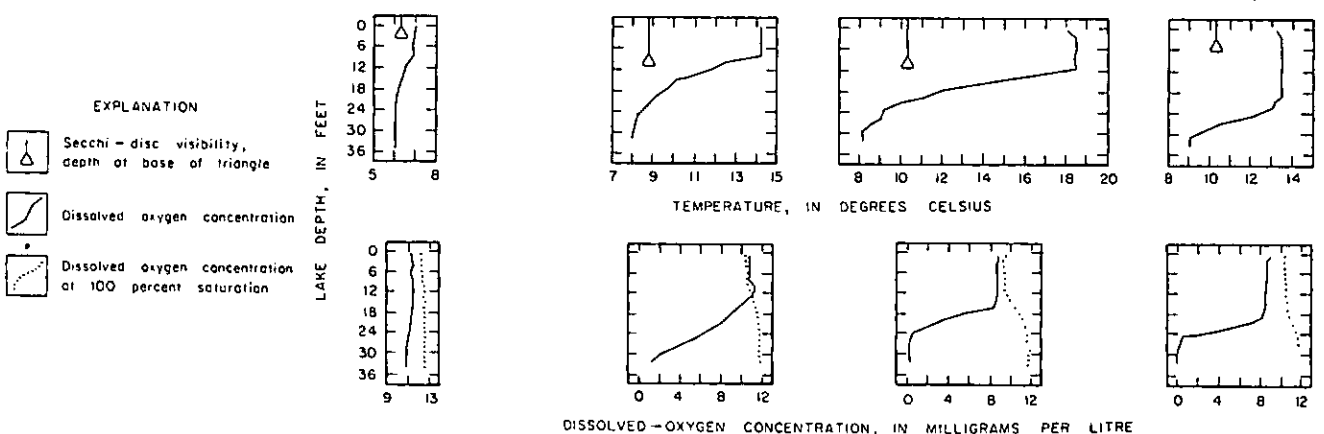


Echo Lake, King County. August 9, 1972. Approx. scale 1:3600.

Water-quality data for Echo Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	March 10		May 8		June 23		October 10	
	3	32	3	28	3	28	3	30
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	0.4	0.5	0.1	0.2	0.4	0.4	0.4	1.4
Dissolved iron (Fe) -----	.01	.14	.12	.35	.12	.63	.16	2.4
Dissolved manganese (Mn) ----	.000	--	.030	.060	.000	.44	.032	1.1
Calcium (Ca) -----	5.3	--	--	--	--	--	6.1	--
Magnesium (Mg) -----	1.2	--	--	--	--	--	1.3	--
Sodium (Na) -----	5.0	--	--	--	--	--	4.8	--
Potassium (K) -----	1.5	--	--	--	--	--	1.6	--
Bicarbonate (HCO <sub>3</sub> ) -----	23	23	23	22	21	19	20	32
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	--	--	trace
Sulfate (SO <sub>4</sub> ) -----	.2	--	--	--	--	--	6.2	--
Chloride (Cl) -----	6.3	--	--	--	--	--	6.8	--
Nitrate nitrogen (as N) ----	.20	.19	.10	.12	.00	.04	.01	.01
Nitrite nitrogen (as N) ----	.00	.00	.01	.01	.00	.00	.00	.00
Ammonia nitrogen (as N) ----	.21	.12	.27	.15	.07	.57	.12	.50
Organic nitrogen (as N) ----	.32	.40	.23	.40	.34	.42	.33	1.7
Total phosphorus (as P) ----	.028	.025	.027	.027	.030	.050	.017	.035
Orthophosphate (as P) -----	.002	.001	.002	.002	.000	.000	.000	.004
Suspended solids (110°C) ----	15	--	--	--	--	--	22	--
Hardness (Ca, Mg) -----	18	--	--	--	--	--	21	--
Specific conductance ----- (micromhos at 25°C)	72	72	67	74	70	95	70	123
pH (pH units) -----	7.1	7.1	7.8	7.6	7.6	7.5	7.5	7.2
Color (Pt-Co units) -----	10	15	15	15	15	35	5	15
Chlorophyll <i>a</i> (µg/l)-----	6.3	--	2.6	--	3.2	--	4.2	--
Fecal coliform Range --	--	--	--	--	26-640		30-84	
(col. per 100 ml) Mean ---	--	--	--	--	302		88	





Frater Lake near Tiger (12408190)Location.

Lat 48°39'18", long 117°29'11", in NW¼NE¼ sec.3, T.36 N., R.42 E.,  
Pend Oreille County, 4.3 miles southwest of Tiger; Colville River  
basin. Ione quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	0.68 sq mi	Maximum depth	15 ft
Altitude	3,205 ft	Length of shoreline	4,100 ft
Surface area	17 acres	Shoreline configuration	1.3
Lake volume	93 acre-ft	Development of volume	0.37
Mean depth	5.5 ft	Bottom slope	1.5 percent

The beach and littoral zone is mostly muck.

Basin geology.

Glacial drift with some granitic rock (Hunting and others, 1961).

Soils.

Sandy loam (Van Duyne and Ashton, 1915).

Land use (percentage of drainage basin). Urban 0, suburban 0,  
agricultural 0, forest or unproductive 96, and lake surface 4.

Nearshore residential development. 0 percent.

Number of nearshore homes. 0.

Surface-water inflow and outflow.

The inflow is from a small unnamed tributary. The outflow, via an  
unnamed channel, had flows less than 0.5 ft<sup>3</sup>/s during the summer.

Lake stage.

The observed gage height from April 20 to September 26, 1972,  
varied 3.6 ft. The variation in gage height was based on four  
observations only.

Macrophytes.

Shoreline covered by emerged plants 76-100 percent.

Lake surface covered by emerged plants 32 percent.

Lake bottom covered by submersed plants 86 percent.

Rooted aquatic plants observed were sedge (Cyperaceae), \* yellow  
lily (Nuphar sp.), two varieties of pondweed (Potamogeton spp.),  
and muskgrass (Chara sp.).

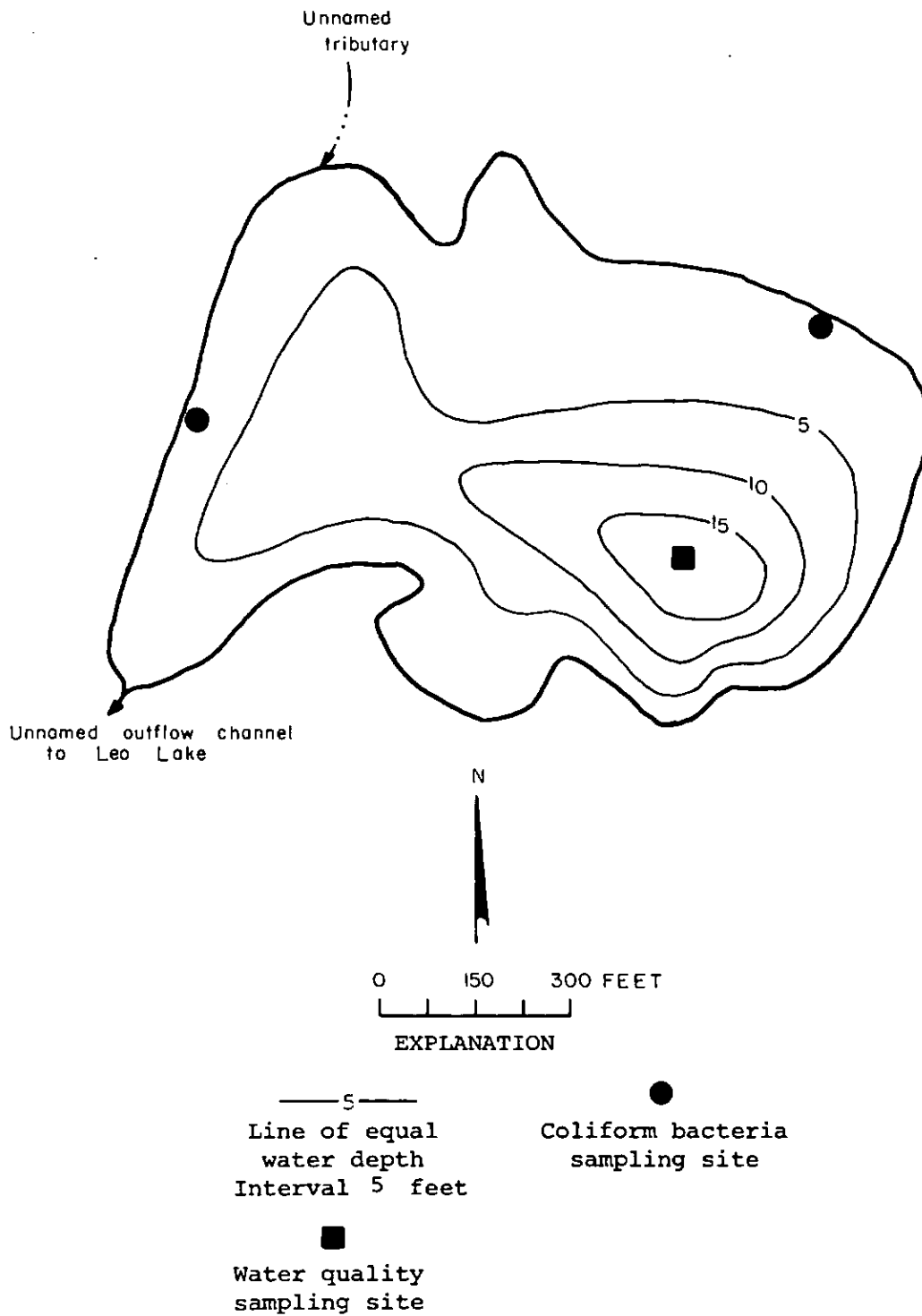
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Asterisk (\*) indicates dominant aquatic plant.

Conclusions.

The lake is medium to high in biological productivity. The lake is very shallow and supports heavy growths of both emerged and submersed aquatic plants. The dominant emerged aquatic plants are sedges, and the primary submersed plants are Potamogeton spp. (pondweeds) and Chara sp. (muskgrass). The lake was relatively dilute in dissolved minerals but total phosphorus and organic nitrogen concentrations were high. However, chlorophyll a concentrations were medium low.

At present, the drainage basin is heavily forested except for grazing land near the lake. Residential development has not occurred along the lake shoreline. As is true for all six lakes in the Little Pend Oreille River valley, Frater Lake has a high ratio of drainage area to volume, which indicates a significant chance for nutrient enrichment if the lake basin were developed or used without proper management.



Frater Lake, Pend Oreille County. From Washington Department of Game, February 11, 1951.






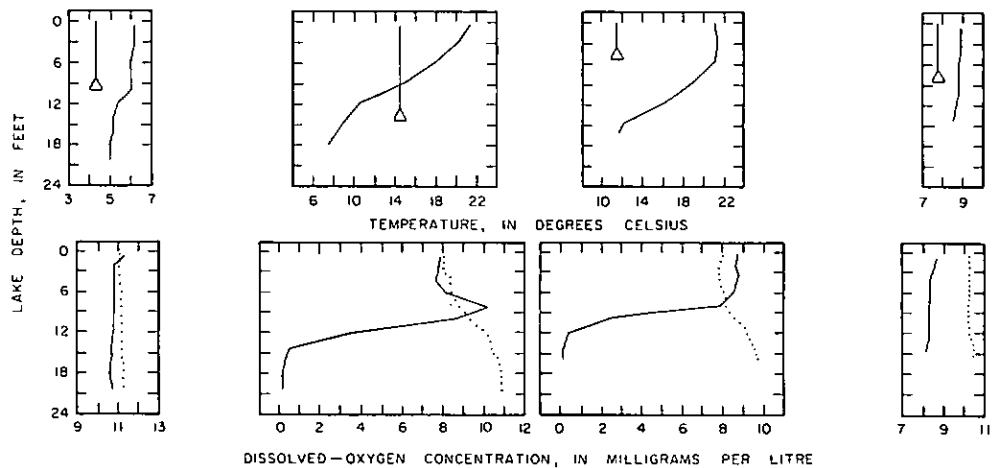
Frater Lake, Pend Oreille County. August 10, 1972.  
Approx. scale 1:7200.

Water-quality data for Frater Lake.

(Milligrams per litre unless otherwise indicated)

Date of collection (1972) ---	April 20		June 6		August 15		September 26	
	3	18	3	17	3	13	3	10
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	15	16	17	17	11	14	8.5	8.7
Dissolved iron (Fe) -----	.04	.08	.09	.09	.16	.15	.10	.11
Dissolved manganese (Mn) ----	.000	.000	.000	.010	.000	.008	.020	.030
Calcium (Ca) -----	4.2	--	--	--	--	--	4.5	--
Magnesium (Mg) -----	.7	--	--	--	--	--	.8	--
Sodium (Na) -----	2.2	--	--	--	--	--	2.3	--
Potassium (K) -----	.9	--	--	--	--	--	1.0	--
Bicarbonate (HCO <sub>3</sub> ) -----	24	21	23	23	24	23	24	27
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	--	--	--
Sulfate (SO <sub>4</sub> ) -----	2.1	--	--	--	--	--	2.5	--
Chloride (Cl) -----	.8	--	--	--	--	--	.1	--
Nitrate nitrogen (as N) ----	.01	.01	.01	.01	.05	.06	.02	.02
Nitrite nitrogen (as N) ----	.01	.01	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N) ----	.07	.07	.17	.50	.07	.46	.22	.23
Organic nitrogen (as N) ----	.19	.19	.30	.26	.80	.94	.68	.77
Total phosphorus (as P) ----	.149	.070	.012	.016	.018	.056	.029	.053
Orthophosphate (as P) -----	.005	.003	.002	.006	.002	.003	.002	.000
Suspended solids (110°C) ----	35	--	--	--	--	--	5	--
Hardness (Ca,Mg) -----	13	--	--	--	--	--	15	--
Specific conductance ----- (micromhos at 25°C)	38	38	39	43	42	49	44	44
pH (pH units) -----	7.6	7.6	7.1	6.8	7.6	6.8	7.9	7.8
Color (Pt-Co units) -----	25	25	15	25	15	25	5	15
Chlorophyll <i>a</i> (µg/l) -----	2.2	--	1.1	--	4.2	--	7.4	--
Fecal coliform Range --- (col. per 100 ml) Mean ---		--	--	--	<1-2 1	<1-2 1		

- EXPLANATION
-  Secchi-disc visibility, depth at base of triangle
  -  Dissolved oxygen concentration
  -  Dissolved oxygen concentration at 100 percent saturation



DISSOLVED-OXYGEN CONCENTRATION, IN MILLIGRAMS PER LITRE

Gillette Lake near Tiger (12408214)Location.

Lat 48°36'43", long 117°32'35", in NW $\frac{1}{4}$ NW $\frac{1}{4}$  sec.20, T.36 N., R.42 E., Stevens County, at bridge between Gillette and Sherry Lakes, 8.1 miles southwest of Tiger; Colville River basin. Lake Gillette quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	14.9 sq mi	Maximum depth	85 ft
Altitude	3,147 ft	Length of shoreline	6,800 ft
Surface area	47 acres	Shoreline configuration	1.3
Lake volume	1,600 acre-ft	Development of volume	0.39
Mean depth	34 ft	Bottom slope	5.3 percent

The beach and littoral zone consists mainly of gravel, coarse sand, and muck.

Basin geology.

Glacial drift with some granitic rock (Hunting and others, 1961).

Soils.

Sandy loam and loam (Van Duyne and Ashton, 1915).

Land use (percentage of drainage basin). Urban 0, suburban 1, agricultural 0, forest or unproductive 95, and lake surface 4.

Nearshore residential development. 30 percent.

Number of nearshore homes. 19 (mostly seasonal).

Surface-water inflow and outflow.

The main inflow is upstream through Thomas Lake. Minor inflow is contributed by Gillette Creek. The outflow is a narrow connecting channel to Sherry Lake.

Lake stage.

The observed gage height from April 19 to September 26, 1972, varied 0.4 ft. The variation in gage height was based on four observations only.

Macrophytes.

Shoreline covered by emerged plants 51-75 percent.

Lake surface covered by emerged plants 14 percent.

Lake bottom covered by submersed plants 26 percent.

Rooted aquatic plants observed were watershield (Brasenia sp.),\* two varieties of pondweed (Potamogeton spp.),\* white lily (Nymphaea sp.), yellow lily (Nuphar sp.), sedge (Cyperaceae),

Macrophytes.--continued

coontail (Ceratophyllum sp.), waterweed (Elodea sp.), muskgrass (Chara sp.), and water milfoil (Myriophyllum sp.).

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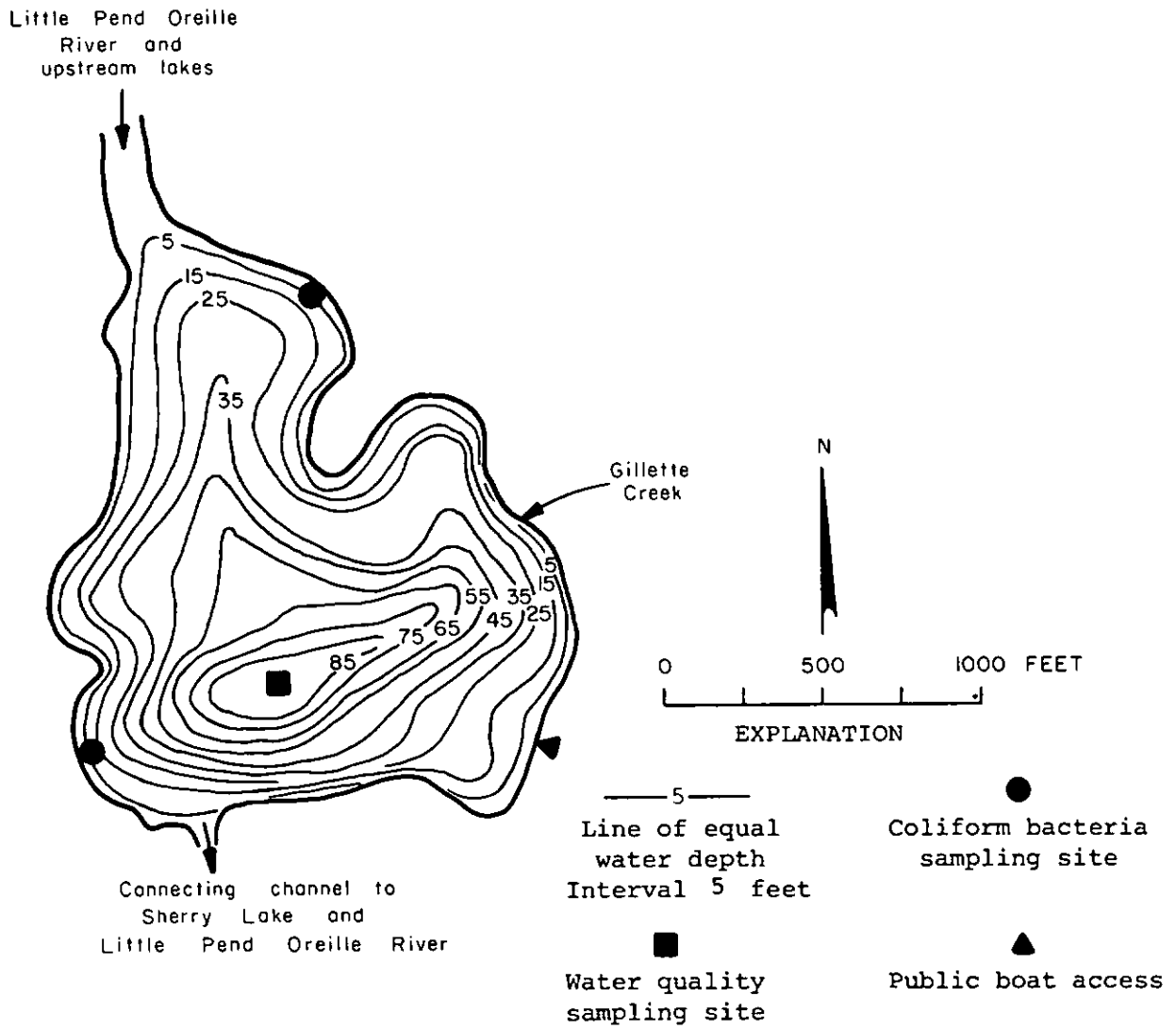
Asterisk (\*) indicates dominant aquatic plants.

Conclusions.

The lake appears to be medium to high in biological productivity. The littoral bottom supports a heavy growth of rooted aquatic plants. The chlorophyll a concentrations are medium.

Profiles of temperature and DO show the lake was strongly stratified in 1972. Early in the year, on April 19, the DO concentration was depleted to near zero below a depth of 24 feet. This condition probably was caused by the prolonged ice and snow cover on the lake. Lack of light penetration through the ice and snow cover would have prevented oxygen production by plants, causing an oxygen deficit in the lake over the course of a winter. Following the spring breakup of the ice, the limited penetration of light and the sheltered nature of the lake tends to favor the generation of temperature layers in the lake, resulting in only partial mixing of the lake water in the spring. During the summer of 1972 about 56 percent of the lake volume had DO concentrations less than that needed to sustain fish life. The specific conductance was about four times greater in the hypolimnetic water than at the lake surface. Also, the mean total phosphorus concentration was about 30 times greater in the hypolimnion than at the 3-foot depth.

Although about one-fourth of the shoreline is occupied by mostly seasonal recreational homes, the number of residential homes has more than doubled since 1966.



Gillette Lake, Stevens County. From Washington Department of Game, March 13, 1950.








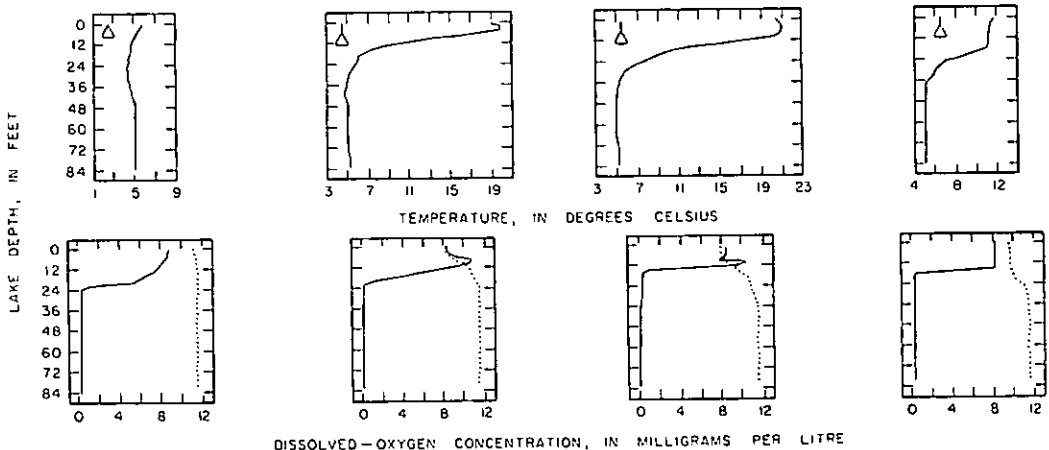
Gillette Lake, Stevens County. August 10, 1972.  
Approx. scale 1:12,000.

Water-quality data for Gillette Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	April 19		June 7		August 16		September 27	
	3	82	3	80	3	80	3	78
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	15	31	16	31	14	29	14	29
Dissolved iron (Fe) -----	.13	.26	.13	.38	.08	.36	.27	.22
Dissolved manganese (Mn) ----	.010	.030	.010	1.2	.000	1.3	.030	1.1
Calcium (Ca) -----	6.3	--	--	--	--	--	9.0	--
Magnesium (Mg) -----	1.1	--	--	--	--	--	1.6	--
Sodium (Na) -----	3.0	--	--	--	--	--	4.0	--
Potassium (K) -----	4.5	--	--	--	--	--	.9	--
Bicarbonate (HCO <sub>3</sub> ) -----	31	94	32	91	33	90	35	93
Sulfide (as H <sub>2</sub> S) -----	--	trace	--	--	--	.2	--	--
Sulfate (SO <sub>4</sub> ) -----	3.0	--	--	--	--	--	4.4	--
Chloride (Cl) -----	1.3	--	--	--	--	--	.1	--
Nitrate nitrogen (as N) -----	.02	.02	.01	.04	.04	.07	.02	.03
Nitrite nitrogen (as N) -----	.01	.02	.00	.01	.00	.00	.00	.01
Ammonia nitrogen (as N) -----	.34	.91	.06	8.3	.04	7.4	.02	.40
Organic nitrogen (as N) -----	.08	8.3	.33	--	.65	1.6	.18	9.1
Total phosphorus (as P) -----	.10	2.6	.010	--	.017	.32	.029	1.1
Orthophosphate (as P) -----	.004	2.5	.002	.10	.003	.15	.000	.42
Suspended solids (110 °C) ----	32	--	--	--	--	--	10	--
Hardness (Ca, Mg) -----	20	--	--	--	--	--	29	--
Specific conductance ----- (micromhos at 25 °C)	55	250	50	265	58	260	63	265
pH (pH units) -----	7.7	7.0	7.5	6.9	7.6	6.9	7.9	7.1
Color (Pt-Co units) -----	35	150	30	1,000	5	140	10	100
Chlorophyll a (µg/l) -----	12.0	--	2.5	--	2.5	--	3.3	--
Fecal coliform Range --	--	--	--	--	<1-2	1	1-5	3
(col. per 100 ml) Mean --	--	--	--	--	1	1	3	3

- EXPLANATION
-  Secchi-disc visibility, depth of base of triangle
  -  Dissolved oxygen concentration
  -  Dissolved oxygen concentration at 100 percent saturation



DISSOLVED-OXYGEN CONCENTRATION, IN MILLIGRAMS PER LITRE

Goodwin Lake near Silvana (12157500)Location.

Lat 48°08'02", long 122°17'57", in SW $\frac{1}{4}$ NE $\frac{1}{4}$  sec.33, T.31 N., R.4 E., Snohomish County, 5.2 miles southwest of Silvana; Tulalip Creek basin. Stanwood quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	5.17 sq mi	Maximum depth	50 ft
Altitude	324 ft	Length of shoreline	29,000 ft
Surface area	560 acres	Shoreline configuration	1.7
Lake volume	13,000 acre-ft	Development of volume	0.46
Mean depth	23 ft	Bottom slope	0.90 percent

The beach and littoral zone is mainly gravel and sand.

Basin geology.

Glacial drift (Newcomb, 1952).

Soils.

Gravelly loam (Anderson and others, 1947).

Land use (percentage of drainage basin). Urban 0, suburban 11, agricultural 0, forest or unproductive 72, and lake surface 17.

Nearshore residential development. 93 percent.

Number of nearshore homes. 347.

Surface-water inflow and outflow.

No inflow was observed. The outflow is a narrow connecting channel to Shoecraft Lake. Shoecraft Lake has an outflow which is controlled by flashboards in a wooden flume.

Lake stage.

The maximum variation observed gage height from October 1, 1971 to September 30, 1972 was 1.36 ft (U.S. Geological Survey, 1973).

The gage was read daily by an observer in 1972.

Macrophytes.

Shoreline covered by emersed plants 0-10 percent.

Lake surface covered by emersed plants <0.1 percent.

Lake bottom covered by submersed plants <1 percent.

Rooted aquatic plants observed were sedge (Cyperaceae) and musk-grass (Chara sp.).

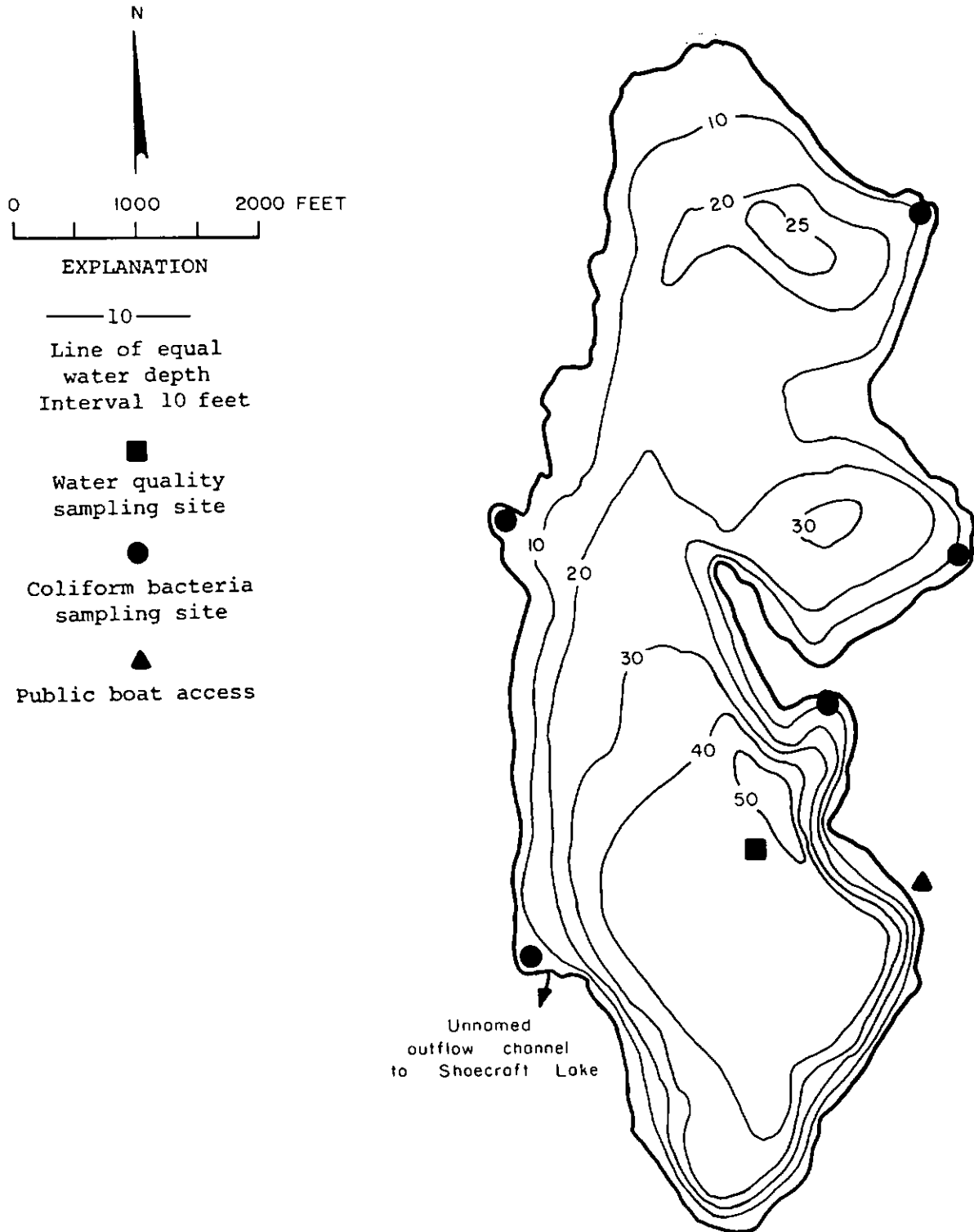
Remarks.

A daily record of water stage is collected by the U.S. Geological Survey at Goodwin Lake.

Conclusions.

The overall trophic nature of Goodwin Lake could be considered medium.

Temperature data show that moderate stratification occurred during the summer. The large surface area and relatively shallow depth of the lake tend to lessen the degree of thermal stratification. In the bottom water, depletion of DO to near zero and an increase in specific conductance had occurred by July; however, by early October the thermal barrier had deteriorated and mixing of the lake waters had begun. The water clarity was less than the average for all the lakes studied in 1972 and the algal concentration, as indicated by chlorophyll a analysis, was among the highest of the lakes studied. The mean total phosphorus concentration in the upper water was medium low, and organic and inorganic nitrogen concentrations were medium. The gravel and sand substrate in the littoral zone probably is responsible for the low macrophyte abundance.



Goodwin Lake, Snohomish County. From Washington Department of Game, May 12, 1952.



Goodwin Lake, Snohomish County. August 9, 1972.  
Approx. scale 1:15,700.




Water-quality data for Goodwin Lake.

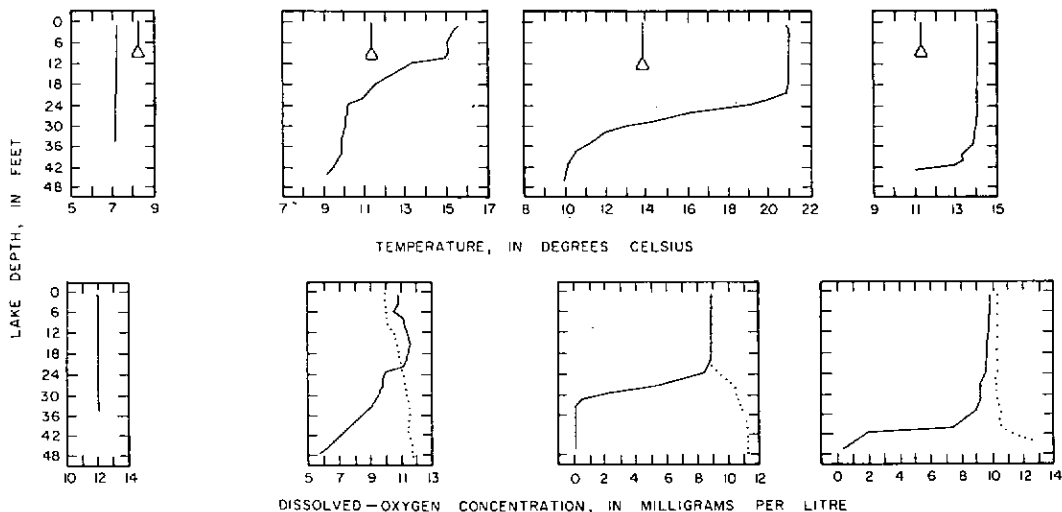
[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	March 13		May 12		July 27		October 10	
	3	32	3	45	3	42	3	38
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	0.4	0.4	0.0	0.1	0.4	0.4	0.8	0.8
Dissolved iron (Fe) -----	.01	.02	.02	.08	.04	.52	.14	.13
Dissolved manganese (Mn) ----	.058	--	.000	.020	.000	.11	.024	.016
Calcium (Ca) -----	4.1	--	--	--	--	--	4.6	5.2
Magnesium (Mg) -----	2.5	--	--	--	--	--	2.9	2.9
Sodium (Na) -----	3.8	--	--	--	--	--	3.8	3.8
Potassium (K) -----	1.0	--	--	--	--	--	1.0	1.0
Bicarbonate (HCO <sub>3</sub> ) -----	27	27	26	26	22	26	24	24
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	--	--	.0
Sulfate (SO <sub>4</sub> ) -----	.1	--	--	--	--	--	5.4	7.0
Chloride (Cl) -----	4.2	--	--	--	--	--	5.4	5.1
Nitrate nitrogen (as N) ----	.04	.04	.04	.06	.05	.05	.01	.01
Nitrite nitrogen (as N) ----	.00	.00	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N) ----	.04	.04	.58	.11	.03	.73	.20	.15
Organic nitrogen (as N) ----	.44	.46	.20	.42	.45	.47	.48	.24
Total phosphorus (as P) ----	.010	.008	.011	.015	.005	.016	.012	.003
Orthophosphate (as P) -----	.001	.000	.001	.001	.003	*.003	.001	.000
Suspended solids (110°C) ----	10	--	--	--	--	--	18	--
Hardness (Ca, Mg) -----	21	--	--	--	--	--	23	25
Specific conductance ----- (micromhos at 25°C)	65	65	62	64	65	81	67	69
pH (pH units) -----	7.8	8.0	7.8	7.3	7.6	7.5	7.4	7.2
Color (Pt-Co units) -----	20	20	10	15	5	5	10	10
Chlorophyll a (µg/l) -----	12.3	--	6.2	--	1.9	--	5.1	--
Fecal coliform Range -- (col. per 100 ml) Mean ---	--	--	--	--	<1-28 15	<1-20 5		

\* Unfiltered

EXPLANATION

-  Secchi - disc visibility, depth at base of triangle
-  Dissolved oxygen concentration
-  Dissolved oxygen concentration at 100 percent saturation



Heritage Lake near Tiger (12408205)Location.

Lat 48°37'47", long 117°31'54", in SW¼SE¼ sec.8, T.36 N., R.42 E., Stevens County, at narrows between Heritage and Thomas Lakes, 7.0 miles southwest of Tiger; Colville River basin. Aladdin Mountain quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	10.2 sq mi	Maximum depth	17 ft
Altitude	3,147 ft	Length of shoreline	14,000 ft
Surface area	73 acres	Shoreline configuration	2.3
Lake volume	750 acre-ft	Development of volume	0.61
Mean depth	10 ft	Bottom slope	0.85 percent

The beach and littoral zone consists mainly of muck and sand.

Basin geology.

Glacial drift with some granitic rock (Hunting and others, 1961).

Soils.

Sandy loam and loam (Van Duyne and Ashton, 1915).

Land use (percentage of drainage basin). Urban 0, suburban <1, agricultural 0, forest or unproductive 98, and lake surface 2.

Nearshore residential development. 17 percent.

Number of nearshore homes. 14 (mostly seasonal).

Surface-water inflow and outflow.

The main inflows are via Deer Creek, Patchen Creek, and Little Pend Oreille River. The combined estimated inflow from all the above tributaries was 2.7 ft<sup>3</sup>/s on August 16, 1972. The outflow is a narrow connecting channel to Thomas Lake.

Lake stage.

The observed gage height from April 19 to September 26, 1972, varied 0.4 ft. The variation in gage height was based on four observations only.

Macrophytes.

Shoreline covered by emersed plants 76-100 percent.

Lake surface covered by emersed plants 30 percent.

Lake bottom covered by submersed plants 54 percent.

Rooted aquatic plants observed were watershield (Brasenia sp.),\* white lily (Nymphaea sp.), yellow lily (Nuphar sp.), waterweed (Elodea sp.), and five varieties of pondweed (Potamogeton spp.).

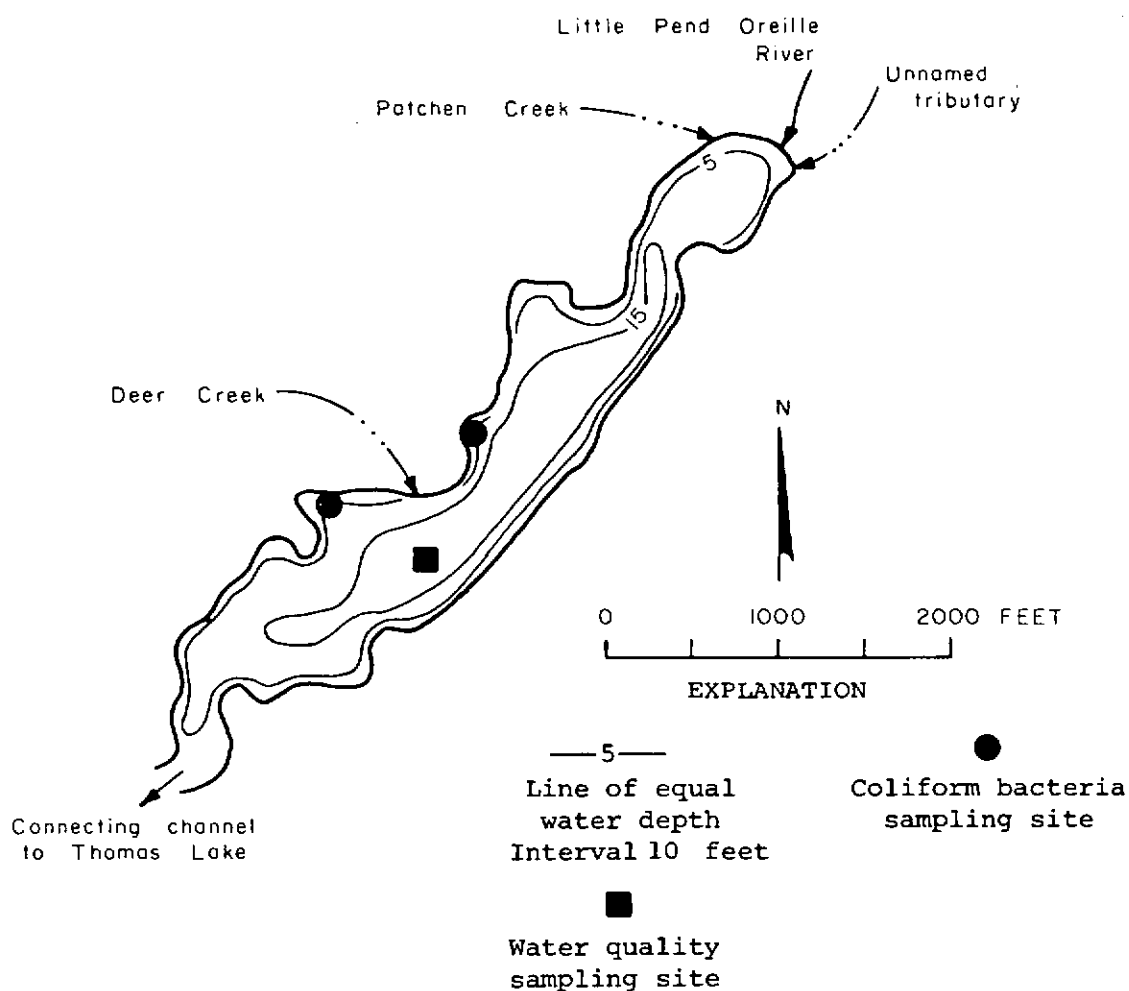
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Asterisk (\*) indicates dominant aquatic plant.



Conclusions.

The lake is very shallow, with a mean depth of 10 feet, and has an irregular shoreline. These morphometric features and the marsh-type environment around most of the lake contribute to the natural rate of eutrophication which is probably high. The muck littoral zone supports a very heavy growth of rooted aquatic plants. However, the rate of nutrient enrichment is probably reduced considerably by the high flushing rate of the lake.



Heritage Lake, Stevens County. From Washington Department of Game, March 11, 1950.



Heritage Lake, Stevens County. August 10, 1972.  
Approx. scale 1:12,000.




Water-quality data for Heritage Lake.

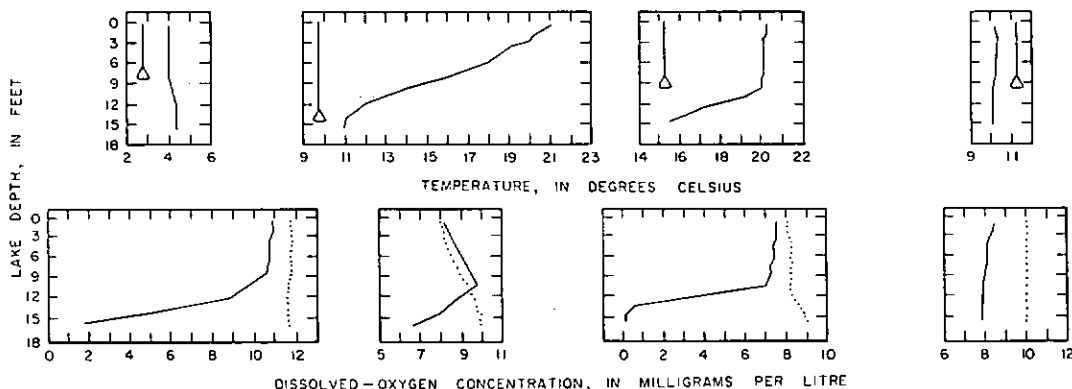
[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	April 19		June 7		August 16		September 26	
	3	12	3	12	3	12	3	11
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	18	18	17	17	13	13	12	13
Dissolved iron (Fe) -----	.18	.36	.11	.10	.18	.21	.21	.23
Dissolved manganese (Mn) ----	.000	.030	.020	.000	.008	.000	.020	.020
Calcium (Ca) -----	4.7	--	--	--	--	--	7.2	--
Magnesium (Mg) -----	.8	--	--	--	--	--	1.3	--
Sodium (Na) -----	2.5	--	--	--	--	--	3.1	--
Potassium (K) -----	1.2	--	--	--	--	--	.7	--
Bicarbonate (HCO <sub>3</sub> ) -----	24	26	25	28	29	30	31	32
Sulfide (as H <sub>2</sub> S) -----	--	.0	--	.0	--	.0	--	.0
Sulfate (SO <sub>4</sub> ) -----	4.1	--	--	--	--	--	4.5	--
Chloride (Cl) -----	1.9	--	--	--	--	--	.1	--
Nitrate nitrogen (as N) -----	.02	.01	.02	.01	.04	.04	.02	.02
Nitrite nitrogen (as N) -----	.00	.01	.00	.01	.00	.00	.00	.00
Ammonia nitrogen (as N) -----	.32	.07	.12	.05	.06	.33	.08	.08
Organic nitrogen (as N) -----	.11	.75	.24	.20	.44	.65	.30	.26
Total phosphorus (as P) -----	.162	.037	.018	.016	.025	.033	.037	.037
Orthophosphate (as P) -----	.007	.008	.005	.007	.003	.002	.001	.001
Suspended solids (110 °C) ----	34	--	--	--	--	--	10	--
Hardness (Ca, Mg) -----	15	--	--	--	--	--	23	--
Specific conductance ----- (micromhos at 25 °C)	42	47	44	41	54	54	57	57
pH (pH units) -----	7.9	7.8	7.3	7.4	7.5	7.4	8.0	8.2
Color (Pt-Co units) -----	30	30	15	25	15	20	20	30
Chlorophyll <i>a</i> (µg/l) -----	5.9	--	1.6	--	4.2	--	5.3	--

Fecal coliform Range --  
(col. per 100 ml) Mean ---

-- -- -- <1 <1 <1-2  
1

- EXPLANATION
-  Secchi-disc visibility, depth at base of triangle
  -  Dissolved oxygen concentration
  -  Dissolved oxygen concentration at 100 percent saturation



Hicks Lake near Lacey (12080550)Location.

Lat 47°01'02", long 122°47'42", in NE $\frac{1}{4}$ SW $\frac{1}{4}$  sec.27, T.18 N., R.1 W., Thurston County, 1.5 miles southeast of Lacey; Woodland Creek basin. Lacey quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	1.80 sq mi	Maximum depth	35 ft
Altitude	162 ft	Length of shoreline	13,000 ft
Surface area	160 acres	Shoreline configuration	1.4
Lake volume	2,700 acre-ft	Development of volume	0.51
Mean depth	18 ft	Bottom slope	1.2 percent

The beach and littoral zone consists of a mixture of muck, sand, and gravel.

Basin geology.

Glacial outwash with local alluvium (Noble and Wallace, 1966).

Soils.

Loamy fine sand, loamy sand, and gravelly loamy sand with some local peat deposits (Ness, 1958).

Land use (percentage of drainage basin). Urban 16, suburban 33, agricultural 31, forest or unproductive 6, and lake surface 14.

Nearshore residential development. 77 percent.

Number of nearshore homes. 90 (mostly permanent).

Surface-water inflow and outflow.

No inflow was observed. The outflow, which is controlled by natural conditions, was perennial. A discharge measurement at the outflow on March 1 was 10.2 ft<sup>3</sup>/s; May 3, 8.20 ft<sup>3</sup>/s; June 27, 4.72 ft<sup>3</sup>/s; and October 3, 2.17 ft<sup>3</sup>/s.

Lake stage.

The observed gage height from March 1 to September 23, 1972, varied 2.4 ft.

Macrophytes.

Shoreline covered by emerged plants 26-50 percent.

Lake surface covered by emerged plants 15 percent.

Lake bottom covered by submersed plants 40 percent.

Rooted aquatic plants observed were white lily (Nymphaea sp.),\* coontail (Ceratophyllum sp.),\* waterweed (Elodea sp.),\* muskgrass (Chara sp.),\* cattail (Typha sp.), yellow lily (Nuphar sp.),

Macrophytes.--continued

sedge (Cyperaceae), and quillwort (Isotes sp.).

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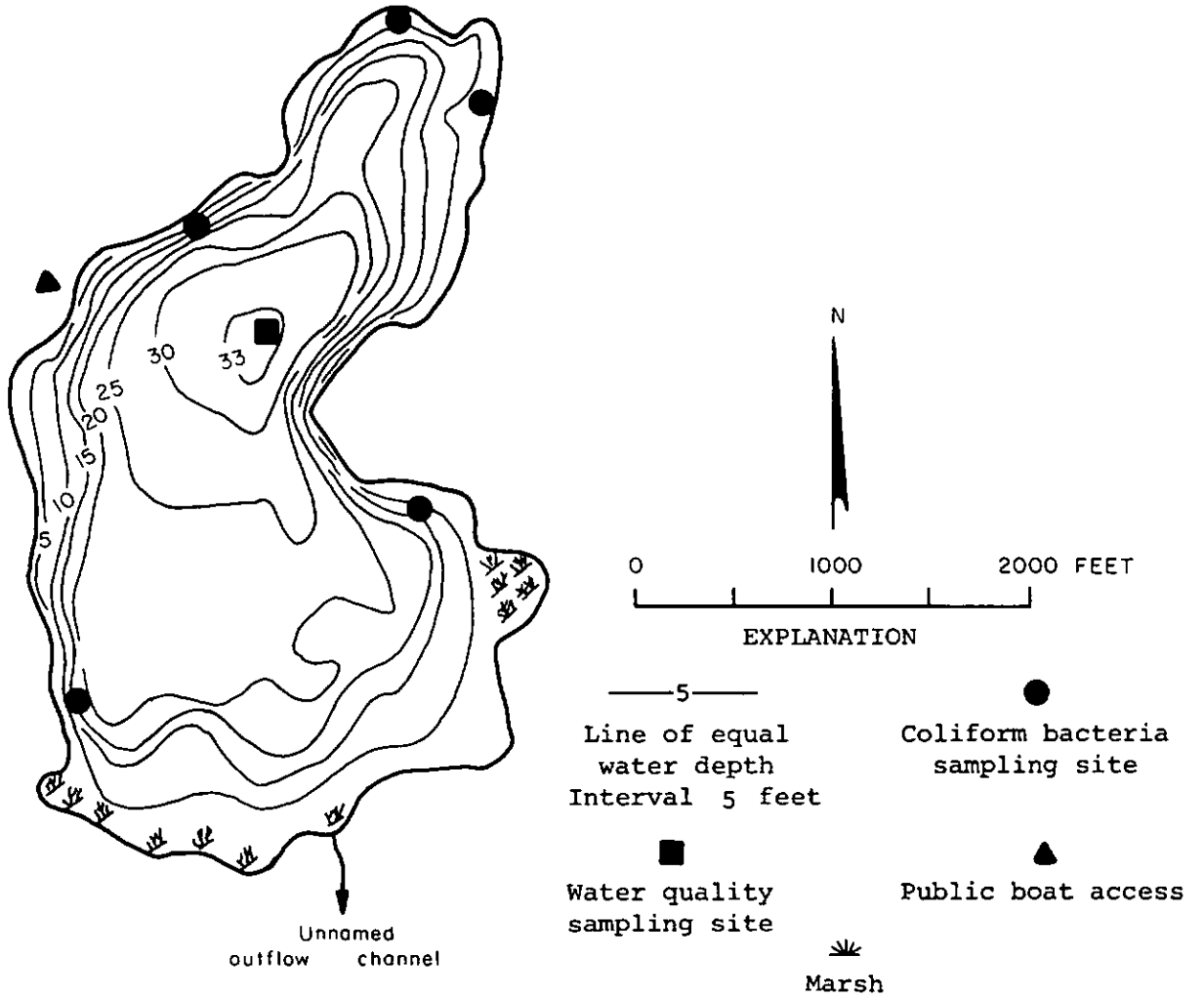
\*Asterisk (\*) indicates dominant aquatic plants.

Remarks.

The south side of the lake is marshy and not suitable for residential development.

Conclusions.

Hicks Lake has a fairly shallow mean depth and is locally bordered by marsh. Also, the lake is in a suburban and urban environment. Because of its environment and shape, the lake has a high potential for increased rates of eutrophication. The total phosphorus concentration in the upper waters was moderately high and the dissolved oxygen in the bottom waters was depleted by early summer. About 15 percent of the lake surface contained emerged plants and roughly 40 percent of the lake bottom was occupied by submersed plants. Overall the lake could be considered moderately high in biological productivity.



Hicks Lake, Thurston County. From Washington Department of Game, June 12, 1949.



Hicks Lake, Thurston County. July 14, 1971.  
Approx. scale 1:9800.

Water-quality data for Hicks Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	March 1		May 3		June 27		October 3	
	3	24	3	31	3	34	3	33
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	0.1	0.2	0.3	0.4	0.6	1.6	1.0	1.9
Dissolved iron (Fe) -----	.01	.03	.09	.09	.10	1.3	.24	2.8
Dissolved manganese (Mn) ----	.000	--	.000	.000	.000	.075	.008	.14
Calcium (Ca) -----	1.7	--	--	--	--	--	3.2	--
Magnesium (Mg) -----	.7	--	--	--	--	--	1.2	--
Sodium (Na) -----	1.8	--	--	--	--	--	2.0	--
Potassium (K) -----	.4	--	--	--	--	--	.4	--
Bicarbonate (HCO <sub>3</sub> ) -----	9	11	12	11	13	16	10	14
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	trace	--	.0
Sulfate (SO <sub>4</sub> ) -----	.1	--	--	--	--	--	3.7	--
Chloride (Cl) -----	1.8	--	--	--	--	--	2.7	--
Nitrate nitrogen (as N) ----	.06	.05	.02	.04	.00	.00	.01	.01
Nitrite nitrogen (as N) ----	.00	.00	.00	.01	.00	.00	.00	.00
Ammonia nitrogen (as N) ----	.06	.06	.30	.12	.04	.17	.05	.31
Organic nitrogen (as N) ----	.31	.17	.35	.13	.39	.28	.31	.49
Total phosphorus (as P) ----	.016	.023	.024	.019	.020	.060	.023	.083
Orthophosphate (as P) -----	.003	.003	.002	.007	.000	.030	.004	.074
Suspended solids (110°C) ---	11	--	--	--	--	--	20	--
Hardness (Ca, Mg) -----	7	--	--	--	--	--	13	--
Specific conductance ----- (micromhos at 25°C)	29	29	30	31	31	37	29	50
pH (pH units) -----	7.0	6.9	7.1	6.7	7.1	6.5	7.5	6.5
Color (Pt-Co units) -----	20	20	25	30	35	40	15	50
Chlorophyll <i>a</i> (µg/l)-----	5.8	--	2.3	--	4.6	--	4.4	--
Fecal coliform Range -- (col. per 100 ml) Mean ---	--	--	--	--	2-34 10		<1-11 5	

EXPLANATION



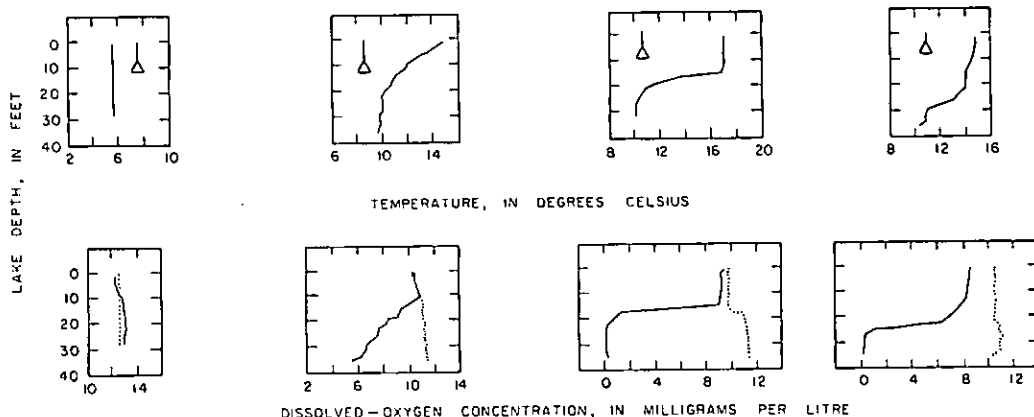
Secchi-disc visibility,  
depth at base of triangle



Dissolved oxygen concentration



Dissolved oxygen concentration  
at 100 percent saturation



DISSOLVED-OXYGEN CONCENTRATION, IN MILLIGRAMS PER LITRE



King Lake near Monroe (12150450)Location.

Lat 47°48'34", long 121°55'19", in SW $\frac{1}{4}$ SW $\frac{1}{4}$  sec.21, T.27 N., R.7 E., Snohomish County, 4.0 miles southeast of Monroe; Snohomish River basin. Monroe quadrangle, 1:62,500.

Physical characteristics of lake.

Drainage area	0.20 sq mi	Maximum depth	65 ft
Altitude	1,359 ft	Length of shoreline	5,100 ft
Surface area	17 acres	Shoreline configuration	1.7
Lake volume	350 acre-ft	Development of volume	0.32
Mean depth	21 ft	Bottom slope	6.7 percent

The beach and littoral zone is mainly muck and mud deposits.

Basin geology.

Metamorphic and volcanic rock (Hunting and others, 1961).

Soils.

Shallow, stony soil on semi-mountainous relief (Anderson and others, 1947).

Land use (percentage of drainage basin). Urban 0, suburban 0, agricultural 0, forest or unproductive 87, and lake surface 13.

Nearshore residential development. 0 percent.

Number of nearshore homes. 0.

Surface-water inflow and outflow.

The inflow is via two unnamed tributaries. The stream entering the lake on the north is dammed by beavers and contributes minor inflow during the dry season. The outflow, via an unnamed channel, had flows less than 0.5 ft<sup>3</sup>/s during the summer.

Lake stage.

The observed gage height from March 14 to October 12, 1972, varied 0.6 ft. The variation in gage height was based on four observations only.

Macrophytes.

Shoreline covered by emerged plants 76-100 percent.

Lake surface covered by emerged plants 6 percent.

Lake bottom covered by submersed plants 12 percent.

Rooted aquatic plants observed were cattail (*Typha* sp.),\* white lily (*Nymphaea* sp.), yellow lily (*Nuphar* sp.), coontail (*Ceratophyllum* sp.), waterweed (*Elodea* sp.), and muskgrass (*Chara* sp.).

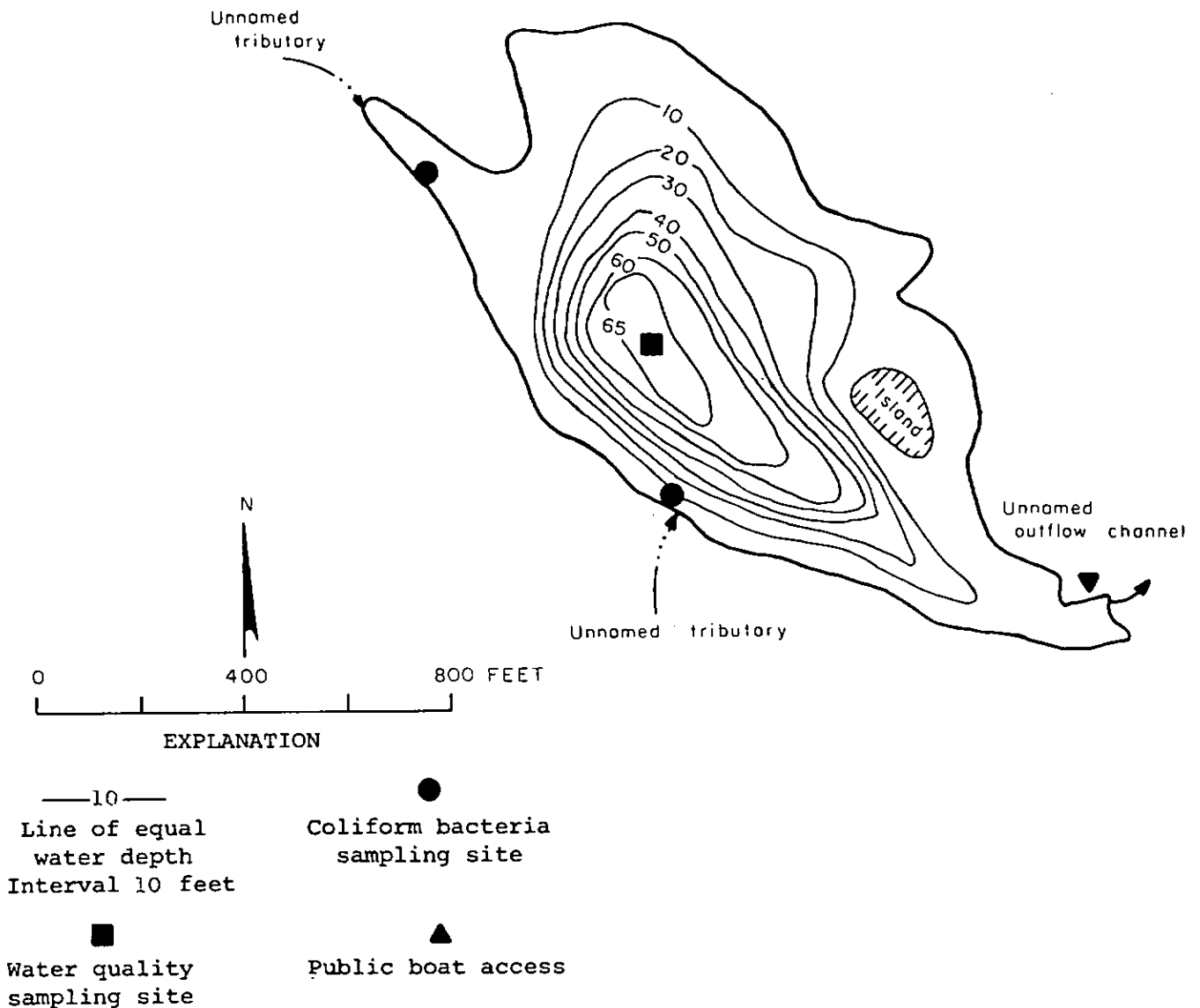
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Asterisk (\*) indicates dominant aquatic plant.

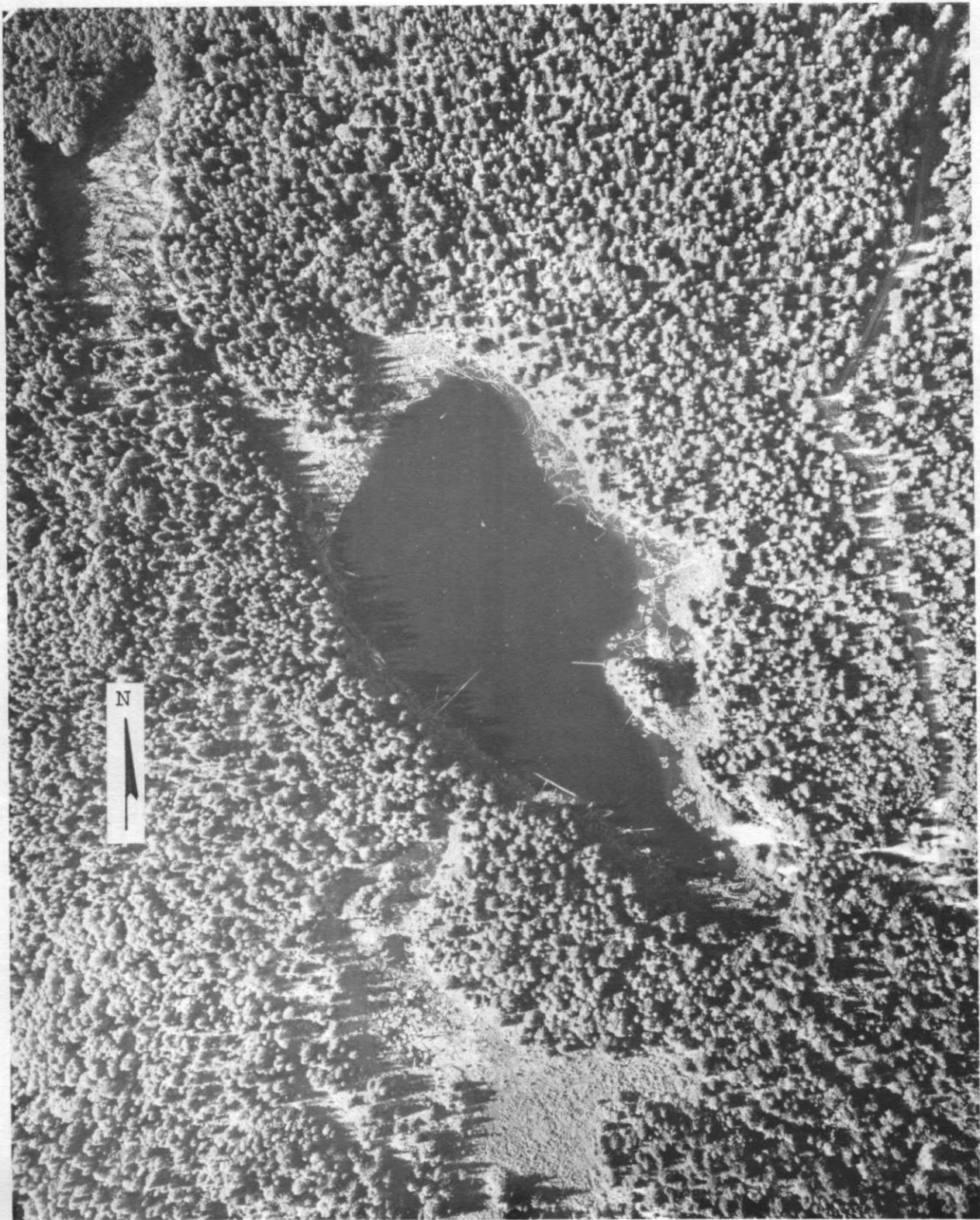
Conclusions.

King Lake has an altitude of 1,359 feet and is situated in the foothills of the Cascade Range, in a drainage basin heavily forested with second-growth timber.

The lake is probably medium in overall trophic nature. The lake water was very dilute in dissolved minerals and was slightly colored. The chlorophyll a concentrations were medium low but the muck littoral bottom supports a moderate growth of aquatic plants. The DO concentration decreased to near zero in the bottom waters in the summer.



King Lake, Snohomish County. From Washington Department of Game, June 14, 1955.



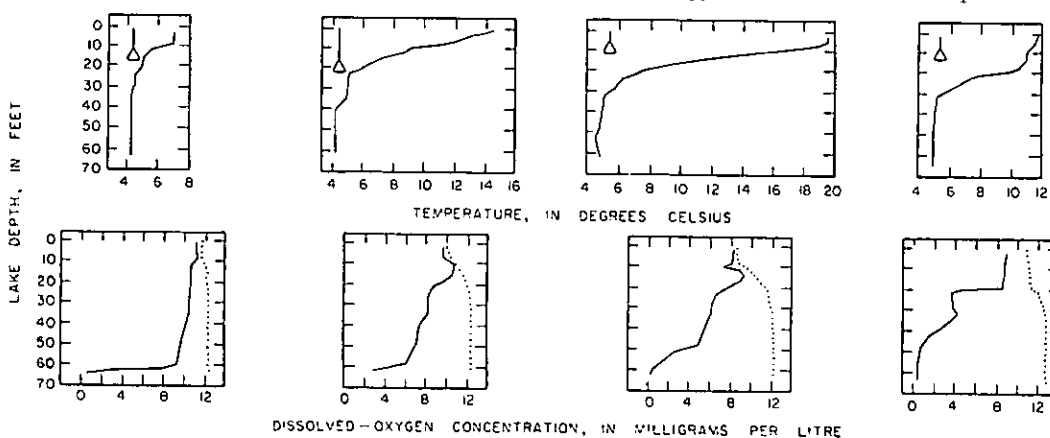
King Lake, Snohomish County. August 9, 1972. Approx. scale 1:3600.

## Water-quality data for King Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	March 14		May 11		July 26		October 12	
	3	62	3	57	3	59	3	60
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	6.0	6.2	4.4	6.6	2.1	7.1	2.7	8.0
Dissolved iron (Fe) -----	.02	.29	.15	.24	.36	.83	.28	4.0
Dissolved manganese (Mn) ----	.038	--	.010	.000	.050	.23	.016	.62
Calcium (Ca) -----	2.1	--	--	--	--	--	2.7	--
Magnesium (Mg) -----	.4	--	--	--	--	--	.7	--
Sodium (Na) -----	1.8	--	--	--	--	--	1.9	--
Potassium (K) -----	.6	--	--	--	--	--	.2	--
Bicarbonate (HCO <sub>3</sub> ) -----	10	12	11	11	11	9	10	12
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	.0
Sulfate (SO <sub>4</sub> ) -----	.1	--	--	--	--	--	2.8	--
Chloride (Cl) -----	1.2	--	--	--	--	--	1.6	--
Nitrate nitrogen (as N) ----	.07	.11	.34	.12	.06	.16	.01	.05
Nitrite nitrogen (as N) ----	.00	.00	.00	.00	.00	.00	.00	.01
Ammonia nitrogen (as N) ----	.02	.05	.02	.03	.23	.31	.12	.56
Organic nitrogen (as N) ----	.21	.38	.20	.08	.22	.07	.88	.00
Total phosphorus (as P) ----	.006	.006	.014	.012	.018	.013	.009	.027
Orthophosphate (as P) -----	.003	.002	.001	.003	.005	.006	.002	.012
Suspended solids (110°C) ----	0	--	--	--	--	--	23	--
Hardness (Ca, Mg) -----	7	--	--	--	--	--	10	--
Specific conductance ----- (micromhos at 25°C)	34	32	26	27	30	30	26	44
pH (pH units) -----	7.8	7.5	7.1	6.6	7.7	6.9	7.6	7.2
Color (Pt-Co units) -----	20	25	20	25	15	25	20	60
Chlorophyll <i>a</i> (µg/l) -----	2.6	--	1.5	--	3.5	--	1.6	--
Fecal coliform Range -- (col. per 100 ml) Mean ---	--	--	--	--	20-300	160	<1-2	1

## EXPLANATION

Secchi-disc visibility,  
depth at base of  
triangleDissolved oxygen  
concentrationDissolved oxygen  
concentration at 100  
percent saturation

Leo Lake near Tiger (12408195)Location.

Lat 48°38'46", long 117°30'06", in SE $\frac{1}{4}$ SE $\frac{1}{4}$  sec.4, T.36 N., R.42 E., Stevens County, 5.2 miles southwest of Tiger; Colville River basin. Ione and Aladdin Mountain quadrangles, 1:24,000.

Physical characteristics of lake.

Drainage area	2.99 sq mi	Maximum depth	37 ft
Altitude	3,165 ft	Length of shoreline	7,100 ft
Surface area	43 acres	Shoreline configuration	1.5
Lake volume	740 acre-ft	Development of volume	0.46
Mean depth	17 ft	Bottom slope	2.4 percent

Large areas of the beach and littoral zone are comprised of muck.

Basin geology.

Glacial drift with some granitic rock (Hunting and others, 1961).

Soils.

Sandy loam with peat and muck (Van Duyne and Ashton, 1915).

Land use (percentage of drainage basin). Urban 0, suburban <1, agricultural 0, forest or unproductive 97, and lake surface 3.

Nearshore residential development. 0 percent.

Number of nearshore homes. One.

Surface-water inflow and outflow.

The combined inflow from three tributary streams to the lake was less than 1 ft<sup>3</sup>/s during four sample visits. The outflow, via Little Pend Oreille River, was perennial. Estimated outflow discharges on April 20 was 4.8 ft<sup>3</sup>/s, June 6, 3.8 ft<sup>3</sup>/s, August 16, 1.2 ft<sup>3</sup>/s, and September 26, 1.5 ft<sup>3</sup>/s.

Lake stage.

The observed gage height from April 20 to September 26, 1972, varied 0.2 ft. The variation in gage height was based on four observations only.

Macrophytes.

Shoreline covered by emerged plants 76-100 percent.

Lake surface covered by emerged plants 12 percent.

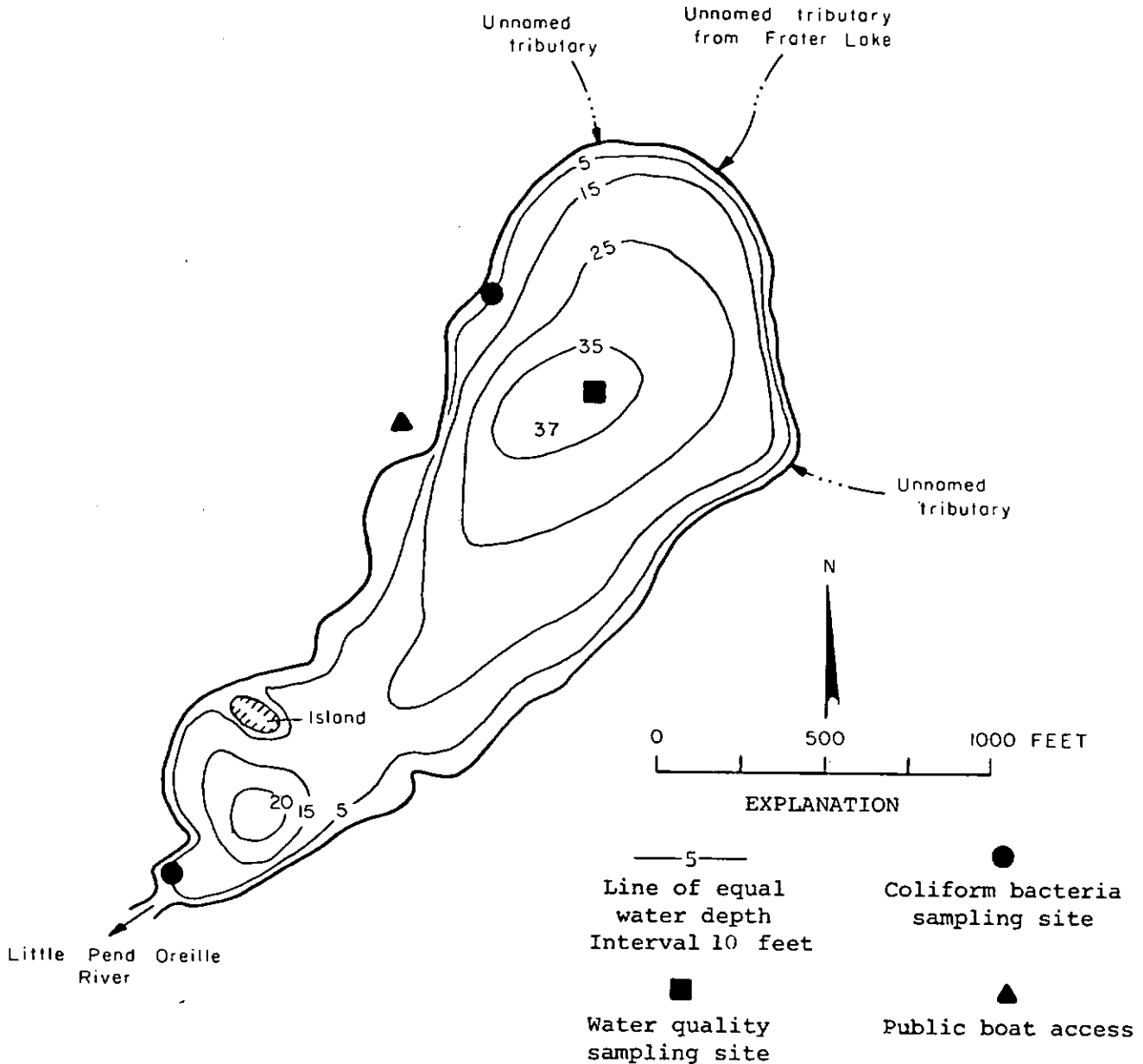
Lake bottom covered by submersed plants 31 percent.

Rooted aquatic plants observed were two varieties of pondweed (Potamogeton spp.),\* yellow lily (Nuphar sp.), sedge (Cyperaceae), waterweed (Elodea sp.), and muskgrass (Chara sp.).

Asterisk (\*) indicates dominant aquatic plant.

Conclusions.

The lake is probably medium to high in trophic nature as shown by the medium high chlorophyll a concentrations, depletion of dissolved oxygen in bottom waters during summer, moderate to high nitrogen and phosphorus concentrations, and heavy growths of rooted aquatic plants. Specific conductance and nutrient concentrations increased appreciably in the bottom water during the summer.



Leo Lake, Stevens County. From Washington Department of Game, March 14, 1950.






Leo Lake, Stevens County. August 10, 1972.  
Approx. scale 1:7200.

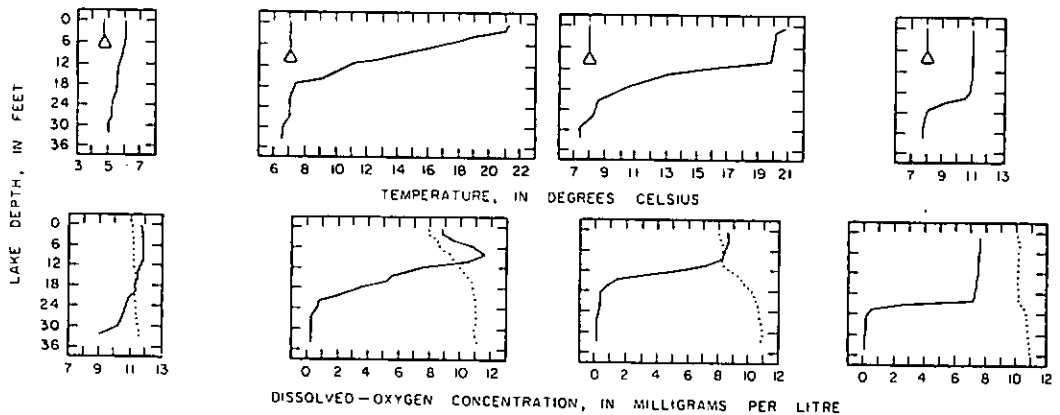
Water-quality data for Leo Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	April 20		June 6		August 16		September 26	
	3	28	3	29	3	29	3	29
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	15	16	16	15	13	20	14	21
Dissolved iron (Fe) -----	.28	.50	.10	.13	.12	2.0	.28	1.8
Dissolved manganese (Mn) ----	.020	.050	.010	.000	.025	.40	.040	.68
Calcium (Ca) -----	6.2	--	--	--	--	--	8.1	--
Magnesium (Mg) -----	1.1	--	--	--	--	--	1.1	--
Sodium (Na) -----	3.0	--	--	--	--	--	3.1	--
Potassium (K) -----	1.0	--	--	--	--	--	.8	--
Bicarbonate (HCO <sub>3</sub> ) -----	33	32	30	31	28	41	31	46
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	--	--	--
Sulfate (SO <sub>4</sub> ) -----	2.4	--	--	--	--	--	3.1	--
Chloride (Cl) -----	1.1	--	--	--	--	--	0	--
Nitrate nitrogen (as N) -----	.01	.01	.01	.01	.05	.06	.02	.02
Nitrite nitrogen (as N) -----	.01	.01	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N) -----	.09	.13	.05	.10	.05	.41	.07	.92
Organic nitrogen (as N) -----	.15	.18	.28	.29	.34	.27	.28	1.3
Total phosphorus (as P) -----	.044	.048	.013	.028	.025	.13	.030	.33
Orthophosphate (as P) -----	.017	.020	.001	.002	.002	.026	.000	.054
Suspended solids (110°C) ----	33	--	--	--	--	--	6	--
Hardness (Ca, Mg) -----	20	--	--	--	--	--	25	--
Specific conductance ----- (micromhos at 25°C)	57	57	46	70	52	87	58	100
pH (pH units) -----	7.6	7.6	7.5	7.3	7.4	6.7	7.5	7.1
Color (Pt-Co units) -----	25	30	20	25	20	30	10	45
Chlorophyll <i>a</i> (µg/l) -----	18.7	--	3.0	--	2.6	--	3.1	--
Fecal coliform Range ---	--	--	--	--	0-2	1	1-10	5
(col. per 100 ml) Mean ---	--	--	--	--	--	--	--	--

EXPLANATION

-  Secchi - disc visibility, depth at base of triangle
-  Dissolved oxygen concentration
-  Dissolved oxygen concentration at 100 percent saturation



DISSOLVED-OXYGEN CONCENTRATION, IN MILLIGRAMS PER LITRE



Mason Lake near Union (12074500)Location.

Lat 47°21'14", long 122°55'17", in SE $\frac{1}{4}$ NW $\frac{1}{4}$  sec.34, T.22 N., R.2 W., Mason County, 8.5 miles east of Union; Sherwood Creek basin. Mason Lake quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	20.2 sq mi	Maximum depth	90 ft
Altitude	194 ft	Length of shoreline	58,000 ft
Surface area	1,000 acres	Shoreline configuration	2.4
Lake volume	49,000 acre-ft	Development of volume	0.53
Mean depth	48 ft	Bottom slope	1.2 percent

The beach and littoral zone is mostly gravel or a gravel and sand matrix.

Basin geology.

Glacial drift plain underlain by till and outwash (Molenaar and Noble, 1970).

Soils.

Mostly gravelly, sandy loam with some silt clay loam, sandy loam, and peat (Ness and Fowler, 1960).

Land use (percentage of drainage basin). Urban 0, suburban 3, agricultural 0, forest or unproductive 89, and lake surface 8.

Nearshore residential development. 87 percent of shoreline.

Number of nearshore homes. 571 (mostly seasonal).

Surface-water inflow and outflow.

The lake has a year-round inflow (Shumocher Creek) as well as numerous small intermittent streams. The outflow (Sherwood Creek), which is controlled by natural conditions, is perennial. A discharge measurement at the outflow on March 6 was 400 ft<sup>3</sup>/s; May 10, 43.2 ft<sup>3</sup>/s; June 29, 21.6 ft<sup>3</sup>/s; and October 5, 6.90 ft<sup>3</sup>/s.

Lake stage.

The maximum variation in gage height from October 1, 1971 to September 30, 1972 was 3.72 ft (U.S. Geological Survey, 1973).

Macrophytes.

Shoreline covered by emerged plants 0-10 percent.  
 Lake surface covered by emerged plants <0.1 percent.  
 Lake bottom covered by submersed plants 8 percent.  
 Rooted aquatic plants observed were watershield (Brasenia sp.),\*  
 three varieties of pondweed (Potamogeton spp.), waterweed

Macrophytes.--continued

(Elodea sp.),\* yellow lily (Nuphar sp.), sedge (Cyperaceae), muskgrass (Chara sp.), and wildcelery (Vallisneria sp.).

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Asterisk (\*) indicates dominant aquatic plants.

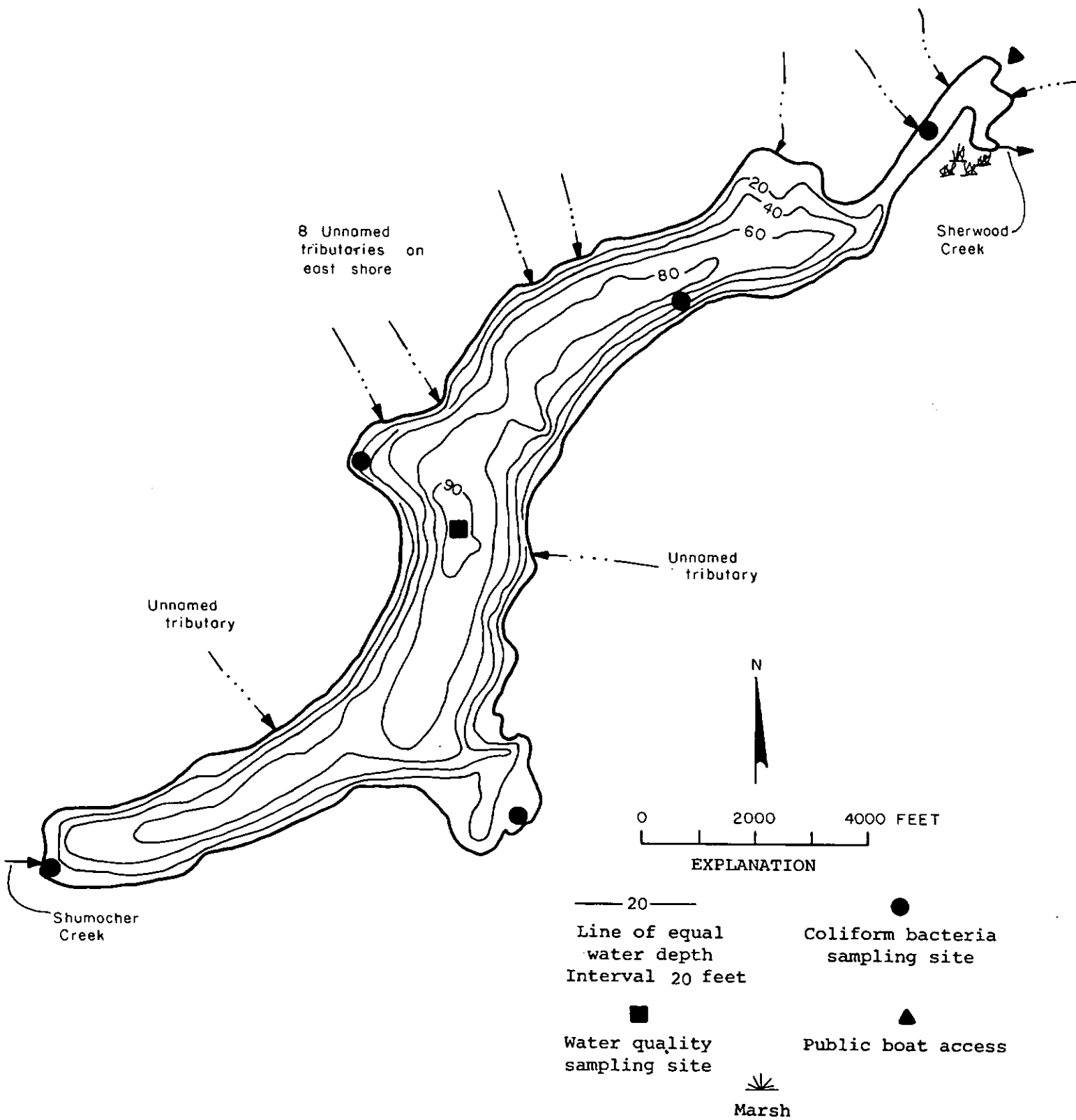
Remarks.

A continuous record of water stage is collected by the U.S. Geological Survey.

Conclusions.

Mason Lake probably could be considered low in biological productivity. The chlorophyll a concentrations were medium low and the submersed rooted aquatic-plant abundance was moderate. However, most of the aquatic plants were found in the long shallow north bay. The lake water is low in dissolved minerals and in nitrogen and phosphorus concentrations. The mean annual concentrations of organic nitrogen in the upper water was the lowest observed among the lakes studied. Although the DO concentration was low in the deep waters, it did not become entirely depleted during the summer. The lake maintains a year-round inflow and outflow, but the flushing rate is only moderate because of the large lake volume.

Because of possible continued development of the uplands and an increased recreational use of this large natural lake, Mason Lake should be closely observed for signs of accelerated nutrient enrichment. The number of nearshore homes, estimated from U.S. Geological Survey topographic map, has more than doubled since 1968.



Mason Lake, Mason County. From Washington Department of Game, May 4, 1954.

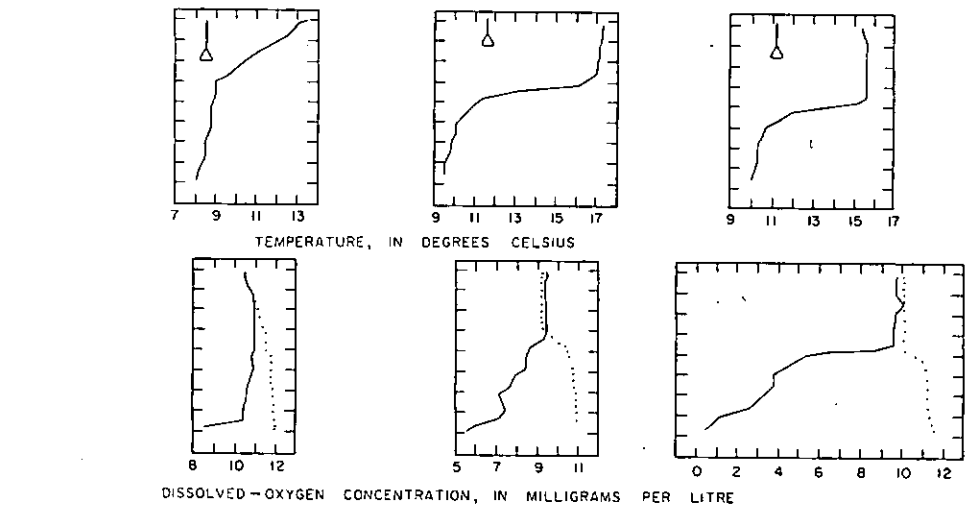
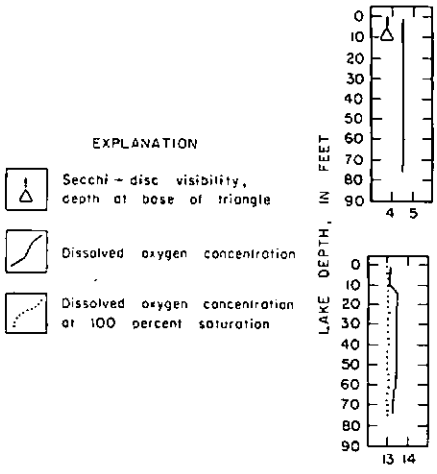


Mason Lake, Mason County.  
August 9, 1972. Approx. scale 1:29,000.

Water-quality data for Mason Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	March 6		May 10		June 29		October 5	
	3	70	3	75	3	77	3	75
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	0.1	4.8	4.8	4.9	5.2	5.7	6.6	9.0
Dissolved iron (Fe) -----	.00	.03	.02	.04	.03	.04	.02	.26
Dissolved manganese (Mn) ----	.000	--	.000	.000	.000	.010	.000	.024
Calcium (Ca) -----	3.1	--	--	--	--	--	4.5	--
Magnesium (Mg) -----	1.6	--	--	--	--	--	1.8	--
Sodium (Na) -----	1.9	--	--	--	--	--	1.9	--
Potassium (K) -----	.2	--	--	--	--	--	.2	--
Bicarbonate (HCO <sub>3</sub> ) -----	24	25	24	24	23	20	24	23
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	.0
Sulfate (SO <sub>4</sub> ) -----	2.4	--	--	--	--	--	2.2	--
Chloride (Cl) -----	1.8	--	--	--	--	--	2.1	--
Nitrate nitrogen (as N) ----	.03	.00	.02	.01	.00	.00	.01	.02
Nitrite nitrogen (as N) ----	.00	.00	.00	.01	.00	.00	.00	.00
Ammonia nitrogen (as N) ----	.05	.04	.07	.12	.00	.00	.06	.05
Organic nitrogen (as N) ----	.08	.09	.19	.31	.19	.14	.16	.08
Total phosphorus (as P) ----	.006	.010	.012	.015	.012	.014	.005	.006
Orthophosphate (as P) -----	.001	.001	.002	.001	.000	.000	.001	.000
Suspended solids (110°C) ----	15	--	--	--	--	--	22	--
Hardness (Ca, Mg) -----	14	--	--	--	--	--	19	--
Specific conductance ----- (micromhos at 25°C)	40	38	40	40	42	41	41	41
pH (pH units) -----	8.1	8.1	7.8	7.9	7.6	7.2	7.4	7.1
Color (Pt-Co units) -----	10	10	10	15	15	15	15	15
Chlorophyll <i>a</i> (µg/l)-----	6.7	--	1.6	--	3.0	--	3.0	--
Fecal coliform Range --	--	--	--	--	<1-2	--	<1-4	--
(col. per 100 ml) Mean ---	--	--	--	--	1	--	2	--



Mineral Lake at Mineral (12082990)Location.

Lat 46°43'08", long 122°10'36", in NW¼NE¼ sec.9, T.14 N., R.5 E.,  
Lewis County, at Mineral; Nisqually River basin.  
Mineral quadrangle, 1:62,500.

Physical characteristics of lake.

Drainage area	2.19 sq mi	Maximum depth	38 ft
Altitude	1,450 ft	Length of shoreline	17,000 ft
Surface area	280 acres	Shoreline configuration	1.4
Lake volume	6,600 acre-ft	Development of volume	0.69
Mean depth	26 ft	Bottom slope	0.95 percent

The beach and littoral zone is composed of sand, gravel, and muck.

Basin geology.

Volcanic rock in hills with alluvium on southern side of lake  
(Hunting and others, 1961).

Soils.

Mostly shallow stony soils on rough mountainous land, with deposits  
of silt loam at lower extremities (Fowler and Ness, 1954).

Land use (percentage of drainage basin). Urban 13, suburban 0,  
agricultural 0, forest or unproductive 67, and lake surface 20.

Nearshore residential development. 28 percent.

Number of nearshore homes. 12 (mostly permanent).

Surface-water inflow and outflow. The inflow, via an unnamed tributary,  
is perennial. The low flow during the October 16 visit was  
estimated at 0.3 ft<sup>3</sup>/s. The outflow, via an unnamed channel, is regu-  
lated by flashboards. A steady outflow from the lake was observed  
throughout 1972.

Lake stage.

The observed gage height from March 10 to September 26, 1972,  
varied 1.7 ft.

Macrophytes.

Shoreline covered by emerged plants 0-10 percent.  
Lake surface covered by emerged plants <0.1 percent.  
Lake bottom covered by submersed plants <1 percent  
Rooted aquatic plants observed were cattail (*Typha* sp.),\* sedge  
(Cyperaceae), and waterweed (*Elodea* sp.),

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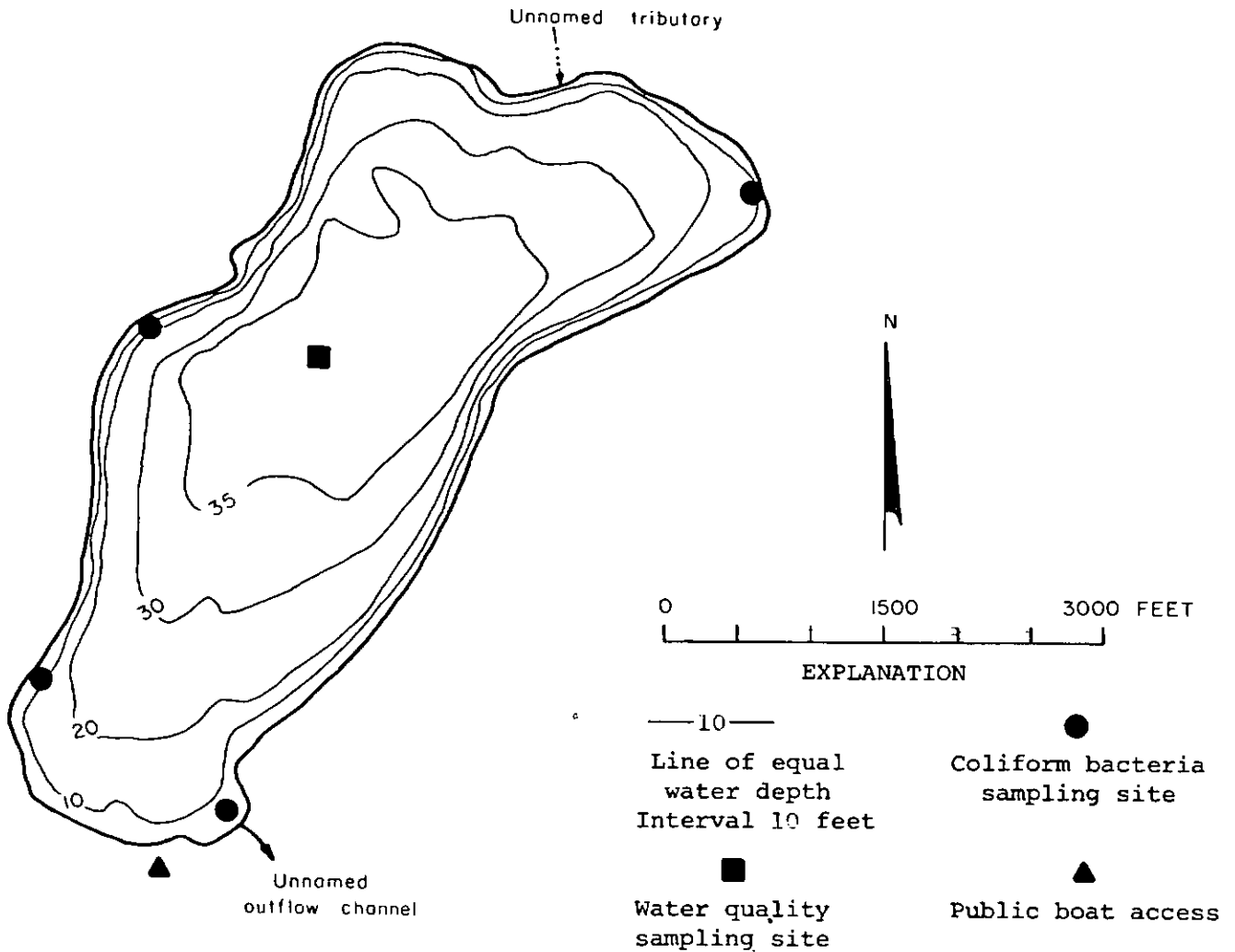
Asterisk (\*) indicates dominant aquatic plant.

Remarks.

Many logs and branches cover the beach and lake bottom.

Conclusions.

Chlorophyll a, DO, and nutrient concentrations, and Secchi-disc-visibility depth indicate the lake is moderately productive.



Mineral Lake, Lewis County. From Washington Department of Game, February 26, 1952.






Mineral Lake, Lewis County. August 9, 1972. Approx. scale 1:10,800.

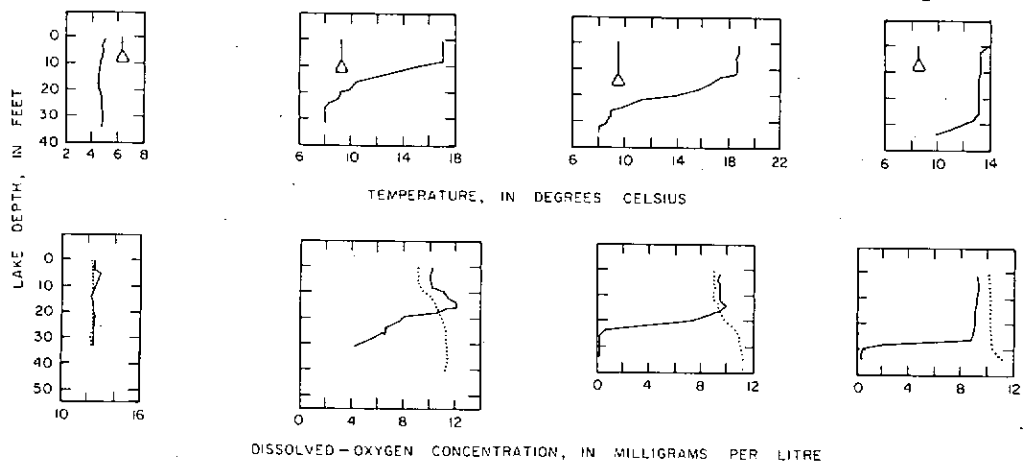


Water-quality data for Mineral Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	March 10		May 15		June 30		October 16	
	3	31	3	29	3	30	3	30
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	11	11	7.5	11	7.0	13	5.0	6.9
Dissolved iron (Fe) -----	.02	.43	.06	.13	.06	.58	.25	1.0
Dissolved manganese (Mn) -----	.067	--	.030	.010	.010	.10	.063	.30
Calcium (Ca) -----	3.4	3.5	--	--	--	--	4.5	--
Magnesium (Mg) -----	.9	1.0	--	--	--	--	1.1	--
Sodium (Na) -----	3.0	3.0	--	--	--	--	3.2	--
Potassium (K) -----	.6	.6	--	--	--	--	.7	--
Bicarbonate (HCO <sub>3</sub> ) -----	23	21	23	22	20	24	23	25
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	.0
Sulfate (SO <sub>4</sub> ) -----	.0	.1	--	--	--	--	1.6	--
Chloride (Cl) -----	2.0	2.6	--	--	--	--	2.6	--
Nitrate nitrogen (as N) -----	.40	.41	.17	.28	.04	.15	.01	.01
Nitrite nitrogen (as N) -----	.00	.00	.01	.01	.01	.01	.00	.00
Ammonia nitrogen (as N) -----	.08	.12	.05	.20	.05	.31	.07	.33
Organic nitrogen (as N) -----	.23	.36	.37	1.1	.26	.19	.26	.16
Total phosphorus (as P) -----	.025	.030	.014	.013	.015	.035	.012	.035
Orthophosphate (as P) -----	.011	.012	.002	.002	.001	.012	.001	.028
Suspended solids (110°C) -----	11	--	--	--	--	--	21	--
Hardness (Ca, Mg) -----	12	13	--	--	--	--	16	--
Specific conductance ----- (micromhos at 25°C)	44	44	40	44	43	64	46	80
pH (pH units) -----	7.3	7.3	7.7	7.6	7.4	6.2	7.7	7.5
Color (Pt-Co units) -----	20	25	15	20	15	30	25	30
Chlorophyll a (µg/l) -----	9.0	--	5.2	--	2.6	--	6.2	--
Fecal coliform Range ---	--	--	--	--	<1-6	1	<1	<1
(col. per 100 ml) Mean ---	--	--	--	--	--	--	--	--

- EXPLANATION
-  Secchi - disc visibility, depth at base of triangle
  -  Dissolved oxygen concentration
  -  Dissolved oxygen concentration at 100 percent saturation



Offutt Lake near East Olympia (12079380)Location.

Lat 46°55'06", long 122°49'04", in SW $\frac{1}{4}$ NW $\frac{1}{4}$  sec.33, T.17 N., R.1 W., Thurston County, 3.5 miles south of East Olympia; Deschutes River basin. East Olympia quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	2.70 sq mi	Maximum depth	25 ft
Altitude	230 ft	Length of shoreline	15,000 ft
Surface area	200 acres	Shoreline configuration	1.5
Lake volume	2,900 acre-ft	Development of volume	0.60
Mean depth	15 ft	Bottom slope	0.76 percent

The gradually sloped beach and littoral zone is composed of coarse sand and gravel and a large percentage of muck deposits.

Basin geology.

Glacial end moraine and outwash (Noble and Wallace, 1966).

Soils.

Mostly gravelly, sandy loam (Ness, 1958).

Land use (percentage of drainage basin). Urban 0, suburban 5, agricultural 16 forest or unproductive 68, and lake surface 11.

Nearshore residential development. 52 percent.

Number of nearshore homes. 73.

Surface-water inflow and outflow.

The main inflow is via an unnamed tributary on the southwest part of the lake. The summer inflow was less than 0.1 ft<sup>3</sup>/s. The outflow was dry during the summer months.

Lake stage.

The observed gage height from March 7 to September 22, 1972, varied 4.4 ft.

Macrophytes.

Shoreline covered by emerged plants 26-50 percent.

Lake surface covered by emerged plants 1 percent.

Lake bottom covered by submersed plants 12 percent.

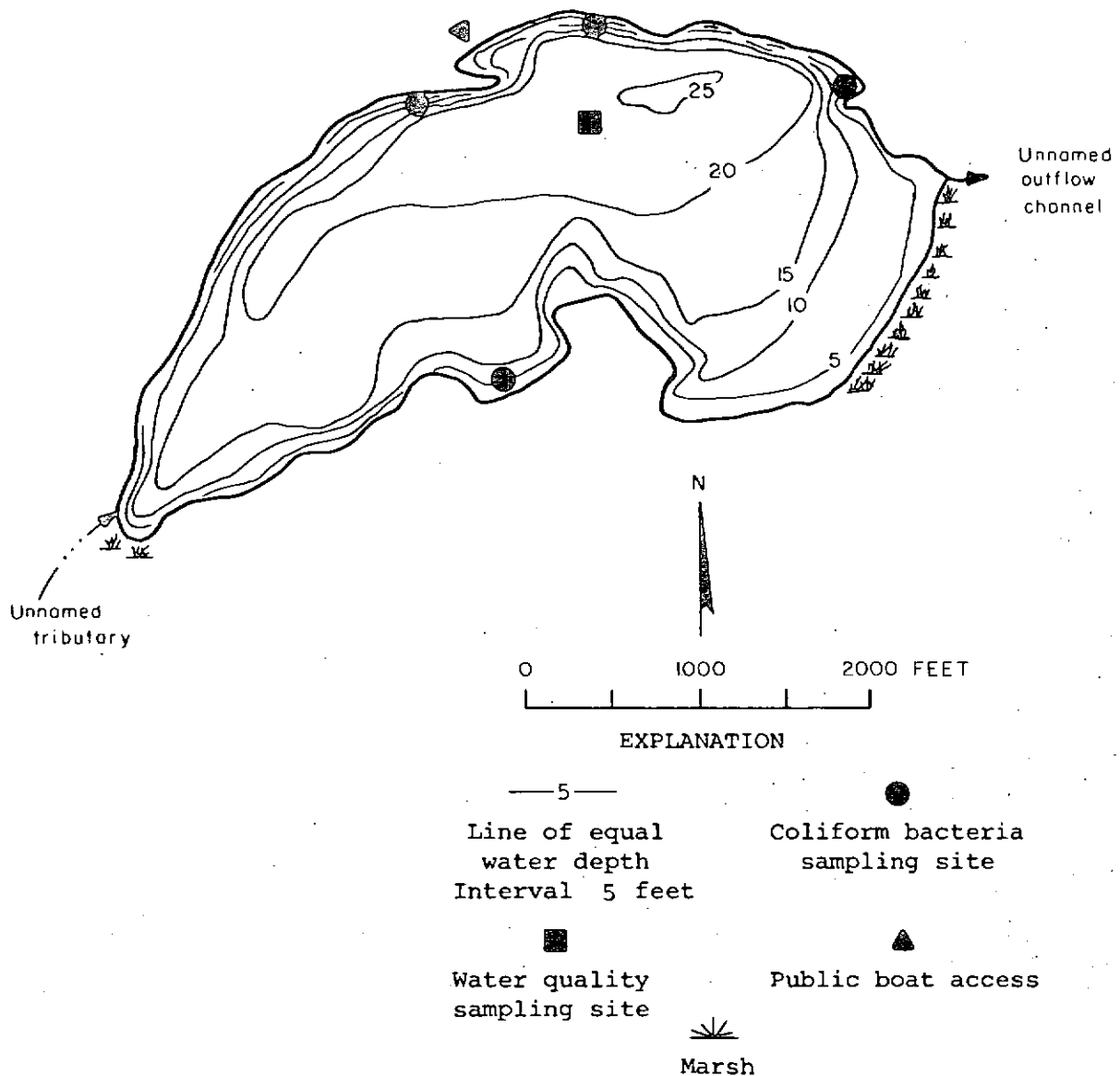
Routed aquatic plants observed were white lily (*Nymphaea* sp.),\* sedge (Cyperaceae), coontail (*Ceratophyllum* sp.), waterweed (*Elodea* sp.), and muskgrass (*Chara* sp.).

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Askerisk (\*) indicates dominant aquatic plant.

Conclusions.

The natural eutrophication rate is probably quite high because of the lake's marsh-type environment. The abundance of macrophytes, the moderately high winter phosphorus concentration, shallow transparency depth, and the summer oxygen deficit in the bottom waters indicate a lake of medium high trophic nature.



Offutt Lake, Thurston County. From Washington Department of Game, May 24, 1949.






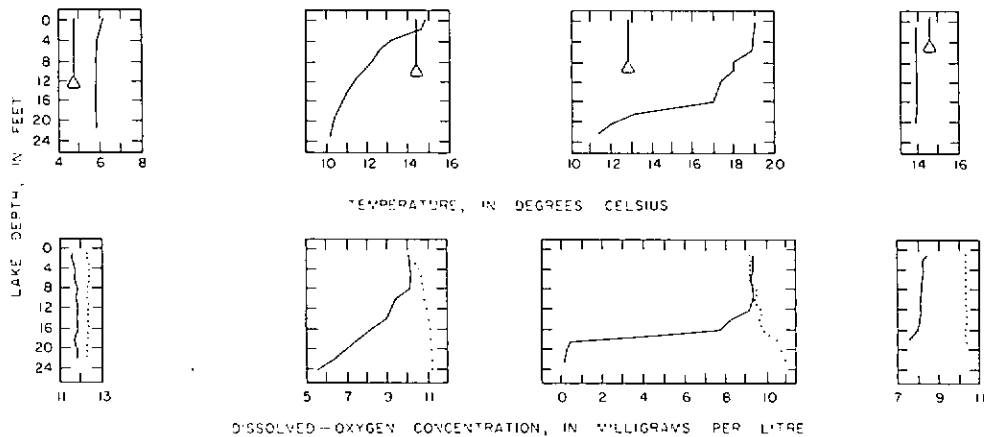
Offutt Lake, Thurston County. August 9, 1972. Approx. scale 1:9600.

Water-quality data for Offutt Lake.

(Milligrams per litre unless otherwise indicated)

Date of collection (1972) --- Water depth (ft) -----	March 7		May 4		June 28		October 4	
	3	20	3	21	3	20	3	15
Silica (SiO <sub>2</sub> ) -----	13	13	12	12	9.2	12	12	12
Dissolved iron (Fe) -----	.02	.07	.04	.12	.09	.44	.43	.44
Dissolved manganese (Mn) ----	.038	--	.010	.000	.010	.100	.008	.016
Calcium (Ca) -----	3.2	--	--	--	--	--	5.2	--
Magnesium (Mg) -----	1.2	--	--	--	--	--	1.8	--
Sodium (Na) -----	3.1	--	--	--	--	--	3.2	--
Potassium (K) -----	.7	--	--	--	--	--	.6	--
Bicarbonate (HCO <sub>3</sub> ) -----	20	20	22	22	19	24	26	25
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	.0
Sulfate (SO <sub>4</sub> ) -----	.1	--	--	--	--	--	4.1	--
Chloride (Cl) -----	2.0	--	--	--	--	--	2.5	--
Nitrate nitrogen (as N) -----	.17	.17	.10	.13	.00	.00	.05	.05
Nitrite nitrogen (as N) -----	.00	.00	.01	.01	.00	.00	.00	.00
Ammonia nitrogen (as N) -----	.07	.06	.04	.30	.09	.05	.26	.18
Organic nitrogen (as N) -----	.15	.15	.21	.24	.32	.33	1.1	.45
Total phosphorus (as P) -----	.024	.006	.019	.020	.020	.030	.029	.026
Orthophosphate (as P) -----	.002	.002	.004	.002	.000	.000	.006	.006
Suspended solids (110°C) ----	9	--	--	--	--	--	19	--
Hardness (Ca,Mg) -----	13	--	--	--	--	--	20	--
Specific conductance ----- (micromhos at 25°C)	45	45	45	48	49	72	57	57
pH (pH units) -----	7.6	7.6	7.5	7.3	7.4	7.1	7.6	7.6
Color (Pt-Co units) -----	25	25	20	25	40	45	20	20
Chlorophyll <i>a</i> (µg/l) -----	.42	--	2.6	--	3.8	--	6.9	--
Fecal coliform Range -- (col. per 100 ml) Mean ---	--	--	--	--	<1-4 2	<1-4 2	<1 <1	<1 <1

- EXPLANATION
-  Secchi disc visibility, depth of base of triangle
  -  Dissolved oxygen concentration
  -  Dissolved oxygen concentration at 100 percent saturation



Phillips Lake near Shelton (12074780)Location.

Lat 47°14'52", long 122°57'52", in NE $\frac{1}{4}$ SW $\frac{1}{4}$  sec.5, T.20 N., R.2 W., Mason County, 7.0 miles northeast of Shelton; Campbell Creek basin. Squaxin Island and Mason Lake quadrangles, 1:24,000.

Physical characteristics of lake.

Drainage area	0.50 sq mi	Maximum depth	25 ft
Altitude	188 ft	Length of shoreline	14,000 ft
Surface area	110 acres	Shoreline configuration	1.7
Lake volume	1,800 acre-ft	Development of volume	0.63
Mean depth	16 ft	Bottom slope	0.99 percent

The beach and littoral zone is mostly sand and gravel.

Basin geology.

Glacial drift plain underlain by till and outwash (Molenaar and Noble, 1970).

Soils.

Gravelly sandy loam and gravelly loamy sand (Ness and Fowler, 1960).

Land use (percentage of drainage basin). Urban 0, suburban 29, agricultural 0, forest or unproductive 36, and lake surface 35.

Nearshore residential development. 100 percent.

Number of nearshore homes. 125.

Surface-water inflow and outflow.

No inflow was observed. The outflow, which is regulated by flashboards, is via an unnamed outflow channel.

Lake stage.

The observed gage height from March 7 to August 24, 1972, varied 2.1 ft.

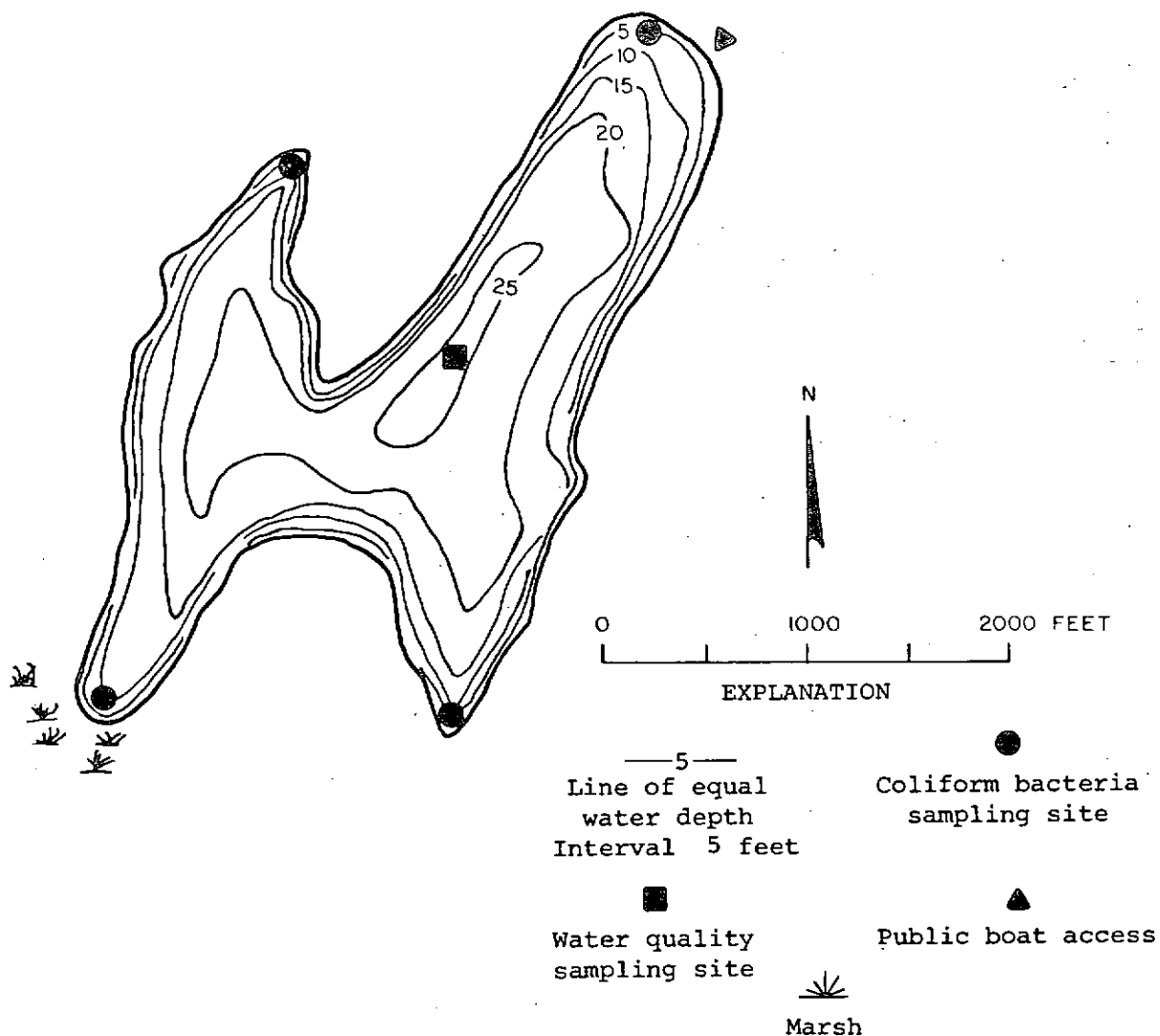
Macrophytes.

Shoreline covered by emerged plants 0-10 percent.  
 Lake surface covered by emerged plants <0.1 percent.  
 Lake bottom covered by submersed plants <1 percent.  
 Rooted aquatic plants observed were cattail (Typha sp.),\*  
 sedge (Cyperaceae), and pondweed (Potamogeton sp.).

Asterisk (\*) indicates dominant aquatic plant.

Conclusions.

Phillips Lake appears to be low in biological productivity, as indicated by high oxygen content, low winter nutrient concentration, medium low chlorophyll *a* concentrations, and lack of macrophytes. The potential for increased rate of nutrient enrichment is high--the number of lakeshore dwellings has increased fourfold in 13 years. This potential, combined with shallow mean depth and low volume of water per nearshore home, may, in the future, tend to increase biological productivity and the rate of lake eutrophication.



Phillips Lake, Mason County. From Washington Department of Game, February 14, 1952.



Phillips Lake, Mason County. August 9, 1972. Approx. scale 1:7200.






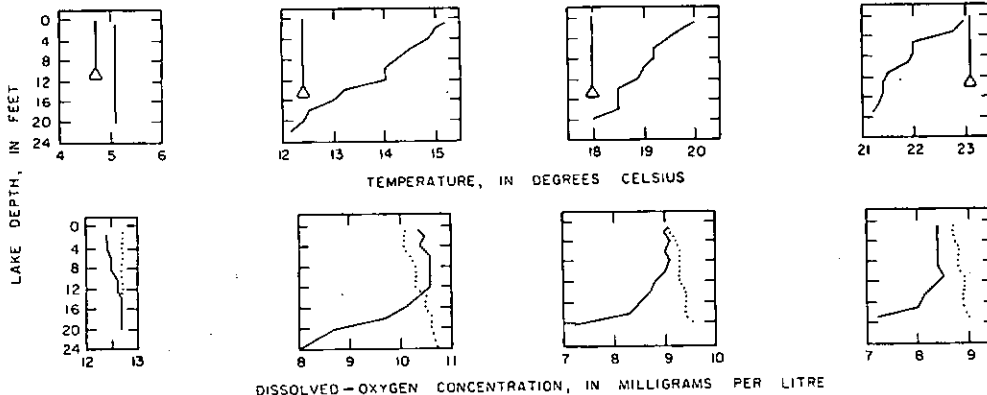
Water-quality data for Phillips Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	March 7		May 10		June 29		August 24	
	3	18	3	18	3	16	3	16
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	1.1	1.2	0.4	0.4	0.4	0.4	0.2	0.2
Dissolved iron (Fe) -----	.01	.03	.04	.05	.07	.07	.10	.14
Dissolved manganese (Mn) ----	.013	--	.030	.030	.010	.020	.020	.058
Calcium (Ca) -----	1.2	--	--	--	--	--	1.5	--
Magnesium (Mg) -----	.4	--	--	--	--	--	.5	--
Sodium (Na) -----	1.2	--	--	--	--	--	1.6	--
Potassium (K) -----	.3	--	--	--	--	--	.2	--
Bicarbonate (HCO <sub>3</sub> ) -----	11	10	10	11	11	6	9	10
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	.0
Sulfate (SO <sub>4</sub> ) -----	.0	--	--	--	--	--	2.5	--
Chloride (Cl) -----	1.3	--	--	--	--	--	1.2	--
Nitrate nitrogen (as N) ----	.05	.05	.02	.03	.00	.00	.01	.01
Nitrite nitrogen (as N) ----	.00	.00	.00	.01	.00	.00	.00	.00
Ammonia nitrogen (as N) ----	.19	.19	.00	.06	.03	.06	.03	.06
Organic nitrogen (as N) ----	.15	.13	.30	.38	.30	.37	.26	.27
Total phosphorus (as P) ----	.004	.010	.019	.017	.015	.038	.005	.006
Orthophosphate (as P) -----	.000	.001	.002	.002	.000	.032	.001	.001
Suspended solids (110°C) ----	10	--	--	--	--	--	19	--
Hardness (Ca, Mg) -----	5	--	--	--	--	--	6	--
Specific conductance ----- (micromhos at 25°C)	21	20	20	20	20	20	22	21
pH (pH units) -----	7.9	7.8	7.7	7.5	7.3	7.3	7.2	7.2
Color (Pt-Co units) -----	5	5	10	10	10	10	10	10
Chlorophyll <i>a</i> (µg/l) -----	5.8	--	1.5	--	2.2	--	1.9	--
Fecal coliform Range ---	--	--	--	--	<1	<1	<1-3	2
(col. per 100 ml) Mean ---	--	--	--	--	<1	<1	2	2

EXPLANATION

-  Secchi - disc visibility, depth at base of triangle
-  Dissolved oxygen concentration
-  Dissolved oxygen concentration at 100 percent saturation



Pierre Lake near Orient (12404860)Location.

Lat 48°53'51", long 118°08'14", in SW $\frac{1}{4}$ NE $\frac{1}{4}$  sec.8, T.39 N., R.37 E., Stevens County, 3.6 miles northeast of Orient; Kettle River basin. Laurier quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	26.8 sq mi	Maximum depth	75 ft
Altitude	2,005 ft	Length of shoreline	15,000 ft
Surface area	110 acres	Shoreline configuration	2.0
Lake volume	3,000 acre-ft	Development of volume	0.38
Mean depth	28 ft	Bottom slope	3.1 percent

The upland slope is steep and the lake is protected by the surrounding mountains. The beach and littoral zone is composed of muck, marl, coarse sand, and gravel; the muck is concentrated mostly in the shallow north arm.

Basin geology.

Glacial drift in valley with volcanic rock in hills (Hunting and others, 1961).

Soils.

Silt loam and sandy loam (U.S. Soil Conservation Service, 1968).

Land use (percentage of drainage basin). Urban 0, suburban 0, agricultural 3, forest or unproductive 96, and lake surface 1.

Nearshore residential development. 1 percent.

Number of nearshore homes. 4.

Surface-water inflow and outflow.

The lake has a year-round inflow (Pierre Creek) and outflow (Toulou Creek). The low summer inflow (Pierre Creek) during the September 28 visit was 2.62 ft<sup>3</sup>/s.

Lake stage.

Records are incomplete.

Macrophytes.

Shoreline covered by emersed plants 26-50 percent.

Lake surface covered by emersed plants 1 percent.

Lake bottom covered by submersed plants 21 percent.

Rooted aquatic plants observed were sedge (Cyperaceae),\* muskgrass (*Chara* sp.),\* cattail (*Typha* sp.), duckweed (Lemnaceae), white lily

Macrophytes.--continued

(Nymphaea sp.), coontail (Ceratophyllum sp.), and three varieties of pondweed (Potamogetan spp.).

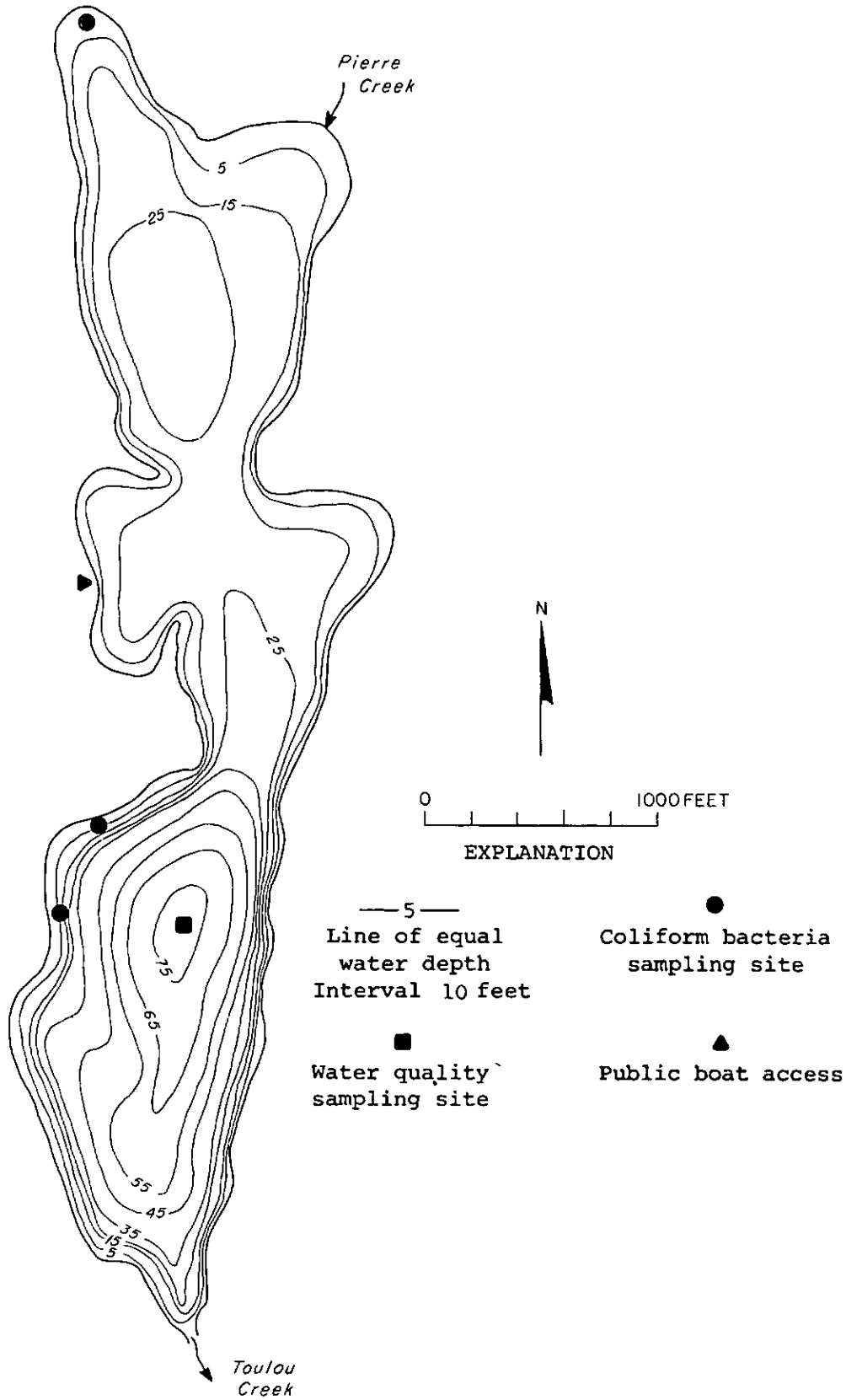
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Asterisk (\*) indicates dominant aquatic plants.

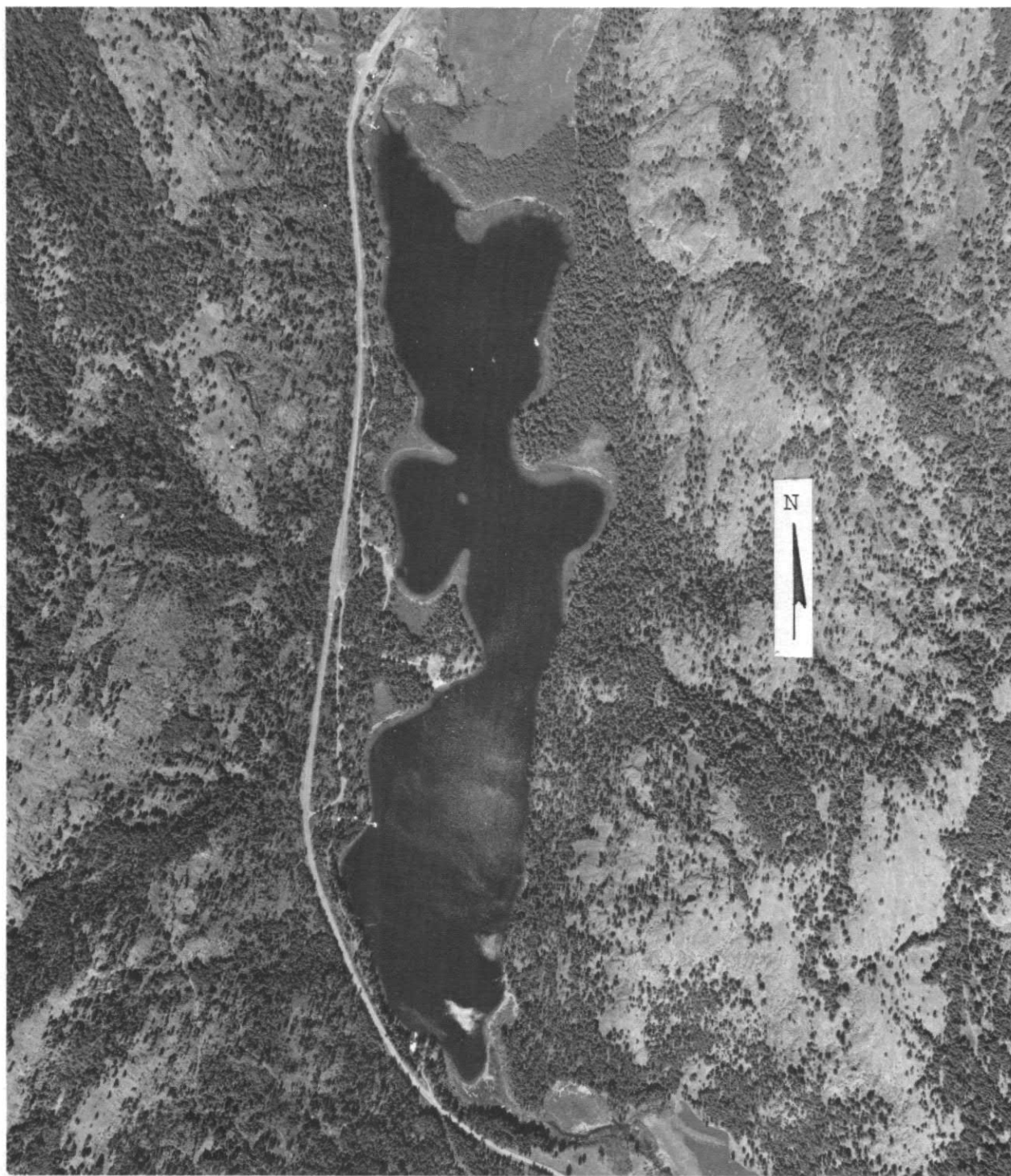
Conclusions.

The lake appears to be moderate to high in biological productivity. The lake waters were high in dissolved-solids concentrations and contained a high concentration of total phosphorus in the epilimnion--with a mean of 30 µg/l--which may be the primary factor that promoted the heavy algal growths (pea-soup appearance) observed during the August 17 and September 28 sampling periods. On September 28, Aphanizomenon sp., a blue-green algae, was the dominant type. The average chlorophyll a concentration was 9.2 µg/l and the maximum was 23.2 µg/l, the highest recorded for any lake studied in 1972. A large part of the lake volume (33 percent) had a DO concentration less than 4.0 mg/l during the summer. A high concentration of hydrogen sulfide (with "rotten-egg" odor) was detected in the deeper water at this time. Nitrogen and phosphorus concentrations were 5 and 6 times higher in the bottom than in the upper water. The submersed aquatic-plant growth, predominantly Chara sp. (muskgrass), is moderate for the lake as a whole, but very heavy in the shallow north arm.

In addition to natural leaching of nutrients from rocks and soils, runoff from grazing land probably contributes to the enrichment of the lake. The potential for an increased rate of eutrophication is probably reduced by the high flushing rate of the lake. This is attributed in part to the drainage area being large relative to the lake volume.



Pierre Lake, Stevens County. From Washington Department of Game, July 22, 1947.




Pierre Lake, Stevens County. August 10, 1972.  
Approx. scale 1:9600.


## Water-quality data for Pierre Lake.


[Milligrams per litre unless otherwise indicated]

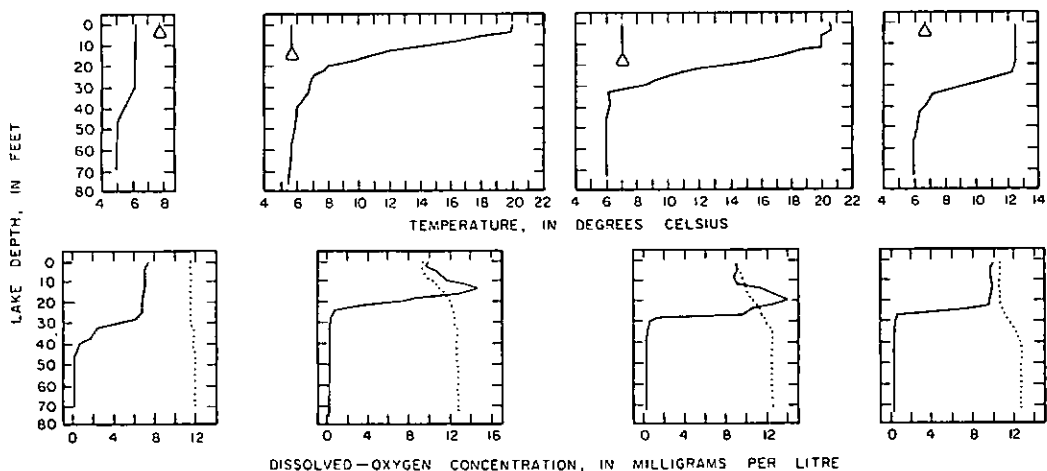
Date of collection (1972) ---	April 20		June 8		August 17		September 28	
	3	68	3	70	3	70	3	70
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	22	23	20	23	20	24	20	24
Dissolved iron (Fe) -----	.01	.02	.02	.05	.04	.06	.03	.07
Dissolved manganese (Mn) ----	.020	.040	.000	.090	.000	.050	.020	.090
Calcium (Ca) -----	55	--	--	--	--	--	49	--
Magnesium (Mg) -----	13	--	--	--	--	--	14	--
Sodium (Na) -----	4.8	--	--	--	--	--	4.8	--
Potassium (K) -----	3.6	--	--	--	--	--	2.1	--
Bicarbonate (HCO <sub>3</sub> ) -----	199	209	182	217	168	216	178	220
Sulfide (as H <sub>2</sub> S) -----	--	.0	--	trace	--	17	--	25
Sulfate (SO <sub>4</sub> ) -----	51	--	--	--	--	--	40	--
Chloride (Cl) -----	.8	--	--	--	--	--	.1	--
Nitrate nitrogen (as N) ----	.05	.01	.01	.02	.02	.03	.02	.02
Nitrite nitrogen (as N) ----	.01	.01	.02	.00	.01	.00	.00	.01
Ammonia nitrogen (as N) ----	.15	.55	.02	1.0	.17	1.9	.08	.20
Organic nitrogen (as N) ----	.53	.45	.20	.10	.26	2.2	.49	.06
Total phosphorus (as P) ----	.058	.094	.016	.15	.011	.24	.037	.39
Orthophosphate (as P) -----	.003	.028	.008	.10	.004	.18	.002	.21
Suspended solids (110°C) ----	28	--	--	--	--	--	11	--
Hardness (Ca, Mg) -----	190	--	--	--	--	--	180	--
Specific conductance ----- (micromhos at 25°C)	330	340	260	325	340	420	325	400
pH (pH units) -----	7.9	7.7	8.8	7.8	8.2	7.3	8.4	7.4
Color (Pt-Co units) -----	10	10	10	15	10	20	10	10
Chlorophyll a (µg/l) -----	7.3	--	2.6	--	3.7	--	23.2	--
Fecal coliform Range ---	--	--	--	--	<1	<1	<1	<1
(col. per 100 ml) Mean ---	--	--	--	--	<1	<1	<1	<1

EXPLANATION

 Secchi-disc visibility, depth of base of triangle

 Dissolved oxygen concentration

 Dissolved oxygen concentration at 100 percent saturation



Retreat Lake near Ravensdale (12118200)Location.

Lat 47°21'02", long 121°56'42", in NE $\frac{1}{4}$ SW $\frac{1}{4}$  sec.32, T.22 N., R.7 E., King County, 1.3 miles east of Ravensdale; Lake Washington basin. Cumberland quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	2.21 sq mi	Maximum depth	50 ft
Altitude	731 ft	Length of shoreline	6,900 ft
Surface area	51 acres	Shoreline configuration	1.3
Lake volume	1,200 acre-ft	Development of volume	0.46
Mean depth	23 ft	Bottom slope	3.0 percent

The beach and littoral zone contains muck, sand, and gravel. About 25 to 50 percent of the shoreline is estimated to contain muck deposits.

Basin geology.

Glacial ice-contact and recessional outwash with sandstone in small part of basin (Luzier, 1969).

Soils.

Gravelly fine sandy loam with some stony, shallow soils (Poulson and others, 1952).

Land use (percentage of drainage basin). Urban 0, suburban 5, agricultural 0, forest or unproductive 91, and lake surface 4.

Nearshore residential development. 81 percent.

Number of nearshore homes. 63 (mostly permanent).

Surface-water inflow and outflow.

No inflow was observed. The outflow, which is controlled by natural conditions, was perennial. A discharge measurement at the outflow on March 3, was 12.2 ft<sup>3</sup>/s; May 9, 1.96 ft<sup>3</sup>/s; June 26, 1.88 ft<sup>3</sup>/s; and October 6, 0.6 ft<sup>3</sup>/s. The October 6 discharge was estimated.

Lake stage.

Records incomplete.

Macrophytes.

Shoreline covered by emerged plants 11-25 percent.

Lake surface covered by emerged plants 2 percent.

Lake bottom covered by submersed plants <1 percent.

Rooted aquatic plants observed were cattail (Typha sp.), white lily (Nymphaea sp.), and pondweed (Potamogeton sp.).

Remarks.

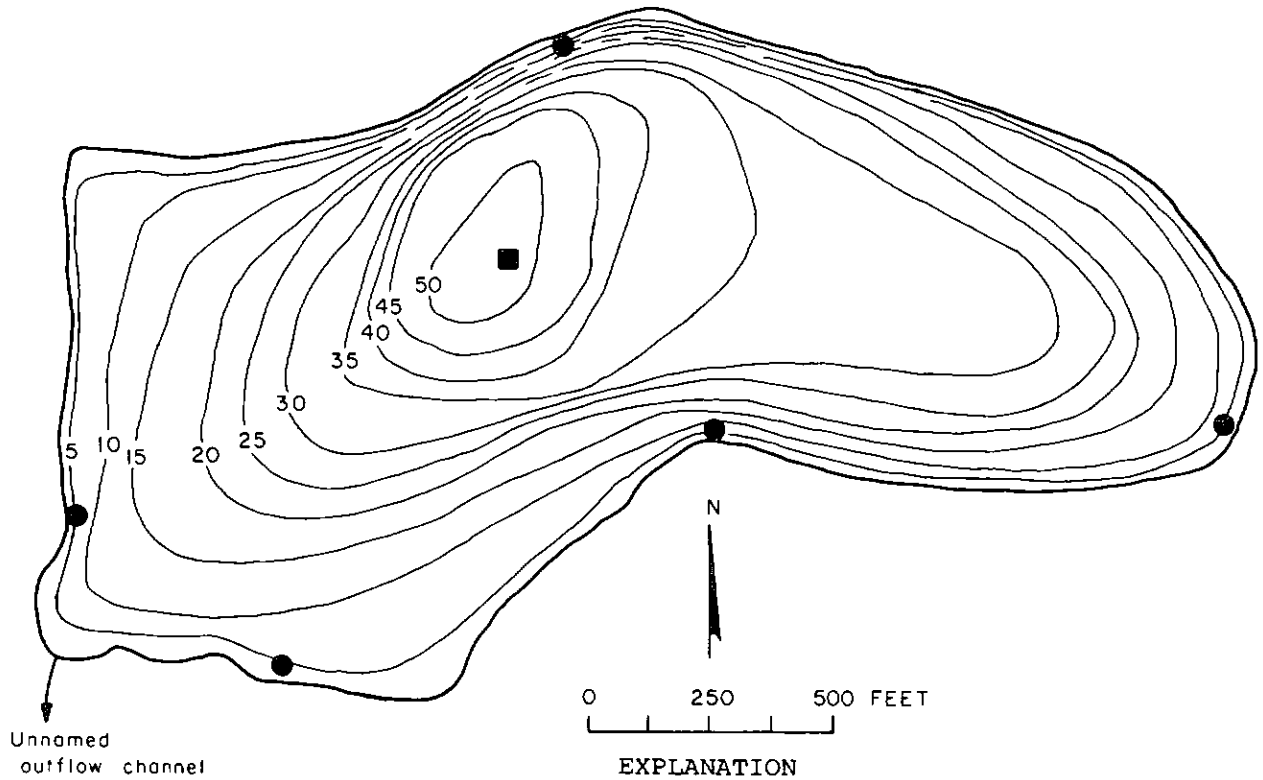
A large church camp is located on the west side of the lake. The lake becomes heavily populated with swimmers during the summer months.

Conclusions.

Retreat Lake has medium biological productivity at present, shown by low winter phosphorus concentration, moderate water clarity, and medium low chlorophyll a concentrations. However, because of a moderate rate of flushing, the lake is not as biologically productive as would be expected when the potential sources of cultural enrichment surrounding the lake are considered.

Fecal-coliform bacteria ranged from 1 to 124 colonies per 100 ml of water for 10 samples collected during four sampling periods.





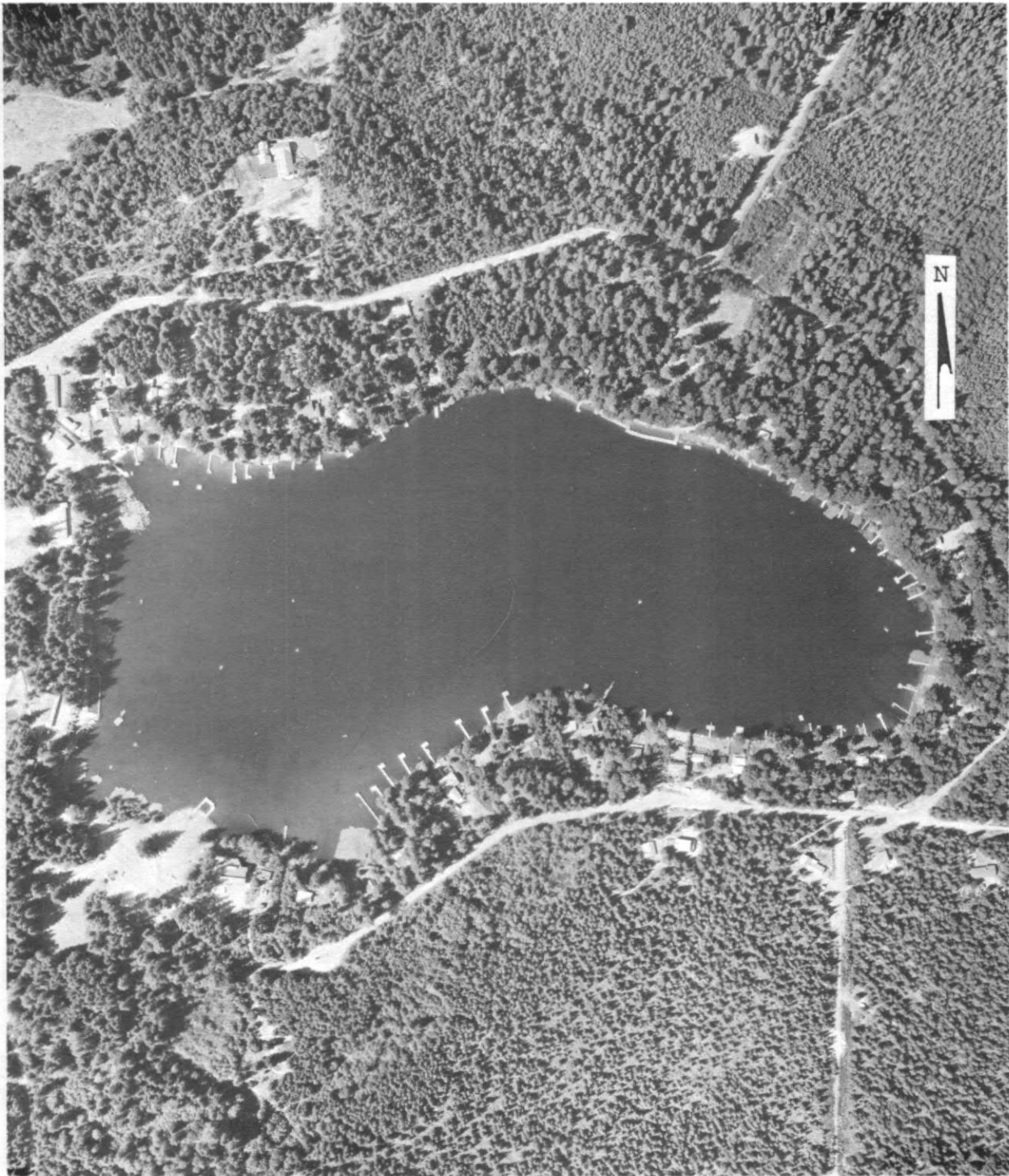
EXPLANATION

— 5 —  
 Line of equal  
 water depth  
 Interval 5 feet

Coliform bacteria  
 sampling site

Water quality  
 sampling site

Retreat Lake, King County. From Washington Department of Game, date unknown.

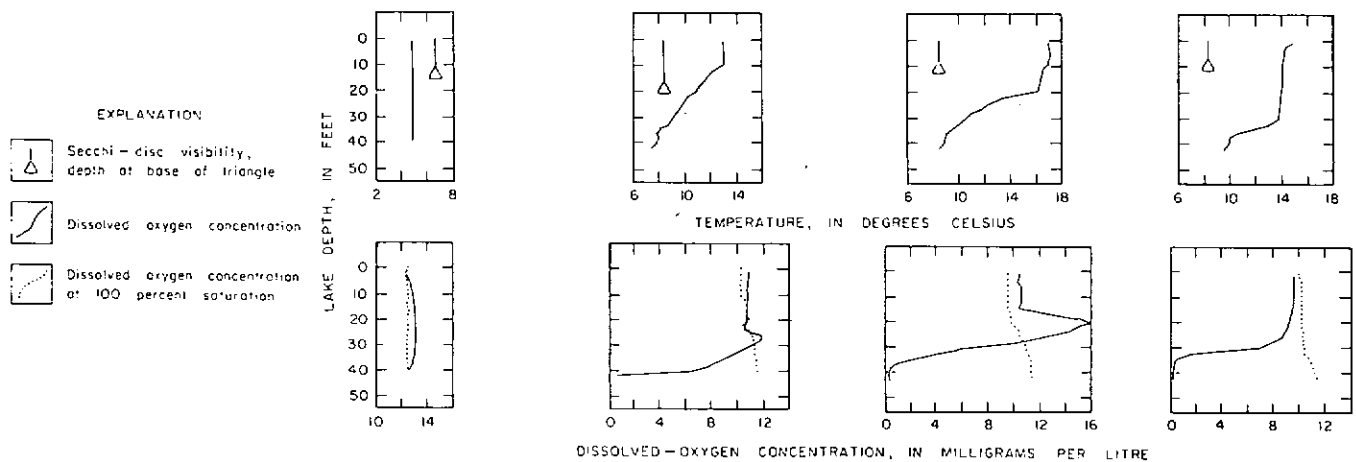


Retreat Lake, King County. August 9, 1972.  
Approx. scale 1:4800.

Water-quality data for Retreat Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	March 3		May 9		June 26		October 6	
	3	39	3	39	3	38	3	39
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	8.4	8.3	8.1	8.2	6.1	8.0	6.9	8.8
Dissolved iron (Fe) -----	.00	.00	.03	.05	.03	.31	.07	1.3
Dissolved manganese (Mn) ----	.025	--	.030	.040	.000	.10	.016	.41
Calcium (Ca) -----	8.6	--	--	--	--	--	9.9	--
Magnesium (Mg) -----	1.6	--	--	--	--	--	1.8	--
Sodium (Na) -----	2.3	--	--	--	--	--	2.3	--
Potassium (K) -----	.4	--	--	--	--	--	.3	--
Bicarbonate (HCO <sub>3</sub> ) -----	38	38	36	39	39	43	38	47
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	.0
Sulfate (SO <sub>4</sub> ) -----	.1	--	--	--	--	--	4.1	--
Chloride (Cl) -----	1.3	--	--	--	--	--	2.0	--
Nitrate nitrogen (as N) ----	.44	.44	.38	.32	.24	.15	.09	.03
Nitrite nitrogen (as N) ----	.00	.00	.01	.01	.01	.01	.00	.00
Ammonia nitrogen (as N) ----	.06	.06	.13	.33	.03	.42	.02	.74
Organic nitrogen (as N) ----	.09	.09	.13	.13	.20	.21	.30	.16
Total phosphorus (as P) ----	.013	.009	.012	.021	.010	.020	.004	.010
Orthophosphate (as P) -----	.003	.003	.002	.002	.000	.000	.001	.000
Suspended solids (110°C) ----	9	--	--	--	--	--	20	--
Hardness (Ca, Mg) -----	28	--	--	--	--	--	32	--
Specific conductance ----- (micromhos at 25°C)	70	70	65	70	70	85	73	115
pH (pH units) -----	7.6	7.6	7.9	7.6	8.1	7.3	7.8	7.2
Color (Pt-Co units) -----	15	10	5	10	15	20	5	20
Chlorophyll <i>a</i> (µg/l) -----	5.6	--	1.9	--	4.5	--	3.2	--
Fecal coliform Range ---	--	--	--	--	30-124	94	1-14	4
(col. per 100 ml) Mean ---	--	--	--	--	--	--	--	--



Roesiger Lake near Monroe (south arm, 12139490)Location.

Lat 47°58'19", long 121°55'23", in SW $\frac{1}{4}$ NW $\frac{1}{4}$  sec.28, T.29 N., R.7 E., Snohomish County, 8.5 miles north of Monroe; Snohomish River basin. Monroe quadrangle, 1:62,500.

Physical characteristics of lake.

Drainage area	3.55 sq mi	Maximum depth	70 ft
Altitude	570 ft	Length of shoreline	16,000 ft
Surface area	140 acres	Shoreline configuration	1.8
Lake volume	200 acre-ft	Development of volume	0.31
Mean depth	22 ft	Bottom slope	2.5 percent

The beach and littoral zone of the south arm is composed primarily of sand and fine silt, with large deposits of muck mainly in the shallow embayments. About 25 to 50 percent of the shoreline contains muck deposits.

Basin geology. Glacial drift (Newcomb, 1952).

Soils.

Gravelly sandy loam (Anderson and others, 1947).

Land use (percentage of drainage basin). Urban 0, suburban 6, agricultural 0, forest or unproductive 88, and lake surface 6.

Nearshore residential development. 100 percent.

Number of nearshore homes. 155 (mostly seasonal).

Surface-water inflow and outflow.

The inflow is from several small intermittent and ephemeral streams originating in the surrounding terrain. The outflow, via Roesiger Creek, was perennial. A discharge measurement at the outflow on March 8 was 43.1 ft<sup>3</sup>/s; May 11, 14.3 ft<sup>3</sup>/s; July 25, 5.5 ft<sup>3</sup>/s, and October 12, 3.25 ft<sup>3</sup>/s. The July 25 discharge was estimated.

Lake stage.

The observed gage height from March 8 to September 23, 1972, varied 1.3 ft. The gage height observations during the period indicated were fragmentary.

Macrophytes.

Shoreline covered by emerged plants 11-25 percent.

Lake surface covered by emerged plants 11 percent.

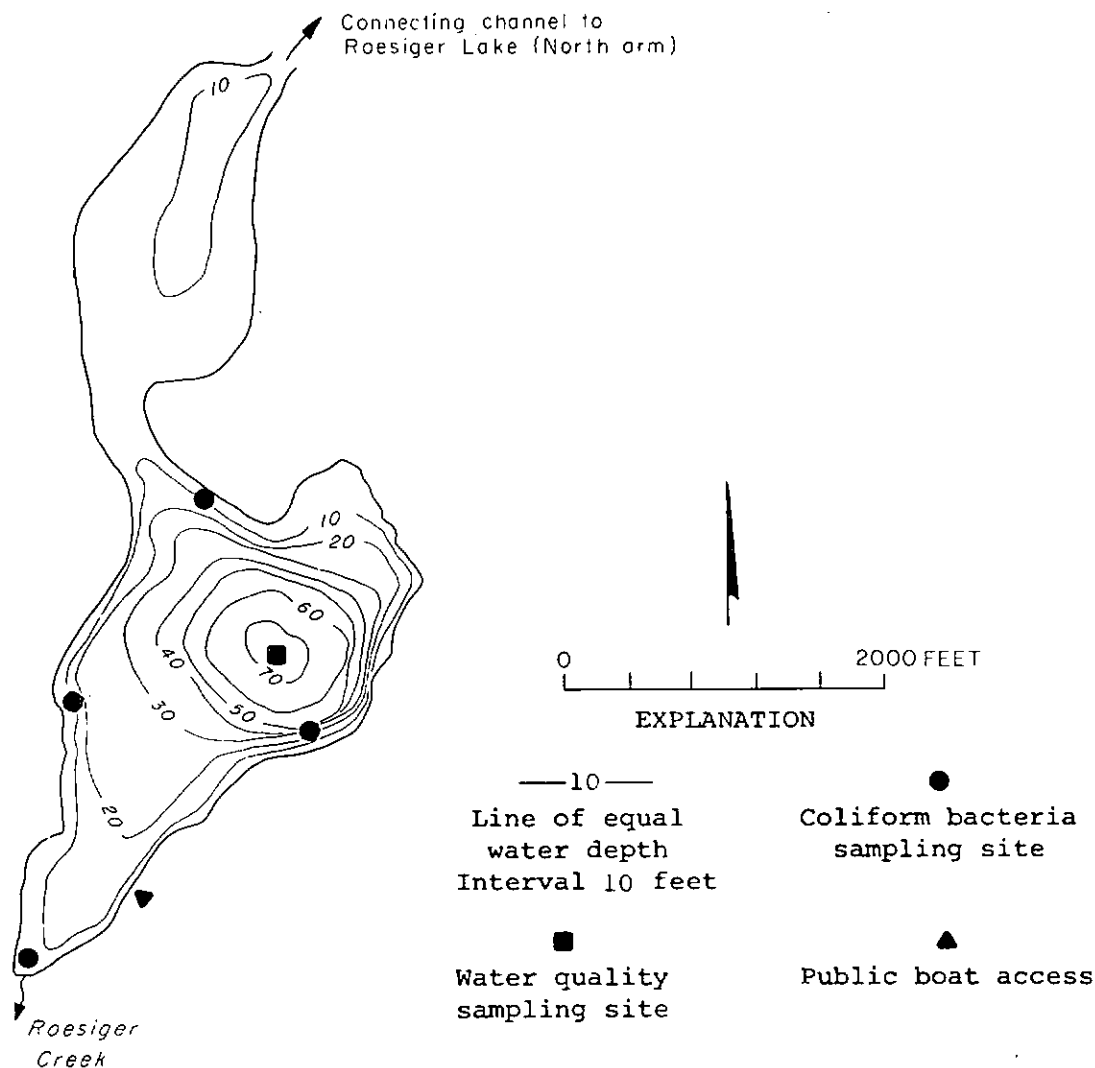
Lake bottom covered by submersed plants 32 percent.

Rooted aquatic plants observed were cattail (Typha sp.), white lily (Nymphaea sp.), sedge (Cyperaceae), and water plantain (Alisma sp.) .

Conclusions.

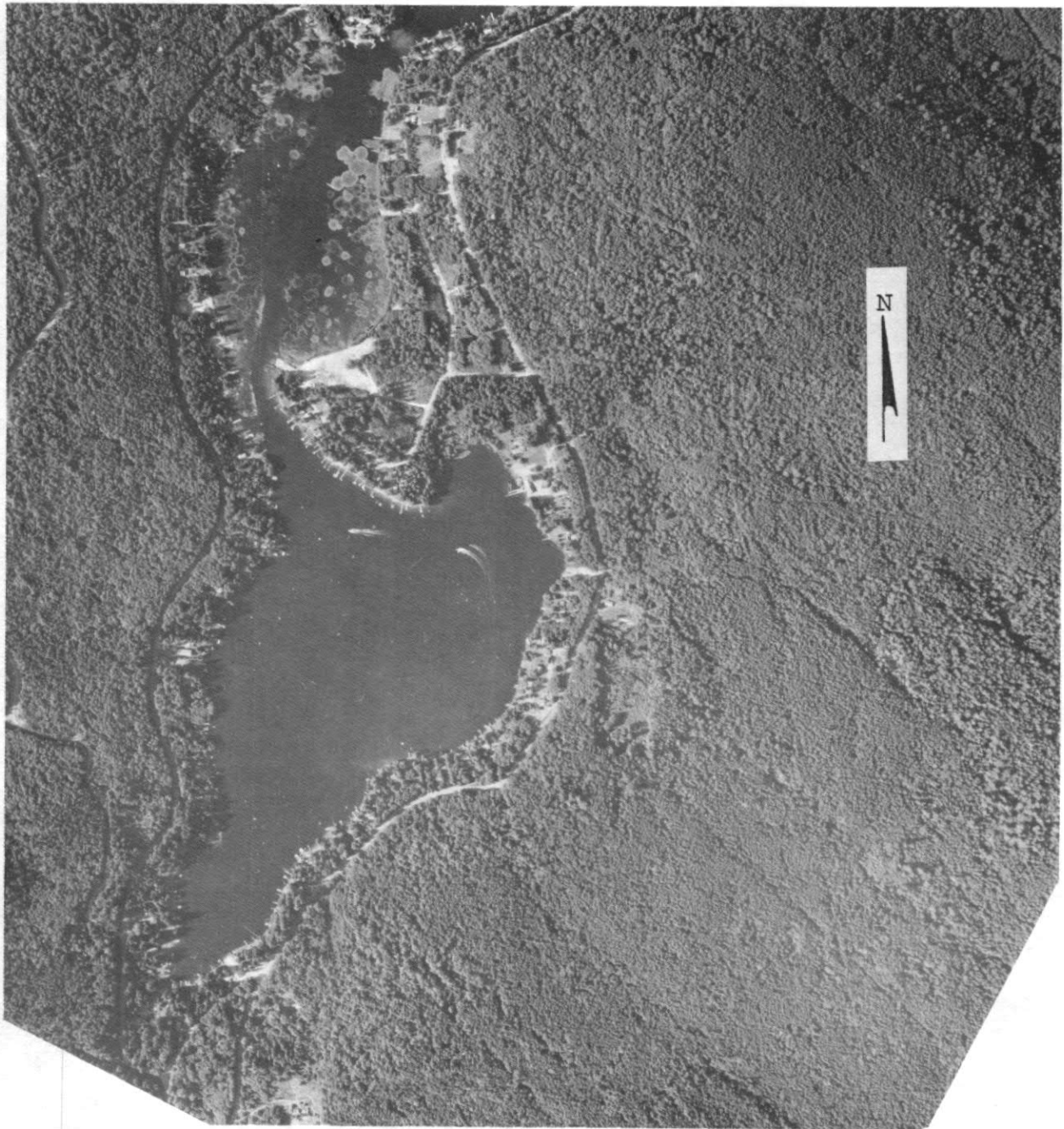
Roesiger Lake (south arm) has about medium biologic productivity at present, as shown by medium chlorophyll *a* concentrations, low to moderate nutrient concentrations, summer oxygen depletion in the bottom waters, and heavy growths of emersed and submersed aquatic plants.

Among the factors contributing to the potential for nutrient enrichment on the south arm are complete shoreline development and small volume of water per nearshore home. However, the potential for increased rate of eutrophication may be reduced by the continuous outflow year round.



Roesiger (South Arm) Lake, Snohomish County.

From Washington Department of Game, February 5, 1952.






Roesiger Lake (South Arm), Snohomish County.  
August 9, 1972. Approx. scale 1:10,800.

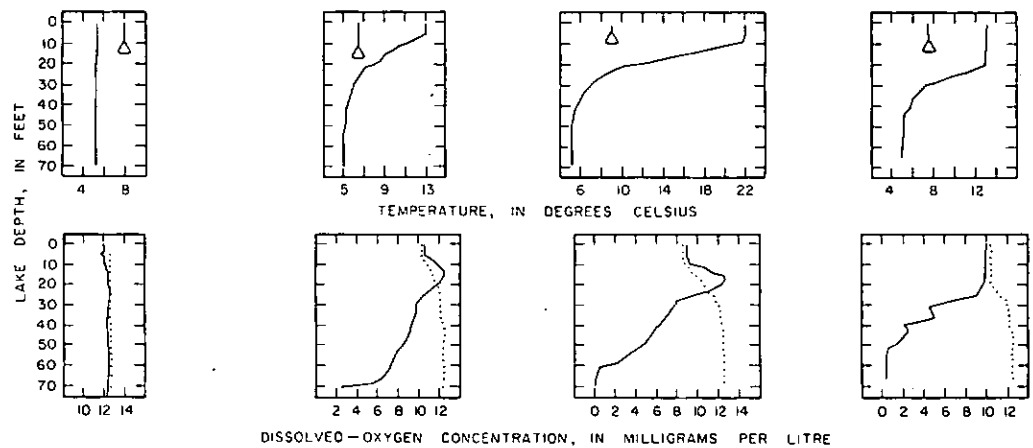
Water-quality for Roesiger Lake (south arm).

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	March 8		May 11		July 25		October 12	
Water depth (ft) -----	3	67	3	66	3	65	3	63
Silica (SiO <sub>2</sub> ) -----	4.6	4.6	4.1	5.1	3.5	5.8	3.6	6.4
Dissolved iron (Fe) -----	.01	.04	.03	.13	.04	.58	.05	.84
Dissolved manganese (Mn) ----	.013	--	.030	.050	.000	.18	.016	1.0
Calcium (Ca) -----	1.8	--	--	--	--	--	3.1	--
Magnesium (Mg) -----	.8	--	--	--	--	--	1.2	--
Sodium (Na) -----	1.5	--	--	--	--	--	1.6	--
Potassium (K) -----	.2	--	--	--	--	--	.3	--
Bicarbonate (HCO <sub>3</sub> ) -----	9	11	10	10	10	8	10	11
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	trace
Sulfate (SO <sub>4</sub> ) -----	.1	--	--	--	--	--	4.0	--
Chloride (Cl) -----	1.3	--	--	--	--	--	2.2	--
Nitrate nitrogen (as N) -----	.34	.33	.27	.29	.06	.36	.01	.03
Nitrite nitrogen (as N) -----	.00	.00	.01	.01	.00	.01	.00	.00
Ammonia nitrogen (as N) -----	.08	.03	.01	.44	.27	.47	.08	.60
Organic nitrogen (as N) -----	.14	.20	.52	.56	.33	.03	.22	.00
Total phosphorus (as P) -----	.010	.006	.008	.024	.005	.018	.011	.012
Orthophosphate (as P) -----	.001	.001	.002	.001	.003	.002	.001	.001
Suspended solids (110°C) ----	7	--	--	--	--	--	17	--
Hardness (Ca,Mg) -----	8	--	--	--	--	--	13	--
Specific conductance ----- (micromhos at 25°C)	26	26	26	27	32	31	26	32
pH (pH units) -----	7.9	7.4	7.3	6.9	8.1	7.6	7.5	7.1
Color (Pt-Co units) -----	10	10	15	15	5	15	15	25
Chlorophyll <i>a</i> (µg/l) -----	2.7	--	1.6	--	3.1	--	4.2	--
Fecal coliform Range ---	--	--	--	--	<1-8	3	<1	<1
(col. per 100 ml) Mean ---	--	--	--	--				

EXPLANATION

-  Secchi - disc visibility, depth at base of triangle
-  Dissolved oxygen concentration
-  Dissolved oxygen concentration at 100 percent saturation



DISSOLVED-OXYGEN CONCENTRATION, IN MILLIGRAMS PER LITRE

Roesiger Lake near Monroe (north arm, 12139490)Location.

Lat 47°59'17", long 121°55'04", in SE $\frac{1}{4}$ NW $\frac{1}{4}$  sec.21, T.29 N., R.7 E., Snohomish County, 7.2 miles north of Monroe; Snohomish River basin. Monroe quadrangle, 1:62,500.

Physical characteristics of lake.

Drainage area	1.95 sq mi	Maximum depth	110 ft
Altitude	570 ft	Length of shoreline	15,000 ft
Surface area	200 acres	Shoreline configuration	1.5
Lake volume	9,600 acre-ft	Development of volume	0.43
Mean depth	48 ft	Bottom slope	3.3 percent

The beach and littoral zone of the north arm consists of silt, sand, and gravel.

Basin geology.

Glacial drift (Newcomb, 1952).

Soils.

Gravelly sandy loam (Anderson and others, 1947).

Land use (percentage of drainage basin). Urban 0, suburban 13, agricultural 0, forest or unproductive 71, and lake surface 16.

Nearshore residential development. 100 percent.

Number of nearshore homes. 189 (mostly seasonal).

Surface-water inflow and outflow.

The inflow is from several small intermittent and ephemeral streams, in addition to seeps and springs. The outflow is via Roesiger Creek on south arm of the lake.

Lake stage.

The observed gage height from March 8 to September 23, 1972 varied 1.3 ft. The gage height observations during the period indicated were fragmentary.

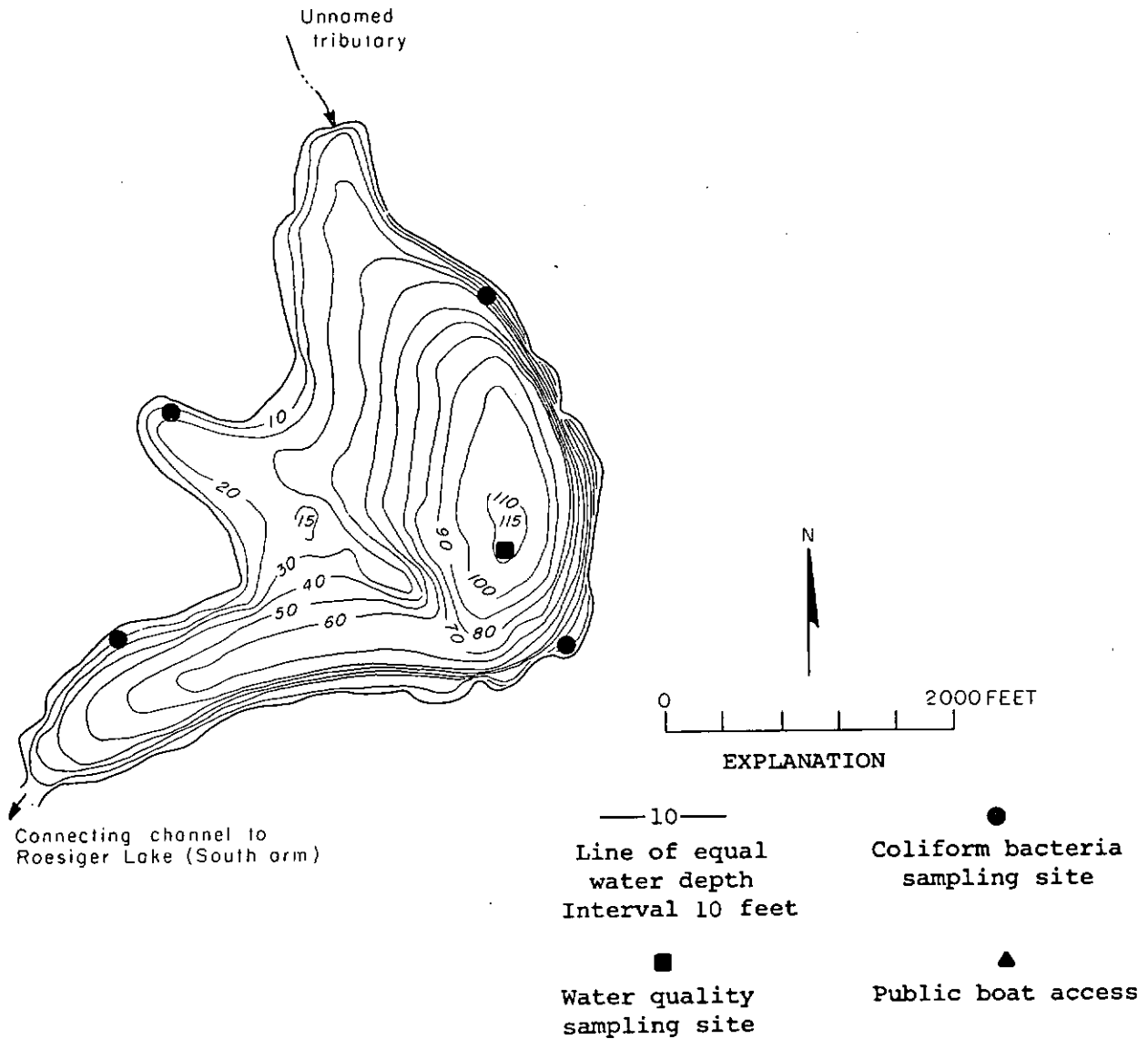
Macrophytes.

Shoreline covered by emerged plants 0-10 percent.  
 Lake surface covered by emerged plants <0.1 percent.  
 Lake bottom covered by submersed plants <1 percent.  
 Rooted aquatic plants observed were sedge (Cyperaceae).

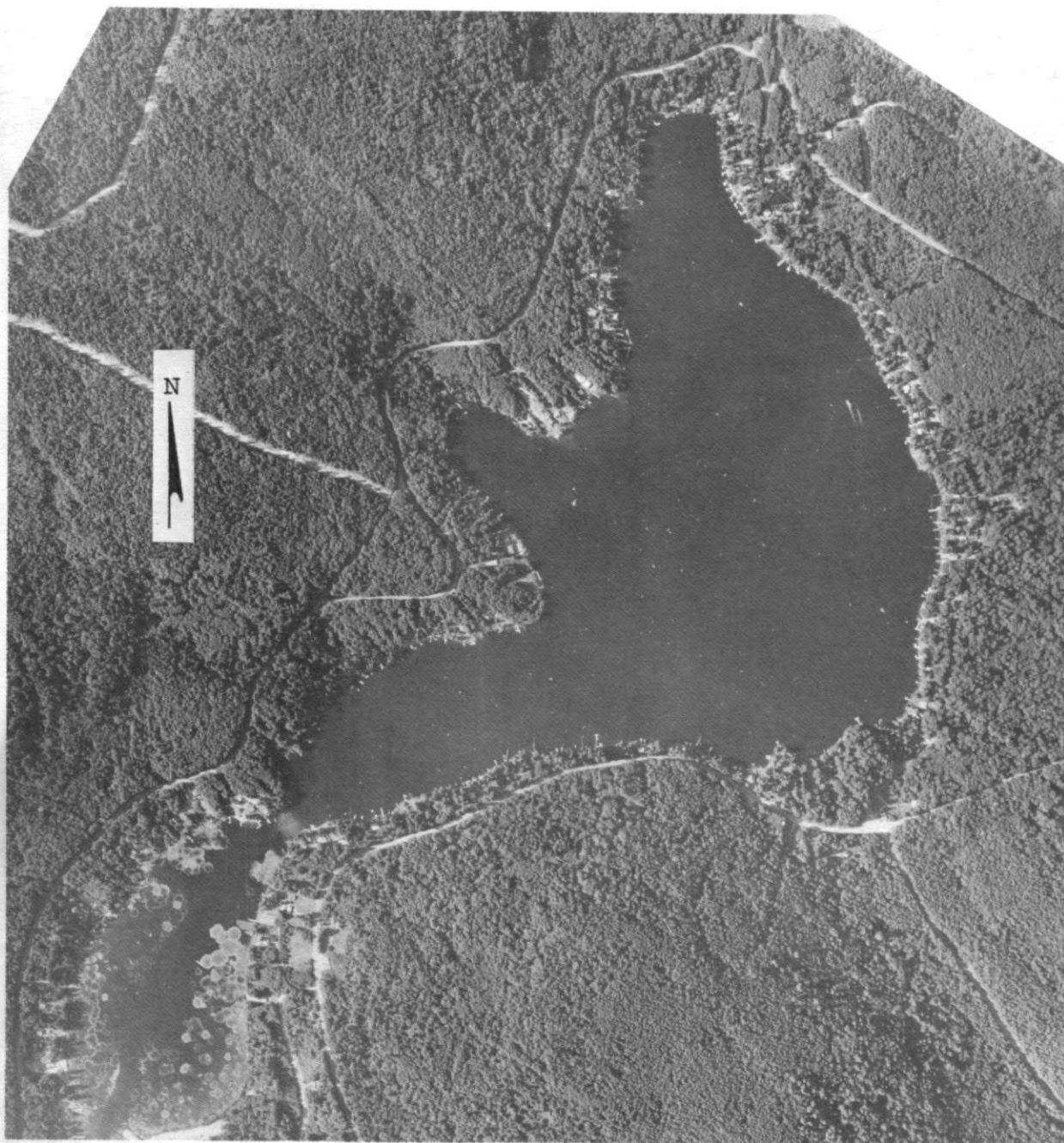


Conclusions.

Roesiger Lake (north arm) has low to medium biologic productivity. The water clarity was good. The nutrient concentrations were low to medium and macrophyte abundance was low. In the deep north arm the DO concentration in the summer bottom waters remained greater than 1 mg/l.



Roesiger (North Arm) Lake, Snohomish County.  
From Washington Department of Game, February 5, 1952.






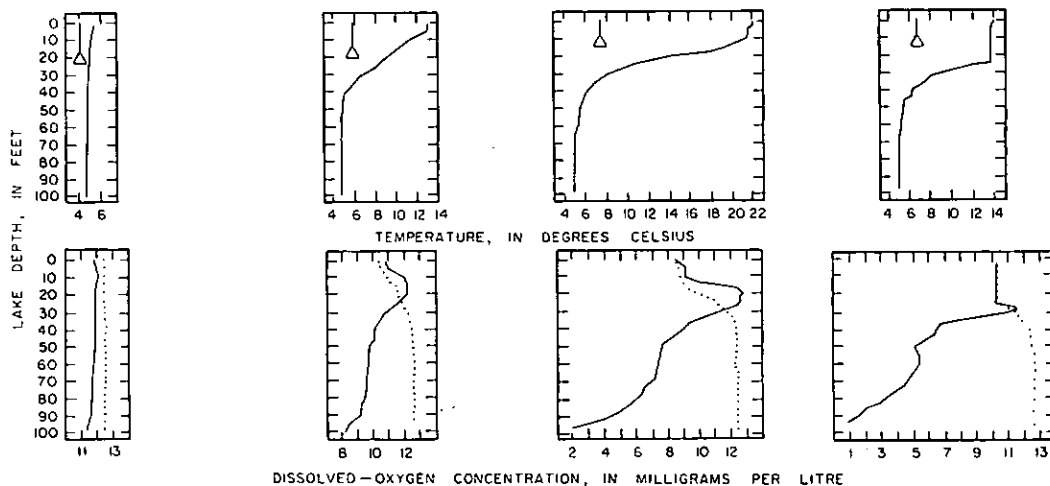
Roesiger Lake (North Arm), Snohomish County.  
August 9, 1972. Approx. scale 1:10,800.

Water-quality data for Roesiger Lake (north arm).

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	March 8		May 11		July 25		October 12	
	3	95	3	100	3	95	3	94
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	4.5	4.5	4.3	4.9	3.9	4.5	4.0	6.1
Dissolved iron (Fe) -----	.00	.03	.02	.11	.03	.02	.04	.18
Dissolved manganese (Mn) ----	.013	--	.010	.010	.000	.000	.000	.17
Calcium (Ca) -----	1.7	--	--	--	--	--	2.0	--
Magnesium (Mg) -----	.8	--	--	--	--	--	.9	--
Sodium (Na) -----	1.5	--	--	--	--	--	1.5	--
Potassium (K) -----	.3	--	--	--	--	--	.3	--
Bicarbonate (HCO <sub>3</sub> ) -----	11	11	11	10	12	9	9	8
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	.0
Sulfate (SO <sub>4</sub> ) -----	.1	--	--	--	--	--	4.0	--
Chloride (Cl) -----	1.1	--	--	--	--	--	2.3	--
Nitrate nitrogen (as N) ----	.40	.39	.35	.37	.22	.39	.07	.32
Nitrite nitrogen (as N) ----	.00	.00	.01	.00	.00	.00	.00	.00
Ammonia nitrogen (as N) ----	.02	.01	.07	.00	.13	.30	.14	.05
Organic nitrogen (as N) ----	.27	.18	.53	.14	.38	.38	.06	.07
Total phosphorus (as P) ----	.004	.006	.010	.028	.029	.033	.005	.006
Orthophosphate (as P) -----	.001	.001	.001	.001	.002	.001	.000	.000
Suspended solids (110°C) ----	8	--	--	--	--	--	20	--
Hardness (Ca, Mg) -----	8	--	--	--	--	--	9	--
Specific conductance ----- (micromhos at 25°C)	26	26	26	27	28	32	24	25
pH (pH units) -----	7.5	7.5	7.3	6.9	7.6	7.6	7.7	7.5
Color (Pt-Co units) -----	5	10	15	15	5	5	5	5
Chlorophyll a (µg/l) -----	1.3	--	1.6	--	2.3	--	4.1	--
Fecal coliform Range --	--	--	--	--	<1-12		<1-9	
(col. per 100 ml) Mean ---	--	--	--	--	3		2	

- EXPLANATION
-  Secchi - disc visibility, depth at base of triangle
  -  Dissolved oxygen concentration
  -  Dissolved oxygen concentration at 100 percent saturation



St. Clair near Yelm (south arm, 12081480)Location.

Lat 46°59'31", long 122°43'22", in SW $\frac{1}{4}$ NE $\frac{1}{4}$  sec.6, T.17 N., R.1 E., at southern tip, Thurston County, 6.5 miles northwest of Yelm; Nisqually River basin. Wier Prairie quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	14.5 sq mi	Maximum depth	110 ft
Altitude	73 ft	Length of shoreline	15,000 ft
Surface area	88 acres	Shoreline configuration	2.2
Lake volume	3,600 acre-ft	Development of volume	0.37
Mean depth	40 ft	Bottom slope	4.8 percent

The beach and littoral zone of the south arm of the lake contains a large quantity of muck in the shallow embayments.

Basin geology.

Glacial end moraine and recessional outwash (Noble and Wallace, 1966).

Soils.

Mostly loamy sand, loam, loamy fine sand, and gravelly sandy loam (Ness, 1958).

Land use (percentage of drainage basin). Urban 0, suburban 1, agricultural 29, forest or unproductive 69, and lake surface 1.

Nearshore residential development. 41 percent.

Number of nearshore homes. 163.

Surface-water inflow and outflow.

The main inflow, via Eaton Creek, is perennial. The low flow, during the August 22 visit, was estimated at 5 ft<sup>3</sup>/s. No outflow was observed.

Lake stage.

The observed gage height from March 9 to September 7, 1972, varied 2.2 ft.

Macrophytes.

Shoreline covered by emersed plants 26-50 percent.

Lake surface covered by emersed plants 10 percent.

Lake bottom covered by submersed plants 14 percent.

Rooted aquatic plants observed were white lily (Nymphaea sp.),\* cattail (Typha sp.), yellow lily (Nuphar sp.), coontail (Ceratophyllum sp.), waterweed (Elodea sp.), pondweed (Potamogeton sp.), muskgrass

Macrophytes--continued

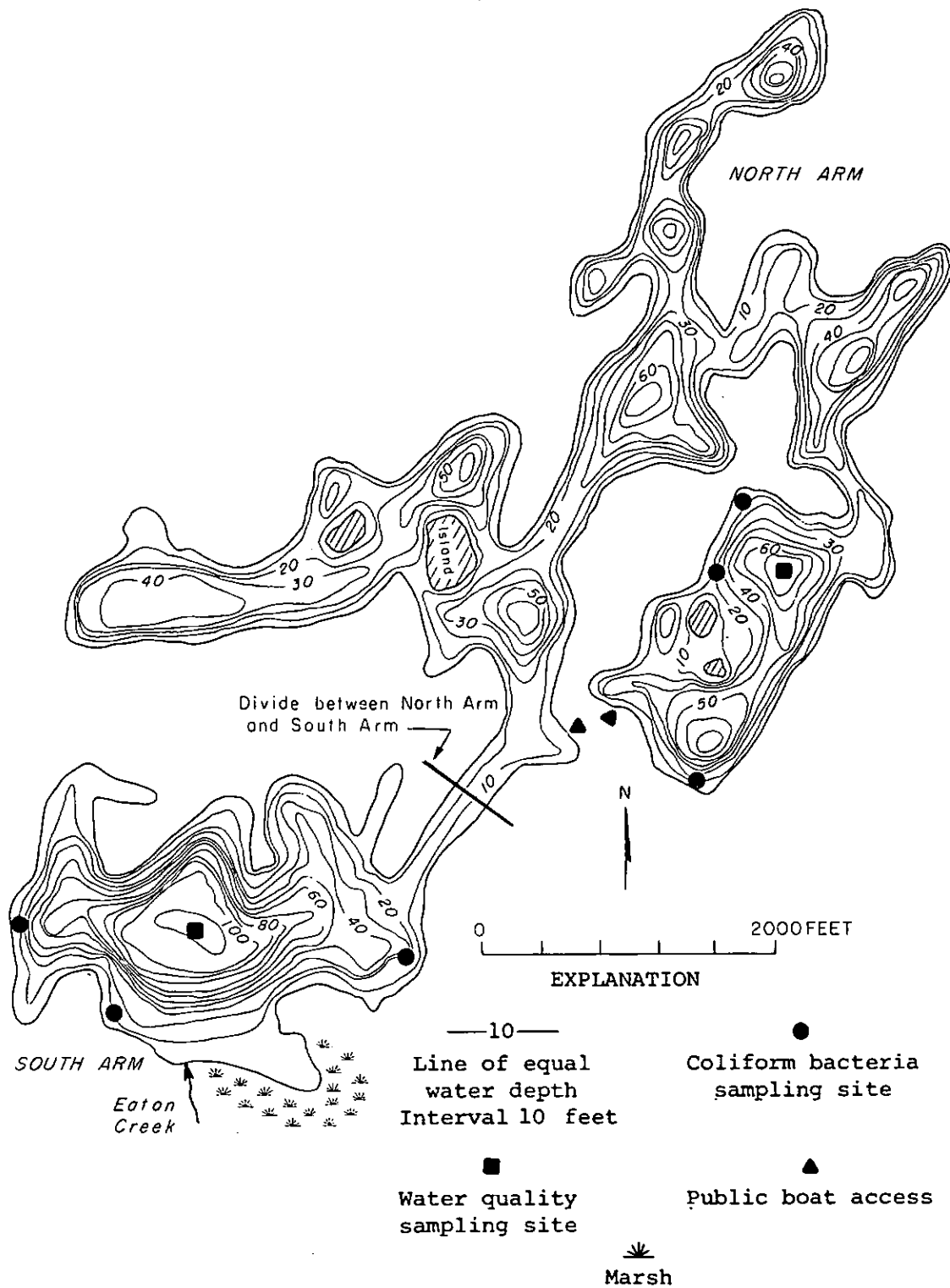
(Chara sp.), and wildcelery (Vallisneria sp.)

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Asterisk (\*) indicates dominant aquatic plant.

Conclusions.

The littoral zone is composed mainly of muck and mud with some sand. Eaton Creek, a perennial inflow stream, drains a large forest and agricultural area. The surface inflow and the littoral bottom are probably the main source of the lake's enrichment. The lake water was highly colored from natural sources but was low in dissolved-mineral concentration. The moderate to high biological productivity of the lake is evidenced by the moderate abundance of macrophytes, low water transparencies, medium high chlorophyll a concentrations, and oxygen depletion in the hypolimnion during summer stratification.



St. Clair (South Arm) Lake, Thurston County.  
 From Washington Department of Game, February 12, 1951.

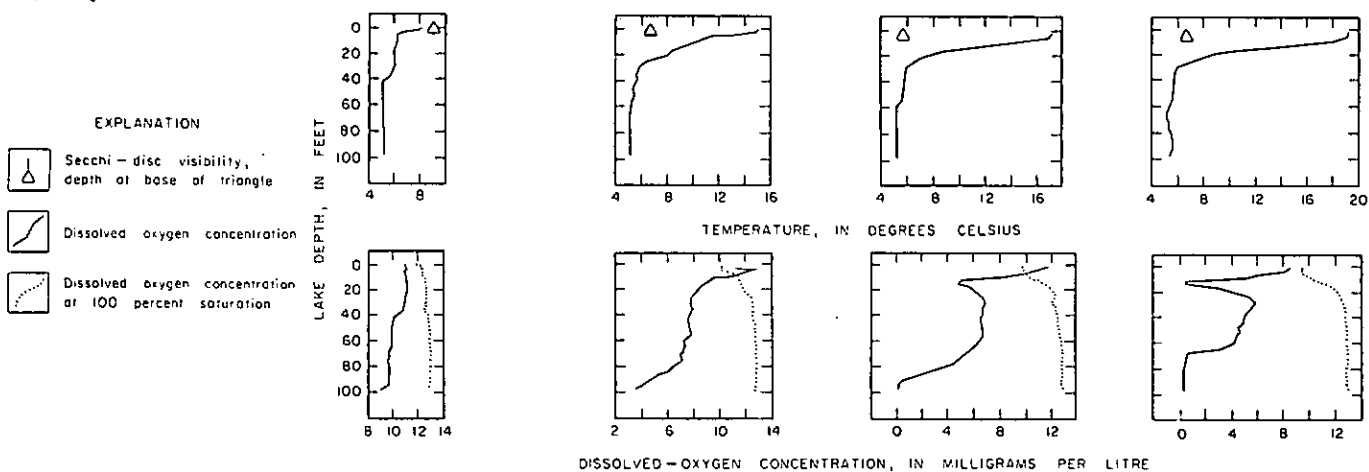


St. Clair Lake (South Arm), Thurston County.  
May 12, 1972. Approx. scale 1:12,000.

Water-quality data for St. Clair Lake (south arm).

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	March 9		May 4		June 28		August 22	
	3	96	3	96	3	94	3	94
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	4.7	26	25	27	30	27	33	26
Dissolved iron (Fe) -----	.08	.58	.40	.72	.39	1.9	.32	1.9
Dissolved manganese (Mn) ----	.025	--	.020	.200	.040	.66	.050	.70
Calcium (Ca) -----	4.6	--	--	--	--	--	6.7	--
Magnesium (Mg) -----	2.6	--	--	--	--	--	5.1	--
Sodium (Na) -----	3.3	--	--	--	--	--	5.4	--
Potassium (K) -----	1.5	--	--	--	--	--	2.1	--
Bicarbonate (HCO <sub>3</sub> ) -----	30	37	47	37	52	39	54	37
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	--	--	--
Sulfate (SO <sub>4</sub> ) -----	.1	--	--	--	--	--	5.0	--
Chloride (Cl) -----	1.1	--	--	--	--	--	3.6	--
Nitrate nitrogen (as N) ----	--	--	.04	.64	.00	.54	.05	.50
Nitrite nitrogen (as N) ----	--	--	.01	.01	.00	.04	.01	.00
Ammonia nitrogen (as N) ----	--	--	.33	.18	.14	.14	.07	.11
Organic nitrogen (as N) ----	--	--	.46	.54	.49	.46	.40	.52
Total phosphorus (as P) ----	.060	.094	.043	.089	.030	.15	.016	.15
Orthophosphate (as P) -----	.026	.036	.010	.054	.010	.090	.005	.098
Suspended solids (110°C) ----	16	--	--	--	--	--	20	--
Hardness (Ca, Mg) -----	22	--	--	--	--	--	38	--
Specific conductance -----	60	76	78	78	95	82	96	89
(micromhos at 25°C)								
pH (pH units) -----	7.8	7.7	8.5	7.3	8.4	7.4	7.6	7.1
Color (Pt-Co units) -----	85	--	85	100	65	125	40	150
Chlorophyll <i>a</i> (µg/l)-----	2.5	--	12.6	--	11.0	--	4.4	--
Fecal coliform Range --	--	--	--	--	2-4	--	<1-1	--
(col. per 100 ml) Mean ---	--	--	--	--	3	--	1	--





St. Clair near Yelm (north arm, 12081480)Location.

Lat 46°59'51", long 122°43'08", in SE $\frac{1}{4}$ SE $\frac{1}{4}$  sec.31, T.18 N., R.1 E., at southern tip, Thurston County, 6.5 miles northwest of Yelm; Nisqually River. Wier Prairie quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	6.40 sq mi	Maximum depth	70 ft
Altitude	73 ft	Length of shoreline	40,000 ft
Surface area	180 acres	Shoreline configuration	4.0
Lake volume	5,100 acre-ft	Development of volume	0.40
Mean depth	28 ft	Bottom slope	2.2 percent

Basin geology.

Glacial and moraine and recessional outwash (Noble and Wallace, 1966).

Soils.

Mostly loamy sand, loam, loamy fine sand, and gravelly sandy loam (Ness, 1958).

Land use (percentage of drainage basin). Urban 0, suburban 6, agricultural 21, forest or unproductive 68, and lake surface 5.

Nearshore residential development. 57 percent.

Number of nearshore homes. 65.

Surface-water inflow and outflow.

No inflow or outflow was observed for the north arm of St. Clair Lake.

Lake stage.

The observed gage height from March 9 to September 7, 1972, varied 2.2 ft.

Macrophytes.

Shoreline covered by emerged plants 11-25 percent.

Lake surface covered by emerged plants 0.9 percent.

Lake bottom covered by submersed plants 5 percent.

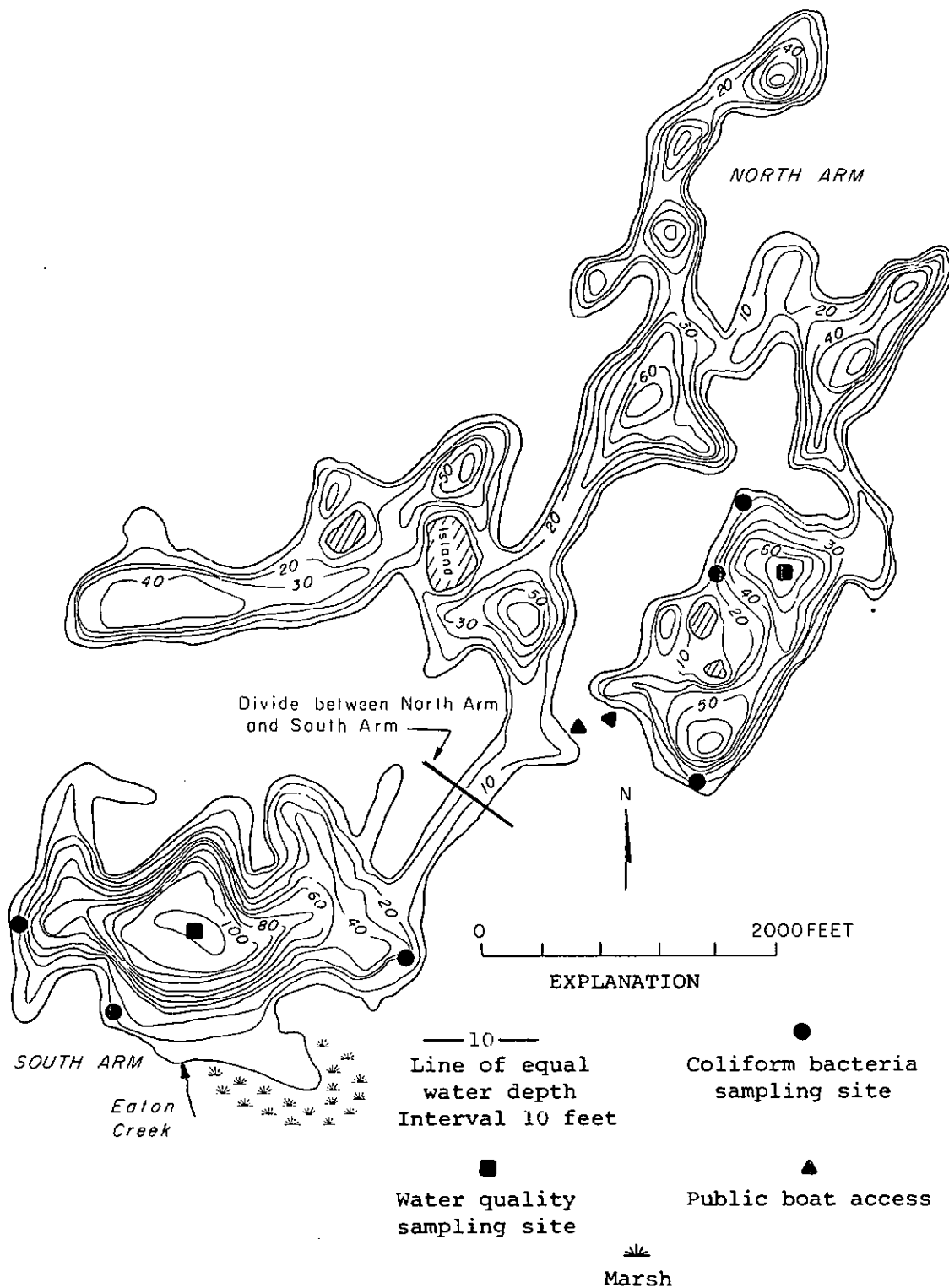
Rooted aquatic plants observed were white lily (Nymphaea sp.),\* pondweed (Potamogeton sp.),\* cattail (Typha sp.), sedge (Cyperaceae), and waterweed (Elodea sp.).

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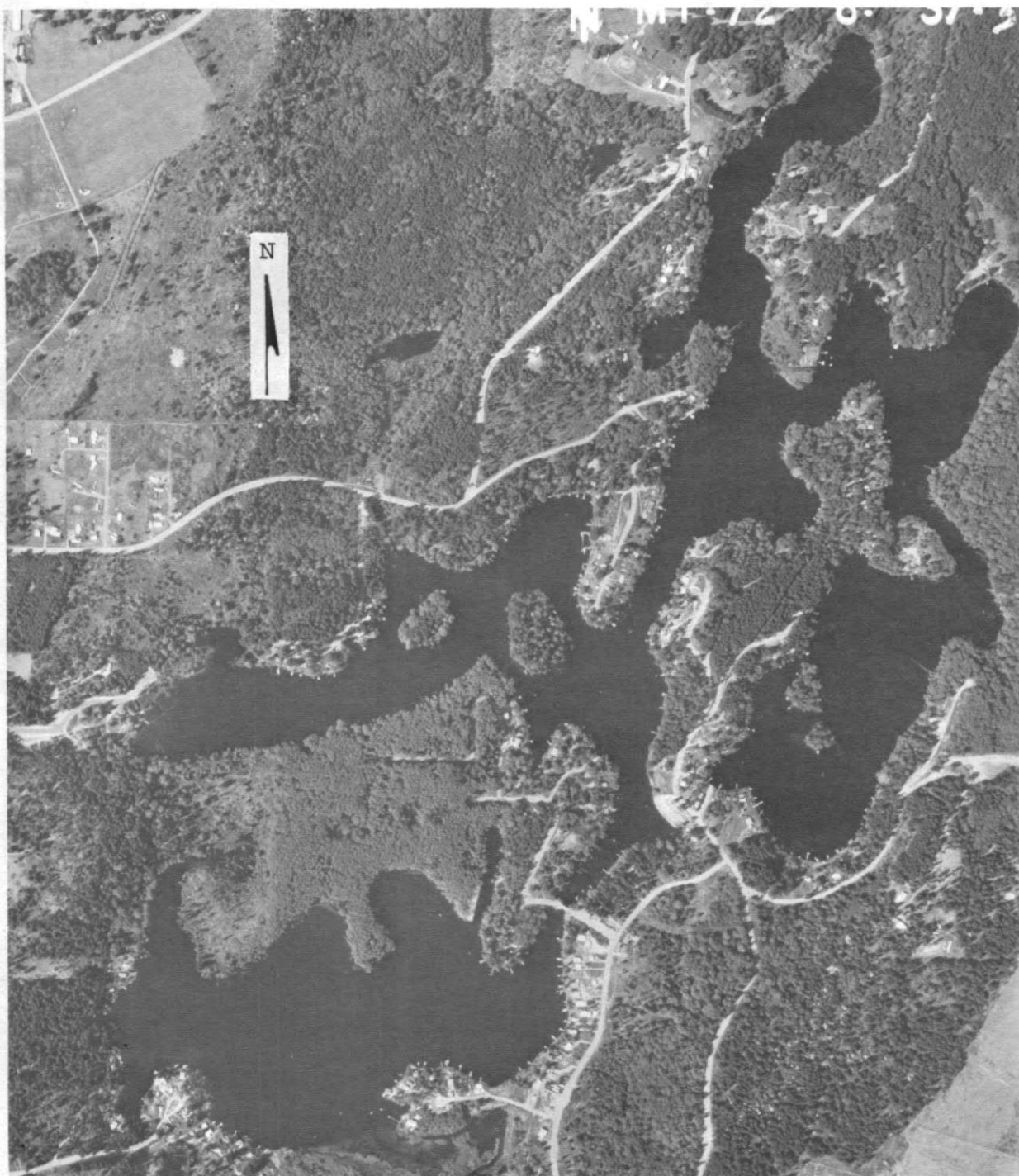
Asterisk (\*) indicates dominant aquatic plants.

Conclusions.

The north arm of St. Clair Lake has water-quality characteristics similar to the south arm.



St. Clair (North Arm) Lake, Thurston County.  
 From Washington Department of Game, February 12, 1951.




St. Clair Lake (North Arm), Thurston County.  
May 12, 1972. Approx. scale 1:12,000.


Water-quality data for St. Clair Lake (north arm).


[Milligrams per litre unless otherwise indicated]

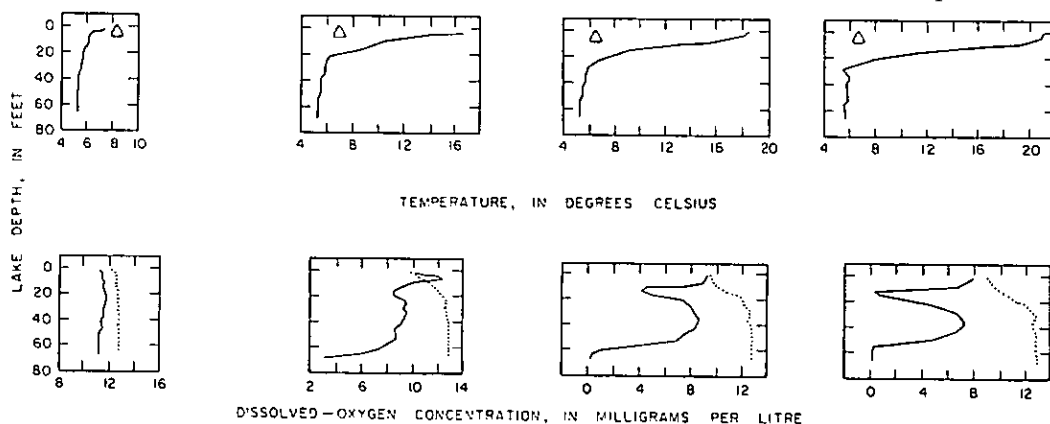
Date of collection (1972) ---	March 9		May 4		June 28		August 22	
	3	65	3	65	3	63	3	63
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	22	25	22	26	22	25	24	27
Dissolved iron (Fe) -----	.06	.24	.27	.32	.20	.47	.17	1.8
Dissolved manganese (Mn) ----	.050	--	.000	.020	.000	.150	.050	.23
Calcium (Ca) -----	5.4	--	--	--	--	--	5.7	--
Magnesium (Mg) -----	3.4	--	--	--	--	--	4.4	--
Sodium (Na) -----	4.1	--	--	--	--	--	4.8	--
Potassium (K) -----	1.8	--	--	--	--	--	1.9	--
Bicarbonate (HCO <sub>3</sub> ) -----	41	42	39	42	40	39	45	46
Sulfide (as H <sub>2</sub> S) -----	--	.0	--	--	--	--	--	--
Sulfate (SO <sub>4</sub> ) -----	.1	--	--	--	--	--	5.7	--
Chloride (Cl) -----	2.3	--	--	--	--	--	2.3	--
Nitrate nitrogen (as N) ----	--	--	.06	.34	.01	.32	.01	.12
Nitrite nitrogen (as N) ----	--	--	.01	.01	.01	.01	.00	.00
Ammonia nitrogen (as N) ----	--	--	.62	.10	.11	.22	.09	.21
Organic nitrogen (as N) ----	--	--	.12	.21	.40	.26	.44	.34
Total phosphorus (as P) ----	.044	.040	.030	.050	.020	.060	.009	.37
Orthophosphate (as P) -----	.031	.026	.010	.035	.010	.040	.003	.25
Suspended solids (110 °C) ----	8	--	--	--	--	--	19	--
Hardness (Ca, Mg) -----	27	--	--	--	--	--	32	--
Specific conductance ----- (micromhos at 25 °C)	76	81	69	81	80	86	87	87
pH (pH units) -----	7.5	7.6	8.4	7.3	7.6	7.2	7.7	7.3
Color (Pt-Co units) -----	60	55	70	65	70	80	55	150
Chlorophyll a (µg/l) -----	1.5	--	3.5	--	4.6	--	4.2	--
Fecal coliform Range -- (col. per 100 ml) Mean ---	--	--	--	--	<1-4 <1	<1-4 <1	<1-1 1	<1-1 1

EXPLANATION

 Secchi-disc visibility, depth at base of triangle

 Dissolved oxygen concentration

 Dissolved oxygen concentration or 100 percent saturation



DISSOLVED-OXYGEN CONCENTRATION, IN MILLIGRAMS PER LITRE

Sherry Lake near Tiger (12408216)Location.

Lat 48°36'24", long 117°32'36", in NW $\frac{1}{4}$ SW $\frac{1}{4}$  sec.20, T.36 N., R.42 E., Stevens County, 8.3 miles southwest of Tiger; Colville River basin. Lake Gillette quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	15.3 sq mi	Maximum depth	85 ft
Altitude	3,147 ft	Length of shoreline	4,100 ft
Surface area	25 acres	Shoreline configuration	1.1
Lake volume	720 acre-ft	Development of volume	0.34
Mean depth	29 ft	Bottom slope	7.2 percent

The beach and littoral zone is composed mainly of gravel and coarse sand.

Basin geology.

Glacial drift with some granitic rock (Huntting and others, 1961).

Soils.

Sandy loam and loam (Van Duyne and Ashton, 1915).

Land use (percentage of drainage basin). Urban 0, suburban 1, agricultural 0, forest or unproductive 95, and lake surface 4.

Nearshore residential development. 57 percent.

Number of nearshore homes. 18 (mostly seasonal).

Surface-water inflow and outflow.

The main inflow is upstream through Gillette Lake. The outflow, which at low stages is controlled by a concrete weir, is via the Little Pend Oreille River. A discharge measurement at the outflow on April 19 was 30.3 ft<sup>3</sup>/s, June 7, 13.6 ft<sup>3</sup>/s, and September 27, 13.4 ft<sup>3</sup>/s.

Lake stage.

The observed gage height from April 19 to September 26, 1972, varied 0.4 ft. The variation in gage height was based on four observations only.

Macrophytes.

Shoreline covered by emerged plants 26-50 percent.

Lake surface covered by emerged plants <0.1 percent.

Lake bottom covered by submersed plants 26 percent.

Rooted aquatic plants observed were watershield (Brasenia sp.),\* white lily (Nymphaea sp.), yellow lily (Nuphar sp.), coontail (Ceratophyllum sp.), waterweed (Elodea sp.), three varieties of

Macrophytes.--continued

pondweed (Potamogeton sp.), and muskgrass (Chara sp.).

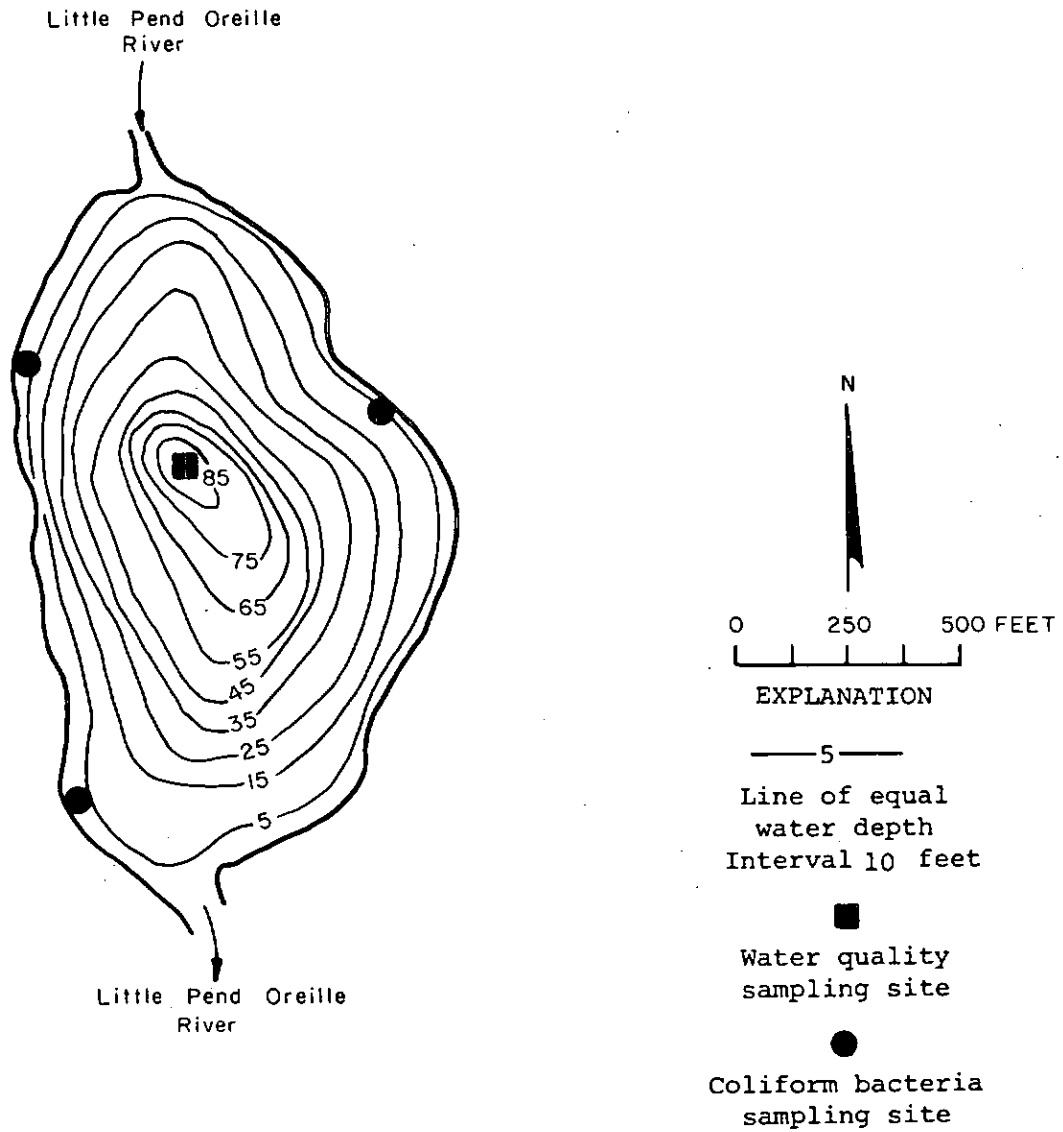
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Asterisk (\*) indicates dominant aquatic plant.

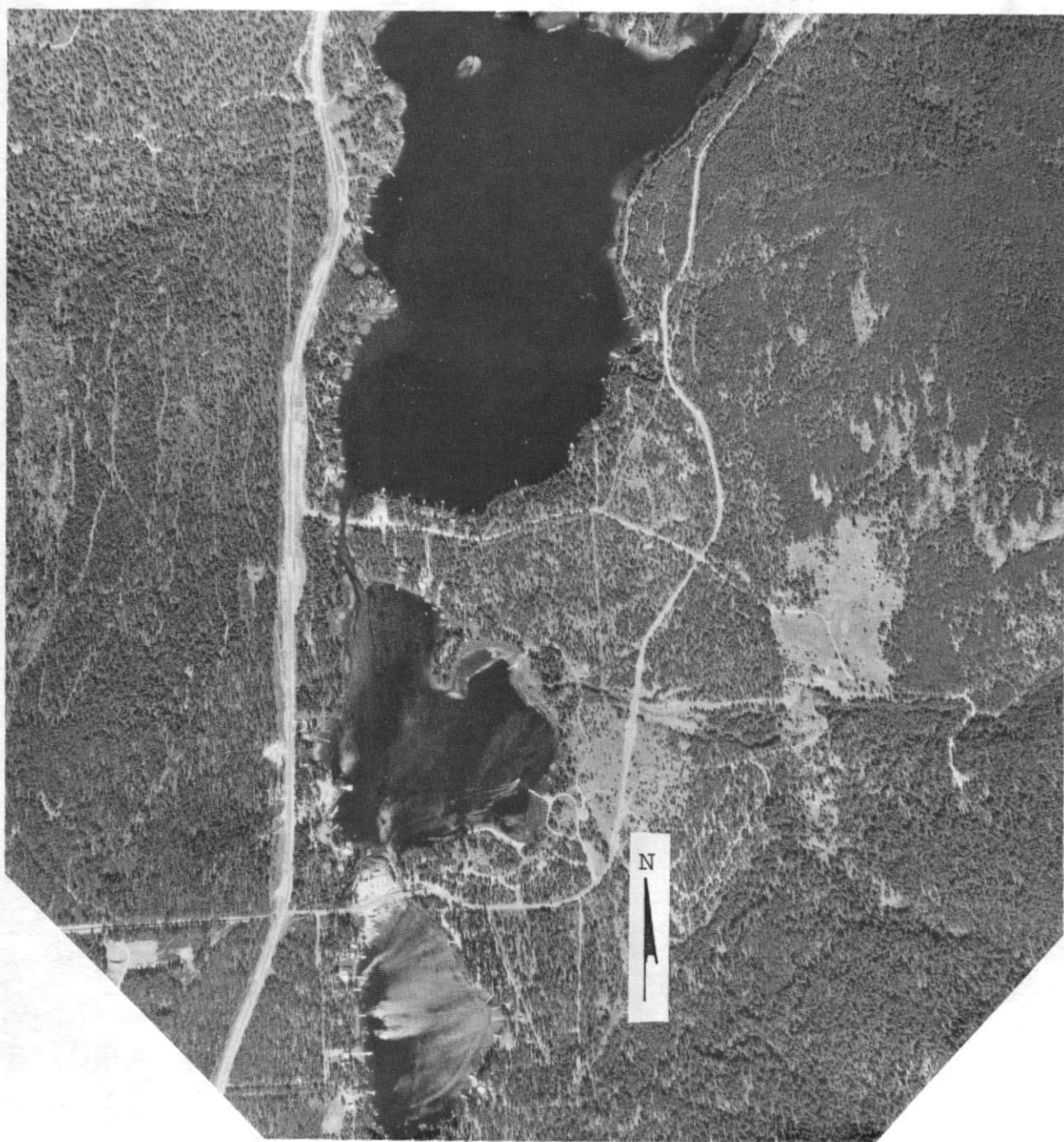
Conclusions.

The biological productivity of the lake is probably about medium. The littoral bottom supports a heavy growth of rooted aquatic plants and the chlorophyll a concentrations were medium.

The lake was strongly stratified in 1972. DO was depleted to near zero in the hypolimnion early in the year, and during the following summer a near-zero DO concentration was detected below about 18 feet. Also, nutrient and dissolved-mineral concentrations increased markedly in the hypolimnion. Total phosphorus concentrations in the epilimnion were high, but the organic and inorganic nitrogen concentrations were generally low.



Sherry Lake, Stevens County. From Washington Department of Game, March 14, 1950.






Sherry Lake, Stevens County. August 10, 1972.  
Approx. scale 1:12,000.

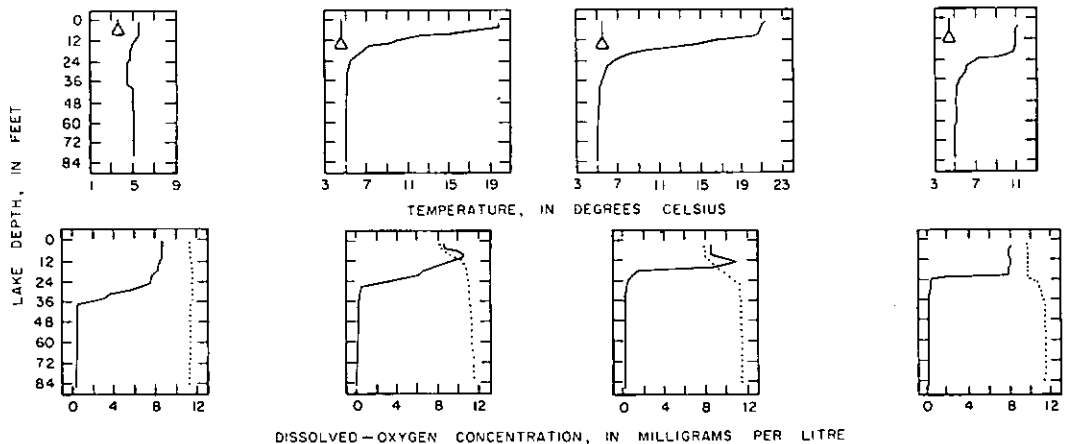


Water-quality data for Sherry Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	April 19		June 7		August 16		September 27	
	3	79	3	84	3	79	3	83
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	15	25	16	25	13	24	13	24
Dissolved iron (Fe) -----	.12	.24	.18	10	.15	9.8	.15	8.8
Dissolved manganese (Mn) ----	.020	.040	.000	.25	.000	.65	.040	.56
Calcium (Ca) -----	6.5	--	--	--	--	--	12	--
Magnesium (Mg) -----	1.2	--	--	--	--	--	1.8	--
Sodium (Na) -----	2.7	--	--	--	--	--	2.8	--
Potassium (K) -----	1.0	--	--	--	--	--	.9	--
Bicarbonate (HCO <sub>3</sub> ) -----	33	82	34	88	39	83	41	85
Sulfide (as H <sub>2</sub> S) -----	--	trace	--	--	--	<.1	--	.1
Sulfate (SO <sub>4</sub> ) -----	2.8	--	--	--	--	--	3.6	--
Chloride (Cl) -----	1.1	--	--	--	--	--	0	--
Nitrate nitrogen (as N) -----	.01	.03	.01	.02	.03	.02	.02	.02
Nitrite nitrogen (as N) -----	.01	.01	.00	.00	.00	.01	.00	.00
Ammonia nitrogen (as N) -----	.17	2.3	.06	2.6	.13	2.3	.04	.17
Organic nitrogen (as N) -----	.50	.20	.26	--	.33	1.0	.14	.21
Total phosphorus (as P) -----	.066	.68	.018	.72	.029	.82	.027	.071
Orthophosphate (as P) -----	.007	.61	.003	.48	.003	.59	.001	.51
Suspended solids (110 °C) ----	24	--	--	--	--	--	10	--
Hardness (Ca, Mg) -----	21	--	--	--	--	--	37	--
Specific conductance ----- (micromhos at 25 °C)	57	157	53	175	70	170	68	172
pH (pH units) -----	7.5	7.1	7.6	7.0	7.9	7.2	8.0	7.5
Color (Pt-Co units) -----	30	45	20	50	15	55	20	30
Chlorophyll <i>a</i> (µg/l) -----	10.9	--	2.1	--	1.7	--	2.4	--
Fecal coliform	Range ---		---		---		2-9	
(col. per 100 ml)	Mean ---		---		---		5	

- EXPLANATION
-  Secchi-disc visibility, depth at base of triangle
  -  Dissolved oxygen concentration
  -  Dissolved oxygen concentration at 100 percent saturation



DISSOLVED-OXYGEN CONCENTRATION, IN MILLIGRAMS PER LITRE

Stevens Lake at Lake Stevens (12153500)Location.

Lat 48°00'53", long 122°03'55", in NE $\frac{1}{4}$ SW $\frac{1}{4}$  sec.8, T.29 N., R.6 E., Snohomish County, at town of Lake Stevens; Snohomish River basin. Snohomish and Lake Stevens quadrangles, 1:24,000.

Physical characteristics of lake.

Drainage area	6.83 sq mi	Maximum depth	155 ft
Altitude	210 ft	Length of shoreline	38,000 ft
Surface area	1,000 acres	Shoreline configuration	1.6
Lake volume	65,000 acre-ft	Development of volume	0.41
Mean depth	63 ft	Bottom slope	2.1 percent

The beach and littoral zone consists primarily of gravel and coarse sand with lesser amounts of sand, silt, and muck.

Basin geology.

Glacial drift with local alluvium (Newcomb, 1952).

Soils.

Mostly gravelly loam and smaller amounts of gravelly sandy loam (Anderson and others, 1947).

Land use (percentage of drainage basin). Urban 0, suburban 76, agricultural 0, forest or unproductive 0, and lake surface 24.

Nearshore residential development. 100 percent.

Number of nearshore homes. 297 (mostly permanent).

Surface-water inflow and outflow.

The inflow is from two small unnamed tributaries. The outflow, which is controlled by natural conditions, was perennial. A discharge measurement at outflow on March 13 was 35.7 ft<sup>3</sup>/s; May 12, 22.9 ft<sup>3</sup>/s; July 27, 5.49 ft<sup>3</sup>/s; and October 11, 2.35 ft<sup>3</sup>/s.

Lake stage.

The observed gage height from March 13 to October 11, 1972 varied 1.5 ft. The variation in gage height was based on four observations only.

Macrophytes.

Shoreline covered by emerged plants 0-10 percent.

Lake surface covered by emerged plants <0.1 percent.

Lake bottom covered by submersed plants 7 percent.

Rooted aquatic plants observed were yellow lily (Nuphar sp.),\* muskgrass (Chara sp.), cattail (Typha sp.), white lily (Nymphaea sp.),

Macrophytes.--continued

sedge (Cyperaceae), watershield (Brasenia sp.), waterweed (Elodea sp.), and pondweed (Potamogeton sp.).

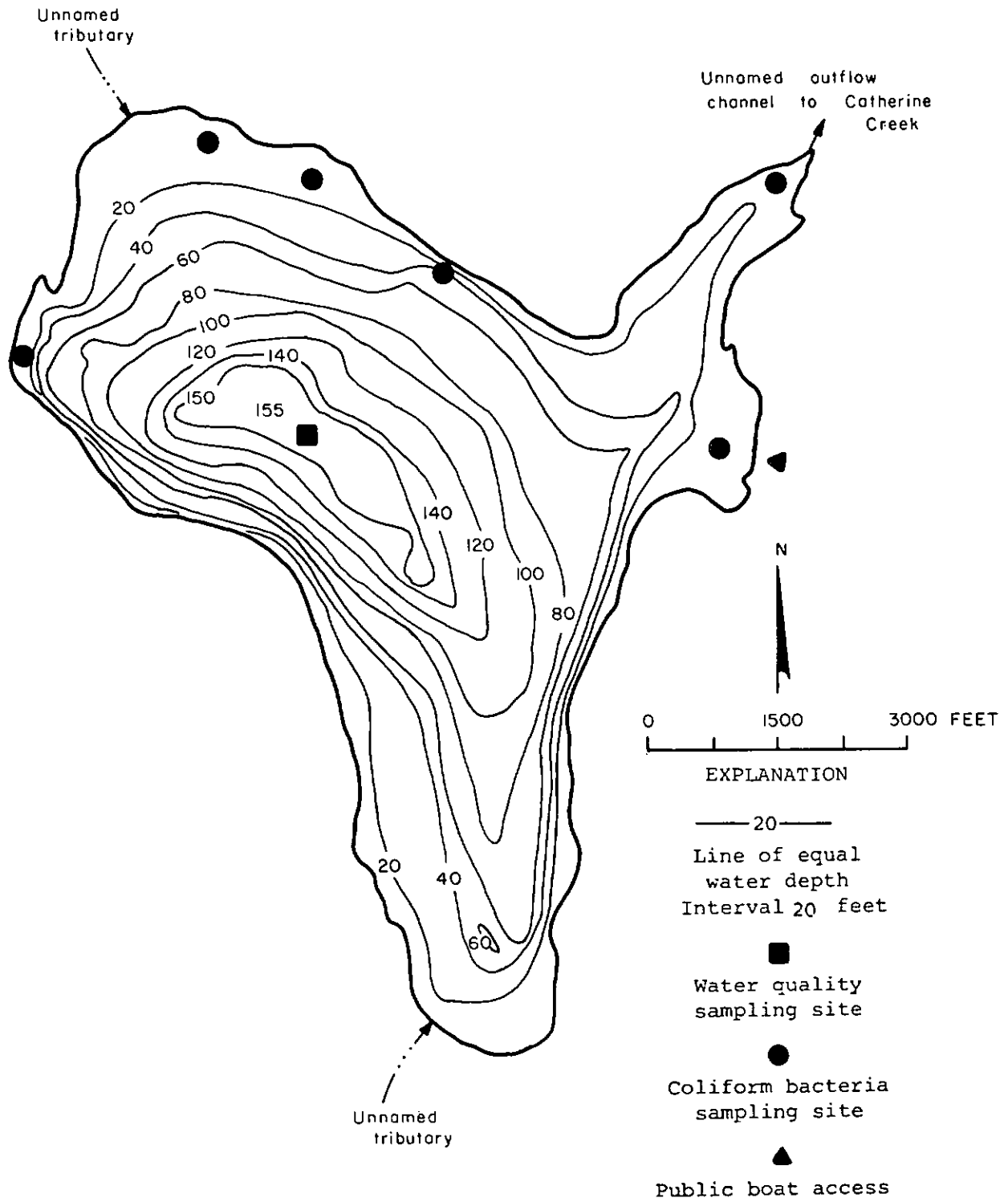
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Asterisk (\*) indicates dominant aquatic plants.

Conclusions

The suburban-urban environment of Stevens Lake probably is the major cause of its medium level of biologic productivity and trophic nature. The biologic productivity of the lake is evidenced by the moderate nutrient concentrations (with the exception of organic nitrogen), medium low chlorophyll a concentrations, a buildup of nutrients in the bottom waters, and moderate growth of submersed aquatic plants. The clarity of the water (Secchi-disc visibility averaged 18 ft) was better than most of the lake studied in this project. Due to the depth of the lake, water temperatures in the hypolimnion during the summer remained at about 6 °C, and during the midsummer sampling on July 27 the DO concentration was greater than 6 mg/l for most of the hypolimnion.

Even though the lake has a perennial surface-water outflow, the lake's estimated water-renewal time is 5.4 years. This would not allow nutrients or other possible contaminants to be quickly flushed from this large lake.



Stevens Lake, Snohomish County. From Washington Department of Game, July 1955.






Stevens Lake, Snohomish County. August 9, 1972.  
Approx. scale 1:18,700.

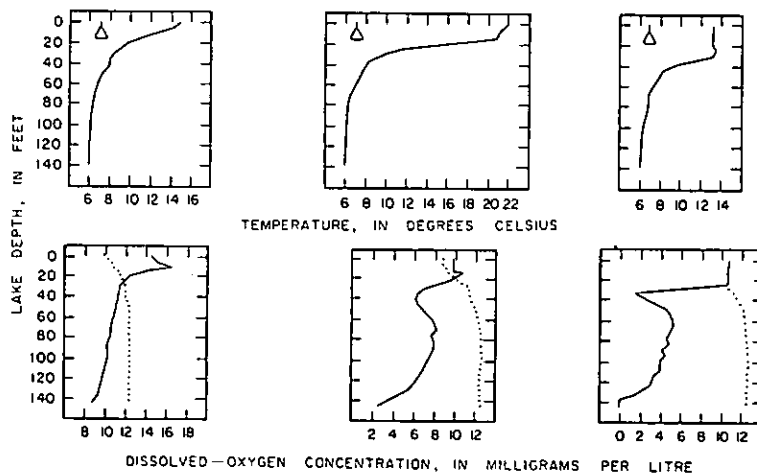
Water-quality data for Stevens Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) --- Water depth (ft) -----	March 13		May 12		July 27		October 11	
	3	145	3	140	3	140	3	140
Silica (SiO <sub>2</sub> ) -----	0.3	0.4	0.5	0.6	0.5	1.5	0.7	2.6
Dissolved iron (Fe) -----	.01	.03	.03	.08	.03	.14	.03	1.6
Dissolved manganese (Mn) ----	.013	--	.000	.030	.020	.300	.000	.420
Calcium (Ca) -----	6.1	--	--	--	--	--	6.7	--
Magnesium (Mg) -----	2.5	--	--	--	--	--	2.8	--
Sodium (Na) -----	3.9	--	--	--	--	--	3.9	--
Potassium (K) -----	1.6	--	--	--	--	--	1.5	--
Bicarbonate (HCO <sub>3</sub> ) -----	33	33	33	32	30	28	31	34
Sulfide (as H <sub>2</sub> S) -----	--	.0	--	.0	--	--	--	--
Sulfate (SO <sub>4</sub> ) -----	.2	--	--	--	--	--	6.0	--
Chloride (Cl) -----	3.4	--	--	--	--	--	4.5	--
Nitrate nitrogen (as N) ----	.43	.41	.10	.45	.05	.55	.02	.56
Nitrite nitrogen (as N) ----	.00	.00	.01	.01	.00	.00	.00	.00
Ammonia nitrogen (as N) ----	.02	.04	.04	.02	.05	.29	.25	.42
Organic nitrogen (as N) ----	.41	.51	.41	.31	.38	.20	.67	.58
Total phosphorus (as P) ----	.022	.028	.020	.054	.005	.056	.012	.078
Orthophosphate (as P) -----	.015	.019	.002	.014	.001	.052	.000	.066
Suspended solids (110 °C) ----	28	--	--	--	--	--	7	--
Hardness (Ca, Mg) -----	26	--	--	--	--	--	28	--
Specific conductance ----- (micromhos at 25 °C)	76	76	80	75	73	80	71	81
pH (pH units) -----	7.9	7.9	10.1	7.3	8.8	7.7	7.5	6.9
Color (Pt-Co units) -----	10	--	15	20	5	5	5	15
Chlorophyll <i>a</i> (µg/l) -----	3.5	--	3.6	--	2.6	--	4.3	--
Pecal coliform Range -- (col. per 100 ml) Mean ---	--	--	--	--	3-10 5		<1-75 14	

EXPLANATION

-  Secchi - disc visibility, depth at base of triangle
-  Dissolved oxygen concentration
-  Dissolved oxygen concentration at 100 percent saturation



Thomas Lake near Tiger (12408210)Location.

Lat 48°37'07", long 117°32'39", in NE¼SE¼ sec.18, T.36 N., R.42 E., Stevens County, at bridge between Thomas and Gillette Lakes, 7.8 miles southwest of Tiger; Colville River basin. Aladdin Mountain quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	12.7 sq mi	Maximum depth	55 ft
Altitude	3,147 ft	Length of shoreline	17,000 ft
Surface area	170 acres	Shoreline configuration	1.8
Lake volume	4,000 acre-ft	Development of volume	0.42
Mean depth	23 ft	Bottom slope	1.8 percent

The beach and littoral zone is composed of gravel and sand.

Basin geology.

Glacial drift with some granitic rock (Hunting and others, 1961).

Soils.

Sandy loam and loam (Van Duyne and Ashton, 1915).

Land use (percentage of drainage basin). Urban 0, suburban 1, agricultural 0, forest or unproductive 95, and lake surface 4.

Nearshore residential development. 74 percent.

Number of nearshore homes. 66 (mostly seasonal).

Surface-water inflow and outflow.

The main inflow is from Heritage Lake. The outflow is a narrow connecting channel to Gillette Lake.

Lake stage.

The observed gage height from April 19 to September 26, 1972, varied 0.4 ft. The variation in gage height was based on four observations only.

Macrophytes.

Shoreline covered by emerged plants 26-50 percent.

Lake surface covered by emerged plants 10 percent.

Lake bottom covered by submersed plants 14 percent.

Rooted aquatic plants observed were watershield (*Brasenia* sp.),\*

Bur reed (*Sparganium* sp.), white lily (*Nymphaea* sp.), yellow lily (*Nuphar* sp.), muskgrass (*Chara* sp.), nitella (*Nitella* sp.), and five

Macrophytes.--continued

varieties of pondweed (Potamogeton spp.).

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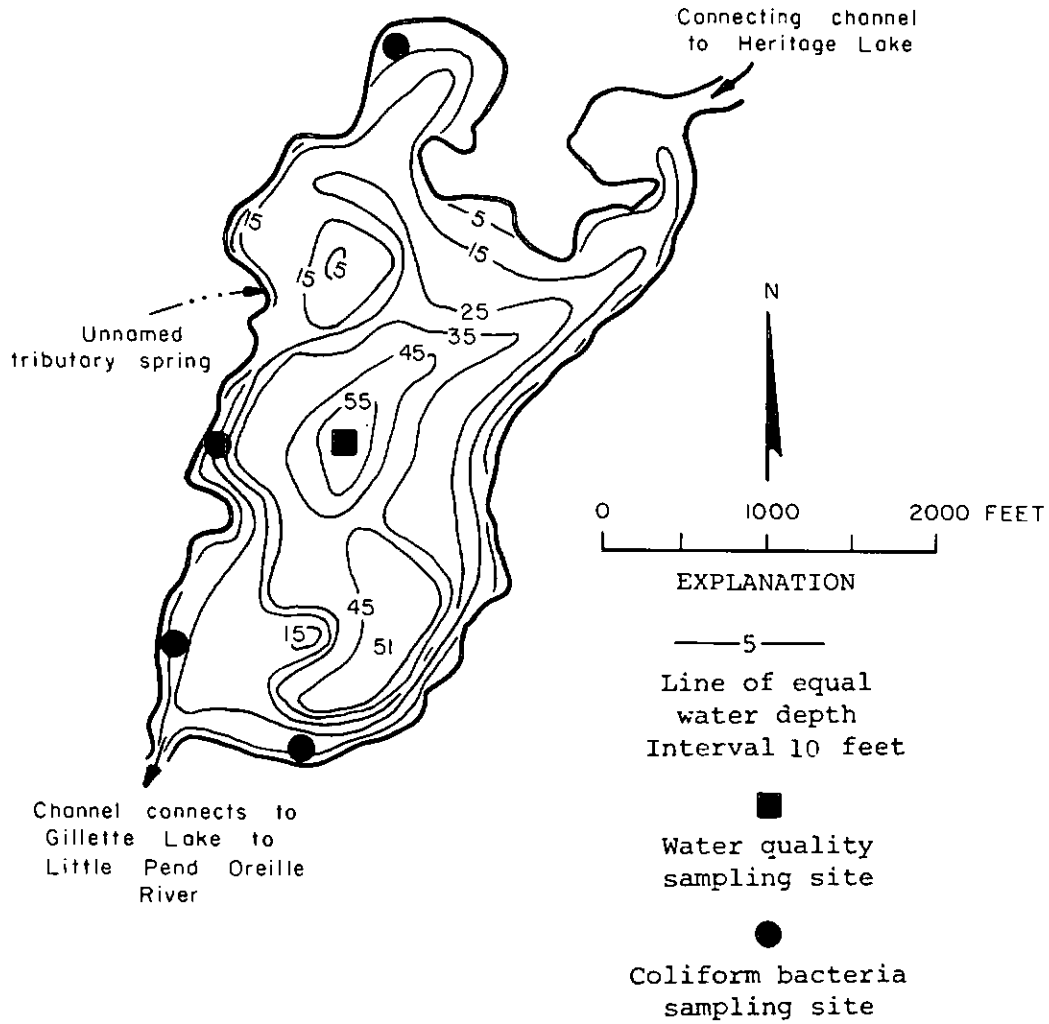
Asterisk (\*) indicates dominant aquatic plant.

Conclusions.

Thomas Lake is directly connected to the downstream end of Heritage Lake and is the largest of the lakes in the headwaters of the Little Pend Oreille River.

The overall trophic nature of the lake is probably medium. The DO concentration in the epilimnion remained high but was depleted to near zero below a depth of 20 feet. The total phosphorus and organic nitrogen concentrations were high. The lake water was slightly colored but dilute in dissolved minerals. Because the waters are slightly colored, natural organic materials may have contributed to the high total phosphorus in the epilimnion (54 µg/l). This is substantiated by the generally low orthophosphate concentrations, which ranged from 1 to 5 µg/l. Inorganic nitrogen concentrations were also low. The littoral bottom supports a heavy growth of emersed aquatic plants, predominantly Brasenia sp. (watershield), and a moderate growth of submersed aquatic plants.





Thomas Lake, Stevens County. From Washington Department of Game, March 11, 1950.

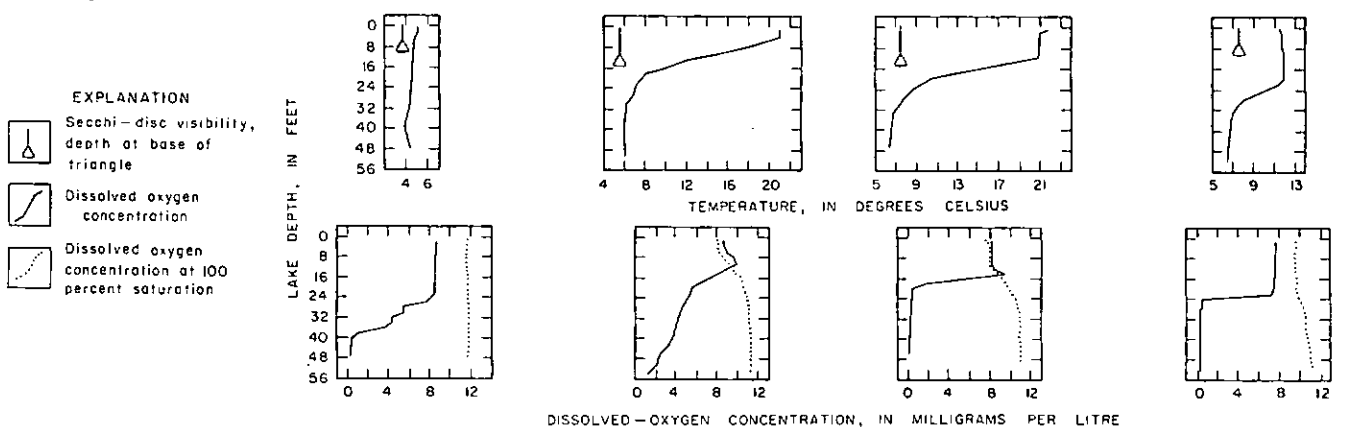


Thomas Lake, Stevens County. August 10, 1972.  
Approx. scale 1:12,000.

Water-quality data for Thomas Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	April 19		June 7		August 16		September 26	
	3	45	3	50	3	45	3	49
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	15	19	16	16	13	16	13	17
Dissolved iron (Fe) -----	.15	.28	.10	1.1	.14	1.9	.18	3.1
Dissolved manganese (Mn) ----	.040	.030	.000	.28	.000	.23	.060	.24
Calcium (Ca) -----	6.1	--	--	--	--	--	6.6	--
Magnesium (Mg) -----	1.1	--	--	--	--	--	1.2	--
Sodium (Na) -----	2.7	--	--	--	--	--	2.9	--
Potassium (K) -----	.9	--	--	--	--	--	.8	--
Bicarbonate (HCO <sub>3</sub> ) -----	31	37	29	33	29	33	31	35
Sulfide (as H <sub>2</sub> S) -----	--	.0	--	--	--	--	--	trace
Sulfate (SO <sub>4</sub> ) -----	2.4	--	--	--	--	--	3.3	--
Chloride (Cl) -----	1.0	--	--	--	--	--	.1	--
Nitrate nitrogen (as N) -----	.01	.04	.02	.05	.05	.04	.02	.02
Nitrite nitrogen (as N) -----	.01	.02	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N) -----	.22	.26	.04	.16	.08	.18	.04	.32
Organic nitrogen (as N) -----	.27	.20	.34	.19	.92	.17	.08	.16
Total phosphorus (as P) -----	.15	.15	.007	.025	.027	.081	.028	.12
Orthophosphate (as P) -----	.005	.012	.002	.014	.001	.030	.001	.093
Suspended solids (110°C) ----	31	--	--	--	--	--	7	--
Hardness (Ca, Mg) -----	20	--	--	--	--	--	21	--
Specific conductance (micromhos at 25°C)	54	68	48	58	53	65	56	74
pH (pH units) -----	7.5	7.3	7.7	7.1	7.8	6.9	8.0	7.4
Color (Pt-Co units) -----	25	45	15	35	10	50	15	25
Chlorophyll <i>a</i> (µg/l) -----	8.2	--	1.8	--	2.1	--	3.2	--
Fecal coliform Range --	--	--	--	--	<1-4	1	<1-1	<1
(col. per 100 ml) Mean ---	--	--	--	--	1	1	<1	<1



Walker Lake near Cumberland (12107290)Location.

Lat 47°15'47", long 121°54'25", in NW $\frac{1}{4}$ SW $\frac{1}{4}$  sec.34, T.21 N., R.7 E., at southern tip, King County, 1.7 miles southeast of Cumberland; Duwamish River basin. Cumberland quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	0.49 sq mi	Maximum depth	54 ft
Altitude	1,140 ft	Length of shoreline	2,900 ft
Surface area	12 acres	Shoreline configuration	1.2
Lake volume	370 acre-ft	Development of volume	0.57
Mean depth	31 ft	Bottom slope	6.6 percent

The beach and littoral zone is composed primarily of coarse sand and gravel.

Basin geology.

Glacial outwash with volcanic rock in eastern part of basin (Luzier, 1969).

Soils.

Shallow, stony soils with outcrops of bedrock. Gravelly loam occupies western part of basin (Poulson and others, 1952).

Land use (percentage of drainage basin). Urban 0, suburban 10, agricultural 0, forest or unproductive 86, and lake surface 4.

Nearshore residential development. 100 percent.

Number of nearshore homes. 29 (mostly seasonal).

Surface-water inflow and outflow.

No inflow or outflow was observed.

Lake stage.

The observed gage height from March 3 to July 20, 1972, varied 2.6 ft.

Macrophytes.

Shoreline covered by emerged plants 0-10 percent.

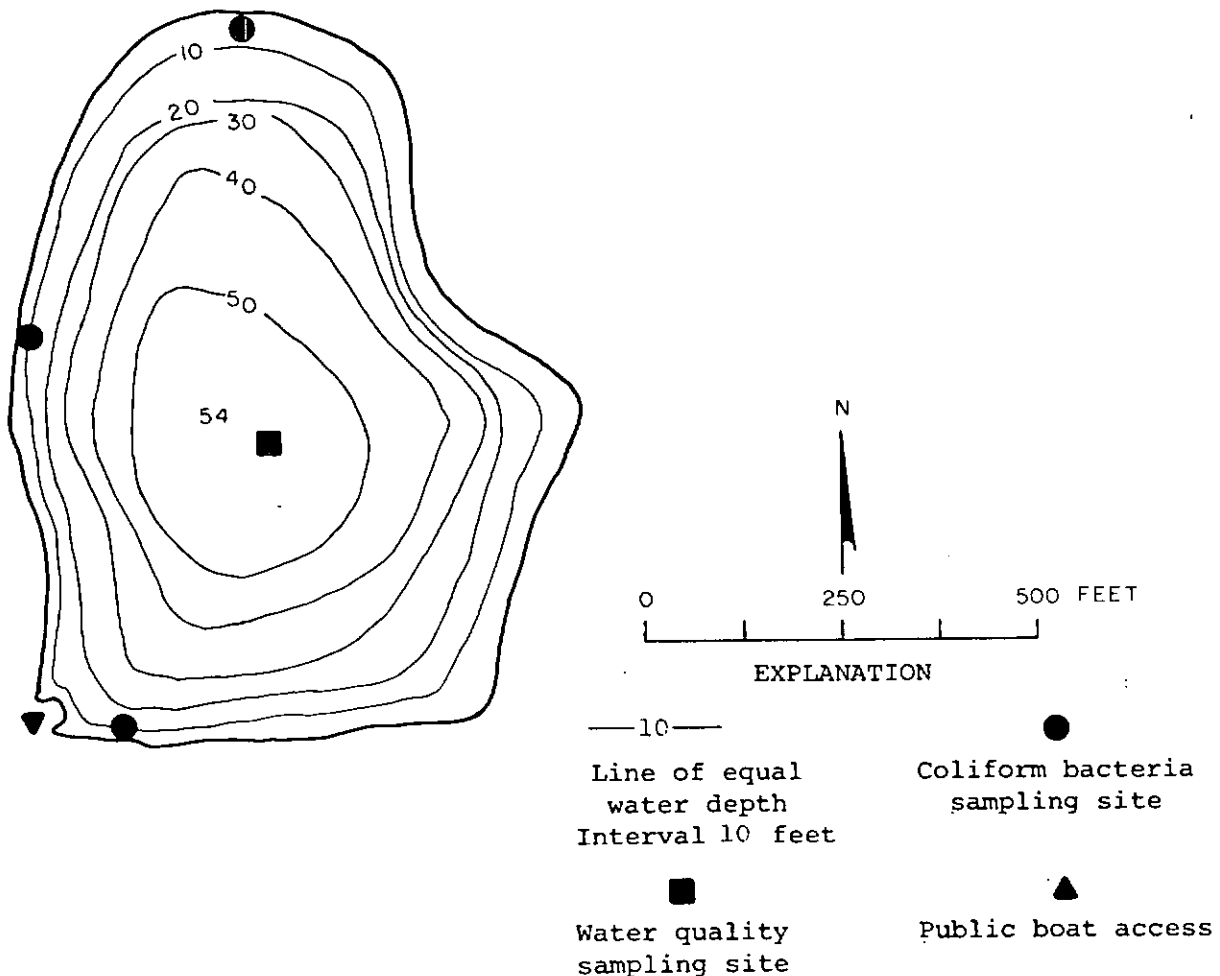
Lake surface covered by emerged plants 0.2 percent.

Lake bottom covered by submersed plants <1 percent.

Rooted aquatic plants observed were yellow lily (Nuphar sp.).

Conclusions. Walker Lake could be considered low to medium in biological productivity and trophic nature, as evidenced by low to medium nitrogen and phosphorus concentrations, medium chlorophyll *a* concentrations, good water clarity, and a sparse growth of aquatic plants.

Temperature profiles show the lake to be strongly stratified during the summer. The DO in the hypolimnion was depleted to near zero between early summer and late fall. A high percentage of the lake volume contained less than 4.0 mg/l DO due to oxygen depletion in the hypolimnion. The strong temperature gradients are due in part to the well sheltered setting of the lake. The steep, heavily forested hills prevent wind action and mixing of the lake waters during much of the year.



Walker Lake, King County. From Washington Department of Game, February 15, 1953.



Walker Lake, King County. August 9, 1972.  
Approx. scale 1:3600.

Water-quality data for Walker Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) ---	March 3		May 9		June 26		October 13	
	3	46	3	45	3	44	3	43
Water depth (ft) -----								
Silica (SiO <sub>2</sub> ) -----	2.7	2.9	3.1	4.3	0.6	4.2	0.9	4.6
Dissolved iron (Fe) -----	.01	.02	.06	.21	.06	.13	.05	.80
Dissolved manganese (Mn) ----	.025	--	.000	.040	.020	.000	.000	.13
Calcium (Ca) -----	2.6	--	--	--	--	--	3.1	--
Magnesium (Mg) -----	.5	--	--	--	--	--	.7	--
Sodium (Na) -----	1.5	--	--	--	--	--	1.6	--
Potassium (K) -----	.4	--	--	--	--	--	.4	--
Bicarbonate (HCO <sub>3</sub> ) -----	17	17	18	17	18	18	14	18
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	trace
Sulfate (SO <sub>4</sub> ) -----	.0	--	--	--	--	--	1.6	--
Chloride (Cl) -----	1.0	--	--	--	--	--	1.4	--
Nitrate nitrogen (as N) ----	.24	.24	.25	.18	.06	.25	.01	.01
Nitrite nitrogen (as N) ----	.00	.00	.01	.01	.00	.02	.00	.00
Ammonia nitrogen (as N) ----	.11	.12	.22	.41	.05	.20	.04	.47
Organic nitrogen (as N) ----	.25	.25	.21	.15	.26	.18	.16	.13
Total phosphorus (as P) ----	.016	.013	.025	.032	.020	.040	.004	.012
Orthophosphate (as P) -----	.003	.003	.002	.005	.000	.000	.001	.002
Suspended solids (110°C) ----	9	--	--	--	--	--	17	--
Hardness (Ca,Mg) -----	9	--	--	--	--	--	11	--
Specific conductance -----	31	30	31	36	30	35	27	48
(micromhos at 25°C)								
pH (pH units) -----	7.6	7.7	7.3	6.6	7.7	6.8	7.5	6.9
Color (Pt-Co units) -----	20	15	5	20	20	25	5	20
Chlorophyll <i>a</i> (µg/l)-----	7.9	--	3.2	--	4.1	--	2.9	--

Fecal coliform Range --  
(col. per 100 ml) Mean ---

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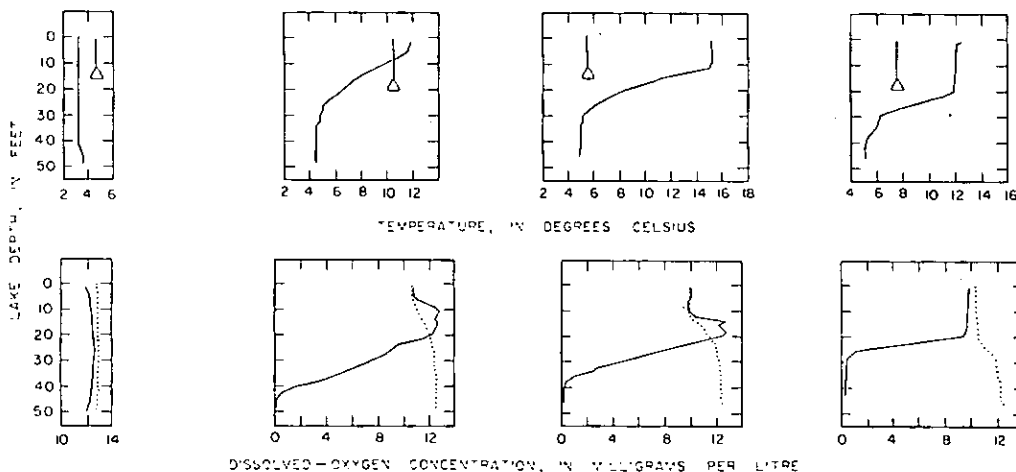
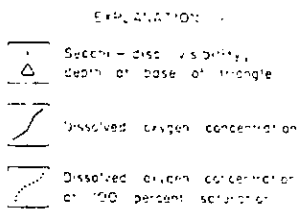
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6-12

9

<1

<1



Wallace Lake near Gold Bar (12134900)Location.

Lat 47°54'08", long 121°40'26", in SW $\frac{1}{4}$ NE $\frac{1}{4}$  sec.20, T.28 N., R.9 E., Snohomish County, 3.3 miles northeast of Gold Bar; Snohomish River basin. Index quadrangle, 1:62,500.

Physical characteristics of lake.

Drainage area	3.76 sq mi	Maximum depth	100 ft
Altitude	1,844 ft	Length of shoreline	6,400 ft
Surface area	54 acres	Shoreline configuration	1.2
Lake volume	3,200 acre-ft	Development of volume	0.60
Mean depth	60 ft	Bottom slope	5.8 percent

Basin geology.

Older sedimentary rocks (Hunting and others, 1961).

Soils.

Shallow, stony soils on steep terrain (Anderson and others, 1947).

Land use (percentage of drainage basin). Urban 0, suburban 0, agricultural 0, forest or unproductive 98, and lake surface 2.

Nearshore residential development. 0 percent

Number of nearshore homes. 0.

Surface-water inflow and outflow.

The inflow is from several small intermittent and ephemeral streams originating in the surrounding mountainous terrain. The outflow is via North Fork Wallace River.

Lake stage.

Records incomplete.

Macrophytes.

Shoreline covered by emerged plants 0-10 percent.

Lake surface covered by emerged plants <1 percent.

Lake bottom covered by submersed plants

Rooted aquatic plants observed were - no plant survey made.

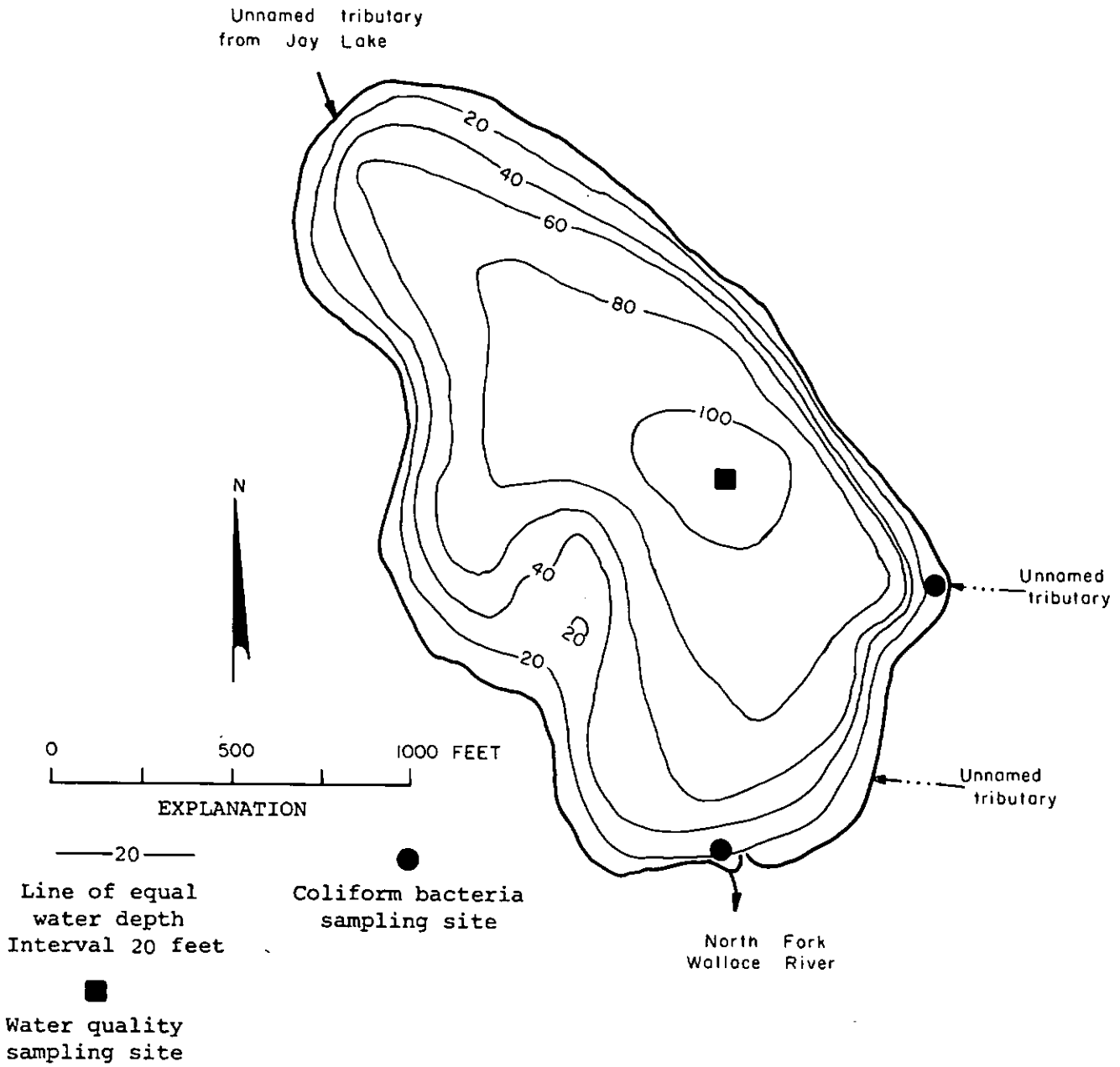


Remarks.

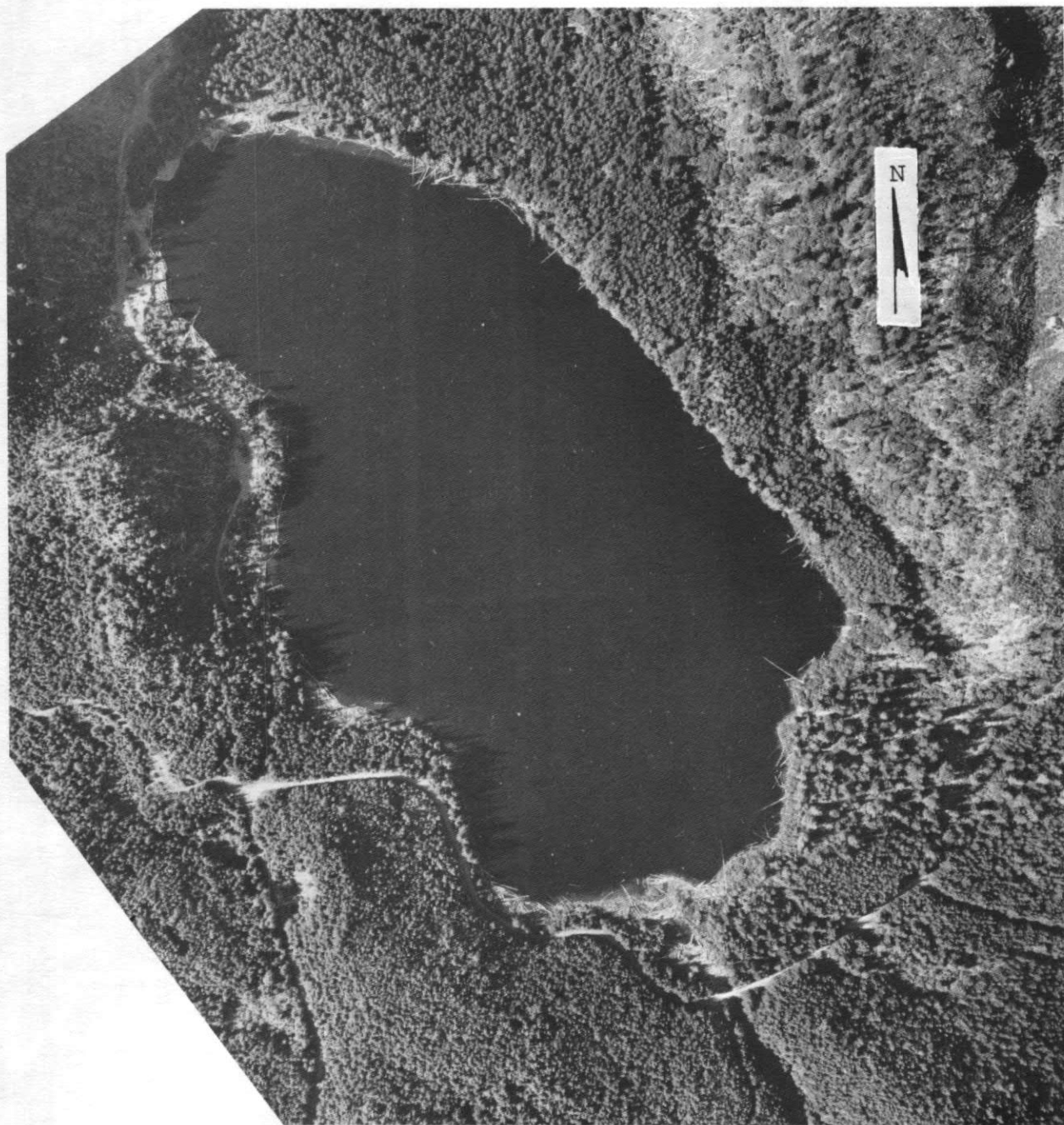
Because there was no road access through private forest lands for part of the year, the lake was sampled only twice and, therefore, the data collection was incomplete.

Conclusions.

The water was dilute in dissolved-mineral and inorganic-nutrient concentrations. A strong outflow flushes the entire lake volume several times during the year. The lake has an altitude of 1,844 feet and is situated entirely on forest land. The lake presently has a low potential for enrichment and probably has a low overall trophic classification.



Wallace Lake, Snohomish County. From Washington Department of Game, June 25, 1957.




Wallace Lake, Snohomish County. August 9, 1972.  
Approx. scale 1:4800.


## Water-quality data for Wallace Lake.


[Milligrams per litre unless otherwise indicated]

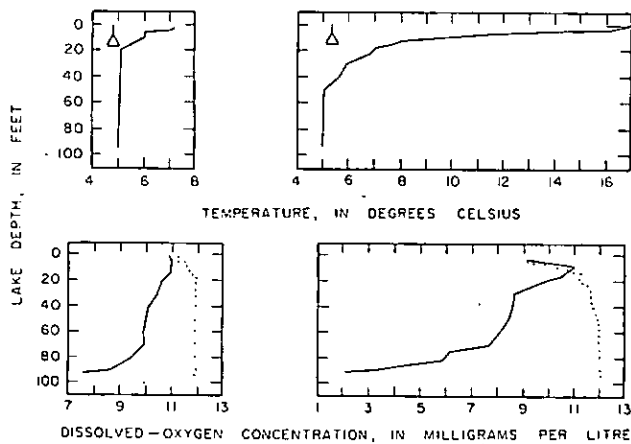
Date of collection (1972) ---	May 18		August 23	
	3	92	3	99
Water depth (ft) -----				
Silica (SiO <sub>2</sub> ) -----	3.8	4.7	3.5	5.5
Dissolved iron (Fe) -----	.05	.05	.05	.14
Dissolved manganese (Mn) ----	.000	.010	.050	.092
Calcium (Ca) -----	4.0	--	--	--
Magnesium (Mg) -----	.3	--	--	--
Sodium (Na) -----	1.1	--	--	--
Potassium (K) -----	.0	--	--	--
Bicarbonate (HCO <sub>3</sub> ) -----	14	18	17	20
Sulfide (as H <sub>2</sub> S) -----	--	.0	--	.0
Sulfate (SO <sub>4</sub> ) -----	2.6	--	--	--
Chloride (Cl) -----	1.3	--	--	--
Nitrate nitrogen (as N) ----	.14	.28	.02	.15
Nitrite nitrogen (as N) ----	.01	.00	.00	.00
Ammonia nitrogen (as N) ----	.01	.07	.06	.01
Organic nitrogen (as N) ----	.07	.14	.78	.10
Total phosphorus (as P) ----	.015	.014	.002	.002
Orthophosphate (as P) -----	.001	.000	.002	.001
Suspended solids (110°C) ----	22	--	--	--
Hardness (Ca, Mg) -----	11	--	--	--
Specific conductance -----	30	38	34	41
(micromhos at 25°C)				
pH (pH units) -----	7.4	7.7	7.6	7.0
Color (Pt-Co units) -----	20	15	20	10
Chlorophyll <i>a</i> (µg/l)-----	1.7	--	1.2	--
Fecal coliform Range ---	--	--	1-2	
(col. per 100 ml) Mean ---	--	--	1	

EXPLANATION

 Secchi-disc visibility, depth at base of triangle

 Dissolved oxygen concentration

 Dissolved oxygen concentration at 100 percent saturation



Ward Lake near Tumwater (12080070)Location.

Lat 47°02'21", long 122°52'35", in SE $\frac{1}{4}$ NW $\frac{1}{4}$  sec.36, T.18 N., R.2 W., at southern tip, Thurston County, 1.5 miles southeast of Tumwater; Indian Creek basin. Lacey and Tumwater quadrangles, 1:24,000.

Physical characteristics of lake.

Drainage area	0.95 sq mi	Maximum depth	67 ft
Altitude	126 ft	Length of shoreline	7,200 ft
Surface area	65 acres	Shoreline configuration	1.2
Lake volume	2,100 acre-ft	Development of volume	0.49
Mean depth	33 ft	Bottom slope	3.5 percent

The steep-sided beach and littoral zone is composed predominantly of silt and fine sand.

Basin geology.

Glacial outwash (Noble and Wallace, 1966).

Soils.

Fine sandy loam (Ness, 1958).

Land use (percentage of drainage basin). Urban 0, suburban 48, agricultural 41, forest or unproductive 0, and lake surface 11.

Nearshore residential development. 67 percent

Number of nearshore homes. 30 (mostly permanent).

Surface-water inflow and outflow.

No inflow or outflow was observed.

Lake stage.

The observed gage height from March 1 to August 3, 1972, varied 1.9 ft.

Macrophytes.

Shoreline covered by emerged plants 11-25 percent.

Lake surface covered by emerged plants 0.6 percent.

Lake bottom covered by submersed plants <1 percent.

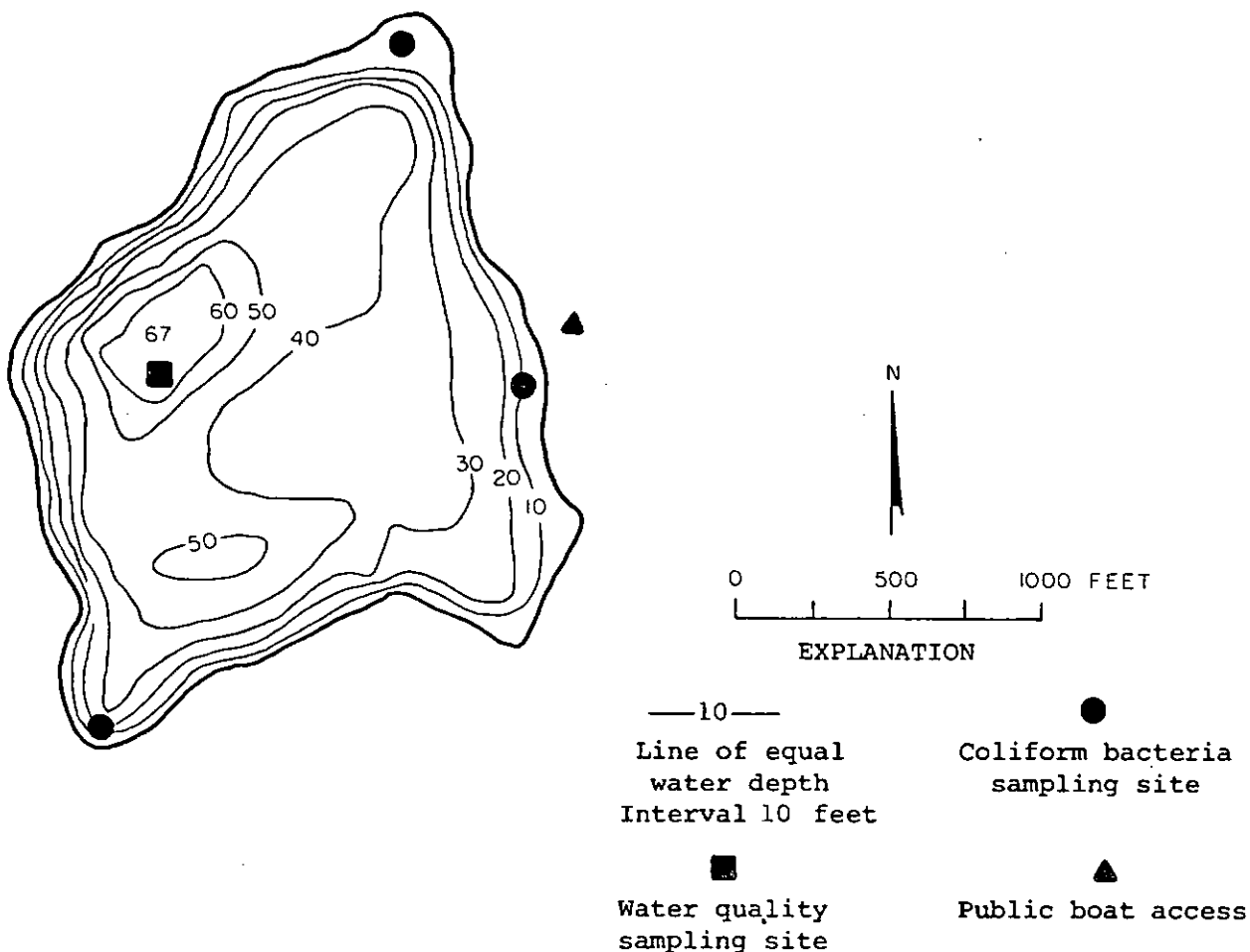
Rooted aquatic plants observed were white lily (Nymphaea sp.),\* cattail (Typha sp.), yellow lily (Nuphar sp.), sedge (Cyperaceae), and muskgrass (Chara sp.).

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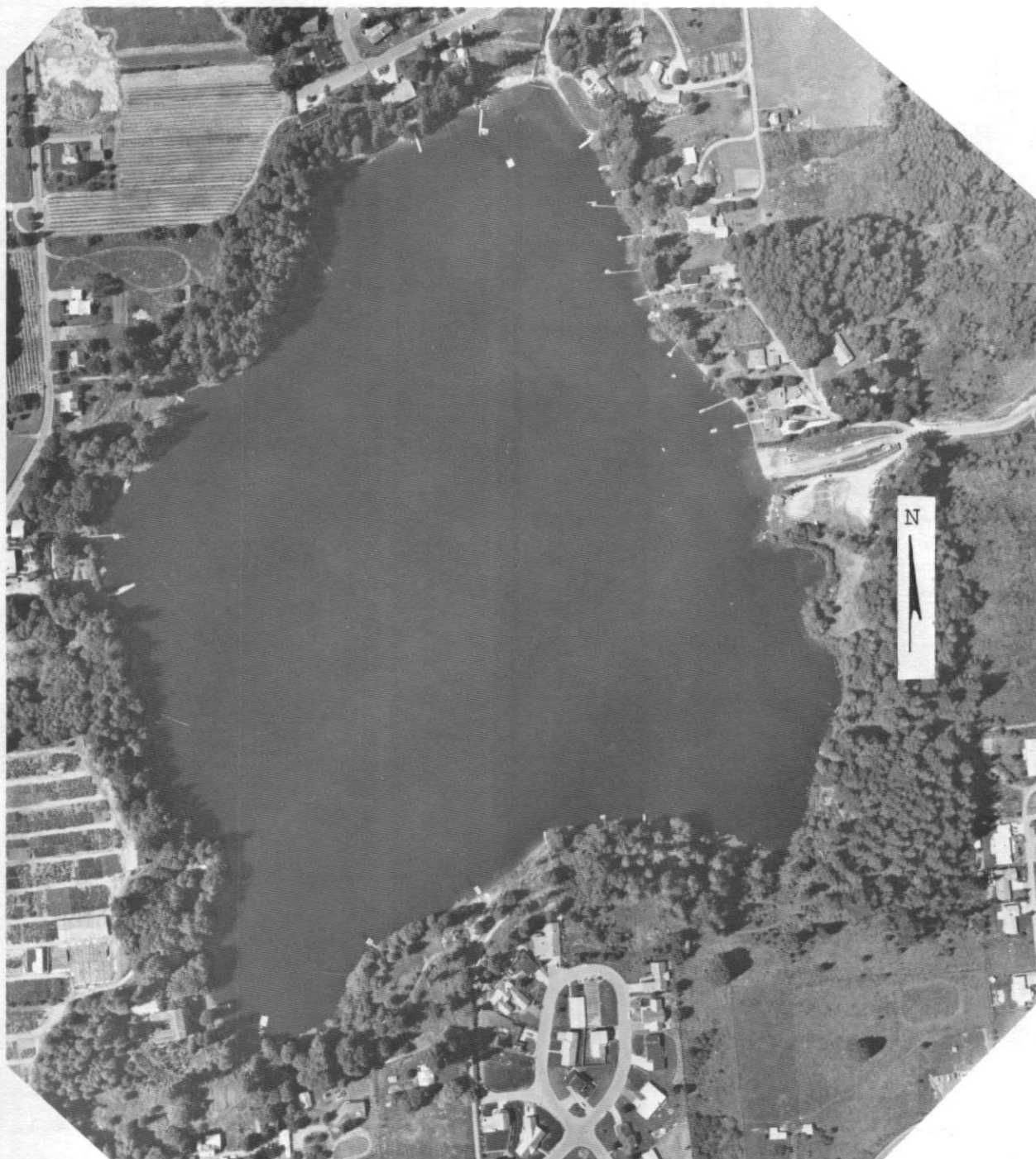
Asterisk (\*) indicates dominant aquatic plant.

Conclusions.

Ward Lake is probably low in biological productivity. The waters of the lake are very dilute in mineral concentration. The water clarity was high, as indicated by the Secchi-disc-visibility depths which ranged from 12 to 33 feet, and the chlorophyll a concentrations were considered medium low. The steep-sided littoral bottom supports only a light growth of aquatic plants.



Ward Lake, Thurston County. From Washington Department of Game, April 14, 1949.






Ward Lake, Thurston County. July 14, 1971.  
Approx. scale 1:4800.

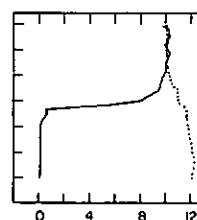
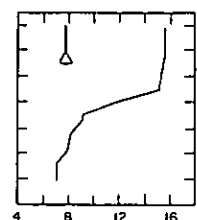
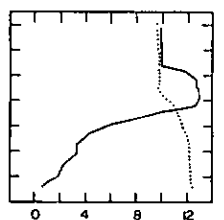
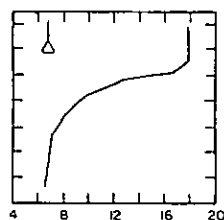
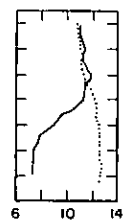
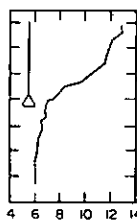
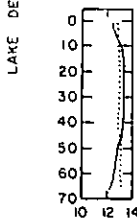
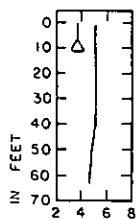
Water-quality data for Ward Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) --- Water depth (ft) -----	March 1		May 3		June 27		October 3	
	3	63	3	62	3	60	3	57
Silica (SiO <sub>2</sub> ) -----	0.2	0.2	0.3	0.3	0.7	0.7	0.4	1.0
Dissolved iron (Fe) -----	.00	.01	.04	.04	.05	.18	.04	3.6
Dissolved manganese (Mn) ----	.000	--	.000	.000	.000	.040	.000	.11
Calcium (Ca) -----	.8	--	--	--	--	--	1.0	--
Magnesium (Mg) -----	.2	--	--	--	--	--	.4	--
Sodium (Na) -----	.9	--	--	--	--	--	1.1	--
Potassium (K) -----	.6	--	--	--	--	--	.7	--
Bicarbonate (HCO <sub>3</sub> ) -----	7	7	7	7	5	3	5	8
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	trace
Sulfate (SO <sub>4</sub> ) -----	.1	--	--	--	--	--	2.5	--
Chloride (Cl) -----	1.6	--	--	--	--	--	2.3	--
Nitrate nitrogen (as N) ----	.05	.05	.04	.02	.00	.02	.08	.01
Nitrite nitrogen (as N) ----	.00	.00	.00	.01	.00	.00	.00	.00
Ammonia nitrogen (as N) ----	.07	.07	.00	.02	.07	.16	.05	.59
Organic nitrogen (as N) ----	.18	.10	.12	.16	.24	.16	.41	3.0
Total phosphorus (as P) ----	.026	.016	.011	.013	.010	.020	.017	.037
Orthophosphate (as P) -----	.003	.003	.004	.004	.000	.000	.004	.037
Suspended solids (110 °C) ----	8	--	--	--	--	--	19	--
Hardness (Ca, Mg) -----	3	--	--	--	--	--	4	--
Specific conductance ----- (micromhos at 25 °C)	19	18	17	17	17	20	15	30
pH (pH units) -----	7.1	6.9	7.1	7.1	6.7	5.9	7.0	6.3
Color (Pt-Co units) -----	10	10	5	5	10	10	10	15
Chlorophyll <i>a</i> (µg/l) -----	3.3	--	1.1	--	7.8	--	2.6	--
Fecal coliform Range -- (col. per 100 ml) Mean ---	--	--	--	--	<1-26 11		1-4 2	

EXPLANATION

-  Secchi-disc visibility, depth at base of triangle
-  Dissolved oxygen concentration
-  Dissolved oxygen concentration at 100 percent saturation



DISSOLVED-OXYGEN CONCENTRATION, IN MILLIGRAMS PER LITRE



Wye Lake near Belfair (12073890)Location.

Lat 47°25'25", long 122°45'37", in NE $\frac{1}{4}$ SE $\frac{1}{4}$  sec.2, T.22 N., R.1 W., Kitsap County, 3.6 miles southeast of Belfair; Rocky Creek basin. Belfair quadrangle, 1:24,000.

Physical characteristics of lake.

Drainage area	1.06 sq mi	Maximum depth	15 ft
Altitude	300 ft	Length of shoreline	9,000 ft
Surface area	39 acres	Shoreline configuration	2.0
Lake volume	370 acre-ft	Development of volume	0.64
Mean depth	10 ft	Bottom slope	1.0 percent

The beach and littoral zone is composed mostly of cobbles, gravel, and sand.

Basin geology.

Glacial drift deposited primarily as ground moraine (Sceva, 1957).

Soils.

Gravelly, sandy loam (Wildermuth and others, 1939).

Land use (percentage of drainage basin). Urban 0, suburban 21, agricultural 0, forest or unproductive 73, and lake surface 6.

Nearshore residential development. 99 percent of shoreline.

Number of nearshore homes. 96 (mostly seasonal).

Surface-water inflow and outflow.

At least four intermittent streams drain to the lake. The combined estimated inflow on March 2, 1972, was 3.9 ft<sup>3</sup>/s. During the summer the inflow channels were dry. The outflow, which is controlled by flashboards, is via an unnamed channel.

Lake stage.

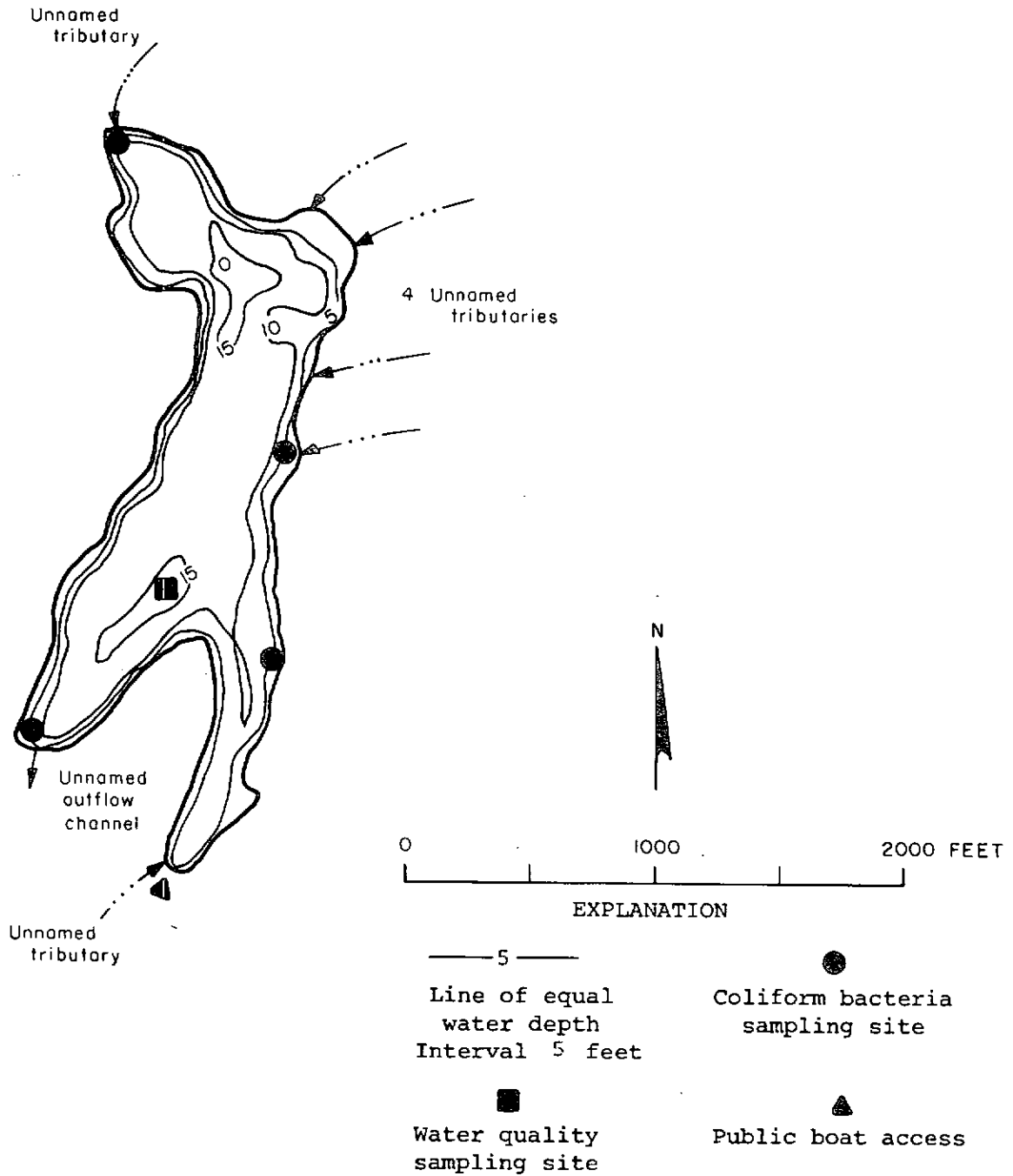
The observed gage height from March 2 to September 30, 1972, varied 3.5 ft.

Macrophytes.

Shoreline covered by emerged plants 0-10 percent.  
 Lake surface covered by emerged plants 0.2 percent.  
 Lake bottom covered by submersed plants 4 percent.  
 Rooted aquatic plants observed were sedge (Cyperaceae) and quillwort (Isoetes sp.).

Conclusions.

The biological productivity of Wye Lake appears low. The gravel and sand littoral bottom supports a sparse growth of aquatic plants and the chlorophyll a concentrations were medium low. The lake was well mixed throughout the summer as indicated by the uniform temperature profile. The DO concentrations at all depths remained near saturation. The dissolved-mineral concentration was low. Wye Lake had the lowest average total phosphorus and inorganic nitrogen concentrations (7 and 40 µg/l, respectively) of the lakes studied.



Wye Lake, Kitsap County. From Washington Department of Game, June 4, 1949.



Wye Lake, Kitsap County. August 9, 1972. Approx. scale 1:6000.

Water-quality data for Wye Lake.

[Milligrams per litre unless otherwise indicated]

Date of collection (1972) --- Water depth (ft) -----	March 2		May 10		June 29		August 24	
	3	12	3	12	3	12	3	11
Silica (SiO <sub>2</sub> ) -----	2.9	3.0	3.6	--	3.0	3.1	2.8	2.7
Dissolved iron (Fe) -----	.00	.01	.06	--	.04	.03	.02	.02
Dissolved manganese (Mn) -----	.000	--	.000	--	.020	.000	.020	.020
Calcium (Ca) -----	1.1	--	--	--	--	--	1.4	--
Magnesium (Mg) -----	.3	--	--	--	--	--	.4	--
Sodium (Na) -----	1.0	--	--	--	--	--	1.3	--
Potassium (K) -----	.2	--	--	--	--	--	.2	--
Bicarbonate (HCO <sub>3</sub> ) -----	8	8	12	--	5	7	7	8
Sulfide (as H <sub>2</sub> S) -----	--	--	--	--	--	.0	--	.0
Sulfate (SO <sub>4</sub> ) -----	0	--	--	--	--	--	4.6	--
Chloride (Cl) -----	1.0	--	--	--	--	--	1.2	--
Nitrate nitrogen (as N) -----	.02	.02	.01	.01	.00	.00	.01	.01
Nitrite nitrogen (as N) -----	.00	.00	.01	.01	.00	.00	.00	.00
Ammonia nitrogen (as N) -----	.03	.03	.01	.08	.02	.00	.05	.04
Organic nitrogen (as N) -----	.15	.15	.18	.38	.23	.17	.46	.49
Total phosphorus (as P) -----	.003	.003	.011	.016	.010	.020	.004	.004
Orthophosphate (as P) -----	.003	.003	.002	.002	.010	.000	.001	.001
Suspended solids (110 °C) -----	10	--	--	--	--	--	18	--
Hardness (Ca, Mg) -----	4	--	--	--	--	--	5	--
Specific conductance ----- (micromhos at 25 °C)	16	17	18	18	18	18	19	18
pH (pH units) -----	7.4	7.1	7.7	7.8	7.2	7.2	7.6	7.5
Color (Pt-Co units) -----	15	15	10	15	10	10	5	15
Chlorophyll <i>a</i> (µg/l) -----	3.0	--	1.1	--	2.2	--	3.0	--




Fecal coliform Range ---  
(col. per 100 ml) Mean ---

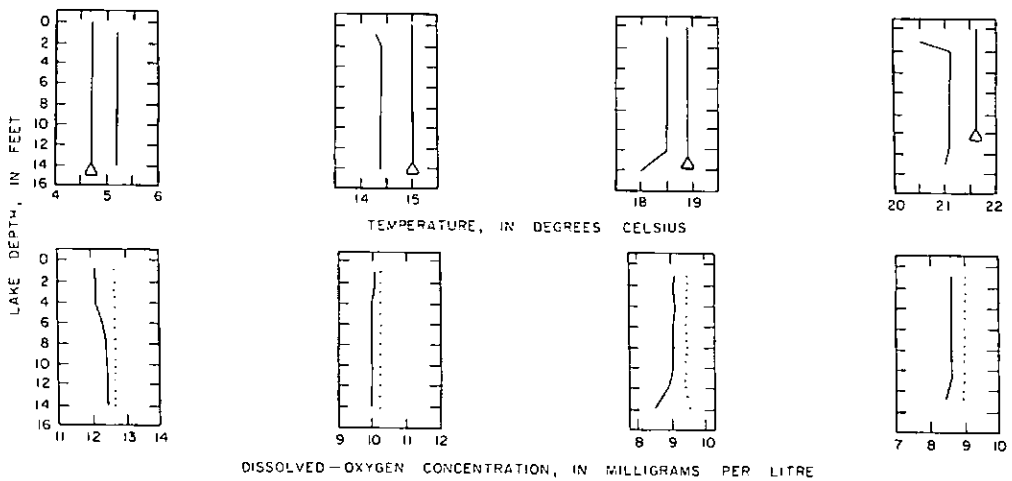
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<1-3  
1

<1-3  
2

- EXPLANATION
-  Secchi - disc visibility, depth at base of triangle
  -  Dissolved oxygen concentration
  -  Dissolved oxygen concentration at 100 percent saturation



DISSOLVED-OXYGEN CONCENTRATION, IN MILLIGRAMS PER LITRE

