



Water-Supply Bulletin 42, Part 5

DATA ON SELECTED LAKES IN WASHINGTON

Part 5

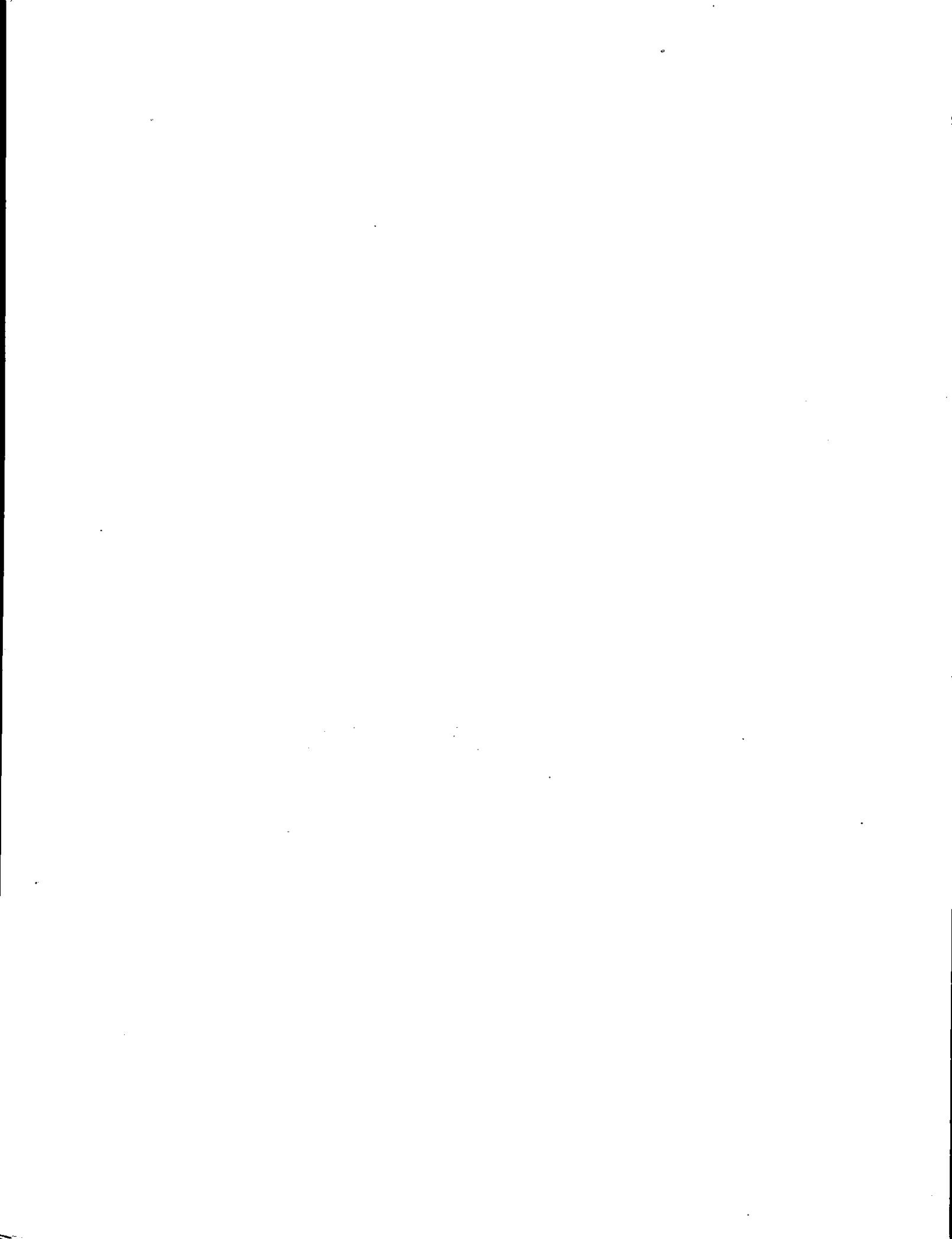


WASHINGTON STATE DEPARTMENT OF ECOLOGY

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

Water-Supply Bulletin 42, Part 5

DATA ON SELECTED LAKES IN WASHINGTON,
PART 5

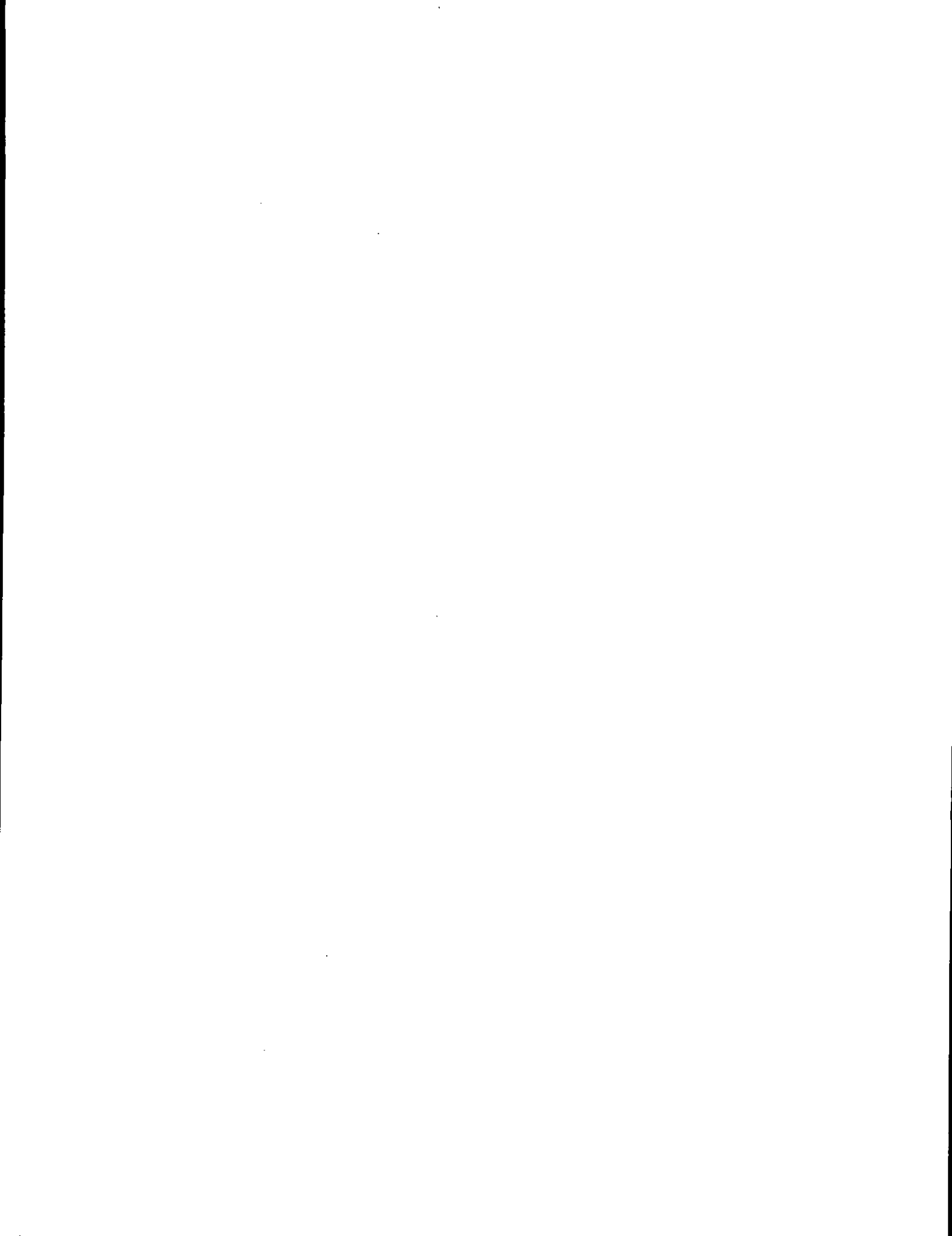
By

N. P. Dion, G. C. Bortleson, J. B. McConnell,
and J. K. Innes

of the
United States Geological Survey

Prepared cooperatively by the
UNITED STATES GEOLOGICAL SURVEY

1976



CONTENTS

	Page
Abstract-----	1
Introduction-----	1
Purpose and scope-----	2
Acknowledgments-----	2
Data collected and definitions-----	4
Glossary of limnological and hydrological terms-----	12
References cited-----	14
Lake data-----	17
Battle Ground Lake near Battle Ground (14212350)-----	18
Beaver Lake near Clear Lake (12200025)-----	22
Big Lake at Big Lake (12199499)-----	26
Big Twin Lake near Winthrop (12448610)-----	30
Borst Park Lake at Centralia (12026615)-----	34
Capitol Lake at Olympia (12080025)-----	39
Carlisle Lake at Onalaska (12024059)-----	44
Cassidy Lake near Lake Stevens (12153100)-----	48
Fish Lake near Plain (12455600)-----	52
Ki Lake near Silvana (12169400)-----	56
Lackamas Lake at Camas (14144590)-----	60
Lawrence Lake near Vail (12078940)-----	64
Martha Lake near Silvana (12158072)-----	68
Minkler Lake at Minkler (12197100)-----	72
Padden Lake at Bellingham (12201900)-----	76
Patterson Lake near Winthrop (12447388)-----	80
Patterson Lake (north arm) near Lacey (12080570)-----	84
Patterson Lake (south arm) near Lacey (12080570)-----	88
Pearrygin Lake near Winthrop (12447900)-----	92
Shadow Lake near Maple Valley (12109450)-----	96
Silver Lake at Silver Lake (14242000)-----	100
Spirit Lake at Spirit Lake (14240305)-----	104
Tennant Lake near Ferndale (12204050)-----	108
Toad Lake near Bellingham (12203900)-----	112
Wapato Lake near Manson (12451800)-----	116
Wenatchee Lake near Plain (12454500)-----	121

ILLUSTRATION

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

3

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

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

DATA ON SELECTED LAKES IN WASHINGTON,

PART 5

By N. P. Dion, G. C. Bortleson, J. B. McConnell,
and J. K. Innes

ABSTRACT

This report, the fifth in a series, contains physical, chemical, and biological data collected from 26 lakes in eastern and western Washington during 1974. For each lake is given 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. These water bodies constitute an important part of the State's total water resources and are an integral part of the hydrology of many drainage basins. As more demands are placed on these lakes, their basins, or their shorelines, problems of nutrient enrichment and water-quality deterioration become more likely. 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 fifth in a series of reports on selected lakes in Washington. The first four reports (Collings, 1973; Bortleson and others, 1974; Bortleson and others, 1976; and McConnell and others, 1976) discuss 91 lakes throughout the State, and this report discusses an additional 26 lakes in the State (fig. 1). One of the 26 lakes has two arms joined by a narrow channel and each arm is discussed as an individual lake. In addition, two of the lakes were each sampled at two sites.

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 cooperation and diligence in reading staff gages for determining lake levels.

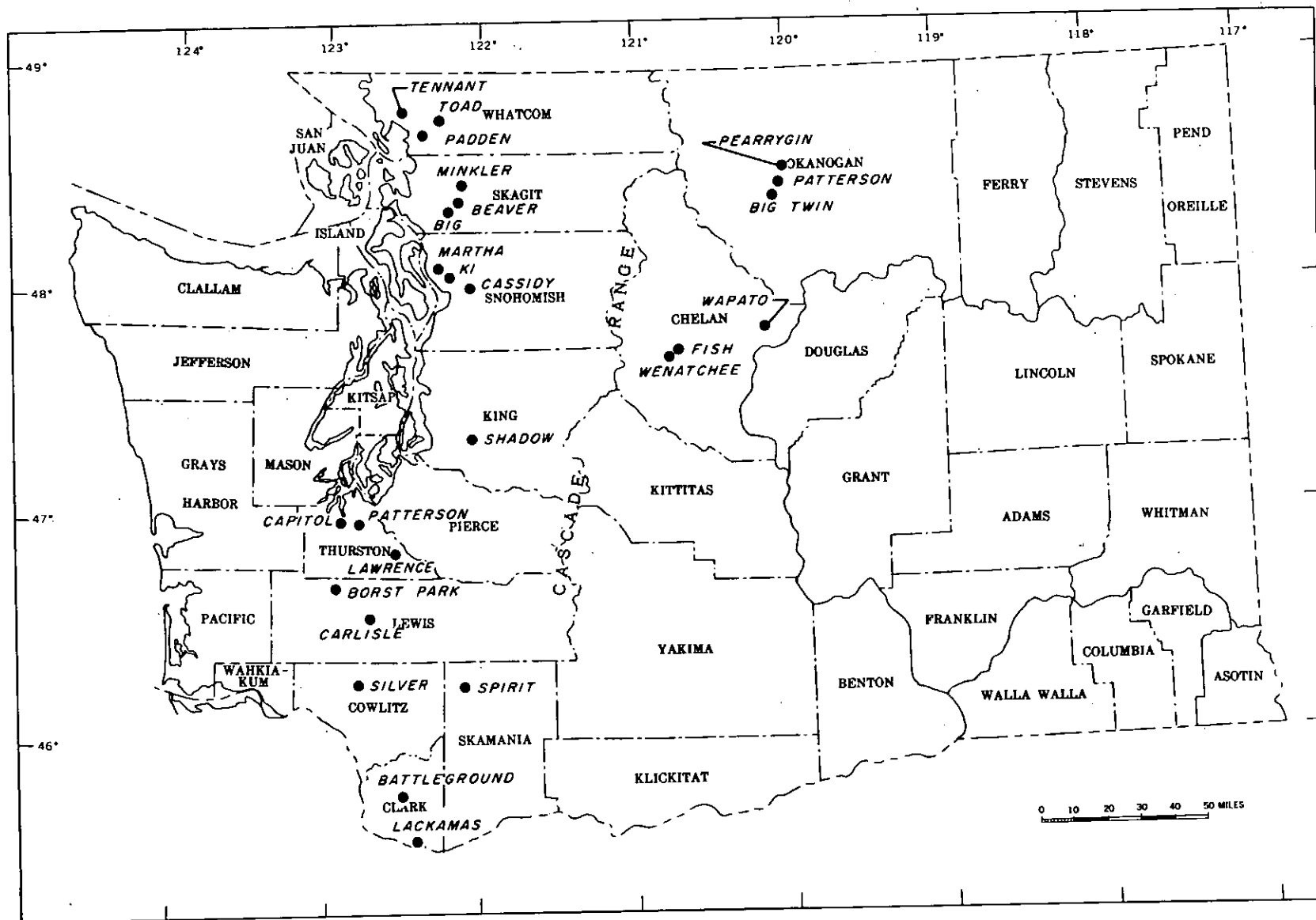


FIGURE 1.--Locations of lakes studied in 1974.

Data Collected and Definitions

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). Samples for algae identification were collected about 1 foot below the lake surface by use of a number 10-mesh size plankton net (160 micrometres). The samples were preserved in Lugol's solution and stored in the dark until examined.

Before presenting the results of each lake survey, an explanation of the 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.12). The parameters are discussed in the sequence they appear on the data sheets.

Lake name. The lake name was taken from U.S. Geological Survey topographic maps. In common usage the term "Lake" may either precede or follow the proper name. However, throughout this report the lake's name is given first and the lakes are discussed in alphabetical sequence.

Identification number. The number associated with each lake is 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. Unless noted otherwise, the location given is for the lake outlet. For lakes without outlets, the southernmost shoreline point is used. Directions and distances from prominent landmarks are provided to aid in rapid, easy location. Latitude, longitude, township, range, section, and altitude were determined from U.S. Geological Survey topographic maps. The name and scale of the topographic quadrangle on which the lake appears, as well as the lake's major drainage system, are indicated.

Physical characteristics of lake. The following physical parameters were determined from a bathymetric map of the lake:

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 feet of elevation, between the bottom and the surface of the lake.

Length of shoreline (L).--The distance around, or perimeter, in miles, 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.

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 the maximum depth (Z_m). Thus, lakes with a low D_v ratio are usually conical depressions, whereas lakes with a high D_v ratio are steep-sided and have flat bottoms. Shallow lakes with large D_v values 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

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

Rooted aquatic plants often grow more profusely in a lake with a gradually sloping bottom than in a deep lake with steep sides.

Drainage basin. The drainage basin is the area that contributes water to the lake.

Size.--The drainage area was delineated on U.S. Geological Survey topographic maps and measured by planimeter. The size of the drainage area is reported in square miles.

Geology.--Information on basin geology was obtained from existing geologic maps and reports.

Soils.--Information on basin soils was obtained from existing soil-survey 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 lands, meadows, wetlands, and seasonal recreational areas.
- e. Lake surfaces.--Includes the surface areas of the lake and upstream tributary lakes.

Nearshore development

Number of nearshore homes.--The number of nearshore homes was determined from field observations and from aerial photographs.

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

Hydrology

Surface-water inflow and outflow.--Miscellaneous measurements of outflow, reported in cubic feet per second (ft^3/s), are given for lakes in which the outflow is controlled by natural conditions; inflow volumes were estimated. All discharge measurements made during the 1974 water year were published by the U.S. Geological Survey (1975).

Lake-stage fluctuations.--The maximum variation in lake stage, in feet, is given, based on either four observations of stage made at the time of lake sampling or the more frequent observations made by lakeside residents. The stage of Silver Lake is monitored by a continuous recorder; the lake-stage variation reported for that lake was the maximum observed in calendar year 1974.

Aquatic plants

Macrophytes.--These are large plants that can be seen without magnification. The rooted aquatic-plant growth was assessed according to the percentage of the shoreline 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. Most macrophytes were identified to genus level according to the descriptions of Steward, Dennis, and Gilkey (1963) or Fassett (1969).

Algae.--These are small, simple plants that usually cannot be seen without magnification. The algal plant growth was assessed qualitatively by project personnel according to the percentage composition of the sample collected. Algae were identified to genus level according to the descriptions of Smith (1950) and Prescott (1970).

Bathymetric map.--Depth-contour maps were prepared either by the State of Washington Department of Game from data obtained by sounding the lake or by the U.S. Geological Survey from data obtained by use of a recording-chart fathometer.

The water-quality sampling site (symbol ■) and fecal-coliform-bacteria sampling sites (symbol ●) are shown on the bathymetric map of each lake. The presence and location of a public boat access (symbol ▲) is shown near the shoreline contour of the map. The locations and directions of inflow and outflow streams are shown graphically.

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

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

Major chemical constituents.--In freshwater, the principal cations are calcium, sodium, magnesium, 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). These cations are associated with the principal anions--bicarbonate, carbonate, sulfate, chloride, fluoride, and, to a lesser extent, nitrate nitrogen and orthophosphate phosphorus.

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. Nitrogen and phosphorus, however, usually are considered the limiting nutrients for aquatic plant growth--algae in particular--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, 1972). The nutrient concentrations that were determined at top and bottom sampling depths included nitrate, nitrite, ammonia, organic nitrogen, total phosphorus, and orthophosphate phosphorus. Samples collected for orthophosphate analysis were filtered immediately through a 0.45- μ m (micrometre)

Millipore¹ filter. The nutrient samples were iced in the field and later refrigerated at 4°C (Celsius) until analyzed.

Suspended solids.--Suspended solids are those retained on a 0.45- μ m filter.

Hardness.--Water hardness is defined as the sum of the polyvalent cations expressed as the equivalent quantity of calcium carbonate (CaCO₃). 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 the 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.

Chlorophyll a.--Chlorophyll a is a green photosynthetic pigment present in plant cells, including algae. The concentration of chlorophyll a in water is a commonly accepted indicator of algal biomass (Lee, 1972). Samples for chlorophyll a (0.5-2 litres) were filtered immediately in the field using a 0.45- μ 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°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 the feces of warm-blooded 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 at two to five stations at each lake. The sample locations are shown on the bathymetric map. The reporting unit is the number of colonies per 100 millilitres of water.

¹The use of a brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Total organic carbon.--The amount of organic carbon present in a lake often is related to the primary productivity of the lake. Organic carbon also may be derived from bottom sediments or it may be transported into the lake from outside sources.

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 may be 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, or zones, 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.

Dissolved-oxygen profiles.--The concentration of DO 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. Also, 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 mid-summer. 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 ft³.

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.

Bathymetric. Relating to the measurement of water depths, as for a lake.

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 produce 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.

Flushing rate. The rate at which the water volume of a lake is replaced as a result of inflows and outflows.

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.

Limnology, limnological. The study of freshwater, especially that of lakes.

Littoral. The shoreward region of a body of water.

Lugol's solution. A preserving solution for algae made from iodine crystals, potassium iodide, glacial acetic acid, and distilled water.

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.

Planimetry. Relating to the measurement of areas.

Plankton. Suspended 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.

REFERENCES CITED

- Anderson, A. C., and others, 1947, Soil survey of Snohomish County, Washington: U.S. Dept. Agriculture, Agr. Res. Admin., ser. 1937, no. 19, 76 p.
- Bhagat, S. K., Bailey, G. C., Funk, W. H., Ongerth, J. E., and Orsborn, J. F., 1975, Study of Silver Lake eutrophication-current problems and possible solutions: Washington Water Research Center, rept. 19, 298 p.
- Brown, Eugene, Skougstad, M.W., and Fishman, M. J., 1970, Methods for collection and analysis of water samples for dissolved minerals and gases: U.S. Geol. Survey Water-Resources Inv. Techniques, book 5, ch. A1, 160 p.
- Bortleson, G. C., Higgins, G. T., and Hill, G. W., 1974, Data on selected lakes in Washington, part 2: Washington Dept. Ecology Water-Supply Bull. 42, 145 p.
- Bortleson, G. C., Higgins, G. T., McConnell, J. B., and Innes, J. K., 1976, Data on selected lakes in Washington, part 3: Washington Dept. Ecology Water-Supply Bull. 42, Part 3, 143 p.
- Collings, M. R., 1973, Data on selected lakes in Washington, part I: U.S. Geol. Survey open-file report, 179 p.
- Fassett, N. C., 1969, A manual of aquatic plants: Madison, Wisconsin Univ. Press, 405 p.
- Federal Water Pollution Control Administration, 1968, Water quality criteria: Report of the National Technical Advisory Committee to the Secretary of the Interior: Federal Water Pollution Control Admin., 234 p.
- Fowler, R. H., and Ness, A. O., 1954, Soil survey of Lewis County, Washington: U.S. Dept. Agriculture, Soil Conserv. Service, ser. 1941, no. 10, 130 p.
- Hunting, M. T., Bennett, W. A. G., Livingston, V. E., Jr., and Moen, W. S., 1961, Geologic map of Washington: Washington Div. Mines and Geology, single sheet.
- Hutchinson, G. E., 1957, A treatise on limnology, v. 1, Geography, physics, and chemistry: New York, John Wiley & Sons, Inc., 1015 p.
- Kocher, A. E., 1922, Soil survey of the Wenatchee area, Washington: U.S. Dept. Agriculture, Bur. Soils, 91 p.

- Lee, G. F., 1972, Eutrophication: Trans. Northeast Fish and Wildlife Conf., p. 39-60.
- Luzier, J. E., 1969, Geology and ground-water resources of southwestern King County, Washington: Washington Dept. Water Resources Water Supply Bull. 28, 260 p.
- Mangum, A. W., and others, 1913, Reconnaissance survey of southwestern Washington: U.S. Dept. Agriculture, Bur. Soils, 136 p.
- McConnell, J. B., Bortleson, G. C., and Innes, J. K., 1976, Data on selected lakes in Washington, Part 4: Washington Dept. Ecology Water-Supply Bull. 42, Part 4, 141 p.
- Ness, A. O., 1958, Soil survey of Thurston County, Washington: U.S. Dept. Agriculture, Soil Conserv. Service, ser. 1946, no. 6, 79 p.
- Ness, A. O., Buchanan, D. E., and Richins, C. G., 1960, Soil survey of Skagit County, Washington: U.S. Dept. Agriculture, Soil Conserv. Service, 91 p.
- Newcomb, R. C., 1952, Ground-water resources of Snohomish County, Washington: U.S. Geol. Survey Water-Supply Paper 1135, 133 p.
- Noble, J. B., and Wallace, E. F., 1966, Geology and ground-water resources of Thurston County, Washington: Washington Div. Water Resources Water Supply Bull. 10, v. 2, 141 p.
- Phang, M. K. S., and Gilkeson, Raymond, 1964, State of Washington engineering soils manual--soils of Clark County: Washington State Univ., Agr. Expt. Station, Div. Ind. Research, Bull. 286, 148 p.
- Poulson, E. N., and Flannery, R. D., 1953, Soil survey of Whatcom County, Washington: U.S. Dept. Agriculture, Soil Conserv. Service, ser. 1941, no. 7, 153 p.
- Poulson, E. N., Miller, J. T., Fowler, R. H., and Flannery, R. D., 1952, Soil survey of King County, Washington: U.S. Dept. Agriculture, Agr. Res. Admin., ser. 138, no. 31, 106 p.
- Prescott, G. W., 1970, The freshwater algae: Dubuque, Iowa, Wm. C. Brown Co. Publishers, 348 p.
- Slack, K. V., Averett, R. C., Greeson, P. E., and Lipscomb, R. G., 1973, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geol. Survey Water-Resources Inv. Techniques, book 5, ch. A4, 165 p.

- Smith, G. M., 1950, The fresh-water algae of the United States: New York, McGraw-Hill Book Co., 719 p.
- Steward, A. N., Dennis, L. J., and Gilkey, H. M., 1963, Aquatic plants of Pacific Northwest: Corvallis, Oregon State Univ. Press, 261 p.
- U.S. Geological Survey, 1975, Water resources data for Washington, Part 1, Surface-water records, 1974: Tacoma, Wash.
- U.S. Soil Conservation Service, 1968, General soil map, State of Washington: 2 sheets.
- Weigle, J. M., and Foxworthy, B. L., 1962, Geology and ground-water resources of west-central Lewis County, Washington: Washington Div. Water Resources Water Supply Bull. 17, 248 p.
- Wolcott, E. E., 1964, Lakes of Washington, vol. 2, Eastern Washington: Washington Div. Water Resources Water Supply Bull. 14, 650 p.
- 1965, Lakes of Washington, vol. 1, Western Washington [2d ed]: Washington Div. Water Resources Water Supply Bull. 14, 619 p.

L A K E D A T A

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Battle Ground Lake near Battle Ground (14212350)Location.

2.3 miles east of Battle Ground, Clark County; lat 45°48'11", long 122°29'37";
NW¼SW¼ sec.30, T.4 N., R.3 E.; Lake River basin; 504 feet altitude.
Yacolt quadrangle (1:24,000 scale).
Location is of southernmost shoreline point of lake.

Physical characteristics of lake.

Surface area-----	27 acres	Length of shoreline-----	0.79 mile
Volume-----	840 acre-ft	Shoreline configuration-----	1.1
Mean depth-----	31 ft	Development of volume-----	0.52
Maximum depth-----	60 ft	Bottom slope-----	4.9 percent

Drainage basin.

Size: 0.13 mi²

Geology: Volcanic rocks, including basalt flows (Hunting and others, 1961).

Soils: Silt loam to silty clay loam (U.S. Soil Conservation Service, 1968).

Land use	Percent
Urban-----	0
Suburban-----	0
Agricultural-----	3
Forest or unproductive-----	65
Lake surface-----	32

Nearshore development.

Number of nearshore homes: 0.

Nearshore residential development: 0 percent.

Hydrology.

The lake has no surface-water inflow or outflow. The lake stage declined 1.0 foot from Apr. 30 to Sept. 10, 1974.

Littoral bottom.

Silt and rock covered by wood debris and sunken logs.

Aquatic plants.Macrophytes:

Shoreline covered by emerged plants: 11-25 percent.

Lake surface covered by emerged plants: <1 percent.

Lake bottom covered by submersed plants: 1-10 percent.

Routed aquatic plants observed: Iris (*Iris* sp.)*, mint (*Mentha* sp.), sedge (Cyperaceae), smartweed (*Polygonum* sp.), waterweed (*Elodea* sp.), and white lily (*Nymphaea* sp.).

Algae observed:

Apr. 30, 1974: None.

June 26, 1974: Greens, blue-greens, and yellow-browns.

Aug. 6, 1974: Dinoflagellates (*Ceratium* sp.)*,

Sept. 10, 1974: Blue-greens and dinoflagellates.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Battle Ground Lake is in an old volcanic crater in Battle Ground State Park. The lake is nearly circular and has a steep bottom slope. Because the drainage area is the smallest of the 26 lakes studied, the lake has no tributaries and receives little direct surface runoff.

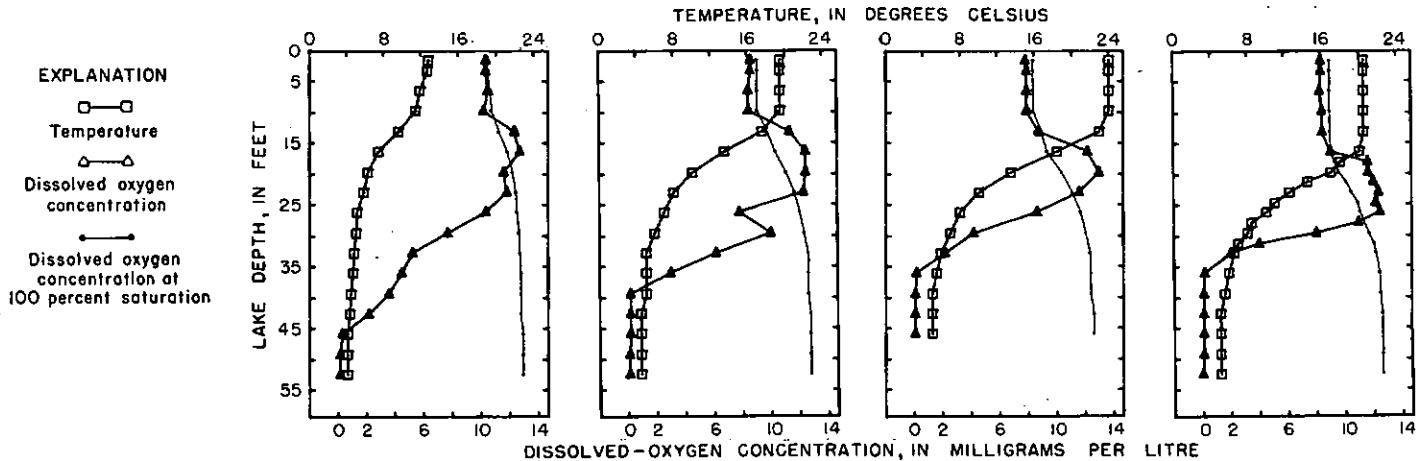
The biological productivity of the lake was low to moderate. The extent of macrophyte coverage of the lake surface and bottom was small. The dominant macrophyte observed was *Iris* sp.

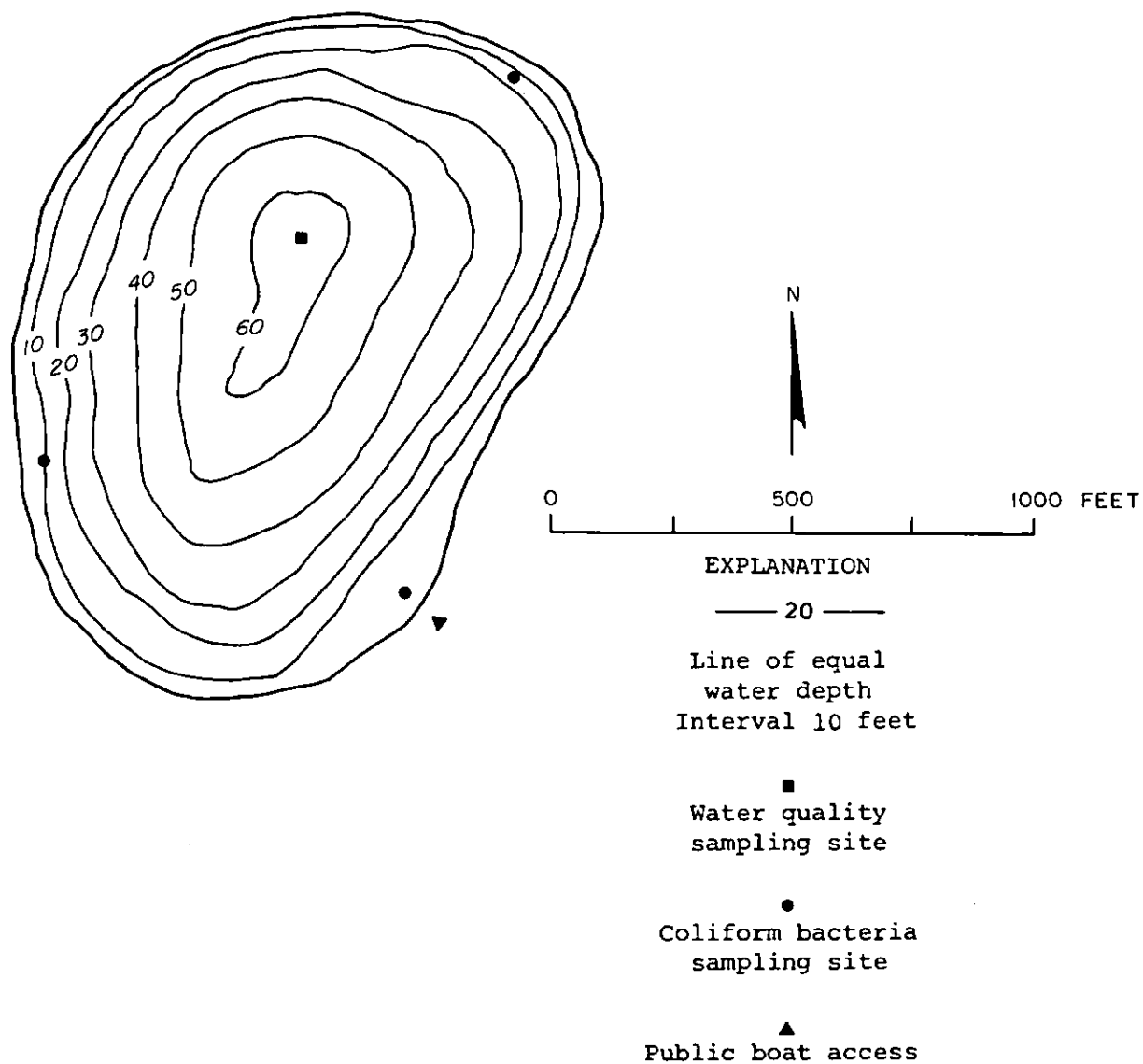
Thermal stratification was well established in June, August, and September. DO concentrations near zero were observed at depth during all four sampling periods.

Water-quality data for Battle Ground Lake near Battle Ground

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	April 30		June 25		August 6		September 10	
	3	49	3	49	3	44	3	49
Water depth (ft)-----								
Silica (SiO ₂)-----	0.5	1.7	0.3	2.1	0.5	2.2	0.4	2.7
Dissolved iron (Fe), in µg/l--	60	760	4,200	60	60	4,700	310	8,800
Dissolved manganese (Mn)----- (in µg/l)	10	120	300	0	20	410	20	530
Calcium (Ca) -----	2.2	--	--	--	--	--	4.1	--
Magnesium (Mg) -----	.5	--	--	--	--	--	.0	--
Sodium (Na) -----	1.3	--	--	--	--	--	1.4	--
Potassium (K) -----	.6	--	--	--	--	--	.5	--
Bicarbonate (HCO ₃) -----	7	7	7	10	3	12	8	14
Carbonate (CO ₃)-----	--	--	--	--	3	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	2.4	--	--	--	--	--	1.3	--
Chloride (Cl)-----	2.0	--	--	--	--	--	1.6	--
Nitrate nitrogen (as N)-----	.01	.22	.00	.01	.00	.00	.00	.00
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.00	.00	.00	.01
Ammonia nitrogen (as N)-----	.06	.15	.01	.37	.01	.37	.03	1.3
Organic nitrogen (as N)-----	.18	.15	.17	.24	.25	.41	.21	.10
Total phosphorus (as P)-----	.016	.047	.027	.18	.009	.16	.009	.35
Orthophosphate (as P)-----	.001	.001	.001	.079	.004	.043	.000	.24
Suspended solids (110°C)-----	1	--	--	--	--	--	0	--
Hardness as CaCO ₃ (Ca,Mg)---	8	--	--	--	--	--	10	--
Specific conductance----- (micromhos at 25°C)	18	21	18	40	18	38	19	56
pH (pH units)-----	7.0	5.9	7.1	6.2	8.4	6.6	6.1	5.9
Water temperature (°C)-----	12.7	4.2	19.5	4.5	24.0	5.0	20.5	5.0
Color (Pt-Co scale)-----	5	25	10	25	5	30	5	35
Secchi-disc (ft)-----		11		19		18		21
Dissolved oxygen (DO)-----	10.3	.2	8.6	.1	7.9	.1	8.4	.1
Chlorophyll <u>a</u> in photic zone- (µg/l)	2.0	--	2.2	--	.8	--	3.8	--
Fecal coliform Range--		<1		<1-9		<1-2		<1-2
(col. per 100 ml) Mean---		<1		3		1		1
Total organic carbon (as.C)--	8.5	--	7.1	--	5.0	--	5.3	--





Battleground Lake, Clark County. From Washington
Department of Game, September 22, 1949.



Battleground Lake, Clark County. July 1, 1968. Approx. scale 1:12,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Beaver Lake near Clear Lake (12200025)Location.

1.3 miles southeast of Clear Lake, Skagit County; lat 48°26'45", long 122°13'10"; NW¼SW¼ sec.7, T.34 N., R.5 E; Skagit River basin; 30 feet altitude. Clear Lake quadrangle (1:62,500 scale).

Physical characteristics of lake.

Surface area-----	74 acres	Length of shoreline-----	1.5 miles
Volume-----	400 acre-ft	Shoreline configuration-----	1.3
Mean depth-----	5 ft	Development of volume-----	0.54
Maximum depth-----	10 ft	Bottom slope-----	0.49 percent

Drainage basin.

Size: 2.28 mi².

Geology: Low-grade metamorphic rocks at higher altitudes; glacial drift and alluvium at lower altitudes (Hunting and others, 1961).

Soils: The uplands are gravelly loam and rough broken land; the lowlands are silt loam, gravelly silt loam, and peat (Ness and others, 1960).

Land use	Percent
Urban-----	0
Suburban-----	0
Agricultural-----	10
Forest or unproductive-----	85
Lake surface-----	5

Nearshore development.

Number of nearshore homes: 0.

Nearshore residential development: 0 percent.

Hydrology.

The lake has no well-defined surface-water inflow. Drainage is southwestward via unnamed streams to East Fork Nookachamps Creek. On Feb. 27, the outflow was estimated to be 30 ft³/s. On subsequent sampling trips (May 8, July 10, and Sept. 18), the outflow was negligible.

The lake stage declined 1.7 feet from Feb. 27 to Sept. 18, 1974.

Littoral bottom.

Mostly muck with some silt and gravel.

Aquatic plants.Macrophytes:

Shoreline covered by emersed plants: 76-100 percent.

Lake surface covered by emersed plants: 11-25 percent.

Lake bottom covered by submersed plants: 76-100 percent.

Rooted aquatic plants observed: Yellow lily (*Nuphar* sp.)*, stonewort (*Nitella* sp.)*, bulrush (*Scirpus* sp.), cattail (*Typha* sp.), coontail (*Ceratophyllum* sp.), horsetail (*Equisetum* sp.), pondweed (*Potamogeton* sp.), smartweed (*Polygonum* sp.), and waterweed (*Elodea* sp.).

Algae observed:

Feb. 27, 1974: Greens and blue-greens.

May 8, 1974: Greens and blue-greens.

July 10, 1974: Diatoms (*Navicula* sp.*, others), blue-greens, and dinoflagellates.

Sept. 18, 1974: Blue-greens (*Aphanizomenon* sp.*, *Trichodesmium* sp.*, others) and greens.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Beaver Lake is a small, shallow, weedy lake in an area of low relief.

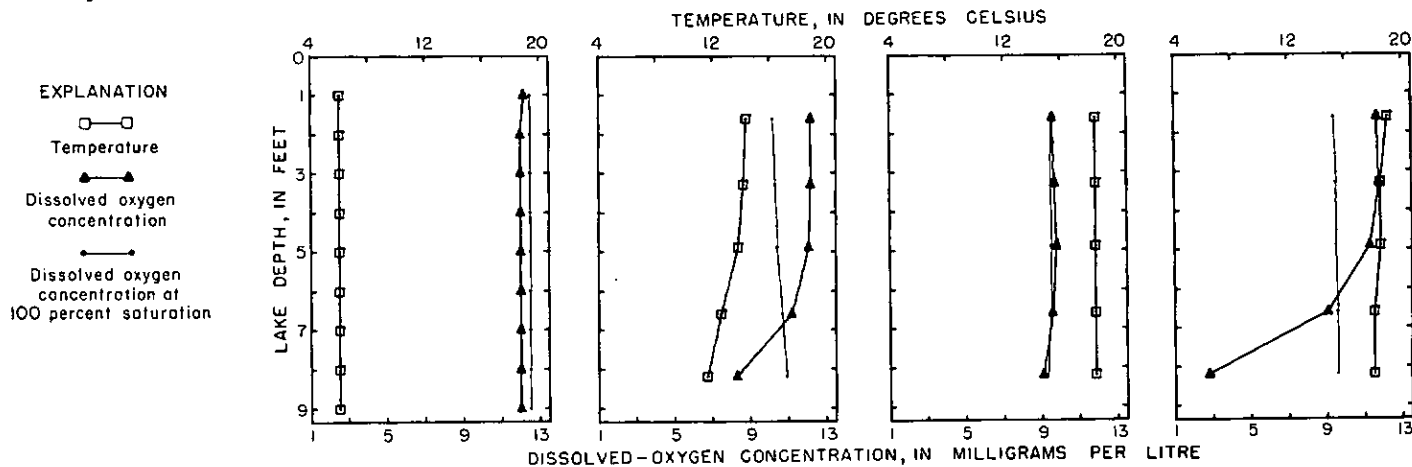
The biological productivity of the lake was moderate to high. The littoral bottom of muck supported heavy growths of both emersed and submersed macrophytes. Orthophosphate concentrations were uniform throughout the year; inorganic nitrogen concentrations were high (0.92 mg/l) in February but had decreased significantly in May, July, and September. The chlorophyll *a* concentration was moderate (5.6 µg/l) in February but had increased to 24 µg/l by September.

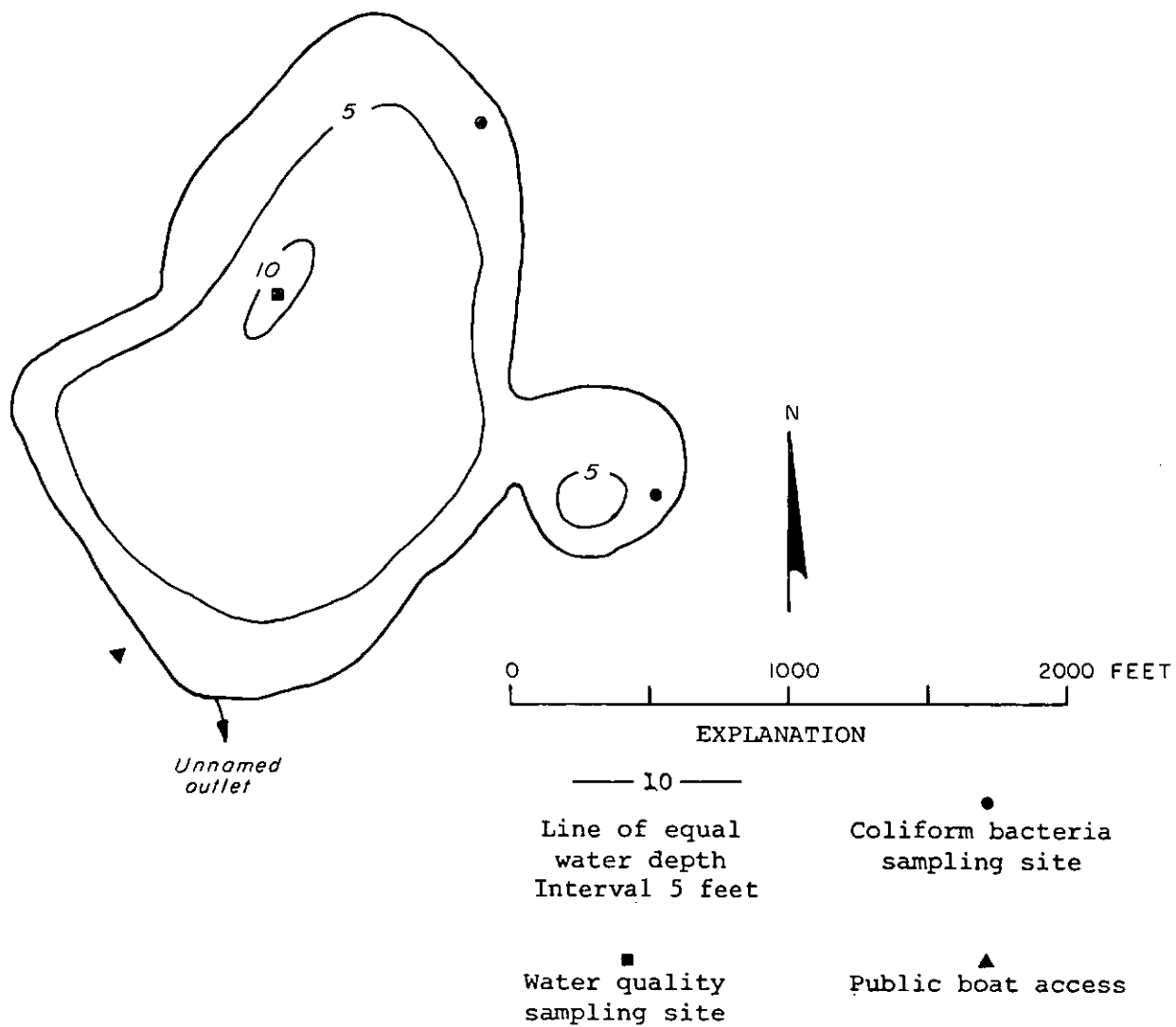
Water-temperature profiles were nearly uniform throughout the year. The only DO depletion observed was in September near the bottom of the lake.

Water-quality data for Beaver Lake near Clear Lake

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 27		May 8		July 10		September 18	
	3	6	3	5	3	7	3	7
Water depth (ft)-----								
Silica (SiO ₂)-----	6.8	7.0	2.5	2.5	2.1	2.1	3.7	3.8
Dissolved iron (Fe), in µg/l--	770	80	830	820	640	540	640	700
Dissolved manganese (Mn)----- (in µg/l)	10	30	80	70	60	80	70	60
Calcium (Ca) -----	8.3	--	--	--	--	--	11	--
Magnesium (Mg) -----	2.9	--	--	--	--	--	5.0	--
Sodium (Na) -----	4.0	--	--	--	--	--	4.8	--
Potassium (K) -----	1.2	--	--	--	--	--	.6	--
Bicarbonate (HCO ₃) -----	31	31	41	44	48	48	59	60
Carbonate (CO ₃)-----	--	--	--	0	--	--	0	0
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	5.4	--	--	--	--	--	3.0	--
Chloride (Cl)-----	3.8	--	--	--	--	--	4.0	--
Nitrate nitrogen (as N)-----	.82	.82	.01	.01	.00	.00	.00	.01
Nitrite nitrogen (as N)-----	.01	.01	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N)-----	.09	.09	.02	.03	.03	.05	.06	.07
Organic nitrogen (as N)-----	.42	.34	.57	.68	.42	.38	.39	.36
Total phosphorus (as P)-----	.029	.026	.039	.033	.016	.020	.030	.031
Orthophosphate (as P)-----	.004	.004	.006	.005	.002	.002	.004	.004
Suspended solids (110°C)-----	7	--	--	--	--	--	1	--
Hardness as CaCO ₃ (Ca, Mg)----	33	--	--	--	--	--	48	--
Specific conductance----- (micromhos at 25°C)	72	72	83	83	88	90	100	100
pH (pH units)-----	7.6	7.7	8.4	8.6	8.1	7.8	8.4	8.6
Water temperature (°C)-----	6.0	6.0	14.2	13.8	18.5	18.5	18.5	18.0
Color (Pt-Co scale)-----	25	25	30	25	30	30	30	30
Secchi-disc (ft)-----		6.4		5.2		>7.2		7.2
Dissolved oxygen (DO)-----	12.0	12.0	12.2	12.1	9.7	9.6	11.8	9.1
Chlorophyll <u>a</u> in photic zone- (µg/l)	5.6	--	18	--	14	--	24	--
Fecal coliform Range--		9-11		4-46		2-24		1-2
(col. per 100 ml) Mean---		10		25		13		2
Total organic carbon (as C)--	7.0	--	8.4	--	10	--	8.3	--





Beaver Lake, Skagit County. From Washington Department of Game, June 28, 1948.



Beaver Lake, Skagit County. July 20, 1974. Approx. scale 1:4800.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Big Lake at Big Lake (12199499)Location.

0.3 mile south of Big Lake, Skagit County. Lat 48°23'52", long 122°14'24";
 NE¼ sec. 36, T.34 N., R.4 E.; Skagit River basin; 81 feet altitude.
 Clear Lake quadrangle (1:62,500 scale).

Physical characteristics of lake.

Surface area-----	520 acres	Length of shoreline-----	6.2 miles
Volume-----	7,500 acre-ft	Shoreline configuration-----	1.9
Mean depth-----	14 ft	Development of volume-----	0.62
Maximum depth-----	23 ft	Bottom slope-----	0.43 percent

Drainage basin.

Size: 22.4 mi².

Geology: Predominantly massive sandstone with interbedded conglomerate and siltstone; local areas of metamorphic rocks, glacial drift, and alluvium (Hunting and others, 1961).

Soils: A coarse pattern of loam and gravelly loam on rough mountainous land with moderate to steep slopes (Ness and others, 1960).

Land use	Percent
Urban-----	0
Suburban-----	2
Agricultural-----	7
Forest or unproductive-----	86
Lake surface-----	5

Nearshore development.

Number of nearshore homes: 179.

Nearshore residential development: 65 percent.

Hydrology.

The lake has several inflows, the largest of which comes from McMurray Lake. On Feb. 26, May 8, July 10, and Sept. 18, the inflow from McMurray Lake was estimated to be 60, 12, 5.0, and 3.0 ft³/s, respectively. Drainage is northwestward via Nookachamps Creek to the Skagit River. On Feb. 26, the outflow was estimated to be 8.0 ft³/s. On May 8 and July 10 the outflow was measured at 24.4 and 7.64 ft³/s, respectively.

The lake stage declined 2.8 feet from Feb. 26 to Sept. 18, 1974.

Littoral bottom.

Silt, sand and gravel, with some muck and wood debris.

Aquatic plants.Macrophytes:

Shoreline covered by emerged plants: 26-50 percent.

Lake surface covered by emerged plants: <1 percent.

Lake bottom covered by submersed plants: 11-25 percent.

Rooted aquatic plants observed: cattail (*Typha* sp.)*, waterweed (*Elodea* sp.)*, bulrush (*Scirpus* sp.), bushy pondweed (*Najas* sp.), coontail (*Ceratophyllum* sp.), pondweed (*Potamogeton* sp.), watershield (*Brasenia* sp.), white lily (*Nymphaea* sp.), wildcelery (*Vallisneria* sp.), and yellow lily (*Nuphar* sp.).

Algae observed:

Feb. 27, 1974: Blue-greens (*Aphanizomenon* sp.)*, greens, and diatoms.

May 8, 1974: Diatoms (*Asterionella* sp.*), others), greens, and blue-greens.

June 10, 1974: Blue-greens, diatoms, and yellow-browns.

Sept. 18, 1974: Blue-greens (*Aphanizomenon* sp.*), others), greens, and diatoms.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Big Lake is a large lake with a moderate amount of shoreline development. Despite its size, the lake has a relatively shallow mean depth (14 ft) and a gentle bottom slope (0.43 percent).

The biological productivity of the lake was moderate. Inorganic nitrogen concentrations in February and May were high (1.1 and 0.54 mg/l) but had decreased significantly in July and September (0.10 and 0.08 mg/l). Blooms of diatoms and blue-green algae were observed in May and September, respectively.

Temperature and DO profiles were nearly uniform throughout the year; no serious DO depletion was observed.

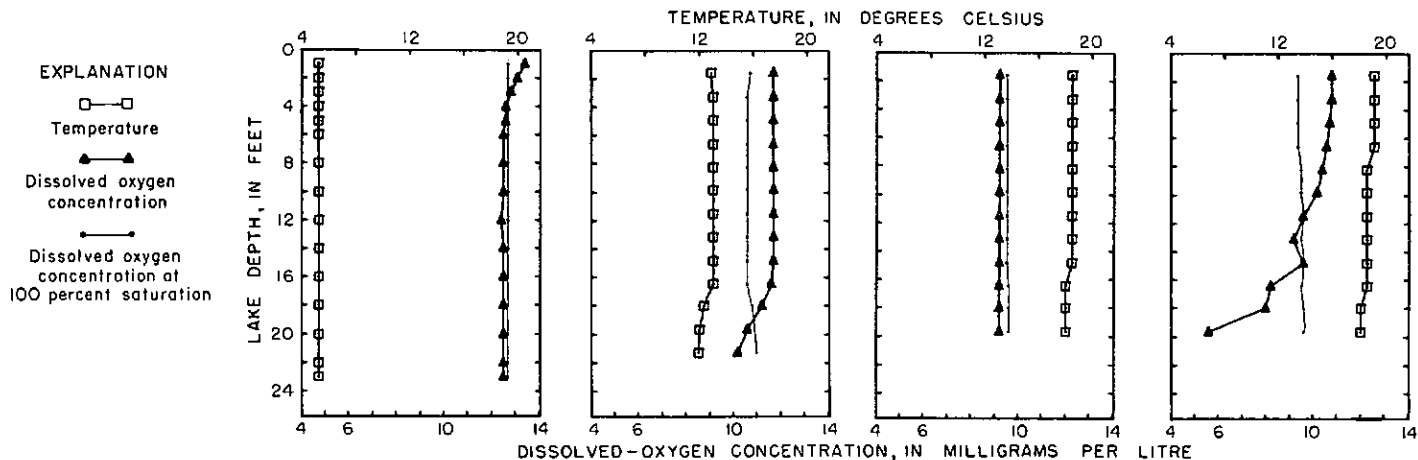
Because of the numerous inflows, the flushing rate of the lake is probably fast.

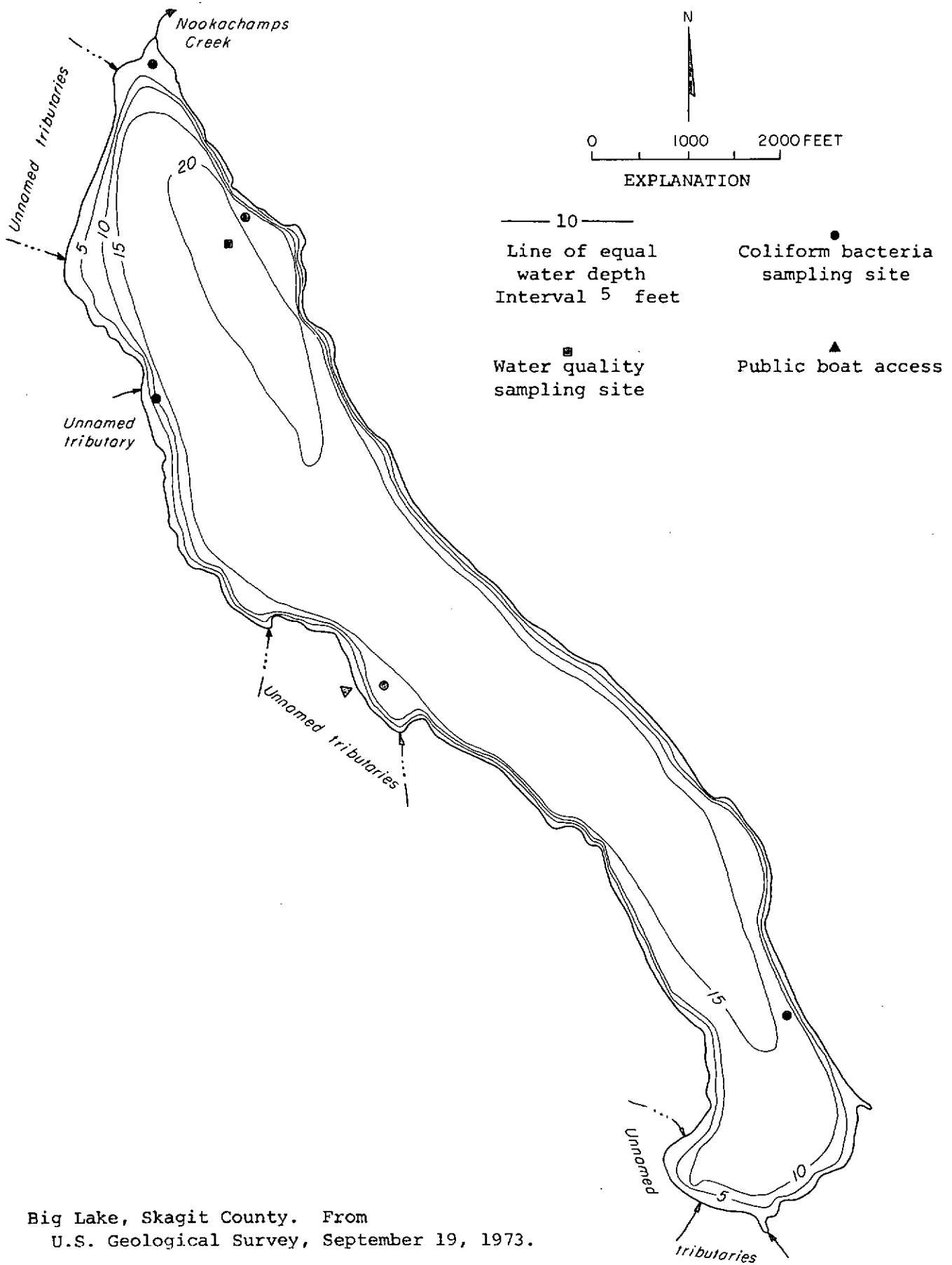
Water-quality data for Big Lake at Big Lake

[Milligrams per litre unless otherwise indicated]

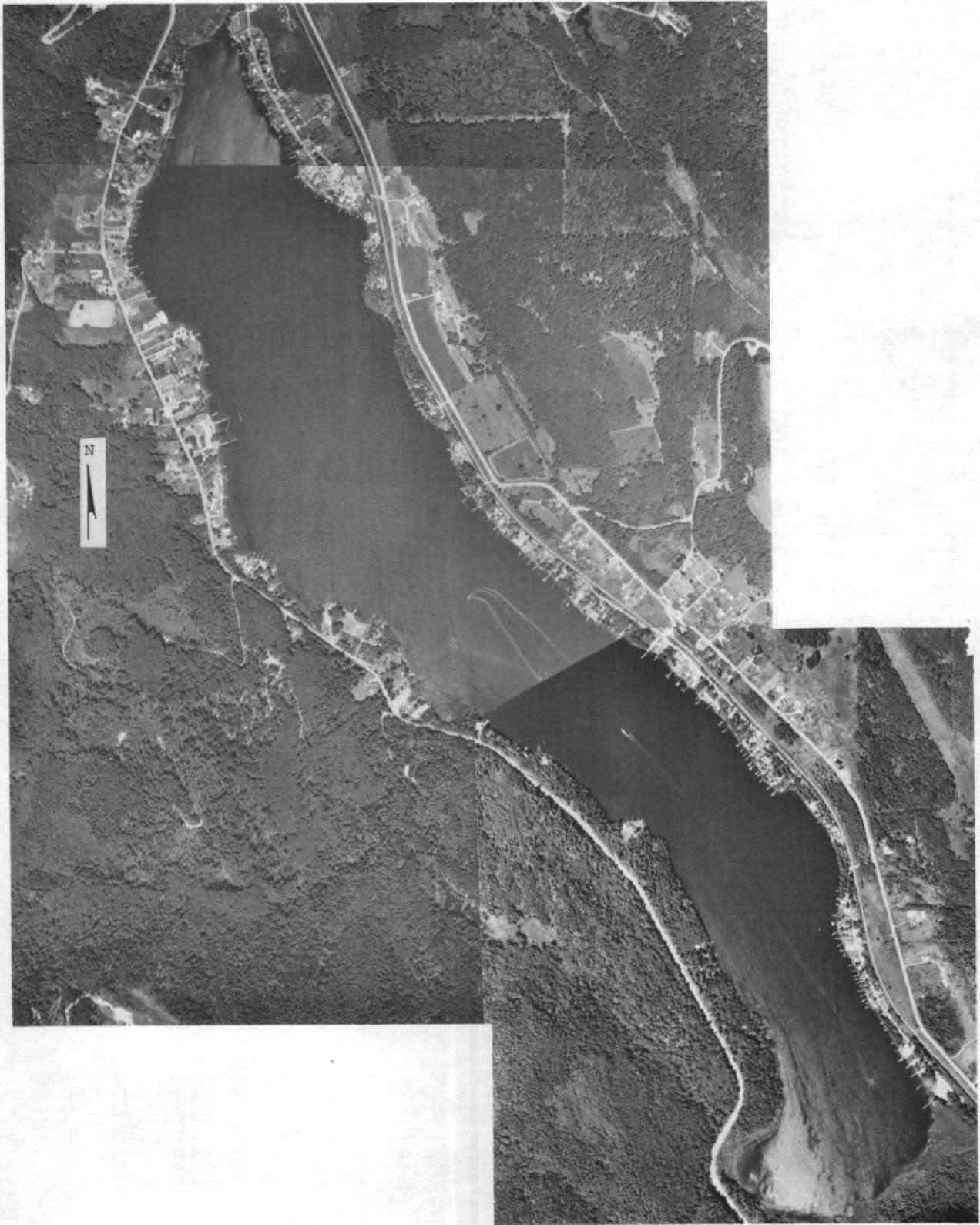
Date of collection (1974)-----	February 27		May 8		July 10		September 18	
	3	20	3	18	3	18	3	18
Water depth (ft)-----								
Silica (SiO ₂)-----	8.7	8.8	2.9	3.0	0.6	0.5	5.3	5.6
Dissolved iron (Fe), in µg/l--	260	370	220	200	110	120	80	90
Dissolved manganese (Mn)----- (in µg/l)	0	20	80	20	20	40	50	50
Calcium (Ca) -----	4.6	--	--	--	--	--	7.0	--
Magnesium (Mg) -----	2.6	--	--	--	--	--	3.4	--
Sodium (Na) -----	4.2	--	--	--	--	--	5.6	--
Potassium (K) -----	.7	--	--	--	--	--	.8	--
Bicarbonate (HCO ₃) -----	20	21	28	28	36	36	44	44
Carbonate (CO ₃)-----	--	--	0	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	5.8	--	--	--	--	--	5.7	--
Chloride (Cl)-----	2.5	--	--	--	--	--	3.8	--
Nitrate nitrogen (as N)-----	1.0	1.0	.51	.52	.06	.08	.00	.00
Nitrite nitrogen (as N)-----	.01	.01	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N)-----	.05	.05	.03	.04	.04	.03	.08	.06
Organic nitrogen (as N)-----	.31	.28	.34	.32	.31	.29	.50	.44
Total phosphorus (as P)-----	.022	.023	.015	.015	.016	.016	.046	.043
Orthophosphate (as P)-----	.003	.003	.001	.003	.002	.002	.001	.001
Suspended solids (110 °C)-----	18	--	--	--	--	--	1	--
Hardness as CaCO ₃ (Ca,Mg)----	22	--	--	--	--	--	31	--
Specific conductance----- (micromhos at 25 °C)	59	59	66	67	74	76	85	86
pH (pH units)-----	7.8	7.8	8.6	8.2	7.4	7.6	8.2	7.8
Water temperature (°C)-----	5.3	5.3	13.0	12.3	18.5	18.0	19.0	18.0
Color (Pt-Co scale)-----	20	20	15	15	20	25	15	15
Secchi-disc (ft)-----	5.0		5.2		8.2		4.3	
Dissolved oxygen (DO)-----	12.8	12.5	11.7	11.2	9.2	9.2	10.8	8.0
Chlorophyll <u>a</u> in photic zone- (µg/l)	2.5	--	8.8	--	10	--	3.6	--
Fecal coliform Range-- (col. per 100 ml) Mean---	8-15 10		2-13 6		1-23 8		< 1 --TNTC --	
Total organic carbon (as C)--	6.5	--	5.6	--	7.0	--	11	--

*Too numerous to count.





Big Lake, Skagit County. From U.S. Geological Survey, September 19, 1973.



Big Lake, Skagit County. June 2, 1970. Approx. scale 1:12,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Big Twin Lake near Winthrop (12448610)Location.

2.5 miles south of Winthrop, Okanogan County; lat 48°26'35", long 120°11'39", SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec.15, T.34 N., R.21 E.; Methow River basin; 1,799 feet altitude. Winthrop quadrangle (1:24,000 scale).

Location is of southernmost shoreline point of lake.

Physical characteristics of lake.

Surface area-----	79 acres.	Length of shoreline-----	1.5 miles
Volume-----	1,900 acre-ft	Shoreline configuration-----	1.2
Mean depth-----	24 ft	Development of volume-----	0.35
Maximum depth-----	70 ft	Bottom slope-----	3.3 percent

Drainage basin.

Size: 1.35 mi².

Geology: Uplands are underlain by undifferentiated sedimentary and volcanic rocks. Lowlands are underlain by unconsolidated deposits of silt, sand, and gravel (Hunting and others, 1961).

Soils: Loam, silt loam, and sandy loam (U.S. Soil Conservation Service, 1968).

Land use	Percent
Urban-----	0
Suburban-----	0
Agricultural-----	30
Forest or unproductive-----	61
Lake surface-----	9

Nearshore development.

Number of nearshore homes: 2 (permanent).

Nearshore residential development: 5 percent.

Hydrology.

The lake has no surface-water inflow or outflow. The records of lake stage are incomplete; the stage rose 1.6 feet from Apr. 16 to May 21, and rose 1.2 feet from July 12 to Sept. 24, 1974.

Littoral bottom.

Mostly rock, gravel, and sand; some muck at the north end.

Aquatic plants.Macrophytes:

Shoreline covered by emersed plants: 51-75 percent.

Lake surface covered by emersed plants: 1-10 percent.

Lake bottom covered by submersed plants: 51-75 percent.

Rooted aquatic plants observed: Bulrush (*Scirpus* sp.)*, cattail (*Typha* sp.), muskgrass (*Chara* sp.), stonewort (*Nitella* sp.), pondweed (*Potamogeton* sp.), rush (*Juncus* sp.), smartweed (*Polygonum* sp.), and waterweed (*Elodea* sp.).

Algae observed:

Apr. 16, 1974: Diatoms and blue-greens.

May 21, 1974: Greens.

July 16, 1974: None.

Sept. 24, 1974: Blue-greens.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Big Twin Lake is a small lake that is in a closed depression in an agricultural part of Okanogan County. Despite its size, the lake is deep and has a relatively steep bottom slope (3.3 percent).

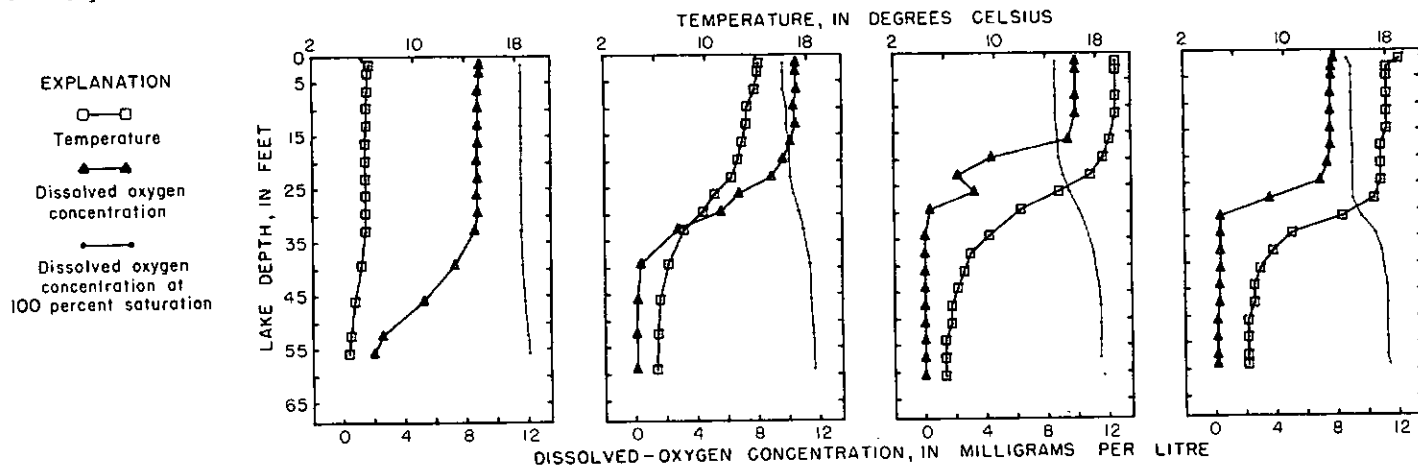
The biological productivity of the lake was moderate. Inorganic nitrogen concentrations were 0.23 mg/l in April but had decreased to 0.10 mg/l by September. More than half the lake bottom was covered with submersed aquatic macrophytes that extended from the shoreline to depths of about 25 feet.

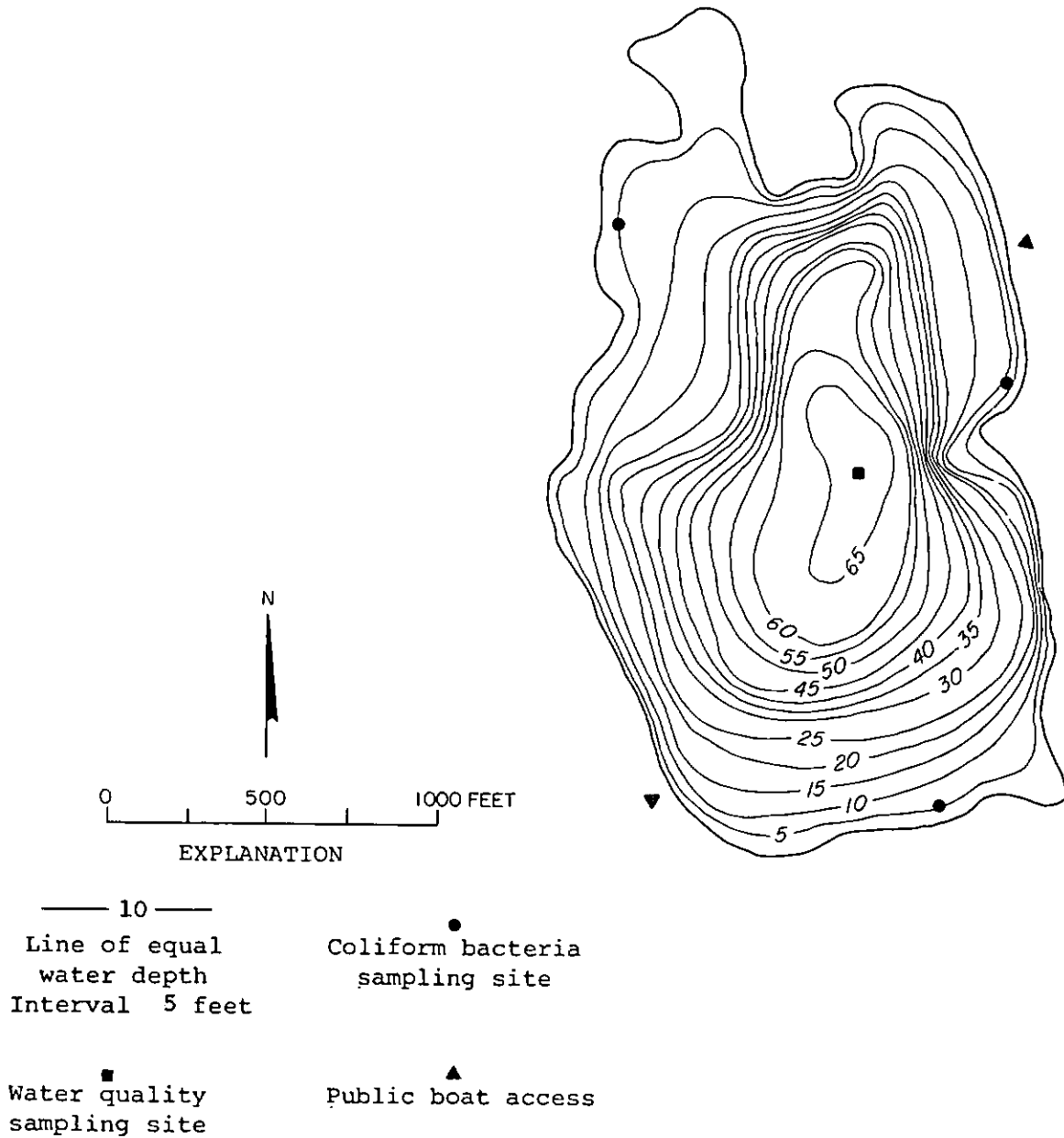
Thermal stratification was weakly developed in May but strongly developed in July and September. During stratification the DO was depleted to near zero in the hypolimnion.

Water-quality data for Big Twin Lake near Winthrop.

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	April 16		May 21		July 16		September 24	
	3	52	3	56	7	56	3	56
Water depth (ft)-----								
Silica (SiO ₂)-----	6.6	7.9	4.1	7.4	1.5	9.1	5.7	10
Dissolved iron (Fe), in µg/l--	20	20	20	30	20	50	20	40
Dissolved manganese (Mn)----- (in µg/l)	30	60	0	100	0	140	10	180
Calcium (Ca) -----	31	--	--	--	--	--	39	--
Magnesium (Mg) -----	13	--	--	--	--	--	15	--
Sodium (Na) -----	11	--	--	--	--	--	11	--
Potassium (K) -----	1.9	--	--	--	--	--	2.2	--
Bicarbonate (HCO ₃) -----	160	160	160	170	150	180	160	180
Carbonate (CO ₃)-----	--	--	0	--	0	--	--	--
Sulfide (S)-----	--	--	--	--	--	>5	--	>5
Sulfate (SO ₄)-----	20	--	--	--	--	--	21	--
Chloride (Cl)-----	.9	--	--	--	--	--	2.5	--
Nitrate nitrogen (as N)-----	.03	.03	.05	.01	.01	.01	.01	.01
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N)-----	.20	.45	.10	.46	.09	1.1	.09	1.7
Organic nitrogen (as N)-----	.60	.65	.49	.64	.12	.20	.45	.10
Total phosphorus (as P)-----	.026	.026	.025	.024	.020	.083	.010	.11
Orthophosphate (as P)-----	.002	.003	.003	.004	.001	.048	.001	.080
Suspended solids (110°C)-----	1	--	--	--	--	--	5	--
Hardness as CaCO ₃ (Ca,Mg)----	130	--	--	--	--	--	160	--
Specific conductance----- (micromhos at 25°C)	240	260	260	260	260	260	260	260
pH (pH units)-----	7.9	7.7	8.9	8.2	8.6	7.3	7.6	7.0
Water temperature (°C)-----	6.4	5.0	14.1	6.1	19.5	6.0	18.0	7.0
Color (Pt-Co scale)-----	15	15	10	10	15	20	0	10
Secchi-disc (ft)-----	9.2		33		9.5		20	
Dissolved oxygen (DO)-----	8.9	2.6	10.5	.1	9.9	.0	7.7	.2
Chlorophyll <u>a</u> in photic zone- (µg/l)	7.0	--	.6	--	2.0	--	2.1	--
Fecal coliform Range--	<1		<1		<1-7		<1-12	
(col. per 100 ml) Mean---	<1		<1		4		7	
Total organic carbon (as C)--	6.8	--	8.1	--	3.4	--	13	--





Big Twin Lake, Okanogan County. From Washington
Department of Game, September 1946.



Big Twin Lake, Okanogan County. July 11, 1973.
Approx. scale 1:60,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Borst Park Lake at Centralia (12026615)Location.

0.9 mile northwest of schoolhouse in center of Centralia, Lewis County; lat 46°43'20', long 122°58'35"; Chehalis River basin; 160 feet altitude.
Centralia quadrangle (1:62,500 scale).

Physical characteristics of lake.

Surface area-----	8 acres	Length of shoreline-----	0.50 mile
Volume-----	44 acre-ft	Shoreline configuration-----	1.3
Mean depth -----	6 ft	Development of volume-----	0.43
Maximum depth-----	13 ft	Bottom slope-----	2.0 percent

Drainage basin.

Size: 0.19 mi²

Geology: Flood-plain deposits of gravel, sand, and silt (Weigle and Foxworthy, 1962).

Soils: Fine sandy loam on moderate slopes (Fowler and Ness, 1954).

Land use	Percent
Urban-----	37
Suburban-----	19
Agricultural-----	0
Forest or unproductive-----	32
Lake surface-----	12

Nearshore development.

Number of nearshore homes: 1 (permanent).

Nearshore residential development: 2 percent.

Hydrology.

The lake has no natural surface-water inflow. Drainage is southward to the Skookumchuck River through an 18-inch culvert.

The lake stage declined 3.6 feet from Apr. 2 to Aug. 23, 1974.

Littoral bottom.

Silt, gravel, and cobble with some muck.

Aquatic plants.

Macrophytes:

Shoreline covered by emersed plants: 26-50 percent.

Lake surface covered by emersed plants: 1-10 percent.

Lake bottom covered by submersed plants: 51-75 percent.

Routed aquatic plants observed: Cattail (*Typha* sp.)*, waterweed (*Elodea* sp.)*, bulrush (*Scirpus* sp.), coontail (*Ceratophyllum* sp.), pondweed (*Potamogeton* sp.), smartweed (*Polygonum* sp.), and white lily (*Nymphaea* sp.).

Algae observed:

Feb. 22, 1974: None.

May 2, 1974: Greens and diatoms.

July 1, 1974: Blue-greens.

Sept. 12, 1974: Greens.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Borst Park Lake is a manmade lake in this city park and is bordered on the east by Interstate Highway 5. The lake is shallow, has a small drainage area (0.19 mi²), and is the smallest of the 26 lakes studied.

The biological productivity of the lake was moderate to high. Inorganic nitrogen concentrations were high (0.73 mg/l) in February but had decreased to 0.08 mg/l in May and even lower in July and September. Chlorophyll a concentrations increased gradually from 3.1 µg/l in February to 19 µg/l in September.

Fecal-coliform counts were low in winter and spring but increased significantly in summer. The colonies in one sample taken in September were too numerous to count. The lake supports a resident population of domestic ducks and geese.

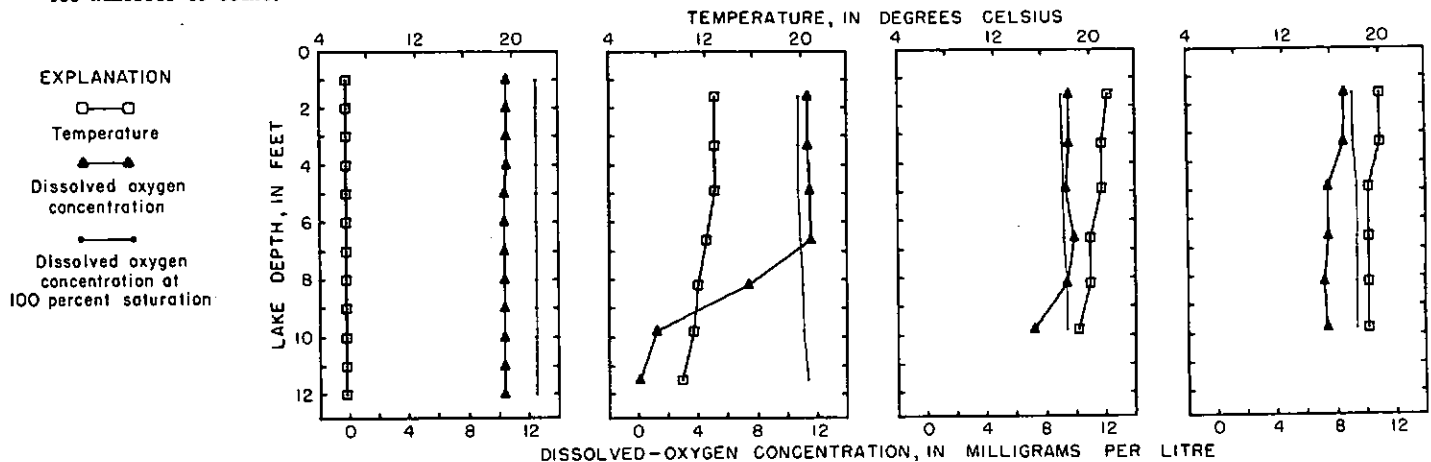
Temperature and DO profiles were nearly uniform throughout the year. The only DO depletion observed was in May and near the bottom of the lake.

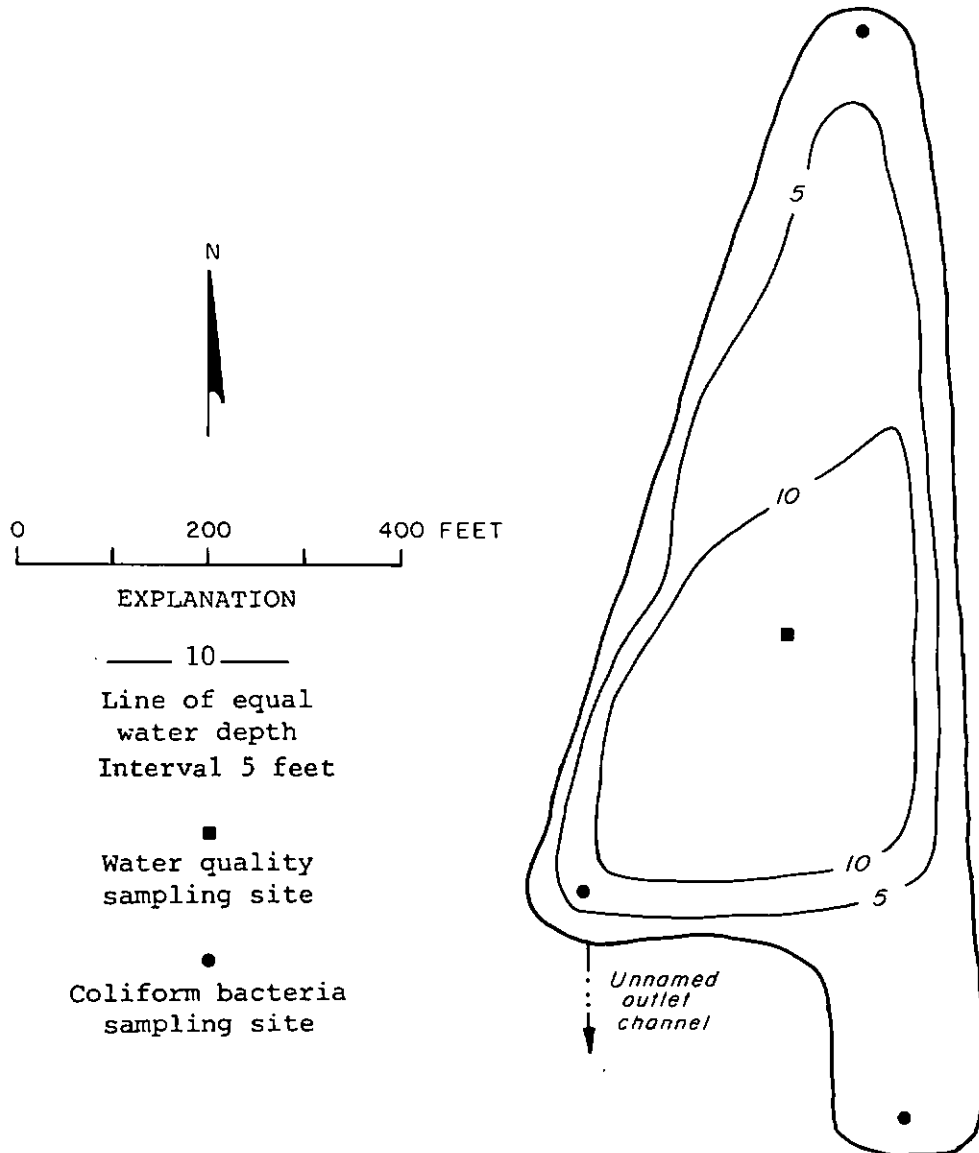
Water-quality data for Borst Park Lake at Centralia

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 22		May 2		July 1		September 12	
	3	9	3	8	3	8	3	8
Water depth (ft)-----								
Silica (SiO ₂)-----	16	16	8.9	9.2	4.3	4.6	5.4	5.4
Dissolved iron (Fe), in µg/l--	590	120	330	150	110	250	440	830
Dissolved manganese (Mn)----- (in µg/l)	120	130	80	70	70	120	130	130
Calcium (Ca) -----	9.1	--	--	--	--	--	13	--
Magnesium (Mg) -----	2.4	--	--	--	--	--	2.6	--
Sodium (Na) -----	6.1	--	--	--	--	--	9.2	--
Potassium (K) -----	.7	--	--	--	--	--	.9	--
Bicarbonate (HCO ₃) -----	33	32	41	42	54	55	57	57
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	8.7	--	--	--	--	--	6.8	--
Chloride (Cl)-----	4.3	--	--	--	--	--	7.7	--
Nitrate nitrogen (as N)-----	.68	.69	.01	.02	.00	.00	.00	.01
Nitrite nitrogen (as N)-----	.01	.01	.00	.00	.00	.00	.00	.01
Ammonia nitrogen (as N)-----	.04	.20	.07	.07	.05	.08	.05	.07
Organic nitrogen (as N)-----	.37	.18	.27	.34	.26	.37	.48	.46
Total phosphorus (as P)-----	.050	.051	.035	.043	.018	.044	.045	.061
Orthophosphate (as P)-----	.008	.007	.002	.002	.002	.003	.004	.002
Suspended solids (110°C)-----	16	--	--	--	--	--	4	--
Hardness as CaCO ₃ (Ca,Mg)----	33	--	--	--	--	--	43	--
Specific conductance----- (micromhos at 25°C)	82	82	89	91	120	120	120	120
pH (pH units)-----	7.2	7.1	7.4	7.3	7.8	6.8	7.7	7.4
Water temperature (°C)-----	6.2	6.2	12.8	11.4	21.0	20.0	20.0	19.0
Color (Pt-Co scale)-----	30	35	20	30	20	30	25	25
Secchi-disc (ft)-----		2.0		4.3		8.2		3.0
Dissolved oxygen (DO)-----	10.5	10.4	11.4	7.4	9.5	9.4	8.5	7.2
Chlorophyll <u>a</u> in photic zone- (µg/l)	3.1	--	6.6	--	14	--	19	--
Fecal coliform (col. per 100 ml) Range-- Mean---		<1-1 <1		<1-4 1		19-84 42		25--*TNTC --
Total organic carbon (as C)--	3.0	--	6.8	--	3.2	--	9.7	--

*Too numerous to count.

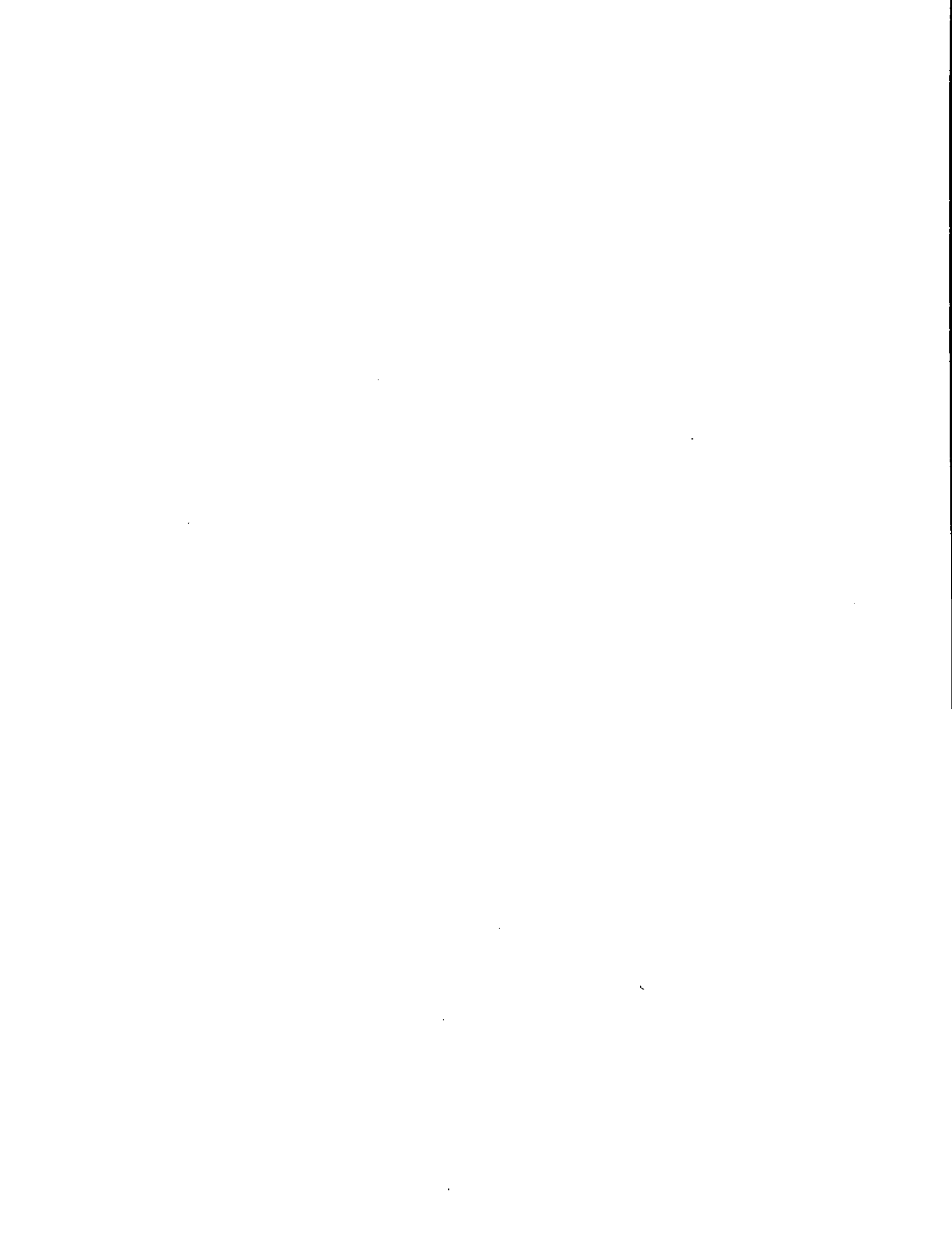




Borst Park Lake, Lewis County. From
U.S. Geological Survey, June 5, 1974.



Borst Park Lake, Lewis County. May 30, 1970. Approx. scale 1:13,000.



Capitol Lake at Olympia (12080025)Location.

0.6 mile northwest of State Capitol, Thurston County; lat 47°02'37", long 122°54'29";
sec.15, T.18 N., R.2 W.; Deschutes River basin; 0 foot altitude.
Tumwater quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	270 acres	Length of shoreline-----	5.3 miles
Volume-----	2,400 acre-ft	Shoreline configuration-----	2.3
Mean depth -----	9 ft	Development of volume-----	0.43
Maximum depth-----	20 ft	Bottom slope-----	0.51 percent

Drainage basin.

Size: 185 mi².

Geology: Volcanic rocks at higher altitudes; glacial drift and unconsolidated deposits at lower altitudes (Huntting and others, 1961).

Soils: Moderate to steep slopes on rough mountainous land at higher altitudes; loam, clay loam, sandy loam, and gravelly loam at lower altitudes (Ness, 1958).

Land use	Percent
Urban-----	} Not determined.
Suburban-----	
Agricultural-----	
Forest or unproductive----	
Lake surface-----	

Nearshore development.

Number of nearshore homes: 2 (permanent).

Nearshore residential development: 2 percent.

Hydrology.

The principal inflows are the Deschutes River and Percival Creek. Neither inflow was measured at the lake. The Deschutes River is gaged about 24 river miles upstream from the lake; the discharge averages about 270 ft³/s. The outflow of the lake, which was not measured, is to Budd Inlet of Puget Sound.

The stage of Capitol Lake is regulated by a tide gate; stage measurements were not made.

Littoral bottom.

Mostly silt with some clay, sand, and gravel.

Aquatic plants.

Macrophytes:

Shoreline covered by emersed plants: 26-50 percent.

Lake surface covered by emersed plants: <1 percent.

Lake bottom covered by submersed plants: 1-10 percent.

Rooted aquatic plants observed: Cattail (*Typha* sp.)*, pondweed (*Potamogeton* sp.), sedge (*Cyperaceae*), waterweed (*Elodea* sp.), and smartweed (*Polygonum* sp.).

Algae observed:

Feb. 11, 1974: None.

Apr. 23, 1974: Blue-greens (*Aphanizomenon* sp.)* and diatoms.

June 17, 1974: Blue-greens (*Aphanizomenon* sp.)* and diatoms.

Aug. 30, 1974: Diatoms and blue-greens.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Capitol Lake is a manmade lake formed by the construction of a tide gate across the southernmost part of Puget Sound. Even though the lake is in an urban environment, the amount of nearshore residential development is small. Because of its irregular shape, the lake was sampled at two sites.

The mean depth of Capitol Lake is only 9 feet; the bottom slope is gentle (0.51 percent). The principal tributary, the Deschutes River, is actively building a delta at the south end of the lake. The lake is flushed quickly as a result of the large inflow volumes. Conductivity measurements indicated the presence of a thin layer of saltwater near the bottom of the lake at site 2.

The biological productivity of the lake was moderate. Nutrient concentrations in general were moderately high in winter and spring but much lower in summer. Chlorophyll a concentrations were generally low in winter and as high as 38 µg/l in summer. Secchi-disc visibility was low at both sample sites, averaging 4.4 feet.

Fecal-coliform levels were high in spring and summer; the colonies in some samples taken in June and August were too numerous to count.

Water-quality data for Capitol Lake at Olympia (site 1)

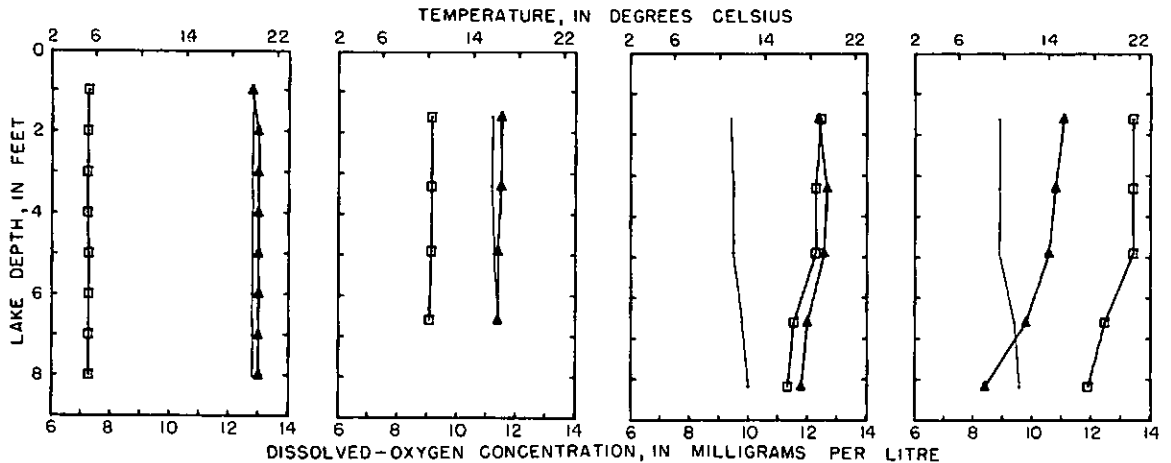
[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 11		April 23		June 17		August 30	
	3	(a)	3	(a)	3	(a)	3	(a)
Water depth (ft)-----								
Silica (SiO ₂)-----	21		21		15		24	
Dissolved iron (Fe), in µg/l--	270		190		200		140	
Dissolved manganese (Mn)----- (in µg/l)	10		20		30		40	
Calcium (Ca) -----	8.3		--		--		11	
Magnesium (Mg) -----	2.5		--		--		5.2	
Sodium (Na) -----	6.0		--		--		7.9	
Potassium (K) -----	.8		--		--		1.2	
Bicarbonate (HCO ₃) -----	34		38		47		59	
Carbonate (CO ₃)-----	--		--		0		0	
Sulfide (S)-----	--		--		--		--	
Sulfate (SO ₄)-----	4.5		--		--		3.8	
Chloride (Cl)-----	5.5		--		--		9.9	
Nitrate nitrogen (as N)-----	.50		.31		.00		.00	
Nitrite nitrogen (as N)-----	.003		.004		.004		.005	
Ammonia nitrogen (as N)-----	.07		.05		.07		.17	
Organic nitrogen (as N)-----	.21		.12		.52		.86	
Total phosphorus (as P)-----	.040		.025		.071		.086	
Orthophosphate (as P)-----	.022		.011		.009		.010	
Suspended solids (110 °C)-----	7		--		--		5	
Hardness as CaCO ₃ (Ca,Mg)-----	31		--		--		49	
Specific conductance----- (micromhos at 25 °C)	70		97		99		118	
pH (pH units)-----	8.0		8.0		9.0		8.8	
Water temperature (°C)-----	5.2		10.3		18.5		21.5	
Color (Pt-Co scale)-----	10		15		35		25	
Secchi-disc (ft)-----		4.0		7.2		3.3		2.6
Dissolved oxygen (DO)-----	13.0		11.5		12.7		10.8	
Chlorophyll <i>a</i> in photic zone- (µg/l)	10.9		1.6		20.1		38.4	
Fecal coliform Range-- (col. per 100 ml) Mean---		2-18 9		12-164 60		3--*TNTC --		1--*TNTC --
Total organic carbon (as C)--	4.4		5.7		7.0		7.6	

*Too numerous to count.

^aNot taken.

EXPLANATION
 □—□ Temperature
 ▲—▲ Dissolved oxygen concentration
 — Dissolved oxygen concentration at 100 percent saturation

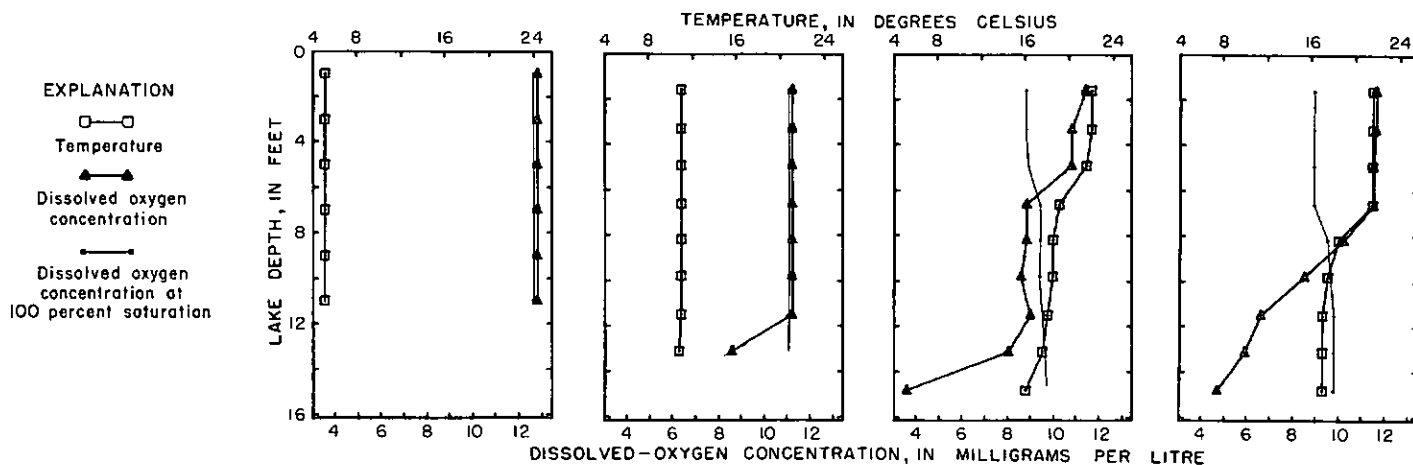


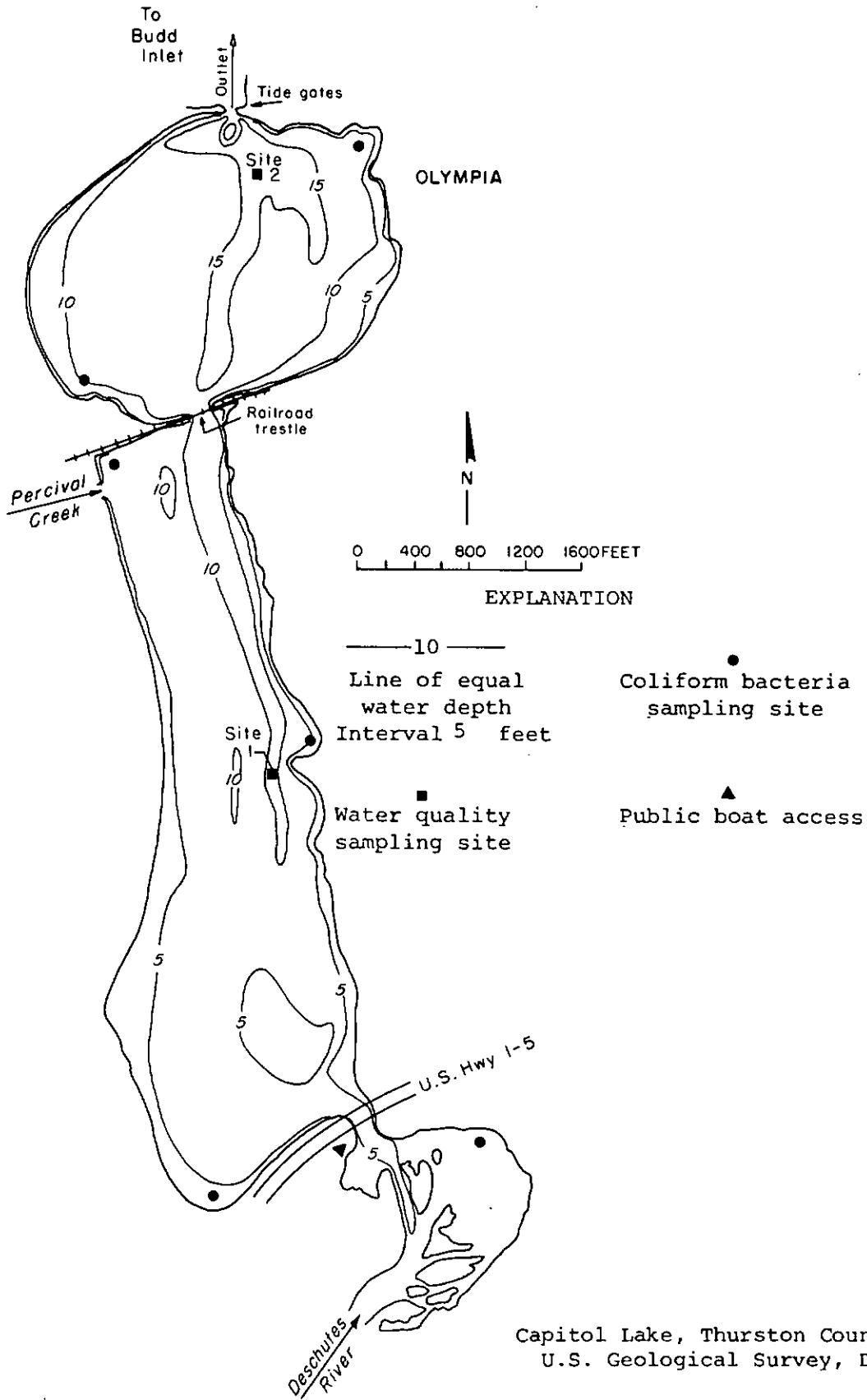
Water-quality data for Capitol Lake at Olympia (site 2)

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 11		April 23		June 17		August 30	
	3	10	3	11	3	11	3	11
Water depth (ft)-----								
Silica (SiO ₂)-----	21	21	20	20	22	23	22	21
Dissolved iron (Fe), in µg/l--	280	300	220	230	180	240	120	190
Dissolved manganese (Mn)----- (in µg/l)	40	10	40	30	30	30	0	140
Calcium (Ca) -----	8.6	--	--	--	--	--	12	--
Magnesium (Mg) -----	2.4	--	--	--	--	--	4.0	--
Sodium (Na) -----	6.9	--	--	--	--	--	9.4	--
Potassium (K) -----	.9	--	--	--	--	--	1.3	--
Bicarbonate (HCO ₃) -----	32	32	38	37	43	45	60	56
Carbonate (CO ₃)-----	--	--	--	--	0	1	0	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	4.1	--	--	--	--	--	3.9	--
Chloride (Cl)-----	10	--	--	--	--	--	11	--
Nitrate nitrogen (as N)-----	.49	.50	.31	.30	.00	.04	.01	.08
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N)-----	.08	.08	.07	.06	.03	.04	.07	.06
Organic nitrogen (as N)-----	.12	.10	.14	.13	.42	.22	.62	.47
Total phosphorus (as P)-----	.035	.036	.027	.030	.044	.029	.047	.033
Orthophosphate (as P)-----	.025	.028	.009	.009	.004	.004	.003	.005
Suspended solids (110°C)-----	5	--	--	--	--	--	3	--
Hardness as CaCO ₃ (Ca,Mg)-----	31	--	--	--	--	--	46	--
Specific conductance----- (micromhos at 25°C)	84	84	210	230	99	120	120	130
pH (pH units)-----	8.1	8.0	8.3	7.6	9.0	8.4	8.8	7.4
Water temperature (°C)-----	5.1	5.1	11.0	11.0	22.0	18.0	21.5	17.0
Color (Pt-Co scale)-----	20	25	20	20	30	30	25	25
Secchi-disc (ft)-----		3.5		6.2		4.6		3.9
Dissolved oxygen (DO)-----	12.8	12.8	11.2	11.2	10.8	9.0	11.6	6.6
Chlorophyll a in photic zone- (µg/l)	1.0	--	3.2	--	11	--	18	--
Fecal coliform Range-- (col. per 100 ml) Mean---		2-18 9		12-64 60		3--*TNTC --		1--*TNTC --
Total organic carbon (as C)--	6.3	--	5.1	--	7.9	--	4.8	--

*Too numerous to count.





Capitol Lake, Thurston County. From U.S. Geological Survey, December 5, 1973.



Capitol Lake, Thurston County. May 12, 1972. Approx. scale 1:15,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Carlisle Lake at Onalaska (12024059)Location.

0.6 mile northwest of Onalaska, Lewis County; lat 46°34'41", long 122°43'34"; SW¹SE¹ sec.30, T.13 N., R.1 E.; Chehalis River basin; 506 feet altitude.
Onalaska quadrangle (1:62,500 scale).

Physical characteristics of lake.

Surface area-----	29 acres	Length of shoreline-----	1.1 miles
Volume-----	85 acre-ft	Shoreline configuration-----	1.5
Mean depth-----	3 ft	Development of volume-----	0.29
Maximum depth-----	10 ft	Bottom slope-----	0.79 percent

Drainage basin.

Size: 4.15 mi².

Geology: Uplands are glaciofluvial deposits of poorly sorted sand and gravel. Lowlands are flood-plain deposits of gravel, sand, and silt, and of glaciofluvial sand and gravel (Weigle and Foxworthy, 1962).

Soils: The uplands contain silty clay loam. The lowlands contain a mixed pattern of silt loam, silty clay loam, and silty clay loam with gravelly subsoil (Fowler and Ness, 1954).

Land use	Percent
Urban-----	0
Suburban-----	1
Agricultural-----	32
Forest or unproductive-----	66
Lake surface-----	1

Nearshore development.

Number of nearshore homes: 0.

Nearshore residential development: 0 percent.

Hydrology.

The lake has no visible surface-water inflow. Drainage is southwestward via Gheer Creek to South Fork Newaukum River. On Feb. 21, May 1, June 28, and Sept. 12 the outflow was 29.0, 7.05, 0.80, and 0.26 ft³/s, respectively.

The lake stage declined about 2.5 feet from Feb. 21 to Sept. 12, 1974.

Littoral bottom.

Silt and muck with some gravel.

Aquatic plants.Macrophytes:

Shoreline covered by emerged plants: 76-100 percent.

Lake surface covered by emerged plants: 26-50 percent.

Lake bottom covered by submersed plants: 76-100 percent.

Rooted aquatic plants observed: Yellow lily (Nuphar sp.*), cattail (Typha sp.), milfoil (Myriophyllum sp.), stonewort (Nitella sp.), pondweed (Potamogeton sp.), and smartweed (Polygonum sp.).

Algae observed:

Feb. 21, 1974: Greens (Desmidiium sp.*, others).

May 1, 1974: Greens (Desmidiium sp.*, others) and diatoms.

June 28, 1974: Greens (Volvox sp.*, others) and yellow-browns.

Sept. 12, 1974: Greens.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Carlisle Lake is an abandoned millpond formed by a log and earthfill dam. The lake is near a small, rural community and has no nearshore residential development. The lake is shallow (mean depth of 3 ft) and has a small volume (85 acre-ft).

The biological productivity of the lake was one of the highest of the 26 lakes studied. The silt and muck bottom supported extensive growths of both emerged and submersed aquatic macrophytes. Orthophosphate concentrations were high in February, June, and September; inorganic nitrogen concentrations were high in February (0.93 mg/l) but much lower during subsequent visits. Chlorophyll *a* concentrations increased from 2.4 µg/l in February to 23 µg/l in September. The high productivity of the lake is demonstrated by the fact that, in spite of the shallowness of the lake, by September the DO concentrations had been reduced to about 1 mg/l.

The water was highly colored and fecal-coliform levels also were high. The colonies in one sample taken in June were too numerous to count.

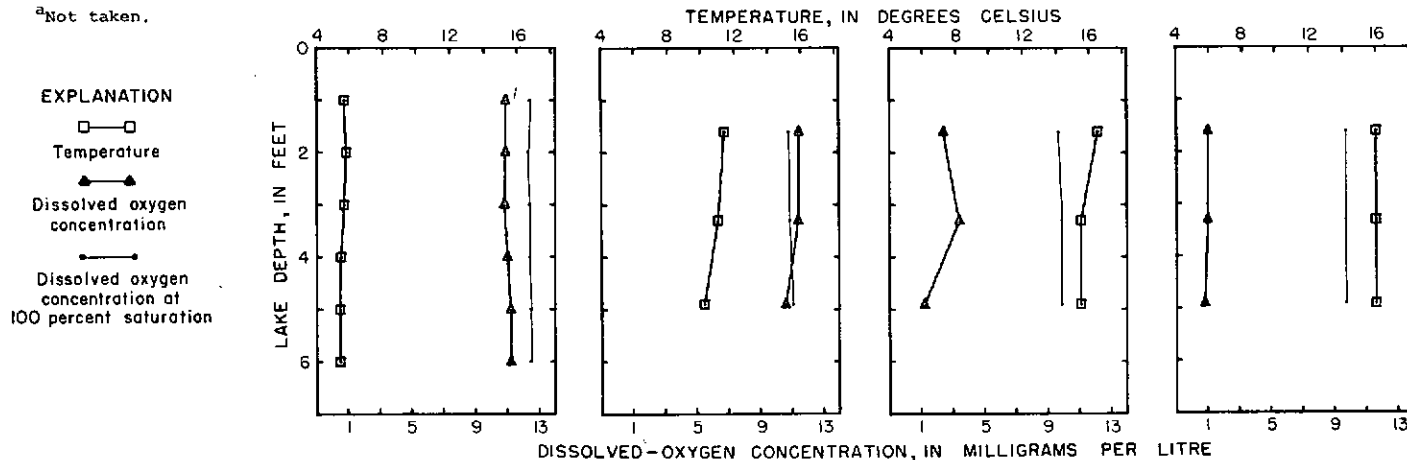
Water-quality data for Carlisle Lake at Onalaska

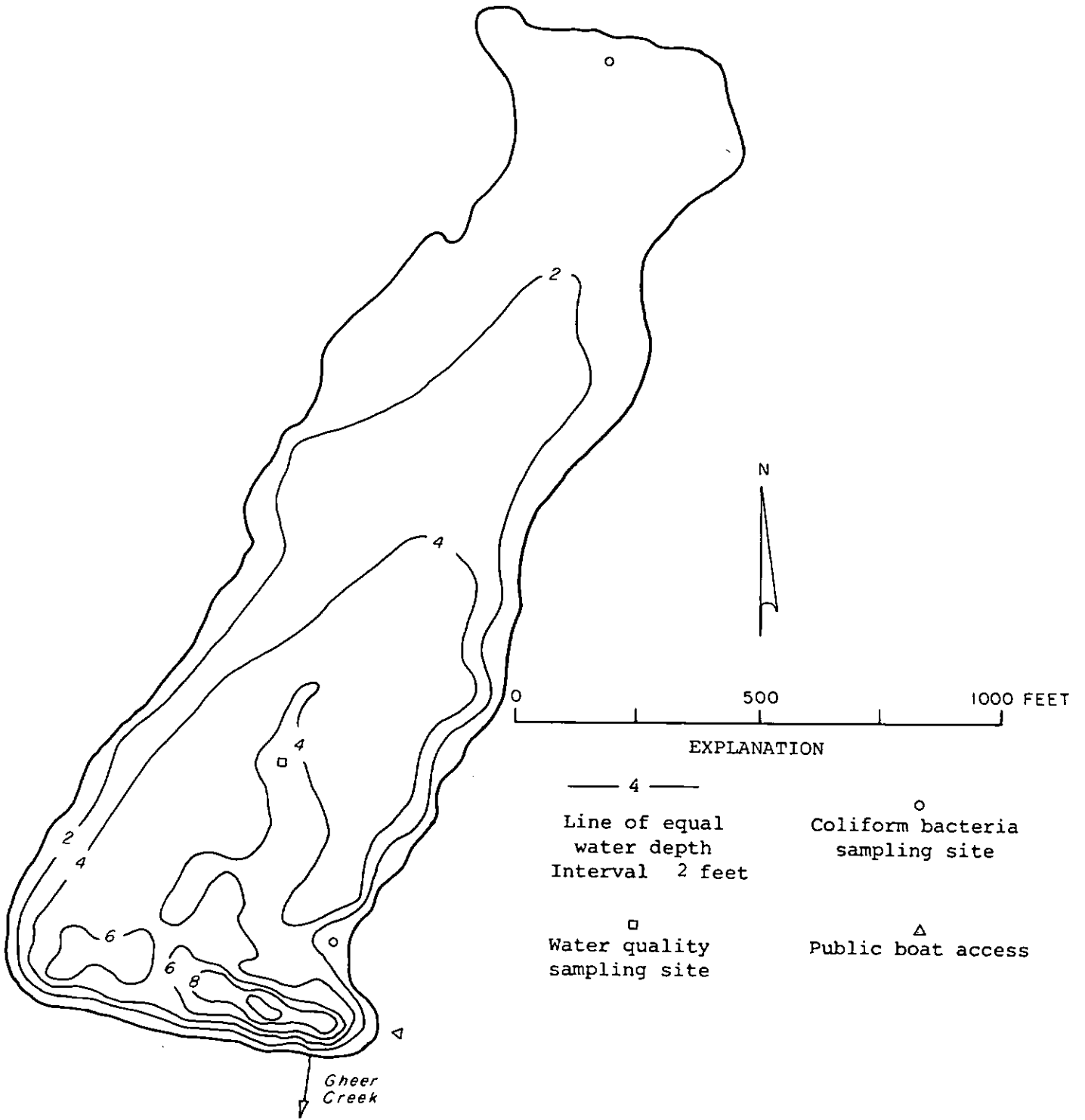
[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 21		May 1		June 28		September 12	
	3	(a)	3	(a)	3	(a)	3	(a)
Water depth (ft)-----								
Silica (SiO ₂)-----	7.7		5.0		6.3		15	
Dissolved iron (Fe), in µg/l--	230		560		3,300		3,900	
Dissolved manganese (Mn)----- (in µg/l)	0		20		380		430	
Calcium (Ca) -----	2.4		--		--		5.8	
Magnesium (Mg) -----	.9		--		--		1.2	
Sodium (Na) -----	2.6		--		--		5.1	
Potassium (K) -----	.7		--		--		.8	
Bicarbonate (HCO ₃) -----	10		20		26		37	
Carbonate (CO ₃)-----	--		--		--		--	
Sulfide (S)-----	--		--		--		--	
Sulfate (SO ₄)-----	1.8		--		--		2.8	
Chloride (Cl)-----	1.5		--		--		1.7	
Nitrate nitrogen (as N)-----	.82		.04		.00		.01	
Nitrite nitrogen (as N)-----	.01		.00		.00		.00	
Ammonia nitrogen (as N)-----	.10		.12		.29		.17	
Organic nitrogen (as N)-----	.27		.30		.49		.63	
Total phosphorus (as P)-----	.035		.042		.17		1.0	
Orthophosphate (as P)-----	.019		.006		.070		.030	
Suspended solids (110 °C)-----	20		--		--		2	
Hardness as CaCO ₃ (Ca, Mg)----	10		--		--		19	
Specific conductance----- (micromhos at 25 °C)	28		36		48		59	
pH (pH units)-----	7.2		7.4		6.2		6.4	
Water temperature (°C)-----	5.7		11.0		15.5		16.0	
Color (Pt-Co scale)-----	25		35		100		100	
Secchi-disc (ft)-----		5.5		5.2		3.6		3.6
Dissolved oxygen (DO)-----	10.8		11.4		3.4		1.0	
Chlorophyll <i>a</i> in photic zone- (µg/l)	2.4		8.5		10.5		23.0	
Fecal coliform Range-- (col. per 100 ml) Mean---		32-70 51		<1-92 32		8--*TNTC --		2-48 25
Total organic carbon (as C)--	3.5		6.9		15		17	

*Too numerous to count.

^aNot taken.





Carlisle Lake, Lewis County. From
U.S. Geological Survey, February 28, 1974.



Carlisle Lake, Lewis County. May 2, 1970. Approx. scale 1:12,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Cassidy Lake near Lake Stevens (12153100)Location.

1.4 miles northwest of high school in Lake Stevens, Snohomish County; lat 48°02'51", long 122°05'28"; NW¹/₄ sec. 31, T. 30 N., R. 6 E.; Snohomish River basin; 319 feet altitude. Lake Stevens quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	120 acres	Length of shoreline-----	1.8 miles
Volume-----	1,300 acre-ft	Shoreline configuration-----	1.2
Mean depth-----	11 ft	Development of volume-----	0.55
Maximum depth-----	20 ft	Bottom slope-----	0.77 percent

Drainage basin.

Size: 4.56 mi².

Geology: Gray, compact ground-moraine deposits; unconsolidated alluvium in valley bottoms (Newcomb, 1952).

Soils: The uplands contain gravelly loam and gravelly sandy loam, underlain by compact glacial till. The lowlands in the immediate vicinity of the lake contain peat (Anderson and others, 1947).

Land use	Percent
Urban-----	0
Suburban-----	<1
Agricultural-----	14
Forest or unproductive-----	82
Lake surface-----	4

Nearshore development.

Number of nearshore homes: 22.

Nearshore residential development: 22 percent.

Hydrology.

The lake has no surface-water inflow. Drainage is southeastward via Catherine Creek to the Pilchuck River. On Feb. 14 and Apr. 25 the outflow was 14.8 and 6.90 ft³/s, respectively. On subsequent sampling trips (June 21 and Aug. 28) the channel of Catherine Creek was filled with stagnant water.

The lake stage declined 3.2 feet from Mar. 2 to Sept. 14, 1974.

Littoral bottom.

Mostly muck with some silt and gravel.

Aquatic plants.Macrophytes:

Shoreline covered by emersed plants: 76-100 percent.

Lake surface covered by emersed plants: <1 percent.

Lake bottom covered by submersed plants: 1-10 percent.

Rooted aquatic plants observed: Yellow lily (Nuphar sp.)*, bulrush (Scirpus sp.), cattail (Typha sp.), pondweed (Potamogeton sp.), sedge (Cyperaceae), and white lily (Nymphaea sp.).

Algae observed:

Feb. 14, 1974: No sample taken.

Apr. 25, 1974: Blue-greens (Aphanizomenon sp.)* and diatoms.

June 21, 1974: Blue-greens (Aphanizomenon sp.)* and diatoms (Tabellaria sp., Asterionella sp.)*.

Aug. 28, 1974: None.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Cassidy Lake is situated in a rural, forested part of Snohomish County and is partly developed for residential purposes. The northern half of the lake is bordered by marsh.

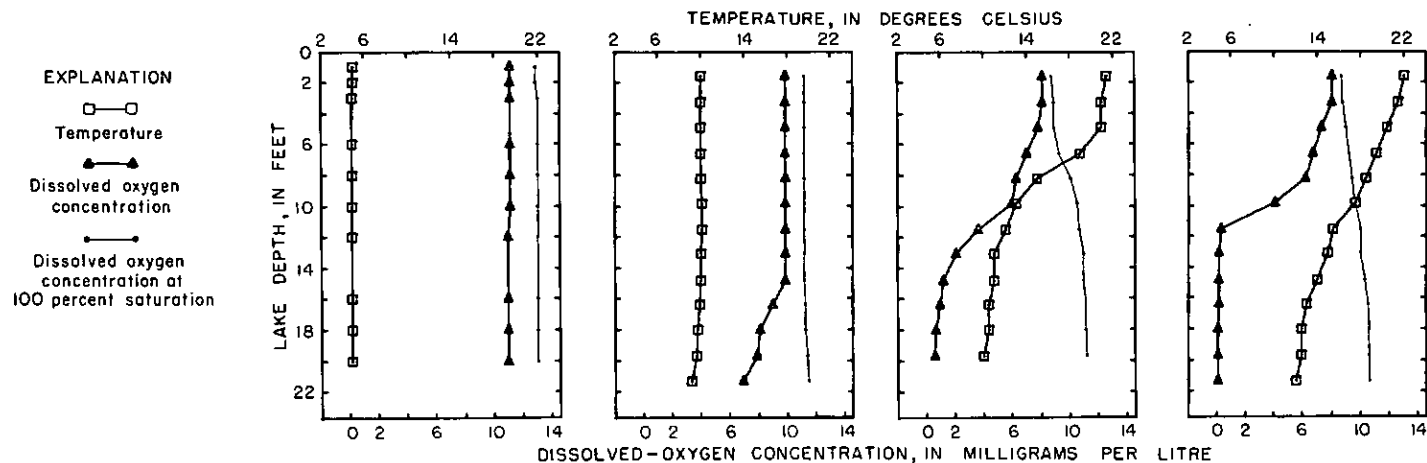
The biological productivity of the lake was moderate to high. Inorganic nitrogen concentrations were high in winter and spring but low to moderate in summer. The littoral bottom of muck supported an extensive growth of bulrush, cattail, and sedge. The water was highly colored and secchi-disc visibility averaged 4.4 feet.

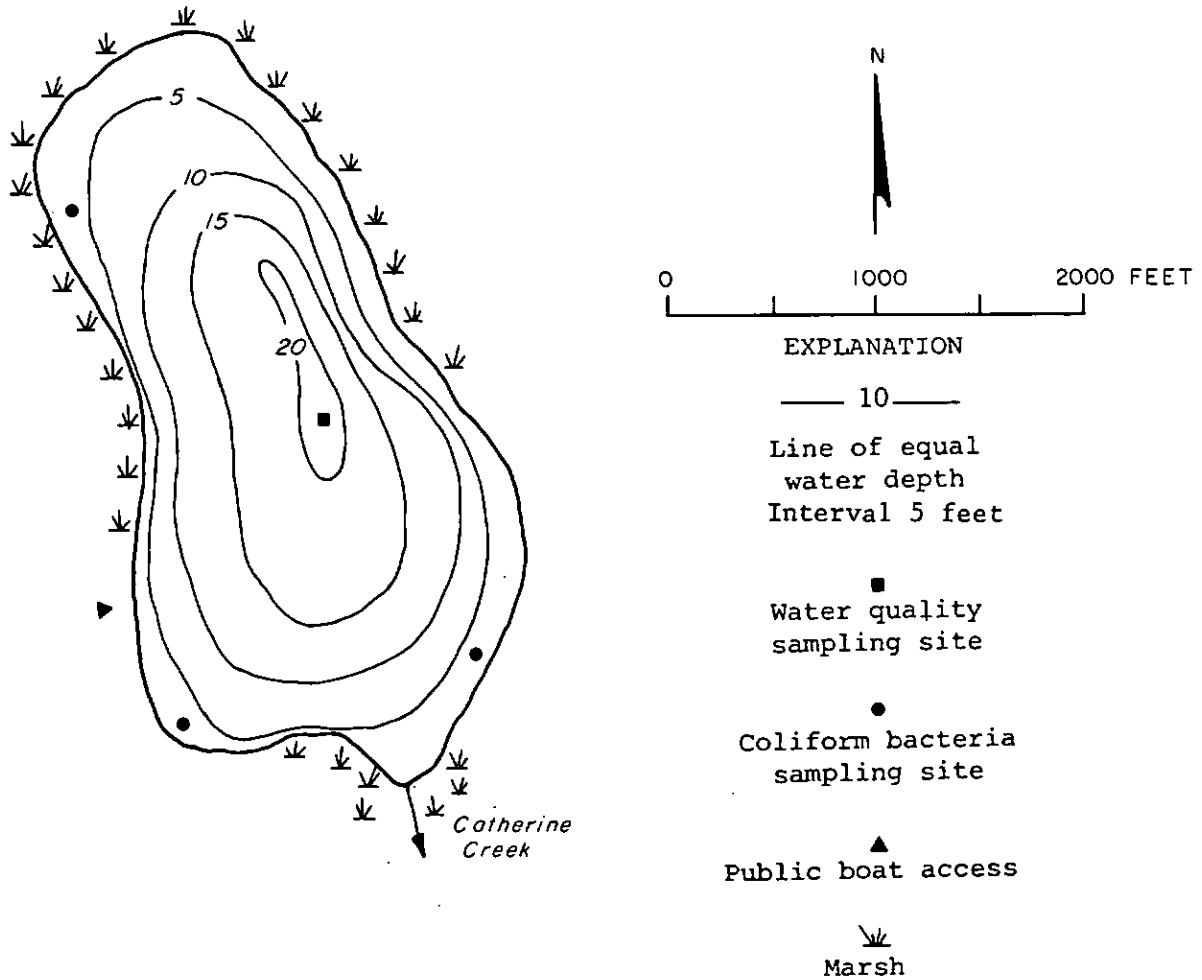
The lake became weakly stratified by summer and DO was depleted to near zero in the hypolimnion.

Water-quality data for Cassidy Lake near Lake Stevens

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 14		April 25		June 21		August 28	
	3	18	3	18	3	18	3	18
Water depth (ft)-----								
Silica (SiO ₂)-----	8.8	8.8	5.9	6.3	1.9	6.7	3.3	6.8
Dissolved iron (Fe), in µg/l--	140	150	150	140	90	230	200	1,200
Dissolved manganese (Mn)----- (in µg/l)	20	20	10	20	0	80	40	280
Calcium (Ca) -----	3.2	--	--	--	--	--	3.0	--
Magnesium (Mg) -----	1.1	--	--	--	--	--	2.6	--
Sodium (Na) -----	2.7	--	--	--	--	--	2.3	--
Potassium (K) -----	.9	--	--	--	--	--	.7	--
Bicarbonate (HCO ₃) -----	6	5	6	7	10	10	13	14
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	6.1	--	--	--	--	--	5.1	--
Chloride (Cl)-----	3.1	--	--	--	--	--	2.4	--
Nitrate nitrogen (as N)-----	.79	.82	.34	.34	.00	.09	.03	.00
Nitrite nitrogen (as N)-----	.01	.01	.01	.00	.01	.01	.01	.01
Ammonia nitrogen (as N)-----	.15	.15	.14	.13	.12	.16	.17	.49
Organic nitrogen (as N)-----	.66	.57	.39	.42	.79	.82	.61	.56
Total phosphorus (as P)-----	.022	.021	.029	.025	.070	.036	.022	.13
Orthophosphate (as P)-----	.014	.014	.008	.008	.009	.010	.009	.10
Suspended solids (110 °C)-----	1	--	--	--	--	--	1	--
Hardness as CaCO ₃ (Ca,Mg)-----	13	--	--	--	--	--	18	--
Specific conductance----- (micromhos at 25 °C)	34	34	32	33	30	32	36	44
pH (pH units)-----	6.4	6.6	7.2	6.6	7.1	6.2	6.1	5.6
Water temperature (°C)-----	4.9	4.9	10.0	9.7	21.0	10.5	21.5	12.5
Color (Pt-Co scale)-----	120	120	150	150	150	150	150	200
Secchi-disc (ft)-----		5.0		4.3		4.6		3.9
Dissolved oxygen (DO)-----	11.1	11.0	9.9	8.1	8.1	.7	8.0	.1
Chlorophyll <u>a</u> in photic zone- (µg/l)	1.4	--	6.8	--	3.8	--	2.4	--
Fecal coliform Range-- (col. per 100 ml) Mean---		4-12 8		<1-10 3		<1-6 3		5-7 6
Total organic carbon (as C)--	16	--	16	--	24	--	16	--





Cassidy Lake, Snohomish County. From Washington Department of Game, July 23, 1956.



Cassidy Lake, Snohomish County. July 17, 1969. Approx. scale 1:12,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Fish Lake near Plain (12455600)Location.

5.2 miles northwest of Plain, Chelan County; lat 47°49'42", long 120°42'35"; SW^{1/4} sec. 22, T.27 N., R.17 E.; Wenatchee River basin; 1,929 feet altitude. Plain quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	530 acres	Length of shoreline-----	5.0 miles
Volume-----	15,000 acre-ft	Shoreline configuration-----	1.5
Mean depth-----	27 ft	Development of volume-----	0.61
Maximum depth-----	45 ft	Bottom slope-----	0.83 percent

Drainage basin.

Size: 5.51 mi².

Geology: Undifferentiated glacial drift, consisting of glacial and glaciofluvial sand, gravel, and till (Hunting and others, 1961).

Soils: Acidic sandy loam to silt loam (U.S. Soil Conservation Service, 1968).

Land use	Percent
Urban-----	0
Suburban-----	1
Agricultural-----	0
Forest or unproductive-----	84
Lake surface-----	15

Nearshore development.

Number of nearshore homes: 20 (mostly seasonal).

Nearshore residential development: 12 percent.

Hydrology.

The lake has no visible surface-water inflow. Drainage is southward via Fish Lake Run to the Wenatchee River. On Apr. 17, May 23, and July 18, the outflow was estimated to be 19, 10, and 2.2 ft³/s, respectively.

The lake stage declined 1.8 feet from Apr. 17 to Sept. 26, 1974.

Littoral bottom.

Silt, gravel, and rock, with some muck.

Aquatic plants.Macrophytes:

Shoreline covered by emerged plants: 51-75 percent.

Lake surface covered by emerged plants: 1-10 percent.

Lake bottom covered by submersed plants: 11-25 percent.

Rooted aquatic plants observed: Bulrush (*Scirpus* sp.)*, cattail (*Typha* sp.), waterweed (*Elodea* sp.)*, pondweed (*Potamogeton* sp.), and yellow lily (*Nuphar* sp.).

Algae observed:

Apr. 17, 1974: Greens (*Microspora* sp.*, others) and diatoms.

May 23, 1974: Greens (*Microspora* sp.*), blue-greens, diatoms, and yellow-browns.

July 18, 1974: Blue-greens (*Aphanizomenon* sp.)*, greens, and diatoms.

Sept. 24, 1974: Blue-greens (*Aphanizomenon* sp.*, others) and greens.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Fish Lake is a large lake in a remote, forested part of Chelan County. A large marsh exists at the west end of the lake and nearshore residential development is localized.

The biological productivity of the lake was moderate. The inorganic nutrient concentrations were low but the chlorophyll *a* concentrations were moderate. The dominant macrophytes observed were bulrush and waterweed.

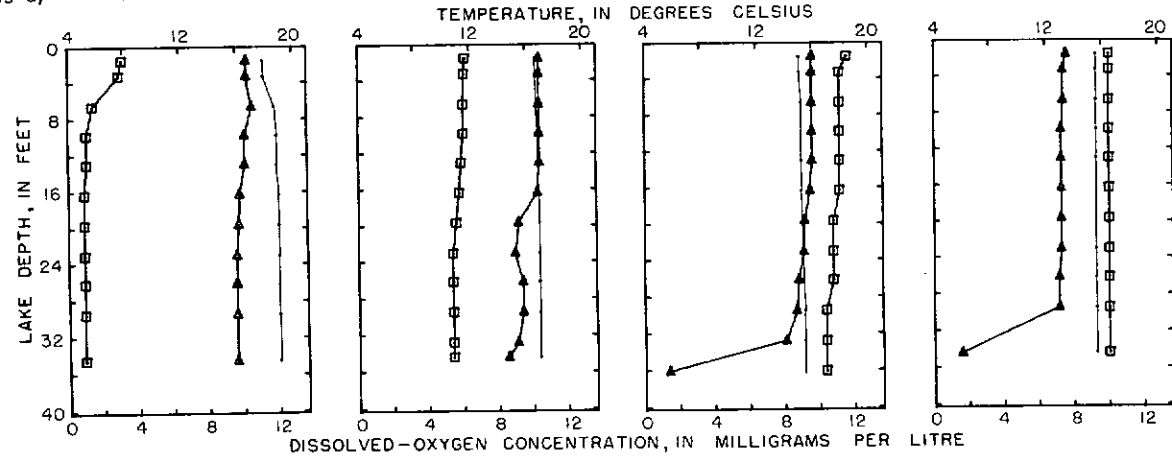
Water-temperature profiles were nearly uniform throughout the year; thermal stratification did not develop, possibly as a result of the frequent winds in the area. The only DO depletion observed was near the bottom of the lake in July and September.

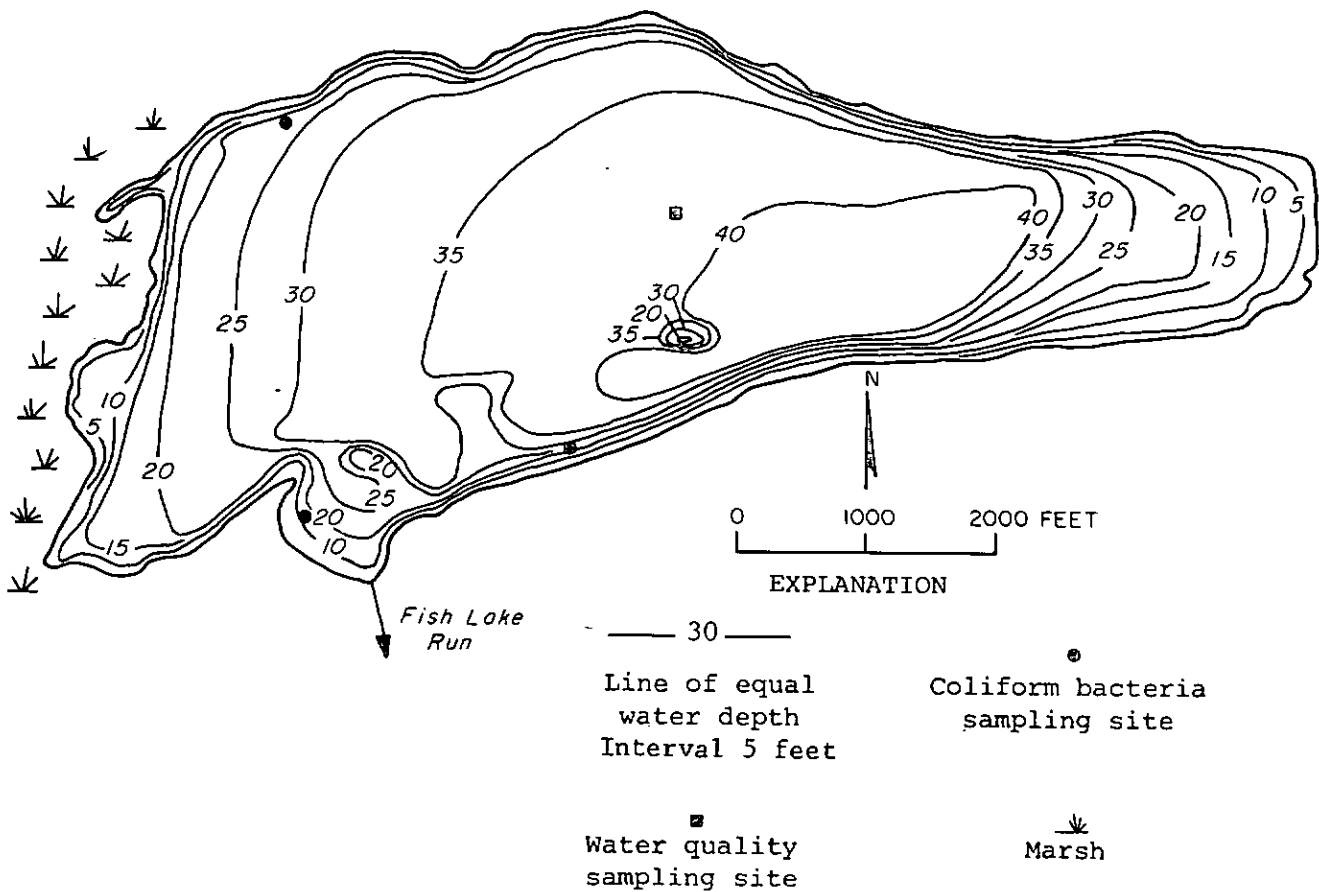
Water-quality data for Fish Lake near Plain

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	April 17		May 23		July 18		September 26	
	3	31	3	33	3	33	3	33
Water depth (ft)-----								
Silica (SiO ₂)-----	14	14	12	12	9.3	10	11	11
Dissolved iron (Fe), in µg/l--	400	440	150	80	80	160	280	270
Dissolved manganese (Mn)----- (in µg/l)	50	60	0	10	30	30	60	80
Calcium (Ca) -----	8.0	--	--	--	--	--	16	--
Magnesium (Mg) -----	4.4	--	--	--	--	--	5.6	--
Sodium (Na) -----	3.1	--	--	--	--	--	3.3	--
Potassium (K) -----	1.2	--	--	--	--	--	1.1	--
Bicarbonate (HCO ₃) -----	50	50	52	52	55	55	58	60
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	1.8	--	--	--	--	--	.9	--
Chloride (Cl)-----	.7	--	--	--	--	--	1.3	--
Nitrate nitrogen (as N)-----	.03	.03	.01	.01	.01	.01	.01	.01
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N)-----	.10	.13	.04	.05	.04	.03	.18	.20
Organic nitrogen (as N)-----	.34	.37	.28	.26	.24	.25	.39	.37
Total phosphorus (as P)-----	.029	.036	.15	.029	.036	.031	.036	.037
Orthophosphate (as P)-----	.006	.011	.003	.002	.003	.005	.004	.004
Suspended solids (110°C)-----	4	--	--	--	--	--	6	--
Hardness as CaCO ₃ (Ca,Mg)----	38	--	--	--	--	--	63	--
Specific conductance----- (micromhos at 25°C)	78	75	75	75	84	82	87	87
pH (pH units)-----	8.1	8.0	8.3	7.6	8.1	7.6	8.2	8.1
Water temperature (°C)-----	7.7	5.2	11.6	10.8	18.0	17.0	16.5	16.5
Color (Pt-Co scale)-----	25	25	10	15	10	10	10	10
Secchi-disc (ft)-----		8.2		11		11		6.9
Dissolved oxygen (DO)-----	10.2	9.6	10.4	9.1	9.6	8.1	7.4	7.1
Chlorophyll <u>a</u> in photic zone- (µg/l)	7.2	--	4.1	--	1.2	--	5.1	--
Fecal coliform Range--		<1		<1-3		<1-8		1-4
(col. per 100 ml) Mean---		<1		1		4		2
Total organic carbon (as C)--	4.1	--	5.2	--	6.2	--	10	--

EXPLANATION
 ○—○ Temperature
 ▲—▲ Dissolved oxygen concentration
 — Dissolved oxygen concentration at 100 percent saturation





Fish Lake, Chelan County. From
U.S. Geological Survey, July 23, 1974.



Fish Lake, Chelan County. August 28, 1972. Approx. scale 1:22,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Ki Lake near Silvana (12169400)Location.

3.1 miles south of Silvana, Snohomish County; lat 48°09'25", long 122°15'45",
NE¼SW¼ sec.23, T.31 N., R.4 E.; Stillaguamish River basin; 414 feet altitude.
Stanwood quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	98 acres	Length of shoreline-----	1.9 miles
Volume-----	3,300 acre-ft	Shoreline configuration-----	1.3
Mean depth-----	33 ft	Development of volume-----	0.47
Maximum depth-----	70 ft	Bottom slope-----	3.0 percent

Drainage basin.

Size: 0.72 mi².

Geology: Gray, compact ground-moraine deposits (Newcomb, 1952).

Soils: Predominantly gravelly sandy loam underlain by compact glacial till; local areas
of clay loam (Anderson and others, 1947).

Land use	Percent
Urban-----	0
Suburban-----	11
Agricultural-----	6
Forest or unproductive-----	62
Lake surface-----	21

Nearshore development.

Number of nearshore homes: 82.

Nearshore residential development: 83 percent.

Hydrology.

The lake has one small, unnamed inflow on the southwest side of the lake. On Feb. 15, the inflow was 0.20 ft³/s. On subsequent sampling trips the inflow channel was dry. Drainage is northward via Portage Creek to South Slough of the Stillaguamish River. The outflow on Feb. 15 and Apr. 24 was 1.09 and 0.13 ft³/s, respectively. On subsequent sampling trips the outflow channel was dry.

The lake stage declined 2.3 feet from Mar. 4 to Oct. 25, 1974.

Littoral bottom.

Silt, gravel, and rock, with much wood debris.

Aquatic plants.Macrophytes:

Shoreline covered by emersed plants: 1-10 percent.

Lake surface covered by emersed plants: <1 percent.

Lake bottom covered by submersed plants: <1 percent.

Rooted aquatic plants observed: White lily (*Nymphaea* sp.)*, cattail (*Typha* sp.),
rush (*Juncus* sp.), and yellow lily (*Nuphar* sp.).

Algae observed:

Feb. 15, 1974: None.

Apr. 24, 1974: Dinoflagellates.

June 20, 1974: Diatoms.

Aug. 27, 1974: Diatoms.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Ki Lake is heavily developed (83 percent) for residential and recreational purposes. The homes are closely spaced and the ratio of lake volume per home (40 acre-ft per home) is small. The lake is deep in relation to its surface area and the bottom slope (3.0 percent) is therefore relatively steep.

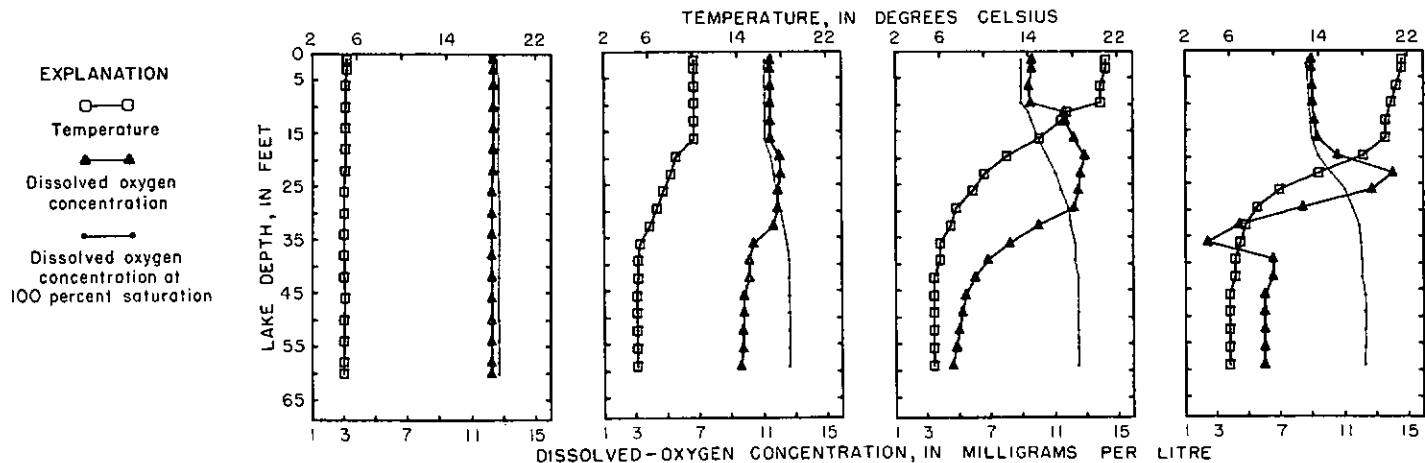
The biological productivity of the lake was low to moderate. Inorganic nitrogen concentrations were moderate and orthophosphate concentrations were low to moderate throughout most of the year. The entire lake bottom and most of the lake surface were free of aquatic macrophytes. The total organic carbon concentrations increased gradually from 3.6 mg/l in February to 8.4 mg/l in August.

Thermal stratification was well established by June but no serious DO depletion was observed.

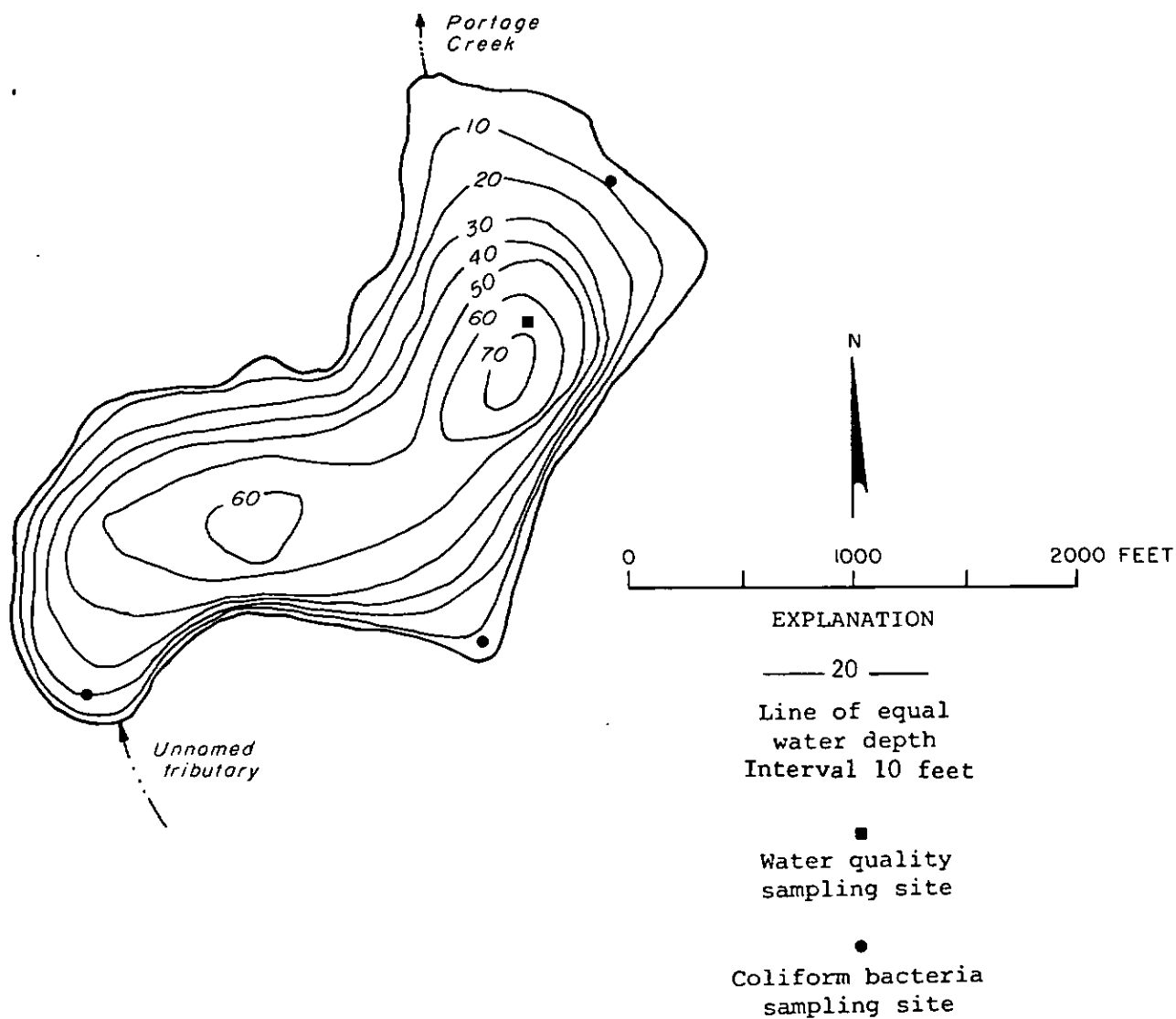
Water-quality data for Ki Lake near Silvana

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 15		April 24		June 20		August 27	
	3	59	3	57	3	57	3	57
Water depth (ft)-----								
Silica (SiO ₂)-----	1.3	1.2	1.0	1.4	0.5	1.7	0.3	1.8
Dissolved iron (Fe), in µg/l--	70	150	40	40	20	50	70	520
Dissolved manganese (Mn)----- (in µg/l)	0	0	10	10	0	20	10	60
Calcium (Ca) -----	2.3	--	--	--	--	--	1.9	--
Magnesium (Mg) -----	1.1	--	--	--	--	--	2.2	--
Sodium (Na) -----	3.2	--	--	--	--	--	2.5	--
Potassium (K) -----	.8	--	--	--	--	--	.7	--
Bicarbonate (HCO ₃) -----	6	6	5	5	6	6	6	10
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	5.6	--	--	--	--	--	5.3	--
Chloride (Cl)-----	3.8	--	--	--	--	--	3.1	--
Nitrate nitrogen (as N)-----	.23	.23	.24	.25	.16	.18	.00	.05
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.00	.00	.00	.01
Ammonia nitrogen (as N)-----	.04	.04	.05	.06	.05	.11	.04	.40
Organic nitrogen (as N)-----	.30	.32	.22	.24	.25	.15	.47	.37
Total phosphorus (as P)-----	.012	.009	.011	.010	.007	.019	.006	.022
Orthophosphate (as P)-----	.001	.002	--	.004	.004	.002	.004	.004
Suspended solids (110 °C)-----	1	--	--	--	--	--	1	--
Hardness as CaCO ₃ (Ca,Mg)-----	10	--	--	--	--	--	14	--
Specific conductance----- (micromhos at 25 °C)	33	33	33	33	36	32	35	37
pH (pH units)-----	6.9	6.8	6.5	7.3	6.8	6.4	6.3	5.7
Water temperature (°C)-----	5.1	4.9	10.1	5.0	21.0	5.5	21.5	6.0
Color (Pt-Co scale)-----	0	0	0	0	10	10	10	15
Secchi-disc (ft)-----		13		15		12		16
Dissolved oxygen (DO)-----	12.3	12.2	11.4	9.7	9.6	4.8	8.9	0.0
Chlorophyll <i>a</i> in photic zone- (µg/l)	2.8	--	2.0	--	2.3	--	.8	--
Fecal coliform Range-- (col. per 100 ml) Mean--		<1-1 <1		<1 <1		<1-7 2		<1-20 8
Total organic carbon (as C)--	3.6	--	4.4	--	6.2	--	8.4	--



EXPLANATION
 □—□ Temperature
 ▲—▲ Dissolved oxygen concentration
 —●— Dissolved oxygen concentration at 100 percent saturation



Ki Lake, Snohomish County. From Washington Department of Game, June 13, 1950.



Ki Lake, Snohomish County. June 2, 1970. Approx. scale 1:12,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Lackamas Lake at Camas (14144590)Location.

0.8 mile north of high school in Camas, Clark County; lat 45°36'16", long 122°24'22", sec. 2, T.1 N., R.3 E.; Washougal River basin; 179 feet altitude. Camas quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	320 acres	Length of shoreline-----	5.3 miles
Volume-----	7,500 acre-ft	Shoreline configuration---	2.1
Mean depth-----	24 ft	Development of volume-----	0.37
Maximum depth----	65 ft	Bottom slope-----	1.6 percent

Drainage basin.

Size: 64.3 mi².

Geology: Uplands are underlain by basalt. Lowlands are underlain by conglomerate, sandstone, shale, and mudstone, and by alluvial valley fill (Hunting and others, 1961).

Soils: Clay loam in the uplands and silt loam in the lowlands. Slopes are gentle to moderate (Phang and Gilkerson, 1964).

Land use	Percent
Urban-----	0
Suburban-----	<1
Agricultural-----	49
Forest or unproductive-----	50
Lake surface-----	1

Nearshore development.

Number of nearshore homes: 11.

Nearshore residential development: 3 percent.

Hydrology.

The lake has three inflows. The largest, Lacamas Creek, enters at the northwest end of the lake. On Feb. 20, Apr. 29, June 26, and Sept. 9, the inflow from Lacamas Creek was estimated to be 200, 40, 30, and 23 ft³/s, respectively. Drainage is southward to Round Lake, Lacamas Creek, and the Washougal River. The outflow is regulated.

The lake stage declined about 0.7 foot from Feb. 20 to Sept. 9, 1974.

Littoral bottom.

Mostly silt with some gravel, rock, muck, and sand.

Aquatic plants.Macrophytes:

Shoreline covered by emersed plants: 26-50 percent.

Lake surface covered by emersed plants: 1-10 percent.

Lake bottom covered by submersed plants: 26-50 percent.

Routed aquatic plants observed: Yellow lily (*Nuphar* sp.)*, cattail (*Typha* sp.), coontail (*Ceratophyllum* sp.), pondweed (*Potamogeton* sp.), rush (*Juncus* sp.), smartweed (*Polygonum* sp.), watershield (*Brasenia* sp.), waterweed (*Elodea* sp.), and white lily (*Nymphaea* sp.).

Algae observed:

Feb. 20, 1974: Greens and diatoms.

Apr. 29, 1974: Diatoms (*Fragillaria* sp.)* and greens (*Microspora* sp.)*.

June 26, 1974: Diatoms (*Fragillaria* sp.*, others), blue-greens, and yellow-browns.

Sept. 9, 1974: Diatoms (*Synedra* sp.*, others) and blue-greens.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Lackamas Lake was formed by the construction of two dams on Lacamas Creek. Nearshore residential development is light and approximately 35 percent of the east shore is bordered by a road. Recreational use of the lake is heavy. The inflow volume is large and the flushing rate is probably high. Numerous dead trees and snags protrude from the water.

The biological productivity of the lake was moderate to high. Inorganic nitrogen concentrations were moderate to high, and orthophosphate concentrations were low, throughout most of the year. Chlorophyll *a* concentrations increased gradually, from 1.6 µg/l in February to 23 µg/l in September. Fecal-coliform counts were very high in February but averaged no more than 2 colonies per 100 ml the remainder of the year.

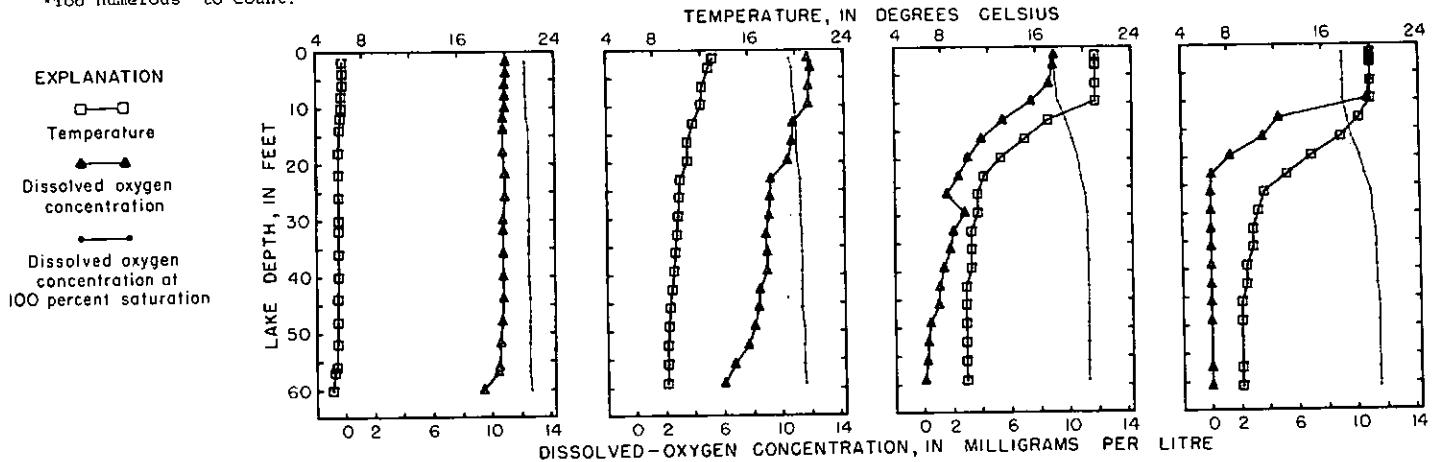
Thermal stratification was well established by June and DO concentrations in the hypolimnion were near zero.

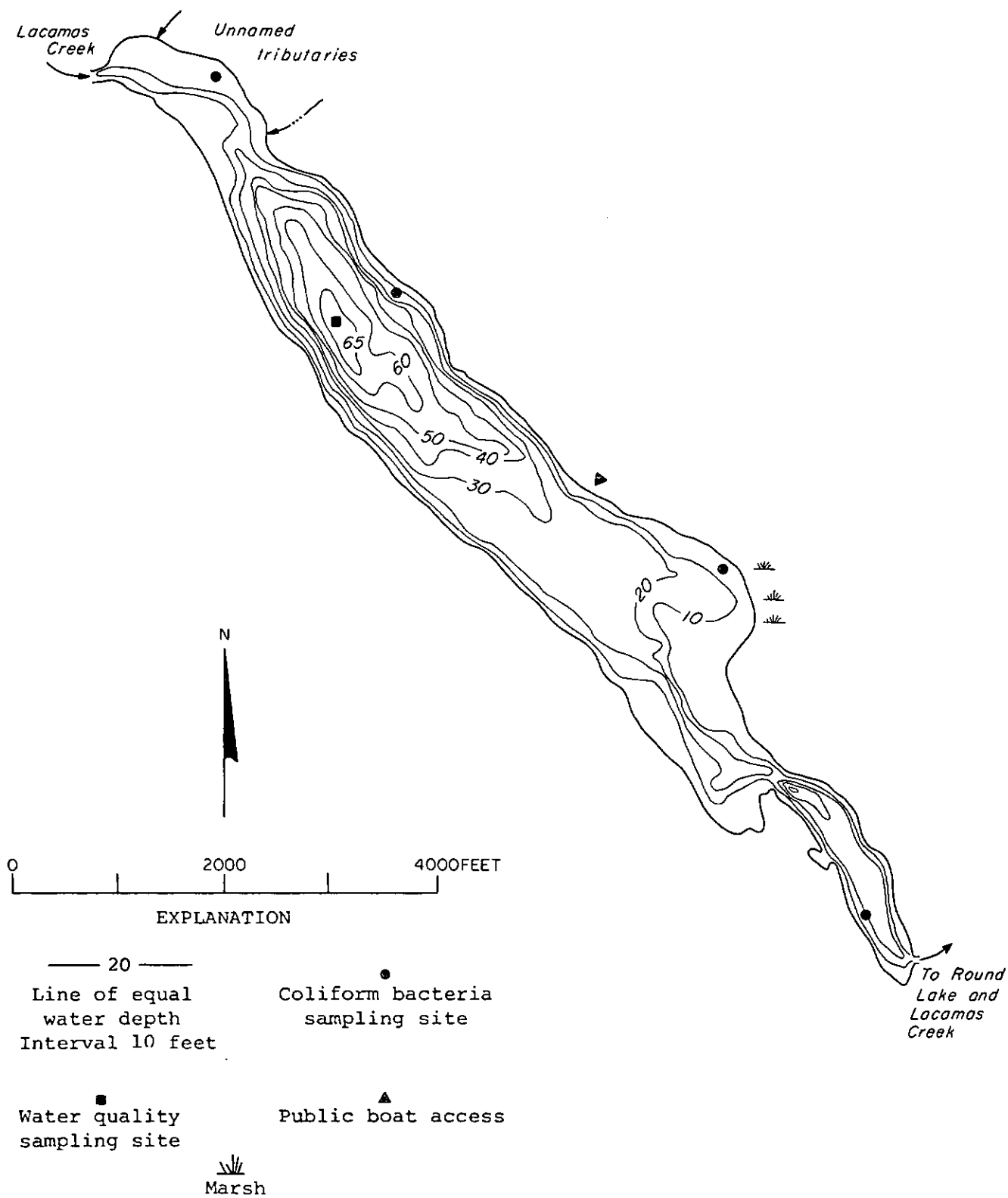
Water-quality data for Lackamas Lake at Camas

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 20		April 29		June 26		September 9	
	3	57	3	57	3	57	3	57
Water depth (ft)-----								
Silica (SiO ₂)-----	13	14	14	14	14	17	20	18
Dissolved iron (Fe), in µg/l--	370	640	240	520	200	1,400	160	6,200
Dissolved manganese (Mn)----- (in µg/l)	0	30	10	90	20	480	0	940
Calcium (Ca) -----	4.9	--	--	--	--	--	9.2	--
Magnesium (Mg) -----	1.4	--	--	--	--	--	2.2	--
Sodium (Na) -----	3.2	--	--	--	--	--	4.3	--
Potassium (K) -----	.9	--	--	--	--	--	1.9	--
Bicarbonate (HCO ₃) -----	18	20	26	22	38	27	44	38
Carbonate (CO ₃)-----	--	--	--	--	--	--	0	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	2.9	--	--	--	--	--	3.2	--
Chloride (Cl)-----	1.8	--	--	--	--	--	2.7	--
Nitrate nitrogen (as N)-----	.58	.61	.43	.41	.32	.53	.03	.00
Nitrite nitrogen (as N)-----	.01	.01	.01	.01	.01	.00	.01	.00
Ammonia nitrogen (as N)-----	.12	.15	.06	.26	.06	.16	.33	.71
Organic nitrogen (as N)-----	.26	.24	.21	.16	.26	.20	.37	.11
Total phosphorus (as P)-----	.045	.052	.034	.045	.047	.086	.038	.13
Orthophosphate (as P)-----	.012	.015	.003	.011	.004	.038	.003	.11
Suspended solids (110°C)-----	10	--	--	--	--	--	7	--
Hardness as CaCO ₃ (Ca,Mg)-----	18	--	--	--	--	--	32	--
Specific conductance----- (micromhos at 25°C)	42	45	52	47	73	55	85	86
pH (pH units)-----	7.1	7.0	7.4	6.6	7.8	6.6	8.4	6.3
Water temperature (°C)-----	6.3	5.6	12.6	9.0	21.0	10.0	20.0	9.0
Color (Pt-Co scale)-----	40	40	10	20	10	25	15	35
Secchi-disc (ft)-----		4.0		5.9		7.9		3.3
Dissolved oxygen (DO)-----	11.0	10.4	12.0	6.3	8.9	.2	11.0	.0
Chlorophyll <u>a</u> in photic zone- (µg/l)	1.6	--	4.2	--	14	--	23	--
Fecal coliform Range-- (col. per 100 ml) Mean---		41--*TNTC --		<1-10 2		<1-1 <1		<1-4 2
Total organic carbon (as C)--	4.5	--	6.4	--	5.2	--	9.2	--

*Too numerous to count.





Lackamas Lake, Clark County. From Washington Department of Game, November 18, 1947.



Lackamas Lake, Clark County. July 1, 1968. Approx. scale 1:15,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Lawrence Lake near Vail (12078940)Location.

4.3 miles east of Vail, Thurston County; lat 46°50'57", long 122°34'51"; NW¼NE¼ sec.29, T.16 N., R.2 E.; Deschutes River basin; 421 feet altitude.
Lake Lawrence quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	330 acres	Length of shoreline-----	4.0 miles
Volume-----	4,400 acre-ft	Shoreline configuration----	1.6
Mean depth-----	13 ft	Development of volume-----	0.51
Maximum depth-----	26 ft	Bottom slope-----	0.61 percent

Drainage basin.

Size: 3.35 mi².

Geology: Glacial drift materials consisting of compacted gravelly clay, and glaciofluvial deposits of poorly sorted gravel and sand (Noble and Wallace, 1966).

Soils: A complex pattern of stony sandy loam, loamy sand, gravelly loam, gravelly sandy loam, and peat (Ness, 1958).

Land use	Percent
Urban-----	0
Suburban-----	4
Agricultural-----	19
Forest or unproductive-----	63
Lake surface-----	14

Nearshore development.

Number of nearshore homes: 117.

Nearshore residential development: 39 percent.

Hydrology.

The lake has no surface-water inflow. Drainage is westward via a regulated stream to the Deschutes River. On Mar. 14 and Apr. 22 the outflow was 6.70 and 4.01 ft³/s, respectively. On subsequent sampling trips (June 18 and Aug. 29) the outflow channel was dry.

The lake stage declined 1.4 feet from Mar. 15 to Aug. 29, 1974.

Littoral bottom.

Cobble, rock, and gravel; some muck in southern part of lake.

Aquatic plants.Macrophytes:

Shoreline covered by emerged plants: 51-75 percent.

Lake surface covered by emerged plants: 1-10 percent.

Lake bottom covered by submersed plants: 26-50 percent.

Rooted aquatic plants observed: Cattail (*Typha* sp.)*, arrowhead (*Sagittaria* sp.), bulrush (*Scirpus* sp.), muskgrass (*Chara* sp.), pondweed (*Potamogeton* sp.), sedge (Cyperaceae), white lily (*Nymphaea* sp.), waterweed (*Elodea* sp.), wildcelery (*Vallisneria* sp.), and yellow lily (*Nuphar* sp.).

Algae observed:

Mar. 14, 1974: Diatoms (*Asterionella* sp., *Fragillaria* sp.)*, greens, and blue-greens.

Apr. 22, 1974: Blue-greens (*Nostoc* sp.*, others), greens, and diatoms.

June 18, 1974: Blue-greens (*Nostoc* sp.*, others), diatoms, and dinoflagellates.

Aug. 29, 1974: Blue-greens (*Nostoc* sp.)*.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Lawrence Lake is a large, spring-fed lake that has heavy recreational use. The nearshore residential development is 39 percent and is restricted in part by marshy conditions on the southeast side of the lake. Because of the large surface area and shallow mean depth, the bottom slope (0.61 percent) is relatively gentle.

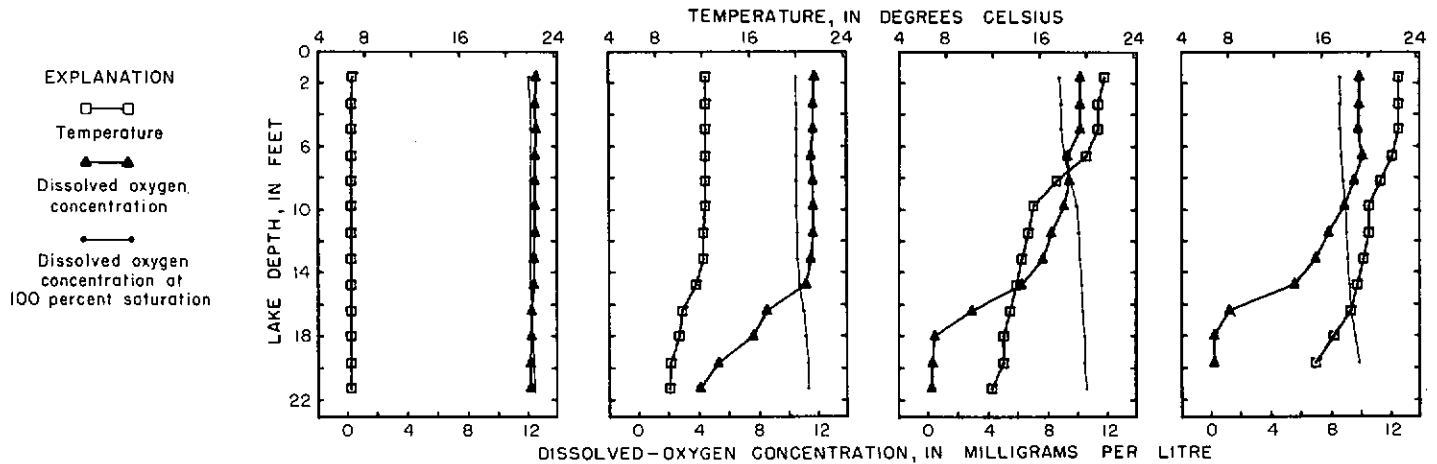
The biological productivity of the lake was moderate to high. Blooms of blue-green algae (*Nostoc* sp.) were observed in the lake as early as April and again in June and August. Chlorophyll *a* concentrations declined gradually, from 14 µg/l in March to 4.2 µg/l in August. The lake bottom in the littoral zone was covered with submersed aquatic macrophytes to a depth of about 20 feet.

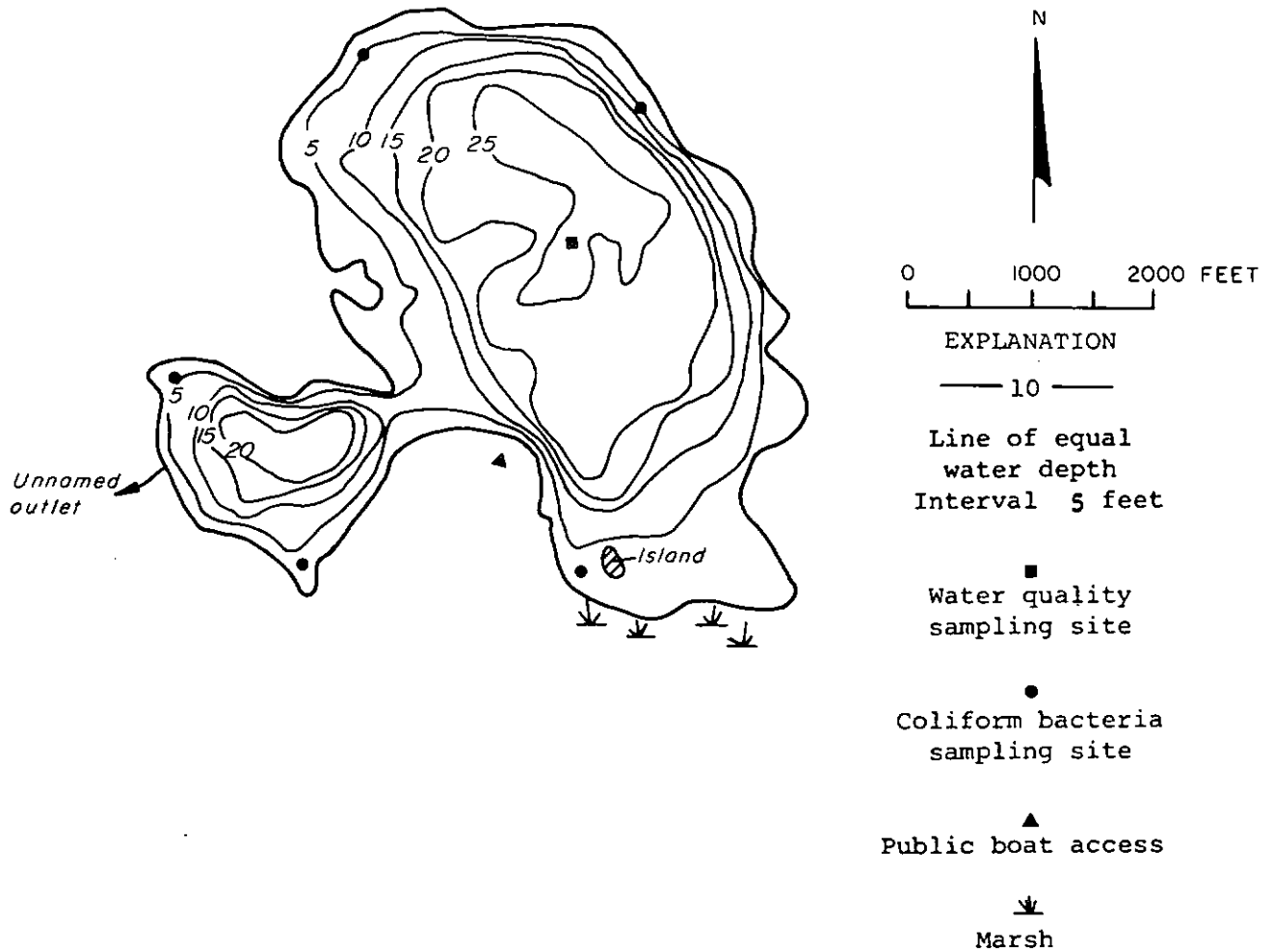
The lake was very weakly stratified in June and August; DO concentrations at that time were near zero at the very bottom of the lake.

Water-quality data for Lawrence Lake near Vail

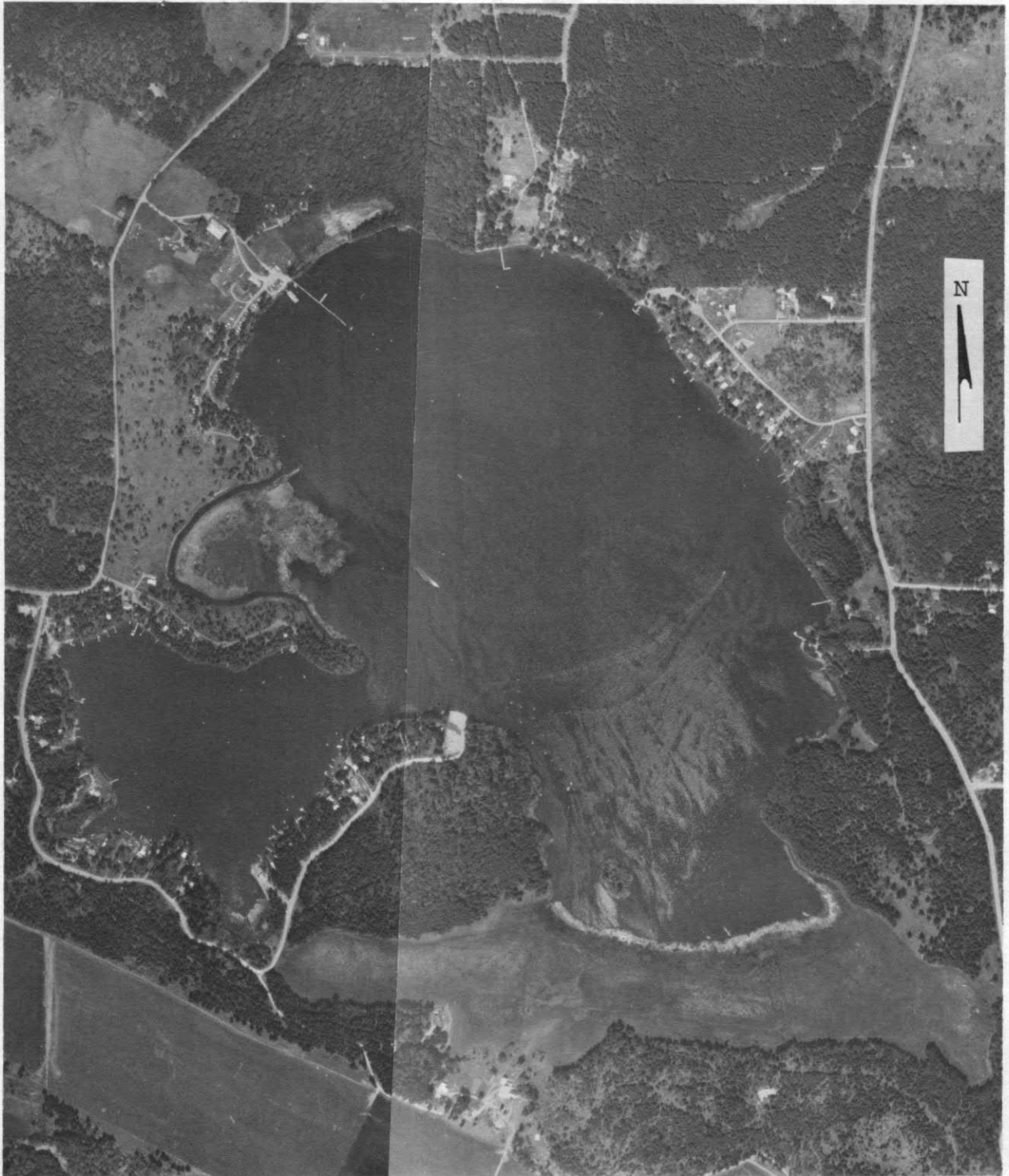
(Milligrams per litre unless otherwise indicated)

Date of collection (1974)-----	March 14		April 22		June 18		August 29	
	3	20	3	20	3	20	3	18
Water depth (ft)-----								
Silica (SiO ₂)-----	2.8	2.7	0.1	0.4	2.1	2.8	0.1	0.5
Dissolved iron (Fe), in µg/l--	220	230	230	350	490	1,700	180	1,400
Dissolved manganese (Mn)----- (in µg/l)	13	0	20	40	20	140	40	200
Calcium (Ca) -----	5.0	--	--	--	--	--	6.0	--
Magnesium (Mg) -----	2.4	--	--	--	--	--	3.0	--
Sodium (Na) -----	3.2	--	--	--	--	--	3.8	--
Potassium (K) -----	.9	--	--	--	--	--	.8	--
Bicarbonate (HCO ₃) -----	29	29	27	30	34	34	36	39
Carbonate (CO ₃)-----	--	--	--	--	0	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	3.0	--	--	--	--	--	1.9	--
Chloride (Cl)-----	3.2	--	--	--	--	--	2.8	--
Nitrate nitrogen (as N)-----	.03	.04	.01	.00	.01	.01	.01	.01
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N)-----	.14	.10	.07	.09	.07	.57	.10	.46
Organic nitrogen (as N)-----	.63	.56	.49	.42	.89	.53	.81	.84
Total phosphorus (as P)-----	.055	.045	.027	.041	.032	.29	.027	.095
Orthophosphate (as P)-----	.002	.002	.003	.002	.003	.092	.002	.011
Suspended solids (110 °C)-----	41	--	--	--	--	--	1	--
Hardness as CaCO ₃ (Ca,Mg)-----	22	--	--	--	--	--	27	--
Specific conductance----- (micromhos at 25 °C)	53	53	60	63	70	82	68	77
pH (pH units)-----	8.3	8.2	8.2	7.8	9.4	7.2	8.2	6.2
Water temperature (°C)-----	6.8	6.8	12.2	9.3	21.0	13.0	22.5	17.0
Color (Pt-Co scale)-----	35	35	35	35	35	55	25	70
Secchi-disc (ft)-----		6.6		5.2		5.2		7.5
Dissolved oxygen (DO)-----	12.4	12.1	11.6	5.3	10.1	.3	9.9	.2
Chlorophyll a in photic zone- (µg/l)	14	--	12	--	11	--	4.2	--
Fecal coliform (col. per 100 ml)	Range-- Mean--	-- --	<1-1 <1		<1-1 1		<1-6 2	
Total organic carbon (as C)---	6.2	--	9.6	--	11	--	11	--





Lawrence Lake, Thurston County. From Washington
Department of Game, June 5, 1951.



Lawrence Lake, Thurston County. May 13, 1972. Approx. scale 1:12,000.

Martha Lake near Silvana (12158072)Location.

4.9 miles southwest of Silvana, Snohomish County; lat 48°10'03", long 122°20'45";
SE¼SW¼ sec.18, T.31 N., R.4 E.; Puget Sound basin; 186 feet altitude.
Stanwood quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	62 acres	Length of shoreline-----	1.8 miles
Volume-----	2,000 acre-ft	Shoreline configuration----	1.6
Mean depth-----	33 ft	Development of volume-----	0.47
Maximum depth-----	70 ft	Bottom slope-----	3.8 percent

Drainage basin.

Size: 1.63 mi².

Geology: Gray, compact ground-moraine deposits (Newcomb, 1952).

Soils: Predominantly gravelly sandy loam underlain by compact glacial till. Local areas of clay loam and peat (Anderson and others, 1947).

Land use	Percent
Urban-----	0
Suburban-----	5
Agricultural-----	13
Forest or unproductive-----	73
Lake surface-----	9

Nearshore development.

Number of nearshore homes: 44.

Nearshore residential development: 77 percent.

Hydrology.

The lake has three small inflows. On Mar. 11 and Apr. 24, the combined inflow volumes were estimated to be 2.7 and 1.1 ft³/s, respectively. On subsequent sampling trips (June 20 and Aug. 27) the inflow channels were dry. Drainage is westward via an unnamed stream to Port Susan of Puget Sound. On Mar. 11 and Apr. 24, the outflow was 4.71 and 1.31 ft³/s, respectively. On subsequent sampling trips the outflow channel was dry.

The lake stage declined 3.0 feet from Mar. 17 to Oct. 26, 1974.

Littoral bottom.

Silt, gravel, rock, and sand, covered with wood debris.

Aquatic plants.Macrophytes:

Shoreline covered by emerged plants: 1-10 percent.

Lake surface covered by emerged plants: <1 percent.

Lake bottom covered by submersed plants: 1-10 percent.

Rooted aquatic plants observed: yellow lily (Nuphar sp.)*, bulrush (Scirpus sp.), cattail (Typha sp.), quillwort (Isoetes sp.), and sedge (Cyperaceae).

Algae observed:

Mar. 11, 1974: Diatoms (Tabellaria sp., Asterionella sp., Fragillaria sp.)* and greens (Microspora sp.)*.

Apr. 24, 1974: Diatoms (Tabellaria sp.*, others) and yellow-browns (Dinobryon sp.)*.

June 20, 1974: Diatoms (Tabellaria sp.)*, greens, and yellow-browns.

Aug. 27, 1974: Blue-greens (Nostoc sp.)* and diatoms.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Martha Lake is in a rural, forested part of Snohomish County. The lake is deep in relation to its surface area and the bottom slope (3.8 percent) is therefore steep. The domestic water for the town of Warm Beach is drawn directly from the lake. The nearshore residential development is 77 percent but localized.

The biological productivity of the lake was moderate. The only submersed aquatic macrophyte observed was quillwort. Fecal-coliform-bacteria counts were low except in August, when the colonies in one sample were too numerous to count.

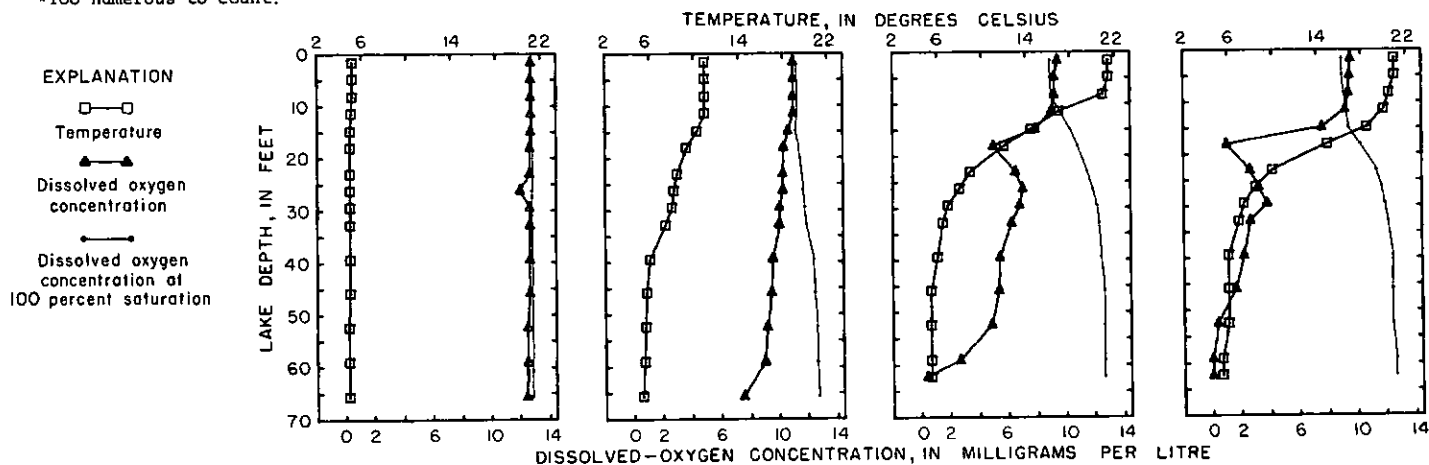
Thermal stratification was well established by June. No serious DO depletion was observed until August, at which time DO was near zero in the hypolimnion.

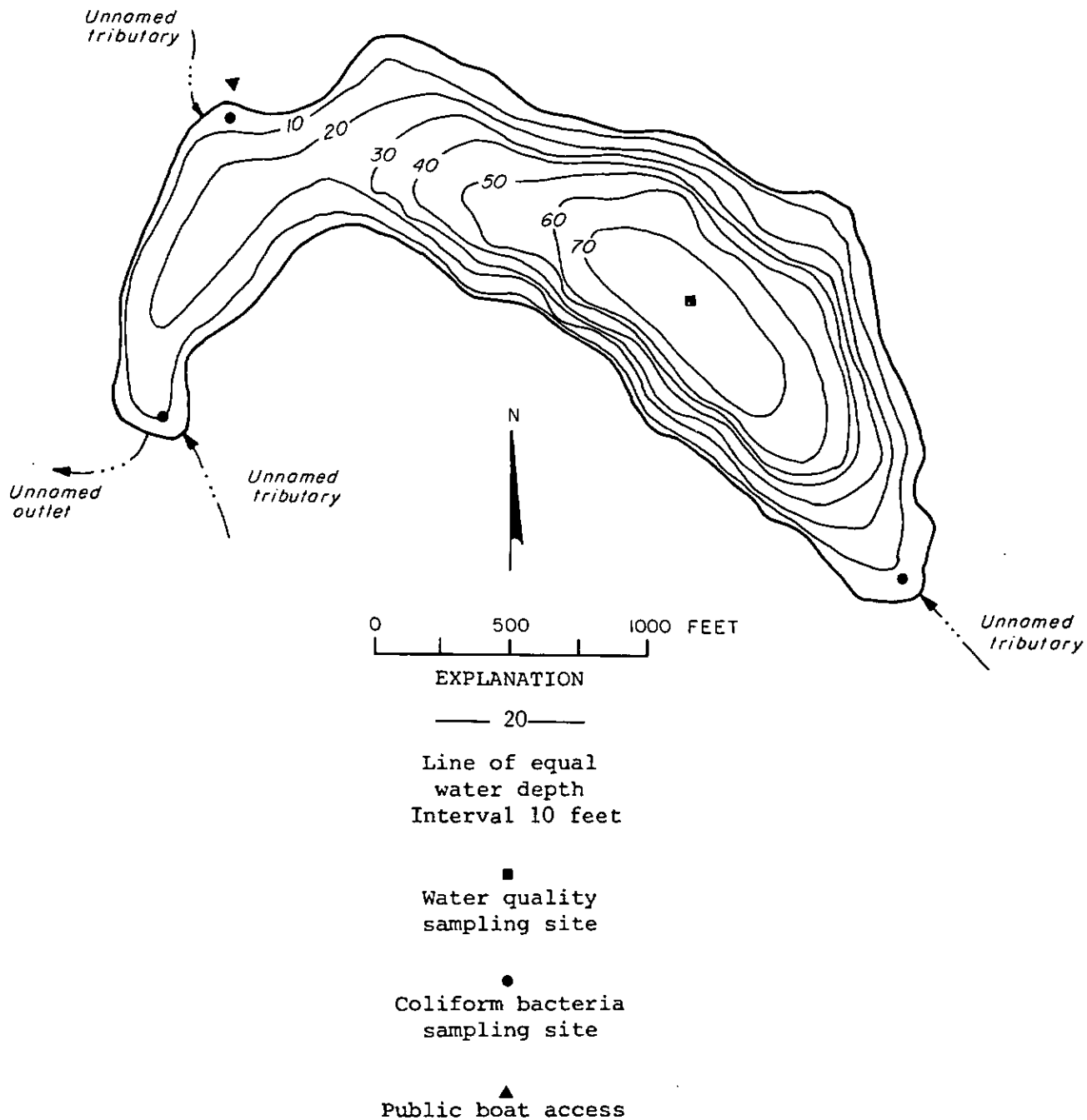
Water-quality data for Martha Lake near Silvana

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	March 11		April 24		June 20		August 27	
	3	62	3	64	3	62	3	59
Water depth (ft)-----								
Silica (SiO ₂)-----	0.4	0.3	0.0	0.6	0.2	1.9	0.1	2.3
Dissolved iron (Fe), in µg/l--	80	80	70	120	50	190	80	330
Dissolved manganese (Mn)----- (in µg/l)	0	0	0	20	10	100	0	220
Calcium (Ca) -----	4.8	--	--	--	--	--	5.0	--
Magnesium (Mg) -----	2.9	--	--	--	--	--	3.0	--
Sodium (Na) -----	4.5	--	--	--	--	--	4.5	--
Potassium (K) -----	1.1	--	--	--	--	--	1.1	--
Bicarbonate (HCO ₃) -----	19	19	18	19	22	21	24	26
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	6.6	--	--	--	--	--	7.4	--
Chloride (Cl)-----	6.7	--	--	--	--	--	5.6	--
Nitrate nitrogen (as N)-----	.43	.46	.42	.41	.15	.47	.01	.19
Nitrite nitrogen (as N)-----	.00	00	.00	.00	.01	.00	.01	.05
Ammonia nitrogen (as N)-----	.05	.05	.06	.16	.07	.05	.06	.32
Organic nitrogen (as N)-----	.43	.36	.38	.32	.35	.32	.40	.13
Total phosphorus (as P)-----	.012	.011	.022	.014	.017	.029	.012	.035
Orthophosphate (as P)-----	.005	.005	.011	.007	.002	.013	.012	.008
Suspended solids (110°C)-----	4	--	--	--	--	--	1	--
Hardness as CaCO ₃ (Ca,Mg)----	24	--	--	--	--	--	25	--
Specific conductance----- (micromhos at 25°C)	64	65	68	66	74	65	72	67
pH (pH units)-----	7.6	7.8	7.4	6.9	7.3	6.8	7.3	6.0
Water temperature (°C)-----	5.2	4.9	11.0	5.4	21.5	5.5	21.0	5.5
Color (Pt-Co scale)-----	40	40	25	25	35	35	25	35
Secchi-disc (ft)-----		9.8		9.8		9.2		9.8
Dissolved oxygen (DO)-----	12.7	12.4	11.0	8.0	9.2	.4	9.6	.0
Chlorophyll <i>a</i> in photic zone- (µg/l)	5.2	--	1.8	--	3.5	--	3.4	--
Fecal coliform Range-- (col. per 100 ml) Mean--		<1-2 1		1-3 2		1-9 4		5-*TNTC --
Total organic carbon (as C)--	7.3	--	7.8	--	11	--	20	--

*Too numerous to count.





Martha Lake, Snohomish County. From Washington Department of Game, January 31, 1948.



Martha Lake, Snohomish County. June 2, 1970.
Approx. scale 1:12,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Minkler Lake at Minkler (12197100)Location.

0.2 mile north of Minkler, Skagit County; lat 48°31'24", long 122°06'11";
sec.13, T.35 N., R.5 E.; Skagit River basin; 60 feet altitude.
Wickersham quadrangle (1:62,500 scale).
Location is of southernmost shoreline point of lake.

Physical characteristics of lake.

Surface area-----	33 acres	Length of shoreline-----	3.1 miles
Volume-----	86 acre-ft	Shoreline configuration----	3.9
Mean depth-----	3 ft	Development of volume-----	0.33
Maximum depth-----	8 ft	Bottom slope-----	0.60 percent

Drainage basin.

Size: 5.61 mi².

Geology: Uplands are underlain by metamorphic rocks. Lowlands are underlain by unconsolidated glacial drift and alluvium (Hunting and others, 1961).

Soils: Gravelly loam mantles rough broken land on the uplands; silt loam and fine sandy loam underlie the lowlands (Ness and others, 1960).

Land use	Percent
Urban-----	0
Suburban-----	0
Agricultural-----	6
Forest or unproductive----	93
Lake surface-----	1

Nearshore development.

Number of nearshore homes: 4 (permanent).

Nearshore residential development: 7 percent.

Hydrology.

The lake has two inflows, Tank Creek and Childs Creek. On Feb. 28, May 9, and July 11, the combined inflows were estimated to be 14, 8.0, and 3.4 ft³/s, respectively. On Sept. 19 both inflow channels were dry. There is no well-defined outflow channel.

The lake stage declined 0.1 foot from Feb. 28 to July 11, 1974.

Littoral bottom.

Mostly clay with some muck, silt, and wood debris.

Aquatic plants.Macrophytes:

Shoreline covered by emerged plants: 51-75 percent.

Lake surface covered by emerged plants: 11-25 percent.

Lake bottom covered by submersed plants: 76-100 percent.

Rooted aquatic plants observed: Yellow lily (Nuphar sp.)*, pondweed (Potamogeton sp.)*, cattail (Typha sp.), coontail (Ceratophyllum sp.), milfoil (Myriophyllum sp.), rush (Juncus sp.), sedge (Cyperaceae), smartweed (Polygonum sp.), and waterweed (Elodea, sp.).

Algae observed:

Feb. 28, 1974: None.

May 19, 1974: None.

July 11, 1974: Greens (Volvox sp.)*.

Sept. 19, 1974: None.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Minkler Lake is a long, narrow, shallow lake situated on the flood plain of the Skagit River in what may be an abandoned river channel. In addition to being shallow, the lake has a small volume (86 acre-ft), high shoreline configuration (3.9), and gentle bottom slope (0.60 percent). Logs and wood debris were scattered throughout the lake.

The biological productivity of the lake was moderate to high. Inorganic nitrogen concentrations were high (0.72 mg/l) in February but had decreased significantly by May. The lake bottom was almost completely covered with aquatic macrophytes; high densities of green algae (Volvox sp.) were observed in July. Fecal-coliform-bacteria counts were generally high and the colonies in some samples taken in July and September were too numerous to count.

The lake is too shallow to stratify; temperature and DO profiles were nearly uniform throughout the year.

Water-quality data for Minkler Lake at Minkler

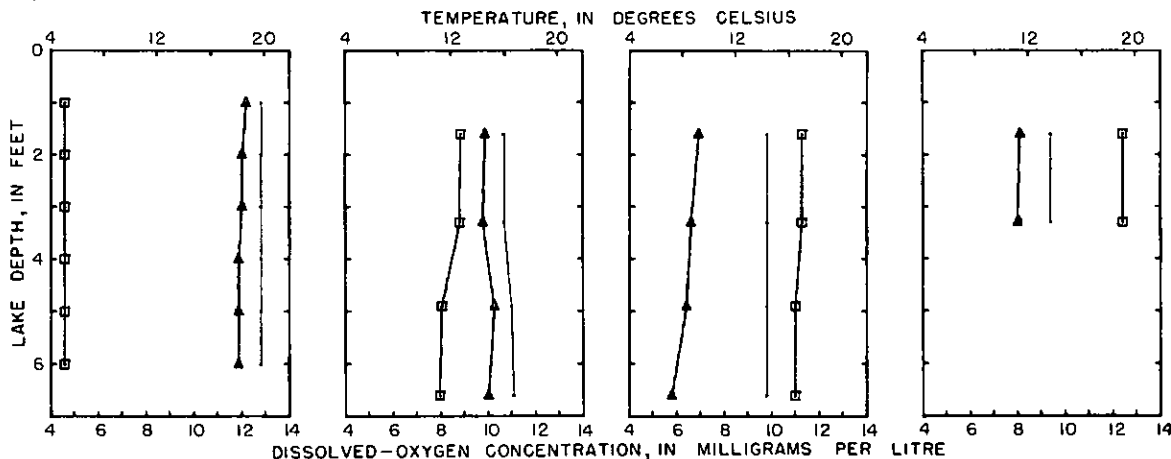
[Milligrams per litre unless otherwise indicated]

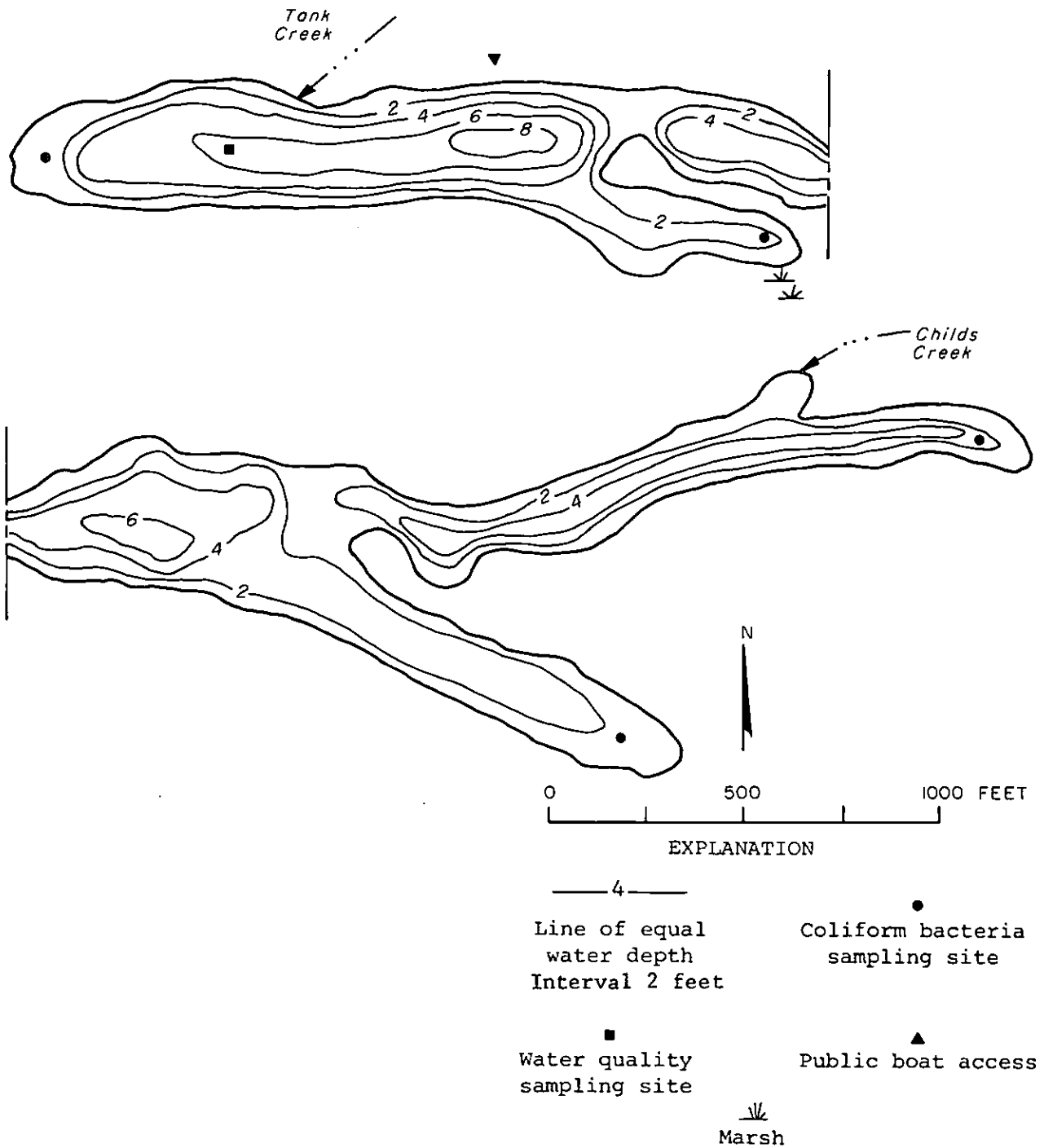
Date of collection (1974)-----	February 28		May 9		July 11		September 19	
	3	(a)	3	(a)	3	(a)	3	(a)
Water depth (ft)-----								
Silica (SiO ₂)-----	8.8	--	4.9	--	4.2	--	0.3	--
Dissolved iron (Fe), in µg/l--	390	--	550	--	980	--	630	--
Dissolved manganese (Mn)----- (in µg/l)	0	--	70	--	60	--	60	--
Calcium (Ca) -----	6.1	--	--	--	--	--	5.9	--
Magnesium (Mg) -----	2.6	--	--	--	--	--	3.3	--
Sodium (Na) -----	2.5	--	--	--	--	--	3.3	--
Potassium (K) -----	1.0	--	--	--	--	--	.6	--
Bicarbonate (HCO ₃) -----	22	--	25	--	36	--	35	--
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	4.3	--	--	--	--	--	3.0	--
Chloride (Cl)-----	1.8	--	--	--	--	--	2.5	--
Nitrate nitrogen (as N)-----	.64	--	.12	--	.00	--	.01	--
Nitrite nitrogen (as N)-----	.00	--	.00	--	.00	--	.00	--
Ammonia nitrogen (as N)-----	.08	--	.04	--	.11	--	.09	--
Organic nitrogen (as N)-----	.30	--	.47	--	.46	--	.33	--
Total phosphorus (as P)-----	.020	--	.038	--	.021	--	.024	--
Orthophosphate (as P)-----	.002	--	.005	--	.005	--	.002	--
Suspended solids (110°C)-----	9	--	--	--	--	--	0	--
Hardness as CaCO ₃ (Ca,Mg)----	26	--	--	--	--	--	28	--
Specific conductance----- (micromhos at 25°C)	53	--	46	--	59	--	61	--
pH (pH units)-----	7.2	--	7.5	--	7.4	--	7.0	--
Water temperature (°C)-----	5.1	--	12.6	--	17.0	--	19.0	--
Color (Pt-Co scale)-----	20	--	30	--	60	--	55	--
Secchi-disc (ft)-----		4.9		5.2		5.2		4.9
Dissolved oxygen (DO)-----	12.0	--	9.8	--	6.6	--	8.0	--
Chlorophyll <u>a</u> in photic zone- (µg/l)	3.7	--	9.3	--	6.9	--	9.4	--
Fecal coliform Range--		4-99		18-86		8- ^a TNTC		2- ^a TNTC
(col. per 100 ml) Mean--		31		58		--		--
Total organic carbon (as C)--	7.9	--	6.4	--	8.6	--	9.1	--

*Too numerous to count.

^aNot taken.

EXPLANATION
 □—□ Temperature
 ▲—▲ Dissolved oxygen concentration
 — Dissolved oxygen concentration of 100 percent saturation





Minkler Lake, Skagit County. From U.S. Geological Survey, January 23, 1974.



Minkler Lake, Skagit County. July 20, 1974. Approx. scale 1:6000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Padden Lake at Bellingham (12201900)Location.

2.5 miles southeast of Western Washington State College, Whatcom County; lat 48°42'15", long 122°27'41"; SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec.8, T.37 N., R.3 E.; Puget Sound basin; 447 feet altitude. Bellingham South quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	160 acres	Length of shoreline-----	2.3 miles
Volume-----	4,300 acre-ft	Shoreline configuration----	1.3
Mean depth-----	27 ft	Development of volume-----	0.46
Maximum depth-----	59 ft	Bottom slope-----	2.0 percent

Drainage basin.

Size: 2.63 mi².

Geology: Massive sandstone with interbedded conglomerate and siltstone (Hunting and others, 1961).

Soils: A mixture of loam and silt loam on rough mountainous land with moderate to steep slopes (Poulson and Flannery, 1953).

Land use	Percent
Urban-----	0
Suburban-----	<1
Agricultural-----	5
Forest or unproductive-----	86
Lake surface-----	9

Nearshore development.

Number of nearshore homes: 0.

Nearshore residential development: 0 percent.

Hydrology.

The lake has three small inflows. On Feb. 26, May 7, and July 9, the combined inflows were estimated to be 0.1, 3.8, and 1.0 ft³/s, respectively. On Sept. 17 all three inflow channels were dry. Drainage is westward via Padden Creek to Bellingham Bay of Puget Sound. The outflow is regulated and was not measured.

The lake stage declined 1.4 feet from Feb. 26 to Sept. 17, 1974.

Littoral bottom.

Silt, sand, and gravel.

Aquatic plants.Macrophytes:

Shoreline covered by emersed plants: 11-25 percent.

Lake surface covered by emersed plants: <1 percent.

Lake bottom covered by submersed plants: 1-10 percent.

Rooted aquatic plants observed: Yellow lily (Nuphar sp.)*, pondweed (Potamogeton sp.)*, Bulrush (Scirpus sp.), bushy pondweed (Najas sp.), cattail (Typha sp.), muskgrass (Chara sp.), sedge (Carex sp.), smartweed (Polygonum sp.), and wildcelery (Vallisneria sp.).

Algae observed:

Feb. 26, 1974: Greens (Microspora sp.)* and diatoms (Asterionella sp.*, others).

May 7, 1974: Diatoms.

July 9, 1974: Yellow-browns.

Sept. 17, 1974: blue-greens.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Padden Lake is on the outskirts of the city of Bellingham. A park and swimming beach are situated on the north shore of the lake and a golf course is on the east shore, but there is no nearshore residential development.

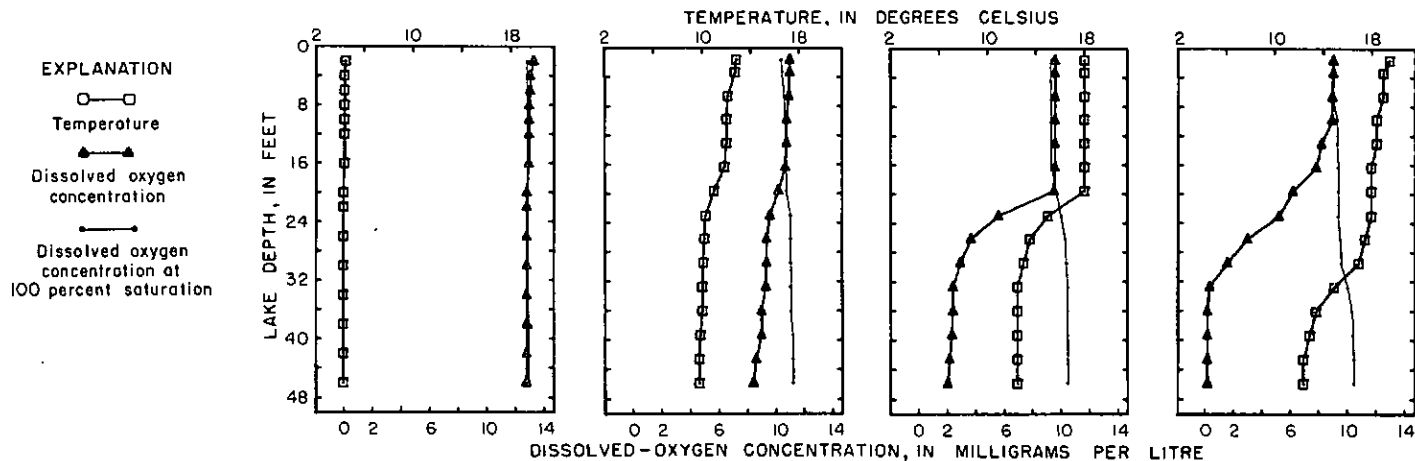
The biological productivity of the lake was low to moderate. Inorganic nitrogen concentrations decreased gradually from 0.58 mg/l in February to 0.04 mg/l in September. Fecal-coliform bacteria levels were moderately high in May and July but considerably lower in February and September.

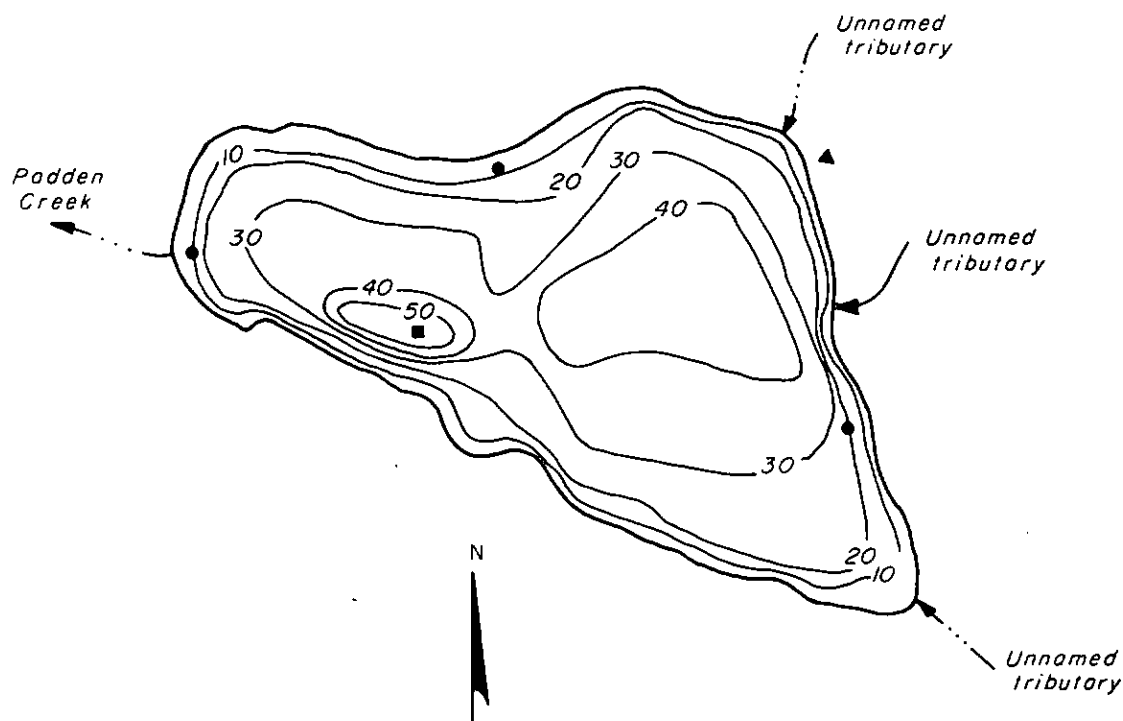
Thermal stratification was weakly developed, but by September approximately 12 percent of the lake volume had DO concentrations near zero.

Water-quality data for Padden Lake at Bellingham

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 26		May 7		July 9		September 17	
Water depth (ft)-----	3	46	3	43	3	43	3	43
Silica (SiO ₂)-----	6.5	6.4	3.3	3.7	3.5	5.8	3.7	8.1
Dissolved iron (Fe), in µg/l--	130	440	100	250	120	110	70	2,600
Dissolved manganese (Mn)----- (in µg/l)	0	10	10	20	0	40	30	570
Calcium (Ca) -----	5.2	--	--	--	--	--	13	--
Magnesium (Mg) -----	1.8	--	--	--	--	--	.8	--
Sodium (Na) -----	7.5	--	--	--	--	--	8.0	--
Potassium (K) -----	.7	--	--	--	--	--	.9	--
Bicarbonate (HCO ₃) -----	17	17	18	19	21	21	23	30
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	8.1	--	--	--	--	--	8.7	--
Chloride (Cl)-----	7.8	--	--	--	--	--	8.1	--
Nitrate nitrogen (as N)-----	.53	.53	.40	.38	.22	.23	.00	.00
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.01	.01	.00	.00
Ammonia nitrogen (as N)-----	.05	.05	.04	.05	.05	.11	.04	.41
Organic nitrogen (as N)-----	.24	.27	.23	.24	.21	.14	.17	.08
Total phosphorus (as P)-----	.015	.013	.011	.010	.008	.011	.008	.070
Orthophosphate (as P)-----	.002	.002	.004	.003	.002	.002	.001	.051
Suspended solids (110°C)-----	10	--	--	--	--	--	0	--
Hardness as CaCO ₃ (Ca,Mg)----	20	--	--	--	--	--	36	--
Specific conductance----- (micromhos at 25°C)	71	71	74	74	77	75	80	88
pH (pH units)-----	7.6	7.8	7.4	7.1	7.3	6.3	7.6	6.6
Water temperature (°C)-----	4.4	4.3	12.7	9.8	18.0	12.5	19.0	12.5
Color (Pt-Co scale)-----	5	5	0	5	10	10	25	40
Secchi-disc (ft)-----	11		14		13		9.8	
Dissolved oxygen (DO)-----	13.2	12.8	11.0	8.6	9.6	2.2	9.0	.2
Chlorophyll <u>a</u> in photic zone- (µg/l)	2.9	--	2.0	--	1.5	--	2.0	--
Fecal coliform Range-- (col. per 100 ml) Mean---	<1-2 1		<1-126 42		10-195 76		1-45 20	
Total organic carbon (as C)--	6.0	--	5.6	--	3.7	--	6.1	--





0 1000 2000 FEET

EXPLANATION

— 20 —

Line of equal
water depth
Interval 10 feet

■
Water quality
sampling site

●
Coliform bacteria
sampling site

▲
Public boat access

Padden Lake, Whatcom County. From U.S. Geological Survey,
January 28, 1974.



Padden Lake, Whatcom County. June 16, 1969. Approx. scale 1:12,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Patterson Lake near Winthrop (12447388)Location.

3.1 miles west of Winthrop, Okanogan County; lat 48°27'59", long 120°14'59";
 NW¼NW¼ sec.8, T.34 N., R.21 E.; Methow River basin; 2,387 feet altitude.
 Winthrop quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	130 acres	Length of shoreline-----	3.1 miles
Volume-----	4,300 acre-ft	Shoreline configuration----	2.0
Mean depth-----	33 ft	Development of volume-----	0.39
Maximum depth-----	85 ft	Bottom slope-----	3.2 percent

Drainage basin.

Size: Not measured because water is imported from outside the drainage basin.
 Geology: Chiefly marine sedimentary rocks with local areas of volcanic rocks
 (Hunting and others, 1961).
 Soils: Acidic sandy loam to silt loam (U.S. Soil Conservation Service, 1968).

Land use	Percent
Urban-----	} Not determined because water is imported from outside the drainage basin.
Suburban-----	
Agricultural-----	
Forest or unproductive-----	
Lake surface-----	

Nearshore development.

Number of nearshore homes: 3.
 Nearshore residential development: 2 percent.

Hydrology.

The principal inflow is Rader Creek, although small amounts of water diverted from outside the drainage basin (Wolf Creek) occasionally reach the lake. On Apr. 16, May 21, and July 16, the inflow from Rader Creek was estimated to be 14, 1.5, and 0.5 ft³/s, respectively. On Sept. 24 Rader Creek was dry. Drainage is northeastward via an unnamed stream to the Methow River. The outflow is regulated and was not measured.

The stage of Padden Lake, which is regulated, declined about 10.7 feet from May 21 to Sept. 24, 1974.

Littoral bottom.

Silt, sand, gravel, and rock, with some wood debris.

Aquatic plants.

Macrophytes:

Shoreline covered by emersed plants: <1 percent.
 Lake surface covered by emersed plants: <1 percent.
 Lake bottom covered by submersed plants: 11-25 percent.
 Rooted aquatic plants observed: Smartweed (*Polygonum* sp.*), bulrush (*Scirpus* sp.),
 milfoil (*Myriophyllum* sp.), muskgrass (*Chara* sp.), stonewort (*Nitella* sp.),
 pondweed (*Potamogeton* sp.), and waterweed (*Elodea* sp.).

Algae observed:

Apr. 16, 1974: Diatoms.
 May 21, 1974: Diatoms and dinoflagellates.
 July 16, 1974: Blue-greens.
 Sept. 24, 1974: Blue-greens (*Nostoc* sp.*, others) and diatoms.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Patterson Lake in Okanogan County is a natural lake that was enlarged by a dam in 1924. The lake is fed in part by diversions from Wolf Creek and therefore large water-level fluctuations are common. The lake water is used for irrigation purposes. The shoreline configuration of the lake (2.0) is high and the bottom slope (3.2 percent) is moderately steep.

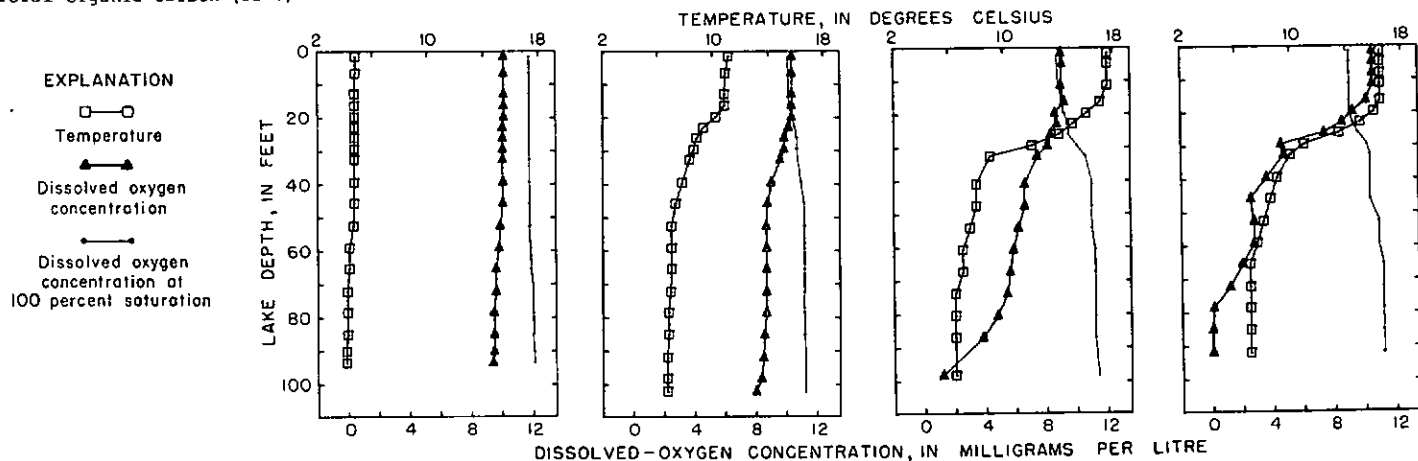
The biological productivity of the lake was low to moderate. Nutrient concentrations and fecal-coliform counts were low throughout the year. Very few aquatic macrophytes were observed along the shoreline, due in part to the large water-level fluctuations.

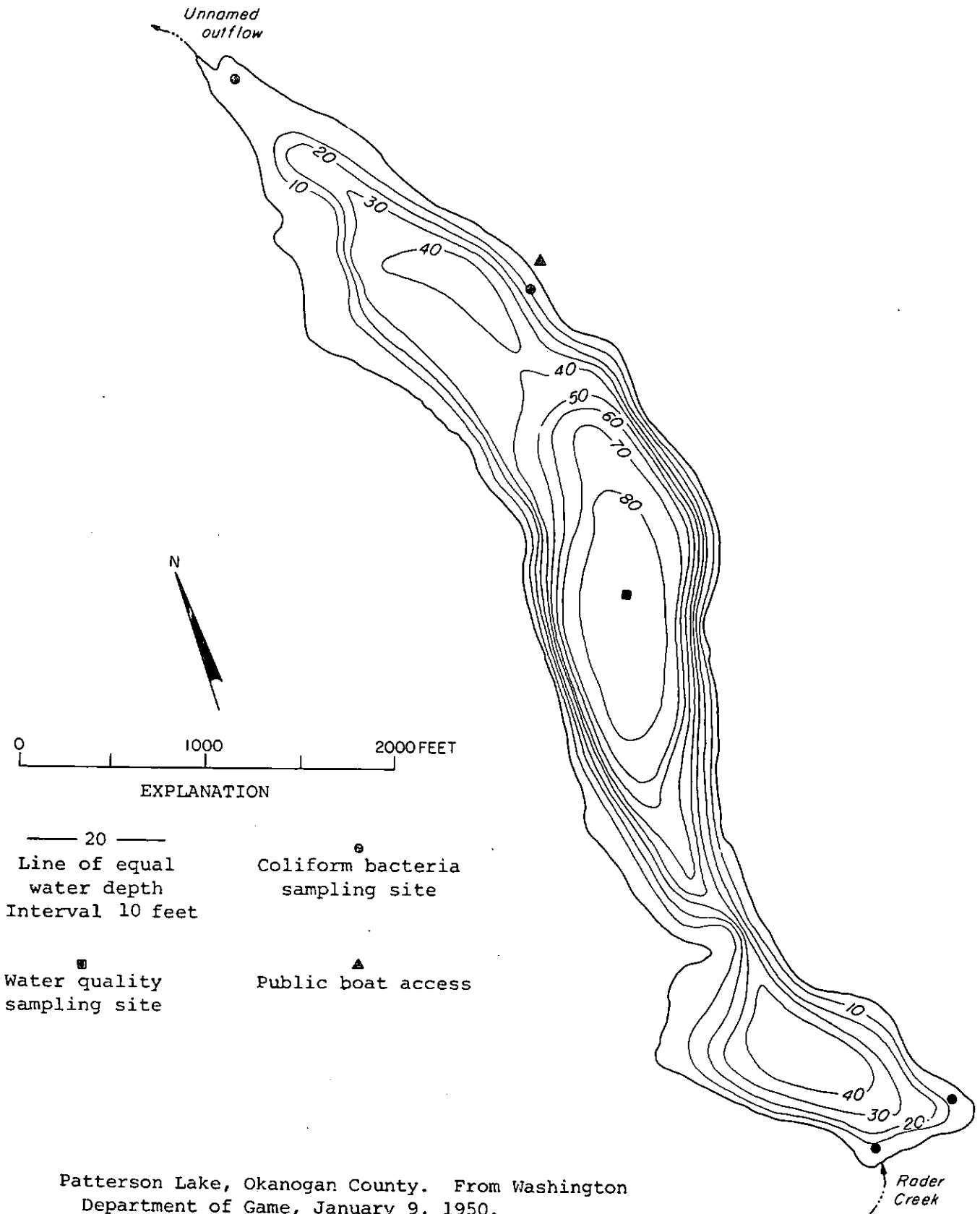
Thermal stratification was well established by July. Serious DO depletions were not observed until September, at which time the DO concentration of the water at the very bottom of the lake was near zero.

Water-quality data for Patterson Lake near Winthrop

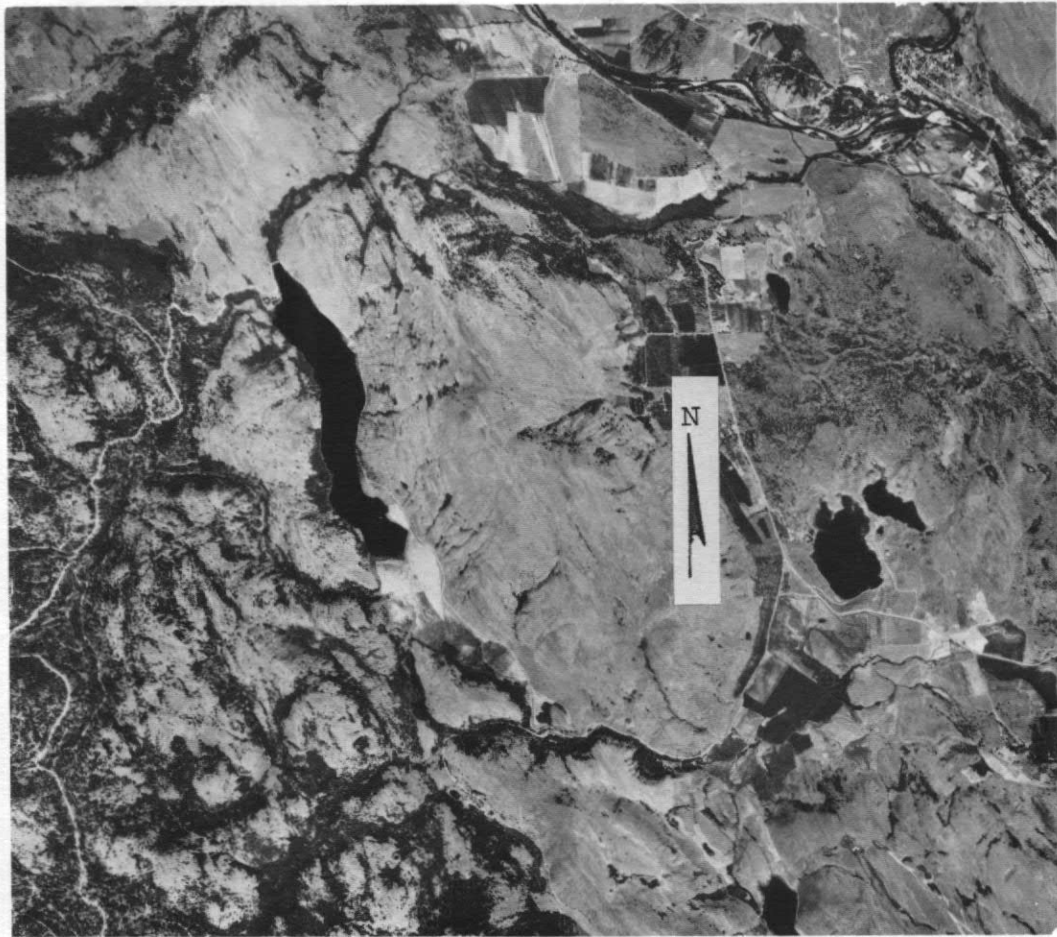
[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	April 16		May 21		July 16		September 24	
	3	90	3	98	3	95	3	89
Water depth (ft)-----								
Silica (SiO ₂)-----	11	11	11	11	9.0	12	7.9	15
Dissolved iron (Fe), in µg/l--	70	180	20	30	40	40	20	310
Dissolved manganese (Mn)----- (in µg/l)	60	80	0	60	30	260	30	1,100
Calcium (Ca) -----	27	--	--	--	--	--	32	--
Magnesium (Mg) -----	7.2	--	--	--	--	--	7.8	--
Sodium (Na) -----	4.8	--	--	--	--	--	4.3	--
Potassium (K) -----	.6	--	--	--	--	--	.6	--
Bicarbonate (HCO ₃) -----	120	120	130	130	120	130	110	130
Carbonate (CO ₃)-----	--	--	0	--	--	--	1	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	6.2	--	--	--	--	--	4.4	--
Chloride (Cl)-----	.3	--	--	--	--	--	1.0	--
Nitrate nitrogen (as N)-----	.03	.03	.01	.02	.01	.24	.01	.14
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N)-----	.05	.05	.04	.07	.02	.07	.02	.21
Organic nitrogen (as N)-----	.29	.22	.18	.14	.14	.12	.16	.16
Total phosphorus (as P)-----	.030	.024	.011	.011	.010	.034	.012	.087
Orthophosphate (as P)-----	.006	.002	.003	.005	.001	.018	.001	.046
Suspended solids (110°C)-----	2	--	--	--	--	--	4	--
Hardness as CaCO ₃ (Ca, Mg)----	97	--	--	--	--	--	110	--
Specific conductance----- (micromhos at 25°C)	160	160	180	180	180	170	160	170
pH (pH units)-----	7.8	7.7	8.6	8.2	8.4	7.5	8.4	7.2
Water temperature (°C)-----	4.8	4.1	11.0	6.7	17.5	6.5	16.5	7.0
Color (Pt-Co scale)-----	20	20	10	15	10	15	0	10
Secchi-disc (ft)-----		8.5		14		16		11
Dissolved oxygen (DO)-----	10.2	9.5	10.4	8.4	9.1	1.6	10.6	.0
Chlorophyll <u>a</u> in photic zone- (µg/l)	5.5	--	1.4	--	.7	--	3.8	--
Fecal coliform Range--	<1-1		<1-1		<1-2		<1	
(col. per 100 ml) Mean--	<1		<1		1		<1	
Total organic carbon (as C)--	6.0	--	5.0	--	3.6	--	3.9	--





Patterson Lake, Okanogan County. From Washington Department of Game, January 9, 1950.



Patterson Lake, Okanogan County. August 4, 1967. Approx. scale 1:60,000.

Patterson Lake (north arm) near Lacey (12080570)Location.

1.1 miles northwest of Kellys Korner, Thurston County; lat 46°59'48", long 122°46'56"; SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec.34, T.18 N., R.1 W.; Puget Sound basin; 154 feet altitude. East Olympia and Lacey quadrangles (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	81 acres	Length of shoreline-----	1.7 miles
Volume-----	1,100 acre-ft	Shoreline configuration----	1.3
Mean depth-----	14 ft	Development of volume-----	0.63
Maximum depth-----	22 ft	Bottom slope-----	1.0 percent

Drainage basin.

Size: 2.90 mi².

Geology: Glaciofluvial materials consisting of poorly sorted gravel and sand, and of sandy and silty outwash with lenses of gravel (Noble and Wallace, 1966).

Soils: Gravelly sandy loam, loamy sand, and peat, on gentle to moderate slopes (Ness, 1958).

Land use	Percent
Urban-----	11
Suburban-----	23
Agricultural-----	21
Forest or unproductive----	32
Lake surface-----	13

Nearshore development.

Number of nearshore homes: 74.

Nearshore residential development: 79 percent.

Hydrology.

The principal inflow comes from Hicks Lake. On Feb. 12, Apr. 22, June 19, and Aug. 29, the inflow from Hicks Lake was estimated to be 3.0, 4.5, 2.8, and 1.4 ft³/s, respectively. The north arm of Patterson Lake drains to the south arm.

The lake stage declined 0.7 foot from Apr. 3 to Oct. 15, 1974.

Littoral bottom.

Silt, gravel, and rock, with some muck.

Aquatic plants.Macrophytes:

Shoreline covered by emersed plants: 26-50 percent.

Lake surface covered by emersed plants: 1-10 percent.

Lake bottom covered by submersed plants: 11-25 percent.

Rooted aquatic plants observed: White lily (*Nymphaea* sp.)*, bulrush (*Scirpus* sp.), coontail (*Ceratophyllum* sp.), yellow lily (*Nuphar* sp.), pondweed (*Potamogeton* sp.), milfoil (*Myriophyllum* sp.), cattail (*Typha* sp.), waterweed (*Elodea* sp.), and muskgrass (*Chara* sp.).

Algae observed:

Feb. 12, 1974: Greens (*Microspora* sp.*, others), blue-greens, and diatoms.

Apr. 22, 1974: Blue-greens (*Aphanizomenon* sp.)*, greens, and diatoms.

June 19, 1974: Yellow-browns (*Dinobryon* sp.)*, greens, blue-greens, and diatoms.

Aug. 29, 1974: Blue-greens (*Aphanizomenon* sp.*, others), greens, and diatoms.

*Asterisk indicates dominant plants present.

Summary and conclusions.

The north arm of Patterson Lake is separated from the south arm by a dike with a narrow channel. The nearshore residential development is localized but heavy; the ratios of length of shoreline per home (120 ft per home) and volume of water per home (15 acre-ft per home) are the lowest of the 26 lakes studied. Recreational use of the lake is heavy.

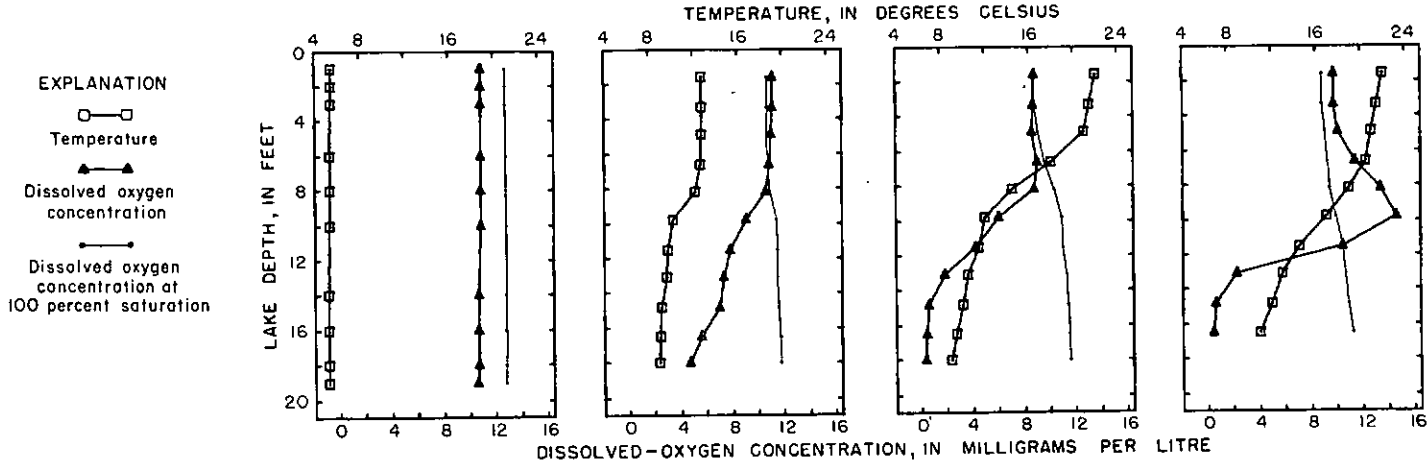
The biological productivity of the lake was moderate to high. The orthophosphate concentrations declined gradually, from 0.012 mg/l in February to 0.002 mg/l in August, but inorganic nitrogen concentrations remained high (0.58 to 0.93 mg/l) throughout the year. A bloom of blue-green algae was observed in April. Fecal-coliform-bacteria counts were low most of the year but increased to an average of 24 colonies per 100 ml in August.

Thermal stratification was moderate by June and DO concentrations in the hypolimnion were near zero at that time.

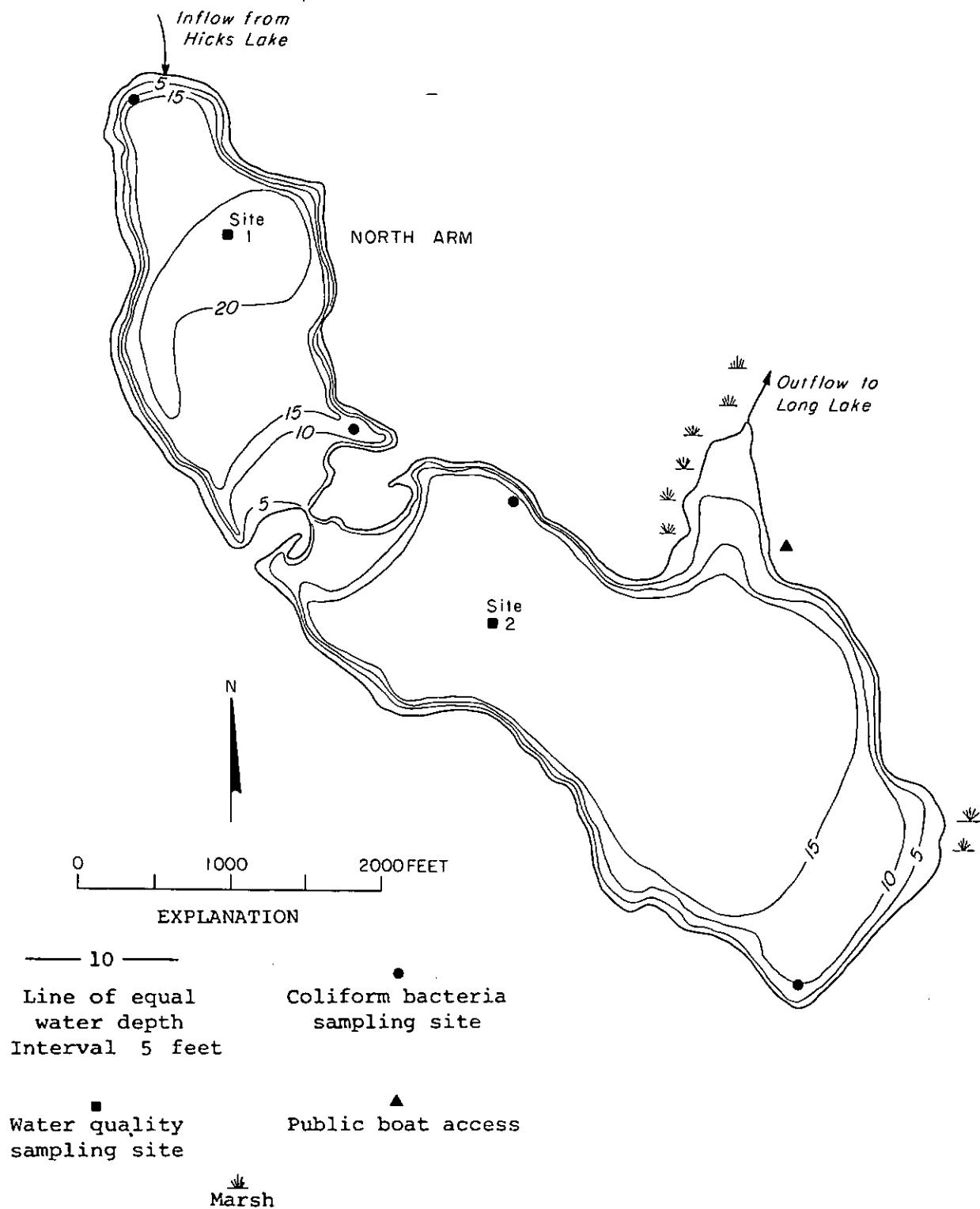
Water-quality data for Patterson Lake (north arm) near Lacey

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 12		April 22		June 19		August 29	
	3	16	3	16	3	16	3	16
Water depth (ft)-----								
Silica (SiO ₂)-----	19	19	16	17	17	24	22	25
Dissolved iron (Fe), in µg/l--	270	290	190	240	180	560	160	440
Dissolved manganese (Mn)----- (in µg/l)	30	40	20	10	10	180	10	130
Calcium (Ca) -----	9.1	--	--	--	--	--	10	--
Magnesium (Mg) -----	2.9	--	--	--	--	--	3.0	--
Sodium (Na) -----	4.7	--	--	--	--	--	4.7	--
Potassium (K) -----	1.0	--	--	--	--	--	.9	--
Bicarbonate (HCO ₃) -----	30	30	27	31	36	41	43	49
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	8.8	--	--	--	--	--	7.5	--
Chloride (Cl)-----	3.2	--	--	--	--	--	3.4	--
Nitrate nitrogen (as N)-----	.75	.75	.69	.79	.51	.54	.88	.72
Nitrite nitrogen (as N)-----	.00	.00	.01	.00	.01	.01	.01	.02
Ammonia nitrogen (as N)-----	.12	.12	.10	.11	.06	.17	.04	.15
Organic nitrogen (as N)-----	.27	.35	.28	.21	.33	.45	.52	.60
Total phosphorus (as P)-----	.030	.031	.018	.014	.014	.041	.012	.030
Orthophosphate (as P)-----	.012	.012	.006	.003	.003	.007	.002	.004
Suspended solids (110 °C)-----	7	--	--	--	--	--	1	--
Hardness as CaCO ₃ (Ca, Mg)-----	35	--	--	--	--	--	37	--
Specific conductance----- (micromhos at 25 °C)	77	77	81	82	89	100	96	99
pH (pH units)-----	7.7	7.6	8.2	7.6	7.4	6.8	7.2	6.2
Water temperature (°C)-----	5.5	5.3	12.8	9.1	21.5	9.5	21.5	11.0
Color (Pt-Co scale)-----	40	45	55	40	55	55	25	50
Secchi-disc (ft)-----	5.0		5.6		7.2		11	
Dissolved oxygen (DO)-----	5.8	5.8	11.1	5.6	8.7	.4	9.8	.4
Chlorophyll <u>a</u> in photic zone- (µg/l)	12	--	5.8	--	10	--	4.2	--
Fecal coliform Range-- (col. per 100 ml) Mean---	<1-2 1		<1-3 1		<1 <1		<1-95 24	
Total organic carbon (as C) --	7.1	--	5.8	--	8.6	--	4.7	--



DATA ON SELECTED LAKES IN WASHINGTON, PART 5



Patterson Lake, Thurston County. From U.S. Geological Survey, December 19, 1973.



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

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Patterson Lake (south arm) near Lacey (12080570)Location.

1.0 mile north of Kelly's Korner, Thurston County; lat 46°59'54", long 122°46'15"; SE¼SW¼ sec. 35, T.18 N., R.1 W.; Puget Sound basin; 154 feet altitude. East Olympia quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	190 acres	Length of shoreline-----	4.6 miles
Volume-----	2,500 acre-ft	Shoreline configuration---	2.4
Mean depth-----	13 ft	Development of volume-----	0.70
Maximum depth-----	19 ft	Bottom slope-----	0.59 percent

Drainage basin.

Size: 3.77 mi².

Geology: Glaciofluvial materials consisting of poorly sorted gravel and sand, and of sandy and silty outwash with lenses of gravel (Noble and Wallace, 1966).

Soils: Gravelly sandy loam, loamy sand, and peat, on gentle to moderate slopes (Ness, 1958).

Land use	Percent
Urban-----	8
Suburban-----	20
Agricultural-----	16
Forest or unproductive----	35
Lake surface-----	21

Nearshore development.

Number of nearshore homes: 95.

Nearshore residential development: 49 percent.

Hydrology.

The principal inflow comes from the north arm of Patterson Lake. Drainage is northward via an unnamed stream to Long Lake, Woodland Creek, and Henderson Inlet of Puget Sound. On Feb. 13, Apr. 22, June 19, and Aug. 29 the outflow was 20.1, 20.6, 14.0, and 7.12 ft.³/s, respectively.

The lake stage declined 0.7 foot from Apr. 3 to Oct. 15, 1974.

Littoral bottom.

Silt, gravel, and rock, with some muck.

Aquatic plants.Macrophytes:

Shoreline covered by emerged plants: 51-75 percent.

Lake surface covered by emerged plants: 1-10 percent.

Lake bottom covered by submersed plants: 26-50 percent.

Rooted aquatic plants observed: Yellow lily (Nuphar sp.)*, bulrush (Scirpus sp.), coontail (Ceratophyllum sp.), white lily (Nymphaea sp.), waterweed (Elodea sp.), wildcelery (Vallisneria sp.), cattail (Typha sp.), pondweed (Potamogeton sp.), muskgrass (Chara sp.), and watershield (Brasenia sp.).

Algae observed:

Feb. 13, 1974: Diatoms (Asterionella sp.*, others), greens (Microspora sp.)*, and blue-greens.

Apr. 22, 1974: Diatoms (Asterionella sp.*, others) and blue-greens.

June 19, 1974: Blue-greens (Aphanizomenon sp.*, others) and diatoms.

Aug. 29, 1974: Greens, blue-greens, and diatoms.

*Asterisk indicates dominant plants present.

Summary and conclusions.

The south arm of Patterson Lake is separated from the north arm by a dike with a narrow channel. Nearshore residential development (49 percent) is locally heavy; recreational use of the lake also is heavy.

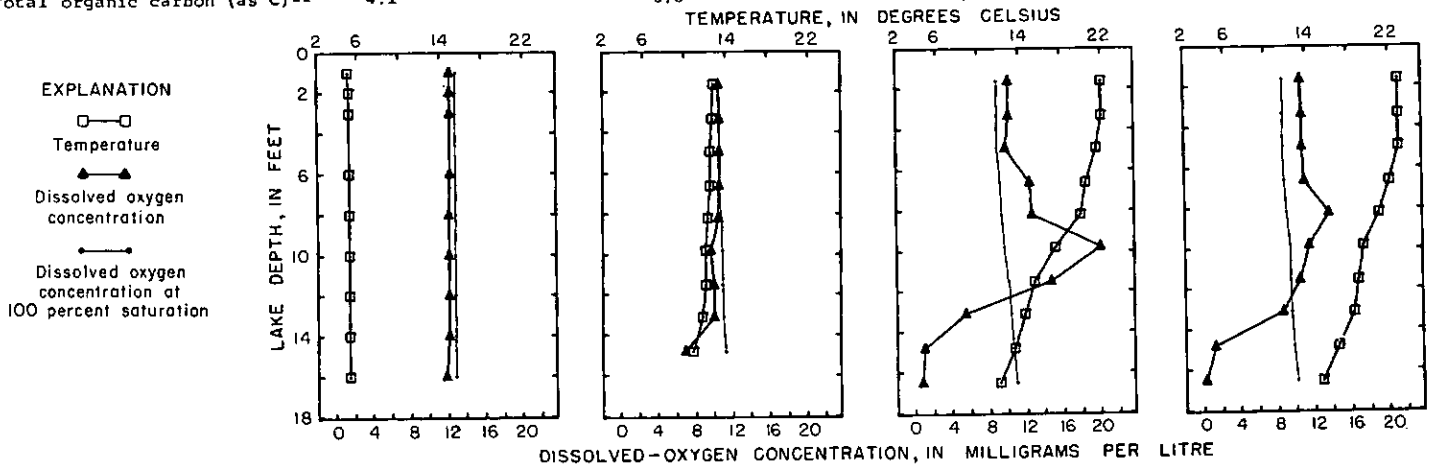
The biological productivity of the lake was moderate. Chlorophyll *a* concentrations were moderate to high; inorganic nitrogen concentrations decreased from 0.53 mg/l in February to 0.04 mg/l in August. Approximately 30 percent of the lake bottom was covered with aquatic macrophytes, chiefly pondweed. Fecal-coliform-bacteria counts were low most of the year but increased to an average of 24 colonies per 100 ml in August.

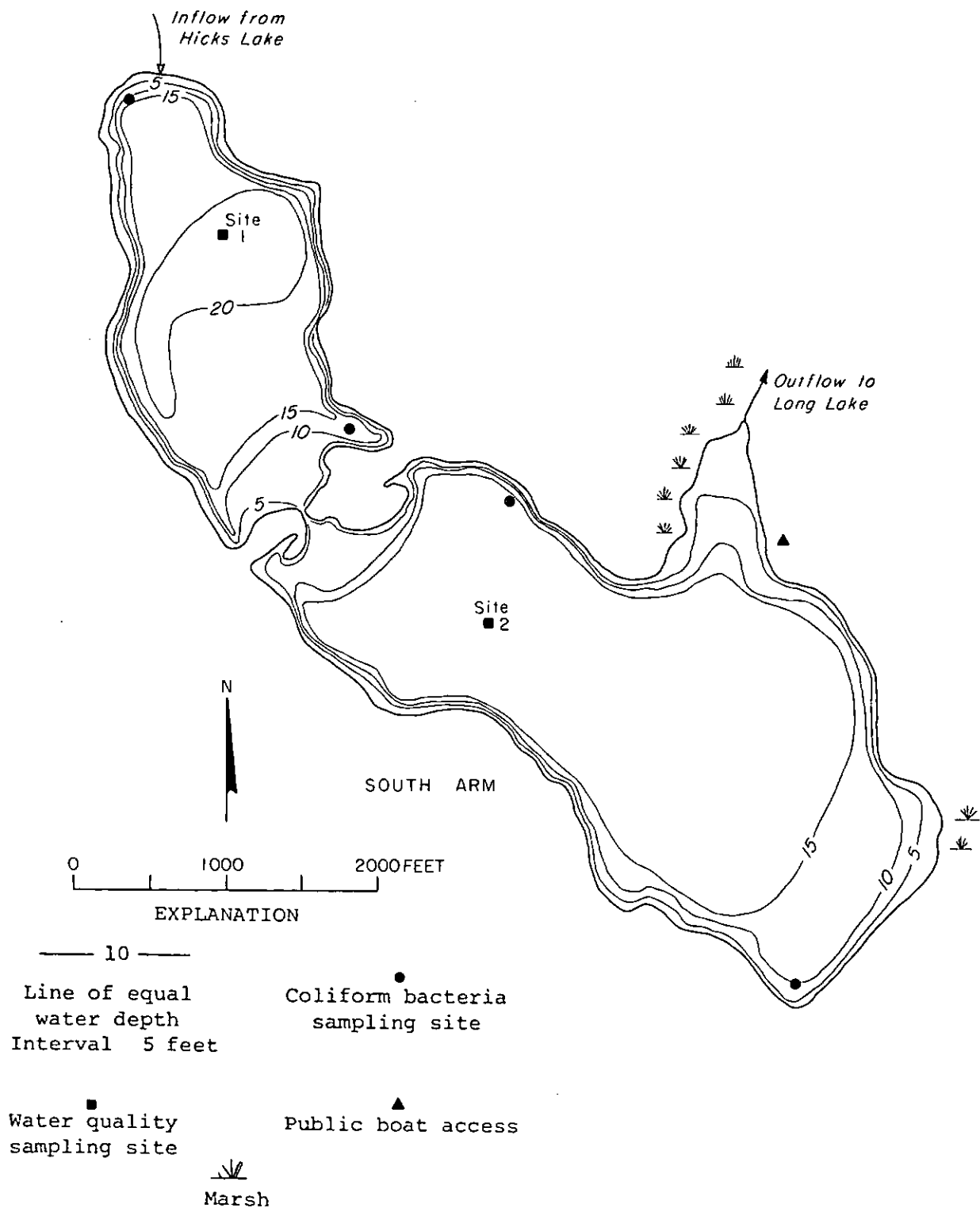
Thermal stratification was weakly developed in June and August. The only serious DO depletions observed at that time were near the very bottom of the lake, where DO concentrations were near zero.

Water-quality data for Patterson Lake (south arm) near Lacey

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 13		April 22		June 19		August 29	
	3	13	3	13	3	13	3	13
Water depth (ft)-----								
Silica (SiO ₂)-----	20	20	11	11	17	17	16	20
Dissolved iron (Fe), in µg/l--	130	150	120	140	80	380	140	790
Dissolved manganese (Mn)----- (in µg/l)	30	30	10	10	20	20	10	10
Calcium (Ca) -----	8.6	--	--	--	--	--	11	--
Magnesium (Mg) -----	3.1	--	--	--	--	--	3.0	--
Sodium (Na) -----	4.7	--	--	--	--	--	4.8	--
Potassium (K) -----	1.2	--	--	--	--	--	1.0	--
Bicarbonate (HCO ₃) -----	36	35	35	39	44	43	52	56
Carbonate (CO ₃)-----	--	--	--	--	0	--	0	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	7.8	--	--	--	--	--	6.3	--
Chloride (Cl)-----	3.2	--	--	--	--	--	3.6	--
Nitrate nitrogen (as N)-----	.44	.46	.34	.34	.05	.11	.01	.02
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.01	.00	.00	.00
Ammonia nitrogen (as N)-----	.09	.11	.09	.11	.03	.05	.03	.08
Organic nitrogen (as N)-----	.24	.29	.22	.22	.39	.72	.60	.67
Total phosphorus (as P)-----	.032	.034	.018	.021	.019	.059	.023	.073
Orthophosphate (as P)-----	.012	.013	.001	.001	.002	.003	.002	.006
Suspended solids (110°C)-----	2	--	--	--	--	--	2	--
Hardness as CaCO ₃ (Ca,Mg)----	34	--	--	--	--	--	40	--
Specific conductance----- (micromhos at 25°C)	80	81	87	86	94	100	98	100
pH (pH units)-----	7.2	7.3	8.4	7.8	8.4	7.4	8.4	7.0
Water temperature (°C)-----	5.1	5.1	12.7	11.7	22.0	14.5	23.0	18.5
Color (Pt-Co scale)-----	25	25	25	25	30	40	25	50
Secchi-disc (ft)-----		6.5		5.9		7.9		8.2
Dissolved oxygen (DO)-----	12.3	12.2	10.6	10.0	10.1	5.4	10.8	8.6
Chlorophyll <i>a</i> in photic zone- (µg/l)	19	--	4.5	--	14	--	6.6	--
Fecal coliform Range-- (col. per 100 ml) Mean---		<1-2 1		<1-3 1		<1 <1		<1-95 24
Total organic carbon (as C)--	4.1	--	6.0	--	4.2	--	5.5	--





Patterson Lake, Thurston County. From U.S. Geological Survey, December 19, 1973.



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

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Pearrygin Lake near Winthrop (12447900)Location.

1.4 miles northeast of Winthrop, Okanogan County; lat 48°29'32", long 120°09'46";
 SW¼NW¼ sec.36, T.35 N., R.21 E.; Methow River basin; 1,924 feet altitude.
 Winthrop quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	210 acres	Length of shoreline-----	3.6 miles
Volume-----	6,300 acre-ft	Shoreline configuration-----	1.8
Mean depth-----	30 ft	Development of volume-----	0.62
Maximum depth-----	48 ft	Bottom slope-----	1.4 percent

Drainage basin.

Size: 11.8 mi².

Geology: Uplands are underlain by granitic rocks, and lowlands are underlain by various undifferentiated sedimentary and volcanic rocks (Hunting and others, 1961).

Soils: Uplands contain acidic sandy loam to silt loam; lowlands contain loam, silt loam, and sandy loam (U.S. Soil Conservation Service, 1968).

Land use	Percent
Urban-----	0
Suburban-----	<1
Agricultural-----	29
Forest or unproductive-----	68
Lake surface-----	3

Nearshore development.

Number of nearshore homes: 3 (seasonal).

Nearshore residential development: 2 percent.

Hydrology.

The lake has four inflows, the largest being Pearrygin Creek. On Apr. 15, May 20, July 15, and Sept. 23, the combined inflow of the stream was estimated to be 6.5, 4.3, 1.6, and 0.4 ft³/s, respectively. Drainage is westward via Lake Creek to the Chewack River. The outflow is regulated and was not measured.

The lake stage, which is regulated, declined about 0.9 foot from May 20 to Sept. 23, 1974.

Littoral bottom.

Mostly silt and muck with some sand and gravel.

Aquatic plants.

Macrophytes:

Shoreline covered by emerged plants: 51-75 percent.

Lake surface covered by emerged plants: 1-10 percent.

Lake bottom covered by submersed plants: 11-25 percent.

Rooted aquatic plants observed: Cattail (*Typha* sp.)*, bulrush (*Scirpus* sp.), bushy pondweed (*Najas* sp.), muskgrass (*Chara* sp.), stonewort (*Nitella* sp.), pondweed (*Potamogeton* sp.), smartweed (*Polygonum* sp.), and waterweed (*Elodea* sp.).

Algae observed:

Apr. 15, 1974: Diatoms.

May 20, 1974: Diatoms.

July 15, 1974: Diatoms (*Tabellaria* sp.)* and blue-greens.

Sept. 23, 1974: Diatoms, blue-greens, and dinoflagellates.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Pearrygin Lake is fed in part by diversions from the Chewack River. The lake water is used for irrigation. A State park and resorts are situated on the lakeshore, but nearshore residential development is light (2 percent).

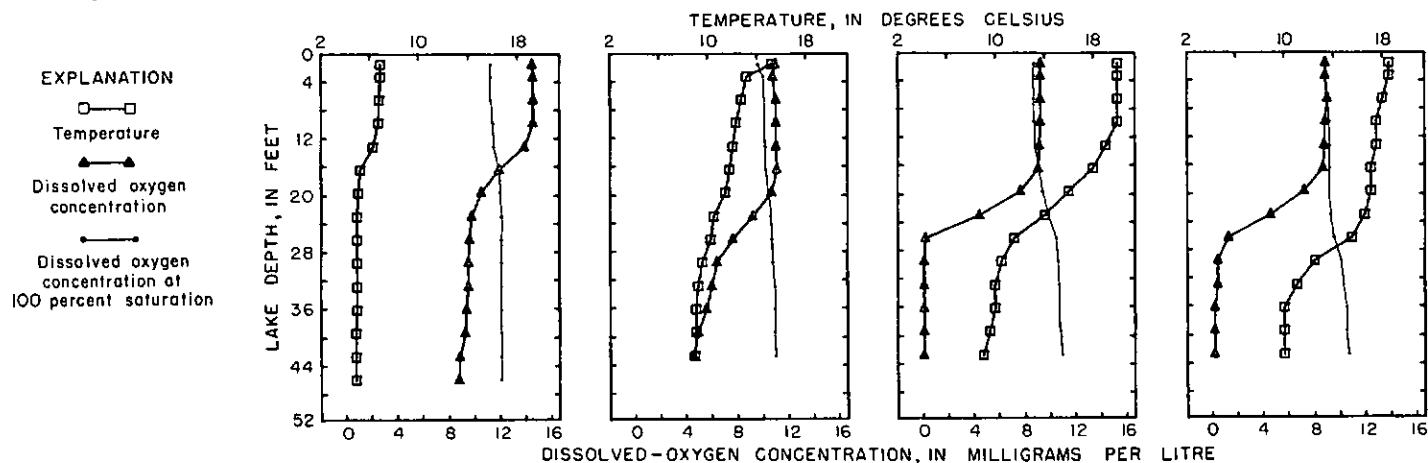
The biological productivity of the lake was moderate. Chlorophyll *a* concentrations were high (41 µg/l) in February but had declined to 2.0 µg/l by May and remained at that general level the rest of the year. A dense growth of diatoms was observed in April. Submersed macrophytes covered the littoral bottom and extended to depths of about 10 feet.

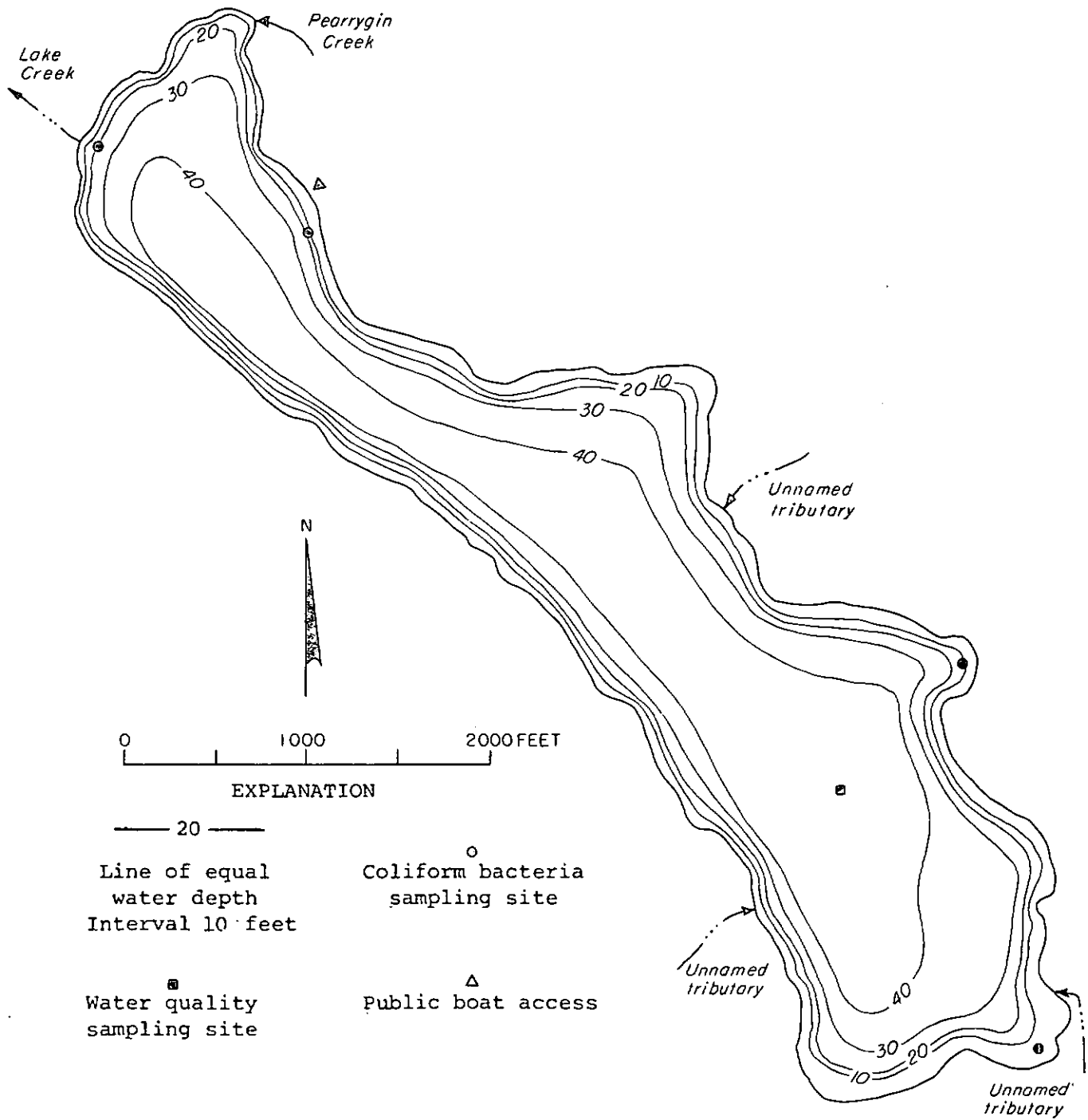
Thermal stratification was moderately well established in July and September. DO concentrations in the hypolimnion at that time were near zero.

Water-quality data for Pearrygin Lake near Winthrop

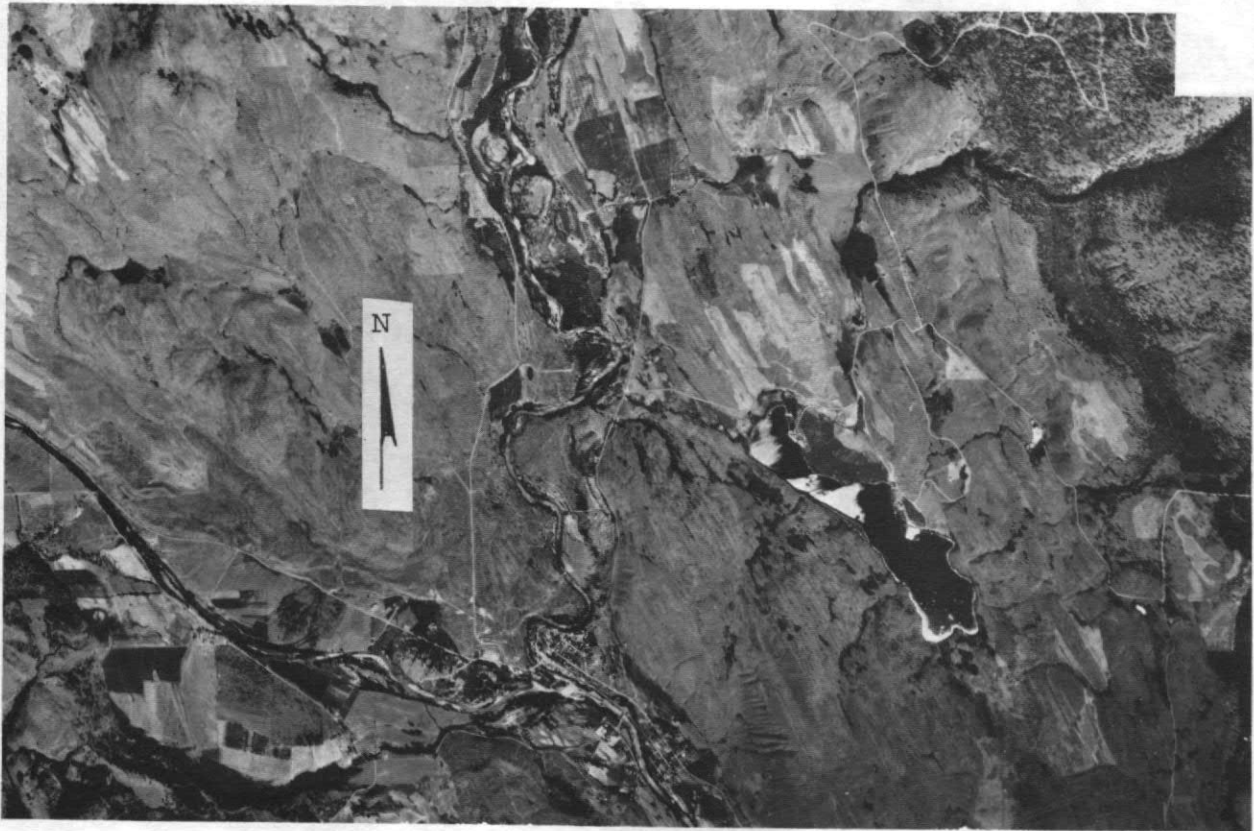
[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	April 15		May 20		July 15		September 23	
	3	43	3	39	3	39	3	39
Water depth (ft)-----								
Silica (SiO ₂)-----	9.5	11	5.6	7.1	6.0	9.7	8.0	14
Dissolved iron (Fe), in µg/l--	40	40	20	50	60	50	20	90
Dissolved manganese (Mn)----- (in µg/l)	80	100	0	240	20	560	10	1,100
Calcium (Ca) -----	49	--	--	--	--	--	34	--
Magnesium (Mg) -----	11	--	--	--	--	--	9.6	--
Sodium (Na) -----	11	--	--	--	--	--	8.4	--
Potassium (K) -----	2.0	--	--	--	--	--	1.6	--
Bicarbonate (HCO ₃) -----	180	180	170	180	150	190	140	200
Carbonate (CO ₃)-----	0	--	4	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	15	--	--	--	--	--	11	--
Chloride (Cl)-----	1.1	--	--	--	--	--	1.6	--
Nitrate nitrogen (as N)-----	.01	.16	.01	.01	.02	.01	.01	.01
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N)-----	.12	.13	.04	.20	.03	.61	.04	1.8
Organic nitrogen (as N)-----	.71	.56	.37	.44	.32	.33	.23	.90
Total phosphorus (as P)-----	.063	.050	.017	.025	.012	.074	.007	.35
Orthophosphate (as P)-----	.010	.003	.002	.003	.001	.038	.001	.18
Suspended solids (110 °C)-----	7	--	--	--	--	--	6	--
Hardness as CaCO ₃ (Ca,Mg)----	170	--	--	--	--	--	120	--
Specific conductance----- (micromhos at 25 °C)	250	250	270	270	240	280	210	290
pH (pH units)-----	8.6	7.9	8.5	7.8	8.2	7.3	8.1	7.1
Water temperature (°C)-----	6.9	4.9	13.2	9.0	20.0	9.5	18.5	10.0
Color (Pt-Co scale)-----	35	35	5	15	10	10	5	15
Secchi-disc (ft)-----		3.9		12		12		15
Dissolved oxygen (DO)-----	14.6	8.9	10.8	4.9	9.2	.1	8.9	.2
Chlorophyll <u>a</u> in photic zone- (µg/l)	41	--	2.0	--	1.6	--	1.6	--
Fecal coliform Range-- (col. per 100 ml) Mean---		<1 <1		<1-1 <1		<1-2 <1		<1-30 8
Total organic carbon (as C)--	11	--	10	--	5.4	--	6.1	--





Pearrygin Lake, Okanogan County. From Washington Department of Game, January 1948.



Pearrygin Lake, Okanogan County. August 4, 1967. Approx. scale 1:60,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Shadow Lake near Maple Valley (12109450)Location.

2.2 miles west of Maple Valley, King County; lat 47°24'08", long 122°04'58";
SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec.7, T.22 N., R.6 E., Duwamish River basin; 540 feet altitude.
Maple Valley quadrangle (1:24,000 scale).
Location is of southernmost shoreline point of lake.

Physical characteristics of lake.

Surface area-----	49 acres	Length of shoreline-----	1.2 miles
Volume-----	1,100 acre-ft	Shoreline configuration----	1.2
Mean depth-----	22 ft	Development of volume-----	0.49
Maximum depth-----	45 ft	Bottom slope-----	2.7 percent

Drainage basin.

Size: 0.71 mi².
Geology: Till, consisting of a compact mixture of gravel and boulders in a clayey sand matrix (Luzier, 1969).
Soils: Predominantly gravelly sandy loam. Peat deposits on the southwest side of the lake and in other scattered locations (Poulson and others, 1952).

Land use	Percent
Urban-----	0
Suburban-----	8
Agricultural-----	23
Forest or unproductive-----	58
Lake surface-----	11

Nearshore development.

Number of nearshore homes: 24.
Nearshore residential development: 66 percent.

Hydrology.

The lake has one small inflow which enters a manmade arm on the northeast side of the lake. On Mar. 6, Apr. 25, and June 21, the inflow was estimated to be 1.0, 0.3, and 0.1 ft³/s, respectively. On Aug. 28 the inflow channel was dry. The lake has no surface-water outflow.

The lake stage declined 1.3 feet from Mar. 6 to Aug. 28, 1974.

Littoral bottom.

Mostly muck with some silt and gravel.

Aquatic plants.Macrophytes:

Shoreline covered by emersed plants: 51-75 percent.
Lake surface covered by emersed plants: <1 percent.
Lake bottom covered by submersed plants: 26-50 percent.
Rooted aquatic plants observed: Watershield (*Brasenia* sp.)*, milfoil (*Myriophyllum* sp.), white lily (*Nymphaea* sp.), yellow lily (*Nuphar* sp.), rush (*Juncus* sp.), cattail (*Typha* sp.), bulrush (*Scirpus* sp.), waterweed (*Elodea* sp.), pondweed (*Potamogeton* sp.), muskgrass (*Chara* sp.), and wildcelery (*Vallisneria* sp.).

Algae observed:

Mar. 6, 1974: Greens (*Microspora* sp.)*, diatoms (*Tabellaria* sp.)* and blue-greens.
Apr. 25, 1974: Blue-greens (*Aphanizomenon* sp.)* and diatoms.
June 21, 1974: None.
Aug. 28, 1974: Blue-greens (*Polycystis* sp.)*.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Shadow Lake is in a suburban-rural, forested part of King County. The west side of the lake is bordered by a marsh, making the nearshore residential development localized and heavy. The area and shoreline of the lake have been increased by dredging at the north end of the lake.

The biological productivity of the lake was moderate. The inorganic nitrogen concentrations decreased from 0.84 mg/l in March to 0.07 mg/l in August. The littoral bottom was covered with aquatic macrophytes that extended to a depth of about 10 feet. The fecal-coliform colonies in one sample collected in August were too numerous to count.

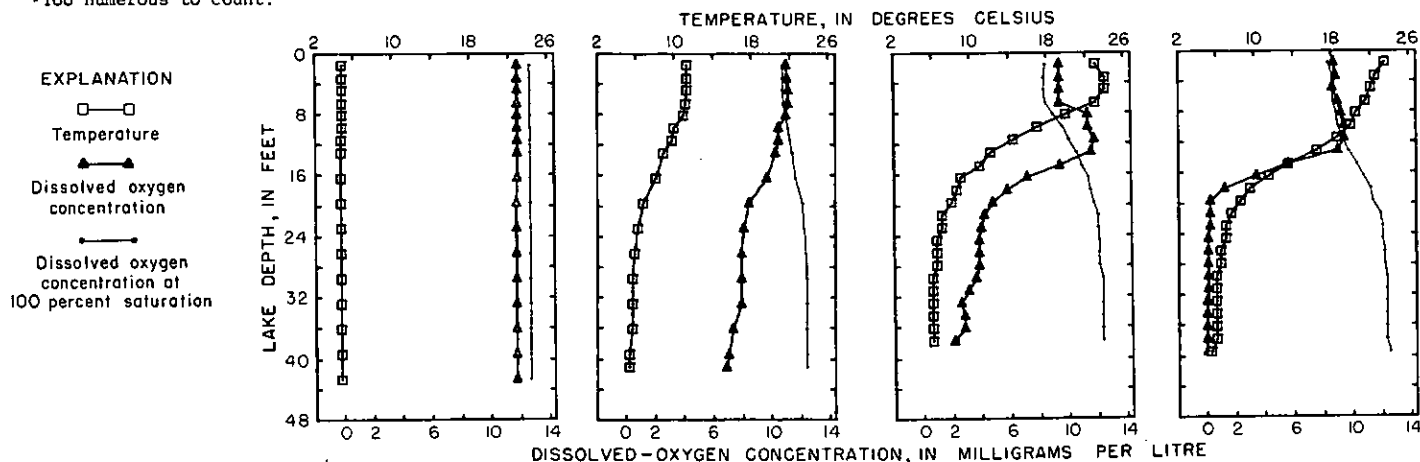
Thermal stratification was well established by June, and by August DO concentrations in the hypolimnion were near zero.

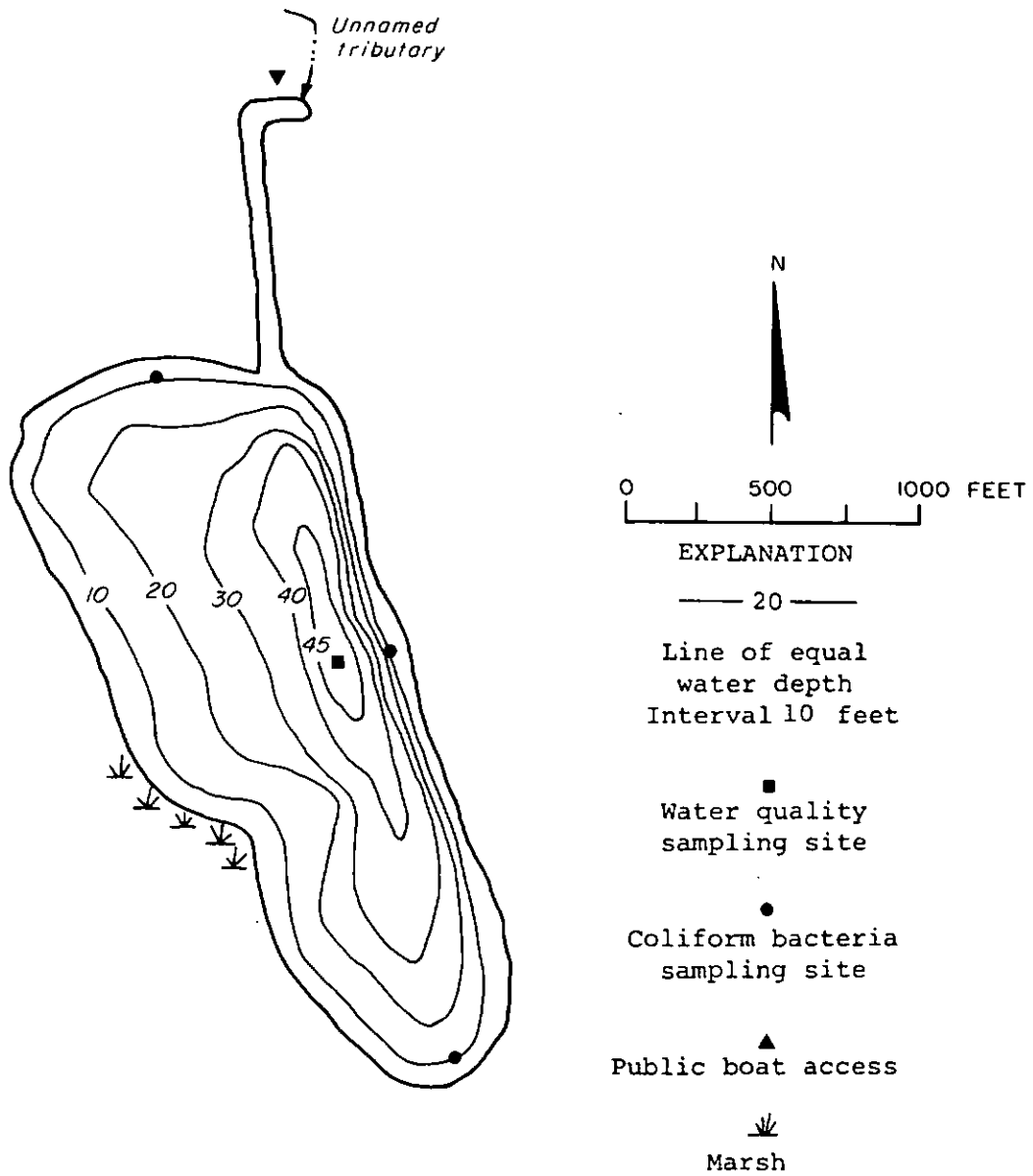
Water-quality data for Shadow Lake near Maple Valley

[Milligrams per litre unless otherwise indicated]

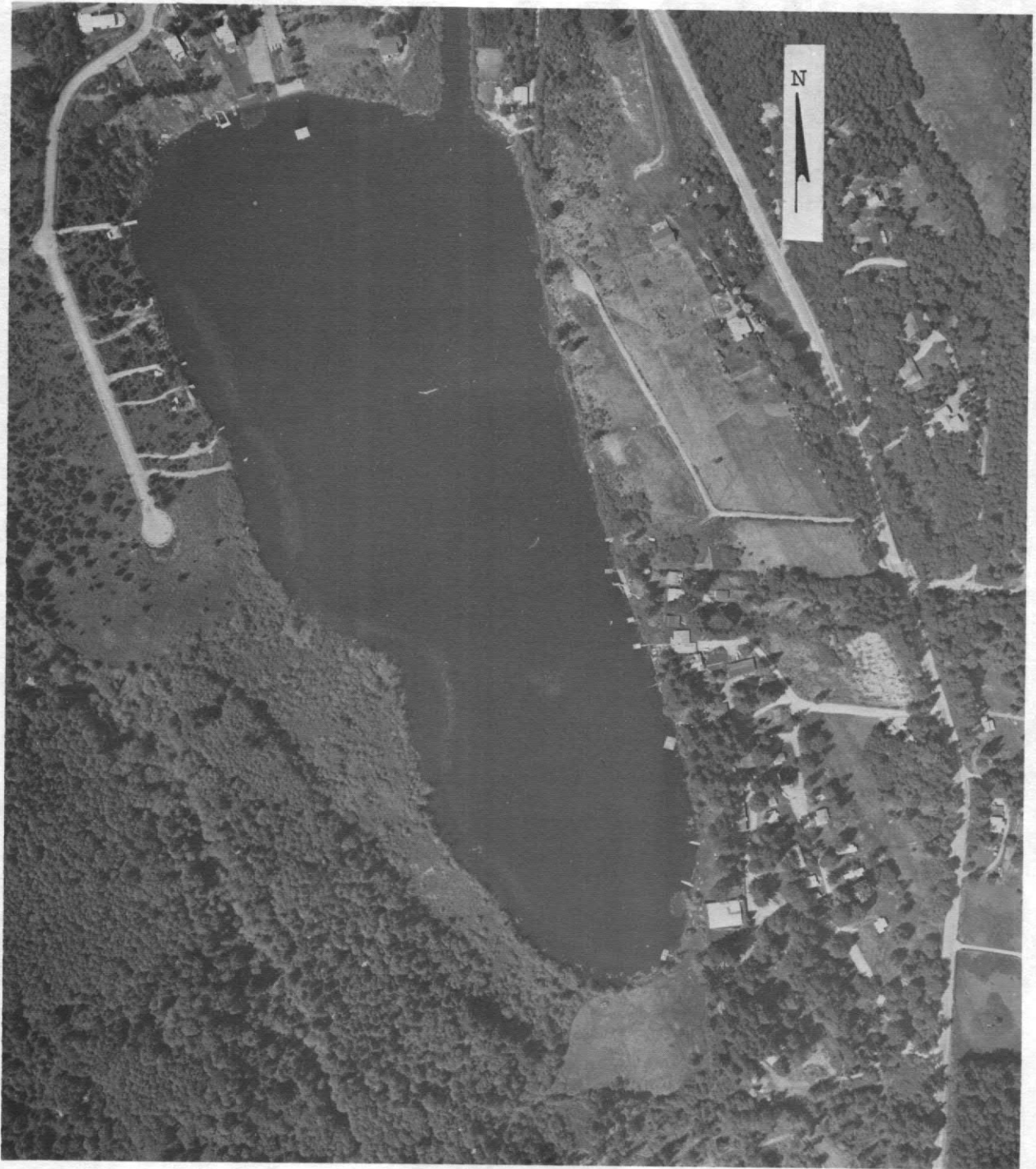
Date of collection (1974)-----	March 6		April 25		June 21		August 28	
	3	39	3	39	3	36	3	36
Water depth (ft)-----								
Silica (SiO ₂)-----	5.9	5.9	4.2	6.0	3.4	7.0	3.1	7.1
Dissolved iron (Fe), in µg/l--	230	160	100	140	80	290	120	990
Dissolved manganese (Mn)----- (in µg/l)	0	0	10	10	20	110	0	370
Calcium (Ca) -----	5.7	--	--	--	--	--	5.0	--
Magnesium (Mg) -----	1.8	--	--	--	--	--	2.0	--
Sodium (Na) -----	3.2	--	--	--	--	--	3.3	--
Potassium (K) -----	1.3	--	--	--	--	--	1.2	--
Bicarbonate (HCO ₃) -----	16	15	14	14	20	18	23	21
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	5.3	--	--	--	--	--	5.3	--
Chloride (Cl)-----	3.3	--	--	--	--	--	2.7	--
Nitrate nitrogen (as N)-----	.77	.76	.58	.72	.16	.62	.00	.26
Nitrite nitrogen (as N)-----	.00	.00	.00	.01	.00	.00	.01	.02
Ammonia nitrogen (as N)-----	.07	.07	.07	.07	.05	.04	.06	.33
Organic nitrogen (as N)-----	.22	.27	.29	.27	.38	.33	.61	.41
Total phosphorus (as P)-----	.018	.017	.012	.012	.014	.022	.009	.034
Orthophosphate (as P)-----	.006	.007	.003	.004	.006	.004	.003	.015
Suspended solids (110°C)-----	8	--	--	--	--	--	1	--
Hardness as CaCO ₃ (Ca,Mg)-----	22	--	--	--	--	--	21	--
Specific conductance----- (micromhos at 25°C)	50	50	52	51	53	49	55	52
pH (pH units)-----	7.6	7.3	7.3	6.8	7.3	6.8	6.8	5.7
Water temperature (°C)-----	4.8	4.7	11.3	5.3	24.0	6.0	22.5	6.0
Color (Pt-Co scale)-----	25	25	40	40	40	40	30	50
Secchi-disc (ft)-----		8.2		8.2		10		11
Dissolved oxygen (DO)-----	11.8	11.7	11.0	7.0	9.4	2.8	8.8	.0
Chlorophyll a in photic zone- (µg/l)	3.8	--	5.2	--	4.0	--	2.0	--
Fecal coliform Range-- (col. per 100 ml) Mean--		1-6 4		<1-1 1		2-21 11		15-*TNTC --
Total organic carbon (as C)--	6.1	--	7.4	--	15	--	9.1	--

*Too numerous to count.





Shadow Lake, King County. From Washington Department of Game, February 1, 1952.



Shadow Lake, King County. May 17, 1973. Approx. scale 1:4800.

Silver Lake at Silver Lake (14242000)Location.

3.1 miles east of Silver Lake, Cowlitz County; lat 46°18'15", long 122°44'45";
SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec.36, T.10 N., R.1 W.; Cowlitz River basin; 484 feet altitude.
Toutle quadrangle (1:62,500 scale).

Physical characteristics of lake.

Surface area-----	2,300 acres	Length of shoreline-----	18 miles
Volume-----	13,000 acre-ft	Shoreline configuration----	2.6
Mean depth-----	6 ft	Development of volume-----	0.56
Maximum depth-----	10 ft	Bottom slope-----	0.09 percent

Drainage basin.

Size: 39.3 mi².
Geology: Predominantly basalt flows with local areas of landslide and terrace deposits and undifferentiated sedimentary rocks (Hunting and others, 1961).
Soils: Silty clay loam with local areas of clay, clay loam, muck, and peat (Mangum and others, 1913).

Land use	Percent
Urban-----	0
Suburban-----	1
Agricultural-----	5
Forest or unproductive-----	85
Lake surface-----	9

Nearshore development.

Number of nearshore homes: 97.
Nearshore residential development: 11 percent.

Hydrology.

The lake has several inflows, the principal ones being Sucker Creek and Hemlock Creek. The inflows were not measured because of their general inaccessibility. Drainage is northeastward via Outlet Creek to the Toutle River. The outflow was not measured because it is artificially regulated.

The stage of Silver Lake is monitored by the U.S. Geological Survey with a continuous recorder. The stage declined 2.6 feet from Jan. 16 to Oct. 9, 1974.

Littoral bottom.

Mostly muck with some silt, clay, sand, and gravel.

Aquatic plants.Macrophytes:

Shoreline covered by emerged plants: 76-100 percent.
Lake surface covered by emerged plants: 26-50 percent.
Lake bottom covered by submersed plants: 76-100 percent.
Rooted aquatic plants observed: Yellow lily (*Nuphar* sp.)*, coontail (*Ceratophyllum* sp.)*, white lily (*Nymphaea* sp.), watershield (*Brasenia* sp.), smartweed (*Polygonum* sp.), bulrush (*Scirpus* sp.), arrowhead (*Sagittaria* sp.), sedge (*Carex* sp.), cattail (*Typha* sp.), waterweed (*Elodea* sp.), milfoil (*Myriophyllum* sp.), wildcelery (*Vallisneria* sp.), pondweed (*Potamogeton* sp.), and stonewort (*Nitella* sp.).

Algae observed:

Feb. 21, 1974: Greens (*Microspora* sp.)*, blue-greens (*Nostoc* sp.)*, and diatoms (*Tabellaria* sp.)*.
Apr. 30, 1974: Greens and blue-greens.
June 28, 1974: Greens and blue-greens.
Sept. 10, 1974: Blue-greens (*Nostoc* sp.)*, greens (*Microspora* sp.)*, and dinoflagellates.

*Astarisk indicates dominant plants present.

Summary and conclusions.

Silver Lake is a large, weedy lake that is popular for spiny-ray fishing. The mean depth is only 6 feet; the bottom slope is very gentle (0.09 percent). Nearshore residential development is light and restricted to the northwest shore of the lake.

The biological productivity of the lake was moderate to high. Inorganic nitrogen concentrations decreased gradually, from 0.23 mg/l in February to 0.12 mg/l in September. Only two chlorophyll a determinations were made; they showed concentrations of 3.7 µg/l in April and 22 µg/l in September. The entire lake bottom and large parts of the lake surface and shoreline were covered with a variety of aquatic macrophytes. A dense growth of green and blue-green algae was observed in June.

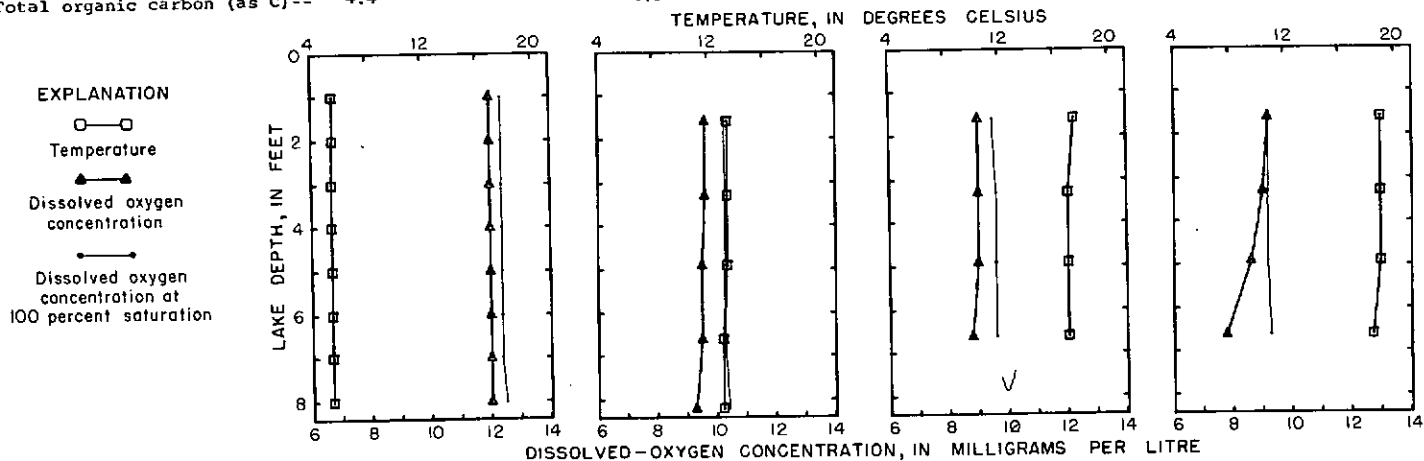
The lake was too shallow to stratify and DO concentrations were generally high throughout the year.

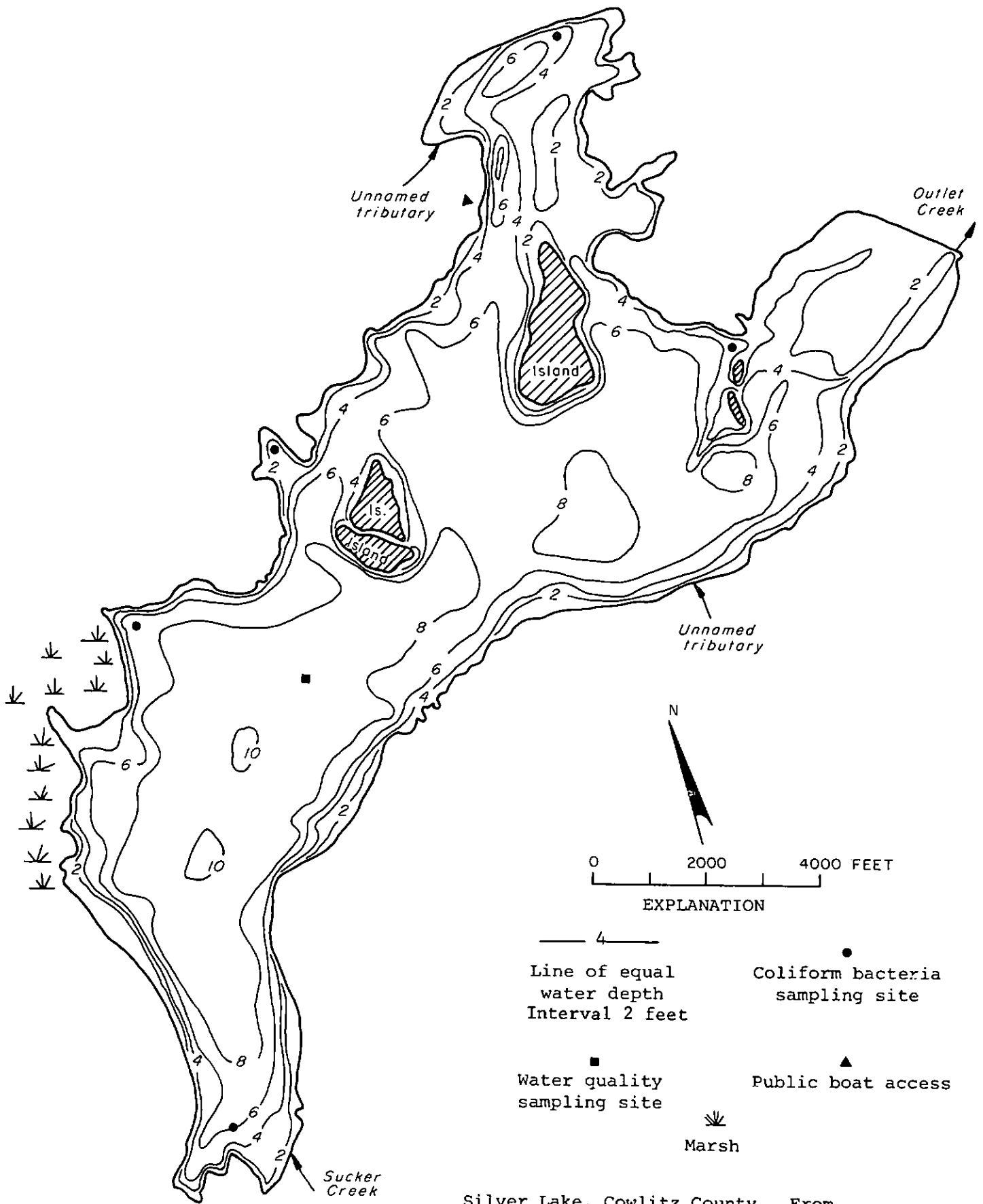
An intensive study of the trophic state of Silver Lake has been completed by Bhagat and others (1975) of the Washington Water Research Center, Pullman, Wash.

Water-quality data for Silver Lake at Silver Lake

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 21		April 30		June 28		September 10	
	3	5	3	7	3	5	3	5
Water depth (ft)-----								
Silica (SiO ₂)-----	7.1	--	3.8	--	2.8	--	5.9	--
Dissolved iron (Fe), in µg/l--	260	--	240	--	340	--	770	--
Dissolved manganese (Mn)----- (in µg/l)	10	--	60	--	110	--	420	--
Calcium (Ca) -----	2.6	--	--	--	--	--	3.3	--
Magnesium (Mg) -----	.8	--	--	--	--	--	1.0	--
Sodium (Na) -----	2.6	--	--	--	--	--	2.8	--
Potassium (K) -----	.4	--	--	--	--	--	.4	--
Bicarbonate (HCO ₃) -----	11	--	13	--	14	--	19	--
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	2.3	--	--	--	--	--	1.0	--
Chloride (Cl)-----	1.4	--	--	--	--	--	1.7	--
Nitrate nitrogen (as N)-----	.13	--	.02	--	.00	--	.01	--
Nitrite nitrogen (as N)-----	.00	--	.00	--	.00	--	.01	--
Ammonia nitrogen (as N)-----	.10	--	.09	--	.08	--	.10	--
Organic nitrogen (as N)-----	.25	--	.26	--	.30	--	.61	--
Total phosphorus (as P)-----	.020	--	.031	--	.025	--	.036	--
Orthophosphate (as P)-----	.007	--	.001	--	.002	--	.004	--
Suspended solids (110 °C)-----	8	--	--	--	--	--	6	--
Hardness as CaCO ₃ (Ca, Mg)-----	10	--	--	--	--	--	12	--
Specific conductance----- (micromhos at 25 °C)	23	23	28	28	28	28	34	34
pH (pH units)-----	7.8	--	6.9	--	6.6	--	6.7	--
Water temperature (°C)-----	5.5	5.5	13.4	13.4	17.0	--	19.0	--
Color (Pt-Co scale)-----	25	--	10	--	25	--	35	--
Secchi-disc (ft)-----		4.5		4.9		3.0		2.6
Dissolved oxygen (DO)-----	12.0	12.0	9.6	9.5	9.0	9.0	9.0	8.6
Chlorophyll <i>a</i> in photic zone- (µg/l)	--	--	3.7	--	--	--	22	--
Fecal coliform (col. per 100 ml) Range--		<1-23		<1-4		<1-3		<1-28
Mean---		8		2		2		9
Total organic carbon (as C)--	4.4	--	4.9	--	5.3	--	8.7	--





EXPLANATION

— 4 —	●
Line of equal water depth Interval 2 feet	Coliform bacteria sampling site
■	▲
Water quality sampling site	Public boat access
↘	
Marsh	

Silver Lake, Cowlitz County. From U.S. Geological Survey, March 11, 1974.



Silver Lake, Cowlitz County. May 8, 1969. Approx. scale 1:63,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Spirit Lake at Spirit Lake (14240305)Location.

1.0 mile east of Spirit Lake Lodge, Skamania County; lat 46°15'58", long 122°09'36";
 NE¼NE¼ sec.15, T.9 N., R.5 E.; Cowlitz River basin; 3,198 feet altitude.
 Spirit Lake quadrangle (1:62,500 scale).

Physical characteristics of lake.

Surface area-----	1,300 acres	Length of shoreline-----	8.8 miles
Volume-----	160,000 acre-ft	Shoreline configuration----	1.8
Mean depth-----	130 ft	Development of volume-----	0.69
Maximum depth-----	190 ft	Bottom slope-----	2.2 percent

Drainage basin.

Size: 14.9 mi².
 Geology: Volcanic rocks (Huntting and others, 1961).
 Soils: Acidic sandy loam to silt loam (U.S. Soil Conservation Service, 1968).

Land use	Percent
Urban-----	0
Suburban-----	0
Agricultural-----	0
Forest or unproductive-----	86
Lake surface-----	14

Nearshore development.

Number of nearshore homes: 15 (mostly seasonal).
 Nearshore residential development: 8 percent.

Hydrology.

The lake has six inflows, the largest being Bear Creek. On June 27, Aug. 7, Sept. 11, and Oct. 9 the combined inflow of these streams was estimated to be 110, 43, 10, and 2.4 ft³/s, respectively. Drainage is westward via North Fork Toutle River. On May 1, June 27, and Sept. 11 the outflow was 114, 412, and 48.7 ft³/s, respectively.

Measurements of lake stage were not made.

Littoral Bottom.

Gravel, rock, and sand.

Aquatic plants.

Macrophytes:
 Shoreline covered by emersed plants: <1 percent.
 Lake surface covered by emersed plants: <1 percent.
 Lake bottom covered by submersed plants: <1 percent.
 Rooted aquatic plants observed: Bog moss (Sphagnum sp.)
 Algae observed:
 June 27, 1974: Diatoms, greens, and yellow-browns.
 Aug. 7, 1974: None.
 Sept. 11, 1974: None.
 Oct. 9, 1974: None.

Summary and conclusions.

Spirit Lake is a large, deep, high-altitude lake near Mount St. Helens. Because of the pleasing esthetics of its setting and high-quality water, recreational use of the lake is heavy. Ice conditions on the lake in 1974 necessitated delaying the first sampling visit until late June.

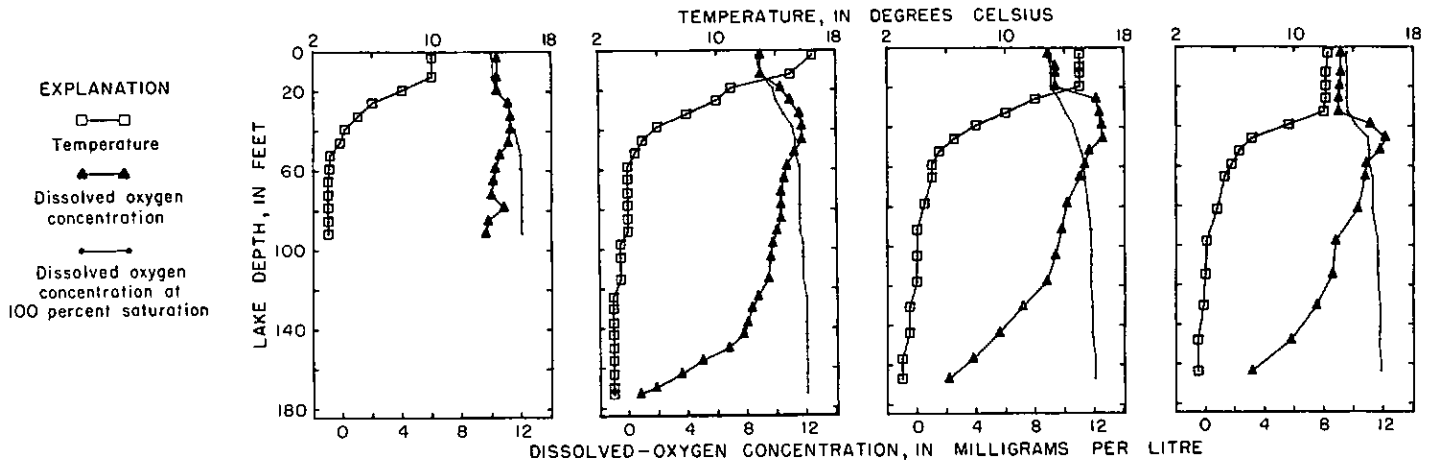
The biological productivity of the lake was the lowest of the 26 lakes studied. Inorganic nitrogen, orthophosphate, and chlorophyll a concentrations were very low. The lake water was low in dissolved minerals and in fecal-coliform bacteria. Secchi-disc visibility was high, averaging 36 feet. There were no emersed macrophytes observed; the only submersed macrophyte observed was bog moss, which occurred in small patches on the southwest shore.

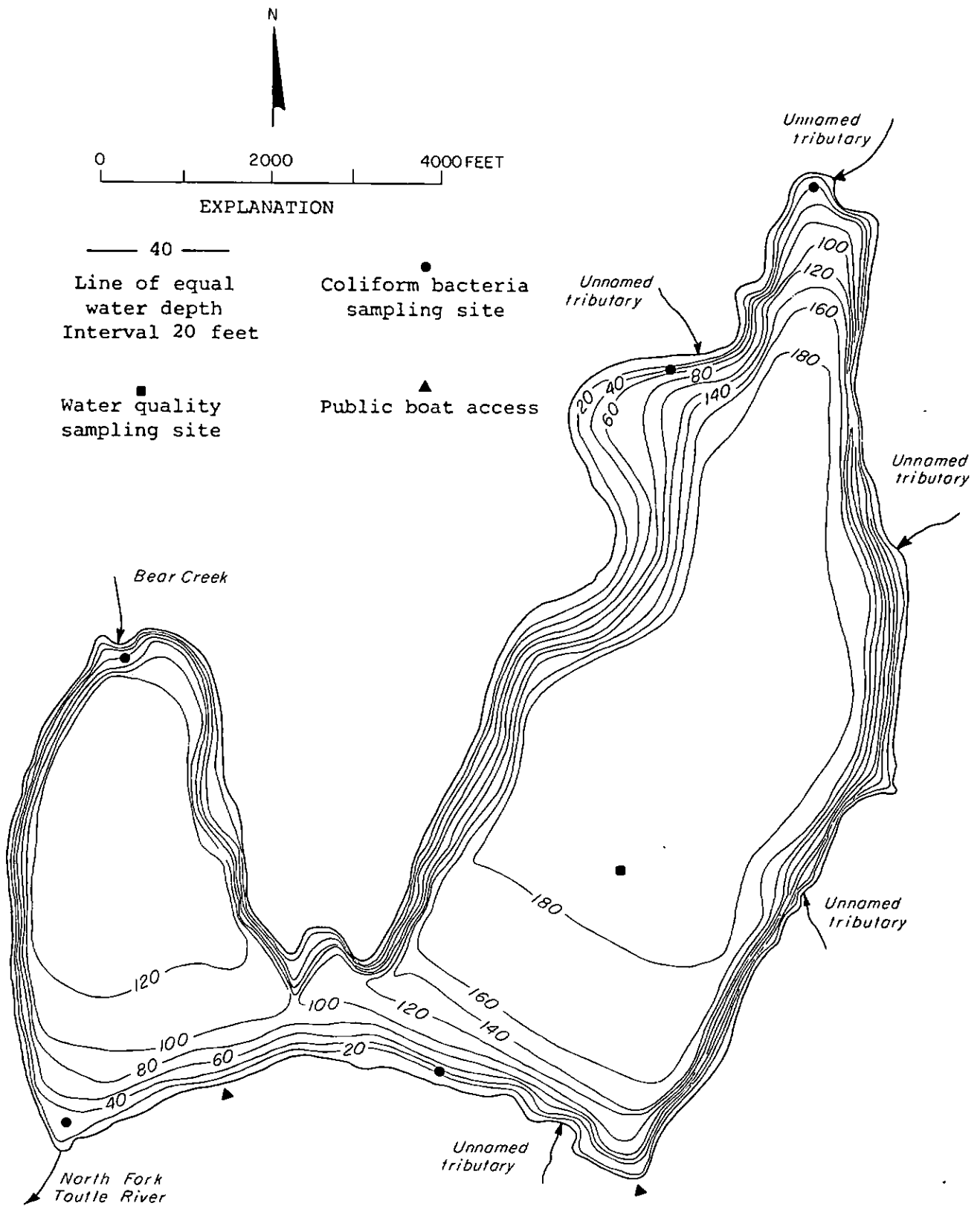
Thermal stratification was well established by August but no serious DO depletions were observed.

Water-quality data for Spirit Lake at Spirit Lake

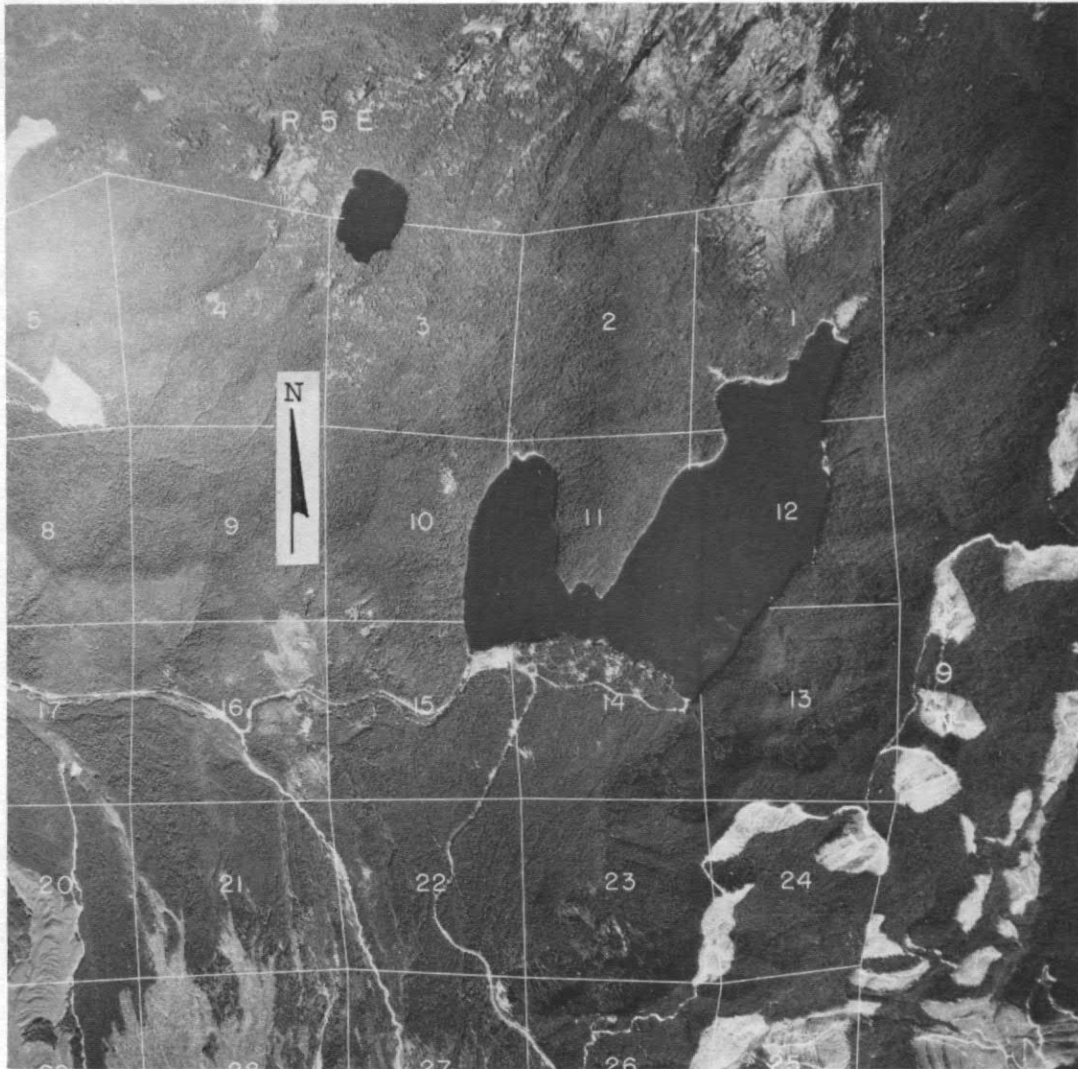
[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	June 27		August 7		September 11		October 9	
	3	170	3	170	3	164	3	164
Water depth (ft)-----								
Silica (SiO ₂)-----	12	15	11	16	11	15	12	15
Dissolved iron (Fe), in µg/l--	20	230	50	180	80	180	50	50
Dissolved manganese (Mn)----- (in µg/l)	0	260	10	70	0	40	0	0
Calcium (Ca) -----	--	--	--	--	--	--	5.0	3.5
Magnesium (Mg) -----	--	--	--	--	--	--	.0	1.9
Sodium (Na) -----	--	--	--	--	--	--	1.8	2.1
Potassium (K) -----	--	--	--	--	--	--	.4	.4
Bicarbonate (HCO ₃) -----	14	20	14	21	14	20	16	20
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	--	--	--	--	--	--	1.3	1.3
Chloride (Cl)-----	--	--	--	--	--	--	1.3	1.5
Nitrate nitrogen (as N)-----	.00	.17	.00	.20	.00	.18	.02	.16
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.00	.01	.00	.00
Ammonia nitrogen (as N)-----	.01	.01	.01	.01	.01	.02	.02	.02
Organic nitrogen (as N)-----	.03	.04	.09	.05	.04	.01	.13	.04
Total phosphorus (as P)-----	.012	.020	.002	.012	.003	.013	.007	.007
Orthophosphate (as P)-----	.002	.005	.002	.009	.003	.004	.000	.003
Suspended solids (110 °C)-----	--	--	--	--	--	--	--	--
Hardness as CaCO ₃ (Ca,Mg)-----	--	--	--	--	--	--	12	17
Specific conductance----- (micromhos at 25 °C)	27	35	25	35	26	33	19	20
pH (pH units)-----	6.9	6.4	8.3	8.2	6.6	6.2	7.2	7.2
Water temperature (°C)-----	10.0	4.0	16.0	4.0	15.0	3.0	12.3	3.5
Color (Pt-Co scale)-----	0	0	5	5	5	5	0	0
Secchi-disc (ft)-----		23		36		46		41
Dissolved oxygen (DO)-----	10.4	--	9.0	1.9	8.9	2.8	9.2	3.2
Chlorophyll <u>a</u> in photic zone- (µg/l)	.7	--	.3	--	.6	--	1.3	--
Fecal coliform Range-- (col. per 100 ml) Mean---		<1 <1		<1-1 <1		<1-8 2		<1 <1
Total organic carbon (as C)--	2.7	--	1.7	--	--	--	1.4	--





Spirit Lake, Skamania County. From U.S. Geological Survey, October 17, 1974.



Spirit Lake, Skamania County. August 22, 1969. Approx. scale 1:63,000.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Tennant Lake near Ferndale (12204050)Location.

1.7 miles southeast of Ferndale High School; Whatcom County; lat 48°49'48", long 122°34'47";
SE 1/4 sec. 32, T. 39 N., R. 2 E.; Nooksack River basin; 15 feet altitude.
Ferndale quadrangle (1:24,000 scale).
Location is of southernmost shoreline point of lake.

Physical characteristics of lake.

Surface area-----	32 acres	Length of shoreline-----	1.0 mile
Volume-----	90 acre-ft	Shoreline configuration----	1.3
Mean depth-----	3 ft	Development of volume-----	0.47
Maximum depth-----	6 ft	Bottom slope-----	0.45 percent

Drainage basin.

Size: 0.92 mi².
Geology: Flood plain of Nooksack River; alluvial valley fill of unconsolidated silt, sand,
and gravel (Hunting and others, 1961).
Soils: A coarse pattern of loam, silt loam, and silty clay loam, on gentle slopes
(Poulson and Flannery, 1953).

Land use	Percent
Urban-----	0
Suburban-----	0
Agricultural-----	78
Forest or unproductive-----	17
Lake surface-----	5

Nearshore development.

Number of nearshore homes: 0.
Nearshore residential development: 0 percent.

Hydrology.

The lake has one surface-water inflow which enters the west side of the lake. The inflow was not measured because of its inaccessibility; the lake is almost completely surrounded by marsh. There is no well-defined surface-water outflow.

The lake stage declined 2.1 feet from Feb. 25 to Sept. 16, 1974.

Littoral bottom.

Muck and soft clay with some wood debris.

Aquatic plants.Macrophytes:

Shoreline covered by emerged plants: 76-100 percent.
Lake surface covered by emerged plants: 76-100 percent.
Lake bottom covered by submersed plants: 76-100 percent.
Rooted aquatic plants observed: Yellow lily (Nuphar sp.)*, coontail (Ceratophyllum sp.)*,
cattail (Typha sp.), watershield (Brasenia sp.), rush (Juncus sp.), smartweed
(Polygonum sp.), pondweed (Potamogeton sp.), and waterweed (Elodea sp.).

Algae observed:

Feb. 25, 1974: Greens (Volvox sp.*, others), blue-greens, diatoms, and yellow-browns.
May 6, 1974: Greens and blue-greens.
July 8, 1974: Greens and blue-greens.
Sept. 16, 1974: None.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Tennant Lake is a shallow, weedy lake in a rural, agricultural part of Whatcom County. Numerous stumps and snags protrude from the lake surface and in summer there is little open water. The mean depth of the lake is shallow (3 ft) and the bottom slope is gentle (0.45 percent).

The biological productivity of the lake was one of the highest of the 26 lakes studied. Nutrient and chlorophyll *a* concentrations were moderate to high throughout the year. The water was highly colored and was relatively high in dissolved minerals; the specific conductance averaged 240 micromhos. Secchi-disc visibility was low, averaging 2.4 feet. The muck-and-clay bottom was completely covered with coontail and pondweed; about 86 percent of the lake surface was covered with a variety of emergent macrophytes, chiefly yellow lily. A dense growth of green and blue-green algae was observed in May. Fecal-coliform-bacteria counts were generally moderate except in May, at which time the average rose to 80 colonies per 100 ml.

The lake was too shallow to stratify but, because of the high productivity, DO concentrations near zero were observed at depth in July and September.

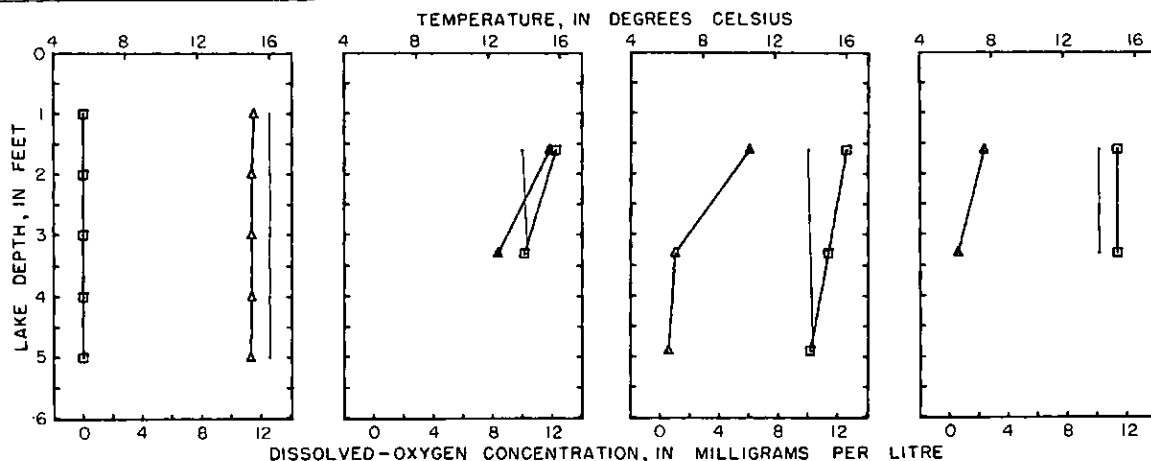
Water-quality data for Tennant Lake near Ferndale

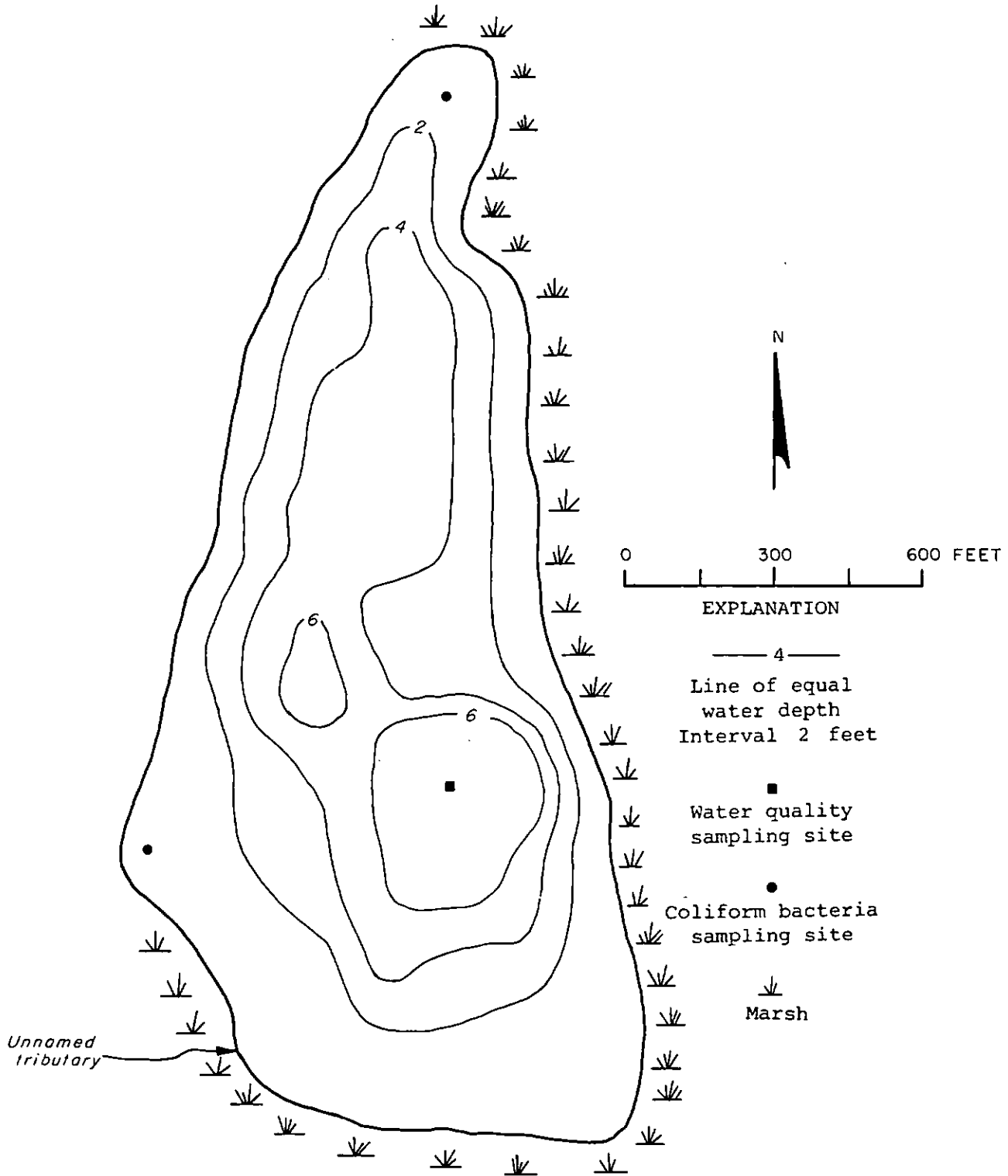
[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 25		May 6		July 8		September 16	
	3	(a)	3	(a)	3	(a)	3	(a)
Water depth (ft)-----								
Silica (SiO ₂)-----	4.1	--	0.5	--	1.9	--	1.8	--
Dissolved iron (Fe), in µg/l--	960	--	1,100	--	6,600	--	25,000	--
Dissolved manganese (Mn)----- (in µg/l)	22	--	140	--	1,700	--	2,100	--
Calcium (Ca) -----	9.5	--	--	--	--	--	19	--
Magnesium (Mg) -----	7.4	--	--	--	--	--	12	--
Sodium (Na) -----	19	--	--	--	--	--	31	--
Potassium (K) -----	9.8	--	--	--	--	--	9.0	--
Bicarbonate (HCO ₃) -----	62	--	86	--	98	--	120	--
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	9.3	--	--	--	--	--	3.2	--
Chloride (Cl)-----	32	--	--	--	--	--	45	--
Nitrate nitrogen (as N)-----	.18	--	.26	--	.00	--	.01	--
Nitrite nitrogen (as N)-----	.00	--	.00	--	.01	--	.01	--
Ammonia nitrogen (as N)-----	.31	--	.21	--	.32	--	.53	--
Organic nitrogen (as N)-----	.89	--	1.4	--	1.2	--	2.4	--
Total phosphorus (as P)-----	.11	--	.14	--	.20	--	.38	--
Orthophosphate (as P)-----	.026	--	.014	--	.010	--	.005	--
Suspended solids (110 °C)-----	9	--	--	--	--	--	39	--
Hardness as CaCO ₃ (Ca,Mg)-----	54	--	--	--	--	--	97	--
Specific conductance----- (micromhos at 25 °C)	200	--	240	--	230	--	280	--
pH (pH units)-----	7.6	--	7.5	--	6.3	--	6.6	--
Water temperature (°C)-----	5.7	--	14.0	--	15.0	--	15.0	--
Color (Pt-Co scale)-----	90	--	80	--	300	--	350	--
Secchi-disc (ft)-----		3.5		2.6		2.3		1.3
Dissolved oxygen (DO)-----	11.4	--	8.4	--	1.0	--	.6	--
Chlorophyll <i>a</i> in photic zone- (µg/l)	26	--	44	--	--	--	--	--
Fecal coliform Range-- (col. per 100 ml) Mean---		13-15 14		1-160 80		7 7		<1-11 6
Total organic carbon (as C)--	15	--	19	--	24	--	34	--

^aNot taken.

EXPLANATION
 □—□ Temperature
 ▲—▲ Dissolved oxygen concentration
 — Dissolved oxygen concentration at 100 percent saturation





Tennant Lake, Whatcom County. From U.S. Geological Survey, October 16, 1974.



Tennant Lake, Whatcom County. July 20, 1974.
Approx. scale 1:4800.

DATA ON SELECTED LAKES IN WASHINGTON, PART 5

Toad Lake near Bellingham (12203900)Location.

2.8 miles northeast of Roosevelt School in Bellingham, Whatcom County; lat 48°47'23", long 122°23'57"; NE1/4 sec.15, T.38 N., R.3 E.; Puget Sound basin; 714 feet altitude. Bellingham North quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	33 acres	Length of shoreline-----	1.2 miles
Volume-----	660 acre-ft	Shoreline configuration----	1.4
Mean depth-----	20 ft	Development of volume-----	0.64
Maximum depth-----	31 ft	Bottom slope-----	2.3 percent

Drainage basin.

Size: 0.50 mi².

Geology: Chiefly sandstone with other sedimentary rocks (Hunting and others, 1961).

Soils: Stony silt loam and rough mountainous land, on moderate to steep slopes (Poulson and Flannery, 1953).

Land use	Percent
Urban-----	0
Suburban-----	5
Agricultural-----	0
Forest or unproductive-----	85
Lake surface-----	10

Nearshore development.

Number of nearshore homes: 33 (mostly seasonal).

Nearshore residential development: 57 percent.

Hydrology.

The lake has one inflow. On Feb. 26, July 9, and Sept. 17 the inflow was estimated to be 0.5, 0.2, and 0.4 ft³/s, respectively. Drainage is westward via an unnamed stream to Squilicum Creek and Bellingham Bay. On Feb. 26, May 7, and July 9, the outflow was 2.29, 0.73, and 0.23 ft³/s, respectively. On Sept. 17 the outflow channel was dry.

The lake stage declined 0.9 foot from Feb. 26 to Oct. 1, 1974.

Littoral bottom.

Silt, sand, and gravel, with some wood debris and sunken logs.

Aquatic plants.

Macrophytes:

Shoreline covered by emersed plants: 1-10 percent.

Lake surface covered by emersed plants: <1 percent.

Lake bottom covered by submersed plants: 11-25 percent.

Rooted aquatic plants observed: Cattail (*Typha* sp.)*, waterweed (*Elodea* sp.)*, yellow lily (*Nuphar* sp.), white lily (*Nymphaea* sp.), rush (*Juncus* sp.), sedge (*Carex* sp.), and pondweed (*Potamogeton* sp.).

Algae observed:

Feb. 26, 1974: Diatoms (*Asterionella* sp.*, others) and greens.

May 7, 1974: Diatoms (*Asterionella* sp.), and dinoflagellates.

July 9, 1974: Yellow-browns (*Dinobryon* sp.)*, blue-greens, and diatoms.

Sept. 17, 1974: Diatoms, dinoflagellates, and yellow-browns.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Toad Lake is in a forested area of moderate relief. Many of the nearshore residences are of relatively recent construction and most are occupied only seasonally.

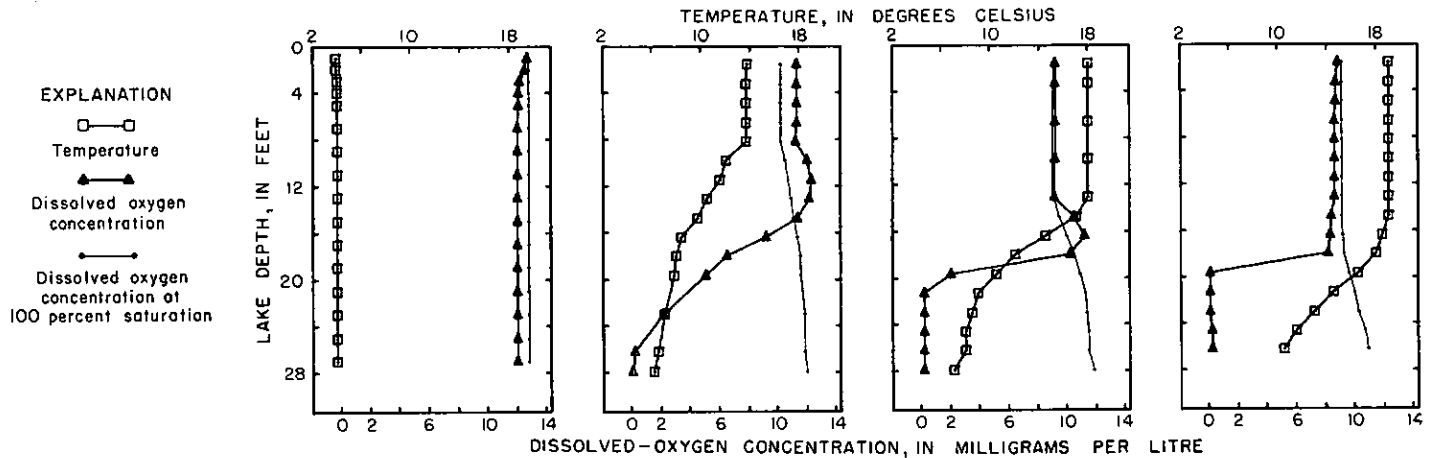
The biological productivity of the lake was moderate. Orthophosphate and chlorophyll a concentrations were moderate; inorganic nitrogen concentrations declined from 0.57 mg/l in February to 0.03 mg/l in September. About 13 percent of the lake bottom was covered with aquatic macrophytes, chiefly waterweed.

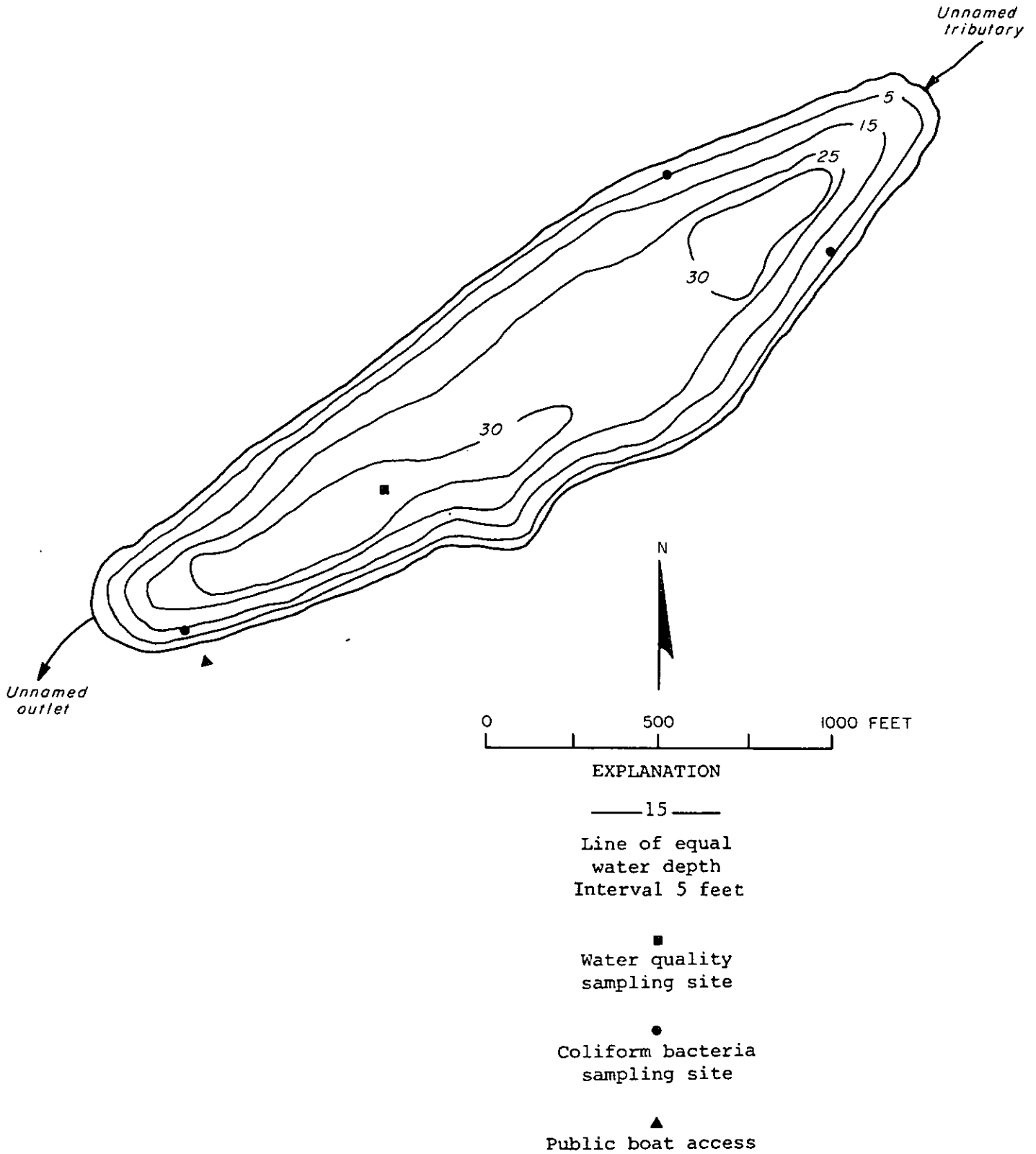
Thermal stratification was well established in July and September, at which time about 20 percent of the lake volume had DO concentrations near zero.

Water-quality data for Toad Lake near Bellingham

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	February 26		May 7		July 9		September 17	
	3	25	3	26	3	25	3	23
Water depth (ft)-----								
Silica (SiO ₂)-----	8.9	8.8	3.5	7.5	0.3	6.7	2.0	11
Dissolved iron (Fe), in µg/l--	440	790	150	650	140	900	130	580
Dissolved manganese (Mn)----- (in µg/l)	10	30	20	160	10	590	10	650
Calcium (Ca) -----	8.6	--	--	--	--	--	8.3	--
Magnesium (Mg) -----	3.0	--	--	--	--	--	2.5	--
Sodium (Na) -----	5.9	--	--	--	--	--	6.3	--
Potassium (K) -----	.7	--	--	--	--	--	.8	--
Bicarbonate (HCO ₃) -----	38	40	39	43	42	54	44	56
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	6.4	--	--	--	--	--	7.0	--
Chloride (Cl)-----	2.4	--	--	--	--	--	3.3	--
Nitrate nitrogen (as N)-----	.47	.47	.21	.18	.00	.00	.00	.00
Nitrite nitrogen (as N)-----	.01	.01	.00	.01	.00	.00	.00	.00
Ammonia nitrogen (as N)-----	.09	.09	.04	.18	.05	.19	.03	.10
Organic nitrogen (as N)-----	.30	.22	.30	.28	.20	.48	.23	.28
Total phosphorus (as P)-----	.037	.036	.023	.052	.013	.071	.013	.053
Orthophosphate (as P)-----	.006	.005	.003	.008	.011	.008	.003	.006
Suspended solids (110 °C)-----	11	--	--	--	--	--	1	--
Hardness as CaCO ₃ (Ca,Mg)-----	34	--	--	--	--	--	31	--
Specific conductance----- (micromhos at 25 °C)	76	78	82	89	84	93	90	120
pH (pH units)-----	--	7.8	8.2	7.0	7.2	6.5	7.4	6.6
Water temperature (°C)-----	4.0	4.0	13.7	6.5	18.0	8.0	19.0	13.0
Color (Pt-Co scale)-----	--	15	0	20	10	35	20	45
Secchi-disc (ft)-----		5.0		8.5		9.2		12
Dissolved oxygen (DO)-----	12.2	12.0	11.3	.2	9.2	.2	8.7	.1
Chlorophyll <u>a</u> in photic zone- (µg/l)	7.4	--	2.8	--	6.8	--	3.9	--
Fecal coliform Range-- (col. per 100 ml) Mean---		<1-1 <1		<1 <1		1-8 5		<1-4 2
Total organic carbon (as C)--	4.8	--	4.7	--	3.7	--	3.9	--





Toad (Emerald) Lake, Whatcom County.
From U.S. Geological Survey, January 21, 1974.



Toad (Emerald) Lake, Whatcom County. July 20, 1974. Approx. scale 1:4800.

Wapato Lake near Manson (12451800)Location.

1.4 miles north of Manson, Chelan County; lat 47°54'44", long 120°09'15"; NE¼SE¼ sec.23, T.28 N., R.21 E.; Chelan River basin; 1,228 feet altitude.
Manson quadrangle (1:24,000 scale).
Location is of southernmost shoreline point of lake.

Physical characteristics of lake.

Surface area-----	220 acres	Length of shoreline-----	3.2 miles
Volume-----	9,500 acre-ft	Shoreline configuration----	1.6
Mean depth-----	44 ft	Development of volume-----	0.64
Maximum depth-----	68 ft	Bottom slope-----	2.0 percent

Drainage basin.

Size: Not measured because water is imported from outside the drainage basin.
Geology: Undifferentiated granitic rocks (Hunting and others, 1961).
Soils: Coarse sandy loam on rough broken land with moderate to steep slopes (Koehler, 1922).

Land use	Percent
Urban-----	} Not determined because water is imported from outside the drainage basin.
Suburban-----	
Agricultural-----	
Forest or unproductive----	
Lake surface-----	

Nearshore development.

Number of nearshore homes: 9.
Nearshore residential development: 7 percent.

Hydrology.

The lake has two inflows, the larger being Joe Creek. The flow of Joe Creek is regulated at the outlet of Antilon Lake, hence the inflow to Wapato Lake was not measured.
Wapato Lake has no surface-water outflow.

The lake stage declined 3.8 feet from Apr. 17 to Sept. 25, 1974.

Littoral bottom.

Rock, sand, and gravel, with some silt.

Aquatic plants.

Macrophytes:

Shoreline covered by emersed plants: 11-25 percent.
Lake surface covered by emersed plants: <1 percent.
Lake bottom covered by submersed plants: 11-25 percent.
Rooted aquatic plants observed: Bulrush (Scirpus sp.)*, smartweed (Polygonum sp.), cattail (Typha sp.), rush (Juncus sp.), waterweed (Elodea sp.), coontail (Ceratophyllum sp.), pondweed (Potamogeton sp.), and milfoil (Myriophyllum sp.).

Algae observed:

Apr. 17, 1974: Diatoms (Tabellaria sp.*, others).
May 22, 1974: Diatoms (Fragillaria sp.*, Tabellaria sp.*, others).
July 17, 1974: Diatoms (Tabellaria sp., Fragillaria sp.)*, greens, and blue-greens.
Sept. 25, 1974: Blue-greens (Aphanizomenon sp.*, others), greens, and diatoms.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Wapato Lake is a natural lake that is controlled by a gate and fed in part by water pumped from Lake Chelan. The lake water is used to irrigate the apple orchards that partly surround the lake.

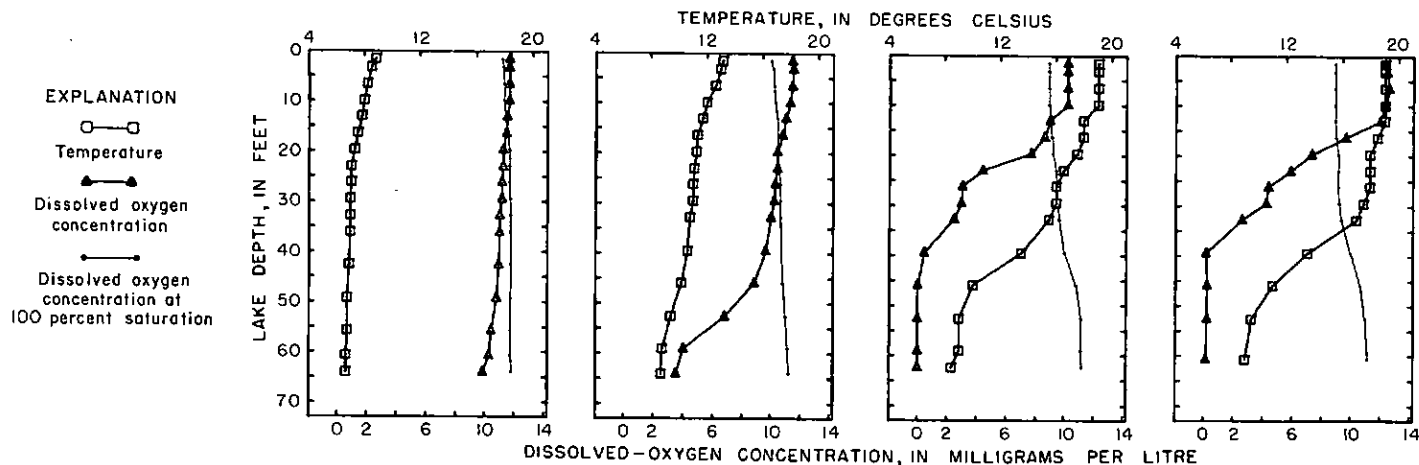
The biological productivity of the lake was moderate. Orthophosphate concentrations were moderate to high in April and May (0.015 and 0.021 mg/l, respectively) but had declined to 0.004 mg/l by July. Inorganic-nitrogen concentrations followed a similar pattern. Chlorophyll a concentrations were moderate throughout the year. A bloom of diatoms was observed in May. The littoral bottom was covered with submersed aquatic macrophytes that extended to depths of about 18 feet.

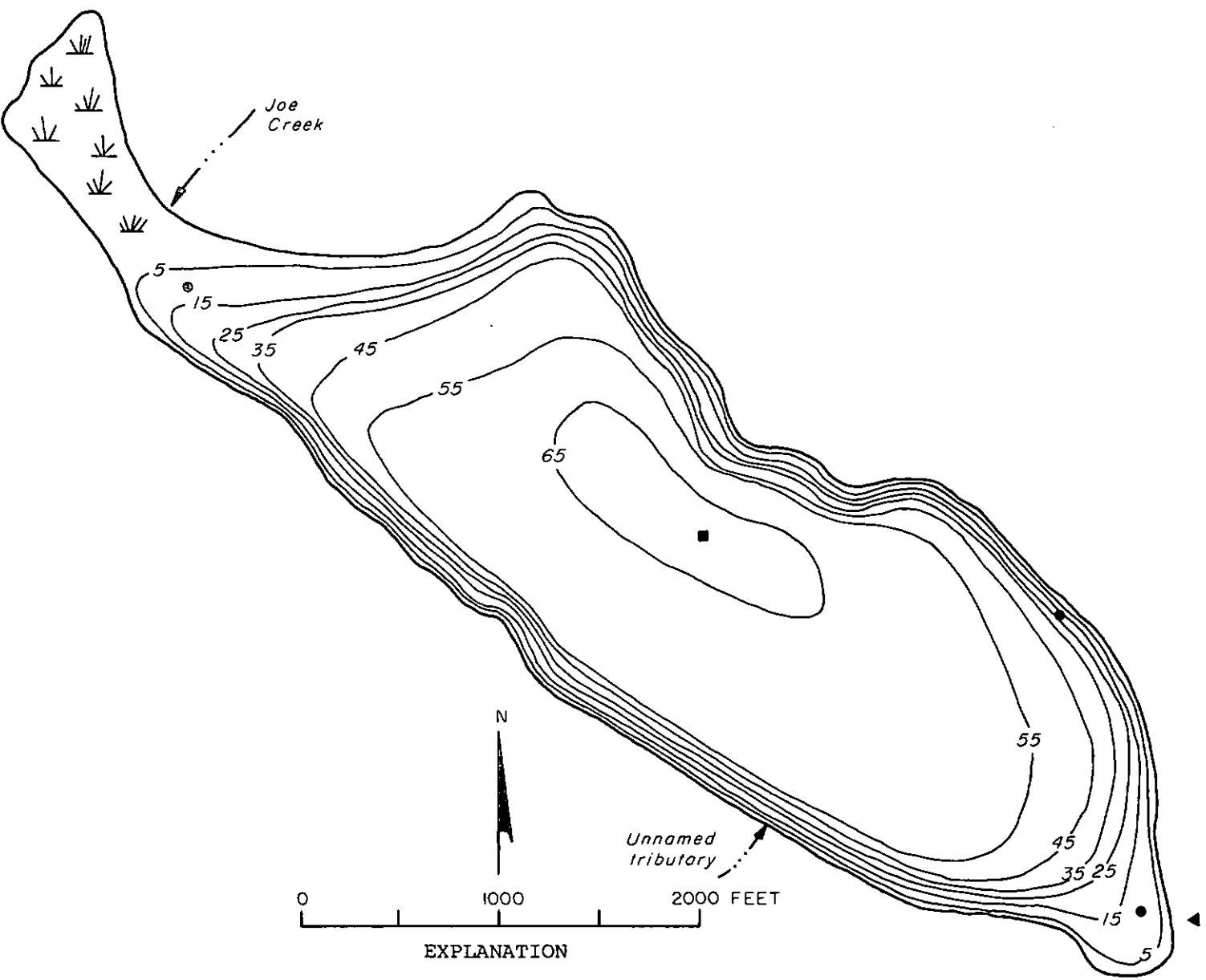
Thermal stratification was well established by July, and DO concentrations in the hypolimnion were near zero.

Water-quality data for Wapato Lake near Manson

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	April 17		May 22		July 17		September 25	
	3	61	3	61	3	59	3	57
Water depth (ft)-----								
Silica (SiO ₂)-----	3.0	4.1	4.2	6.0	3.6	7.8	4.2	9.8
Dissolved iron (Fe), in µg/l--	50	50	50	40	30	50	20	80
Dissolved manganese (Mn)----- (in µg/l)	80	70	30	220	0	2,700	10	750
Calcium (Ca) -----	37	--	--	--	--	--	40	--
Magnesium (Mg) -----	10	--	--	--	--	--	13	--
Sodium (Na) -----	10	--	--	--	--	--	12	--
Potassium (K) -----	2.1	--	--	--	--	--	2.3	--
Bicarbonate (HCO ₃) -----	150	140	160	160	150	170	150	190
Carbonate (CO ₃)-----	--	--	0	--	0	--	4	--
Sulfide (S)-----	--	--	--	--	--	>5	--	>5
Sulfate (SO ₄)-----	21	--	--	--	--	--	20	--
Chloride (Cl)-----	1.4	--	--	--	--	--	3.0	--
Nitrate nitrogen (as N)-----	.16	.17	.19	.17	.00	.00	.00	.01
Nitrite nitrogen (as N)-----	.01	.01	.01	.01	.00	.00	.00	.00
Ammonia nitrogen (as N)-----	.14	.18	.07	.46	.02	1.6	.02	2.9
Organic nitrogen (as N)-----	.54	.49	.49	.64	.45	.40	.40	.1
Total phosphorus (as P)-----	.057	.055	.075	.15	.029	.37	.018	.60
Orthophosphate (as P)-----	.015	.027	.021	.12	.004	.37	.001	.58
Suspended solids (110°C)-----	3	--	--	--	--	--	6	--
Hardness as CaCO ₃ (Ca,Mg)----	130	--	--	--	--	--	150	--
Specific conductance----- (micromhos at 25°C)	240	240	250	250	250	270	250	290
pH (pH units)-----	8.3	8.4	8.7	8.1	8.6	7.1	8.6	7.0
Water temperature (°C)-----	8.5	6.7	13.0	8.8	19.0	9.0	19.0	9.0
Color (Pt-Co scale)-----	10	20	5	5	10	20	15	25
Secchi-disc (ft)-----		12		13		7.2		12
Dissolved oxygen (DO)-----	11.6	10.3	11.5	3.8	10.2	.0	12.4	.2
Chlorophyll <i>a</i> in photic zone- (µg/l)	3.4	--	3.1	--	5.8	--	4.7	--
Fecal coliform Range-- (col. per 100 ml) Mean---		<1-1 <1		<1 <1		<1-3 1		<1-1 1
Total organic carbon (as C)--	6.8	--	4.7	--	6.3	--	7.0	--





- EXPLANATION
- 15 —
Line of equal
water depth
Interval 5 feet

●
Coliform bacteria
sampling site
 - Water quality
sampling site

▲
Public boat access
 - ▾
Marsh

Wapato Lake, Chelan County. From Washington Department of Game, February 15, 1950.



Wapato Lake, Chelan County. May 25, 1972. Approx. scale 1:13,000.

Wenatchee Lake near Plain (12454500)Location.

4.6 miles northwest of Plain, Chelan County; lat 47°48'31", long 120°43'35";
NE¼SW¼ sec.28, T.27 N., R.17 E.; Wenatchee River basin; 1,868 feet altitude.
Plain quadrangle (1:24,000 scale).

Physical characteristics of lake.

Surface area-----	2,500 acres	Length of shoreline-----	13 miles
Volume-----	360,000 acre-ft	Shoreline configuration----	1.9
Mean depth-----	150 ft	Development of volume-----	0.60
Maximum depth-----	240 ft	Bottom slope-----	2.1 percent

Drainage basin.

Size: 273 mi².

Geology: Undifferentiated granitic and metamorphic rocks, with some sandstone and glacial silt (Hunting and others, 1961).

Soils: Acidic sandy loam to silt loam (U.S. Soil Conservation Service, 1968).

Land use	Percent
Urban-----	0
Suburban-----	<1
Agricultural-----	0
Forest or unproductive----	98
Lake surface-----	2

Nearshore development.

Number of nearshore homes: 276.

Nearshore residential development: 59 percent.

Hydrology.

The lake has several inflows, the two largest being the White and Little Wenatchee Rivers. The discharge of the White River where it is gaged, approximately 6 river miles upstream from the lake, averages about 820 ft³/s. Drainage is eastward to the Wenatchee River.

The lake stage rose 2.4 feet from May 18 to July 18, 1974.

Littoral bottom.

Rock, gravel, and sand, with some silt.

Aquatic plants.Macrophytes:

Shoreline covered by emersed plants: 11-25 percent.

Lake surface covered by emersed plants: 1-10 percent.

Lake bottom covered by submersed plants: 1-10 percent.

Rooted aquatic plants observed: Horsetail (*Equisetum* sp.)*, waterweed (*Elodea* sp.)*, rush (*Juncus* sp.), white lily (*Nymphaea* sp.), bur reed (*Sparganium* sp.), quillwort (*Iscoetes* sp.), milfoil (*Myriophyllum* sp.), and pondweed (*Potamogeton* sp.).

Algae observed:

Apr. 18, 1974: None.

May 22, 1974: None.

July 18, 1974: None.

Sept. 27, 1974: None.

*Asterisk indicates dominant plants present.

Summary and conclusions.

Wenatchee Lake is a large, deep lake in a remote, forested part of Chelan County. The lake is considered to be the head of the Wenatchee River. A large marsh occurs at the northwestern (upper) end of the lake. Because of its large size and irregular shape, the lake was sampled at two sites.

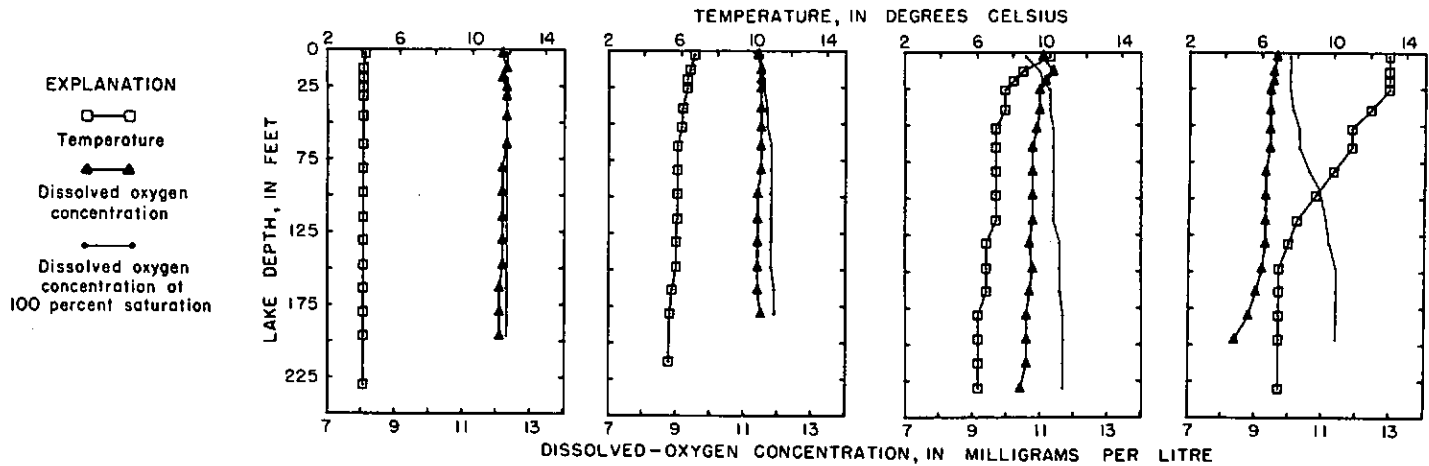
The biological productivity of the lake was one of the lowest of the 26 lakes studied. Nutrient and chlorophyll *a* concentrations were low. The water was relatively low in dissolved minerals; the specific conductance averaged 23 micromhos. Secchi-disc transparency was high, averaging 21 feet. Among the aquatic macrophytes observed were horsetail, bur reed, and quillwort.

Thermal stratification had developed only slightly by September and DO concentrations were generally above 8.0 mg/l at both sites throughout the year. The lack of pronounced stratification and the presence of high DO concentrations may be attributable to the frequent high winds that cross the lake surface.

Water-quality data for Wenatchee Lake near Plain (site 1)

[Milligrams per litre unless otherwise indicated]

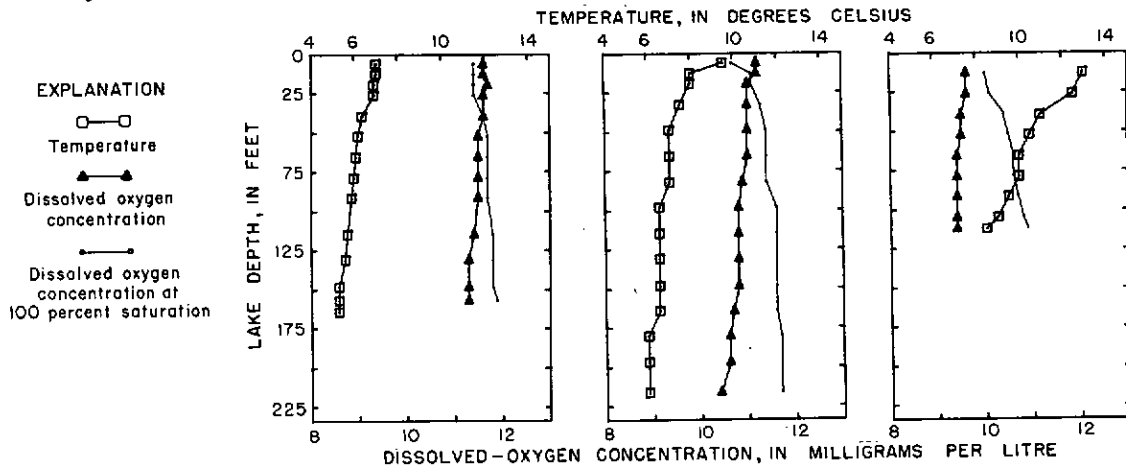
Date of collection (1974)-----	April 18		May 22		July 18		September 27	
	3	230	3	213	3	230	3	223
Water depth (ft)-----								
Silica (SiO ₂)-----	5.5	8.9	7.7	7.7	5.8	5.9	5.3	5.9
Dissolved iron (Fe), in µg/l--	70	70	50	70	50	90	40	60
Dissolved manganese (Mn)----- (in µg/l)	0	0	0	0	0	0	0	20
Calcium (Ca) -----	4.8	--	--	--	--	--	2.3	--
Magnesium (Mg) -----	.8	--	--	--	--	--	1.0	--
Sodium (Na) -----	1.3	--	--	--	--	--	.8	--
Potassium (K) -----	.9	--	--	--	--	--	.7	--
Bicarbonate (HCO ₃) -----	13	15	15	15	10	10	11	11
Carbonate (CO ₃)-----	--	--	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--	--	--
Sulfate (SO ₄)-----	2.5	--	--	--	--	--	2.0	--
Chloride (Cl)-----	.7	--	--	--	--	--	.9	--
Nitrate nitrogen (as N)-----	.10	.10	.11	.12	.05	.07	.00	.09
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.00	.00	.01	.00
Ammonia nitrogen (as N)-----	.02	.02	.01	.02	.02	.03	.02	.03
Organic nitrogen (as N)-----	.16	.08	.08	.10	.01	.03	.04	.03
Total phosphorus (as P)-----	.005	.002	.005	.003	.004	.005	.005	.004
Orthophosphate (as P)-----	.002	.002	.000	.003	.004	.002	.001	.001
Suspended solids (110°C)-----	5	--	--	--	--	--	6	--
Hardness as CaCO ₃ (Ca, Mg)-----	15	--	--	--	--	--	10	--
Specific conductance----- (micromhos at 25°C)	27	27	28	27	19	17	20	17
pH (pH units)-----	7.4	7.6	7.9	7.7	6.7	6.4	7.2	7.2
Water temperature (°C)-----	4.1	4.0	6.7	5.3	10.0	6.0	13.0	7.0
Color (Pt-Co scale)-----	0	0	0	0	0	0	0	0
Secchi-disc (ft)-----		21		25		20		20
Dissolved oxygen (DO)-----	12.2	--	11.4	--	11.1	10.4	9.6	--
Chlorophyll <i>a</i> in photic zone- (µg/l)	.8	--	1.0	--	1.4	--	2.1	--
Fecal coliform Range--	<1		<1		<1-1		<1-2	
(col. per 100 ml) Mean---	<1		<1		<1		<1	
Total organic carbon (as C)--	3.7	--	1.3	--	2.3	--	2.9	--

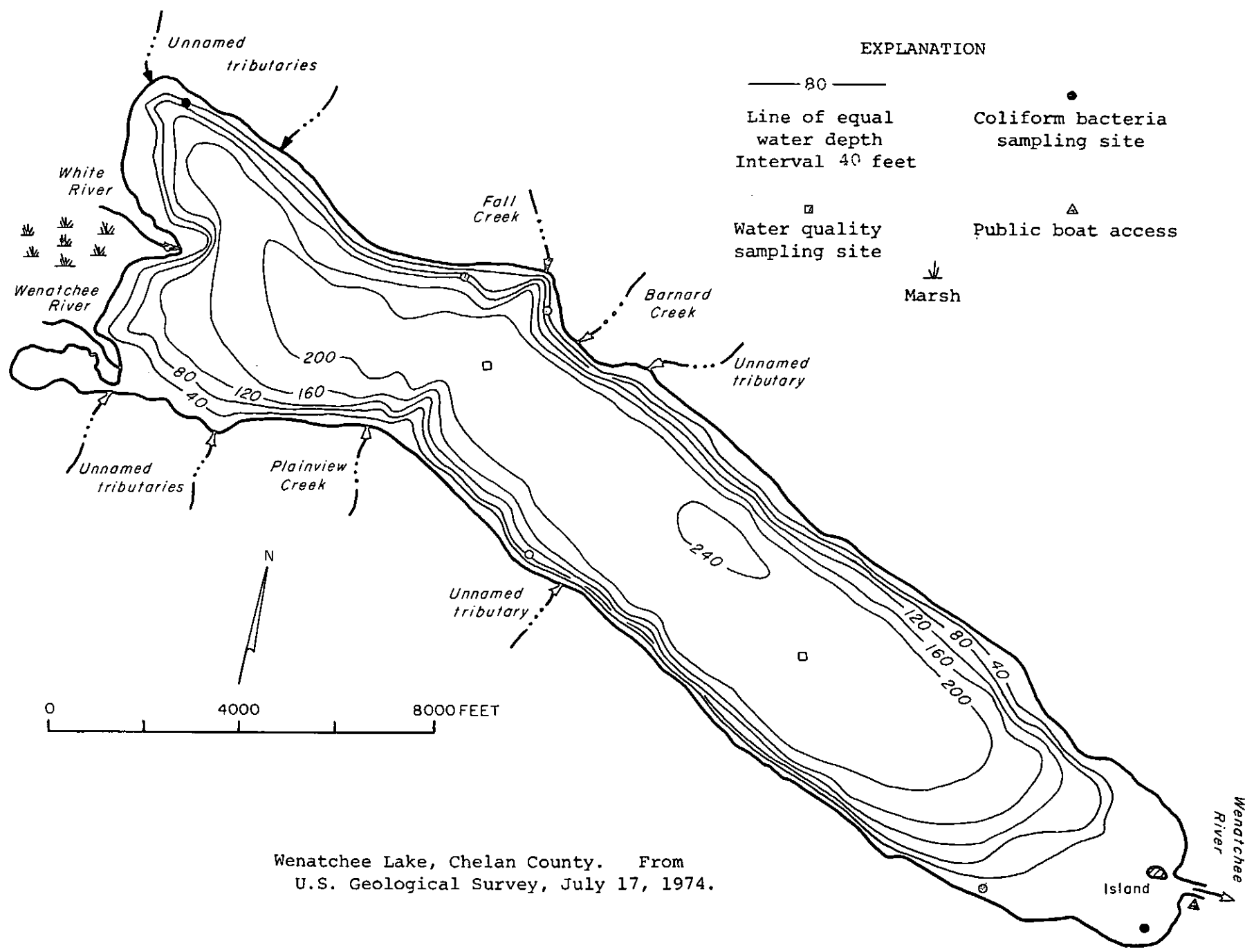


Water-quality data for Wenatchee Lake near Plain (site 2)

[Milligrams per litre unless otherwise indicated]

Date of collection (1974)-----	May 22		July 18		September 27	
	3	154	3	217	3	105
Water depth (ft)-----						
Silica (SiO ₂)-----	7.6	7.7	5.8	5.8	5.4	5.4
Dissolved iron (Fe), in µg/l--	50	90	90	100	50	40
Dissolved manganese (Mn)----- (in µg/l)	0	0	10	0	10	0
Calcium (Ca) -----	--	--	--	--	14	--
Magnesium (Mg) -----	--	--	--	--	1.9	--
Sodium (Na) -----	--	--	--	--	1.0	--
Potassium (K) -----	--	--	--	--	.5	--
Bicarbonate (HCO ₃) -----	15	15	10	13	11	11
Carbonate (CO ₃)-----	--	--	--	--	--	--
Sulfide (S)-----	--	--	--	--	--	--
Sulfate (SO ₄)-----	--	--	--	--	1.7	--
Chloride (Cl)-----	--	--	--	--	1.0	--
Nitrate nitrogen (as N)-----	.11	.11	.05	.08	.01	.05
Nitrite nitrogen (as N)-----	.00	.00	.00	.00	.00	.00
Ammonia nitrogen (as N)-----	.02	.02	.02	.02	.02	.03
Organic nitrogen (as N)-----	.07	.17	.03	.00	.03	.03
Total phosphorus (as P)-----	.002	.029	.004	.005	.003	.003
Orthophosphate (as P)-----	.002	.002	.001	.001	.000	.000
Suspended solids (110°C)-----	--	--	--	--	3	--
Hardness as CaCO ₃ (Ca, Mg)----	--	--	--	--	43	--
Specific conductance----- (micromhos at 25°C)	28	28	19	17	19	18
pH (pH units)-----	7.8	7.5	6.6	6.4	7.4	7.4
Water temperature (°C)-----	7.0	5.3	10.0	6.0	13.0	9.0
Color (Pt-Co scale)-----	0	0	0	0	0	0
Secchi-disc (ft)-----		25		20		18
Dissolved oxygen (DO)-----	11.6	11.3	10.8	10.4	9.6	9.4
Chlorophyll <i>a</i> in photic zone-- (µg/l)	1.0	--	1.0	--	1.8	--
Fecal coliform Range-- (col. per 100 ml) Mean---		<1 <1		<1-1 <1		<1-2 <1
Total organic carbon (as C)--	5.0	--	2.3	--	4.7	--





Wenatchee Lake, Chelan County. From U.S. Geological Survey, July 17, 1974.



Wenatchee Lake, Chelan County. August 20, 1970. Approx. scale 1:34,600.



