WASHINGTON STATE DEPARTMENT OF ECOLOGY

Lake Water Quality Assessment Program

1991-1992

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Lake Water Quality Assessment Program

1991-1992

by
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and Laboratory Services Program
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This assessment report has been prepared to partially fulfill the state of Washington's obligations under Sections 305(b) and 314 of the Federal Clean Water Act.

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Washington's Citizen Lake Monitoring Program costs about $112,000 annually. During 1991 and 1992, approximately 29% of the project was funded by a Federal Clean Water Act 314 grant, 31% by a Federal 205 (j) grant, and 40% by matching state monies.

EXECUTIVE SUMMARY

The objectives of Ecology's lake water quality assessment program are to identify lakes that are exhibiting water quality problems, to assess significant publicly-owned lakes by estimating the trophic status of monitored lakes, and to promote public awareness of lake ecology and protection. In 1991 and 1992, Ecology's lake water quality assessment program consisted of a statewide volunteer lake monitoring program, supplemented with data collected by Ecology staff. This report presents lake monitoring results and discusses informal case-studies on the effectiveness of three citizen-initiated lake protection efforts. Also included in this report are 46 individual lake assessments, which were written for volunteers who participated in the program. In 1992, the lake water quality assessment program also included sampling sediment from ten lakes for potentially toxic compounds. Results of this sediment monitoring component of the project is reported in Survey of Chemical Contaminants in Ten Washington Lakes (Serdar *et al.*, in prep).

In 1991 and 1992, volunteers participating in Washington's Citizen Lake Monitoring Project measured Secchi disk transparency and surface water temperature bimonthly for six months (May through October). To supplement volunteer-collected data, Ecology staff met onsite with each of the volunteers to collect water samples and profile data. In 1991, onsite visits were made during May and early June, and water samples were composited from the epilimnion of each lake. In 1992, the scope of the onsite visits was expanded to include two visits (May and August), and composite samples were collected from both the epilimnion and hypolimnion of stratified lakes. Water samples were analyzed for total phosphorus (TP), total nitrogen (TN), and chlorophyll *a* during both years. Twenty-three of the lakes monitored in 1992 were also sampled for total suspended solids, total nonvolatile suspended solids, and fecal coliform bacteria.

Carlson's Trophic State Index (1977) was used to evaluate volunteer-collected Secchi depth data and Ecology-collected phosphorus and chlorophyll *a* data. Trophic state estimates were assigned to a total of 50 lakes; 46 of these lakes were monitored by volunteers during one or both years, and the remaining four lakes were sampled by Ecology staff only. Of the 42 lakes assessed from 1991 data, 19 were characterized as oligotrophic or oligo-mesotrophic, 13 were characterized as mesotrophic or meso-eutrophic, and 10 lakes were characterized as eutrophic. Of the 45 lakes assessed from 1992 data, 21 were characterized as oligotrophic or oligo-mesotrophic, 17 were characterized as mesotrophic or meso-eutrophic, and seven were characterized as eutrophic. One lake, Lake Kahlotus, dried up in 1992 and could not be assessed. There were not enough data available to assess water quality trends in individual lakes.

The majority of lakes were assigned the same trophic state for both 1992 and 1991. The availability of additional TP and chlorophyll *a* data in 1992 improved the assessments in 1992. Six lakes were assigned improved (less eutrophic) trophic states in 1992 than in 1991, primarily because of these additional data.

Citizen-initiated lake protection efforts from three lakes (Lake Martha, Snohomish County; Phillips Lake, Mason County; and Lake Roesiger, Snohomish County) are described here as case studies of the effectiveness of citizen-initiated lake protection efforts. The major conclusion from these case studies is that for citizen-initiated efforts to be successful, citizen groups need individuals who are highly motivated, well organized, and resourceful in getting the help they need to accomplish their goals.

Additional Federal Clean Water Act grant reporting requirements will be addressed in a separate publication, or in the state's 305(b) report.

INTRODUCTION

The purpose of this report is to describe Ecology's 1991-1992 lake water quality assessment program, and to present data and individual lake assessments from the 46 lakes which were monitored by volunteers in 1991 and 1992. Also included are the results from three case studies to determine the success or failure of citizen-initiated lake protection measures.

Background

Ecology's lake water quality assessment program was established in 1989 to gather general water quality information from "significant, publicly-owned lakes." Significant, publicly-owned lakes are defined as:

> "those lakes, including impoundments which meet the definition of Lake Class in the state Water Quality Standards (a mean detention time of greater than 15 days), which have an area of 20 acres or greater within the bounds of their ordinary high water mark, support or have the potential to support the fishable-swimmable goals of the Clean Water Act, and are publicly owned or have a public access point; in addition to any other lakes specifically identified as significant by the Department of Ecology" (Ecology, 1992).

Data collected from the program are used primarily to assess each monitored lake for the state's biennial Water Quality Assessment (305 (b)) Report. Lake water quality assessments are required under Section 314 (a)(2) of the Clean Water Act, as amended by the Water Quality Act of 1987. Although a schedule for assessing significant publicly-owned lakes is required, it is very difficult to develop an assessment schedule because of the large number of lakes in Washington and our reliance on volunteers to collect data. As a result, no formal schedule has been developed for Ecology's lake water quality assessment program. Instead, Ecology intends to assess as many of Washington's significant, publicly-owned lakes as funds and the availability of volunteers allow.

The 1989 lake water quality assessment program was funded from a Federal 314 Water Quality Assessment grant. The project consisted of volunteer monitoring on 48 lakes, a supplemental water quality survey conducted by Ecology staff on 25 lakes (Brower and Kendra, 1990), and a toxics survey conducted by Ecology staff on fish tissues and sediments from 10 lakes (Johnson and Norton, 1990). Results from the 1989 program are discussed in <u>Lake Water Quality Assessment Project, 1989</u> (Rector and Hallock, 1991).

In 1990, a Water Quality Management and Planning (205 (j)) grant funded the majority of the program. The volunteer monitoring program was expanded to include additional lakes (for a total of 73 lakes), and Ecology staff met with each of the volunteers during May and August to collect water samples and vertical profile data. There was no toxics component in the 1990 program, and the water quality survey was conducted on only 15 lakes. Results of this survey are reported in Coots (1991). Results of all data collected from 1990 are discussed in Lake Water Quality Assessment Project, 1990 (Rector and Hallock, 1993).

The 1991-1992 program is described below.

Program Objectives

The goal of the lake water quality assessment program was to assess the current water quality of significant publicly-owned lakes in Washington, and to build a relationship with volunteers to foster data exchange, education, and technical assistance. Specific objectives were as follows:

1) Determine the trophic status of monitored lakes.
2) Assess water quality in lakes not evaluated in the last five years and determine the degree to which beneficial uses are supported.
3) Promote public awareness of lake processes and lake protection measures and foster a conservation ethic.
4) Separate monitored lakes by ecoregion (Omernik and Gallant, 1986) and identify anomalies within these regions for further investigation.
5) Determine trends once a sufficiently long period of record is established.
6) Establish a data set for analysis and dissemination.

METHODS

Volunteer Recruitment/Lake Selection

All Washington lakes that cover at least 20 acres and have a public access were eligible for inclusion in the volunteer monitoring program. The main factor for selecting lakes was whether someone volunteered to monitor a lake for the program. Volunteers were recruited through press releases, or were referred to the program from Ecology or county offices, or from other volunteers. Potential volunteers were accepted into the program if they indicated that 1) they wanted to monitor an eligible lake, 2) they were willing and able to collect monitoring data for the six month monitoring period, and 3) they had access to a boat to use while collecting data.

The number of lakes included in the volunteer monitoring program was affected by the level of funding each year. Because of reduced funding in 1991 (in comparison with 1990), volunteers were not actively recruited and the number of volunteers was reduced through attrition. A few lakes were added only as a result of the prospective volunteer's prior knowledge of the program. In 1992, more funding was available and an attempt was made to focus recruitment specifically within the central area of the state (Douglas, Grant, Chelan, and Okanogan Counties) in order to improve the geographical distribution of monitored lakes. A press release about the program was printed in local papers in these areas in

March 1992. Unfortunately, despite a desire to recruit volunteers for about 15 lakes from these counties, the press release resulted in adding only one new volunteer to the program.

Lakes monitored for the Municipality of Metropolitan Seattle's (METRO) Small Lakes Program were generally excluded from the State's monitoring program, in order to avoid duplication of effort, although some exceptions have been made (Lake Killarney and Lake Sawyer were monitored by both METRO and Ecology programs in 1992).

Each new volunteer was trained at his/her monitoring site during the May onsite visits (see discussion of onsite visits, below). New volunteers were provided with a one-page summary of monitoring instructions, a monitoring manual for reference, monitoring equipment (Secchi disk and thermometer), and business-reply data cards for mailing in data (Figure 1). Each volunteer was also provided with a vial containing a small amount of Lugol's solution, to be used for collecting an algae sample. Collecting algae samples was optional, but having the vial readily available made it easier for volunteers to collect and preserve a sample for later identification. Algae identification was provided as a service to the volunteers.

Field Methods

There were three separate field data collection efforts for the program: 1) Secchi depth data collected by the volunteers, 2) water samples and profiles collected by Ecology staff during "onsite visits" with the volunteers, and 3) sediment samples collected from five lakes to be analyzed for pesticides, and from five lakes to determine levels of copper accumulated in lake sediments that may have resulted from long-term use of copper sulfate as an algicide. Methods for the first two data collection efforts are discussed separately below. Methods and results for the toxics survey are discussed in Survey of Chemical Contaminants in Ten Washington Lakes (Serdar *et al.*, in prep).

Volunteer-Collected Data

Volunteers measured Secchi disk transparency and surface water temperature from one lake station (the deepest site). Data were collected approximately every two weeks from mid-May through mid-October. For consistency of methods and to maximize available sunlight for the Secchi depth readings, the volunteers were instructed to collect data between 10 a.m. and 2 p.m. After anchoring at their sampling site, each volunteer measured water clarity by leaning over the shady side of their boat, lowering a 20 cm diameter limnological style Secchi disk until it was no longer visible, and then slowly raising the disk until it was just barely visible. This depth was then read from the line attached to the Secchi disk (which is marked at one-foot intervals) and recorded to the nearest 1/4 foot. The procedure was performed twice during each sampling trip so that consistency between readings could be evaluated by Ecology staff (see the quality assurance evaluation in the Results Section). If the Secchi disk hit the lake bottom and was still visible, or was obscured by macrophyte growth, this was indicated on the data reporting card (Figure 1).

Figure 1. Business-reply postcard used by volunteers to report data to Ecology.

WASHINGTON'S CITIZEN LAKE MONITORING PROJECT

Your Name ______________________ Sample Date__________

Lake/County ______________________ Sample Time __________

1st Secchi Reading ______________feet 2nd Secchi Reading ______________feet

Did the Secchi disk: ☐ hit bottom ☐ enter weeds ☐ N/A

Surface Water Temperature __________ degrees

Percent Cloud Cover:	0%	10%	25%	50%	75%	90%	100%
Rain Within Last 2 Days:	None	Trace	Light	Moderate	Heavy		
Wind: Calm Light	Breezy	Strong	Gusty	Lake Height __________ ft/in			

Water Color:

Light Green	Moderately Green	Pea-Soup Green	Other: __________
Light Brown	Dark Brown	Greenish-Brown	
Black	Milky Green	Clear	

Field Observations/Questions/Comments

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL

FIRST CLASS MAIL PERMIT NO. 433, OLYMPIA, WA

POSTAGE WILL BE PAID BY ADDRESSEE

ATT: JULIE RECTOR
DEPARTMENT OF ECOLOGY
PO BOX 47600
OLYMPIA WA 98599-7600

Surface water temperature was measured using red alcohol pocket thermometers. Two styles of pocket thermometers were used: a BCR model (range -40 to 50°C) and a model from Bacharach Instrument Company (range -35 to 120°F). Surface temperature was measured by holding the thermometer six to eight inches below the water surface until temperature equilibrated. The temperature was then quickly read and recorded on the data card to the nearest 0.5 degree. Subjective assessments of weather conditions and water color were also reported on the data cards.

All volunteers were mailed a questionnaire on lake and watershed uses near the end of each monitoring season (Appendix A). The purpose of these questionnaires was to gather additional information from the monitored lakes that may be used when assessing the lakes. Several questions required the volunteers to make additional observations around their lakes (e.g., counting the number of nearshore homes). Questionnaire results for each lake are presented with the individual lake assessments at the end of this report.

Data Collected During Onsite Visits with the Volunteers

Ecology staff visited most of the volunteers during 1991 and 1992. In 1991, volunteers were visited once, during late May or early June. In 1992, the volunteers were visited twice; the first visit occurred during late May or early June, and the second occurred during late August or early September. The purpose of these "onsite visits" was to 1) observe the volunteer's Secchi disk reading technique, and compare the Ecology staff reading to the volunteer's reading to determine whether the volunteer needed suggestions for improving his or her technique; 2) collect profile data and water samples from the volunteers' sampling sites; 3) collect macrophyte and/or algae samples for identification; and 4) answer questions or discuss lake issues with each of the volunteers.

During an onsite visit, each volunteer took staff from Ecology to their monitoring site, and anchored if possible. The volunteers and Ecology staff each measured Secchi depth. Temperature, pH, dissolved oxygen, and conductivity were profiled using a Hydrolab® Surveyor II. Temperature profile data were used to determine whether the lakes were stratified, and if they were, to determine depths within the epilimnion and hypolimnion for collecting water samples. Weather conditions, water color, and general observations about the lake were recorded. If an obvious algal bloom was occurring at the surface or at depth (indicated by a large increase in dissolved oxygen with no concurrent decrease in temperature), a sample was collected for later identification. Plant samples were either identified onsite, or collected for later identification. Algae and macrophyte samples were collected for qualitative purposes only, and results are not inclusive of all species present.

During each onsite visit, water samples for total phosphorus (TP), total nitrogen (TN), and chlorophyll *a* were collected using a Kemmerer or Van Dorn style water sampler, and were composited from two to three equidistant depths within the strata (epilimnion or hypolimnion) sampled (Table 1). Composite aliquots were approximately equal volumes for each depth sampled. Sample bottles for TP and TN contained concentrated sulfuric acid as a sample preservative, to lower the pH of the sample below 2 pH units.

Table 1. Methods used for samples collected during onsite visits, 1991 and 1992.

Parameter	Strata Sampled[1]	Sample Preservation[2]	Analytical Method	Method Detection Limit	Holding Time	Analytical Lab[3]
<u>1991</u>						
Total Phosphorus	epilimnion	H_2SO_4 to pH<2	EPA 365.1[4]	10 μg/L	28 days	MEL
Total Nitrogen	epilimnion	H_2SO_4 to pH<2	EPA 353.2	0.010 mg/L	28 days	MEL
Chloro-phyll *a*[5]	epilimnion	$CaCO_3$[6]	SM 10200H(3)	0.05 μg/L	28 days	MEL
<u>1992</u>						
Total Phosphorus	epilimnion, hypolimnion	H_2SO_4 to pH<2	SM 4500-P D	3 μg/L	28 days	EWU
Total Nitrogen	epilimnion, hypolimnion	H_2SO_4 to pH<2	EPA 353.2	0.010 mg/L	28 days	MEL
Chloro-phyll *a*[5]	epilimnion	$CaCO_3$[6]	SM 10200H (2,B)	0.05 μg/L	28 days	EWU
Solids	epilimnion		SM 2540D,E	1 mg/L	7 days	MEL
Color	epilimnion		SM 2120B	5 Pt-Co units	48h	MEL
Fecal Coliform Bacteria	nearshore grab samples (2 sites)		SM 9222D	1 colony/ 100 mL	30h	MEL

1 All samples except fecal coliform bacteria were composited.
2 All samples kept on ice or stored at 4°C until delivery to the lab, or until filtered.
3 Manchester Environmental Laboratory (MEL), or the Limnological Lab at Eastern Washington University (EWU).
4 Modified by digesting samples using the Valderrama method, which uses potassium persulfate/sodium hydroxide/boric acid.
5 Corrected for pheophytin.
6 Approximately 2 mL saturated $CaCO_3$ added with last of filtrate onto filter. Filters were iced or frozen until delivered to lab.

In 1992, samples for total suspended solids (TSS), total nonvolatile suspended solids (TNVSS), and color were collected from the epilimnion of 23 lakes, at the same sites and sample depths as the nutrient samples. Lakes to be sampled for TSS, TNVSS, and color were selected, in part, by the likelihood of the lake not fitting the expected relationship between Secchi, TP, and chlorophyll *a*.

Two fecal coliform bacteria samples were collected from 20 lakes during May 1992, and from 23 lakes during August 1992. Samples were collected approximately 20-35 feet from shore in areas which appeared (to the sampling staff) of having some potential source of bacteria. Fecal coliform bacteria sample bottles were filled by "scooping" water from about eight inches below the water surface to avoid surface films.

All samples, except those for chlorophyll *a*, were transported on ice to the lab and stored at 4°C. Chlorophyll *a* samples were filtered through Whatman 4.7 cm GF/C filters as soon as possible after collection. For most samples, 500 mL aliquots were filtered. About 2 mL of saturated $CaCO_3$ was added to the last of the filtrate to preserve the sample on the filter. Filters were placed into small plastic petri dishes, then wrapped in foil, and the lab number and volume of sample filtered was written on the foil. Packaged filters were bagged and stored in ice while in the field, and kept in a freezer until transported to the lab for analysis.

Sample Analysis Methods

Methods used for sample analyses are listed in Table 1. Sample preservation and analytical methods used by Manchester Environmental Laboratory (MEL) are from Huntamer and Hyre (1991).

Keys used for algal identifications were Smith (1950), Edmondson (1959), Prescott (1962; 1978), and VanLandingham (1982). Keys used for macrophyte identifications were Hitchcock and Cronquist (1973), Tarver *et al.* (1978), and Prescott (1980).

Quality Assurance/Quality Control Methods

The following summarize methods used to evaluate the quality of Secchi depth data collected by the volunteers, profile data measured by Ecology staff with the profiling instrument, and water samples analyzed by the laboratories. A more detailed discussion of quality assurance/quality control (QA/QC) methods used for this program is in <u>Lake Water Quality Assessment Program Quality Assurance Program Plan (QAPP)</u> (Hallock, in prep).

<u>Volunteer-Collected Secchi Data</u>

On each sampling date, volunteers measured the Secchi depth two times. Each set of duplicate Secchi depth readings was evaluated using the coefficient of variation (CV). The CV is the standard deviation of two Secchi depth values divided by their mean, multiplied by

100. Acceptable values of CV for three ranges of Secchi depths were used to determine whether replication was acceptable. Three ranges of Secchi depths were chosen because duplicate readings of shallow Secchi depths need to be almost identical to have a low CV, whereas when Secchi depths are greater than 20 feet, duplicate readings can differ by more than two feet and still have a small CV. To emphasize our preference for good replication even for Secchi depths greater than 20 feet, acceptable ranges of CV were identified for Secchi depths between 0-10 feet, 10-20 feet, and greater than 20 feet. Acceptable CV values for each of these ranges are listed in Table 2.

Table 2. Acceptable CV for duplicate Secchi readings collected by volunteers.

Secchi depth (ft)	Acceptable CV (%)
0 - 10	< 8
10 - 20	< 6
20 +	< 4

Because the duplicate readings were not collected independently of each other, the estimation of precision may be biased. The ranges of CVs were chosen to be conservative.

Although many volunteers collected at least one set of duplicate readings that had poor replication as indicated by the CV, the overall replication for all readings for each lake was evaluated using the root mean square (RMS), which pools the CVs for each lake. The RMS is calculated as follows:

$$\sqrt{\frac{CV_1^2+CV_2^2+CV_3^2 \ldots CV_n^2}{n}}$$

where n is the number of pairs.

Profile Data from Onsite Visits

The Hydrolabs were pre- and postcalibrated daily for pH and dissolved oxygen. The manufacturer's instructions were followed for pH calibration using pH 7 and pH 10 standard buffer solutions. Postcalibration readings ≤ 0.2 pH unit of the standard buffer values were considered acceptable. Dissolved oxygen was checked against azide-modified Winkler titrations, rather than the theoretical water-saturated air method. At least two samples were collected and titrated, and the mean value used for comparison with the profiler. Postcalibration results ≤ 0.3 mg/L of the mean of the Winkler titration values were considered acceptable. Conductivity, a more stable parameter on the Hydrolab, was checked periodically using the manufacturer's instructions. Potassium chloride standards used for conductivity calibration ranged from 101 to 147 μmhos/cm at 25°C (the molarity varied between individual solutions used). Postcalibration values ≤5 μmhos/cm of the standard value were considered acceptable. Temperature was also checked periodically against a National Bureau of Standards (NBS) thermometer.

Water Chemistry Data from Onsite Visits

Total precision of chlorophyll *a* and fecal coliform bacteria was reported as the RMS of field duplicates. Because variability of both parameters is generally rather high, no precision limits were placed on these parameters. Precision limits for TSS, TNVSS, and color were not based on the RMS of field duplicates, mainly because results were mostly near the detection limit of 1 mg/L for TSS and TNVSS, and 5 Pt-Co units for color. Therefore, results within 1 mg/L for both field duplicates and lab duplicates were considered acceptable for solids. Color results were considered acceptable if results for duplicates (both field and lab duplicates) were within 5 Pt-CO units.

Laboratory quality control for TP and TN consisted of analyzing lab duplicates, lab check standards, matrix spikes, and lab blanks. Analytical precision for TP and TN was determined by calculating the RMS from lab duplicates. Analytical precision <7.5% was considered acceptable for TP, and <5% was acceptable for TN. Bias due to calibration error was estimated as the difference between the results for lab check standards and the true concentration, divided by the true concentration. Bias <6.5% from the lab check standards was considered acceptable for both parameters. Bias due to the sample matrix was calculated as the percent recovery for matrix spikes. Mean recoveries within 80-120% were considered acceptable.

An additional check on laboratory quality control was to submit diluted standard reference materials for TP and TN as "blind" samples. Results from these samples were compared against the 95% confidence intervals provided in the literature with the samples. However, because the standard reference materials were diluted considerably to be in the expected range of lake samples, the ranges of the extrapolated confidence intervals (calculated from equations provided with the reference materials) were extremely wide (e.g., 47 μg/L - 111 μg/L for a known TP concentration of 75 μg/L).

Total precision of TP, TN, and chlorophyll *a* was calculated as the RMS of all field duplicates. In 1991, five lakes (11% of those sampled) were sampled in duplicate at the same site for TP, TN, and chlorophyll *a*. Methods for collecting quality assurance data were changed in 1992, in part to evaluate whether epilimnetic data collected from a single lake station was representative of an entire lake. In August 1992, duplicate samples were collected from the epilimnion at a second site at 13 lakes (28% of those sampled). Results of these duplicate samples are discussed in the QA Results Section of this report.

Graphing Methods

Secchi depth graphs were created from Lotus spreadsheets, and enhanced using Freelance Plus version 3.0. Profile data were graphed using SYSTAT version 5.0. These graphs are presented in the individual lake assessments.

Methods Used for Estimating Trophic States

Carlson's (1977) trophic state indices (TSI) for Secchi depth (TSI_{SD}), total phosphorus (TSI_{TP}), and chlorophyll *a* (TSI_{CHL}), tempered with some professional judgment, were used to estimate the trophic status of the monitored lakes.

Equations for calculating TSI_{SD}, TSI_{TP}, and TSI_{CHL} from Carlson (1977) are as follows:

$$TSI_{SD}=10\,[6-\frac{\ln SD}{\ln 2}]$$

$$TSI_{TP}=10\,[6-\frac{\ln\frac{48}{TP}}{\ln 2}]$$

$$TSI_{CHL}=10\,[6-\frac{2.04-0.68\ln CHL}{\ln 2}]$$

Where:

SD	=	Secchi (meters)
TP	=	epilimnetic total phosphorus (μg/L)
CHL	=	epilimnetic chlorophyll *a* (μg/L)

A minimum of three Secchi depth readings were used to calculate the TSI_{SD} for each lake, and data invalidated from the QA evaluation were excluded from the TSI_{SD} calculations. The TSI_{SD} values reported for 1991 data were calculated as the mean TSI for data collected from June through September 1991. TSI_{SD} values from 1992 data were calculated from a time-weighted mean Secchi depth calculated from all Secchi data collected between May and October 1992.

The decision to calculate a time-weighted TSI_{SD} was based on concern that not all volunteers measured Secchi depth regularly, and the number of Secchi depths collected varied between volunteers. For example, some volunteers collected three to four Secchi readings in a two-month period, while measuring Secchi depth maybe one to two times during the other four months of the monitoring season. So that the two months with regular data would not be overrepresented when calculating TSI_{SD}, the other one to two readings would be given greater weight. Another difference in calculating TSI_{SD} in 1992 is that all data collected from May through October 1992 (except for data invalidated through the QA evaluation) were used to calculate the TSI_{SD}. This is in contrast to the method used from 1989-1991, which used only data collected from June through September. One of the main reasons for excluding May and October data was that few volunteers actually collected data during these months, making it difficult to compare TSI_{SD} data between lakes. Time-weighting the Secchi depths to calculate the TSI_{SD}, as well as using the first onsite visit in May as a means of encouraging the volunteers to begin collecting data, minimizes this concern. To evaluate the differences between various methods used to calculate TSI_{SD} for this program, TSI_{SD} was calculated three ways using data collected in 1992: the mean of TSI values of data collected from June-September, the mean of TSI values from data collected from May-October, and TSI calculated from a time-weighted mean of Secchi depths collected from May-October.

In general, TSIs of 40 or less indicate oligotrophy, TSIs greater than 40 indicate mesotrophy, and TSIs greater than 50 indicate eutrophy (Carlson, 1979). However, several lakes exhibited characteristics of more than one trophic state (e.g., mean summer Secchi depth in the upper region of the oligotrophic range, but hypolimnetic anoxia was measured during an onsite visit). To describe lakes which appeared to be between trophic states, the terms "oligo-mesotrophic" and "meso-eutrophic" were used.

Not all of the trophic state estimations were based on TSI alone. For some lakes, one or more anomalous conditions may have affected the trophic state index calculated from Secchi depth data. For example, some lakes were chemically treated to kill algae and improve water clarity. As a result, water clarity measurements will indicate a less eutrophic condition than other water quality data may indicate. In lakes where Secchi depth was occasionally deeper than the depth of the lake (indicated when the volunteer reported the "Secchi hit bottom"), only readings collected when the Secchi disk did not reach the bottom were used to calculate the TSI_{SD}. As a result, the average Secchi depth will be biased low, and the average trophic state reported will be more eutrophic than it should be. Also, some lakes had extensive macrophyte growth or localized algae growth, yet high open-water clarity. The productivity of these lakes would be underestimated by Secchi depth data.

When there were discrepancies between TSI_{SD}, TSI_{TP}, and/or TSI_{CHL}, or when any of the anomalous conditions mentioned above occurred, the trophic state estimation was tempered using other available information. For example, dissolved oxygen profile data may indicate hypolimnetic hypoxia; algae and macrophyte species and/or coverage may indicate increased productivity; and the presence of hydrogen sulfide in the hypolimnion may indicate reducing conditions that would affect internal phosphorus loading. Sources of other available information included the water quality surveys from 1989 and 1990 (Brower and Kendra, 1990; Coots, 1991), consultants' reports from Ecology-funded lake restoration activities, and lake surveys conducted by universities. When no other data were available, the TSI_{TP} usually took precedence over the TSI_{SD}, because TP is generally affected by fewer factors than Secchi depth. According to Carlson (1977), "the best indicator of trophic status may vary from lake to lake and also seasonally, so the best index to use should be chosen on pragmatic grounds." Carlson (1977) also stated that only one number should be generated for classifying lakes, and it is not legitimate to average TSI values when they do not agree. Therefore, we used a subjective assessment of available data to determine which index to use for assigning trophic states. The basis for each trophic state assessment is discussed in the Comments section of the Individual Lakes Assessments at the end of this report.

RESULTS AND DISCUSSION

During the 1991 and 1992 monitoring seasons, 63 volunteers made 786 monitoring trips on 46 lakes. Four additional lakes without volunteers were sampled by Ecology staff during 1992, so a total of 50 lakes are assigned trophic states in this report. Thirty-five of these lakes were monitored by volunteers during both 1991 and 1992. In 1991, 41 lakes were monitored by volunteers and 38 of these lakes were sampled by Ecology staff during the single onsite visit. In 1992, all 39 lakes monitored by volunteers were sampled during one or both of the onsite visits. Locations of the 46 volunteer-monitored lakes are shown in Figure 2. Water quality data from additional lakes sampled by Ecology staff in 1991 could not be used for lake assessment because TP and chlorophyll *a* data did not pass the quality assurance evaluation (see Results of QA/QC Evaluation of Water Chemistry Data, below).

Monitoring results and trophic state estimates are presented after the discussion of quality assurance and quality control of the data.

Results of QA Evaluation of Volunteer-Collected Secchi Depths

Secchi data collected by both volunteers and Ecology staff during the onsite visits were not included in the QA evaluation. However, a paired t-test used to analyze the variability in the difference between 53 data pairs collected in 1992 indicated that there was a significant difference ($P < 0.05$) between volunteer-collected Secchi depths and Ecology-collected Secchi depths. Although transforming the Secchi depths to TSIs did not improve the relationship between the two data sets, the difference in TSIs for most lakes was one to three units. These small differences in TSI values would not affect the trophic state estimates for most lakes; therefore, rather than using Ecology staff as standards against which to compare volunteer-collected Secchi depths (especially considering that one of the "standards" is far-sighted), more importance has been placed on standardizing monitoring procedures, training the volunteers, and evaluating whether the volunteers can replicate their readings.

Poor replication of Secchi depth measurements, determined by CV values which exceeded the limits listed in Table 2, was indicated by 19 data pairs (5.6%) from the 1991 dataset, and by 21 pairs (4.7%) from the 1992 dataset. These data were excluded from TSI calculations, and from comparisons with other data. Because several of the poor data pairs were collected outside of the recommended time range or under less than ideal weather conditions, this

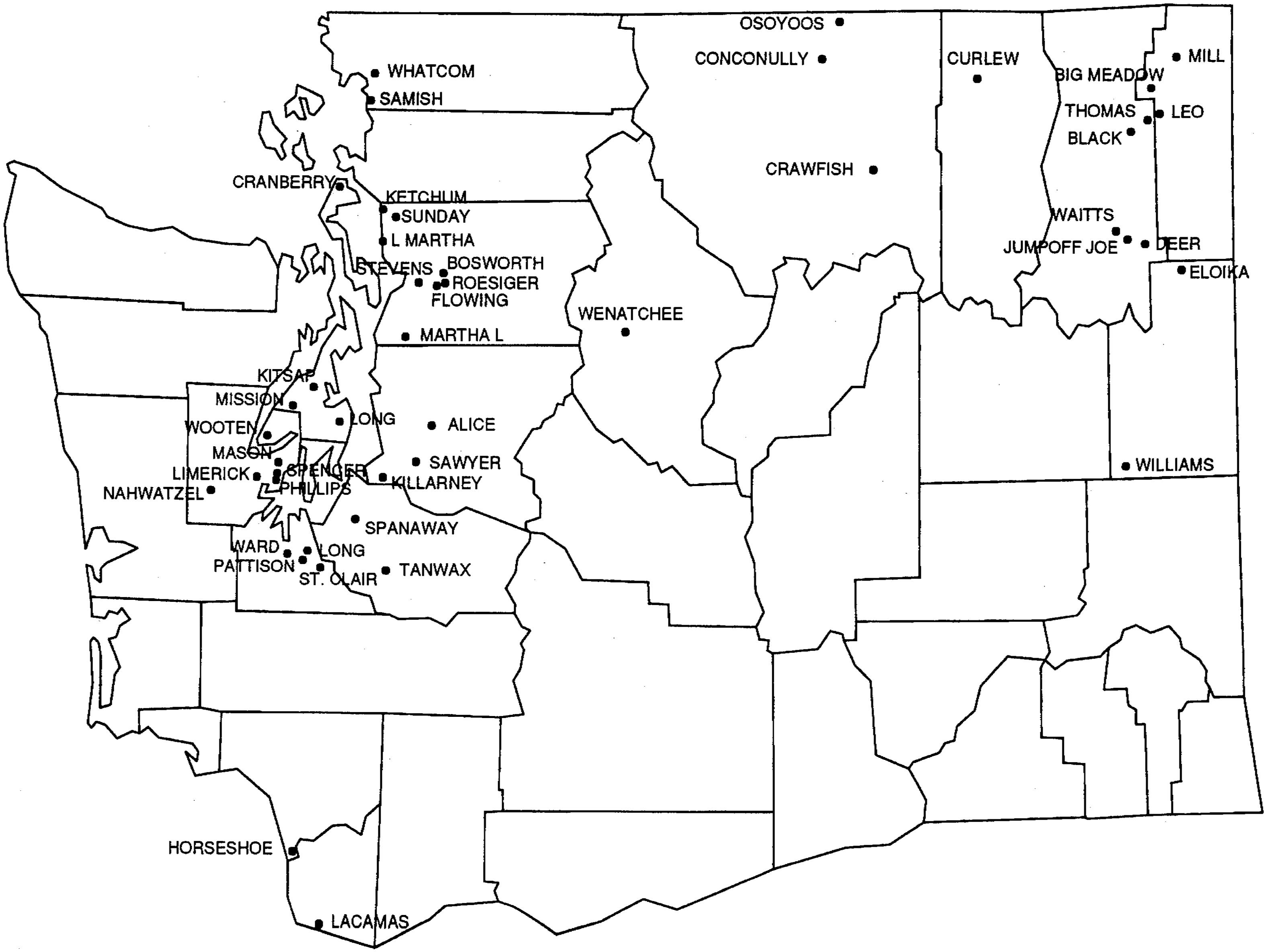


Figure 2. Locations of lakes monitored by volunteers in 1991 and 1992.

method appears to be very effective for identifying data that should not be compared with other data collected for the program. Overall replication, evaluated using the RMS for all data collected by a volunteer, was poor for Lake Bosworth in 1991, and for Mission Lake in 1992. Although these data will be used in part for assessing these lakes, Secchi data for these lakes and years will not be used for comparisons with other data collected for the program.

Results of QA Evaluation of Profile Data

Hydrolab postcalibration data from the onsite visits indicated that dissolved oxygen data were unacceptable for Big Meadow Lake and Mill Lake in 1991, for Black, Thomas, and Leo Lakes in May 1992, and Mission Lake in August 1992. These data are not reported here.

All pH and conductivity data from the 1991-1992 onsite visits were within acceptable limits. Hydrolab postcalibration data for both years are compiled in Appendix C.

Results of QA/QC Evaluation of Water Chemistry Data

All QA/QC data are compiled in Appendix D, and results of the QA/QC evaluation are summarized in Tables 3 and 4. Total nitrogen data from 1991 were acceptable, although the result from the 0.050 mg/L standard reference material was rather high. It is likely that the high result was from a dilution error. Results from all parameters analyzed in 1992 were acceptable. Some individual samples, though, were qualified by the lab(s) due to holding time exceedences or other problems; results and qualifications from these samples are indicated in the individual lake summaries. All TP and chlorophyll *a* data from 1991 were rejected based on method problems and on quality control results which did not meet QA/QC requirements for this program. These problems are discussed below.

Rejection of 1991 TP Data

Initial review of TP data indicated that 36% of the results were below the criterion of detection (5 μg/L). Internal QC standards by MEL were considered to be met, and though mean recoveries of the matrix spikes were low, they were within MEL's accepted limits (D. Thomson, Ecology MEL, pers. comm). Results from the lab check standards were very good (Table 3), albeit the concentrations of the standards were considerably higher than the majority of the lake samples.

The 1991 TP data were initially rejected based on the results from the three standard reference materials which were submitted as "blind" samples. Results were roughly 30% lower than the known concentrations, and the result for the 150 μg/L standard was outside the 95% confidence intervals (Table 4). Although dilution of the standard reference

Table 3. QA/QC results for total phosphorus, total nitrogen, chlorophyll *a*, and fecal coliform bacteria data.

Survey	Mean of lab blanks	Analytical Precision	Total Precision	Bias: low standard	Bias: high standard	Bias: mean recovery
May '91 TP	2.1 μg/L	40%	38%	-1.3%[1]	1.9%[2]	85%
May '92 TP	0	6%	28%	0%[1]	1.2%[2]	102%
Aug '92 TP	0	([3])	15%	0%[1]	0%[2]	95%
May '91 TN	--	--	2%	--	--	--
May '92 TN	0.005	2.6%	13%	-5.8%	0.2%	105%
Aug '92 TN	-0.007	4.0%	10%	4.8%	4.9%	97%
May '91 Chl	0	--	31%	--	--	--
May '92 Chl	0	--	31%	--	--	--
Aug '92 Chl	0	--	25%	--	--	--
May '92 FC	--	--	8%	--	--	--
Aug '92 FC	--	--	30%	--	--	--

[1] low standard for '91 (MEL) was 75 μg/L; low standard for '92 (EWU) was 3 μg/L.
[2] high standard for '91 (MEL) was 500 μg/L; high standard for '92 (EWU) was 24.5 μg/L.
[3] not enough pairs to calculate (1992 DQOs specify 10 pairs)

Table 4. Lab results from standard reference materials.

Standard Reference Value	95% CI	May 91	May 92	Aug 92
μg/L	μg/L	μg/L	μg/L	μg/L
TP 150	113 -197	108	--	--
TP 75	47 -111	48	--	--
TP 15	-5 - 42	10	13	18
TP 7.5	-12 - 34	--	6	8
mg/L	mg/L	mg/L	mg/L	mg/L
TN 0.500	0.175 -0.907	0.500	--	--
TN 0.250	-0.031 -0.623	0.270	--	--
TN 0.050	-0.196 -0.396	0.090	0.048	0.041
TN 0.025	-0.216 -0.367	--	0.021	0.026

materials could introduce error, the same diluted samples were also analyzed for TN (the standard reference material contained both TP and TN). Results from the TN reference materials were at or higher than the expected value, suggesting that the dilutions were not weak.

Discussion with staff at MEL revealed that a new method for digesting and analyzing TP samples had been adopted prior to analyzing the lake samples. This method (referred to as the "TPN" or Valderrama method) allows for the simultaneous determination of TP and TN with an auto analyzer, and uses potassium persulfate/sodium hydroxide/boric acid to digest the samples. Although the method was tested at MEL using river samples, the digestion and detection methods were not checked using samples known to contain low TP concentrations (*i.e.*, <10 μg/L; Lombard, 1992). To determine whether analysis of TP from lake samples using the TPN method yielded different results than the method previously used (EPA method 365.1, with samples digested using ammonium persulfate/sulfuric acid), a method comparison study was conducted in February 1992. Conclusions from the study were that results from the two methods were significantly different ($P<0.01$), and that results from the TPN method were biased low compared to the other method (Lombard, 1992). These conclusions confirmed that the 1991 TP results should not be used.

To minimize further quality control problems, data quality objectives (DQOs) for TP were prepared in 1992 (Appendix B). These DQOs address concerns for detecting bias in the method, and for achieving low detection limits. This is accomplished by specifying laboratory QC required for the program, such as concentrations of calibration standards, lab check standards, and matrix spikes, as well as the number of method blanks required for calculating the method detection limit. These data quality objectives were used to evaluate the performance of four labs prior to selecting a lab to analyze lake samples for the 1992 program.

<u>Rejection of 1991 Chlorophyll *a* Data</u>

The decision to discard the chlorophyll *a* data from 1991 was more difficult because there is no chlorophyll standard that can be filtered and submitted to the laboratory as a blind standard. The only checks for fluorometric analysis of chlorophyll *a* are calibration, lab duplicates, and field duplicates. Calibration of the instrument is not done with each run (the fluorometer at MEL is checked yearly), and both analytical and field variability of chlorophyll is generally high, making it difficult to determine acceptable precision limits.

The first indicator of a problem with the 1991 data was the unexpectedly low data results. Based on program results from 1990, several lakes sampled in 1991 were expected to yield chlorophyll *a* concentrations greater than 2.6 μg/L, which would indicate mesotrophy or eutrophy. However, results from 38 of 41 lakes were less than 2.6 μg/L, which would indicate oligotrophy (see discussion on determining trophic states in the next section). There were also problems with the method:

1) A high sensitivity door was used on the fluorometer, so all the lake samples were diluted, some up to 1:423, before analysis. The high sensitivity door is recommended for analyzing low levels of chlorophyll in marine samples.

2) APHA *et al.* (1992) states that the fluorometric method for determining chlorophyll in the presence of pheophytin *a* is not applicable to freshwater samples, because the measurement of pheophytin *a* is unreliable. Instead, spectrophotometry is recommended for analysis of freshwater samples.

3) Sonication was used to extract the pigments. APHA *et al.* (1992) recommends using a tissue grinder to mechanically disrupt the cells, because extraction will be affected by the species of algae present in the samples. Weber *et al.* (1986) also note that sonication was ineffective for disrupting cells of "coccoid green algae and other extraction-resistant forms."

Because of these concerns about methods used, and the unexpectedly low results for almost all of the 1991 samples, 1991 chlorophyll *a* data were rejected.

Trophic State Assessments

Trophic states were assigned to 50 lakes (Table 5). The basis for the trophic state assignments for the 46 volunteer-monitored lakes are explained in the Comments section for each lake's individual lake assessment. Individual lake assessments were written only for lakes which were monitored by volunteers, so there are no individual lake assessments for American, Deep, Kahlotus, or Leech Lakes. These lakes were not monitored by volunteers during either year.

Comparisons of Trophic States Assigned in 1992 and 1991

Most monitored lakes were oligotrophic or mesotrophic. The number of lakes falling into each trophic state were as follows:

	Oligotrophic	Oligo-mesotrophic	Mesotrophic	Meso-eutrophic	Eutrophic
1991	13	6	13	0	10
1992	12	9	15	2	7

Thirty-seven lakes were assigned trophic states in both 1991 and 1992. Of these, 30 lakes (81%) were assessed the same trophic status during both years. Six lakes (16%) were assessed to be less eutrophic in 1992 than in 1991, and one lake (3%) was assessed to be more eutrophic in 1992 than in 1991 (Table 5); these seven lakes had one or both assessments based primarily on data other than Secchi data. As a result, the "change" in

Table 5. Trophic state indices and trophic states for lakes monitored in 1991 and 1992.

Lake	1991 TSI_{SD}	Trophic Status, 1991	1992 TSI_{SD}	1992 TSI_{TP} May	1992 TSI_{TP} Aug	1992 TSI_{CHL} May	1992 TSI_{CHL} Aug	Trophic Status, 1992
Alice	43	Mesotrophic	44	40	42	35	24	Oligo-mesotrophic*
American	--	--	--	39	--	33	--	Mesotrophic*
Big Meadow	44	Mesotrophic	42	49	49	35	42	Mesotrophic
Black	39	Mesotrophic	37	49	38	21	31	Oligo-mesotrophic*
Bosworth	--	Oligotrophic*	41	37	37	35	38	Oligotrophic
Conconully	--	--	36	54	50	28	47	Mesotrophic
Cranberry	47	Eutrophic	--	--	--	--	--	--
Crawfish	33	Oligo-Mesotrophic	--	49	43	33	25	Oligo-mesotrophic*
Curlew	36	Mesotrophic*	33	57	41	21	31	Mesotrophic*
Deep	--	--	--	42	42	29	34	Oligo-mesotrophic*
Deer	34	Oligo-mesotrophic*	32	32	34	22	33	Oligotrophic
Eloika	50	Eutrophic*	46	51	53	38	47	Meso-eutrophic*
Flowing	43	Mesotrophic	--	--	--			--
Horseshoe	58	Eutrophic	--	59	--	61	--	Eutrophic*
Jumpoff Joe	--	--	46	37	47	28	47	Mesotrophic
Kahlotus	--	Eutrophic*	--	109	**	--	**	**
Ketchum	--	--	54	96	92	52	56	Eutrophic
S. Killarney	47	Eutrophic*	49	57	57	46	40	Eutrophic*
Kitsap	--	--	42	46	47	33	39	Mesotrophic
Lacamas	50	Eutrophic*	54	49	57	43	55	Eutrophic*
Leech	--	--	--	40	40	--	29	Mesotrophic*
Leo	38	Oligo-mesotrophic*	35	39	41	28	41	Oligo-mesotrophic
Limerick	42	Mesotrophic	43	40	40	32	24	Mesotrophic*
Long (Kitsap)	55	Eutrophic	--	--	49	--	--	Eutrophic*
Long (Thurston)	44	Mesotrophic	47	54	56	42	49	Mesotrophic
L. Martha	39	Oligotrophic	36	40	40	37	25	Oligotrophic
Martha L.	38	Oligo-mesotrophic*	37	44	39	22	32	Oligo-mesotrophic*
Mason	32	Oligotrophic	33	27	24	32	31	Oligotrophic
Mill	38	Oligotrophic	--	--	--	--	--	--
Mission	--	Mesotrophic*	--	36	41	32	32	Mesotrophic*
Nahwatzel	36	Oligotrophic	38	36	34	32	17	Oligotrophic
Osoyoos	46	Mesotrophic	44	40	40	29	33	Mesotrophic*
N. Pattison	43	Mesotrophic	41	--	49	--	44	Mesotrophic
Phillips	43	Mesotrophic	42	34	39	29	32	Oligo-mesotrophic*
N. Roesiger	36	Oligotrophic	36	27	30	23	--	Oligotrophic
E. Samish	39	Oligo-mesotrophic	41	24	37	32	33	Oligo-mesotrophic*
W. Samish	37	Oligo-mesotrophic	40	--	--	--	--	Oligo-mesotrophic*
Sawyer	--	--	39	47	42	42	34	Mesotrophic
Spanaway	46	Mesotrophic	42	34	45	32	42	Mesotrophic
Spencer	37	Oligotrophic	40	37	32	33	31	Oligotrophic
St. Clair	48	Eutrophic*	47	51	54	31	48	Eutrophic
Stevens	34	Oligotrophic	36	--	40	--	38	Oligotrophic
Sunday	51	Eutrophic	48	62	58	51	45	Eutrophic
Tanwax	48	Eutrophic*	48	53	51	35	49	Meso-eutrophic
Thomas	38	Oligotrophic	37	41	27	42	32	Oligo-mesotrophic*
Waitts	38	Oligo-mesotrophic	35	44	37	28	38	Oligo-mesotrophic
Ward	28	Oligotrophic	35	40	34	bdl	25	Oligotrophic
Wenatchee	36	Oligotrophic	33	20	20	15	33	Oligotrophic
S. Whatcom	35	Oligotrophic	--	--	--	--	--	--
Williams	40	Mesotrophic*	45	46	43	37	38	Mesotrophic
Wooten	32	Oligotrophic	35	30	34	32	36	Oligotrophic

* Trophic status based primarily on data other than TSI_{SD} ** lake dried up in mid-late summer, 1992

trophic status does not necessarily indicate a change in water quality in a lake, but may have resulted from having additional data available when assigning the trophic state (TP and chlorophyll data for 1991 were not available for assessing lakes). When other data were available which did not agree with a trophic state based entirely on Secchi depth, the trophic state assignment was likely to be tempered.

Of the 37 lakes monitored during both 1992 and 1991, TSI_{SD} values were generally within three index units of each other (except for Ward Lake and Williams Lake), despite the different methods used to calculate TSI_{SD} each year. When 1992 Secchi data were used to calculate TSI_{SD} using the three different methods that have been used for the program, TSI_{SD} values from all three methods were very similar, usually within one unit and not varying more than three units for each lake. The different methods used to calculate TSI_{SD} in 1991 and 1992, then, were not likely to affect the trophic states assigned to each lake.

Until sufficient data are available for determining trends, slight changes in these trophic state assessments from year to year could be considered as subjective trends, although statistical trends will be determined in the future for lakes which have at least five consecutive years of data. Trend analysis of Secchi depth data will begin at the end of the 1993 monitoring season, which will mark the end of the fifth year of this lake water quality assessment program.

Climatic Variations

Yearly climatic variations should be considered when evaluating trophic states between years. For example, incident sunlight and ambient air temperature will affect algal photosynthesis, and precipitation will affect the availability of nutrients for algal uptake by affecting runoff and the lake's flushing rate. In addition, concern about low rainfall in Washington in the last few years, and the observation that 11 of the 12 lakes with higher TSI_{SD} in 1992 than in 1991 were located in Western Washington, prompt at least a cursory evaluation of available climatic data.

Climatic data from Seattle and Spokane for 1989-1992 are listed in Table 6. Also listed are the average values over the entire period of record available for both stations. The mean maximum temperatures in both 1991 and 1992 for the Seattle station were higher than the mean maximum temperature from the period of record (Table 6). In addition, for the period of record, the highest daily average for both the minimum and maximum temperatures occurred in 1992 (EarthInfo, 1993). Data from the Spokane station also indicated that the mean maximum temperature was higher in 1992 than the mean maximum temperature from the period of record.

Although warmer air temperatures would suggest warmer water temperatures in the monitored lakes, comparisons of the mean surface water temperatures (from volunteer-collected data) indicated that only 14 lakes had a higher mean surface water temperature in 1992 than in 1991. A paired t-test of mean surface water temperatures for the 34 lakes monitored during both years indicated that there was no significant difference ($P<0.01$).

Table 6. Daily average temperatures and annual snowfall and precipitation for Seattle and Spokane.

Parameter	Period of Record*	1989	1990	1991	1992
Station: SEATTLE TACOMA AIRPORT					
Temp., Min (°F)	44	45	45	45	46
Temp., Max (°F)	59	60	60	61	63
Snow (in.)	12.25	14.2	13.6	2.9	6.7
Precip. (in.)	38.01	34.69	44.75	35.42	32.78
Station: SPOKANE AIRPORT					
Temp., Min (°F)	38	37	38	37	39
Temp., Max (°F)	58	57	58	58	60
Snow (in.)	42.05	45.2	49.9	34.8	61.7
Precip. (in.)	16.01	14.71	19.61	14.45	14.52

Source of Data: EarthInfo (1993)
*Period of record for Seattle station: 1931-1992
Period of record for Spokane station: 1889-1992 (temperature and precipitation)
1892-1992 (snowfall)

Precipitation at the Seattle station for 1991 and 1992 was lower than the annual average for the period of record (Table 6). Snowfall at the Seattle station was very low in 1991 and 1992, in comparison to average annual snowfall reported for the 61 year period of record. At the Spokane station, precipitation for both 1991 and 1992 was also lower than the average value for the period of record. Although snowfall in 1991 was lower than the average annual snowfall for the period of record in Spokane, snowfall in 1992 was high.

Evaluating the possible effects on lakes from low precipitation and snowfall is difficult, not only because of the varying hydrogeologies of the monitored lakes and their watersheds, but because lake level at many of the monitored lakes is affected by control weirs, beaver dams, or blocked outlet tributaries. Another problem in evaluating lake level is that not all volunteers measured lake level each year (or if they did, not all measured lake level on a regular basis, or consistently used the same marker to measure level). Despite these, volunteer comments and recorded lake levels did suggest that, in general, lake levels were low in 1992. Of particular note is Lake Kahlotus (Franklin County), which dried up between May and August 1992. Lake Kahlotus is fed primarily by irrigation return and runoff, and was reported to have also dried up in the 1970s (A. Moore, Ecology, pers. comm.). Another noteworthy lake is Williams Lake (Spokane County), which dropped 24 inches from May through October 1992, and the volunteer noted that the level was the "lowest [the] lake has been in 90 years." (Unfortunately, the volunteer did not measure lake level in 1991.) Other lakes which decreased in level from May through October 1992 included Waitts Lake (-12 inches), Lake Leo (-13 inches), Lake Alice (-16 inches), Phillips Lake (-19 inches), Lake Killarney (-20 inches), Lake Wooten (-21 inches), Spencer Lake (-24 inches), Lake St. Clair (-24.5 inches), Ward Lake (-26 inches), and Lake Sawyer (-29 inches). Volunteers from Waitts Lake, Lake St. Clair, Sunday Lake, and Lake Stevens noted that lake level was unusually low in 1992.

Of these lakes, TSI_{SD} was higher in 1992 (than in 1991) for Williams Lake, Ward Lake, Lake Killarney, Spencer Lake, Lake Stevens, and Lake Wooten. The greatest TSI_{SD} increases occurred at Williams Lake and Ward Lake; TSI_{SD} in Williams Lake increased from 40 in 1991 to 45 in 1992, and TSI_{SD} in Ward Lake increased from 28 in 1991 to 35 in 1992 (Table 5). Although these increases in TSI_{SD} did not affect the trophic state estimates for either lake, and while there are not enough data available to attribute these TSI_{SD} changes to decreased water level, further study on either lake should include the relationship between the water budget and water quality.

CASE STUDIES ON THE EFFECTIVENESS OF CITIZEN-INITIATED LAKE PROTECTION EFFORTS

Because objectives of this program include promoting public awareness of lake processes and lake protection measures, and to foster a conservation ethic, I wanted to evaluate the success and failure of citizen-initiated lake restoration or protection activities at a few of the volunteer-monitored lakes. Results of these case studies are intended to provide insight to other volunteers who may initiate their own lake restoration or protection activities.

The case studies were intended to target lakes identified as having threatened or poor water quality and a potential for protection or restoration. As part of the case studies, I wanted to work with the volunteers for these lakes and assist them through processes needed for restoration or protection of the lakes. These processes may include application for Centennial Clean Water Funds, identification of the specific water quality problem or potential problem sources, or strategies for creating lake associations and lake management districts.

Although several volunteers in the program were active in lake protection efforts in 1991-1992, activities from three lakes stood out in particular, and are discussed here. Residents at Lake Martha (Snohomish County) organized a lake association which is still active. Residents at Phillips Lake (Mason County) petitioned county staff to submit a proposal for a Centennial Clean Water Fund grant in order to address water quality problems in the lake. Lake association members at Lake Roesiger (Snohomish County) designed and implemented a water quality monitoring program for the lake.

The Formation of a Lake Association, "Lake Martha Residents"

The process started around spring-summer 1992, when a few lakeshore residents began talking about the possibility of forming a lake association. The interest in forming an association was primarily for education and information sharing, as well as meeting other lakeshore residents. A few of these residents took the initiative to bring a small core of interested people together at a meeting to discuss forming an association. I was asked to attend one of these early steering committee meetings to talk about lake associations, why they are set up, and the benefits of having one. I also talked about rules for reaching consensus at the meetings, and offered suggestions for running the meetings. The steering committee met a few times before a full association meeting was held in September 1992. Duties for advertising the meeting (including distributing flyers), and making arrangements for the meeting (inviting speakers, reserving a meeting area, providing refreshments) were split up primarily among three people among the steering committee. Each association meeting has a subject which features a guest speaker; at their second meeting which focused on water quality, I was asked to speak about data collected for my program and to discuss the results. At this meeting, attendees followed up on unfinished business from the previous meeting, decided on a name for the group (Lake Martha Residents), discussed boating issues on the lake, and solicited ideas of topics and speakers to be highlighted at future meetings. The meeting was run very well, and was well organized.

The association has since had several meetings (they meet quarterly), and appear to be accomplishing their goal of meeting each other and learning more about the lake together. Their summer meeting was a group picnic, held at one of the association member's yard. This idea of a picnic was popular with the steering committee in the early planning stages of the association.

Lessons

Many lake residents have a difficult time forming an association. Often, the difficulty stems from residents who are unclear on, or cannot agree on, the purpose that the group will serve and what the group hopes to accomplish. Members of Lake Martha Residents had clear objectives, and are very resourceful people as they accomplish their objectives. There are some other lessons that can be learned from this group.

1) They asked for information and help on what an association is, what is involved in forming one, and what the benefits are, BEFORE holding a large meeting of all lakeshore residents. Once a small group of people is convinced that an association is possible and beneficial, it is easier for them to also convince a large group of people.

2) They formed a steering committee so that the first meeting could be well-planned and organized. Steering committees are important for delegating the large responsibility of setting up association meetings, as well as researching meeting topics and finding speakers.

3) They did not try to tackle too much during their association meetings. Effective meetings accomplish 1-3 modest goals; if too many issues are confronted at once, or if meetings get lost in endless discussions, it is difficult to get people to continue attending the meetings.

The Phillips Lake CCWF Grant Proposal

For several years, lakeshore residents at Phillips Lake have been very concerned about severe algal blooms and declining water quality. Partly because of these concerns, a resident volunteered to participate in Washington's Citizen Lake Monitoring Project during the 1989 monitoring season. From 1989-1991, several water quality complaints from residents, mainly regarding algae, were received by Ecology's regional office and by the Environmental Investigations and Laboratory Services Program, as well as by the Mason County Office of Water Quality.

In 1991, a lakeshore resident submitted a Centennial Clean Water Fund (CCWF) grant application to get assistance with the problems in Phillips Lake. However, because these grants may only be awarded to public agencies, the application was disqualified and no funds were awarded. In November 1991, Phillips Lake residents circulated a petition, asking the Mason County Commissioners to apply for a CCWF grant on their behalf. The petition requested that the grant be used "to help us determine the reason for the deteriorating condition of Phillips Lake and stop it. We would like Phillips Lake to remain as clear and clean as it was in 1970". The petition was signed by 133 lakeshore residents. The petitioners collected information and historical data (some of it was provided by this program) to include in the proposal, and county staff were to write and submit the grant. Because of this initiative by lakeshore residents to do something about nuisance algal blooms, I was interested in Phillips Lake getting a CCWF grant for a Phase I Diagnostic/Feasibility Study. A Phase I Diagnostic/Feasibility monitoring study funded through CCWF would identify the extent and sources of the nutrients which fertilize algal blooms, and would result in recommendations for actions that may improve water quality of the lake.

Wayne Clifford of the Mason County Office of Water Quality contacted me because he wanted information and assistance preparing the grant proposal. The objectives of the grant were to monitor the lake to identify the extent and sources of nutrient loading to the lake, and to develop an education program for lakeshore residents that would include a volunteer monitoring component and assisting the residents to form an organization for the lake.

Despite the intent of the county to prepare a grant application for Phillips Lake, which proposed to devote staff time to the project as well as funds, there appeared to be an adversarial relationship between county staff and some lakeshore residents. One lakeshore resident in particular was not satisfied with the level of effort expended by the county in preparing the proposal, and felt there was a lack of interest on the part of the county in preparing a successful grant proposal for Phillips Lake. Although this resident had gathered some information for inclusion in the proposal (including aerial photos showing the extent of algae blooms in 1991), county staff chose not to include this information.

Unfortunately, the grant proposal was not funded. The county's Office of Water Quality did not do any followup with Phillips Lake, primarily because of time and resource restrictions (D. Shaw, Office of Water Quality, pers. comm.). County staff were surprised that there was no public outcry after the grant application was denied. Mason County did not submit a grant application for Phillips Lake in 1993.

Lessons

Successful lake protection and restoration requires good organization, effective communication, and innovation. Unfortunately, all three were lacking in the Phillips Lake experience. Problems with the approach taken at Phillips Lake included the following:

1) Members of the Phillips Lake Association needed to organize themselves and their activities more effectively. For example, the volunteer monitoring program conducted by two lake residents, and paid for by the association, was a very good idea for educating members of the association. However, the grant proposal submitted by the county included provisions for helping the residents form a lake organization and to develop a volunteer monitoring program, without acknowledging either existing

program. When I asked county staff about this, I was told that the association was too loose to be effective, and the monitoring program generated nutrient data from Hach kits, and therefore the data could not be used for drawing conclusions about the lake, or in the grant application.

2) Communication between Phillips Lake residents and staff at the Office of Water Quality needed improvement. This was indicated by the adversarial relationship between some residents and county staff, and by the fact that the grant proposal did not acknowledge the lake association or the volunteer monitoring program. Although partial blame lies with both parties, it may only take one dedicated individual with good communication skills (from either group) to establish a good working relationship.

   Ideally, the association would keep county agencies informed about their activities and water quality concerns by sending county agencies copies of newsletters or other pertinent materials prepared by the association, and by inviting county staff to attend or speak at association meetings. This way, agency staff can also be invited to give their input on association activities (such as monitoring), so that association efforts can be more effective. Also, local agencies are more likely to give attention to water quality concerns and public education needs when they are presented by a cohesive, organized group than from a loose group of individuals.

3) Problems at Phillips Lake needed to be approached using a bit more innovation. For example, there was much more energy placed on getting a CCWF grant to investigate the lake's problems, and little energy expended on what to do for the lake if the grant application was not funded. Lake management is a long-term commitment; although a grant can pay for investigating sources of problems and implementing the more expensive restoration measures, grants do not (and should not be expected to) pay for everything that can be done to protect a lake. A well organized strategy would not rely exclusively on grants to fund solutions to a lake problem, and would have an action plan for interim measures that can be taken if it takes several tries to secure a grant. Public education, information gathering and sharing, and involvement with local government can be done by lake association members, even without a CCWF grant.

4) Finally, a grant application requires dedication and perseverance by the lake residents and the sponsoring public agency. It is not unusual for proposals to require several attempts to be successful, because the level of competition with other proposals, and available funding, can vary between years. As a result, determined groups may submit proposals every year, may submit proposals under more than one funding category, or may find other potential sources of funding education or monitoring activities.

Overall, members of the Phillips Lake Association needed to be active, or even take the lead role, in approaching management of the lake. For an association to become active in lake management issues, it is important for some members of the association to research and learn about the various management options available for their lake. Although it may seem overwhelming to delve into lake management and lake protection issues, it is the lake residents and lake users who will be affected by any management decision. As a result, it is important that these residents and users become informed and active participants in the process.

Designing and Implementing a Monitoring Program for Lake Roesiger

Members of the Lake Roesiger Property Owners have been very active the past few years. In addition to educating and encouraging lakeshore residents to use non-phosphorus detergents, to conserve water, and to install low-flow toilet fixtures, they have been very active regarding the lake restoration strategy that was recommended for their lake. An interesting twist, though, is that the residents are fighting against the implementation of the lake restoration strategy. Because this lake restoration issue is still unresolved and controversial, it won't be discussed here. However, one reason for the controversy was that residents felt that the restoration recommendations were based on data collected during a year of atypical conditions. The association decided to collect their own data for several years to demonstrate typical conditions, and to use their data to characterize the trophic status of the lake's two basins.

Two members of the association of Lake Roesiger Property Owners were particularly active in requesting information on lake monitoring and lake monitoring equipment. Information on Secchi disk theory and various types of monitoring equipment, and a list of accredited laboratories, were sent to them. The association purchased equipment for their program (a YSI temperature/dissolved oxygen meter and a water sampler), and they sent me a copy of their monitoring plan to review. I met with the group in February 1992 to discuss their monitoring plan, and to demonstrate equipment. I suggested several changes to their plan, particularly with regard to QA/QC elements (which included discussion of criteria to look for when selecting a lab).

Association members began collecting monthly Secchi data, water samples, and profile data (dissolved oxygen and temperature) in February 1992. Water samples were analyzed for TP and chlorophyll *a*. Because of their concern about data quality, association members collected profile data and water samples during my onsite visits with the volunteers in May and August 1992.

In December 1992, I met twice with an association member to talk about public education materials and about methods for calculating the precision and accuracy of the data. By learning and using more QA/QC procedures, association members hope to increase the credibility of their data.

Association members also interpreted and summarized data collected for the program, and presented the results to other association members. Their results and conclusions, which were based on data collected throughout the year, confirmed the trophic state estimation determined from Ecology's lake water quality assessment program. They continued their monitoring program in 1993.

Lessons

Designing and implementing a monitoring program can be very difficult, because the study must be planned to satisfy monitoring objectives. Members of the Association of Lake Roesiger Property Owners had clear monitoring objectives, and were very conscientious in designing their study to fit their needs and to be able to compare their data with data collected by others. They researched many different monitoring schemes, designed a study that fit their needs and their budget, and had several people experienced in monitoring and monitoring design review their study plan. They took the time to learn about, develop, and implement quality control procedures. Overall, their data should be of good quality.

Conclusions from the Case Studies

Both the Lake Martha and the Lake Roesiger groups had at least two people who were willing to spend time researching information, and to talk to others involved in various capacities of lake monitoring and protection. On the other hand, the Phillips Lake group had some people who were very interested in improving the water quality of the lake, but were set on using a CCWF grant to accomplish their goals. As a result, they relied on local agency personnel to obtain the grant on their behalf. The county's Office of Water Quality, though sympathetic to the concerns of the homeowners, was already overextended with other commitments, resulting in no followup action on the lake after the grant application was denied.

For citizen-initiated efforts to work effectively, it is necessary to have motivated individuals who can search out others who have had similar problems, and experts and agency personnel who can provide them with information that may make their task possible, and are willing to try innovative solutions. In all cases, patience and perseverance is required.

INDIVIDUAL LAKE ASSESSMENTS

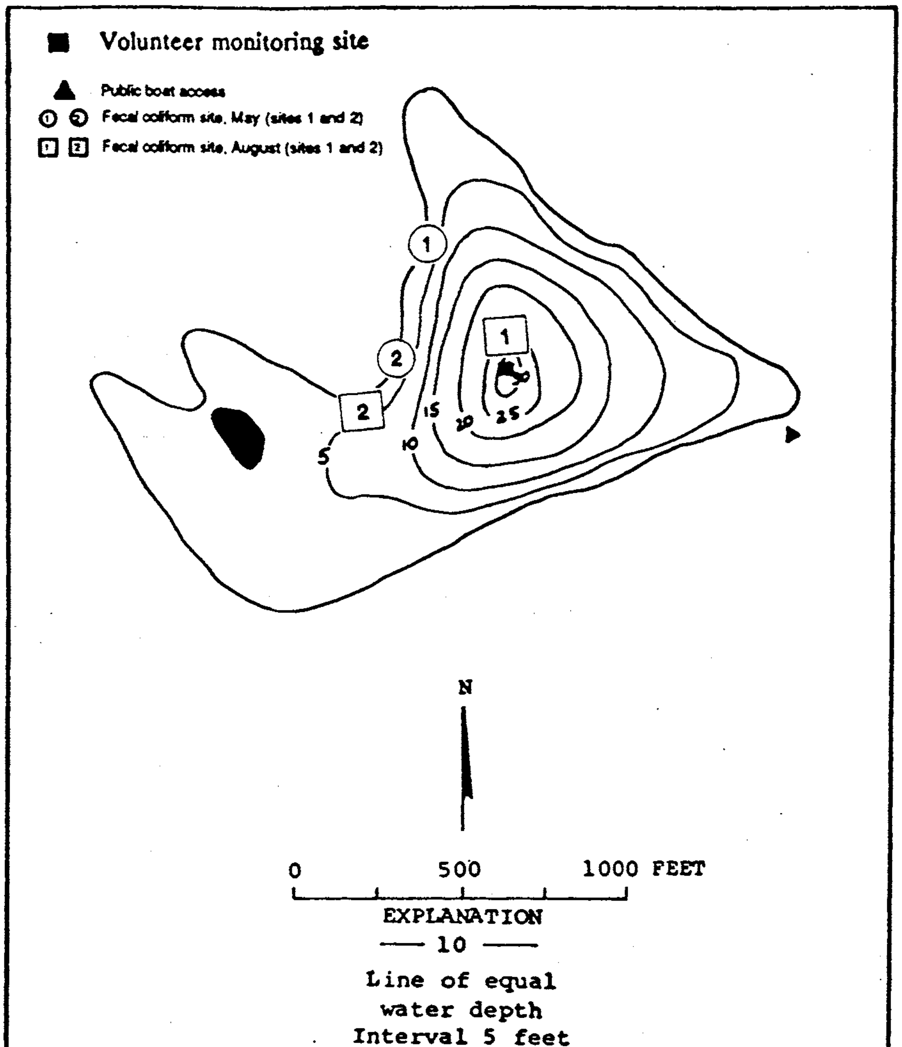
The 46 individual lake summaries presented here were written primarily for the volunteers who participated in Washington's Citizen Lake Monitoring Project. As a result, layperson's terms are used, and many basic limnological concepts are discussed or described. The original 1991 data summaries were mailed to the volunteers in June 1992, and the 1992 data summaries were mailed to the volunteers in June 1993. Accompanying each individual report were materials that explain the sources of the data, the methods used for interpreting the data, and a glossary of terms. An example of materials accompanying the 1992 reports is in Appendix E.

Lake Alice -- King County

Lake Alice is located 2.5 miles south of Fall City. It has no surface inlets or outlets, and seeps to the Raging River.

Size (acres)	32
Maximum Depth (feet)	30
Mean Depth (feet)	8
Lake Volume (acre-feet)	260
Drainage Area (miles^2)	0.2
Altitude (feet)	875
Shoreline Length (miles)	1.3

Data from Bortleson *et al.* (1976)



Alice Lake, King County. From Washington Department of Game, June 3, 1946.

Lake Alice -- King County

1992 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	44
Mean Trophic State Index (Total Phosphorus):	41
Mean Trophic State Index (Chlorophyll *a*):	31

Volunteer-Collected Data

Date 1992	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
12-May	1028	13.3	56.0	12.0	36.25	Lt-Green	50	Light	Light	
25-May	1350	16.7	62.0	12.0	34.00	Lt-Green	10	None	Light	
09-Jun	1305	20.0	68.0	11.0	31.00	Lt-Green	50	Trace	Breezy	
25-Jun	1235	25.0	77.0	8.0	29.00	Lt-Green	10	None	Light	
11-Jul	1030	18.9	66.0	10.0	29.00	Lt-Green	25	Trace	Light	
26-Jul	1130	20.0	68.0	8.0	26.50	Lt-Green	0	None	Light	
09-Aug	1030	18.3	65.0	11.2	24.20	Lt-Green	10	Trace	Light	
23-Aug	1015	20.0	68.0	13.3	21.00	Lt-Green	25	None	Light	
07-Sep	1005	17.8	64.0	10.3	19.50		75	None	Light	
21-Sep	1200	16.1	61.0	8.0	17.50	Lt-Green	75	Trace	Light	
06-Oct	1315	14.4	58.0	8.0	19.50	Lt-Green	0	None	Light	
22-Oct	1025	11.2	52.0	6.5	19.75	Pea-Green	90	Heavy	Light	

[1] Trophic State Indices calculated from Carlson (1977)

Lake Alice -- King County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/12	0.0	15.0	7.0	9.6	13
	1.0	14.9	6.5	9.2	13
	2.0	14.8	6.4	9.1	13
	3.0	14.4	6.3	9.0	13
	4.0	12.6	6.1	6.6	14
	5.0	10.3	5.7	1.4	15
	6.0	9.0	5.5	0.6	15
	7.0	8.5	5.5	0.1	15
	8.0	8.3	5.5	0.1	16
08/24	0.0	22.6	8.1	8.6	22
	1.0	22.3	8.1	8.3	22
	2.0	21.7	8.0	8.3	22
	3.0	20.9	8.0	8.1	22
	4.0	19.1	7.9	4.4	23
	5.0	15.4	7.7	1.9	23
	6.0	12.5	7.5	0.2	25
	7.0	10.4	7.3	0.1	28
	8.0	9.7	7.0	0.1	44

1992 Onsite Visit Data - Water Chemistry

Date	05/12/92		08/24/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (meters)	1, 2	6, 7, 8	1, 2	7, 8
Total Phosphorus (μg/L)	12	30	14	8
Total Nitrogen (mg/L)	0.31	0.38	0.38	0.64
Chlorophyll *a* (μg/L)	1.6	--	0.5	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	2	--	2	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	2	--	<1	--
Total Suspended Solids (mg/L)	1	--	2	--
Total Nonvolatile Suspended Solids (mg/L)	<1	--	1	--
Color (Pt-Co units)	25	--	20	--

Lake Alice -- King County

Historical Data From Ecology

Date	6/25/73[a]	5/24/91[b]
Secchi (feet)	14	12
Total Phosphorus, epilimnion (μg/L)	11	--
Total Nitrogen, epilimnion (mg/L)	--	0.23
Chlorophyll *a* (μg/L)	0.8	--
Dissolved Oxygen, surface (mg/L)	8.6	9.7
Dissolved Oxygen, bottom (mg/L)	1.0	0.2

a. Bortleson *et al.* (1976)
b. Rector (1992)

Lake Alice -- King County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Secchi depths in 1992 were moderately deep, ranging from 6.5 to 13.3 feet. Shallowest Secchi depths were measured during July and October.

Total Phosphorus
Total phosphorus in the epilimnion (upper layer of water) wwas 12 μg/L in May, and 14 μg/L in August. These concentrations were moderately high, and fall within the low end of the mesotrophic range. These concentrations were not much higher than the concentration of 11 μg/L which was measured in June 1973 (Bortleson *et al.*, 1976).

Total Nitrogen
Total nitrogen in the epilimnion was 0.31 mg?l in May, and 0.38 mg/L in August. These concentrations were higher than the concentration of 0.23 mg/L measured in 1991 (Rector, 1992), and 0.17 mg/L measured in 1973 (Bortleson *et al.*, 1976).

Fecal Coliform Bacteria
Sampling sites for fecal coliform bacteria samples are indicated on the map. All sample results were low, and within acceptable state standards.

Solids and Color
Total suspended solids, total nonvolatile suspended solids, and color data were all low. These indicate that Secchi depths were most likely related to algal growth at the time of sampling, rather than by suspended sediments or water color.

Profile Data
On both sampling dates, the lake was stratified and there was very little dissolved oxygen below the thermocline. Low dissolved oxygen can result from springs which enter the lake, because springwater is low in oxygen. Dissolved oxygen can also be consumed during bacterial decomposition adn respiration in the water and sediments. The low oxygen will affect fish distribution in the lake. Trout probably migrate between the metalimnion of the lake, where dissolved oxygen is higher, to the hypolimnion of the lake, where temperatures are lower. The 1992 profile data were very similar to profile data collected in 1991 (Rector, 1992).

Plants
On both sampling dates, chlorophyll *a* was low, indicating that there was little algal growth in the lake at the time of sampling. A sample of algae collected during the August 1992 onsite visit was the filamentous blue-green alga *Mougeotia*. This alga was isolated in nearshore areas.

Aquatic plants collected from Lake Alice during the May 1992 onsite visit were identified as quillwort (*Isoetes* spp.), water star-wort (*Callitriche* spp.), and water-moss (*Fontinalis*). Plants collected during the August 1992 onsite visit were identified as iris (*Iris pseudacorus*), yellow-flowering lily (*Nuphar*), watershield (*Brasenia schreberi*), cattails (*Typha* spp.), bulrush (*Scirpus*), mint (*Labiatae*), and ribbonleaf pondweed (*Potamogeton epihydrus*). The volunteer noted that the iris was particularly prolific this year.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1991 to 1992.

> Lake Alice is used for fishing, swimming, and non-motorized boating. There is one public boat ramp on the lakeshore, making about 1 percent of the shoreline publicly-owned. No motor boats are allowed on the lake. Trout were stocked in the lake. Currently, the watershed is used only for lakeshore development for residences. In the past, the watershed was used for logging, and the lake was dredged.
>
> None of the houses on lakeshore are connected to a sewer. There are no culverts which drain into the lake. There is no lake association or community association for the lake. Currently, the minimum setback for lakeshore development is 50 feet for residences and 20 feet for agriculture. The minimum lot length for residential development is 50 feet, and residential density is restricted to 2 houses per acre. Lake water is withdrawn for drinking and other domestic uses.
>
> Overall, the volunteer finds that Lake Alice had good water quality. Problems in the lake in 1992 were ranked as 1) high water level, 2) algae, and 3) excessive aquatic plant growth. Possible sources of problems are Canada geese and fertilizer runoff. In comparison to 1991, the lake level in 1992 was about 7 inches higher, despite low rainfall. Beavers were a severe nuisance last winter and spring, because they damaged many valuable trees. Canada geese were also a nuisance.
>
> In 1991, lily growth was dense at the west end of the lake, and algae grew in shallow areas.

Comments

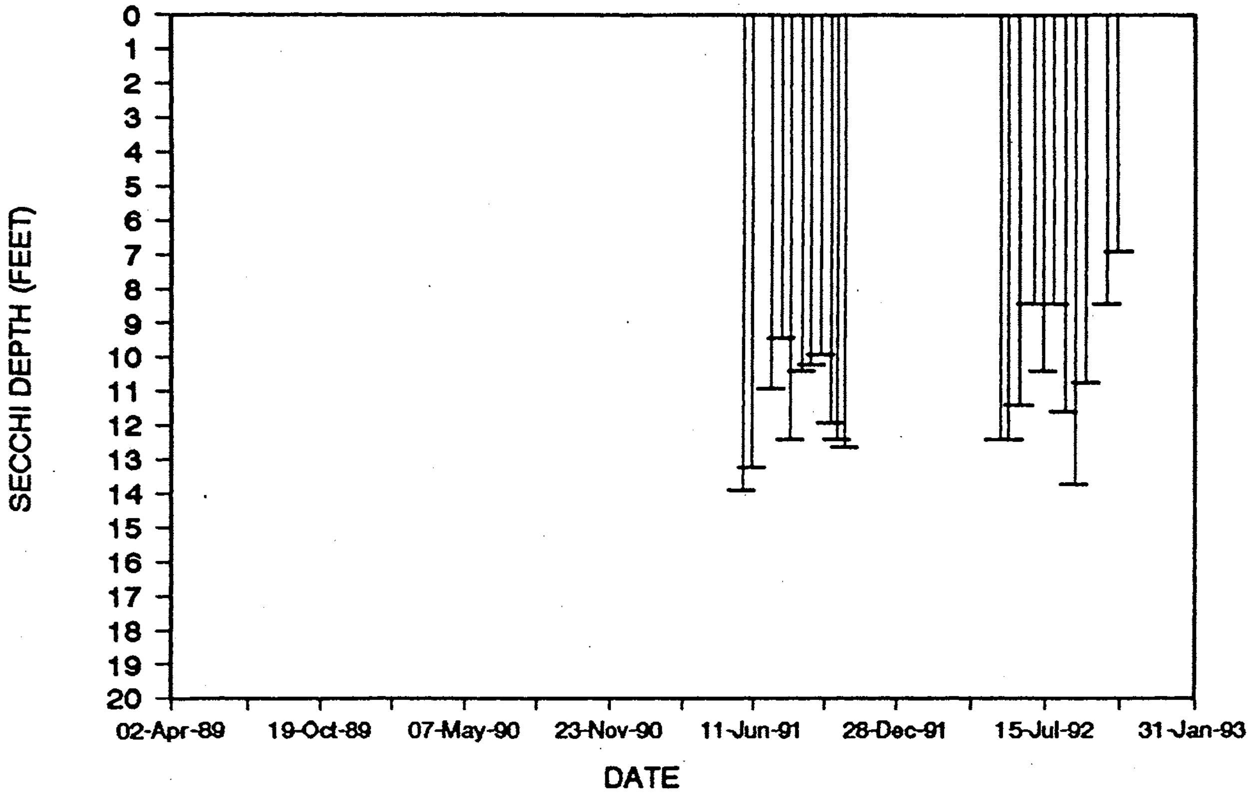
Although Secchi depths were clearly in the mesotrophic range, both total phosphorus and chlorophyll *a* were in the oligotrophic range. Other mesotrophic characteristics of the lake include the low dissolved oxygen in the hypolimnion, and the moderate amount of plant growth along some shoreline areas. Because the lake exhibits both oligotrophic and mesotrophic characteristics, the lake was estimated as oligo-mesotrophic. In 1991, there was no phosphorus or chlorophyll data available, and Secchi and profile data indicated that the lake was mesotrophic. It appears that in addition to Secchi depth data, phosphorus and chlorophyll data are needed to assess Lake Alice.

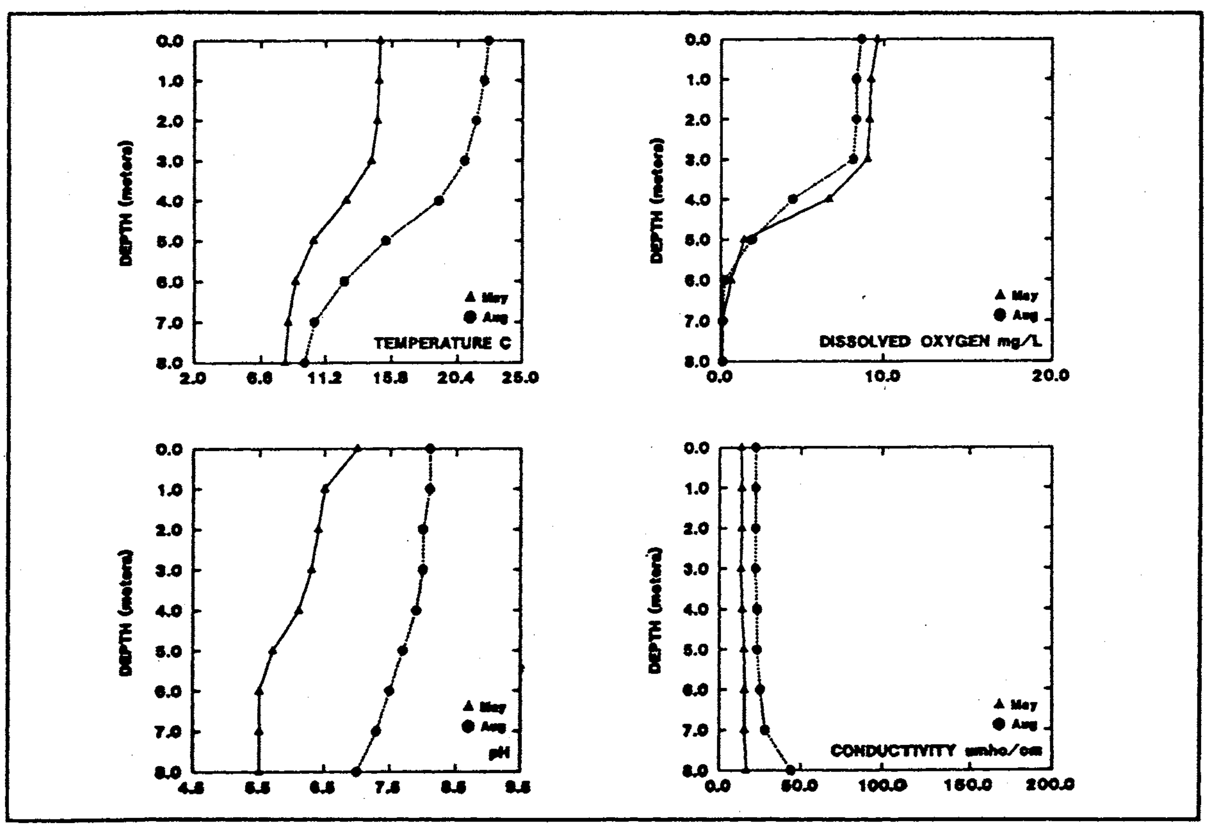
In comparison to other lakes monitored for the program in 1992, Lake Alice had very low algal growth (as indicated by chlorophyll *a* concentrations).

Acknowledgement

I thank Antony Johnson for volunteering his time to monitor Lake Alice during 1991-1992.

LAKE ALICE (KING COUNTY)

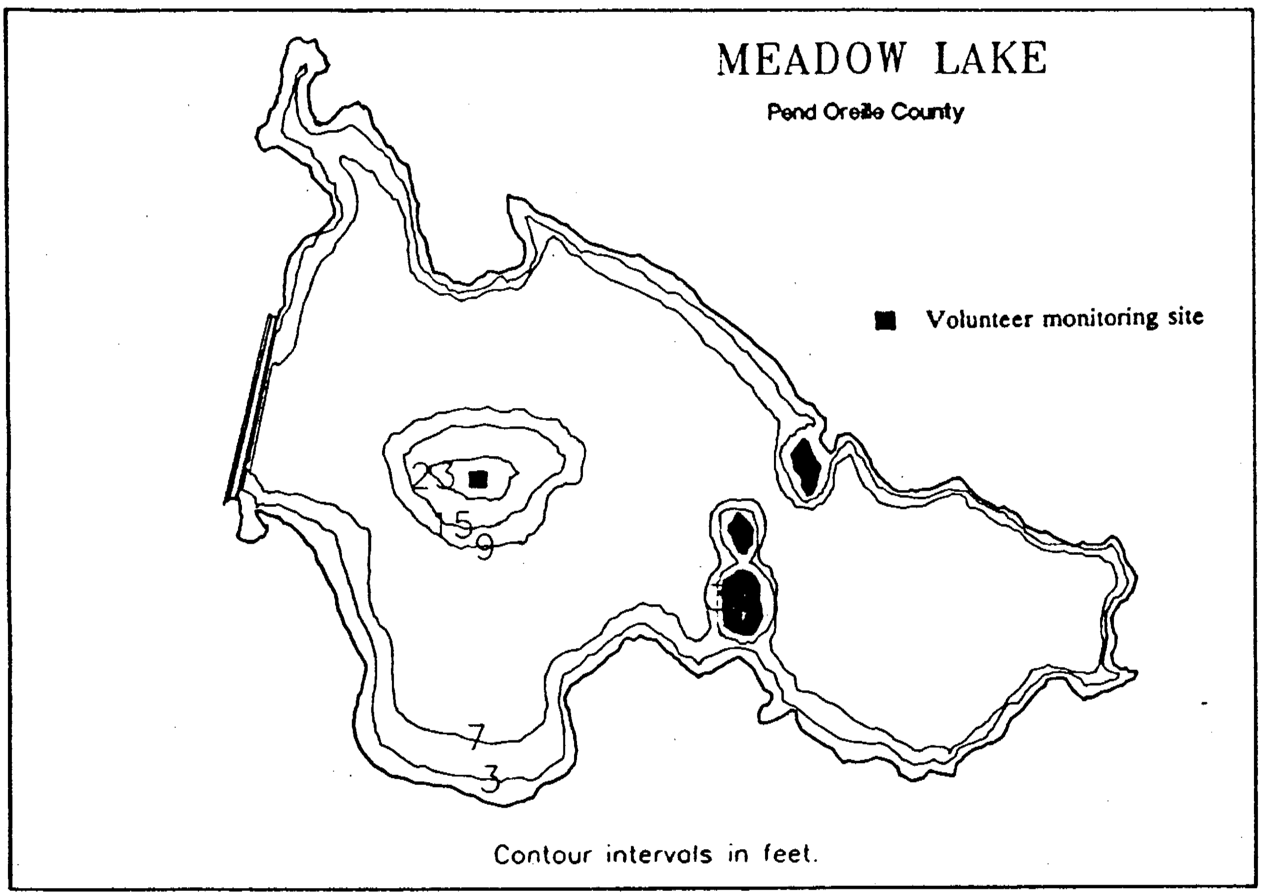




Big Meadow Lake -- Pend Oreille County

Big Meadow Lake lies in a peat area about 20 miles northeast of Colville at the head of Meadow Creek. It drains westerly to the south fork of Deep Creek and ultimately to the Columbia River. Big Meadow Creek was dammed in the mid-seventies, which enlarged the lake from its original size of about 4 acres to its present size of about 72 acres.

Size (acres)	72
Maximum Depth (feet)	23
Mean Depth (feet)	7.2
Lake Volume (acre-feet)	512
Drainage Area (miles^2)	2.59
Altitude (feet)	3450
Shoreline length (miles)	3.81



Big Meadow Lake -- Pend Oreille County

1992 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	42
Mean Trophic State Index (Total Phosphorus):	49
Mean Trophic State Index (Chlorophyll *a*):	39

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
06-May	1145	18.5	65.3	13.3	0.00	Dark-Gr				Water color dark green.
22-May	1340	17.0	62.6	12.0	0.00	Dark-Gr	90			Water color dark green.
03-Jun	1255	20.0	68.0	10.3	-2.00	Gr-Brown	25	None	Light	Algae bloom light green filamentous structure along north and southwest part of the lake.
17-Jun	1305	18.5	65.3	8.0	0.00	Gr-Brown	90	Moderate	Breezy	A little of last report's algae bloom left. Had about 3" rain since last Friday.
01-Jul	1242	20.7	69.3	7.4	-2.00	Gr-Brown	90	Moderate	Breezy	One small island has floated up from the bottom.
15-Jul	1235	20.1	68.2	9.3	-2.00	Gr-Brown	10	None	Strong	
29-Jul	1135	22.0	71.6	10.0	-4.00	Gr-Brown	10	Trace	Breezy	Another "island" has appeared, this one covered with grass.
12-Aug	1145	23.0	73.4	10.9	-6.00	Gr-Brown	75	None	Light	The first "island" has disappeared.
26-Aug	1310	18.1	64.6	12.1	-8.00	Gr-Brown	50	Light	Calm	
01-Sep				13.5						Onsite visit.
09-Sep	1310	15.5	59.9	14.0	-8.00	Gr-Brown	0	Moderate	Light	Got familiar with DO kit - 5.7 mg/L about 3 ft off the bottom.
23-Sep	1000	14.2	57.6	14.7	-6.00	Gr-Brown	25	Trace	Strong	
20-Oct	1257	7.0	44.6	12.7	-8.00	Gr-Brown	50	Trace	Breezy	The two "islands" have sunk. Surface DO was 9.6 mg/L.

[1] Trophic State Indices calculated from Carlson (1977)

Big Meadow Lake -- Pend Oreille County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/19	0.0	17.3	8.0	9.6	49
	1.0	16.5	7.9	9.5	49
	2.0	16.3	7.9	9.5	49
	3.0	15.5	7.8	9.4	49
	4.0	12.7	7.6	7.8	49
	5.0	11.4	7.4	7.1	50
09/01	0.0	17.8	7.8	8.5	50
	1.0	17.4	7.7	8.6	50
	2.0	17.3	7.6	8.6	50
	3.0	16.5	7.5	7.4	50
	4.0	15.8	7.4	5.6	50
	5.0	15.5	7.3	2.5	52

1992 Onsite Visit Data - Water Chemistry

Date	05/19/92		09/01/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	--	1, 3, 4	--
Total Phosphorus (μg/L)	23	--	22	--
Total Nitrogen (mg/L)	0.60	--	0.71	--
Chlorophyll *a* (μg/L)	1.60	--	3.10	--

Big Meadow Lake -- Pend Oreille County

Historical Data From Ecology

Date	05/29/90[a]	09/12/90[a]	06/12/91[b]
Secchi (feet)	--	8.4	11.0
Total Phosphorus, epilimnion (μg/L)	31	30	--
Total Nitrogen, epilimnion (mg/L)	0.70	0.91	0.34
Chlorophyll *a* (μg/L)	--	--	--
Dissolved Oxygen, surface (mg/L)	10.7	--	9.3
Dissolved Oxygen, bottom (mg/L)	1.6	--	1.0

a. Rector (1991)
b. Rector (1992)

Big Meadow Lake -- Pend Oreille County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was good to fair during 1992, with Secchi depths ranging from 7.4 to 14.7 feet. During June and July, lower Secchi depths resulted from an algal bloom (see comments with Volunteer-Collected Data). Except during those months, most Secchi depths were in the mesotrophic range.

Total Phosphorus
Total phosphorus was moderately high, and in the mesotrophic range, on both sampling dates. Concentrations measured in May and September 1992 (23 and 22 μg/L, respectively) were lower than concentrations measured in 1990 (31 and 30 μg/L; Rector, 1991).

Total Nitrogen
Total nitrogen was high relative to the concentrations of total phosphorus, indicating that algal growth in Big Meadow Lake was limited by the amount of phosphorus in the water. Concentrations measured in 1992 (0.60 and 0.91 mg/L) were more similar to those measured in 1990 (0.70 and 0.91 mg/L; Rector, 1991) than in 1991 (0.34 mg/L; Rector, 1992).

Profile Data
During May, the lake was stratified with respect to temperature, and both pH and dissolved oxygen decreased from surface to bottom. During September, stratification was weak (there was less than 3 degrees difference from surface to bottom), and pH was similar to the values measured in May. Dissolved oxygen, though, decreased to only 2.5 mg/L at the lake bottom.

Plants
Chlorophyll *a* was low (1.6 μg/L) during May, indicating that there was little algae growth in the lake at the time of sampling. During September, the higher value (3.10 μg/L) was in the mesotrophic range and indicated that there was a moderate amount of algae growing. Most of the eastern Washington lakes sampled for the program had low chlorophyll during May and June, probably due to low water temperatures at the higher elevations.

Plants identified during the 1992 onsite visits were flatleaf pondweed (*Potamogeton robbinsii*), largeleaf pondweed (*Potamogeton amplifolius*), floatingleaf pondweed (*Potamogeton natans*), yellow-flowering lily (*Nuphar polysepalum*), waterweed (*Elodea canadensis*), two other unidentified pondweeds, and muskgrass (*Chara*). During the June 12, 1991 onsite visit with the volunteer, *Chara* (an alga), pondweed, and sedge (*Carex* sp.) were observed growing in the lake and along the shore. Two other plants, a pondweed and bur-reed (*Sparganiaceae* family) were also noted. Decomposing blue-green algae were found along the shoreline.

Big Meadow Lake -- Pend Oreille County

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

Big Meadow Lake is used for fishing, picnicking, camping and waterfowl habitat. There is one public boat ramp, and there are no restrictions for motorboat use on the lake. There are no nearshore houses, although there is a Forest Service campground on the lakeshore; 100% of the shoreline is publicly-owned. Eastern brook trout were stocked in the lake.

Areas flooded when the lake was enlarged were covered with submerged weeds, but the original lake area was not covered with plant growth. Open areas about seven feet deep had floating-leaved type weeds. "Floating islands" (parts of the lake bottom which rise to the water surface and float) were common in the lake. These islands occur when gases produced during decomposition loosen sediments they are trapped in, and eventually make a portion of the sediments buoyant.

In January and February 1989 there was a winterkill of fish. The Department of Wildlife installed an aeration system on August 25, 1989 to prevent the fish kills. No fish kills have been reported since the aerator was installed.

Overall, the volunteer found that Big Meadow Lake had good water quality. The worst problem in the lake in 1992 was excessive aquatic plant growth. There was more aquatic plant growth in 1992 than in 1991.

Comments

All three trophic state parameters (Secchi depth, total phosphorus, and late summer chlorophyll *a*) indicate that the lake was mesotrophic.

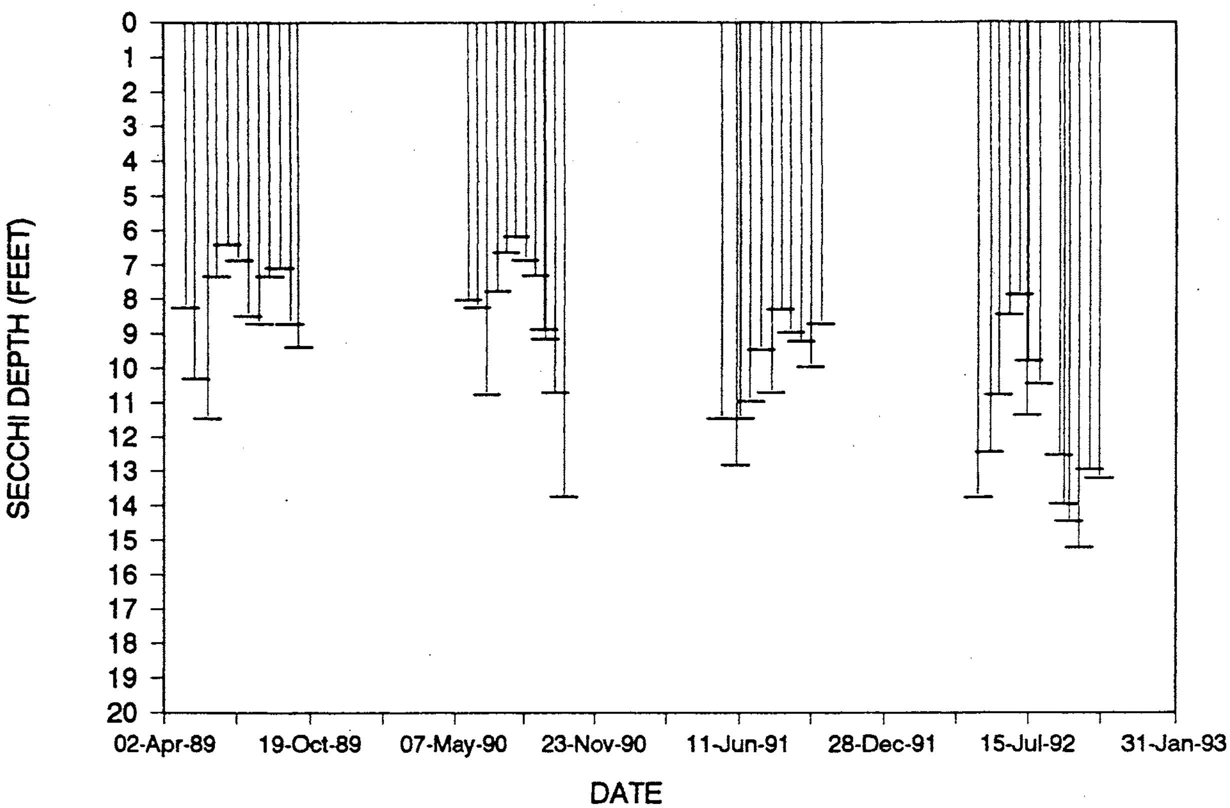
Lake Leo was the only other Pend Oreille County lake monitored for the program in 1992. Compared to Lake Leo, Big Meadow Lake had lower water clarity, and higher phosphorus and chlorophyll *a*. Lake Leo was characterized as oligotrophic in 1992.

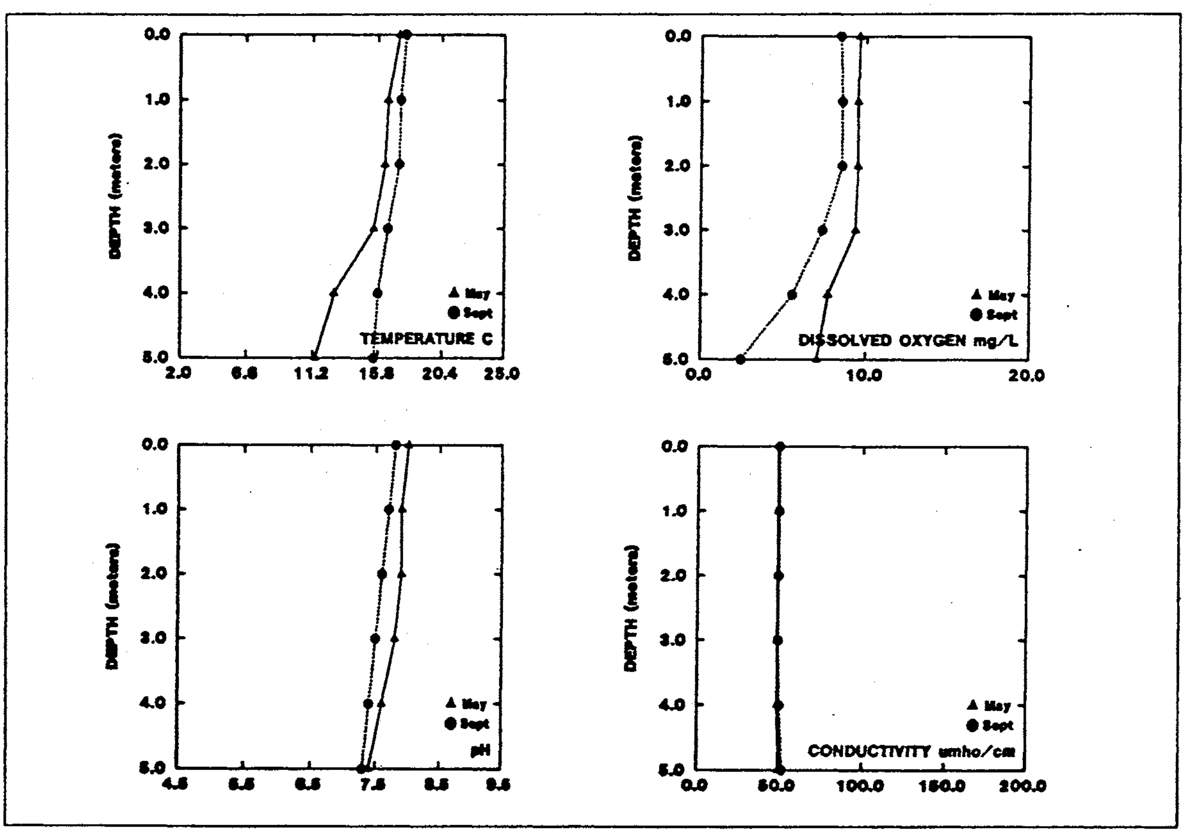
The floating chunks of lake bottom (referred to as "floating islands" in the volunteer's field comments) have been reported by the volunteer since 1989.

Acknowledgement

I thank Terry Williams for volunteering his time to monitor Big Meadow Lake during 1989-1992.

BIG MEADOW LAKE (PEND OREILLE COUNTY)



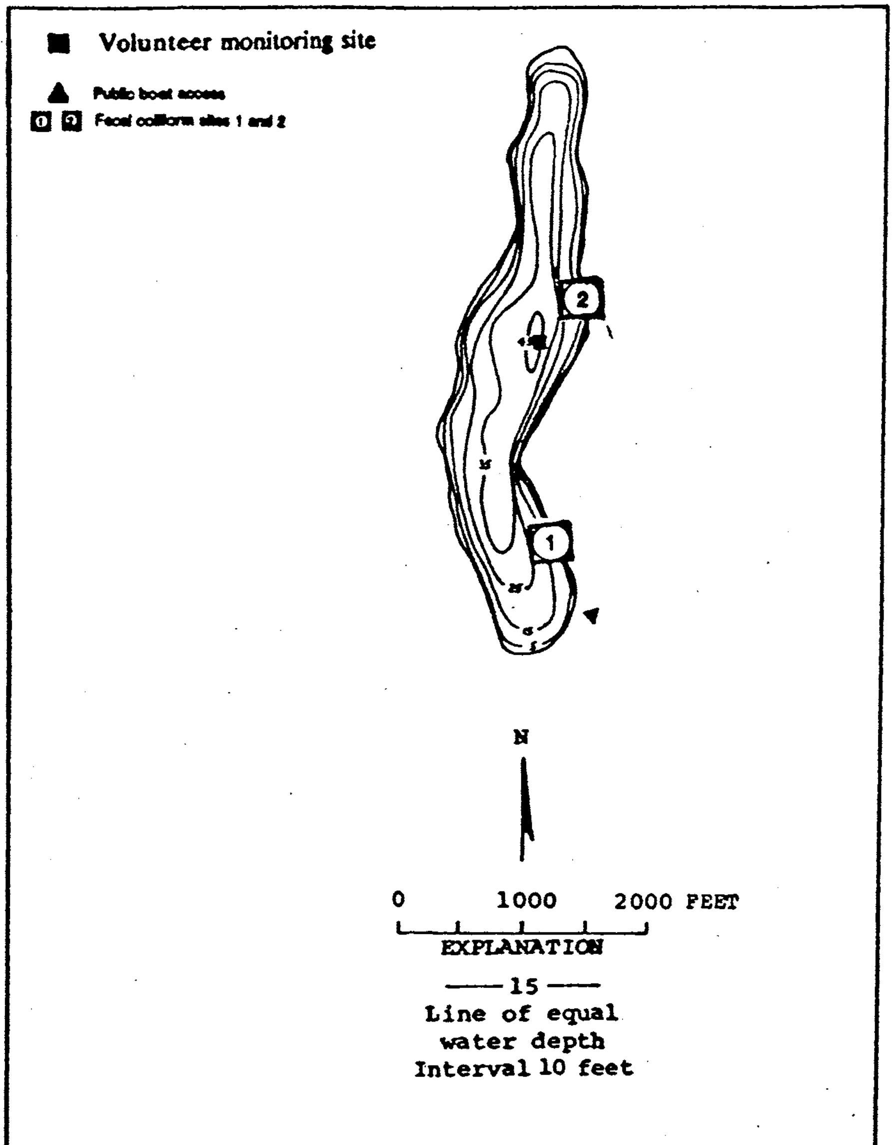


Black Lake -- Stevens County

Black Lake is located about 12.5 miles east of Colville. It is 4,800 feet long. The main inflow is intermittent into the north end of the lake, and there is a smaller inlet on the east side of the lake. Black Lake drains southeast via Gap Creek to the Little Pend Oreille River.

Size (acres)	70
Maximum Depth (feet)	45
Mean Depth (feet)	27
Lake Volume (acre-feet)	1,863
Drainage Area (miles^2)	0.9
Altitude (feet)	3,701
Shoreline Length (miles)	2.0

Data From Dion *et al.* (1976)



Black Lake, Stevens County. From Washington Department of Game, March 31, 1949.

Black Lake -- Stevens County

1992 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	36
Mean Trophic State Index (Total Phosphorus):	45
Mean Trophic State Index (Chlorophyll *a*):	27

Volunteer-Collected Data

Date 1992	Time	Temperature (°C)	(°F)	Secchi (ft)	pH	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
11-May				16.0							Onsite visit.
02-Jun	1400	19.4	67.0	16.0	7.9	16.00	Cl-Brown	50	None	Light	Water color clear-brownish. pH with colorpHast strip: 6.5. Cole-Parmer method very time consuming.
19-Jun	1030	20.0	68.0	13.5	7.6	22.00	Cl-Brown	0	None	Light	Heavy rain 3 days ago - raised lake level 3". pH on colorpHast strip 6.3.
15-Jul	1315	18.9	66.0	16.0	7.5	21.00	Cl-Brown	0	None	Light	pH with colorpHast strips 6.0
19-Aug	1430	22.8	73.0	22.0	7.7		Brown	10	None	Light	Water color brownish. pH on colorpHast strips 6.5.
24-Aug				24.0							Onsite visit.
21-Sep	1200	14.4	58.0	20.0	7.9	13.00	Cl-Brown	10	Trace	Light	
15-Oct	1300	10.0	50.0	14.0		12.00	Cl-Brown	50	Moderate	Light	Snowed in last 2 days. Lake turned over recently - hence decrease in Secchi reading.

[1] Trophic State Indices calculated from Carlson (1977)

Black Lake -- Stevens County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/11	0.0	12.7	6.5	8.9	36
	1.0	12.7	6.5	8.8	36
	2.0	12.6	6.6	8.8	36
	3.0	12.5	6.6	8.7	35
	4.0	11.0	6.6	8.5	34
	5.0	8.7	6.6	7.3	35
	6.0	7.8	6.5	6.4	35
	8.0	7.3	6.5	5.6	35
	10.0	7.2	6.5	5.5	35
	12.0	7.2	6.5	5.4	35
08/24	0.0	17.5	7.6	8.4	32
	1.0	17.6	7.5	8.2	32
	2.0	17.6	7.5	8.2	32
	3.0	17.6	7.4	8.1	32
	4.0	17.6	7.4	8.1	32
	5.0	17.2	7.4	9.1	32
	6.0	12.7	7.1	4.0	33
	7.0	10.4	6.9	0.2	34
	8.0	9.0	6.7	0.1	37
	9.0	8.5	6.6	0.1	43
	10.0	8.3	6.6	0.1	45
	12.0	8.2	6.5	0.1	46

1992 Onsite Visit Data - Water Chemistry

Date	05/11/92		08/24/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	5, 8, 10	1, 3, 5	7, 8, 10
Total Phosphorus (μg/L)	23	13	10	23
Total Nitrogen (mg/L)	0.30	0.33	0.30	0.28
Chlorophyll *a* (μg/L)	0.37		1.07	
Fecal Coliform Bacteria Site 1 (organisms/100 mL)	<1		<1	
Fecal Coliform Bacteria Site 2 (organisms/100 mL)	<1		1	
Total Suspended Solids (mg/L)	1		2	
Total Nonvolatile Suspended Solids (mg/L)	<1		1	
Color (Pt-Co units)	25		20	

Black Lake -- Stevens County

Historical Data From Ecology

Date	07/08/74[a]	06/20/89[b]	09/05/89[b]	05/29/90[c]	09/11/90[c]	06/13/91[d]
Secchi (feet)	12	11.5	16.7	--	15.6	--
Total Phosphorus, epilimnion (µg/L)	9	11	4	19	12	--
Total Nitrogen, epilimnion (mg/L)	--	0.28	0.31	0.35	0.30	0.25
Chlorophyll *a* (µg/L)	--	1.6	1.2	--	--	--
Dissolved Oxygen, surface (mg/L)	8.2	9.4	8.6	10.6	8.4	8.9
Dissolved Oxygen, bottom (mg/L)	0.4	0.3	0.1	2.5	0.0	2.2

a. Dion *et al.* (1976)
b. Brower and Kendra (1990)
c. Rector (1991)
d. Rector (1992)

Black Lake -- Stevens County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was very good, as indicated by all Secchi depths which ranged from 14.0 to 22.0 feet. Shallower Secchi readings in mid-June and mid-October followed periods of rain or snow, and were not likely the result of increased algal growth.

Total Phosphorus
Total phosphorus was high during May 1992 (23 μg/L), but was low during August (10 μg/L). In 1990, phosphorus was also higher during May compared to the late summer concentration. Recent lake thaw and subsequent lake turnover could cause higher total phosphorus concentrations during spring than in late summer.

Total Nitrogen
Total nitrogen was the same (0.30 mg/L) on both sampling dates, and was similar to concentrations measured during 1989, 1990, and 1991.

Fecal Coliform Bacteria
All results for fecal coliforms were very low, and were within acceptable state standards.

Solids and Color
Samples for total suspended solids and total nonvolatile suspended solids were low. There was some color in the lake, but color values were also low. Because of the name of the lake, and because the volunteer consistently reported the water color as clear-brown, it was suspected that natural color in the lake would be higher. In 1974, color was only 10 platinum-cobalt units (Dion *et al.*, 1976).

Profile Data
On both sampling dates the lake was stratified with respect to temperature, and dissolved oxygen decreased from surface to bottom. During the August onsite visit, dissolved oxygen was very low (0.1 - 0.2 mg/L) throughout the hypolimnion. Low dissolved oxygen in the hypolimnion was also recorded during September 1990 (0.0 mg/L at 11 meters; Rector, 1991) and in 1974 (0.4 mg/L at 30 feet; Dion *et al.*, 1976). It is likely that low dissolved oxygen near the lake bottom has been occurring for many years. Low dissolved oxygen concentrations result from the bacterial decomposition of organic material (such as vegetation and woody debris) in the water and sediments.

Plants
Despite the high phosphorus concentration during May, chlorophyll *a* during May was very low and indicated that there was very little algal growth at the time of sampling. It is possible that the phosphorus was not in a form that is available for uptake by algae (that is, adsorbed onto suspended sediments), which would explain the low algal productivity. It is also possible that low water

temperature during May inhibited algal growth. The chlorophyll *a* value during August was also low. Most eastern Washington lakes sampled for the program had much lower algal growth (as indicated by chlorophyll *a*) during May than in August. If algae were observed during May, they were usually isolated in nearshore areas rather than growing throughout the lakes.

On the day of the May onsite visit with the volunteer, plants identified by Ecology staff near the public access were largeleaf pondweed (*Potamogeton amplifolius*), waterweed (*Elodea candensis*), and muskgrass (*Chara*).

During the September 1990 onsite visit with the volunteer, aquatic plants covered 90 - 95% of the shoreline, with scattered patches offshore. There was not a lot of aquatic plant growth near the sampling area, except in small coves. Yellow-flowering lily (*Nuphar* sp.), pondweeds (*Potamogeton amplifolius*, *P. berchtoldii*, and *P. epihydrus*) and waterweed (*Elodea* sp.) were identified during the visit. Aquatic plants were not surveyed during the 1991 sampling.

In 1989, Most of the shoreline was ringed with reeds and grasses, and scattered aquatic plants reached the surface up to 20 - 40 feet offshore. Photos and aquatic weed descriptions were sent in by the volunteer in 1989, showing submerged species of aquatic plants (*Elodea*), pondweeds (*Potamogeton* spp.), yellow-flowering pond lily (*Nuphar*), and emergent species of cattail, reeds, and grasses.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

> Black Lake is used for fishing, swimming, rowing, camping, and during the winter, skating and skiing. Recreational facilities on the lakeshore include a picnic area, a camping area, a beach, one resort. There is one public boat ramp. About 4 percent of the shoreline is publicly-owned. Rainbow and eastern brook trout are stocked in the lake. Currently, the lakeshore is being developed further for residences. In the past, the watershed was used for logging and crop agriculture.
>
> There are 28 houses on the lakeshore, and none of the houses are connected to a sewer. There are no culverts which drain to the lake. There is no lake association for the lake. Lake water is withdrawn for drinking and other domestic uses.
>
> Overall, the volunteer finds that Black Lake had excellent water quality. There were no water quality problems in the lake in 1992. (In 1991, the volunteer cited fish species and aquatic plants as the worst problems in the lake. In 1990, the increasing amount of aquatic plant growth during summer was the worst problem in the lake.) There were no changes in the lake since the 1991 monitoring season. Sewage,

garbage, and large boats are the only potential sources of pollutants to the lake now. The volunteer is concerned about drinking water quality.

The volunteer also noted that the thermocline dropped from about 25 feet in September, until the lake turned over in early October. Trout in the lake were holding above the thermocline. 1992 was a record year for rainbow trout--up to 5.5 pounds, due to shiners.

The lake has been chemically treated in the past to control undesirable fish species. Aquatic plants grow in 6-10 feet of water, with some reaching to the surface. There are wetlands areas near both inlets. In 1989, there was a beaver dam and a wetland area at the north end of the lake at the main inlet.

Comments

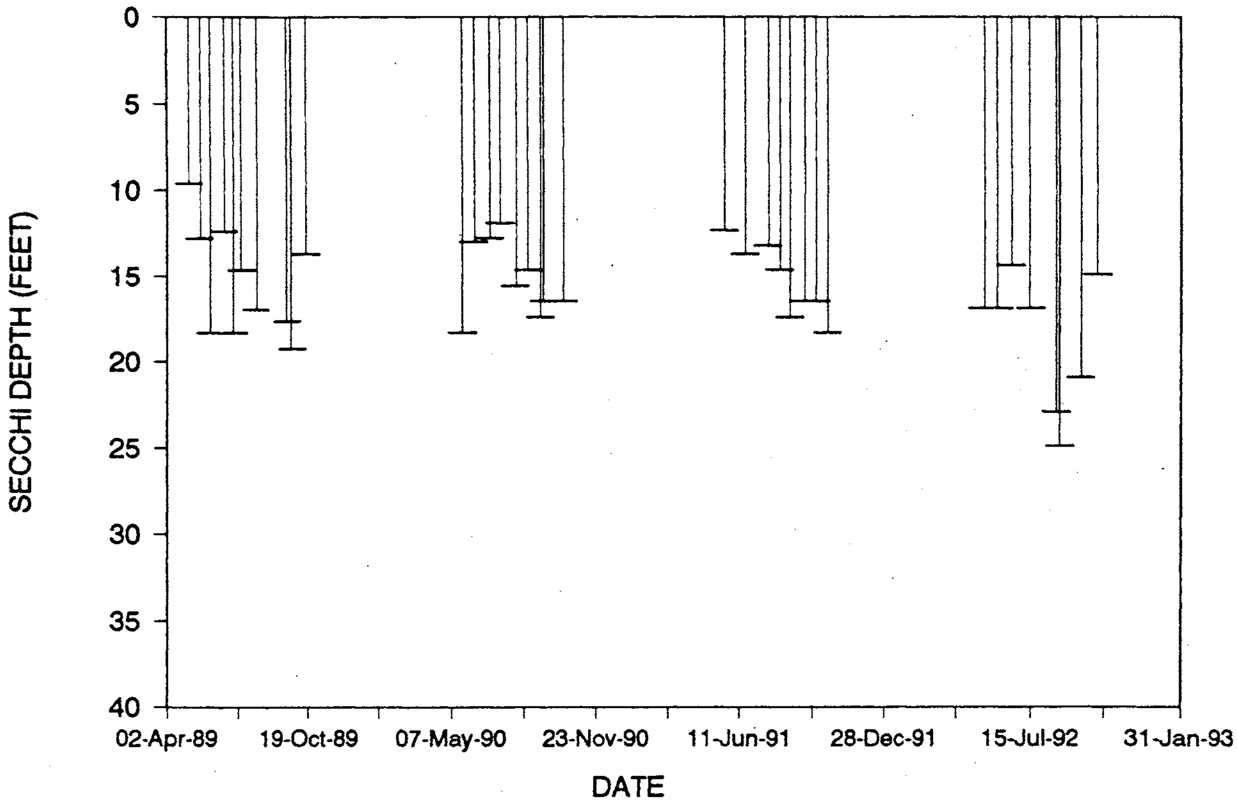
Black Lake exhibited both oligotrophic and mesotrophic characteristics. Oligotrophic characteristics include the low concentrations of chlorophyll *a*, and good water clarity. Mesotrophic characteristics of the lake include very low hypolimnetic dissolved oxygen during August, prolific plant growth which is particularly noticeable near the public boat launch, and high total phosphorus during May. Most of these characteristics were also noted in 1991. Because the Secchi depths were deeper in 1992 than in 1991, though, the lake was estimated as oligo-mesotrophic in 1992.

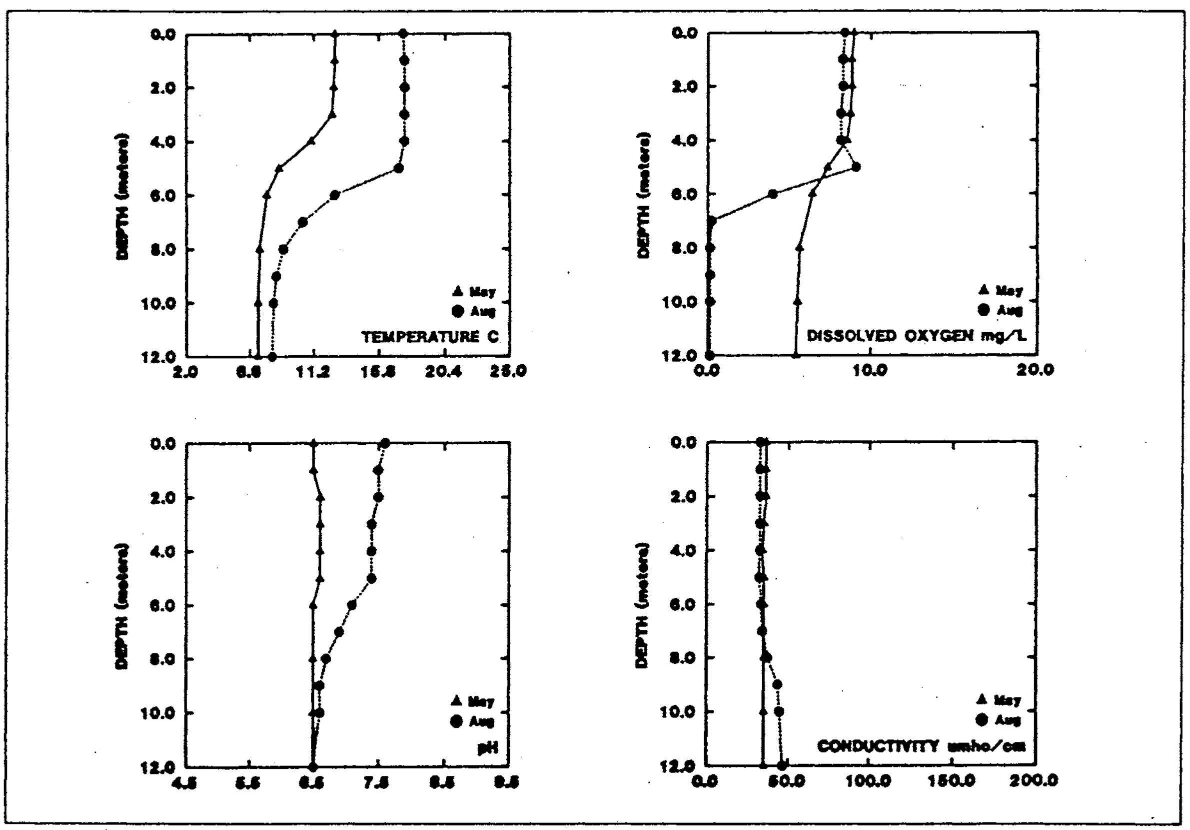
Four other Stevens County lakes (Deer, Jumpoff Joe, Thomas, and Waitts) were monitored for the program during 1992. In comparison to these lakes, only Jumpoff Joe Lake had higher total phosphorus and shallower Secchi depths than Black Lake.

Acknowledgement

I thank Norman S. LaVigne for volunteering his time to monitor Black Lake during 1989-1992.

BLACK LAKE (STEVENS COUNTY)



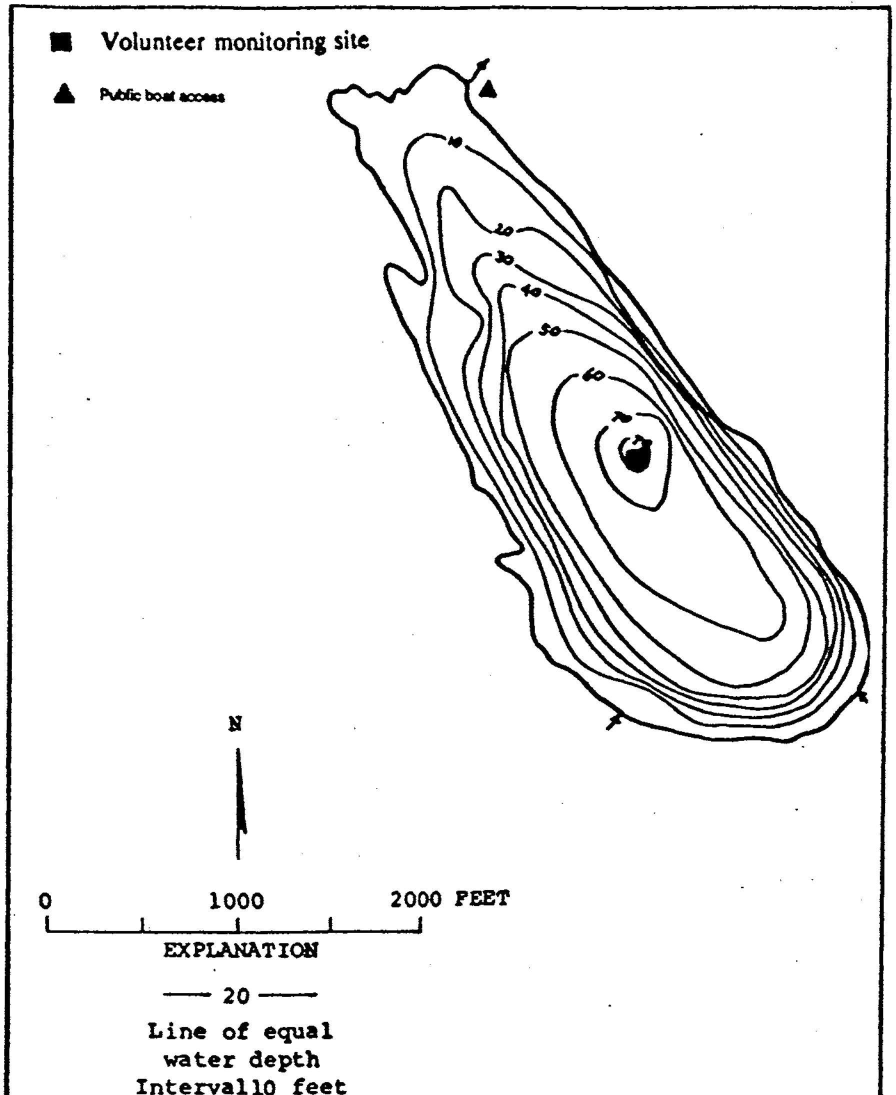


Lake Bosworth -- Snohomish County

Lake Bosworth is located 2.3 miles south of Granite Falls. It is fed by two unnamed inlets, and drains northeast to the Pilchuk River.

Size (acres)	105
Maximum Depth (feet)	79
Mean Depth (feet)	35
Lake Volume (acre-feet)	3,671
Drainage Area (miles^2)	1.4
Altitude (feet)	563
Shoreline length (miles)	2.0

Data From Bortleson *et al.* (1976)



Bosworth Lake, Snohomish County. From Washington Department of Game, January 25, 1949.

Lake Bosworth -- Snohomish County

1992 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	41
Mean Trophic State Index (Total Phosphorus):	37
Mean Trophic State Index (Chlorophyll *a*):	37

Volunteer-Collected Data

Date 1992	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
15-May				12.0						Onsite visit.
01-Jun	1215	17.8	64.0	12.0	15.00	Pea Green	100	None	Light	
15-Jun	1045	17.8	64.0	11.5	14.00	Pea Green	75	Heavy		
02-Jul	0915	20.6	69.0	13.0	15.00	Pea Green	10	Trace	Calm	
15-Jul	1100	20.6	69.0	12.0	14.00	Pea Green	0	Trace	Light	
04-Aug	1115	22.2	72.0	11.0		Pea Green	100	Trace	Light	Lake height reported as 16'6"
16-Aug	1030	23.3	74.0	12.5	17.5	Pea Green	0	None	Light	
21-Aug				10.0						Onsite visit.
01-Sep			70.0	10.0		Pea Green	50	None	Light	
15-Sep	0945	16.7	62.0	14.0	21.00	Pea Green	25		Calm	
02-Oct	1500	16.7	62.0	17.0		Lt-Green	100	Trace	Calm	
15-Oct	1545	13.3	56.0	14.0	19.00	Pea green	10	Light	Breezy	

[1] Trophic State Indices calculated from Carlson (1977)

Lake Bosworth -- Snohomish County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/15	0.0	16.6	7.8	11.3	29
	1.0	16.7	7.6	10.9	29
	2.0	15.8	7.7	11.3	29
	3.0	15.0	7.8	11.5	29
	4.0	13.5	7.6	11.8	29
	5.0	9.9	7.3	10.1	29
	6.0	9.0	7.2	9.5	29
	7.0	8.0	7.1	8.9	29
	8.0	7.0	6.9	8.0	29
	10.0	6.5	6.9	7.3	29
	12.0	6.3	6.8	6.5	29
	15.0	5.9	6.6	4.3	29
	20.0	5.8	6.5	2.2	30
	22.0	5.8	6.5	0.9	31
08/21	0.0	23.1	8.0	10.8	41
	1.0	23.3	8.3	10.5	41
	2.0	23.3	8.5	10.3	41
	3.0	23.1	8.6	11.3	42
	4.0	21.3	9.0	11.7	43
	5.0	17.3	9.0	13.9	41
	6.0	14.7	8.9	13.1	40
	7.0	11.8	8.7	9.1	40
	8.0	9.2	8.5	5.8	40
	9.0	8.0	8.4	4.1	40
	10.0	7.3	8.3	3.7	40
	12.0	6.7	8.2	1.4	40
	14.0	6.4	8.1	0.4	41
	16.0	6.1	7.9	0.1	48
	18.0	6.1	7.5	0.1	58
	19.0	6.1	7.3	0.1	61

1992 Onsite Visit Data - Water Chemistry

Date	05/15/92		08/21/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	10, 12, 15	1, 2, 3	14, 16, 18
Total Phosphorus (μg/L)	10	9	10	17
Total Nitrogen (mg/L)	0.67	0.84	0.32	0.65
Chlorophyll *a* (μg/L)	1.54		2.21	

Lake Bosworth -- Snohomish County

Historical Data From Ecology

Date	08/02/73[a]	06/06/90[b]	05/29/91[c]
Secchi (feet)	13	--	--
Total Phosphorus, epilimnion (µg/L)	4	7	--
Total Nitrogen, epilimnion (mg/L)	--	--	0.72
Chlorophyll *a* (µg/L)	--	--	--
Dissolved Oxygen, surface (mg/L)	8.6	11.3	10.2
Dissolved Oxygen, bottom (mg/L)	1.0	4.6	2.9

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)

Lake Bosworth -- Snohomish County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Most Secchi depths in Lake Bosworth were moderately deep and in the mesotrophic range, although Secchi depths improved in mid-September and October to values in the oligotrophic range. The mean Secchi depth for data collected from May through Ocotber (12.4 feet) indicated good to fair water clarity.

Total Phosphorus
Total phosphorus was low (10 μg/L) and in the oligotrophic range on both sampling dates. These concentrations were slightly higher than those measured in 1973 (4 μg/L; Bortleson *et al.*, 1976) and 1990 (7 μg/L; Rector, 1991).

Total Nitrogen
Total nitrogen on both dates was moderately high, and during May (0.67 mg/L) it was very similar to the concentration measured during May 1991 (0.72 mg/L; Rector, 1992).

Profile Data
On both sampling dates, the lake was stratified with respect to temperature. Both pH and dissolved oxygen increased in the metalimnion, most likely from the decreased water temperatures at these depths. In the hypolimnion, both pH and dissolved oxygen decreased with depth. Some decrease in dissolved oxygen near the lake bottom is normal for most lakes, and results from bacteria using oxygen when they decompose organic material in the water and sediments. During the August onsite visit with the volunteer, though, dissolved oxygen was very low (0.1 - 0.4 mg/L) in the bottom 7 meters of the lake. Although very low dissolved oxygen in the hypolimnion can affect fish habitat, the metalimnion had higher dissolved oxygen yet low water temperature, which is preferred by game fish such as salmonids.

Low dissoved oxygen near the lake bottom has probably been occurring for many years; in August 1973, dissolved oxygen near the bottom of the lake was 1.0 mg/L (Bortleson *et al.*, 1976). Dissolved oxygen can be high in the epilimnion and low in the hypolimnion during stratification, because during stratification these layers do not mix.

Plants
Algal growth in the lake, as indicated by concentrations of chorophyll *a*, was low on both sampling dates.

Aquatic plants were not prevalent in the lake, although iris (*Iris pseudacorus*) grew along parts of the shoreline.

Lake Bosworth -- Snohomish County

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

> Lake Bosworth is used for fishing, swimming, and non-motorized boating. There is one public boat ramp, making about 1 percent of the shoreline publicly-owned. Only electric motors are allowed on the lake. Rainbow and cutthroat trout were stocked in the lake. Currently, the only activity in the watershed is lakeshore development for residences. In the past, the watershed was also used for logging.
>
> There are 111 houses on the lakeshore, and none of the houses are connected to a sewer. About 6 culverts/stormdrains drain into the lake. There is no lake association for the lake. Lake water is withdrawn for drinking and other domestic uses.
>
> Overall, the volunteer finds that Lake Bosworth had good water quality. The only problem noted in the lake in 1992 was that not enough fish were stocked. There were no changes in the lake since the 1991 monitoring season.
>
> The lake was chemically treated in the past to control undesirable fish species. Lily pads grow in cove areas, and aquatic plants grow at the south end of the lake.

Comments

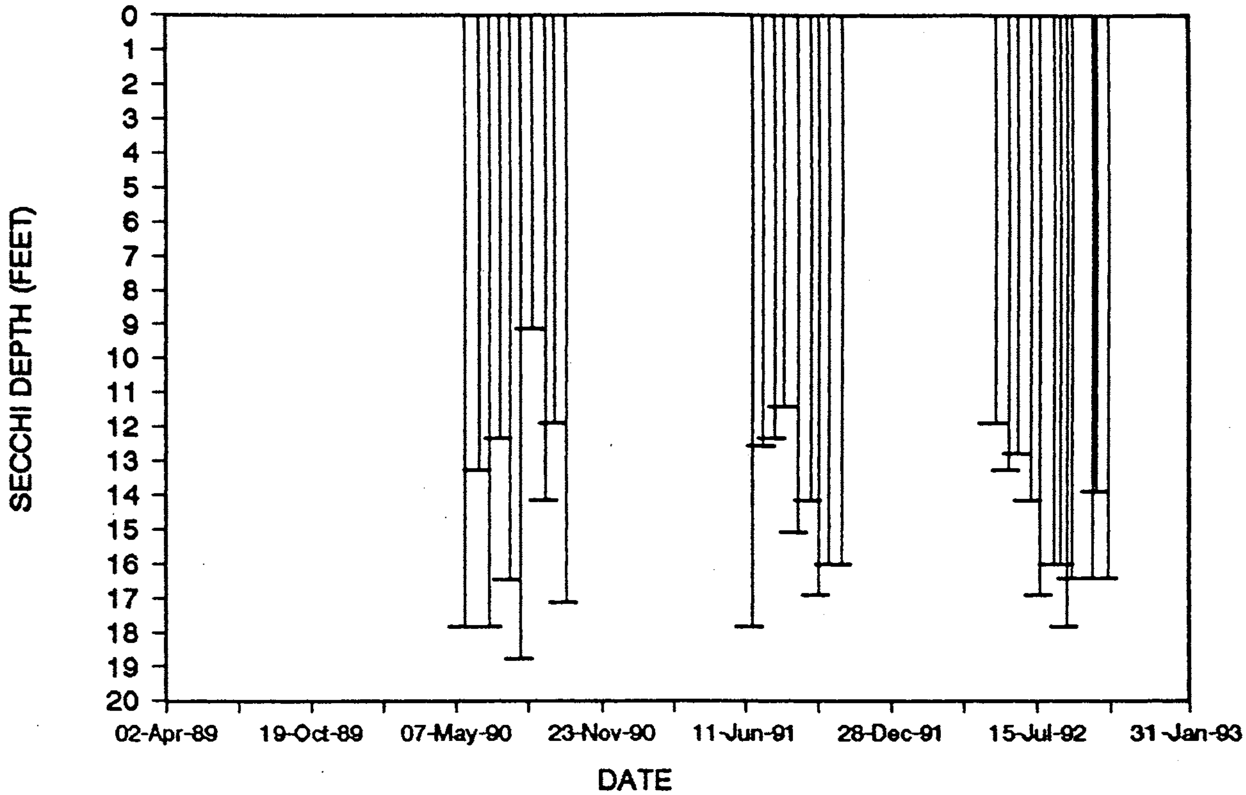
Lake Bosworth was characterized as oligotrophic based on the good water clarity, and low total phosphorus and chlorophyll *a*.

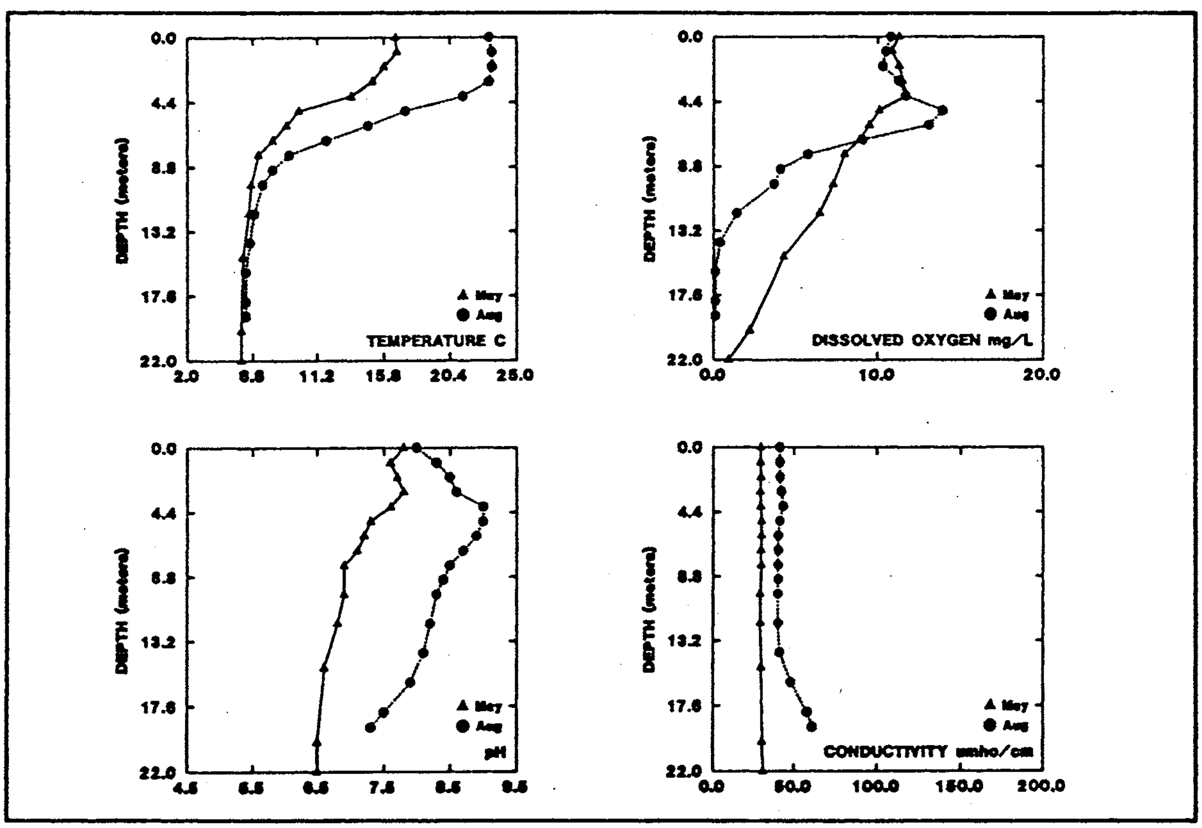
Other Snohomish County lakes monitored for the program in 1992 are Ketchum, Lake Martha, Martha Lake, Roesiger, Stevens, and Sunday. In comparison to these lakes, Secchi depths in Lake Bosworth were not as deep as those from Martha Lake, Lake Martha, Lake Roesiger, and Lake Stevens. Only Lake Roesiger had lower total phosphorus than Lake Bosworth.

Acknowledgement

I thank Dick McFadden for volunteering his time to monitor Lake Bosworth during 1992 and part of 1991, and Robert and Delores Maxwell for monitoring the lake during 1990-1991.

LAKE BOSWORTH (SNOHOMISH COUNTY)



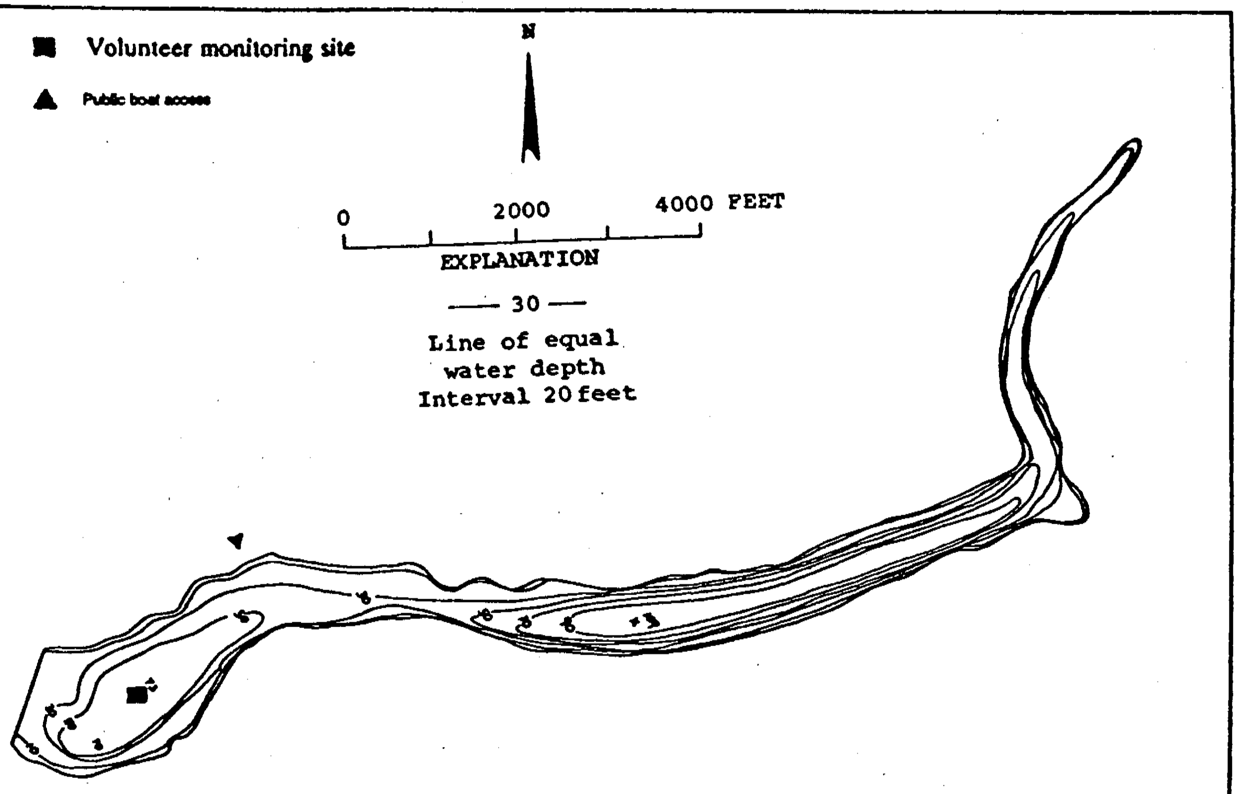


Conconully Lake -- Okanogan County

The south end of Conconully Lake is located at Conconully. It is an artificial reservoir created in 1919-1921 by damming Salmon Creek. It is fed by the North Fork of Salmon Creek, which divides to enter Conconully Lake just above the dam. The lake drains south via Salmon Creek to Conconully Reservoir. Before enlargening, the lake was known as Salmon Lake.

Size (acres)	270
Maximum Depth (feet)	110
Mean Depth (feet)	47
Lake Volume (acre-feet)	13,000
Drainage Area (miles^2)	50
Altitude (feet)	2319
Shoreline Length (miles)	6.8

Data From Dion *et al.* (1976)



Conconully (Salmon) Lake, Okanogan County.
From Washington Department of Game, January 1950.

Conconully Lake -- Okanogan County

1992 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	36
Mean Trophic State Index (Total Phosphorus):	52
Mean Trophic State Index (Chlorophyll *a*):	41

Volunteer-Collected Data

Date 1992	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
18-May	1300	15.0	59.0	18.0		Lt-Olive	50	Trace	Breezy	Onsite Visit. Second Secchi reading 22' with view tube.
01-Jun	1330	18.3	65.0	25.5		Gr-Brown	25	None	Light	need new color chart.
17-Jun	1230	20.0	68.0	17.0		Dark-Gr	10	Trace	Light	DO 8.5, pH 8.5 (source of data not mentioned).
14-Aug	1200	24.4	76.0	15.0		Mint	10		Light	
25-Aug	1130	16.7	62.0	14.0		Mint	10	Light		
31-Aug	1130	18.3	65.0	14.0		Mint	10	None	Light	

[1] Trophic State Indices calculated from Carlson (1977)

Conconully Lake -- Okanogan County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/18	0.0	15.2	8.3	10.3	179
	1.0	14.8	8.4	10.3	179
	2.0	14.6	8.4	10.2	179
	3.0	14.3	8.4	10.0	177
	4.0	13.7	8.3	10.0	178
	5.0	13.1	8.3	9.8	178
	6.0	12.7	8.3	9.6	179
	7.0	11.8	8.2	9.4	180
	8.0	10.5	8.0	8.4	181
	9.0	9.5	7.8	7.5	183
	10.0	8.4	7.7	6.2	184
	12.0	7.4	7.6	5.4	184
	14.0	6.9	7.5	4.9	184
	16.0	6.3	7.4	3.5	185
	18.0	5.9	7.4	2.0	186
	20.0	5.7	7.3	1.6	186
08/31	0.0	19.4	8.9	9.9	167
	1.0	19.3	8.9	10.0	168
	2.0	19.0	9.0	10.0	168
	3.0	19.0	9.0	9.9	168
	4.0	18.8	9.0	9.5	168
	5.0	18.8	9.0	9.5	168
	6.0	18.6	9.0	9.1	169
	7.0	18.6	9.0	9.1	170
	8.0	17.7	8.6	5.2	180
	9.0	14.2	7.9	1.5	195
	10.0	11.5	7.8	0.3	194
	12.0	9.4	7.8	0.2	192
	14.0	8.4	7.8	0.1	191
	16.0	7.1	7.8	0.0	194
	18.0	6.7	7.8	0.0	197
	20.0	6.5	7.8	0.0	197

1992 Onsite Visit Data - Water Chemistry

Date	05/18/92		08/31/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 3, 5	9, 12, 15	2, 4, 6	12, 14, 18
Total Phosphorus (μg/L)	32	48	24	146
Total Nitrogen (mg/L)	0.31	0.27	0.33	0.39
Chlorophyll *a* (μg/L)	0.77		5.27	

Conconully Lake -- Okanogan County

Historical Data From Ecology

Date	07/16/74[a]
Secchi (ft)	11
Total Phosphorus, epilimnion (μg/L)	19
Total Nitrogen, epilimnion (mg/L)	--
Chlorophyll *a* (μg/L)	--
Dissolved Oxygen, surface (mg/L)	9.4
Dissolved Oxygen, bottom (mg/L)	0.6

a. Dion *et al.* (1976)

Conconully Lake -- Okanogan County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was very good, as indicated by deep Secchi depths which ranged from 14.0 to 25.5 feet.

Total Phosphorus

Total phosphorus was high on both sampling dates (32 μg/L on May 18, and 24 μg/L on August 31). During the August sampling date, there was a very high concentration of total phosphorus in the hypolimnion sample which suggests that phosphorus was released from the sediments into the water column (see Profile Data, below). The total phosphorus concentration reported from 1974 (19 μg/L; Dion *et al.*, 1976) was moderately high.

Total Nitrogen

Total nitrogen was low on both sampling dates.

Profile Data

On both sampling dates, the lake was stratified with respect to temperature. Dissolved oxygen decreased from surface to bottom, but during August there was less than 0.5 mg/L dissolved oxygen from 10 to 20 meters. This is very low, and probably restricts fish within the metalimnion of the lake, where temperatures and dissolved oxygen levels are more favorable. Low oxygen usually results when bacteria use oxygen to decompose organic material (such as algae and aquatic plants) in lake water and sediments. Very low oxygen concentrations are often associated with other reactions, such as phosphorus being released from sediments into the water column (known as internal loading) and the formation of hydrogen sulfide. Both of these occurred during August; the hypolimnion sample for total phosphorus was very high (146 μg/L), and the 18 meter sample from the hypolimnion smelled strongly of hydrogen sulfide ("rotten-egg" smell). These reactions are typical of eutrophic lakes.

Plants

Chlorophyll *a* was very low during May, yet was very high during August. During the May onsite visit, Ecology staff noted clumps of algae in the water at the south end of the lake. Algae in a sample of the clumps were identified as *Anabaena*, a blue-green alga, and *Asterionella*, a diatom. The low chlorophyll result for May suggests that the algae bloom was localized, and not spread throughout the lake. An algae sample collected during the August onsite visit consisted mostly of *Anabaena circinalis*, although *A. spiroides* may also have been sparsely present.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1992 questionnaire.

Conconully Lake -- Okanogan County

Conconully Lake is used for fishing, swimming, motor boating, non-motorized boating, jet skiing, and lakeshore camping. There is one resort on the lakeshore, and one public boat ramp. Trout were stocked in the lake. Currently, the watershed is used for logging, crop agriculture, and animal grazing/feeding. The lakeshore is also being developed further for residences. In the past, the watershed was used for logging, animal grazing/feeding, and mining.

There are 55 houses on the lakeshore, and all the houses are connected to a sewer. About 4 culverts/stormdrains drain into the lake. There is no lake association for the lake.

Overall, the volunteer finds that Conconully Lake had fair water quality. Problems in the lake in 1992 were ranked as 1) excessive aquatic plant growth, 2) gradually degrading water quality over the years, 3) recently degraded water quality, 4) low water level, 5) impaired fisheries, and 6) degraded aesthetics.

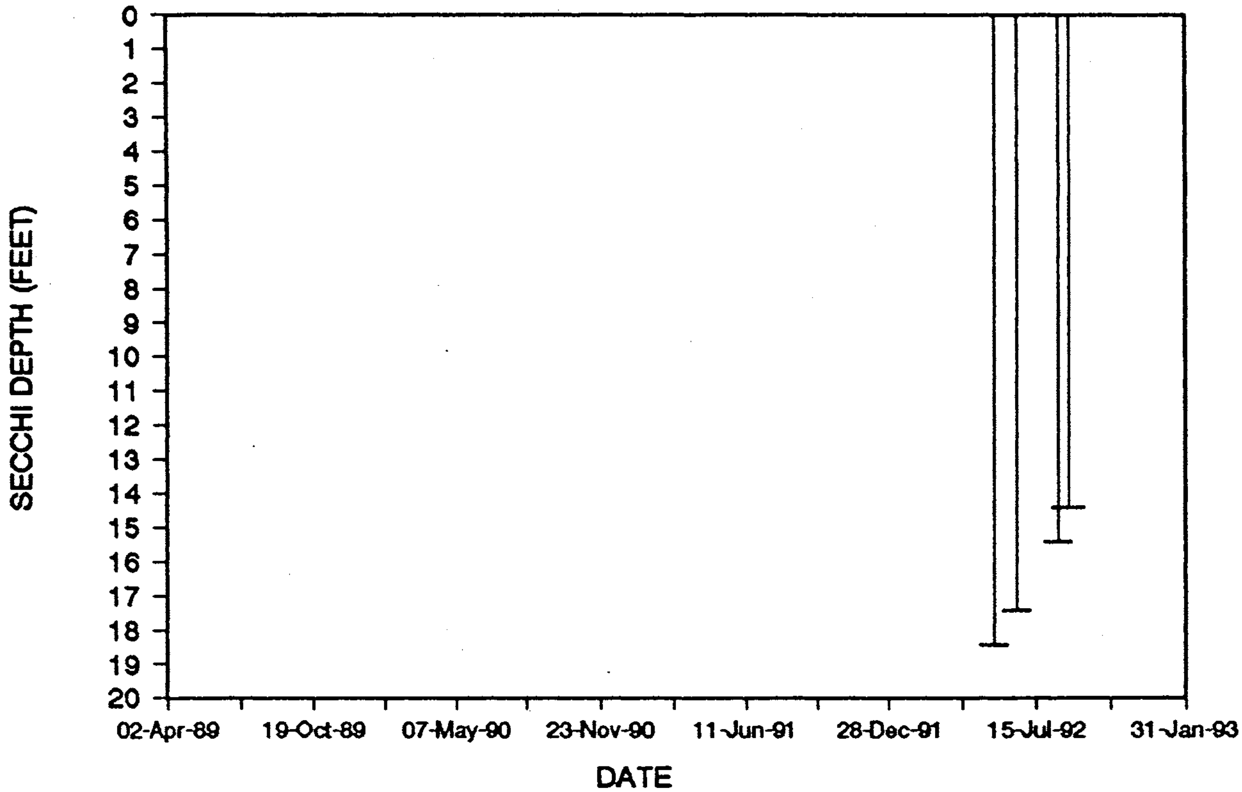
Comments

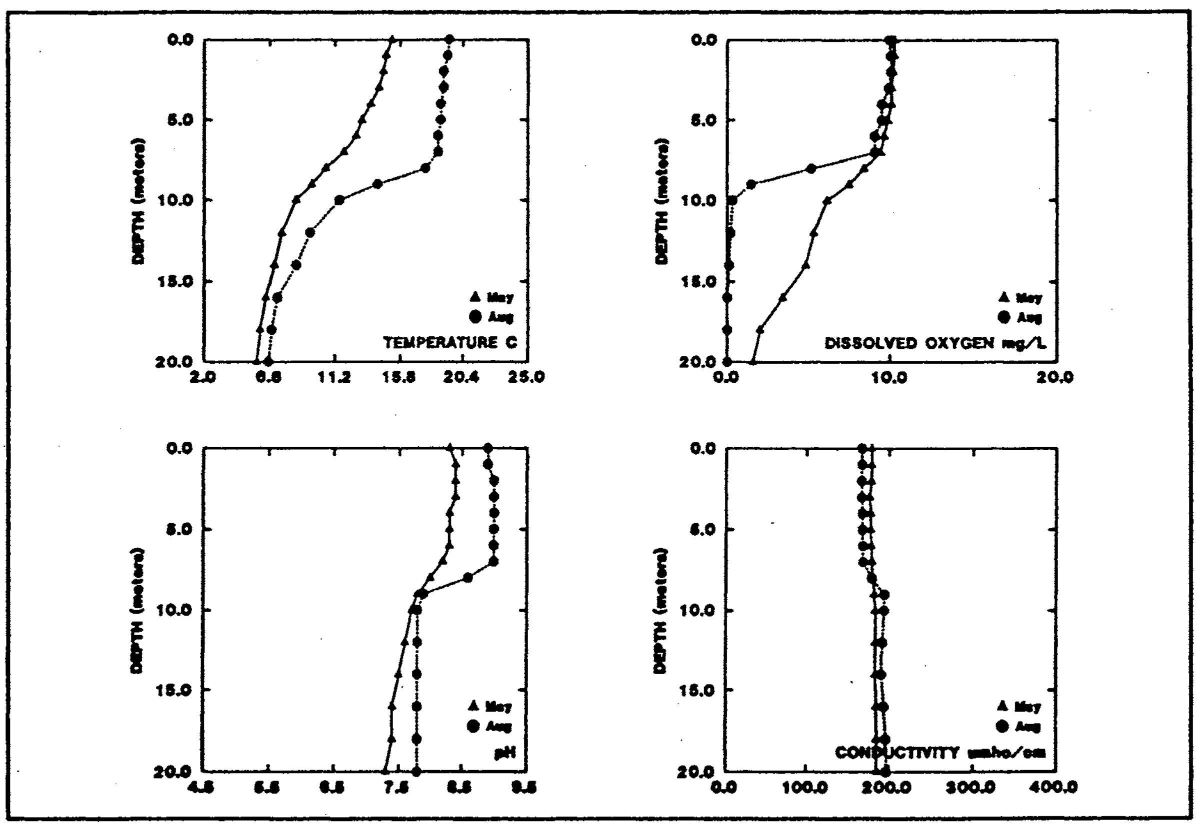
Conconully Lake was new to the lake monitoring program in 1992. The lake exhibited characteristics of all three trophic states; Secchi depths were in the oligotrophic range, mean chlorophyll *a* was in the mesotrophic range (although the August value was definitely high and indicated eutrophy), and total phosphorus on both sampling dates was in the eutrophic range. Based on the total phosphorus concentrations, the August concentration of chlorophyll *a*, the moderate amount of aquatic plants, and the very low dissolved oxygen in the hypolimnion, the lake was characterized as meso-eutrophic. Although Secchi depth is not a good indicator of the trophic status of Conconcully Lake (more than four readings may be needed for Secchi depth to be a good indicator), it is encouraging that clarity in the open-water area of the lake was good, despite the high concentration of total phosphorus.

Acknowledgement

I thank Lee Moore for volunteering his time to monitor Conconully Lake during 1992.

CONCONULLY LAKE (OKANOGAN COUNTY)





Cranberry Lake -- Island County

Cranberry Lake lies in Deception Pass State Park, at the north end of Whidbey Island. The inflow is intermittent and the lake drains to Rosario Strait. The lake level is stabilized by a dam. No motor boats are allowed on the lake.

Size (acres)	125
Maximum Depth (feet)	25
Mean Depth (feet)	13
Lake Volume (acre-feet)	1,576
Drainage Area (miles^2)	0.6
Altitude (feet)	20
Shoreline Length (miles)	2.8

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	47
Trophic State Index* (Chlorophyll *a*):	52

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The 1991 questionnaire on lake and watershed uses was not returned by the volunteer. The following are from the volunteer's remarks and to the 1990 questionnaire. Cranberry Lake is used for fishing, swimming, rowing, and camping. Recreational facilities on the lakeshore include a state park (which includes a picnic area, a camping area, a beach, and one boat ramp). The watershed is used for animal grazing and crop agriculture, both currently and in the past. There are no houses on the lakeshore, and there is one storm drain that empties into the lake. Fish were not reported as being stocked in the lake. Presently there is no citizen's organization for the lake. The worst problems in the lake, in the opinion of the volunteer, are ranked as: 1) aquatic plants, and 2) algae. In 1989, the volunteer noted that the worst water quality problems in the lake were suspended sediments and algal blooms. Overall, in 1990 the volunteer found that Cranberry Lake had good recreational water quality. There is a culvert at the south end of the lake that is dammed by beavers. The volunteer reports that Park rangers are concerned because this has raised the lake level over the last few years.

During the May 1991 onsite visit, the volunteer noted that the lake level rose considerably after the previous November's floods, so that the area surrounding the lake was flooded. According to the volunteer, the Army Corps of Engineers drained the lake to lower the level about six feet (presumably, through the outlet). About three feet of bleached rock and vegetation were exposed during the onsite visit, showing the lingering effects from the flooding. The volunteer noted that the lake level during the onsite visit was approximately the level at the end of last summer's monitoring season.

Cranberry Lake -- Island County

The volunteer noted that the fishing was good during 1991.

There are about 50 houses uphill from the lake, behind a 100 foot buffer of trees. Lily pads grow along most of the southern shore, and are especially thick near both southern coves of the lake. Submerged aquatic plants also grow at both coves at the south end of the lake, and grow thickly up to 200 feet out from the shore. The lake is very "scummy" near the fishing pier on the east side.

The volunteer sent in a newspaper article from the Whidbey News-Times dated August 1, 1990. The article reported that during the previous week a small fish kill that lasted about three days occurred in Cranberry Lake. The Island County Health Department and the assistant ranger at Deception Pass State Park attributed the kill to a dying algae bloom which consumed dissolved oxygen in the water.

Monitoring Results/Summary of Other Available Information

The volunteer has monitored Lake Curlew for the program since 1989. Data from 1989 are reported in Rector (1990) and data from 1990 are reported in Rector (1991).

Volunteer-collected Secchi data from 1991 show that water clarity ranged from 3.9 to 9.5 feet, and was lowest during May. Of the three years that Cranberry Lake has been monitored for the program, mean water clarity was poorest during 1989 and best during 1990. Varying weather most likely affects the varying water clarity between years.

Ecology staff collected profile data and water samples during the May 1991 onsite visit with the volunteer. The profile data show that the lake was beginning to stratify, and dissolved oxygen and pH decreased from surface to bottom. Conductivity changed little throughout the water column. Profile data from May 1991 and August 1990 illustrate nicely the differences between pre-stratification and late stratification profiles in an eutrophic lake. The surface-to-bottom differences for each parameter are much more marked during late summer than during early stratification. The decreased dissolved oxygen and pH, and increased conductivity, with depth are most likely related to decomposition occurring in the water and sediments. Although the conductivity was lower in 1991 than in 1990 (213 μmhos/cm and 280 μmhos/cm at the surface, respectively), these differences may not be significant and may be related to dilution by precipitation. Surface conductivity was 280 μmhos/cm in 1989 (Brower and Kendra, 1990) and 220 μmhos/cm in 1981 (Sumioka and Dion, 1985).

Total nitrogen in 1991 (0.79 mg/L) was moderate to high compared to other sampled lakes and was very similar to 1990 total nitrogen in Cranberry Lake (0.71 mg/L). In 1989, however, total nitrogen was much higher, at 1.15 mg/L in June and 1.16 mg/L in September (Brower and Kendra, 1990). Total nitrogen was even higher in July 1981 at 1.4 mg/L (Sumioka and Dion, 1985).

Cranberry Lake -- Island County

Chlorophyll *a* in 1989 was 30.0 μg/L in June and 16.8 μg/L in September (Brower and Kendra, 1990). In July 1981, chlorophyll *a* was 8.16 μg/L (Sumioka and Dion, 1985). All these concentrations are in the eutrophic range.

Samples for total phosphorus and chlorophyll *a* were collected in 1991, but the data could not be used due to analytical problems. In August 1990, total phosphorus was 0.029 mg/L. In 1989, total phosphorus was very high, at 0.059 mg/L in June and 0.107 mg/L in September (Brower and Kendra, 1990). In July 1981, total phosphorus was 0.03 mg/L (Sumioka and Dion, 1985), and was similar to the concentration found in August 1974 (0.035 mg/L; Bortleson *et al.*, 1976). All these values are high, and are in the eutrophic range.

The "grass clipping" algae noted by the volunteer on June 23 and September 8 was probably *Aphanizomenon*, a blue-green algae that was also reported in the lake in 1989 by Brower and Kendra (1990). The plant sample collected from the public access during the August 1990 onsite visit with the volunteer was identified as a milfoil species (*Myriophyllum*), but was not thought to be the aggressive Eurasian milfoil variety.

Comments

Cranberry Lake is a shallow, coastal lake with high nutrient concentrations. Although the lake is eutrophic and experiences a moderately high amount of blue-green algal growth, the lake supports recreational activities and wetland vegetation. Comparisons of data from 1989 - 1991 with data from 1981 and 1974 suggest that 1989 was a particularly poor year for the lake in terms of excessive algal growth and low concentrations of dissolved oxygen.

Since 1989, Secchi disk data were in the mesotrophic range and were somewhat better than would be expected given the eutrophic characteristics of the lake. In 1990, the lake had high nutrient concentrations and very low dissolved oxygen below the thermocline. High nutrient concentrations and low dissolved oxygen were not measured in 1991, most likely because the lake was not fully stratified when it was sampled. Prolific aquatic plant and algal growth are also eutrophic characteristics of the lake.

Acknowledgement

I thank Terri Thomas for volunteering her time to monitor Cranberry Lake during 1989-1991.

Cranberry Lake -- Island County

Volunteer-Collected Data

Date 1991	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
27-May	17.5	63.5		Lt-Brown	90	Trace	Light	3.9*	-11.3	
28-May								5.5*		Onsite visit
23-Jun			7.0	Lt-Brown	75	Trace	Calm	8.3	-12.6	Lake much clearer. "Grass clipping" algae not as apparent. Small pellet-like green algae in some places around edge, floats about 1" below surface.
20-Jul			6.5	Lt-Brown	100	None	Light	7.5	-16.0	Water color still relatively clear. Small "pellet" algae gone.
11-Aug	19.5	67.1	6.5	Lt-Brown	10	Moderate	Calm	9.5	-17.7	
08-Sep	18.5	65.3	6.0	Lt-Brown	100		Calm	7.0	-19.3	"Grass clipping" algae prevalent. Surface covered with oil-slick-like green algae (looks like powder) to 100' from shore. In parts of lake, algae is so thick it looks like spilled paint.

* Secchi data corrected for rope shrinkage for this date only; rope replaced after May 28 onsite visit.

Onsite Visit Data

Date 1991	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)	Composite Sample Depths (m)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Phosphorus (mg/L)
05/28	0.0	18.5	7.4	9.9	213	1.0	0.79	9.3	ND
	1.0	17.6	7.3	9.3	214				
	2.0	16.7	7.3	8.5	214				
	3.0	15.5	7.1	6.9	214				
	4.0	15.4	7.0	6.5	213				
	5.0	15.2	6.9	6.1	214				
	5.5	15.1	6.8	5.7	214				

ND No data; data lost due to analytical error

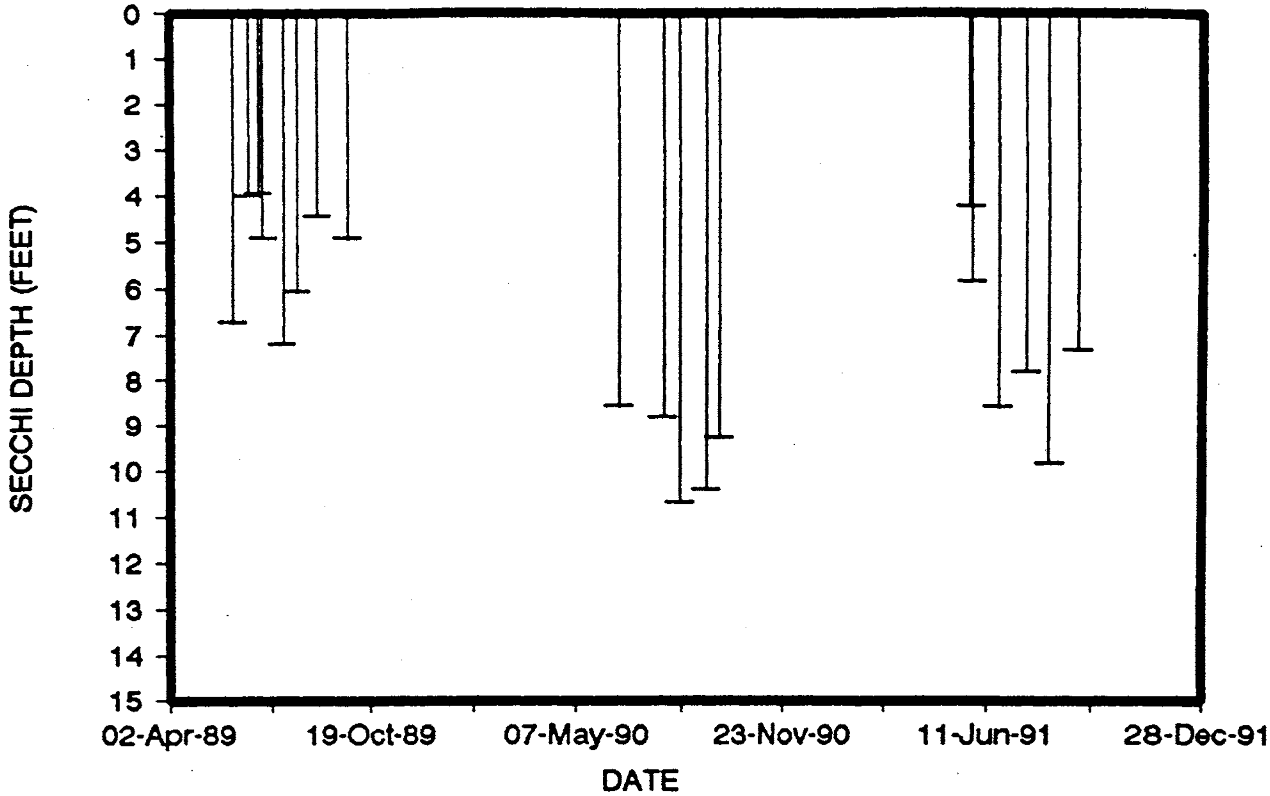
Data From Bortleson *et al.* (1976) and Sumioka and Dion (1985)

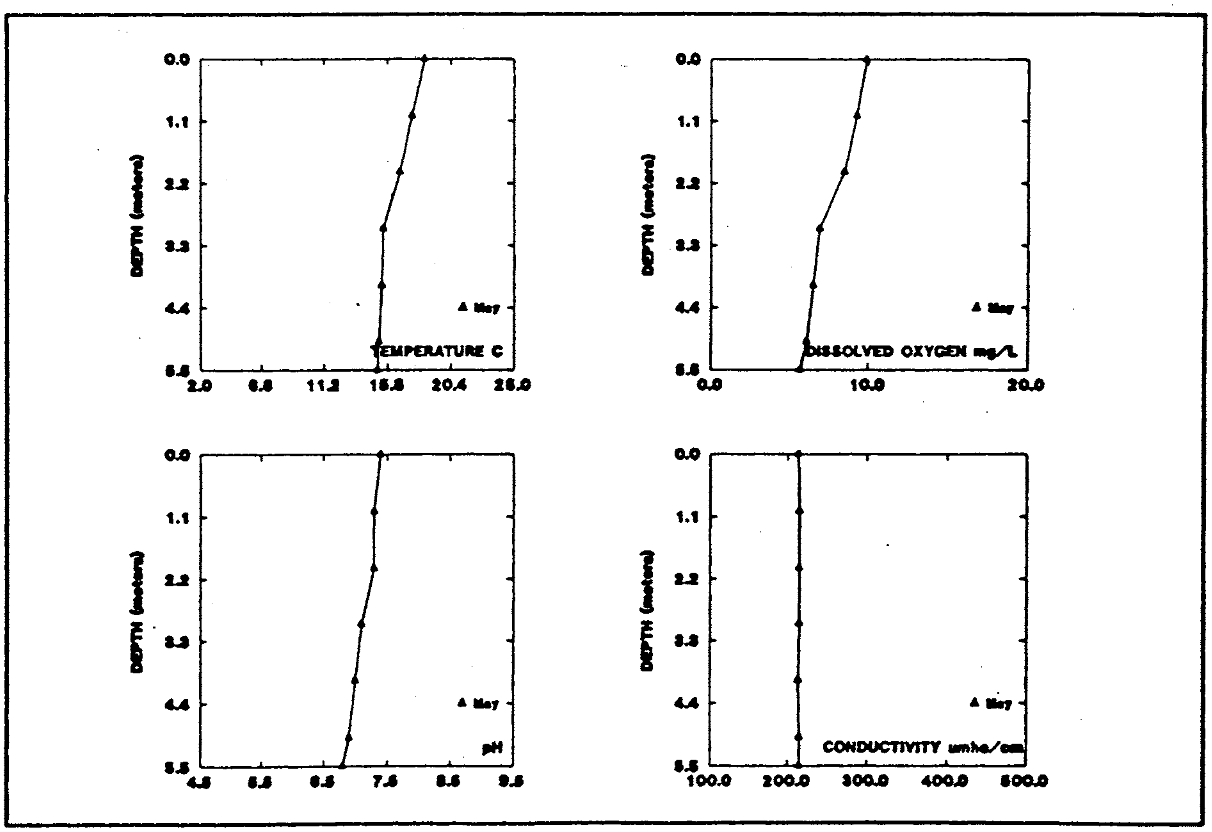
Date	08/09/74
Secchi (feet)	7
Total Phosphorus (mg/L)	0.035

Remarks THE LAKE IS IN DECEPTION PASS STATE PARK. THE LITTORAL BOTTOM IS MOSTLY MUCK.

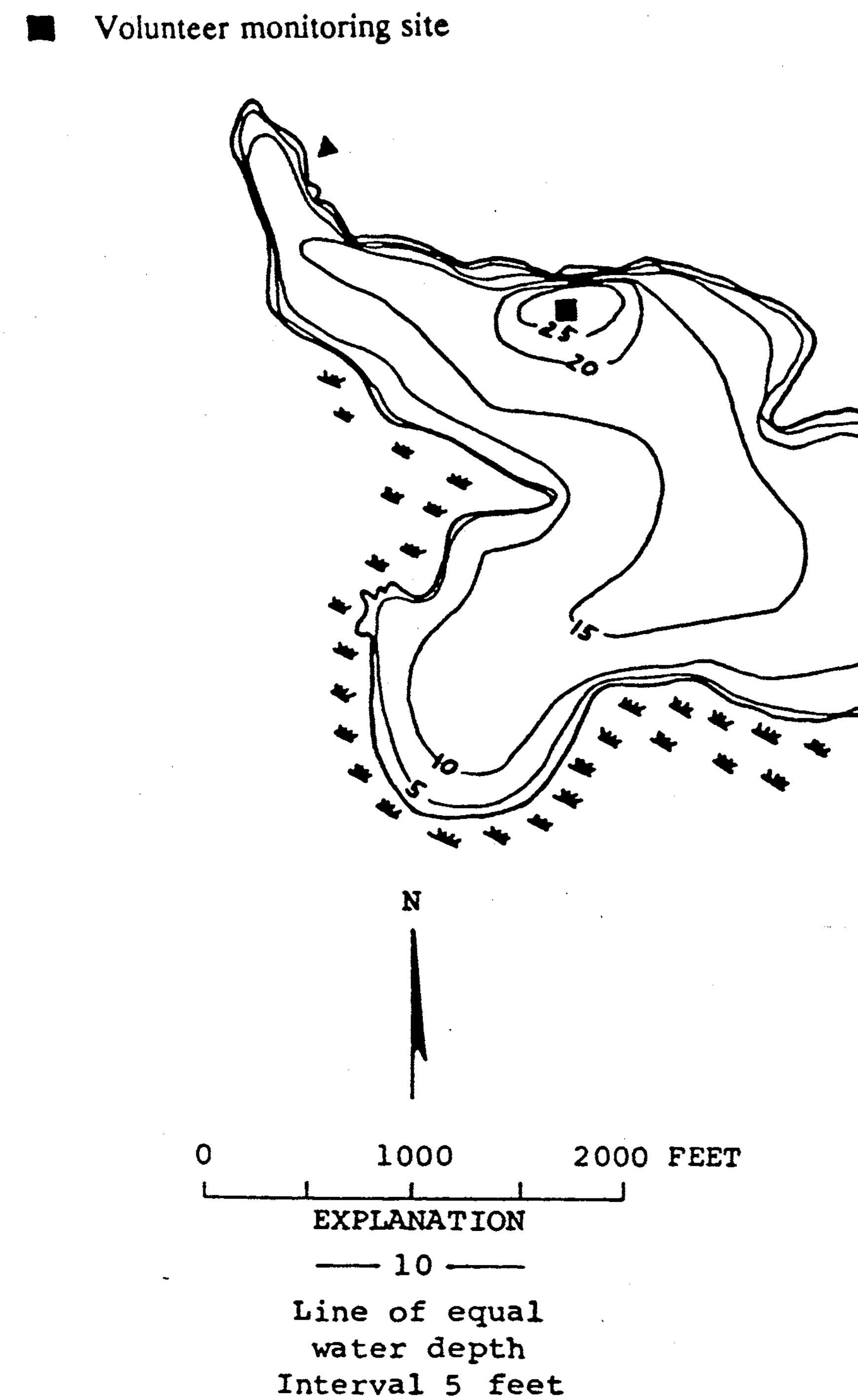
Date	07/09/81
Secchi (feet)	9
Total Phosphorus (mg/L)	0.03
Chlorophyll *a* (µg/L)	8.16

CRANBERRY LAKE (ISLAND COUNTY)





Profile and Secchi Data Graphs



Cranberry Lake, Island County. From Washington Department of Game, July 23, 1950.

Crawfish Lake -- Okanogan County

Crawfish Lake is located 15 miles northeast of Omak, and 8.5 miles north of Disautel. It drains intermittently to the east to Lost Creek and the West Fork of the Sanpoil River. The north half of the lake is on USFS land, and the south half is on the Colville Indian Reservation.

Size (acres)	80
Maximum Depth (feet)	36
Mean Depth (feet)	*
Lake Volume (acre-feet)	*
Drainage Area (miles^2)	*
Altitude (feet)	4475
Shoreline Length (miles)	*

*information not available

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index* (Secchi):	33
Trophic State Index* (Chlorophyll *a*):	22

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The 1991 questionnaire on lake and watershed uses was not returned by the volunteer. The following are the volunteer's remarks and responses to the 1990 questionnaire. Crawfish Lake is used for fishing, swimming, camping, canoeing, and rowing. Recreational facilities on the lakeshore include a picnic area, a state park, a camping area, and two boat ramps. There are no restrictions for motorboat use on the lake. There is ice on the lake from October through April. The primary watershed use is logging. There are 41 houses on the lakeshore although none of these are occupied year-round. The lakeshore is not sewered. Rainbow and eastern brook trout are stocked in the lake. A lake association was formed in 1990. The lake has been chemically treated in the past to control undesirable fish species. Presently the lake does not have any water quality problems and the volunteer finds that the lake has excellent water quality. In 1989, though, the volunteer noted that dead fish were apparent during April and May and that the crawfish population decreased in recent years.

There is a three acre wetland area at the north end of the lake, and a one-acre wetland at the southeast end.

Crawfish Lake -- Okanogan County

Monitoring Results/Summary of Other Available Information

The volunteer has monitored Crawfish Lake for the program since 1989. Data from 1989 are reported in Rector (1990) and data from 1990 are reported in Rector (1991).

Volunteer-collected Secchi data show that in 1991 water clarity ranged from 11.0 to 19.3 feet, and was lowest during May. Because the lake usually thaws in April, suspended sediments from spring turnover probably affects the water clarity. Secchi data collected in 1989, 1990 and 1991 show that mean water clarity improved each year.

Ecology staff collected profile data and water samples from the lake on June 27, 1991. Profile data show that the lake was stratified and dissolved oxygen decreased considerably below the thermocline. The decrease in pH and increase in conductivity from surface to bottom are most likely related to the decomposition of organic material (such as algae, aquatic plants and woody debris) in the lower water and sediments. Dissolved oxygen can be high in the epilimnion (upper layer of water) and low in the hypolimnion (lower layer of water), because these layers do not mix during stratification.

Total nitrogen in 1991 (0.24 mg/L) was lower than in 1990 (which averaged 0.38 mg/L). Samples for total phosphorus and chlorophyll *a* were collected in 1991, but the data could not be used due to analytical problems. In 1990, total phosphorus was 0.011 mg/L in June and 0.012 mg/L in August. Although the August concentration was in the mesotrophic range, the mean of both samples (which were used to calculate the total phosphorus trophic state index in 1990) indicated oligotrophy.

Comments

Water clarity was very good and in the oligotrophic range from 1989 to 1991. However, in 1991 Crawfish Lake had low dissolved oxygen in the hypolimnion (0.3 mg/L at 8 meters), which is more characteristic of mesotrophic lakes than of oligotrophic lakes. Also, in 1990 total phosphorus in the lake (0.011 mg/L) was almost borderline between oligotrophy and mesotrophy. Because the lake exhibits both oligotrophic and mesotrophic characteristics, the lake was estimated as oligo-mesotrophic.

Compared with other lakes monitored for the program in 1991, Crawfish Lake had very good water clarity and total nitrogen.

Acknowledgement

I thank Barry Nelson for volunteering his time to monitor Crawfish Lake during 1989-1991.

Crawfish Lake -- Okanogan County

Volunteer-Collected Data

Date 1991	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
27-May	12.0	53.6	5.5	Gr-Brown	75	Trace	Light	11.0		
30-Jun	16.0	60.8		Gr-Brown	25	Heavy	Light	19.3		
24-Jul	24.0	75.2	5.5	Gr-Brown	90	Moderate	Light	18.3		
31-Aug	18.5	65.3	5.5	Gr-Brown	0		Light	19.3		
06-Oct	14.0	57.2	5.5	Gr-Brown	0	None	Breezy	14.7		

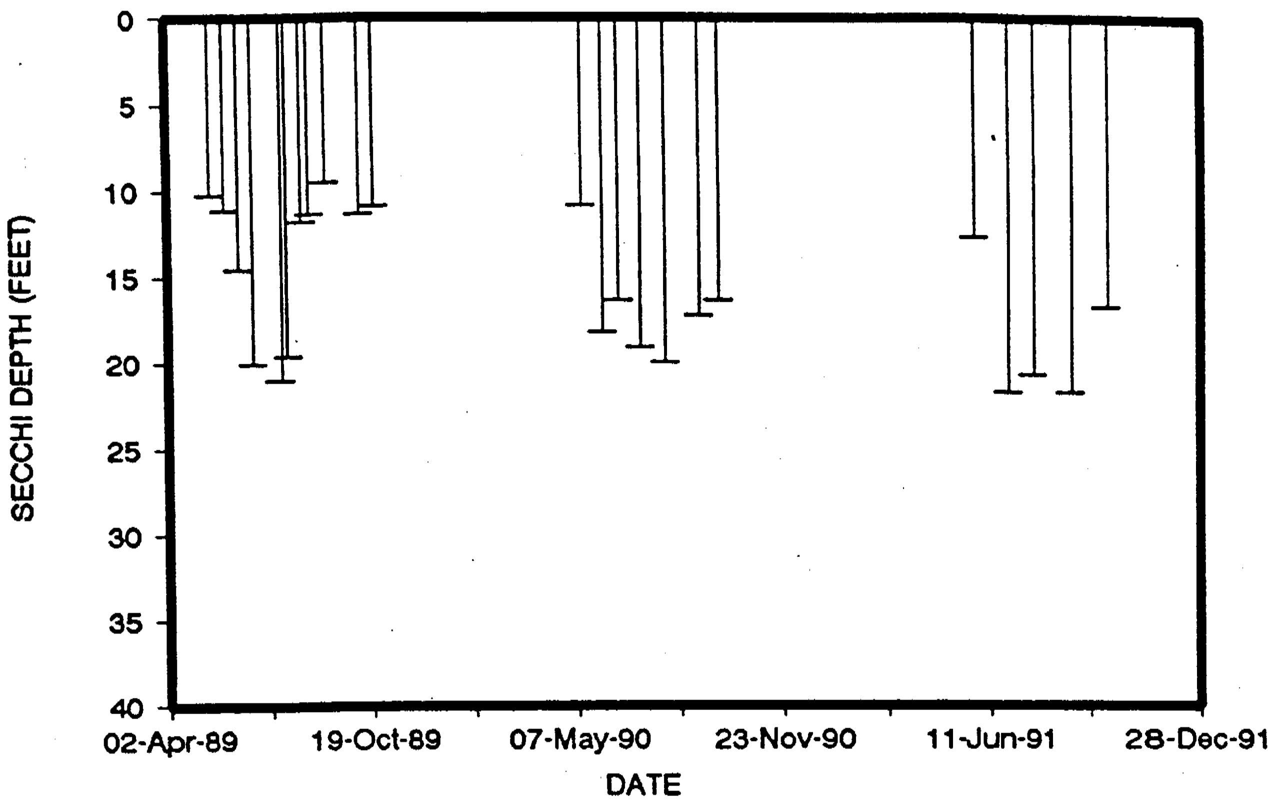
* Secchi data corrected for rope shrinkage

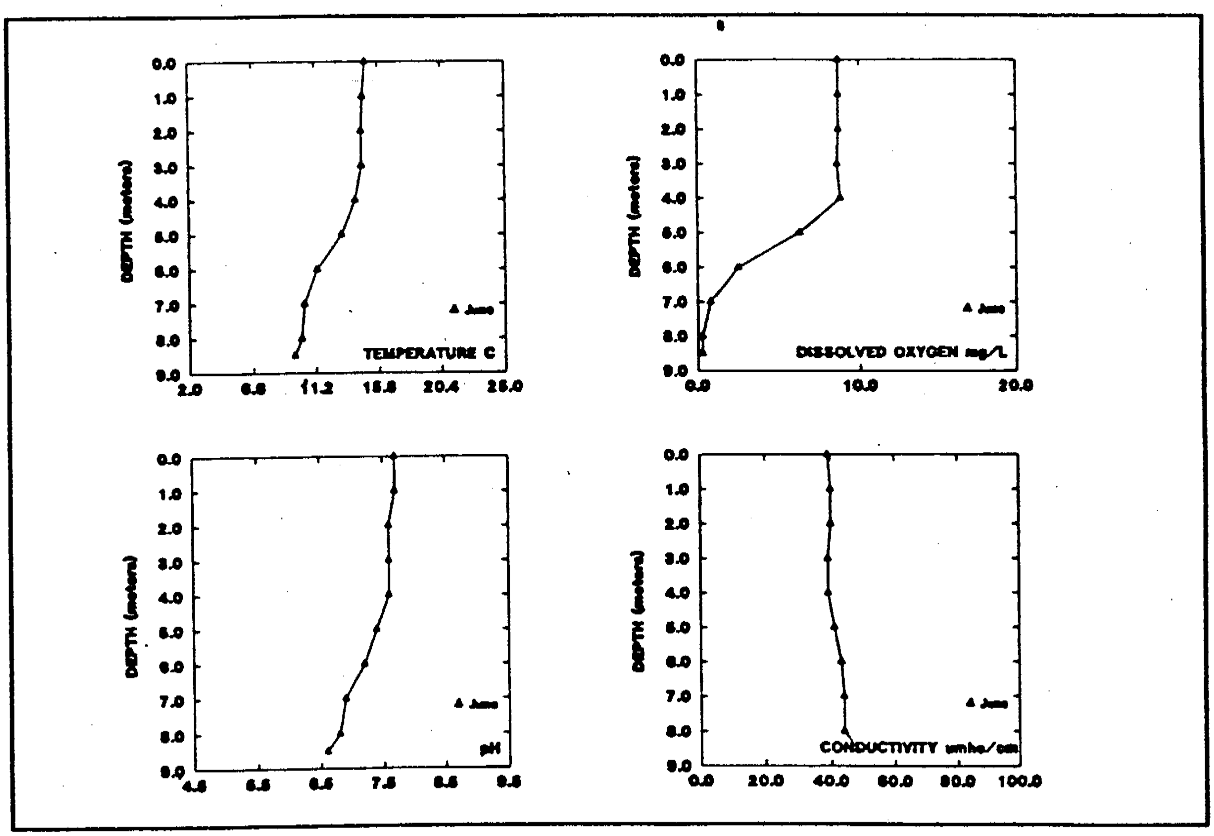
Onsite Visit Data

Date 1991	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Composite Sample Depths (m)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Phosphorus (mg/L)
06/27	0.0	14.9	7.7	8.7	39	1.5, 3	0.27	ND	ND
	1.0	14.7	7.7	8.7	40				
	2.0	14.6	7.6	8.7	40				
	3.0	14.6	7.6	8.6	39				
	4.0	14.1	7.6	8.8	39				
	5.0	13.1	7.4	6.3	41				
	6.0	11.3	7.2	2.5	43				
	7.0	10.3	6.9	0.8	44				
	8.0	10.1	6.8	0.3	44				
	8.5	9.6	6.6	0.3	48				

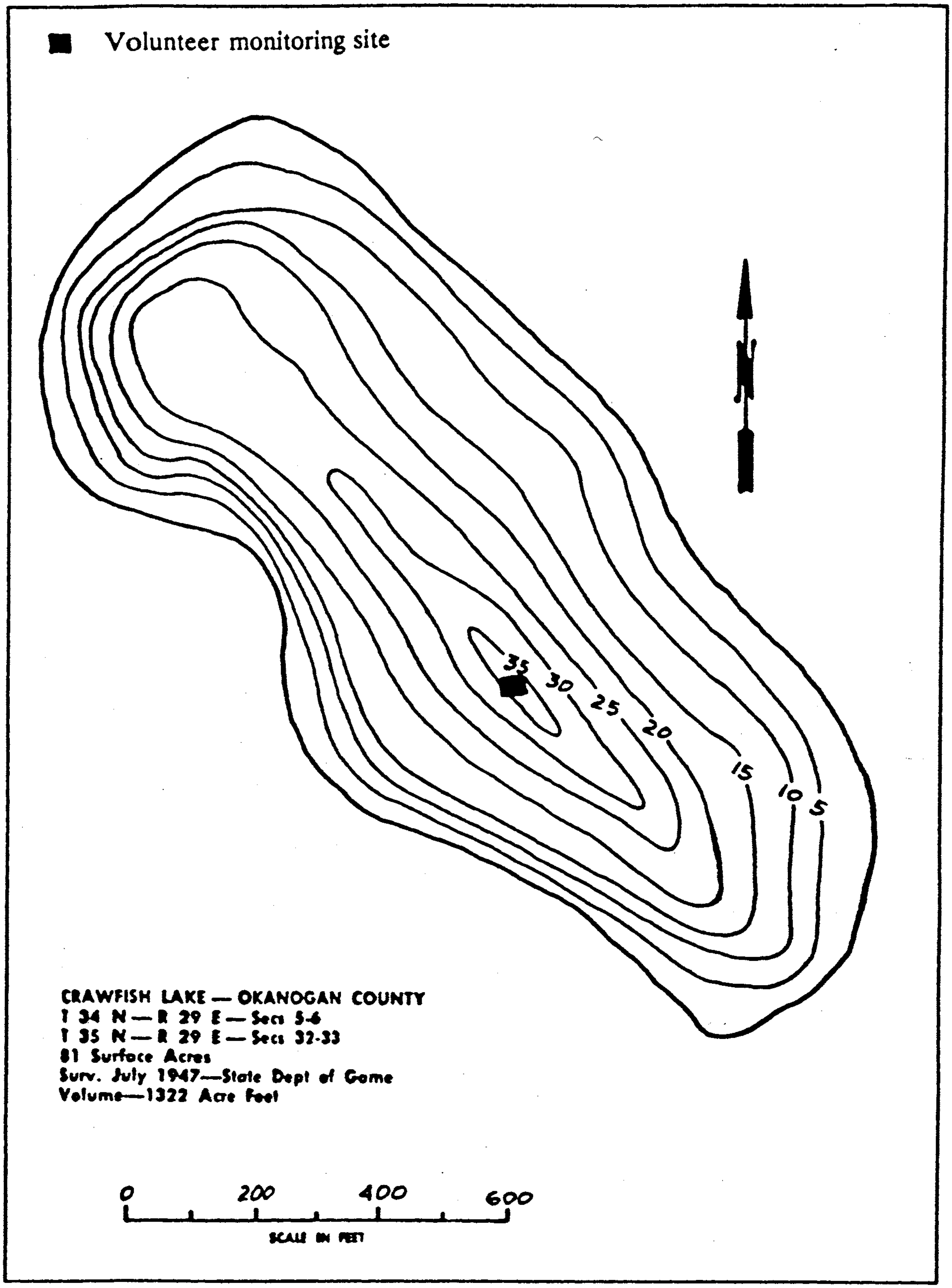
ND No data; data lost due to analytical problems

CRAWFISH LAKE (OKANOGAN COUNTY)





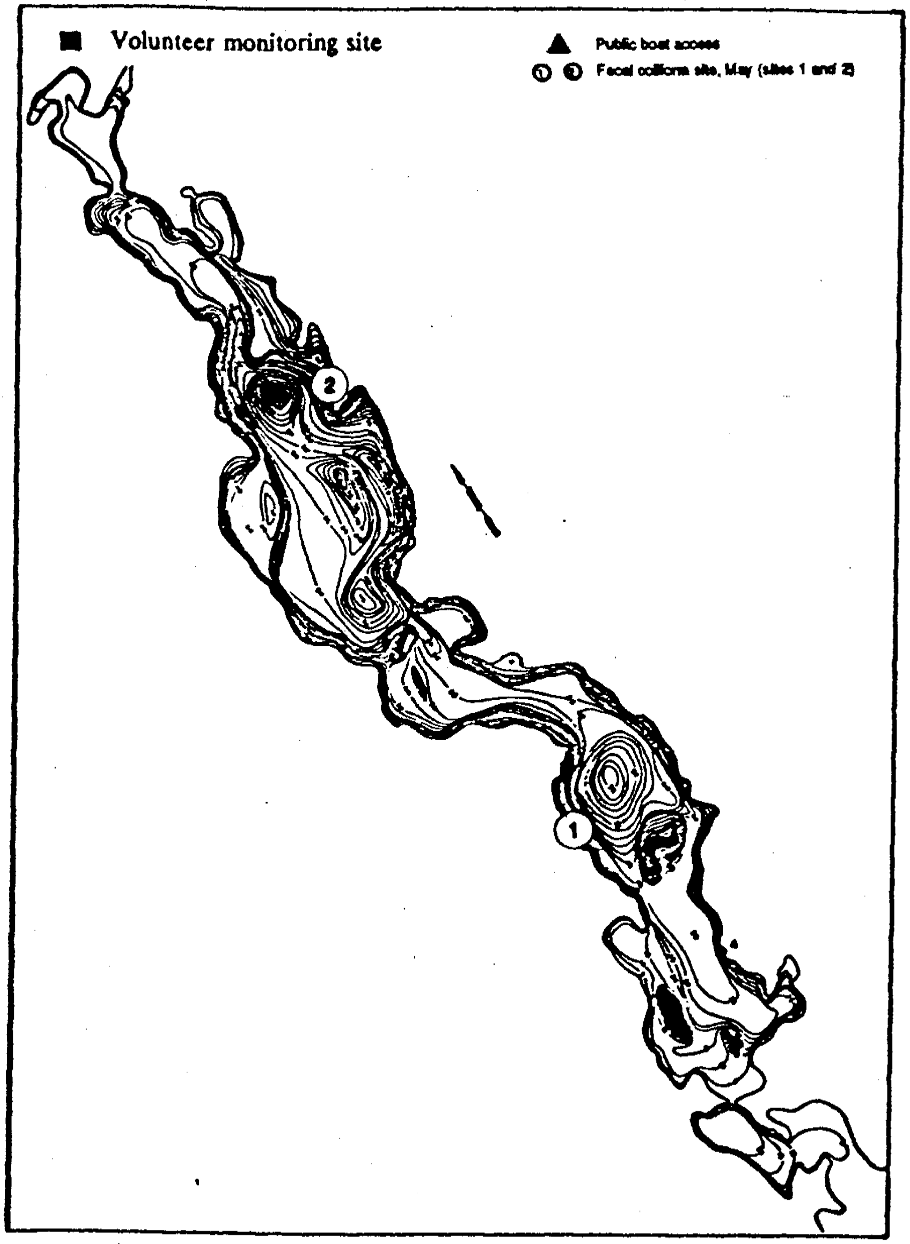
Profile and Secchi Data Graphs


Volunteer monitoring site
35
30
25
20
15
10
5
N
CRAWFISH LAKE — OKANOGAN COUNTY
T 34 N — R 29 E — Secs 5-6
T 35 N — R 29 E — Secs 32-33
81 Surface Acres
Surv. July 1947—State Dept of Game
Volume—1322 Acre Feet
0
200
400
600
SCALE IN FEET

Curlew Lake – Ferry County

Curlew Lake is located 4.8 miles northeast of Republic. It is a natural lake, and water level fluctuations are stabilized by a three foot dam built in 1926. The lake extends northerly 4.8 miles to the outlet. There are four islands, totaling 20 acres, that are not included in the reported acreage. Inlets include Herron, Mires, Barrett, and Trout Creeks, and the Sanpoil River. Data From Dion *et al.* (1976)

Size (acres)	921
Maximum Depth (feet)	130
Mean Depth (feet)	43
Lake Volume (acre-feet)	39,519
Drainage Area (miles^2)	64.5
Altitude (feet)	2,333
Shoreline Length (miles)	15.8



Curlew Lake -- Ferry County

1992 Trophic Status[1]

Estimated Trophic State:	Mesotrophic[2]
Mean Trophic State Index (Secchi):	34
Mean Trophic State Index (Total Phosphorus):	51
Mean Trophic State Index (Chlorophyll *a*):	27

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
20-May	0915	15.6	60.0	14.0	24.00	Green	90	Moderate	Gusty	Floating clumps of Chara.
20-Jun	0730	21.1	70.0	19.0		Dk-Brown	25	None	Calm	Heavy Chara growth surfacing. Much floating algae. "Rotten-egg" smell.
20-Jul	0730	23.3	74.0	20.5	1.50	Dk-Green	75	Moderate	Calm	
19-Aug	0800	23.3	74.0	22.0		Dk-Green		None	Calm	Clear of particulates. Lake height 12'88".
02-Sep				21.0						Onsite visit.
21-Sep	0730	14.4	58.0	20.0		Dk-Green	90	None	Calm	Yellow particles in waves throughout the lake - heavy on shore.
13-Oct	1000	14.4	58.0	22.5	2.83	Dk-Green	0	Trace	Calm	

[1] Trophic State Indices calculated from Carlson (1977)

[2] See Comments section

Curlew Lake -- Ferry County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/20	0.0	15.6	8.5	10.8	218
	1.0	15.7	8.6	10.7	219
	2.0	15.7	8.7	11.0	219
	3.0	15.6	8.7	10.7	222
	4.0	15.6	8.7	10.6	220
	5.0	12.5	8.4	9.5	225
	6.0	10.8	8.1	8.3	228
	7.0	8.7	7.9	5.8	228
	8.0	7.7	7.8	4.7	228
	9.0	7.3	7.8	3.9	228
	10.0	7.1	7.7	3.6	228
	12.0	6.8	7.7	3.2	228
	14.0	6.5	7.6	2.9	228
	16.0	6.4	7.6	2.7	228
	18.0	6.3	7.5	2.6	228
	20.0	6.2	7.5	2.3	228
	25.0	5.9	7.5	1.6	230
	30.0	5.7	7.4	0.7	230
09/09	0.0	18.5	8.6	9.8	216
	1.0	18.6	8.6	9.6	216
	2.0	18.7	8.6	9.5	216
	3.0	18.7	8.6	9.5	215
	4.0	18.7	8.7	9.5	216
	5.0	18.7	8.7	9.5	215
	6.0	18.7	8.7	9.5	215
	7.0	16.7	8.5	9.1	233
	8.0	11.5	8.1	3.9	243
	9.0	9.9	8.0	1.9	240
	10.0	8.5	7.9	0.2	240
	12.0	7.6	7.9	0.1	239
	14.0	7.3	7.9	0.1	239
	16.0	7.1	7.9	0.1	239
	18.0	7.0	7.9	0.1	240
	20.0	6.8	8.0	0.0	239
	25.0	6.3	8.1	0.0	241
	30.0	5.9	8.1	0.1	247
	34.9	5.9	8.1	0.1	249

Curlew Lake -- Ferry County

1992 Onsite Visit Data - Water Chemistry

Date	05/20/92		09/09/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 4	6, 12, 18	2, 4, 6	12, 18, 24
Total Phosphorus (μg/L)	39	72	13	122
Total Nitrogen (mg/L)	0.47	0.50	0.44	0.51
Chlorophyll *a* (μg/L)	0.38		1.06	
Fecal Coliform Bacteria Site 1 (organisms/100 mL)	<1			
Fecal Coliform Bacteria Site 2 (organisms/100 mL)	<1			
Total Suspended Solids (mg/L)	4			
Total Nonvolatile Suspended Solids (mg/L)	2			
Color (Pt-Co units)	15			

Historical Data From Ecology

Date	07/13/74[a]	07/15/81[b]	09/13/90[c]	06/26/91[d]
Secchi (feet)	11.5	9	14.7	
Total Phosphorus, epilimnion (μg/L)	22	20	15	--
Total Nitrogen, epilimnion (mg/L)	--	--	0.60	0.40
Chlorophyll *a* (μg/L)	--	2.42	--	--
Dissolved Oxygen, surface (mg/L)	8.8	9.4	9.7	10.9
Dissolved Oxygen, bottom (mg/L)	0.0	0.2	--	0.3

a. Dion *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)

Curlew Lake -- Ferry County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity at the deep site was very good, as indicated by the deep Secchi depths. Lower water clarity during May may be due to gusty winds at the time of sampling, as well as debris (see Solids and Color section, below) and some plant growth following lake thaw.

Total Phosphorus
Total phosphorus in the epilimnion was high during May (39 μg/L), and the much lower concentration during September (13 μg/L) was still high enough to be able to cause some algae growth. The high value from May may have been the result of sediments in the water, since phosphorus can be attached to sediment particles, but the phosphorus would not have been available for algae to use (see Solids and Color section below). There were high concentrations of phosphorus in the hypolimnion on both sampling dates; internal loading probably contributed to the very high concentration (122 μg/L) during September.

Total Nitrogen
Total nitrogen concentrations were not high on either sampling date, and were similar to concentrations measured in 1991 (0.40 mg/L; Rector, 1992).

Fecal Coliform Bacteria
Fecal coliforms were sampled at two sites May. None were detected and were within state standards.

Solids and Color
Solids were not high, but the total suspended solids sample was one of the higher results of all the lakes sampled for solids. The result for total nonvolatile suspended solids (which gives an indication of suspended material that is organic in nature, such as algae), when compared to the results of the total suspended solids, suggests that there were some nonorganic sediments in the water during May. This may explain why the May phosphorus sample was higher, and both chlorophyll *a* and Secchi were much lower, than during the September sampling.

Profile Data
Profile data show that the lake was stratified on both sampling dates, and that both dissolved oxygen and pH decreased with depth below the thermocline. During September, dissolved oxygen was very low (less than 0.5 mg/L) from 10 meters to the bottom. Because of low oxygen concentrations, fish are probably restricted to the metalimnion, where oxygen levels are higher and water temperatures were not too warm.

During the September onsite visit, the water sample collected from 24 meters smelled slightly of hydrogen sulfide ("rotten-egg" smell). Hydrogen sulfide was probably produced as a result of the very low concentrations of oxygen in the hypolimnion.

Curlew Lake -- Ferry County

In July 1974, dissolved oxygen was 0.0 mg/L at 115 feet (Dion *et al.*, 1976), so it is likely that low dissolved oyxgen in the hypolimnion has been occurring for many years.

<u>Plants</u>

Despite the high total phosphorus concentration during May, chlorophyll *a* on both sampling dates was low and indicated that there was very little algal growth at the time of sampling. During the May onsite visit with the volunteer, muskgrass (*Chara*) was abundant. Many other eastern Washington lakes sampled during May also had lower algal growth (as indicated by chlorophyll *a* concentrations) than in August. This may have been due to lower water temperatures during May.

Heavy algal growth in Curlew Lake was reported for the first time in 1968 (Lee, 1969). The Washington Water Research Center (WWRC) reported in 1988 that floating mats of algae have grown in the lake, and that faulty septic systems and grazing livestock are likely sources of nutrient loading to Curlew Lake (WWRC, 1988). A news article from the Republic News-Miner (October 5, 1989) written by the Curlew Lake Association stated that the algae bloom at Curlew Lake was unusually heavy in 1989, and that there was a bloom of the blue-green alga *Anabaena*, floating mats of algae, a heavy scum, and a strong smell of rotten plants.

Aquatic plants identified in the lake in 1990 included *Chara* (according to the volunteer, this plant creates the biggest problem in the lake), milfoil (*Myriophyllum* species; this was not the aggressive Eurasian species), and pondweeds (*Potamogeton pectinatus* and *P. richardsonii*). The blue-green alga *Gloeotrichia* was also present. This algae appears as tiny green fuzzy balls floating in the water.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

> Curlew Lake is used for fishing, boating, swimming, rowing, camping, waterfowl hunting, and bird watching. Recreational facilities on the lakeshore include a picnic area, a state park, a camping area, a beach, and four resorts. There are five public boat ramps, and there are no restrictions for motorboat use on the lake. Rainbow trout were stocked in the lake. Lake water is withdrawn for irrigation. Currently the watershed is used for logging, animal grazing, and the lakeshore is being developed further for residences. In the past the lake was dredged and the shoreline was altered, and the watershed was used for logging, animal grazing, crop agriculture, and mining.
>
> There are 220 residences, and about 65 rental units, on the lakeshore. None of the residences are connected to a sewer. About 6 culverts/stormdrains drain into

the lake. There is a lake association and a sewer district for the lake. Currently, the minimum setback for lakeshore development is 50 feet, minimum lot lengths are 100 feet, and residential density is restricted to 2.5 houses per acre.

Overall, the volunteer finds that Curlew Lake had fair water quality. Problems in the lake in 1992 were ranked as 1) algae, 2) excessive aquatic plant growth, 3) decaying plants, 4) swimmer's itch, 5) degraded aesthetics, 6) odor from decaying algae, 7) fluctuating water level, 8) suspended sediments, 9) gradually degrading water quality over the years, and 10) low water level. (In 1991, the three worst problems were 1) aquatic plants, 2) algae, and 3) undesirable fish species.) Possible sources of problems are yard fertilizing, logging, and an increasing number of fulltime residents with pets. There used to be a lumber mill at the north end of the lake, and the lake was once used as a holding pond for logs. As a result, there are many old sunken logs in the lake. The lake was dredged at the site of the old sawmill. Changes in the lake since last year's monitoring was an increase in building with removal of lakeshore vegetation and wetlands. Also, a gold mine is being developed in the eastside watershed, less than one mile from the lake.

Cinquefoil (*Potentilla palustris*; identified by the County) is in one bay of the lake and appears to be replacing cattails. The lake was chemically treated in the past to control weeds and algae. The Washington State University Cooperative Extension Service and the Ferry County Conservation District studied the west watershed in 1990, and a grant from Ecology was allocated for a study of the east watershed beginning in 1991.

There are several wetland areas along the lakeshore, especially along the south end. Submerged plants grow along most of the shoreline and are particularly dense in cove areas, around the islands, and in the northernmost and southernmost basins. Surface plants and algae growth are localized in several areas. There are fish pens on the west side of the lake which are used as squawfish traps. There are springs in the north end of the lake.

Comments

Curlew Lake data summaries from 1989-1991 recommended that trophic state estimations for the lake be based on chemical, as well as physical, data. Although mean Secchi depth and chlorophyll *a* were in the oligotrophic range, Curlew Lake exhibited several characteristics that are more mesotrophic than oligotrophic. Mesotrophic characteristics of the lake are the moderate to high concentrations of total phosphorus, very low dissolved oxygen in the hypolimnion, and heavy plant growth in areas of the lake. Based on these, the lake was characterized as mesotrophic.

Curlew Lake -- Ferry County

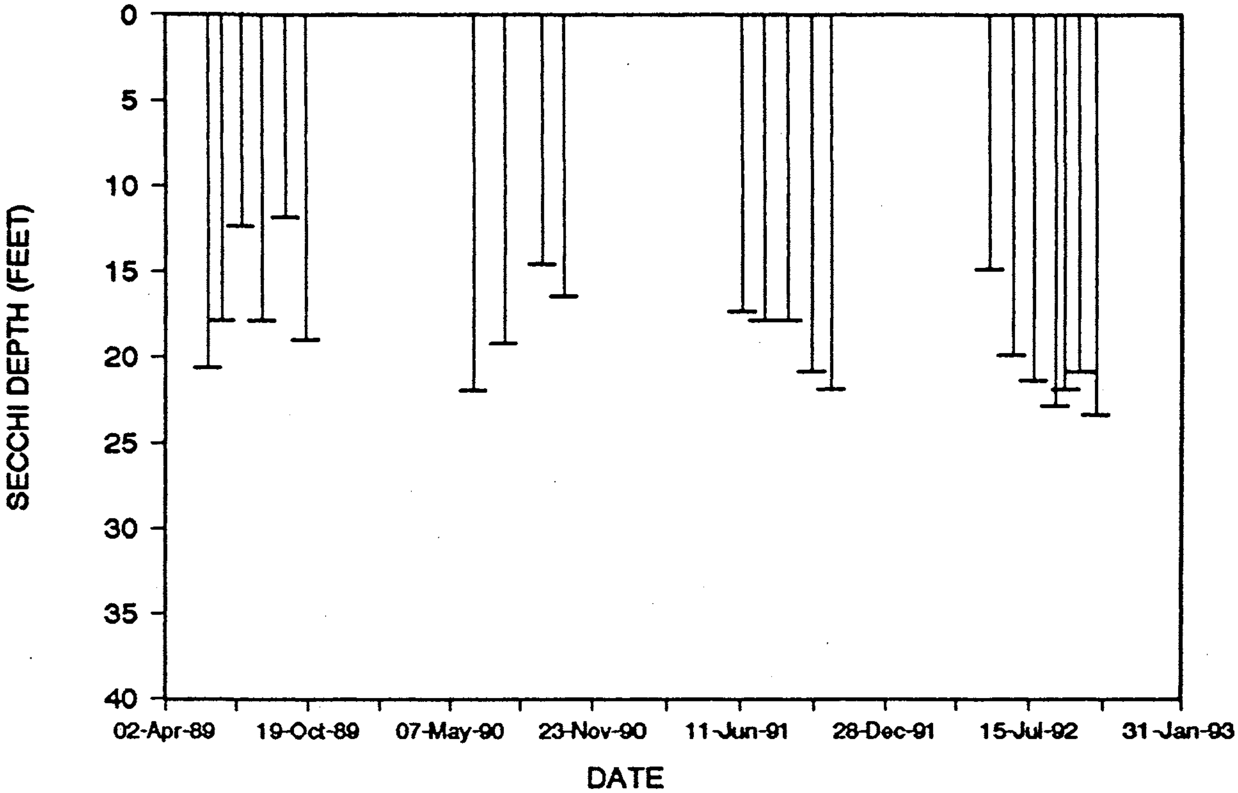
In comparison to other lakes monitored for the program in 1992, Curlew Lake had high phosphorus concentrations, but very good water clarity in open water (problems were localized nearshore). Based on water clarity data collected in 1990 which also indicated good water clarity in open water, we recommended Curlew Lake as a good candidate for restoration management (Rector and Hallock, 1993).

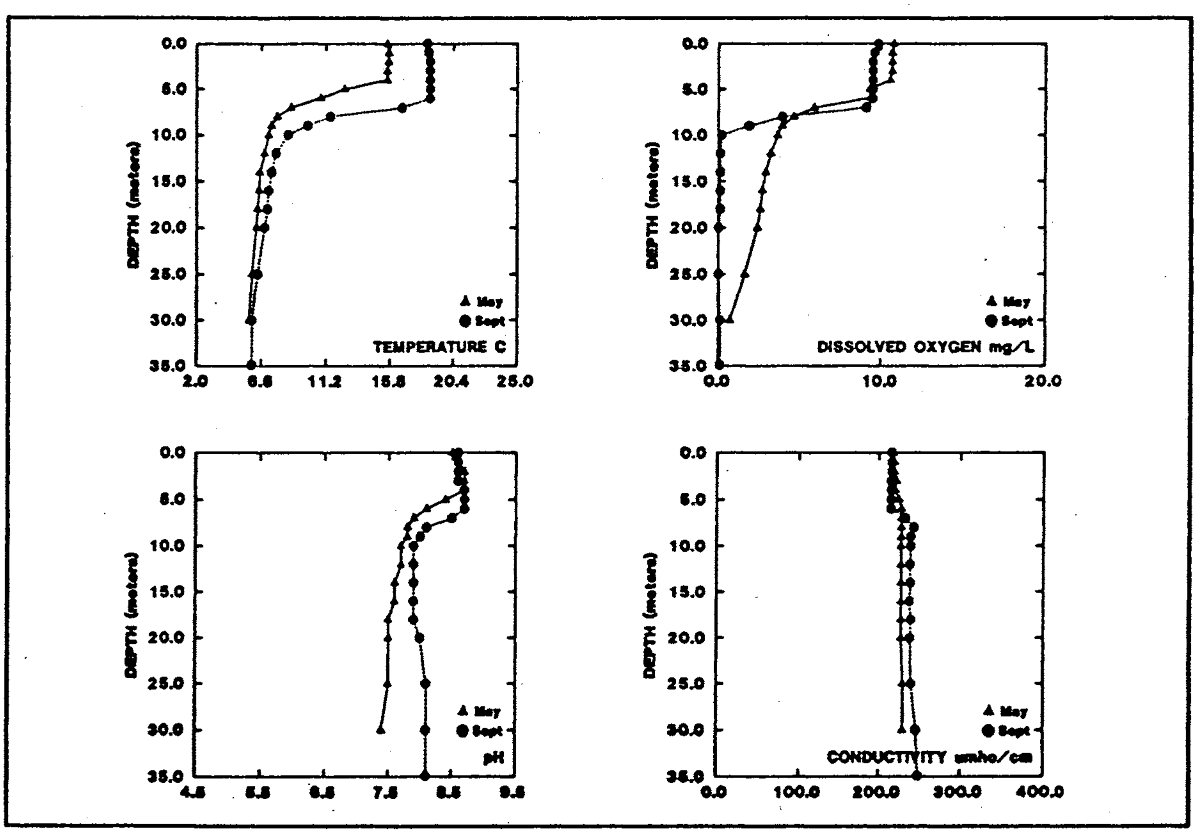
In 1991, the Washington Water Research Center (WWRC) reported that based on results from studies of Trout Creek and Barrett Creek (which drain into Curlew Lake), best management practices for controlling the effects from grazing cattle on these streams have been implemented (WWRC, 1991).

Acknowledgement

I thank Marion Dammann for volunteering her time to monitor Curlew Lake during 1989-1992.

CURLEW LAKE (FERRY COUNTY)



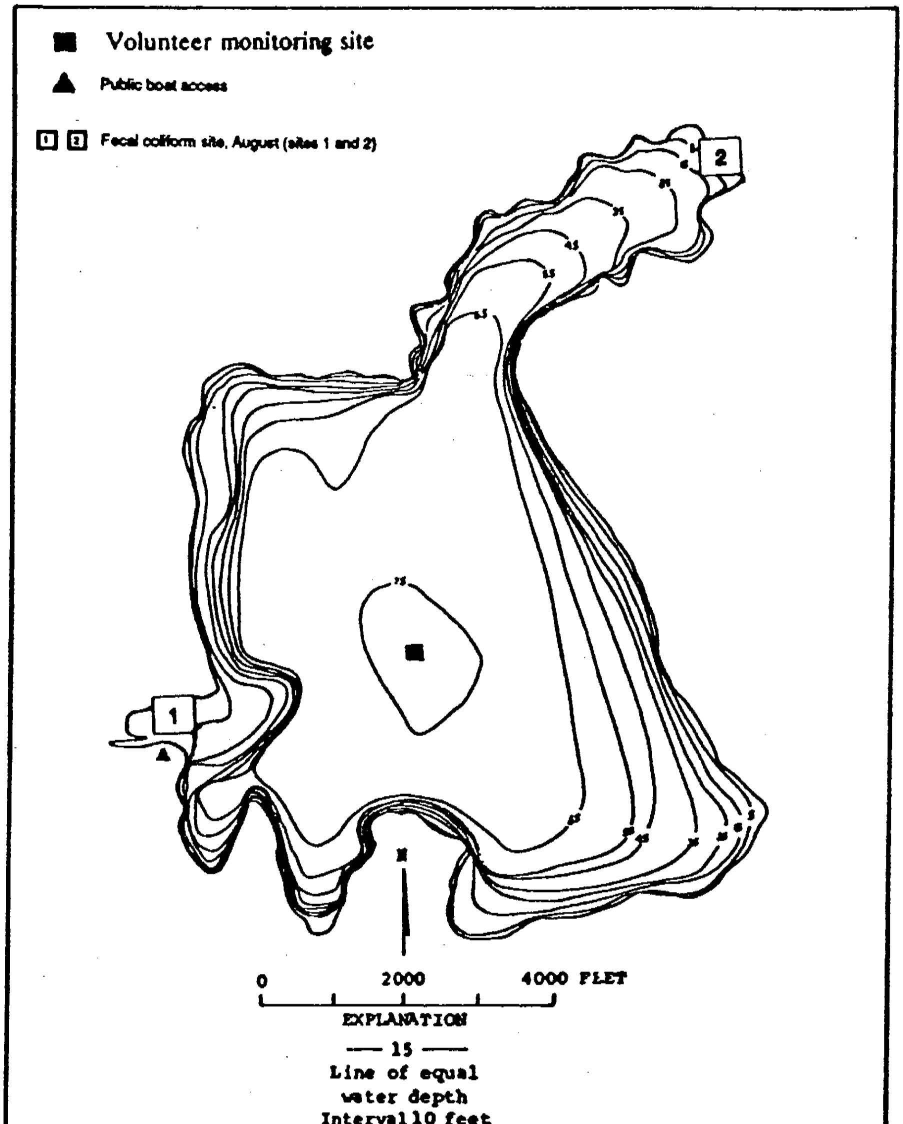


Deer Lake -- Stevens County

Deer Lake is located about 32 miles north of Spokane and 3.5 miles northeast of the town of Loon Lake. It is a natural lake in the Colville River watershed. Deer Lake drains southwest, intermittently, via a ditch. There is a large bog area (about 100 acres) at the northeast end of the lake.

Size (acres)	1,110
Maximum Depth (feet)	75
Mean Depth (feet)	52
Lake Volume (acre-feet)	57,000
Drainage Area (miles^2)	18
Altitude (feet)	2,474
Shoreline Length (miles)	8.6

Data from Dion *et al.* (1976)



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

Deer Lake -- Stevens County

1992 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	32
Mean Trophic State Index (Total Phosphorus):	33
Mean Trophic State Index (Chlorophyll *a*):	29

Volunteer-Collected Data

Date 1992	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
12-May	1445	14.4	58.0	19.6		Green	25		Calm	Percent clouds noted as 0%, 25%, and 50%.
01-Jun	1330	18.9	66.0	27.0		Green	10	None	Light	
18-Jun	1515	21.1	70.0	19.0		Green	10	Moderate		
03-Jul	1630	22.2	72.0	20.0		Green	25	Heavy	Light	
17-Jul	1530	22.2	72.0	21.0		Green	10	None	Breezy	
05-Aug	1405			24.0		Green	0		Light	Some algae.
25-Aug	1455	20.0	68.0	26.0		Green	0	Light		Some algae.
09-Sep	1515	18.9	66.0	24.0		Green	10	Light	Light	Some algae in big part of lake. Lots along the shore.
29-Sep	1530	15.6	60.0	23.0		Green	0	None	Calm	Lake just turned.
23-Oct	1415	11.1	52.0	21.0		Green	10	Light	Calm	Too much wind to take mid-month sample.

[1] Trophic State Indices calculated from Carlson (1977)

Deer Lake -- Stevens County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/12	0.0	14.3	7.6	9.8	81
	1.0	13.0	7.6	10.0	82
	2.0	12.9	7.6	10.0	82
	3.0	12.8	7.7	10.0	81
	4.0	12.7	7.7	10.0	81
	5.0	12.7	7.7	10.0	82
	6.0	12.7	7.8	10.0	81
	7.0	12.2	7.8	10.2	80
	8.0	11.7	7.8	10.5	82
	9.0	10.0	7.8	10.9	81
	10.0	9.2	7.8	11.0	81
	12.0	7.8	7.7	10.7	81
	14.0	7.2	7.7	10.6	80
	16.0	6.7	7.7	10.0	80
	18.0	6.4	7.6	9.5	80
	20.0	6.1	7.5	9.0	79
08/25	0.0	20.1	8.0	8.6	84
	1.0	20.0	8.0	8.5	84
	2.0	19.7	8.0	8.5	84
	3.0	19.6	8.0	8.5	84
	4.0	19.5	8.0	8.5	84
	5.0	19.5	8.0	8.5	84
	6.0	19.5	8.1	8.6	84
	7.0	19.4	8.1	8.5	84
	8.0	18.5	8.1	9.5	83
	9.0	15.7	8.3	11.8	81
	10.0	14.1	8.3	11.7	81
	12.0	15.5	8.1	9.8	80
	14.0	8.7	7.9	7.6	80
	16.0	8.0	7.9	7.5	79
	18.0	7.3	7.9	5.5	79
	20.0	6.7	7.8	2.6	80
	22.0	6.2	7.7	0.0	105

Deer Lake -- Stevens County

1992 Onsite Visit Data - Water Chemistry

Date	05/12/92		08/25/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	2, 4, 6	10, 12, 14	2, 4, 6	10, 14, 18
Total Phosphorus (µg/L)	7	10	8	15
Total Nitrogen (mg/L)	0.29	0.30	0.33	0.33
Chlorophyll *a* (µg/L)	0.40		1.25	
Fecal Coliform Bacteria Site 1 (colonies/100 mL)			<1	
Fecal Coliform Bacteria Site 2 (colonies/100 mL)			1	

Historical Data From Ecology

Date	08/15/72[a]	07/14/81[b]	05/25/90[c]	08/09/90[c]
Secchi (ft)	22	27	--	18.3
Total Phosphorus, epilimnion (µg/L)	10	10	14	17
Total Nitrogen, epilimnion (mg/L)	--	0.75	--	0.34
Chlorophyll *a* (µg/L)	1.7	0.99	--	--
Dissolved Oxygen, surface (mg/L)	8.4	9.1	10.7	8.2
Dissolved Oxygen, bottom (mg/L)	1.5	2.5	7.1	0.5

a. Dion *et al.* (1976), Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)

Deer Lake -- Stevens County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was very good, as indicated by the deep Secchi depths which ranged from 19.6 to 26.0 feet. Secchi depths varied throughout the monitoring season, with no obvious pattern in water clarity.

Total Phosphorus

Total phosphorus in the epilimnion was very low on both sampling dates (7 μg/L in May, and 8 μg/L in August). These concentrations were lower than those reported in 1972, 1981, and 1990. In 1972 and 1981, total phosphorus was 10 μg/L (Dion *et al*, 1976; Sumoika and Dion, 1985). In 1990, total phosphorus was 14 μg/L in May and 17 μg/L in August (Rector, 1991).

Total Nitrogen

Total nitrogen concentrations were low on both sampling dates (0.29 and 0.33 mg/L), and were similar to the concentration measured in 1990 (0.34 mg/L; Rector, 1991).

Fecal Coliform Bacteria

Fecal coliforms sampled during August were very low and within state standards.

Profile Data

The lake was stratified with respect to temperature on both sampling dates. During August, the extreme change in temperature in the metalimnion, and possibly some increased algal growth at these depths, may have contributed to the increase in dissolved oxygen and pH at 9 and 10 meters. Below the metalimnion, dissolved oxygen and pH decreased with depth. Decreases of oxygen and pH in the hypolimnion are usually related to the bacterial decomposition of aquatic plants and algae in the water and sediments.

Profile data collected for the program in August 1990 also showed an increase in dissolved oxygen and pH in the metalimnion, and virtually depleted dissolved oxygen near the lake bottom.

Plants

Chlorophyll *a* was low and in the oligotrophic range on both sampling dates, indicating that there was very little algal growth at the time of sampling. Chlorophyll was higher during August (1.25 μg/L) than during May (0.40 μg/L). During August, the higher value was probably from a blue-green alga, possibly *Gloeotrichia*, which was noted by Ecology staff. This alga has less effect on Secchi depths because the colonies are usually large, and do not affect water clarity as much as other algae species. Many of the eastern Washington lakes sampled for the program had very little algal growth during May, which was probably due to lower water temperatures at the higher elevations.

Deer Lake -- Stevens County

Plants identified by Ecology staff during the August 1992 onsite visit with the volunteer included watershield (*Brasenia schreberi*) in the vicinity of the public boat access. Just past the boat launch channel, largeleaf pondweed (*Potamogeton amplifolius*) was abundant. Near the inlet, largeleaf pondweed, water celery (*Vallisneria americana*) and milfoil (*Myriophyllum* spp., but not the aggressive Eurasian variety) were identified.

During the May 1990 onsite visit with the volunteer, algae were present in the water, although not in bloom proportions. During the August 1990 onsite visit, aquatic plants identified in the lake included watershield, milfoil, large-leaved pondweed, water buttercup (*Ranunculus* species), and coontail (*Ceratophyllum demersum*). The water color was dark green during the August onsite visit.

Other Available Information

Deer Lake was surveyed by Ecology in 1978. The mean value for Secchi disk transparency was 7.3 meters, and the mean value for chlorophyll *a* was 1.31 μg/L (Singleton *et al.*, 1980). These values indicate that in 1978 the lake was oligotrophic, according to the trophic state index (Carlson, 1977) used to evaluate data for the current lake program.

The following is a summary of a presentation given by John Buchanan, Associate Professor at Eastern Washington University, on September 28, 1991 at the Washington Lake Protection Association (WALPA) conference in Everett. The Stevens County PUD initiated a study because the public perceived there was a decrease in the lake's water quality. The work was completed by Eastern Washington University from November 1989 - October 1990. This survey found that there were 542 nearshore residences on Deer Lake, about 60 of these were occupied year-round, and 40% of these residences have cesspools, outhouses, or holding tanks. An in-lake leachate sweep indicated no failures of wastewater disposal systems. The outflow was intermittent, so most water loss from the lake is from evaporation and groundwater outflow. In the watershed near the inlet, there was a large population of grazing cattle. Seventy-two percent of the total phosphorus loading was coming from streamflow, and 21% from atmospheric deposition. About 5% of the loading was internal (from lake sediments). Overall, the tributary with grazing cattle contributed most of the total phosphorus loading to the lake.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

> Deer Lake was used for fishing, swimming, boating, jet skiing, picnicking, camping, hiking, and waterfowl hunting. There are two resorts and three boat ramps on the lakeshore. About 10% of the lakeshore is publicly-owned. There is a speed limit for motor boats. Rainbow trout were stocked in the lake.

Deer Lake -- Stevens County

Currently the watershed is used for logging and animal grazing, and the lakeshore is being developed further for residences.

There are about 700-800 houses on the lakeshore. In 1992, the lakeshore was sewered and a water system was installed. Prior to 1992, none of the homes were connected to a sewer and lake water was withdrawn for drinking and other domestic uses. There is a lake association for the lake.

Overall, the volunteer finds that Deer Lake had good water quality. Problems in the lake in 1992 were ranked as 1) algae, and 2) swimmer's itch. Possible sources of problems are cattle at the head of the lake. No plant or algae management occurred in the lake in 1992.

During the August 1992 onsite visit with the volunteer, the volunteer noted that water quality in Deer Lake was the best it's been in three years, and that the sewer was completed this summer. He also noted that swimmers itch occurred for the first time.

There is a wetland on the north part of the lake. In 1989, the volunteer noted that ten years ago one could see the bottom of the lake (40 - 50 feet down) and now this is not possible because of algae blooms.

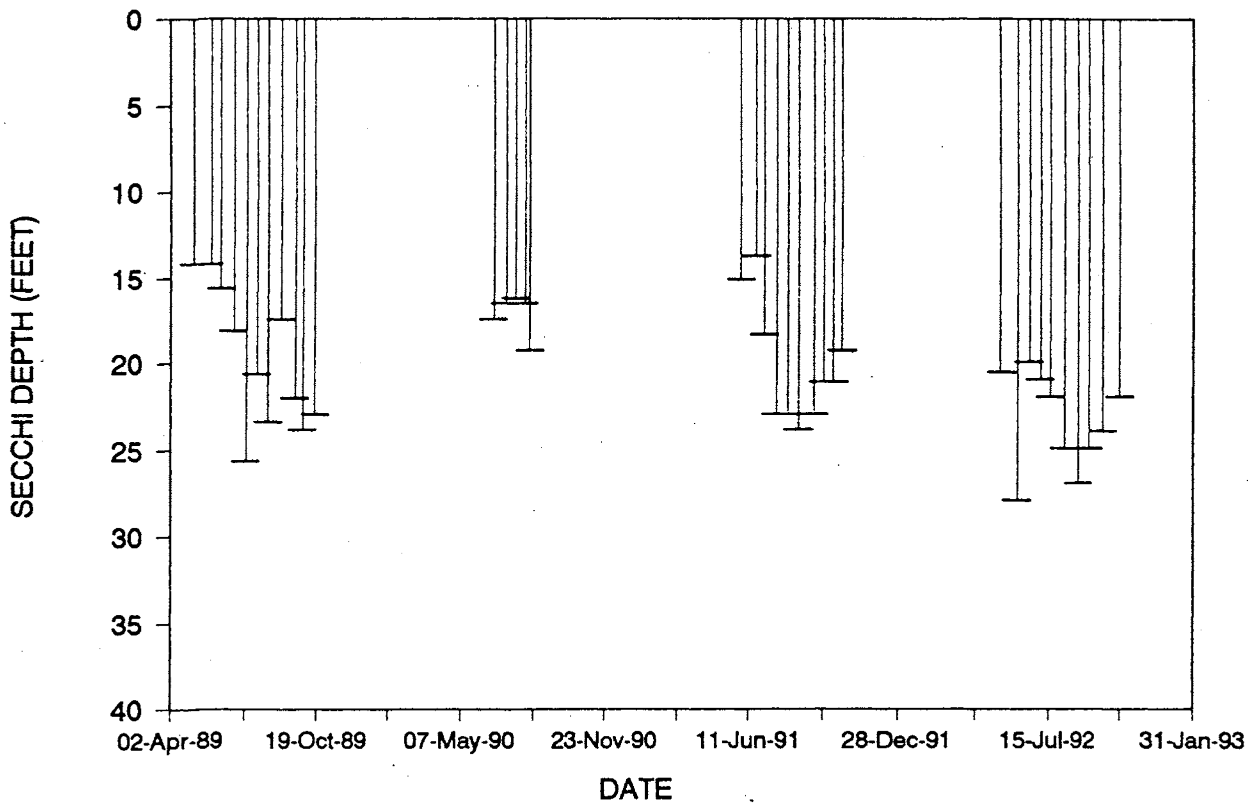
Comments

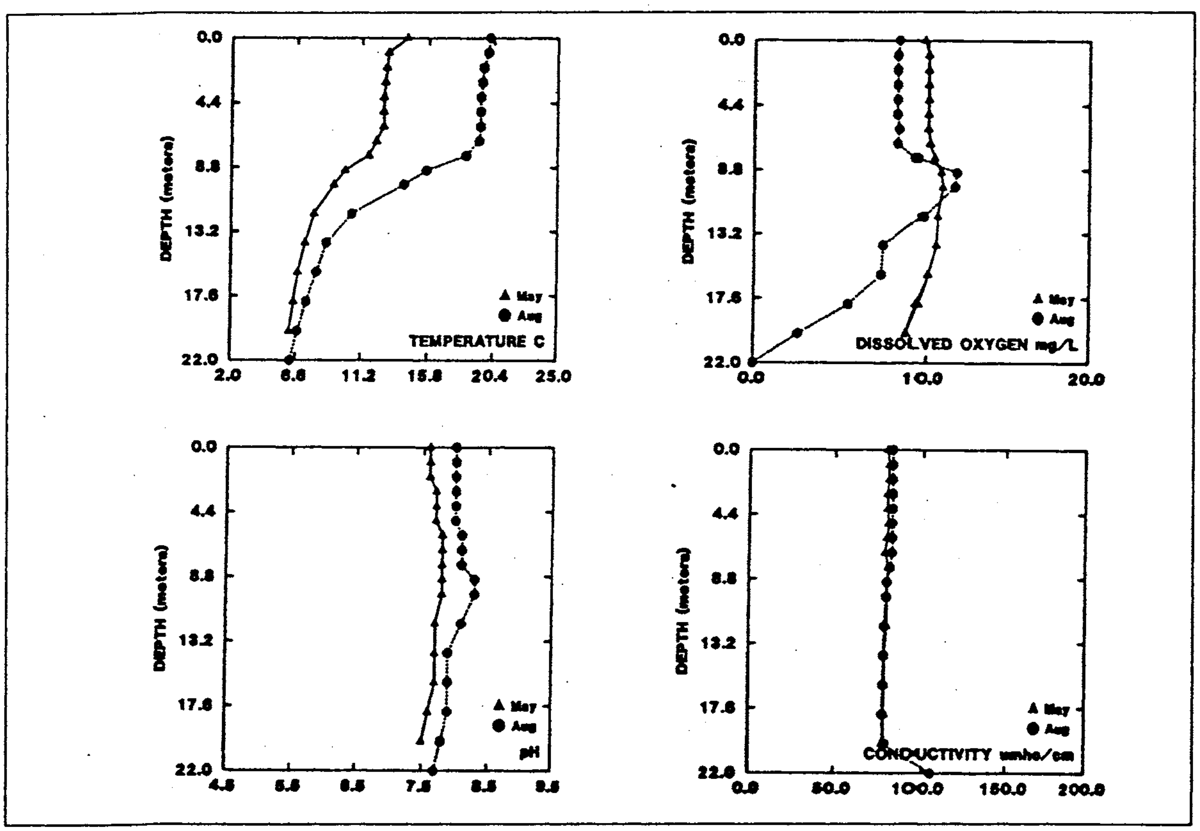
Both mean Secchi depth and mean total phosphorus data collected for the program have improved since 1990. Since all three trophic state parameters (Secchi depth, total phosphorus, and chlorophyll *a*) were in the oligotrophic range, Deer Lake was characterized as oligotrophic in 1992. In 1991, the lake was characterized as oligo-mesotrophic, based largely on moderately high concentrations of total phosphorus which were seen in 1990. Because total phosphorus concentrations were lower in 1992, the trophic state was upgraded.

Acknowledgement

I thank Wesley Wagoner for volunteering his time to monitor Deer Lake during 1989-1992.

DEER LAKE (STEVENS COUNTY)



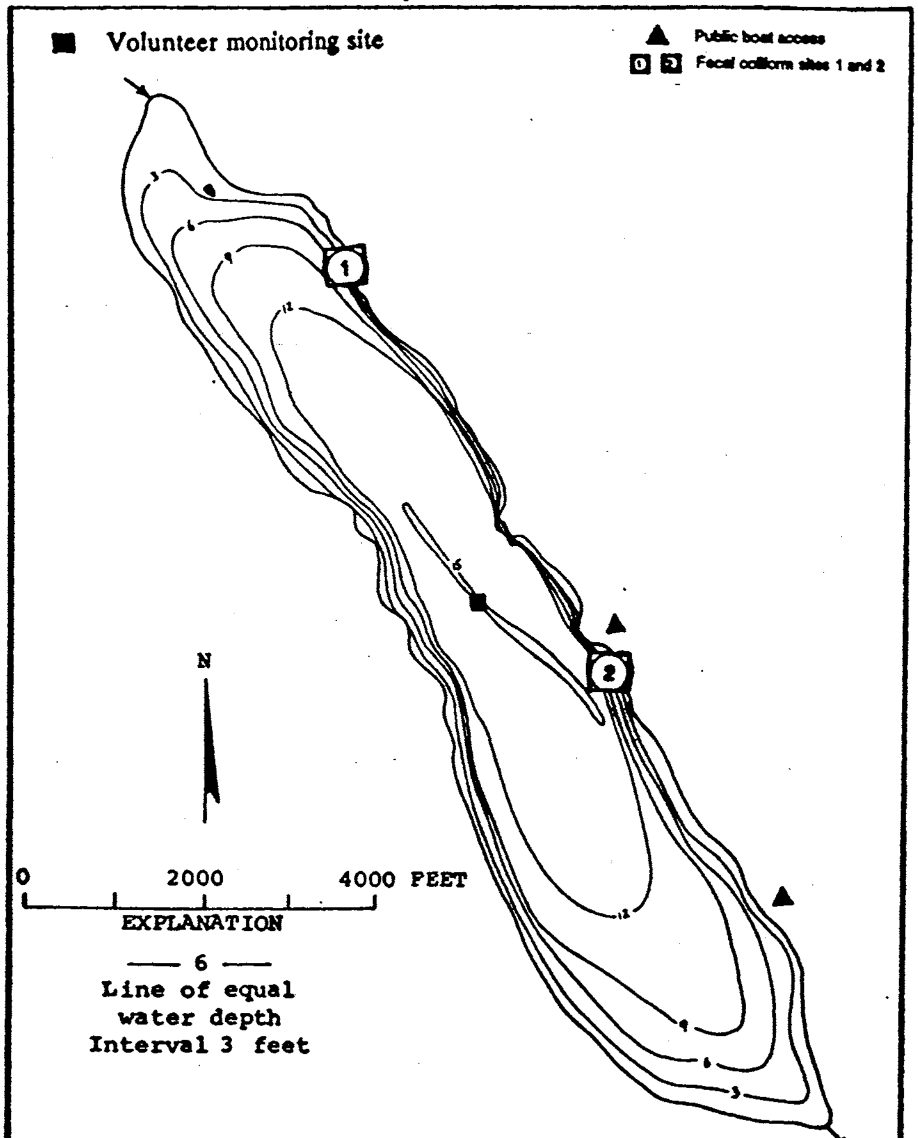


Lake Eloika -- Spokane County

Lake Eloika is located four miles west of Elk. It is three miles long and lies in a northeast/southwest direction. It is a natural lake, and is an enlargement of the west branch of the Little Spokane River. Lake Eloika extends north about 1000 feet into Pend Oreille County at high water periods.

Size (acres)	662
Maximum Depth (feet)	15
Mean Depth (feet)	9
Lake Volume (acre-feet)	6,018
Drainage Area (miles^2)	111
Altitude (feet)	1,905
Shoreline Length (miles)	5.9

Data From Dion *et al.* (1976)



Eloika Lake, Spokane County. From Washington Department of Game, January 29, 1958.

Eloika Lake -- Spokane County

1992 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	46
Mean Trophic State Index (Total Phosphorus):	52
Mean Trophic State Index (Chlorophyll *a*):	44

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (ft)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
13-May	0905			8.9		Green	0		Calm	
15-Jun	1030	18.9	66.0	7.5	1905.2	Gr-Brown	25	Moderate		Clouds around, sunshine here.
03-Jul	1140	22.8	73.0	7.2	1905.0	Gr-Brown	10	Moderate	Breezy	Water level was lower (or seemed to be) earlier this year.
15-Jul	1255	23.3	74.0	7.0	1904.9	Gr-Brown	50	Light	Light	Bottom weeds seem much thicker this year.
03-Aug	1235	27.2	81.0	12.1	1905.1	Green	0	None	Calm	Last week mostly 90 degrees with no rain. Lake depth 13.2 feet at site.
18-Aug	1500	25.0	77.0	9.1	1905.4	Green	25	None	Light	Some water ski activity -- may have affected sample.
26-Aug	0847	17.2	63.0	8.0	1905.5	Gr-Brown	10	Light	Light	Second Secchi using view tube.
17-Sep	1330	15.0	59.0	7.0	1905.7	Gr-Brown	10		Calm	Light odor from lake.
05-Oct	1315	14.4	58.0	9.9	1905.8	Gr-Brown	25	Trace	Light	Strong show of fall colors around shoreline.
18-Oct	1250	10.0	50.0	10.9	1906.0	Gr-Brown	100		Calm	Anchor brought up some elodea.

[1] Trophic State Indices calculated from Carlson (1977)

Eloika Lake -- Spokane County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/13	0.0	15.8	8.5	10.0	88
	1.0	15.9	8.5	9.9	89
	2.0	15.8	8.6	9.8	89
	3.0	15.8	8.7	9.8	88
08/26	0.0	18.2	8.1	8.1	97
	1.0	18.3	8.1	8.0	97
	2.0	18.3	8.1	8.0	97
	3.0	18.3	8.1	8.0	97

1992 Onsite Visit Data - Water Chemistry

Date	05/13/92		08/26/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	--	1, 2, 3	--
Total Phosphorus (μg/L)	25	--	29	--
Total Nitrogen (mg/L)	0.40	--	0.57	--
Chlorophyll *a* (μg/L)	2.23	--	5.45	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	<1		1	
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	1		1	
Total Suspended Solids (mg/L)	2		5	
Total Nonvolatile Suspended Solids (mg/L)	1		1	
Color (Pt-Co units)	25		--	

Eloika Lake -- Spokane County

Historical Data From Ecology

Date	7/01/74[a]	07/13/81[b]	08/21/90[c]	06/10/91[d]
Secchi (ft)	9	13	4.7	8.7
Total Phosphorus, epilimnion (μg/L)	28	20	55	--
Total Nitrogen, epilimnion (mg/L)	--	0.98	0.68	0.29
Chlorophyll *a* (μg/L)	--	3.7	--	--
Dissolved Oxygen, surface (mg/L)	10.7	9.8	8.8	9.9
Dissolved Oxygen, bottom (mg/L)	17.2	3.1	7.3	8.2

a. Dion *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)

Eloika Lake -- Spokane County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was fair to good, as indicated by Secchi depths which ranged from 7.0 to 12.1 feet. Mean Secchi depth for 1992 (8.8 feet) was fair, but was better than mean Secchi depths from 1989-1991.

Total Phosphorus
Total phosphorus was high on both sampling dates (25 μg/L in May, and 29 μg/L in August). Concentrations were lower than the concentration measured in 1990 (55 μg/L; Rector, 1991), but were similar to a concentration measured in 1974 (28 μg/L; Dion *et al.*, 1976).

Total Nitrogen
Total nitrogen was moderately high (0.40 mg/L and 0.57 mg/L) on both sampling dates. Historical Data From Ecology listed on page 4 indicate total nitrogen has varied widely from 0.29 mg/L to 0.98 mg/L.

Fecal Coliform Bacteria
All samples for fecal coliforms were very low, and were within state standards.

Solids and Color
Suspended solids were low in May. During the August onsite visit, suspended solids were high, and total nonvolatile suspended solids were low. The low total nonvolatile suspended solids during August indicate that the high total suspended solids most likely resulted from the blue-algae bloom that was observed at the time of sampling. Solids results indicate that Secchi depths were most likely affected more by algal growth than by suspended sediments. Color results indicate that the lake was somewhat colored, which may affect Secchi depths.

Profile Data
The lake was not stratified during either sampling date, so only one set of water samples were collected for each onsite visit. There was very little difference from surface to bottom for all of the profile parameters. Profile data were very similar to those measured for the program in 1990 and 1991.

Plants
Chlorophyll *a* was low to moderate during May, indicating that there was a low to moderate amount of algae growth at the time of sampling. During August, algal growth (as indicated by the chlorophyll *a* concentration) was higher. On both sampling dates, particularly in May, chlorophyll *a* was lower than expected given the high phosphorus concentrations. The reason for this is unknown, but it is likely that lower water temperatures during May contributed to the

lower algal productivity. In August, algal growth may have been low due to shading from plants or water color, or conversely, algal growth rates may have been high, but algae were eaten by zooplankton or fish.

Plants identified by Ecology staff during the May 13, 1992 onsite visit with the volunteer include waterweed (*Elodea* spp.), flatleaf pondweed (*Potamogeton robbinsii*), coontail (*Ceratophyllum demersum*), and watershield (*Brasenia schreberi*).

During the August 1990 onsite visit with the volunteer, blue-green clumps about 2 - 6 inches in diameter were floating along the shore. The clumps consisted primarily of filaments of the blue-green alga *Oscillatoria*. Plants identified during the onsite visit included fairly extensive patches of watershield, coontail, bladderwort (*Utricularia vulgaris*), two pondweeds (including flatleaf pondweed), duckweed (*Lemna* spp.), and waterweed (*Elodea* spp.). Waterweed and watershield were also observed during the June 1991 onsite visit.

In 1974, the entire shoreline was covered with aquatic plants (sedge, cattail, and watershield), and 11 - 25% of the lake surface was covered by emersed plants (Dion *et al.*, 1976). This description of the shoreline is similar to the volunteer's descriptions of the lake in 1989 and 1990.

Other Available Information

A water quality assessment and restoration feasibility study conducted by Eastern Washington University (EWU) concluded there was a large amount of sediment in Eloika Lake from natural erosion. The thick sediment and the shallow water depth are optimal for macrophyte rooting and growth. Control of the macrophyte communities was recommended for reducing internal phosphorus recycling in the lake (Soltero *et al.*, no date).

In 1990, Centennial Clean Water Funds were awarded for EWU to study the nutrient loading from the watershed, and to investigate designs for a water level control structure at the lake outlet (Soules, 1989). Initially it was proposed to install a dam at the lake outlet to maintain the water level at the natural spring high level throughout most of the year. However, design and construction of the dam is currently on hold until the lake level to be established is adjudicated (Soules, 1992). Water level drawdown during the winter was also proposed in order to freeze some of the aquatic plant roots. The proposed actions are intended to thin, but not eliminate, aquatic plants in the lake.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

Eloika Lake -- Spokane County

Eloika Lake is used for fishing, rowing, camping, and waterfowl hunting. There are two resorts on the lakeshore. There is one public boat ramp, and there are no restrictions for motorboat use on the lake. About 2% of the lakeshore is publicly-owned. Currently the watershed is used for logging and animal grazing, and the lakeshore is being developed further for residences. In the past, the watershed was used for logging and crop agriculture, the lake was dredged, and the shoreline was altered.

There are about 50 houses on the lakeshore, and none of these houses are connected to a sewer. There are six stormdrains which drain into the lake. There is a community association for the lake. Currently, the minimum setback for lakeshore development is 100 feet. Lake water is withdrawn for irrigation.

Overall, the volunteer finds that Eloika Lake had fair water quality. Problems in the lake in 1992 were ranked as 1) excessive aquatic plant growth, 2) suspended sediments, and 3) gradually degrading water quality over the years. Possible sources of problems are excessive silt (both natural and from logging); nutrient loading from other lakes in the chain of lakes; and internal loading of nutrients from dying aquatic plant growth. No plant or algae management occurred in 1992, although chemicals have been used in the past to control weeds. In comparison to the 1991 monitoring season, in 1992 there were large areas where there were fewer "dollar pads" (presumably watershield, *Brasenia* spp.), but in other areas there were lily pads where previously there were none. The volunteer is concerned that the entire lake could be covered with lily pads. The water quality was better overall in 1992 than in past four years, possibly from the Diamond Lake sewer and nonpoint source controls by the Pend Oreille Conservation District.

Much of the shoreline is wetlands, especially at the north and south ends of the lake. Except for the two resort areas and a few private beaches, the lake is ringed with a combination of reeds, cattails, and grasses. Purple Loosestrife was identified in a wetland area and it has since been sprayed and removed. Patches of large-leafed plants grow in the water and protrude above the surface.

Comments

From 1989 - 1991, Secchi depth and total phosphorus data collected for the program indicated that Eloika Lake was eutrophic. In 1992, though, Secchi depth and mean chlorophyll *a* data were in the mesotrophic range, while total phosphorus remained in the eutrophic range. Because the lake exhibited both mesotrophic and eutrophic characteristics in 1992, the lake was given a meso-eutrophic trophic state estimation. This estimation is also consistent with the high amount of plant growth in the lake, and the periodic algal blooms.

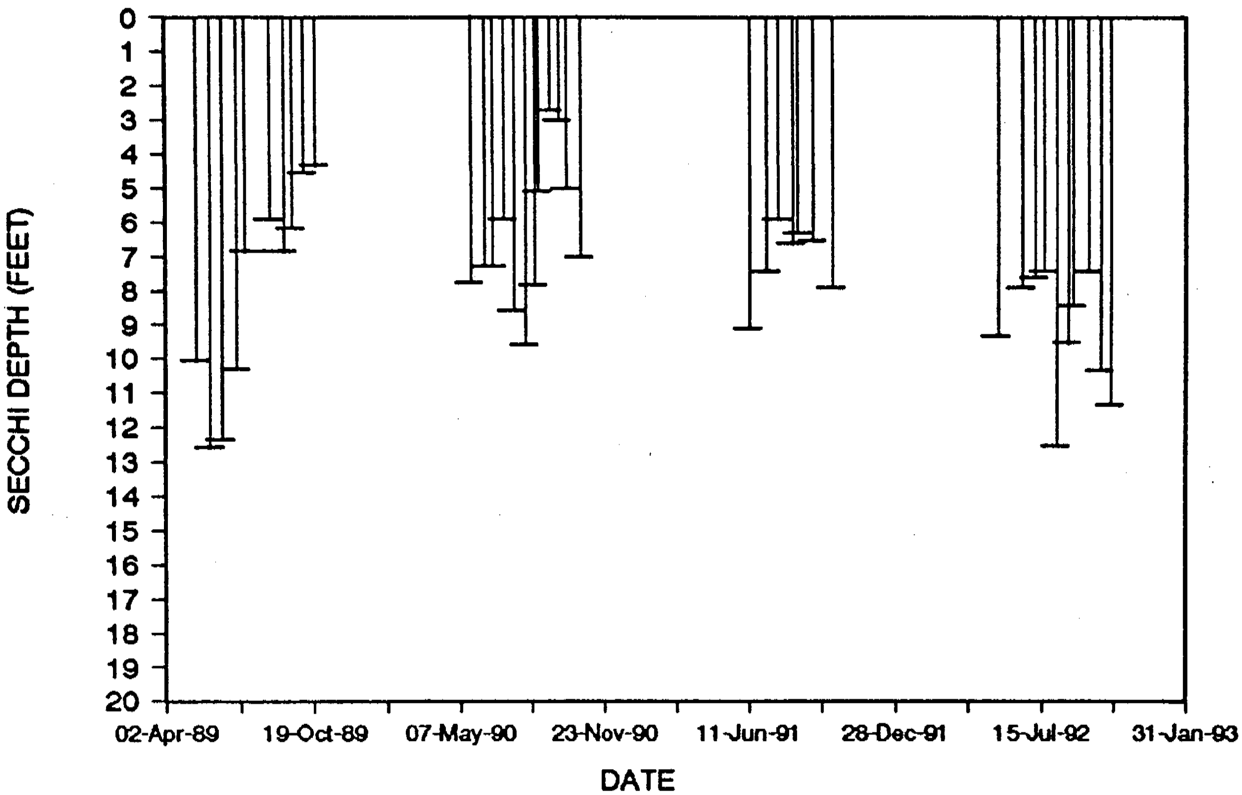
Eloika Lake -- Spokane County

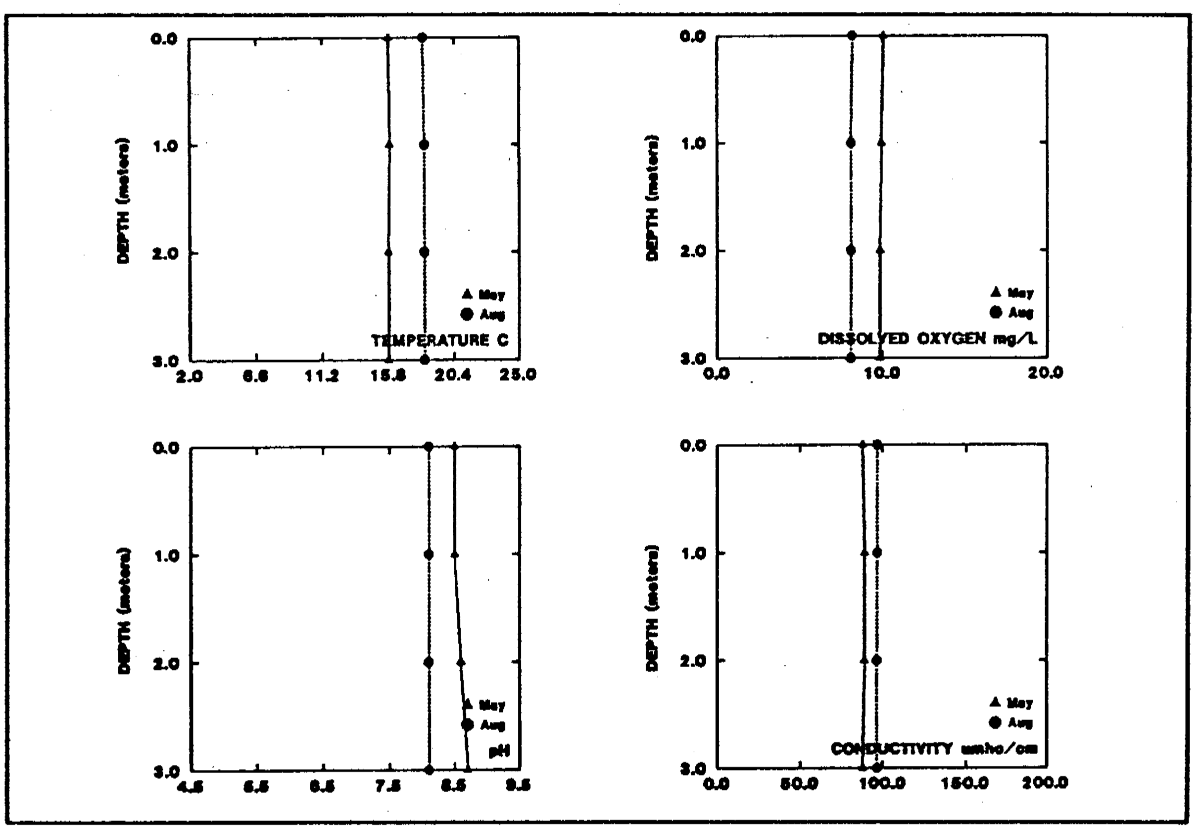
Williams Lake was the only other Spokane County lake monitored for the program in 1992. Williams Lake was characterized as mesotrophic. Deer Lake is in Stevens County, but is closer to Eloika Lake; Deer Lake was characterized as oligotrophic.

Acknowledgement

I thank Victor H. Soules for volunteering his time to monitor Eloika Lake during 1989-1992.

ELOIKA LAKE (SPOKANE COUNTY)





Flowing Lake -- Snohomish County

Flowing Lake is located six miles north of Monroe, and 800 feet west of Storm Lake. It is fed by Storm Lake and drains to Panther Lake and ultimately to the Pilchuk River. It was called Rowing Lake on historical maps. The inflow is intermittent.

Size (acres)	134
Maximum Depth (feet)	69
Mean Depth (feet)	28
Lake Volume (acre-feet)	3,790
Drainage Area (miles^2)	0.8
Altitude (feet)	526
Shoreline Length (miles)	2.2

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	43

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and responses to the 1991 questionnaire. There are 95 houses on the lakeshore (the volunteer reported 94 nearshore homes in 1990 and 92 homes in 1989); of these, 61 are occupied year-round. Rainbow trout are stocked in the lake. After parking was restricted at Flowing Lake County Park in 1991, far less motorboat activity was observed on the lake. Overall, the volunteer finds that Flowing Lake has excellent water quality. The volunteer did not observe any changes in the lake since the 1990 monitoring season.

The following are the volunteer's remarks and responses to the 1990 questionnaire. Flowing Lake is used for fishing, boating, swimming, rowing, jet skiing and camping. Recreational facilities on the lakeshore include a county park, a state park, a camping area, a beach, and one boat ramp. There is a speed restiction of 8 mph for motorboats that does not apply to water skiing (most likely, the restriction is for near shore). Lake water is withdrawn for drinking and irrigation. Currently the watershed is used for crop agriculture, and the lakeshore is being developed further for residences. In the past the watershed was used for logging and animal grazing. The lakeshore is not sewered, and there are 15 storm drains that empty into the lake. Presently there is a ski association and a water association (serves three lakes) for the lake. The lake has been chemically treated in the past to control undesirable fish species.

In 1989, the volunteer reported that flocks of cormorants used the lake. They roost on the ski floats and eat fish when the lake is stocked in the spring, and leave in April after the fishing season opens.

Flowing Lake -- Snohomish County

According to the volunteer, there are two manmade "lagoons" (presumably, dredged embayments that extend shoreline) on the lake. Lilies, iris and cattails grow in areas. Wetland plants and algae grow at the inlet (near the public access area) and areas not developed for residences.

Monitoring Results/Summary of Other Available Information

The volunteer has monitored Flowing Lake for the program since 1989. Data from 1989 are reported in Rector (1990) and data from 1990 are reported in Rector (1991).

Volunteer-collected Secchi data from 1991 show that water clarity ranged from 8.9 to 12.4 feet. Patterns in algal growth were similar in 1991 and 1990 (Secchi depths were lowest during August and highest during May), although mean Secchi depth was more similar between the 1989 and 1991 data sets. In 1990, overall mean water clarity was somewhat worse, and seasonal changes in Secchi depth were more erratic, than in 1991 and 1989. During all three years, Secchi data indicated the lake was mesotrophic.

Ecology staff collected water samples and profile data from Flowing Lake on May 29, 1991. The profile data show that the lake was stratified, and both pH and dissolved oxygen decreased somewhat below the thermocline. Dissolved oxygen was 5.9 mg/L at the lake bottom. In 1990, dissolved oxygen was 1.8 mg/L at 17 meters on June 6 and 0.3 mg/L at 15 meters on August 30. By September 17, 1990, dissolved oxygen was extremely low throughout the hypolimnion; just below the themocline at 5.0 meters, dissolved oxygen was 0.6 mg/L (Coots, 1991). In 1973, published data also show that low dissolved oxygen (1.0 mg/L at 56 feet) occurred in the lower layer of Flowing Lake (Bortleson *et al.*, 1976), so it is likely that low dissolved oxygen has been occurring near the lake bottom for many years.

The lower dissolved oxygen in the lake's lower layer most likely resulted from the bacterial decomposition of organic material (such as algae, aquatic plants and woody debris) in the water and sediments. Dissolved oxygen can be depleted from the lower layer of the lake (the hypolimnion) yet remain high in the upper layer (the epilimnion) because the lower layer of water does not mix with the upper layer during thermal stratification. This was especially apparent in the 1990 profiles from the 1990 data summary.

Total nitrogen in 1991 (0.56 mg/L) was moderate compared to other monitored lakes and was very similar to the June 6, 1990, concentration (0.54 mg/L). Chlorophyll *a* was very low and in the oligotrophic range (1.3 μg/L) on June 18, 1990 (Coots, 1991).

Samples for total phosphorus and chlorophyll *a* were collected in 1991, but the data could not be used due to analytical problems. In 1990, four water samples were analyzed for total phosphorus for Ecology (two for the citizen lake monitoring program and two for a lake survey designed to supplement volunteer-collected data). Total phosphorus was 0.015 mg/L on June 6, 0.004 mg/L on June 18, 0.012 mg/L on August 30 and 0.009 mg/L on September 15 (June 18 and September 15 data from Coots, 1991). Because it rained heavily on June 6, increased runoff may have increased the total phosphorus concentrations in the lake on this date. Total phosphorus in published data from 1974 (0.007 mg/L; Bortleson *et al.*, 1976) was in the range of concentrations found in 1990.

On April 20, 1989, about 10 - 15 gallons of diesel oil were washed into the lake and required cleanup (R. Newman, Ecology Northwest Regional Office, personal communication).

The lake was dredged at the northeast corner (Bortleson *et al.*, 1976). Residential development of the lakeshore has increased since 1973, when there were 61 nearshore homes (Bortleson *et al.*, 1976).

Comments

Since 1989, volunteer-collected Secchi data indicated that Flowing Lake was mesotrophic. Other mesotrophic characteristics of the lake include very low hypolimnetic dissolved oxygen which was documented in 1990, and presence of a blue-green algae species (*Gloeotrichia*) noted during the 1990 Ecology survey.

Flowing Lake was one of six Snohomish County lakes monitored for the program in 1991, and was the only one of these lakes that was mesotrophic. Lake Stevens, Martha Lake (near Alderwood Manor), Lake Martha (near Warm Beach) and Lake Bosworth all had better mean Secchi depth than Flowing Lake, and were characterized as oligotrophic. However, mean Secchi depth at Sunday Lake was very low (6.8 feet) and the lake was considered eutrophic.

Acknowledgement

I thank Betty Williams for volunteering her time to monitor Flowing Lake during 1989-1991.

Flowing Lake -- Snohomish County

Volunteer-Collected Data

Date 1991	Temperature (°C)	(°F)	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
15-May	15.0	59.0	Lt-Brown	0	Trace	Breezy	12.4	14.7	Lake height taken from baseline at dock.
29-May	15.0	59.0	Lt-Brown	100	None	Calm	11.5	13.0	
13-Jun	17.0	62.6	Lt-Brown	50	Moderate	Breezy	12.5	13.5	Very little lake activity due to inclement weather.
27-Jun	21.0	69.8	Lt-Brown	0	None	Calm	10.5	.	
11-Jul	24.0	75.2	Lt-Brown	0	None	Light	9.6	18.0	Moderate lake activity - boaters, swimmers, ski boats.
25-Jul	28.0	82.4	Lt-Brown	100	None		9.2	19.0	Moderate activity increased due to hot weather and boaters, swimmers and ski boats.
08-Aug	25.0	77.0	Lt-Brown	10	None	Light	8.9	19.0	
22-Aug	25.0	77.0	Lt-Brown	0	None	Light	9.6	22.0	Noticeably less activity on lake due to parking restrictions at the Flowing Lake County Park. When the parking lots are full, park is closed to further occupancy.
05-Sep	22.0	71.6	Lt-Brown	0	None	Light	11.0	22.5	Lake height previous reading should have read 22". 1991 Season County Park restricted capacity. A noticeable difference in readings since park restrictions.
20-Sep	20.0	68.0	Lt-Brown	10	None	Breezy	11.9	23.0	
03-Oct	18.0	64.4	Lt-Brown	0	None	Light	11.9	24.5	
17-Oct	16.0	60.8	Lt-Brown	10	HHeavy	Light	11.0	26.0	

* Secchi data corrected for rope shrinkage.

Onsite Visit Data

Date 1991	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)	Composite Sample Depths (m)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Phosphorus (mg/L)
05/29	0.0	15.9	6.8	10.3	39	0.5, 1, 2	0.56	ND	ND
	1.0	15.1	6.8	10.0	39				
	2.0	14.8	6.8	9.9	39				
	3.0	14.4	6.8	9.7	39				
	4.0	12.5	6.6	9.0	40				
	5.0	9.9	6.3	7.2	40				
	6.0	9.1	6.2	6.8	39				
	8.0	8.3	6.1	6.3	40				
	10.0	7.5	5.9	6.1	39				
	12.0	7.2	5.9	6.1	39				
	12.5	7.2	5.7	5.9	39				

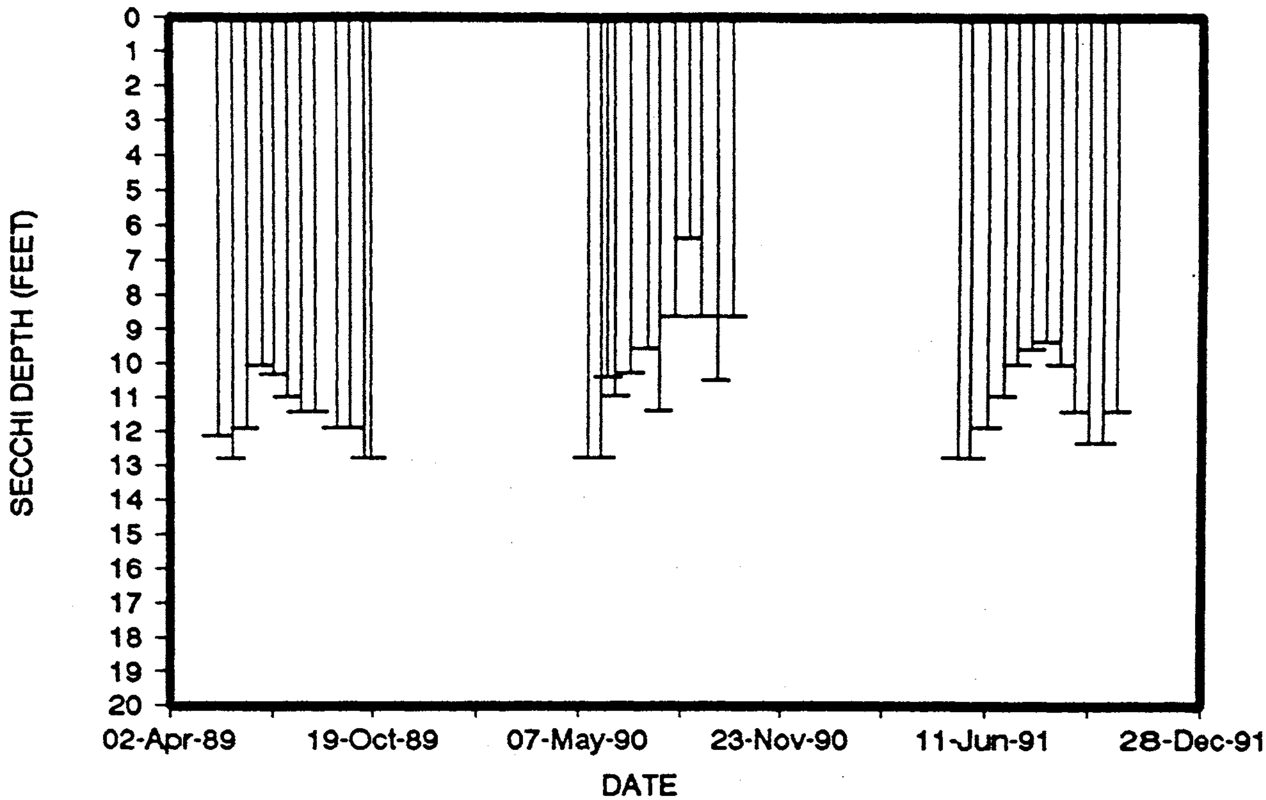
ND No data; data lost due to analytical problems

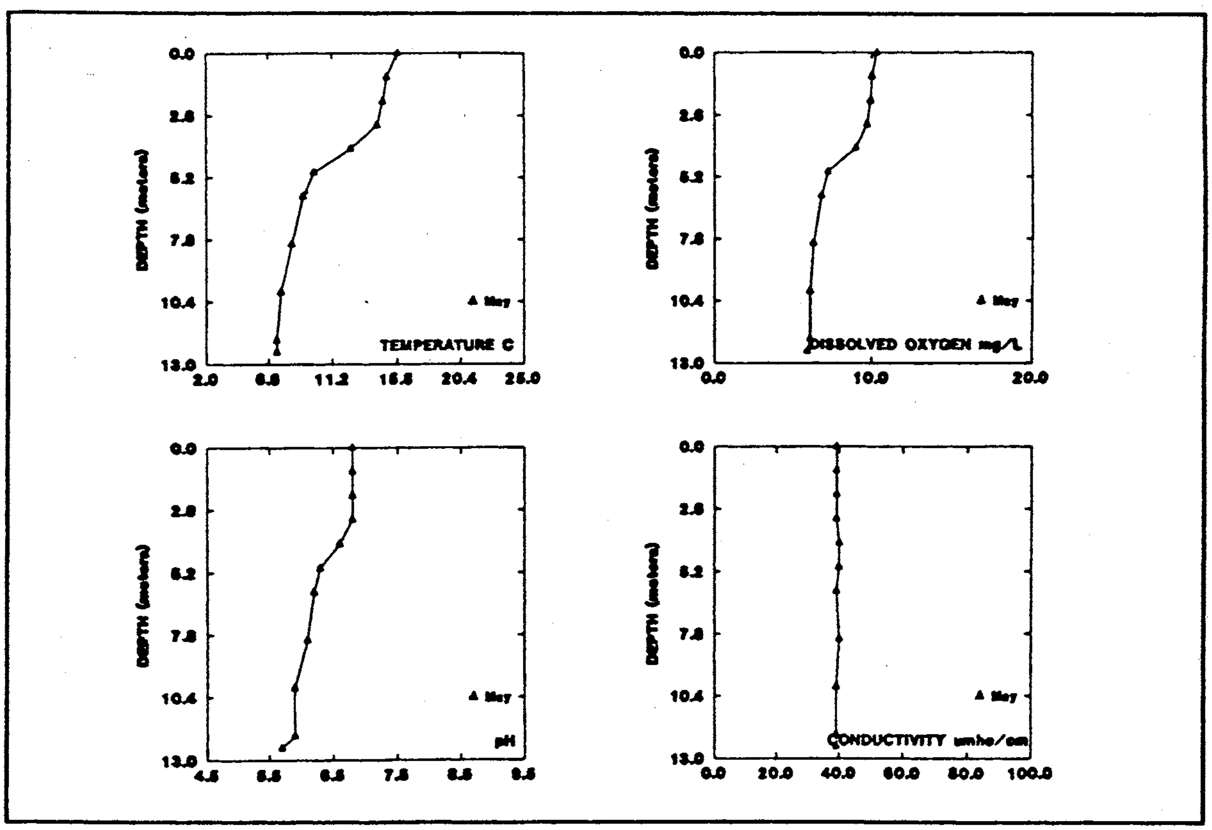
Data From Bortleson *et al.* (1976)

Date	07/23/73
Secchi (feet)	9
Total Phosphorus (mg/L)	0.007

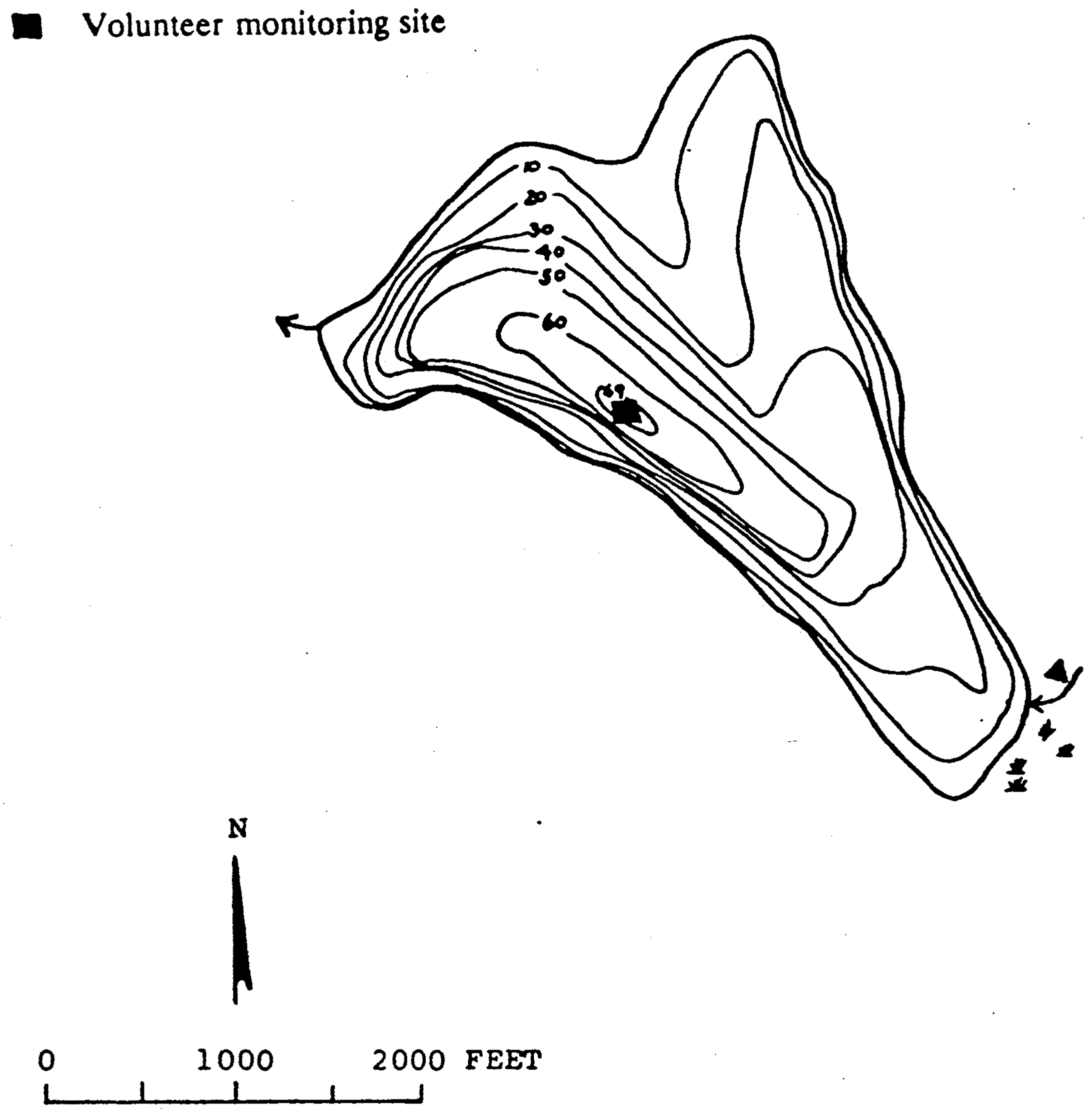
Remarks THE LAKE IS FED BY STORM LAKE. A PARK AND SWIMMING BEACH ARE LOCATED ON THE LAKE. DURING THE SUMMER RECREATIONAL USE IS HEAVY. THE LAKE HAS BEEN DREDGED ON THE NORTHEAST CORNER.

FLOWING LAKE (SNOHOMISH COUNTY)





Profile and Secchi Data Graphs



EXPLANATION

— 20 —

Line of equal water depth Interval 10 feet

Flowing Lake, Snohomish County. From Washington Department of Game, March 20, 1948.

Horseshoe Lake -- Cowlitz County

Horseshoe Lake is located on the Cowlitz-Clark County line adjacent to the town of Woodland. It was formed when US 99 (now I-5) was built in 1940, isolating a bend in the Lewis River. The acreage of the lake varies during flood seasons. Horseshoe Lake drains to the north fork of the Lewis River.

Size (acres)	85
Maximum Depth (feet)	16
Mean Depth (feet)	6
Lake Volume (acre-feet)	473
Drainage Area (miles^2)	0.4
Altitude (feet)	20
Shoreline Length (miles)	3.0

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	58

* From Carlson (1977)

<u>Summary of Questionnaire Results and Information From the Volunteer</u>

The following are from the volunteer's remarks and responses to the 1991 questionnaire. Algae growth first appears at the south end of the lake in 7 - 10 feet of water during the first week in August. Rainbow trout are stocked in the lake. The worst problems in the lake, in the opinion of the volunteer, are ranked as: 1) suspended sediments, 2) algae, 3) undesirable fish species, and 4) garbage and debris. In contrast, in 1990 the volunteer found that water odor was the worst problem in the lake. Overall, the volunteer finds that Horseshoe Lake has fair water quality, and is concerned about water quality effects from ducks, large carp, and people dumping grass clippings on the bank. The volunteer was also concerned about impending development of the lakeshore lots. The lake level was kept up thoughout the year, which was a change since the 1990 monitoring season. The University of Washington is conducting a one-year Phase I study of the lake and watershed.

In the 1990 questionnaire, the volunteer responded that Horseshoe Lake is used for fishing, boating, swimming, and rowing. Recreational facilities on the lakeshore include a park, a picnic area, a beach, and one boat ramp. Water skiing is restricted to specific times, and no jet skis are allowed on the lake. Lake water is withdrawn for irrigation. Currently the watershed is used for animal grazing and crop agriculture. In the past the watershed was used for animal grazing and crop agriculture, the lake was dredged and the shoreline was altered. There are 19 houses on the lakeshore, and all are occupied year-round. The lakeshore is 50% sewered, and there are five storm drains that empty into the lake. There is a community association for the lake. There is a slaughterhouse, a trucking company and a welding shop on the lakeshore. There were no submerged weeds or lily pads growing in the lake. Algae blooms were not localized in any area. The lake depths on the 1947 Department of Game map are not accurate. A water quality study was conducted in 1988-89 by the Cowlitz County Conservation District.

Monitoring Results/Summary of Other Available Information

The volunteer has monitored Horseshoe Lake for the program since 1990. Data from 1990 are reported in Rector (1991).

Volunteer-collected data show that in 1991 Secchi depth ranged from 2.0 to 11.5 feet. Secchi depth was lowest on July 1 and highest on May 16. Except for the one relatively deep Secchi reading in 1991, the pattern in water clarity was very similar in 1991 and 1990.

Ecology staff collected water samples and profile data from Horseshoe Lake on June 21, 1991. The profile data show that the lake was not stratified, and both pH and dissolved oxygen decreased from surface to bottom. Temperature, dissolved oxygen and conductivity profiles were very similar in June 1991 and May 1990. Although late summer profile data were not collected in 1991, the August 1990 profiles showed that pH and dissolved oxygen both increased at 1-2 meters, and then decreased considerably. The lower pH and dissolved oxyen near the lake bottom was most likely related to decomposition of organic material (such as algae, aquatic plants and woody debris) in the water and sediments.

Total nitrogen in 1991 (0.30 mg/L) was similar to the May 1990 concentration (0.32 mg/L; 0.49 mg/L was measured in August). Samples were collected in 1991 for total phosphorus and chlorophyll *a*, but the data could not be used due to analytical problems. In 1990, total phosphorus was high (0.038 mg/L in May and 0.035 mg/L in August). Published data from 1973 showed much higher concentrations of total phosphorus (0.073 mg/L; Bortleson *et al.*, 1976) than in 1990.

During the August 1990 onsite visit with the volunteer, large particles and clumps of algae were observed in the water. An algal sample sent in by the volunteer (date unknown) was badly decomposed, but may have been *Aphanocapsa*, a genus of blue-green algae.

From Canning *et al.* (1975): The lake has a history of lake management concerns. When the lake was connected to the Lewis River with culverts, it was thought that this would be enough to prevent stagnation of the lake. However, the lake still stagnated. In 1957 a pumping system was installed by the State Department of Highways to feed Lewis River water into the lake. In 1961, the Department of Highways dredged the lake at the north end and installed a new system to actively pump water into the lake. In 1964 the Lewis River flooded and deposited about 50,000 cubic meters of silt and debris (backwashed from the local dump) into the south part of the lake. Because of public health concerns, Horseshoe Lake was studied during 1974-1975 to investigate the distribution, relative abundance and potential sources of bacteria in the lake. The study concluded that the lake was not "polluted" and that there were no significant sources (including the Lewis River) of nutrients or bacteria to the lake; the quality of Lewis River water was suspected to be better in some respects than the lake water. Researchers suspected that the upgraded sewage treatment plant for the city of Woodland reduced nutrient and bacteria loading into the lake from wastewater, and sediments were cited as the primary source of nutrients to the lake. Ducks and geese were cited as the main sources of fecal coliform bacteria in the lake, although fecal coliform bacteria counts did not exceed state standards at any point during the study period. The study recommended pumping river water into the lake to maintain a constant lake level.

From Somers (1989): In 1981, the pump was replaced with one that had a greater capacity. The pump was running during 1988-1989 when the Cowlitz County Conservation District studied the lake. During the study period, none of the Lewis River stations exceeded state Class A standards, although two stations near Horseshoe State Park, a stormwater station (during rain events), a station near the cattle lot, and other south end lake stations had high fecal coliform bacteria counts that exceeded state standards. Secchi depth measured from the North Arm of the lake ranged from 2.25 - 4.5 feet, indicating that the lake was eutrophic. The lowest readings were in September 1988 and April 1989, and highest readings were in August 1988 and February 1989.

A Centennial Clean Water Fund grant was awarded for the University of Washington to study Horseshoe Lake. The following is from Whiley (1991): Lewis River water is now pumped continuously into the lake at the rate of about 4000 gallons per minute. Four lake stations, six stormwater stations and twenty wells (located near the lake) are monitored for the study. Lake station data collected from April through August 1991 show that Secchi depths were lowest during June and July, and highest during May. Secchi depths for all lake stations ranged from 0.6 meters on July 5, to 2.9 meters on May 24. Total phosphorus at the surface was in the eutrophic range for all lake stations (concentrations ranged from 12.5 to 36.1 μg/L from April through July). In general, total phosphorus concentrations were highest at station 3, which is located at the south end of the lake, about 250 - 300 meters from the outlet. Chlorophyll *a* concentrations at the lake surface ranged from 0.0 to 80.2 μg/L. Highest concentrations occurred during June and July, when there was a blue-green algal bloom. Other parameters measured in the lake include nitrate, ammonia, alkalinity, temperature, dissolved oxygen, conductivity, pH, turbidity and seston. Ground water elevation is measured using the wells. Stormwater sampling results were not presented.

Comments

Because the trophic state index (TSI) for Secchi data was calculated using data only from June - September 1991, the one high reading in May 1991 did not affect the TSI. As a result, TSI(Secchi) values for 1991 and 1990 (58 and 57, respectively) were very close.

Horseshoe Lake -- Cowlitz County

The following is from the 1990 data summary. Compared to other lakes monitored for the program, Horseshoe Lake was very unusual in its physical shape and dependence on pumped river water for maintaining its lake level. Because the lake receives unfiltered Lewis River water, some suspended solids from the river will settle in the lake. In this respect, the lake serves as a settling pond for solids from the Lewis River. Concerns among the local users of the lake include past reports of high fecal coliform levels in the lake, bad odors that occur during certain times of the year, maintaining the lake level, improving the quality of the Lewis River water that is pumped into the lake, and keeping the lake at a quality that can be used for contact recreation. Presently, the Horseshoe Lake Management Committee is working towards reducing loading from stormwater, educating the public about reducing nonpoint source pollution within the lake's watershed, improving the shoreline near the cattle lot, and ensuring that discharges and runoff into the lake are done properly, legally and with a minimum of impact to lake quality.

Acknowledgement

I thank Timothy Chase for volunteering his time to monitor Horseshoe Lake during 1990 - 1991.

Horseshoe Lake -- Cowlitz County

Volunteer-Collected Data

Date 1991	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(ft)	Abbreviated Comments
16-May	16.7	62.0		Green	0	None	Light	11.5	11.10	Cottonwood just beginning to bloom. Water flowing over overflow.
17-Jun	16.1	61.0	6.5	Pea-Green	90	Light	Calm	4.0	0.00	
01-Jul	20.0	68.0	8.5	Pea-Green	0	None	Light	2.0	7.20	
19-Jul	20.0	68.0	7.0	Milky-Gr	100	None	Light	3.0	8.20	Blue-green algae bloom now over with.
01-Aug	22.2	72.0	6.5	Pea-Green	50	Light	Light	6.0	8.20	
13-Aug	21.1	70.0	7.0	Gr-Brown	25	None	Breezy	4.2	7.80	Another bloom has occurred. A developer has removed all vegetation from about 400' of bank - violation of shorelines?
30-Aug	20.0	68.0		Gr-Brown	75	Light	Breezy	4.5	8.20	
14-Sep	17.2	63.0	6.0	Green	0	Trace	Calm	3.5	8.40	

Onsite Visit Data

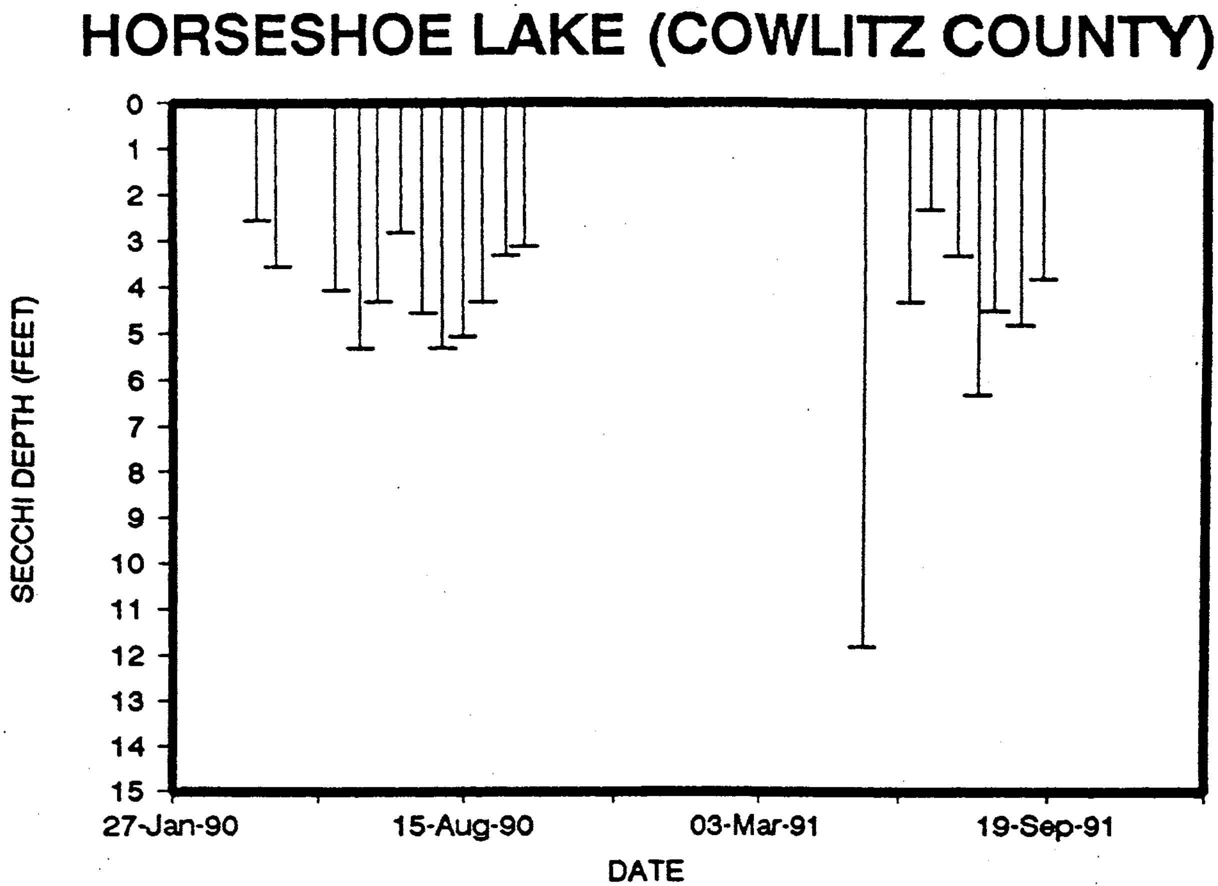
Date 1991	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Composite Sample Depths (m)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Phosphorus (mg/L)
06/21	0.0	18.5	8.7	11.9	40	1, 3, 4	0.30	ND	ND
	1.5	17.5	8.9	12.2	41				
	1.0	17.0	8.9	12.2	41				
	1.5	16.9	8.9	11.8	40				
	2.0	16.7	8.6	10.8	40				
	2.5	16.5	8.3	10.5	40				
	3.0	16.5	8.3	10.5	39				
	3.5	16.4	8.4	10.7	39				
	4.0	16.4	8.4	10.8	39				
	4.5	16.4	8.5	10.8	39				
	5.0	16.3	8.5	10.8	39				
	5.5	16.3	8.4	10.6	39				

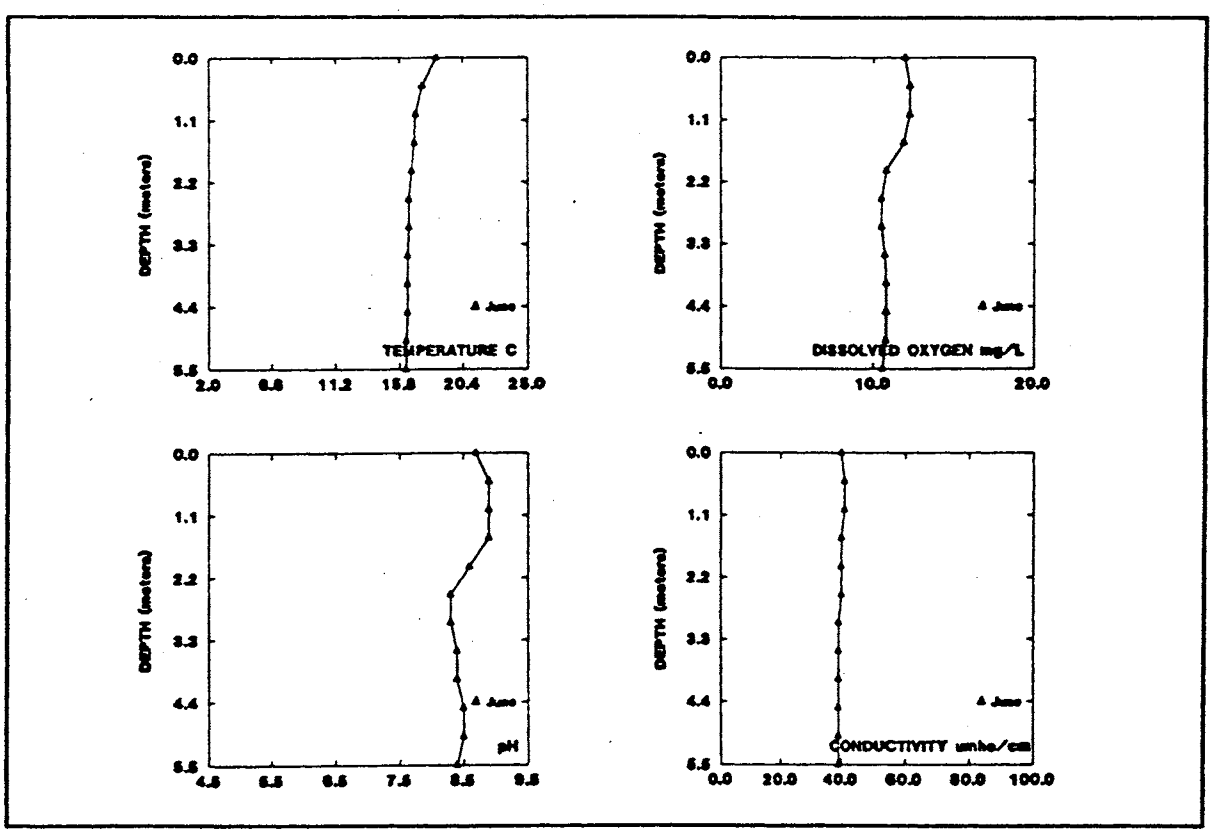
ND No data; data lost due to analytical problems

Data From Bortleson *et al.* (1976)

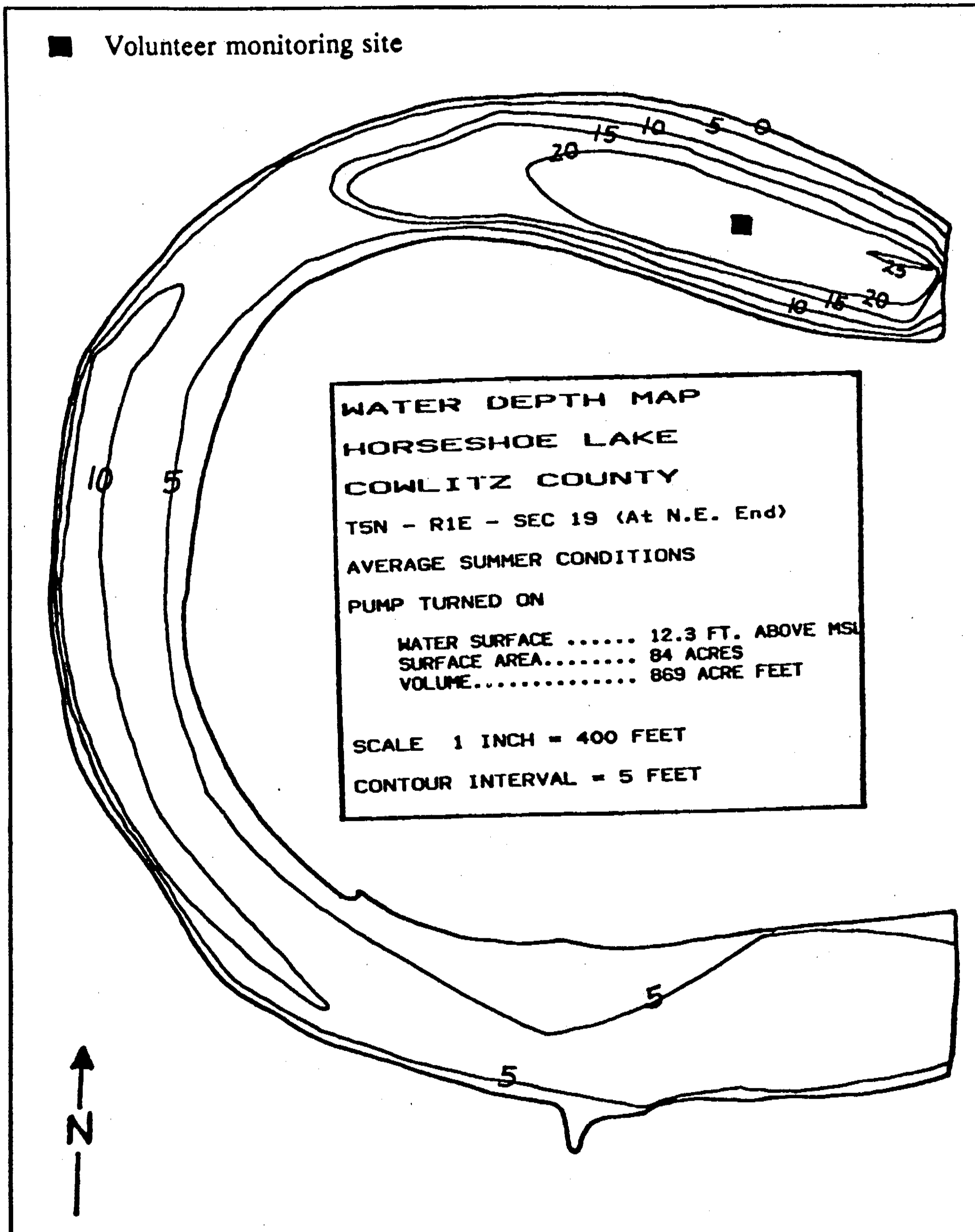
Date	09/12/74
Secchi (feet)	2
Total Phosphorus (mg/L)	0.073

Remarks AN OXBOW LAKE (OLD RIVER CHANNEL OF LEWIS RIVER) DIKED BY A HIGHWAY FILL. THE LAKE IS ON THE SOUTH SIDE OF THE TOWN OF WOODLAND AND LIES IN BOTH CLARK AND COWLITZ COUNTIES. A CITY PARK AND SWIM AREA ARE LOCATED ON THE NORTH SIDE OF THE LAKE.





Profile and Secchi Data Graphs



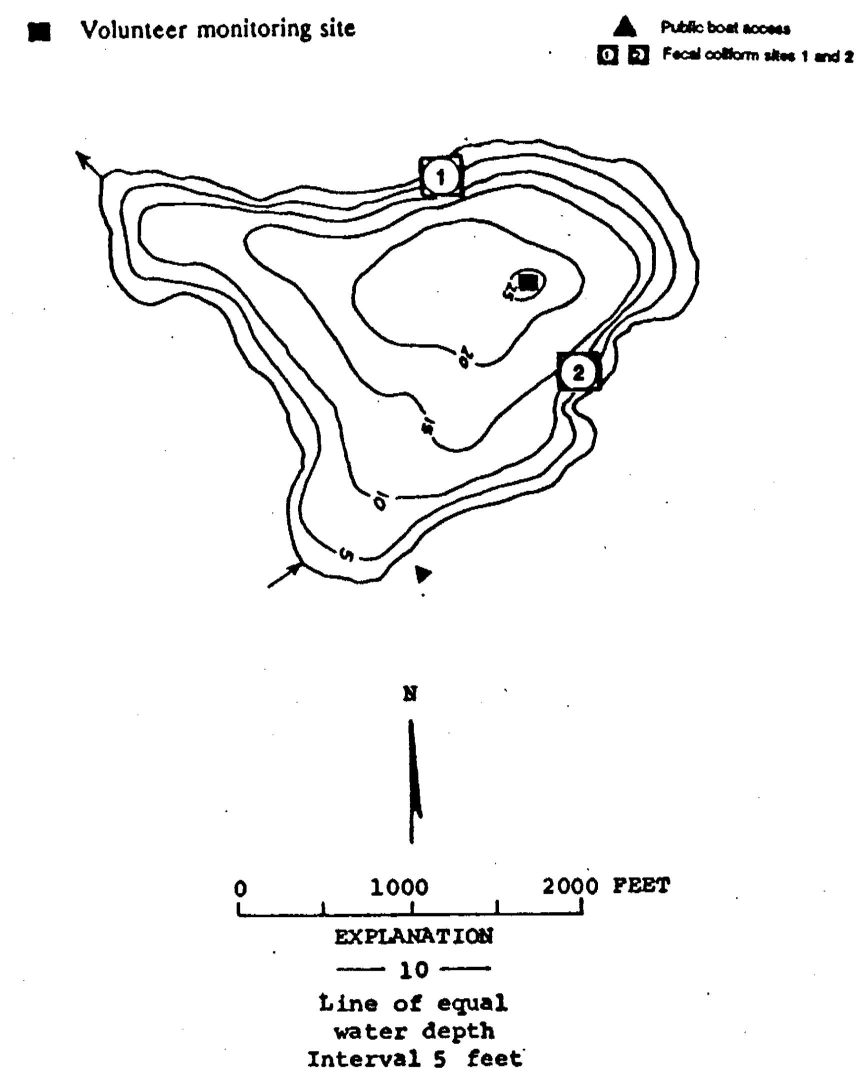
Map reproduced from <u>Horseshoe Lake Water Quality Study 1988 - 1989</u> (Somers, 1989).

Jumpoff Joe Lake -- Stevens County

Jumpoff Joe Lake is located 10 miles south from Chewelah and six miles northeast from Springdale. It is fed by an unnamed inlet, and drains via Jumpoff Creek to the Colville River.

Size (acres)	110
Maximum Depth (feet)	25
Mean Depth (feet)	13
Lake Volume (acre-feet)	1400
Drainage Area (miles^2)	15.3
Altitude (feet)	2031
Shoreline Length (miles)	1.9

Data From Dion *et al.* (1976)



Jumpoff Joe Lake, Stevens County. From Washington Department of Game, date unknown.

Jumpoff Joe Lake -- Stevens County

1992 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	46
Mean Trophic State Index (Total Phosphorus):	43
Mean Trophic State Index (Chlorophyll *a*):	42

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
12-May				13.5						Onsite visit.
31-May	1330	22.2	72.0	9.5		Mint	10	None	Calm	Water color "mint".
21-Jun	1600	24.4	75.9	10.0		Mint	0	None	Light	Water color "mint".
30-Jul	1400	25.6	78.1	6.0		Apple-Green	0	None	Calm	Lots of yellow pollen on the surface (collecting near docks).
25-Aug	1400			7.7						Onsite visit.
04-Oct	1500	16.1	61.0	6.4		Mint	40	Moderate	Light	Water color gray-green.

[1] Trophic State Indices calculated from Carlson (1977)

Jumpoff Joe Lake -- Stevens County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/12	0.0	16.5	8.8	12.7	201
	1.0	16.3	9.0	12.8	202
	2.0	16.1	9.1	12.9	202
	3.0	15.9	9.1	13.4	201
	4.0	15.8	9.2	13.6	201
	4.5	15.8	9.2	13.8	200
08/25	0.0	19.9	8.9	9.8	204
	1.0	19.5	9.0	9.5	203
	2.0	19.4	9.0	9.6	203
	3.0	19.2	9.0	9.7	204
	4.0	19.1	9.0	9.7	204
	5.0	19.1	9.1	10.1	203

1992 Onsite Visit Data - Water Chemistry

Date	05/12/92		08/25/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2.5, 4		1, 2.5, 4	
Total Phosphorus (μg/L)	10		19	
Total Nitrogen (mg/L)	0.25		0.55	
Chlorophyll *a* (μg/L)	0.80		5.57	
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	<1		<1	
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	<1		<1	
Total Suspended Solids (mg/L)	2		5	
Total Nonvolatile Suspended Solids (mg/L)	1		2	
Color (Pt-Co units)	20		--	

Jumpoff Joe Lake -- Stevens County

Historical Data From Ecology

Date	07/08/74[a]	06/20/89[b]	09/19/89[b]
Secchi (ft)	12	8.5	7.2
Total Phosphorus, epilimnion (μg/L)	14	13	17
Total Nitrogen, epilimnion (mg/L)	--	0.29	0.44
Chlorophyll *a* (μg/L)	--	2.6	4.6
Dissolved Oxygen, surface (mg/L)	11.6	12.3	11.7
Dissolved Oxygen, bottom (mg/L)	12.6	13.9	12.7

a. Dion *et al.* (1976)
b. Brower and Kendra (1990)

Jumpoff Joe Lake -- Stevens County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was fair to good, as indicated by Secchi depths which ranged from 6 feet to 13.5 feet. Most Secchi depths were in the mesotrophic range.

Total Phosphorus
Phosphorus was low during May (10 μg/L), and moderately high during August (19 μg/L). Values were similar to those measured in 1989 (14 μg/L in June, and 17 μg/L in September; Brower and Kendra, 1990).

Total Nitrogen
Total nitrogen was not high, although the August value (0.55 mg/L) was considerably higher than the May value (0.25 mg/L). In 1989, values were also lower during spring than during late summer.

Fecal Coliform Bacteria
No fecal coliforms were detected in any of the fecal coliform bacteria samples taken.

Solids and Color
Solids samples indicate that there were more particles in the water during August than during May, and that the majority of the particles were organic (such as algae), as opposed to nonorganic (such as suspended sediments). This indicates that Secchi depths were more likely affected by algal growth at the time of sampling, rather than by suspended sediments. The lake water was somewhat colored.

Profile Data
The lake was not stratified on either sampling date, so there was little change in profile parameters from surface to bottom. The increase in dissolved oxygen with depth was probably from the prolific growth of submerged aquatic plants in the lake; like terrestrial plants, actively photosynthesizing aquatic plants will use carbon dioxide, and release oxygen. Similar profile data, including the increase in dissolved oxygen with depth, was also reported in 1989 (Brower and Kendra, 1990).

Plants
Chlorophyll *a* was low during May, indicating that there was little algal growth at the time of sampling. During August, though, there was much more algal growth (as indicated by higher chlorophyll *a*). Results from Secchi data and the solids samples also suggest that there was more algal growth during August than during May.

Aquatic plants identified by Ecology staff during the May 12, 1992 onsite visit with the volunteer include coontail (*Ceratophyllum demersum*), waterweed (*Elodea canadensis*), and milfoil (*Myriophyllum* spp., but not the aggressive Eurasian variety). During the August 25, 1992 onsite visit, the lake water color was bright green, and a soft brown highly organic muck came up with the anchor.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1992 questionnaire.

> Jumpoff Joe Lake is used for fishing, swimming, motor boating, lakeshore camping, and waterfowl hunting. There is one resort on the lakeshore. There is one public boat ramp, and there are no restrictions for motorboating on the lake. About 10 percent of the shoreline is publicly-owned. Eastern brook, brown, and Kootenai trout were stocked in the lake. Currently, the watershed is used for logging, crop agriculture, and animal grazing/feeding. The lakeshore is also being developed further for residences. In the past, the watershed was used for logging, crop agriculture, and animal grazing/feeding, and the shoreline was altered.
>
> There are about 19 houses on the lakeshore, and none of the houses are connected to a sewer. There is no lake association for the lake. Lake water is withdrawn for irrigation.
>
> Overall, the volunteer finds that Jumpoff Joe Lake had good water quality. Problems in the lake in 1992 were ranked as 1) impaired fisheries, 2) excessive aquatic plant growth, 3) degraded aesthetics, and 4) low water level. Possible sources of problems are the type and quantity of fish stocked in the lake, aquatic plant growth, and the small lake size warrants a boat speed restriction.

Comments

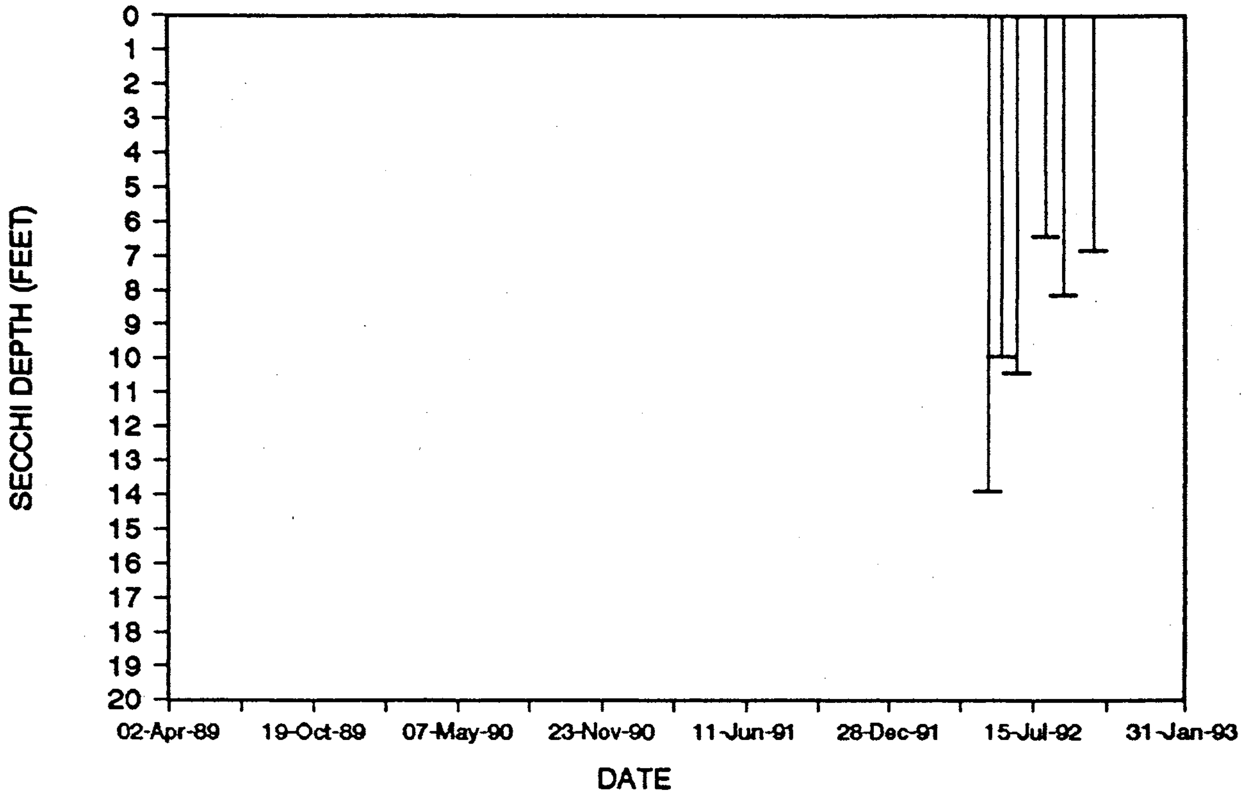
Jumpoff Joe Lake was estimated as mesotrophic based on the moderate values for mean Secchi depth, total phosphorus, and chlorophyll *a*, as well as the prolific plant growth.

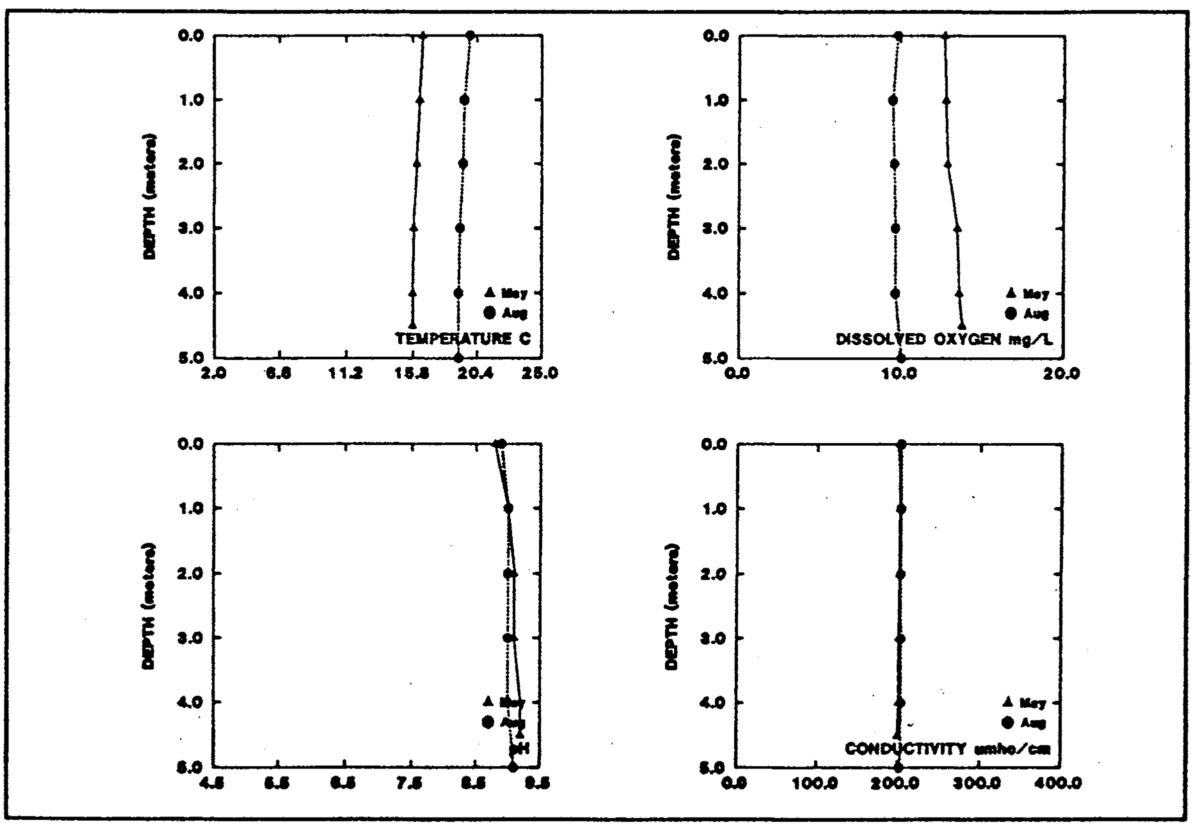
Other Stevens County lakes monitored for the program in 1992 are Black, Deer, Thomas, and Waitts. In comparison with these lakes, only Deer Lake had lower total phosphorus concentrations, but Jumpoff Joe Lake had the lowest mean summer water clarity.

Acknowledgement

I thank Lu Caudill for volunteering her time to monitor Jumpoff Joe Lake during 1992.

JUMPOFF JOE LAKE (STEVENS COUNTY)



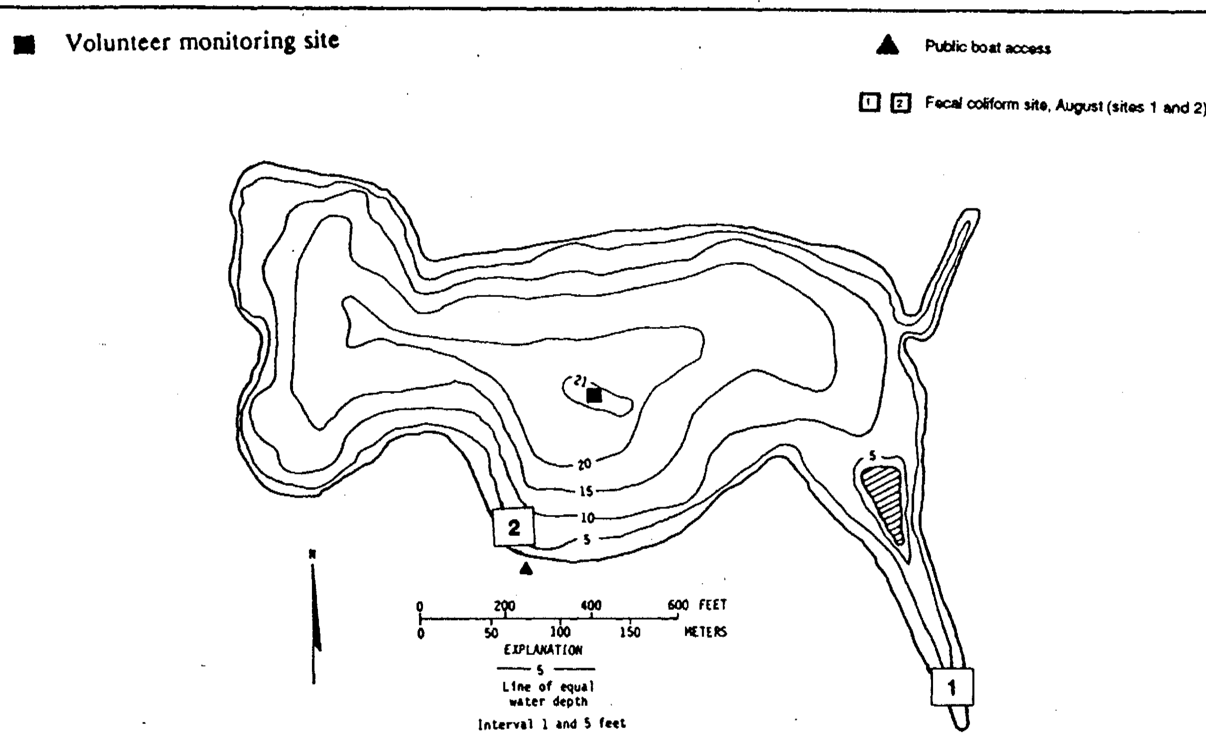


Lake Ketchum -- Snohomish County

Lake Ketchum is located three miles north from Stanwood. It is fed by two unnamed intermittent inlets, and drains via an unnamed intermittent outlet to Skagit Bay.

Size (acres)	24
Maximum Depth (feet)	21
Mean Depth (feet)	12
Lake Volume (acre-feet)	296
Drainage Area (miles^2)	0.5
Altitude (feet)	190
Shoreline Length (miles)	1.3

Data From Sumioka and Dion (1985)



Ketchum Lake, Snohomish County. Photo taken July 9, 1981, view southwesterly.
Bathymetric map from U.S. Geological Survey, June 15, 1981.

Lake Ketchum -- Snohomish County

1992 Trophic Status[1]

Estimated Trophic State:	Eutrophic
Mean Trophic State Index (Secchi):	54
Mean Trophic State Index (Total Phosphorus):	95
Mean Trophic State Index (Chlorophyll *a*):	54

Volunteer-Collected Data

Date 1992	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
18-May				3.5						Onsite visit.
03-Jun	1900	23.3	73.9	6.0	14.00	Lt-Brown	0	None	Calm	Lake treated with copper sulfate on 5/30/92. Surface growth seems to be sinking.
18-Jun	1700	23.3	73.9	5.5	13.00	Lt-Brown	0	None	Breezy	Lake treated with Endothall 6/17/92.
28-Jun	0830	23.9	75.0	6.5	14.50	Lt-Brown	10	None	Light	
18-Jul	1800	25.6	78.0	6.0	12.00	Lt-Brown	25	None	Breezy	
02-Aug	1800	23.3	74.0	4.5	14.00	Lt-Brown	0	None	Breezy	Heavy vegetation bloom occurred earlier this week, now floating.
20-Aug	1700	24.4	76.0	6.5	17.00	Lt-Brown	0	None	Breezy	Large scale duck weed bloom in progress.
27-Sep	1600	16.7	62.0	4.5	22.00	Lt-Brown	0	Moderate	Breezy	The duckweed bloom has died and sank. Minimal new growth of duckweed.
25-Oct	1000	13.3	56.0	4.00	24.00	Lt-Brown	50	Light	Breezy	Lake level very low. Old duckweed pushed to shore by wind, taking root on beach. Minimal new duckweed bloom.

[1] Trophic State Indices calculated from Carlson (1977)

Lake Ketchum -- Snohomish County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/18	0.0	21.0	10.2	16.1	154
	1.0	20.2	10.2	16.6	153
	2.0	16.2	9.3	10.9	137
	2.5	15.5	8.5	9.4	137
	3.0	14.1	7.4	0.6	146
	4.0	12.3	7.4	0.2	155
	5.0	9.6	7.2	0.1	170
	6.0	8.8	6.9	0.1	182
08/31	0.0	21.5	7.8	9.1	153
	1.0	21.3	7.8	8.9	152
	2.0	20.3	7.7	4.9	153
	3.0	17.2	7.4	0.2	179
	4.0	13.0	7.1	0.2	220
	5.0	10.7	6.6	0.1	263

1992 Onsite Visit Data - Water Chemistry

Date	05/18/92		08/31/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	0.5, 1	5, 6	1, 2	4, 4.5
Total Phosphorus (μg/L)	592	2342	460	3095
Total Nitrogen (mg/L)	1.12	2.44	1.11	3.43
Chlorophyll *a* (μg/L)	9.16		13.35	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	--	--	2	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	--	--	1	--
Total Suspended Solids (mg/L)	--	--	4	--
Total Nonvolatile Suspended Solids (mg/L)	--	--	<1	--
Color (Pt-Co units)	--	--	60	--

Lake Ketchum -- Snohomish County

Historical Data From Ecology

Date	07/09/81[a]
Secchi (ft)	10
Total Phosphorus, epilimnion (μg/L)	190
Total Nitrogen, epilimnion (mg/L)	1.6
Chlorophyll *a* (μg/L)	1.98
Dissolved Oxygen, surface (mg/L)	7.2
Dissolved Oxygen, bottom (mg/L)	0.0

a. Sumioka and Dion (1985)

Lake Ketchum -- Snohomish County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was poor, as indicated by shallow Secchi depths which ranged from 3.5 to 6.0 feet. None of the Secchi depths were as deep as the only other available reading from an earlier study (10 feet; Sumioka and Dion, 1985).

Total Phosphorus

Total phosphorus was very high and in the hyper-eutrophic range on both sampling dates (592 μg/L in May, and 460 μg/L in August). No other lake sampled since the program began in 1989 had phosphorus concentrations this high. Plant and algae problems are inevitable because of the high phosphorus content of the lake. The phosphorus concentration from 1981 was also high and in the hyper-eutrophic range (190 μg/L; Sumioka and Dion, 1985).

Internal loading of phosphorus from the sediments is probably a very large source of phosphorus to the water column. Internal loading may result in extremely high phosphorus concentrations near the lake bottom, particularly during late summer, and is often suspected when dissolved oxygen concentrations are completely depleted in the hypolimnion (bottom layer of water). Oxygen depletion in the hypolimnion was measured during both onsite visits with the volunteer. Also, the oxidation-reduction potential (redox) was measured while profile data were collected, although these data are not reported in the profile data table. Redox values decreased by 200 volts from surface to bottom on both sampling dates, with the bottom of the lake having redox values from -140 to -181 volts. Reduction, the chemical process that results in phosphorus being released from the sediments, occurs when redox values are less than 0 volts. Since measuring redox with a probe is not always reliable, only values less than -50 were assumed to indicate reducing conditions.

Total Nitrogen

Total nitrogen concentrations were also very high (1.1 mg/L on both sampling dates), but were somewhat lower than the value reported in 1981 (1.6 mg/L; Sumioka and Dion, 1985). Relative to the concentrations of total phosphorus, though, the proportion of total nitrogen was very low. Algal growth in Lake Ketchum is most likely limited by the amount of nitrogen in the water; if nitrogen concentrations increase, algal growth will increase also.

Fecal Coliform Bacteria

Fecal coliform bacteria samples were collected from two sites during August. Results were very low, and were within state standards. Samples were collected from near the inlet and near the public boat access.

Solids and Color

Lake Ketchum had a relatively high amount of suspended solids during August, in comparison with other lakes monitored for the program, which was probably due to algae and duckweed in the water. A color sample collected during August indicates that the lake is colored, although whether the source of the color is from algae, as opposed to the watershed geology, cannot be determined.

Profile Data

Although temperature decreased considerably from surface to bottom on both sampling dates, there is no clear distinction between the epilimnion and hypolimnion. Dissolved oxygen, pH, and conductivity data, though, did indicate that the lake was stratified. The very low dissolved oxygen below 3 meters probably resulted from bacterial decomposition of organic material (such as aquatic plants and algae) in the water and sediments. This same process may result in the decrease in pH, and increase in conductivity, which were also seen in the lake.

During the May 1992 onsite visit, the hypolimnion samples (collected from 5m and 6m depths) were yellowish and smelled of hydrogen sulfide. Hydrogen sulfide is produced by bacteria in the absence of oxygen.

Plants

Chlorophyll *a* was very high on both sampling dates, showing that there was a lot of algal growth at the time of sampling.

During May, a filamentous algae was prolific in the lake; a sample was identified as water net (*Hydrodictyon* spp.). This alga reproduces very rapidly. Other aquatic plants identified during the May visit were duckweed (*Lemna* spp.), which was growing with the filamentous algae along the shore, cattails (*Typha* spp.), and yellow-flowering lily (*Nuphar polysepalum*). During August, duckweed was the predominant plant in the lake; it covered the lake's surface in places, and was extremely thick (about 1 inch) nearshore.

The chlorophyll *a* sample from July 1981, 1.98 μg/L (Sumioka and Dion, 1985), was low and in the oligotrophic range.

Summary of Questionnaire Results and Information From the Volunteer

The questionnaire on lake and watershed uses was not returned.

Comments

Lake Ketchum is eutrophic and needs to have the sources of phosphorus and nitrogen into the lake investigated and identified, so that those sources can be controlled. It is very important, though, that the present state of nitrogen limitation be considered when the nutrient sources are controlled; if phosphorus concentrations decrease while nitrogen remains the same, algal growth in the lake could remain unchanged. For effective control of algae in the lake, control of both nitrogen and phosphorus should be addressed in any lake management strategy for the lake.

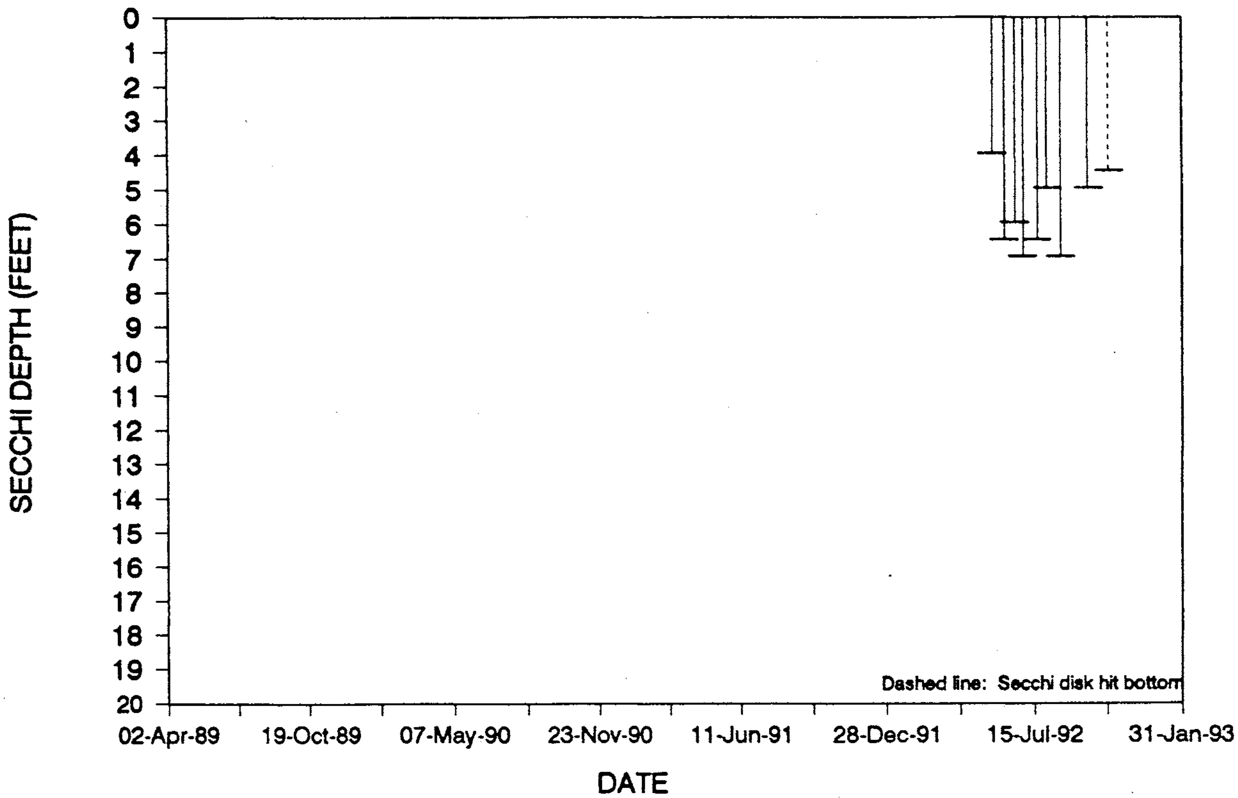
When the lake was sampled during May, a large bloom of water net was occurring. To control plants and algae, the lake was treated with copper sulfate at the end of May, and with endothall during June. By August, the duckweed bloom began and completely covered the lake.

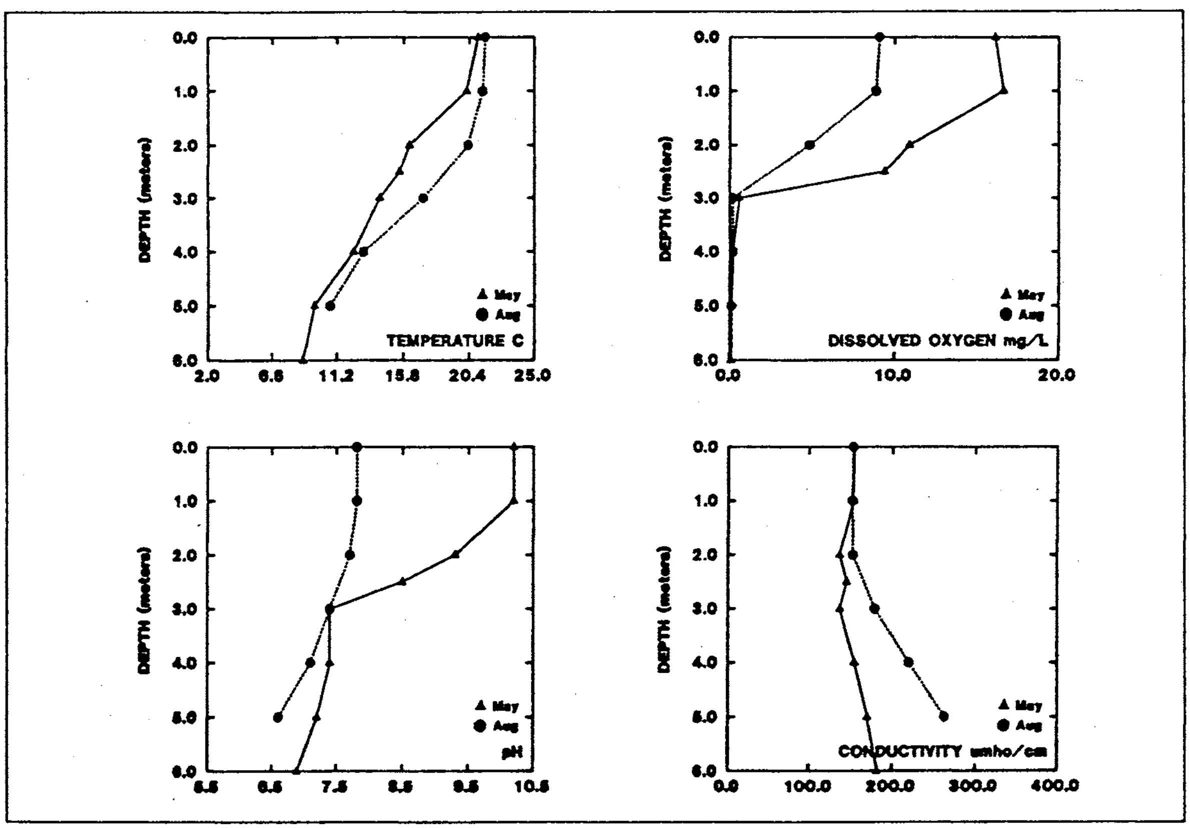
During the August onsite visit, the volunteer mentioned that earlier in the month some residents briefly opened the control weir, in order to flush some of the duckweed downstream (note that in the volunteer-collected data, the lake level decreased 5 inches from August 20 to September 27).

Acknowledgement

I thank Anton Ehinger for volunteering his time to monitor Lake Ketchum during 1992.

LAKE KETCHUM (SNOHOMISH COUNTY)



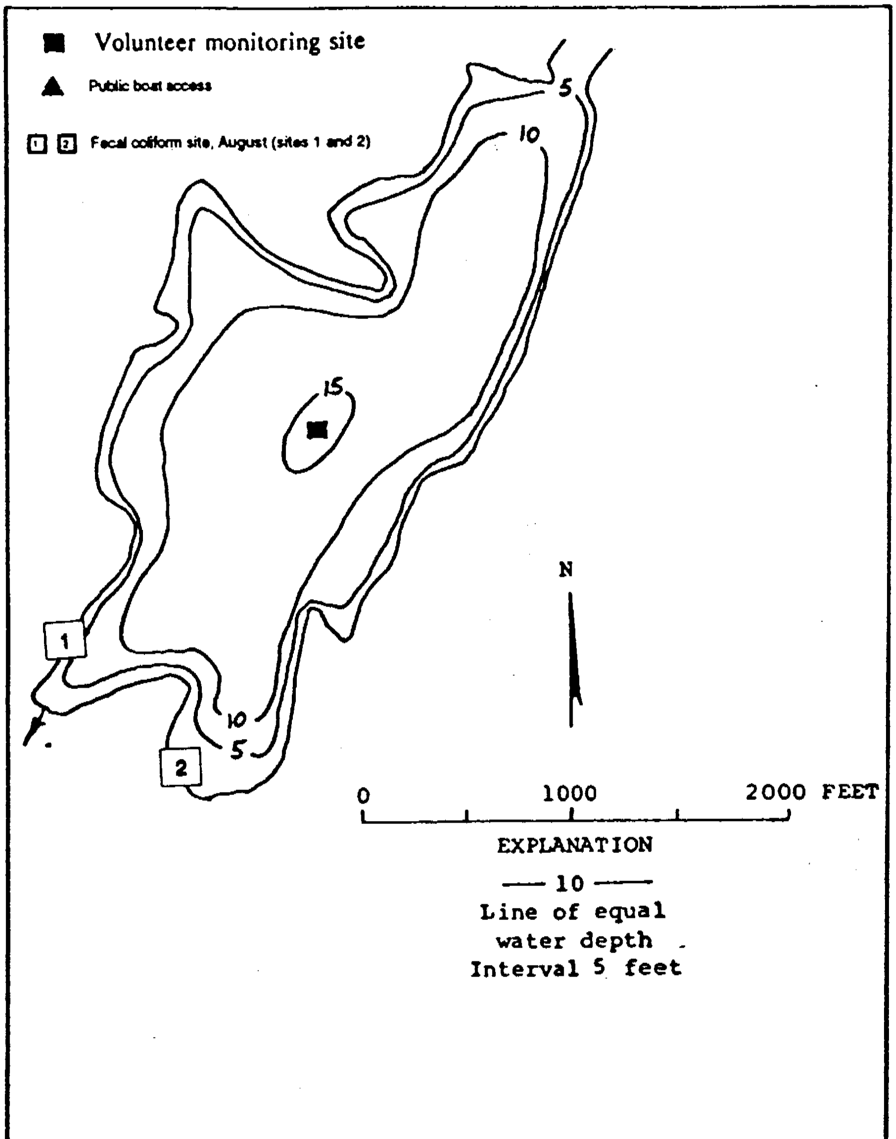


Lake Killarney -- King County

Lake Killarney is located 3.5 miles southwest of Auburn. It drains via Hylebos Creek to Commencement Bay. The volunteer monitored the south arm of the lake; the size of the south arm is 24 acres.

Size (acres)	46
Maximum Depth (feet)	15
Mean Depth (feet)	9
Lake Volume (acre-feet)	230
Drainage Area (miles^2)	0.2
Altitude (feet)	385
Shoreline Length (miles)	1.3

Data From Bortleson *et al.* (1976)



Killarney (South Arm) Lake, King County.
From Washington Department of Game, February 1, 1949.

Lake Killarney -- King County

1992 Trophic Status[1]

Estimated Trophic State:	Eutrophic[2]
Mean Trophic State Index (Secchi):	49
Mean Trophic State Index (Total Phosphorus):	57
Mean Trophic State Index (Chlorophyll *a*):	43

Volunteer-Collected Data

Date 1992	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
11-May				6.0						Onsite visit.
01-Jun	1130	22.8	73.0	7.7	-5.50	Gr-Brown	100	None	Light	No lake treatment as yet. Green algae is growing good. Pondweed is spreading. Lake height dropped 5.5".
16-Jun	1315	19.4	67.0	6.7	-8.50	Gr-Brown	100	Trace	Calm	Several days of rain last week. Cooler temps.
01-Jul	1300	24.4	76.0	5.7	-11.00	Gr-Brown	50	Moderate	Light	Been hot and dry until Sunday 28th. Rained Sun night and Monday, overcast last two days.
16-Jul	1330	24.4	76.0	6.5	-13.00	Gr-Brown	0	None	Light	Rain during the first two weeks of July has kept lake level up.
31-Jul	1100	25.0	77.0	7.7	-16.50	Gr-Brown	0	None	Calm	Algae growth has increased. Hope to treat today.
18-Aug	1345	26.0	78.8	8.0	-19.50		0	None	Light	
01-Sep	1415	23.5	74.3	6.7	-22.75	Gr-Brown	0	None	Light	
14-Sep	1200	17.5	63.5	8.0	-25.00	Gr-Brown	90	None	Light	
02-Oct	1245	17.0	62.6	8.3	-26.00	Lt-Green	100	None	Calm	
14-Oct	1500	16.0	60.8	8.0	-27.00	Gr-Brown	10	Trace	Calm	

[1] Trophic State Indices calculated from Carlson (1977)

[2] see Comments section

Lake Killarney -- King County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/11	0.0	17.0	6.9	8.9	43
	0.5	17.0	6.8	8.9	43
	1.0	16.4	6.8	8.8	43
	1.5	16.1	6.8	8.8	43
	2.0	16.0	6.8	8.8	43
	2.5	15.9	6.8	8.4	43
	3.0	15.6	6.7	7.6	43
	3.5	14.7	6.4	1.2	49
08/19	0.0	25.0	7.5	8.4	57
	0.5	24.7	7.4	8.3	58
	1.0	24.1	7.5	8.3	58
	2.0	22.7	7.5	5.8	58
	2.5	21.6	7.3	1.4	60
	3.0	21.0	7.4	0.6	61

1992 Onsite Visit Data - Water Chemistry

Date	05/11/92		08/18/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 2.5	--	0.5, 1	2.5, 3
Total Phosphorus (μg/L)	38	--	39	50
Total Nitrogen (mg/L)	0.72	--	0.52	0.56
Chlorophyll *a* (μg/L)	4.86		2.50	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	--	--	8	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	--	--	6	--
Total Suspended Solids (mg/L)	--	--	4	--
Total Nonvolatile Suspended Solids (mg/L)	--	--	2	--
Color (Pt-Co units)	--	--	35	--

Lake Killarney -- King County

Historical Data From Ecology

Date	07/05/73[a]	06/14/90[b]	05/22/91[c]
Secchi (ft)	9	7.3	7.8
Total Phosphorus, epilimnion (μg/L)	22	43	--
Total Nitrogen, epilimnion (mg/L)	--	0.45	0.43
Chlorophyll *a* (μg/L)	1.4	--	--
Dissolved Oxygen, surface (mg/L)	8.1	9.4	7.9
Dissolved Oxygen, bottom (mg/L)	7.6	4.6	0.2

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)

Lake Killarney -- King County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was fair, as indicated by Secchi depths which ranged from 5.75 to 8.0 feet. No pattern in Secchi depths was apparent during 1992, although mean Secchi depth was somewhat lower in 1992 than in 1991.

Total Phosphorus

Total phosphorus was high and in the eutrophic range on both sampling dates (38 and 39 μg/L). Both concentrations were very similar to the one measured in 1990 (43 μg/L; Rector, 1991).

Total Nitrogen

Total nitrogen was low to moderate (0.72 mg/L in May, and 0.53 mg/L in August), but was higher than concentrations measured in 1991 and 1990 (0.43 and 0.45 mg/L, respectively; Rector, 1992; Rector, 1991). The concentration relative to total phosphorus was not very high, and as in 1990, raises the question of whether algal growth was limited by phosphorus or by nitrogen.

Fecal Coliform Bacteria

Samples for fecal coliform bacteria were collected from two sites during August. Results were low (8 and 6 colonies/100 mL), and were within state standards.

Solids and Color

Both total suspended solids and nonvolatile suspended solids were present in the sample collected during August. This suggests that solids in the water consisted of suspended sediments as well as algae. The lake was also somewhat colored. Suspended sediments and water color may reduce water clarity (and hence, Secchi depths) to some extent.

Profile Data

The lake was not stratified with respect to temperature on either sampling date, and normally one would expect no change in profile parameters from surface to bottom. During August, though, dissolved oxygen decreased considerably with depth. This decrease probably resulted from bacteria decomposing algae and aquatic plants in the water and sediments. Because bacterial decomposition can affect phosphorus release from sediments, a water sample was composited from the lake bottom. Profile data were similar to those collected in 1990 and 1991.

Plants

Algal growth (as indicated by concentrations of chlorophyll *a*) was moderately high on both sampling dates.

Aquatic plants collected from the public boat access area during the May 1992 onsite visit were identified as water star-wort (*Callitriche* spp.), bladderwort (*Utricularia vulgaris*), and watershield (*Brasenia schreberi*). Plants collected during the August onsite visit included a hair-like plant which was not identified, and *Nitella*, a large plant-like alga.

An algae sample collected by the volunteer on May 27, 1992 contained primarily the filamentous green alga *Spirogyra*, and there was a considerable amount of the green alga *Mougeotia* present also. The volunteer noted that the "algae showed up last year and has got a good start this year. Most if it floats below the surface (but) in heavy concentrations it collects at the surface."

<u>Other Available Information</u>

Herbicide treatment in Lake Killarney requires a permit from King County in addition to the short-term water quality variance permit required by Ecology. Ecology will also require sediment samples to be collected and analyzed for copper before treatment with copper sulfate. Before the county considers granting its permit, a treatment plan must be submitted to the county (C. Maynard, Dept. of Ecology, pers. comm.).

Eurasian watermilfoil (*Myriophyllum spicatum*) was successfully eradicated from Lake Killarney with Sonar®, an aquatic herbicide (K. Hamel, Department of Ecology, pers. comm.).

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

> Lake Killarney is used for fishing, swimming and rowing. There is one boat ramp on the lakeshore, and combustion engines were banned from the lake during spring 1992. The lakeshore is being developed further for residences. In the past, the watershed was logged and the shoreline was altered.
>
> There are 63 houses on the lakeshore, and about 30% of the houses are connected to a sewer. There are storm drains on both the north and south ends of the lake. There is a lake improvement group, and most residents voluntarily pay $100 per year for chemical control of plants and algae in the lake. Currently, the minimum setback for lakeshore development is 20 feet, minimum lot size is 15,000 square feet, and there is no restriction on residential density.
>
> Overall, the volunteer finds that Lake Killarney had good water quality. Problems in the lake in 1992 were ranked as 1) algae, 2) suspended sediments, 3) aquatic plants, 4) water level, and 5) degraded aesthetics. Possible sources of problems are runoff from streets and drainage ditches. In 1992, the lake was treated with chemicals to control plants and algae. The volunteer noted that algae was persistent in 1992, so that the lake was treated three times with algicides. There were changes in the lake since last year's monitoring season: no "islands" popped

up from the lake bottom, and combustion engines were banned in the lake during spring 1992.

In 1991, bladderwort was growing heaviest in the north end of the lake, and was spreading south. Most pondweed grew in the north and center areas of the lake. Algae grew throughout the lake. The amount of submerged weed and pond lily growth was increasing over the years. Most of the aquatic plants grow in 0-10 feet of water; lily pads were localized in cove areas. Emergent plants grew in the north basin only, on the north side.

During the May 22, 1991 onsite visit with the volunteer, the volunteer noted that chunks of lake bottom ("islands") rise to the surface and float. He used an oar to knock the gas out and sink them again. No "islands" popped up from the lake bottom in 1992.

Comments

Although mean Secchi depth and chlorophyll *a* were in the mesotrophic range, the trophic state estimation was based mainly on the high phosphorus concentrations in the lake and the moderately high amount of aquatic plant growth.

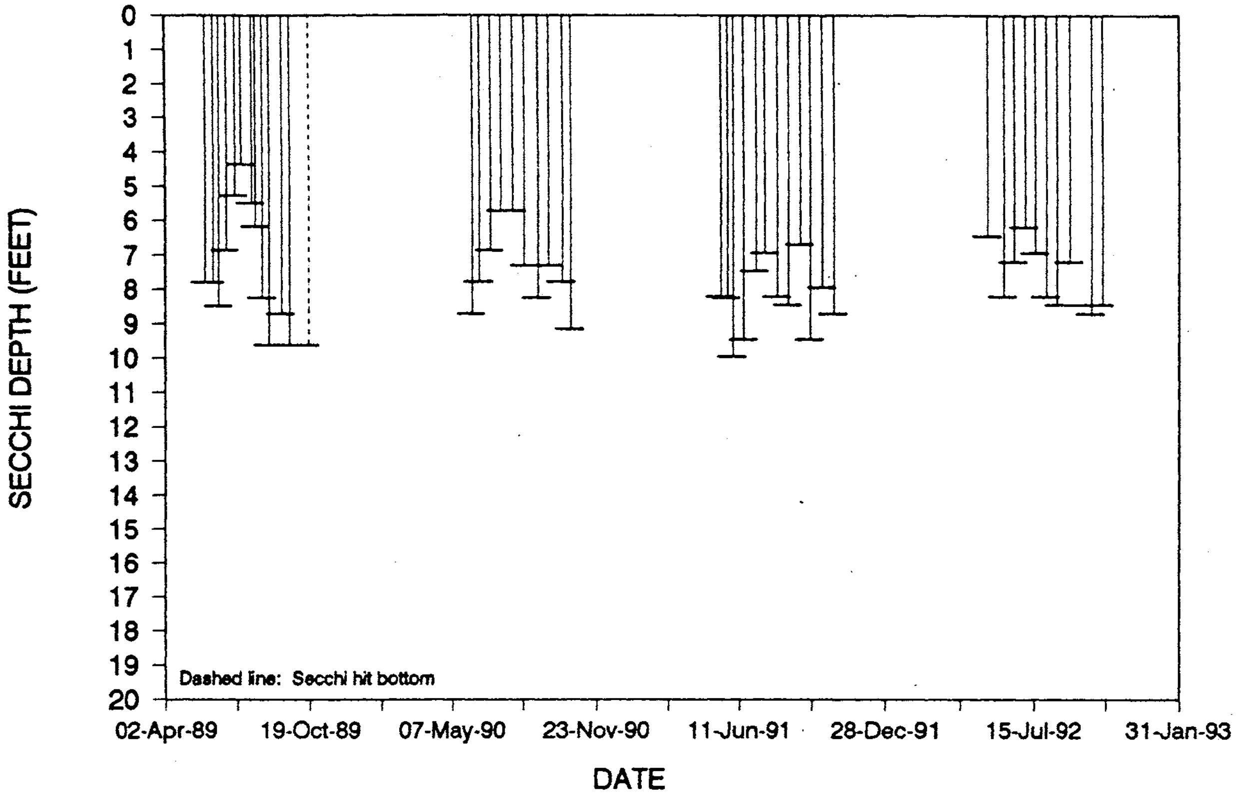
It is difficult to assess what is affecting algal growth and water clarity in the lake. On the one hand, suspended sediments may affect the water clarity by shading the water, reducing sunlight penetration through the water, and therefore limiting photosynthesis of algae. On the other hand, the lake has a history of being treated with algicides to control algae growth. As a result, the presence of suspended sediments will decrease water clarity, whereas an algicide treatment will increase water clarity. Without knowing when each occurs, phosphorus is probably the best indicator of trophic status for Lake Killarney.

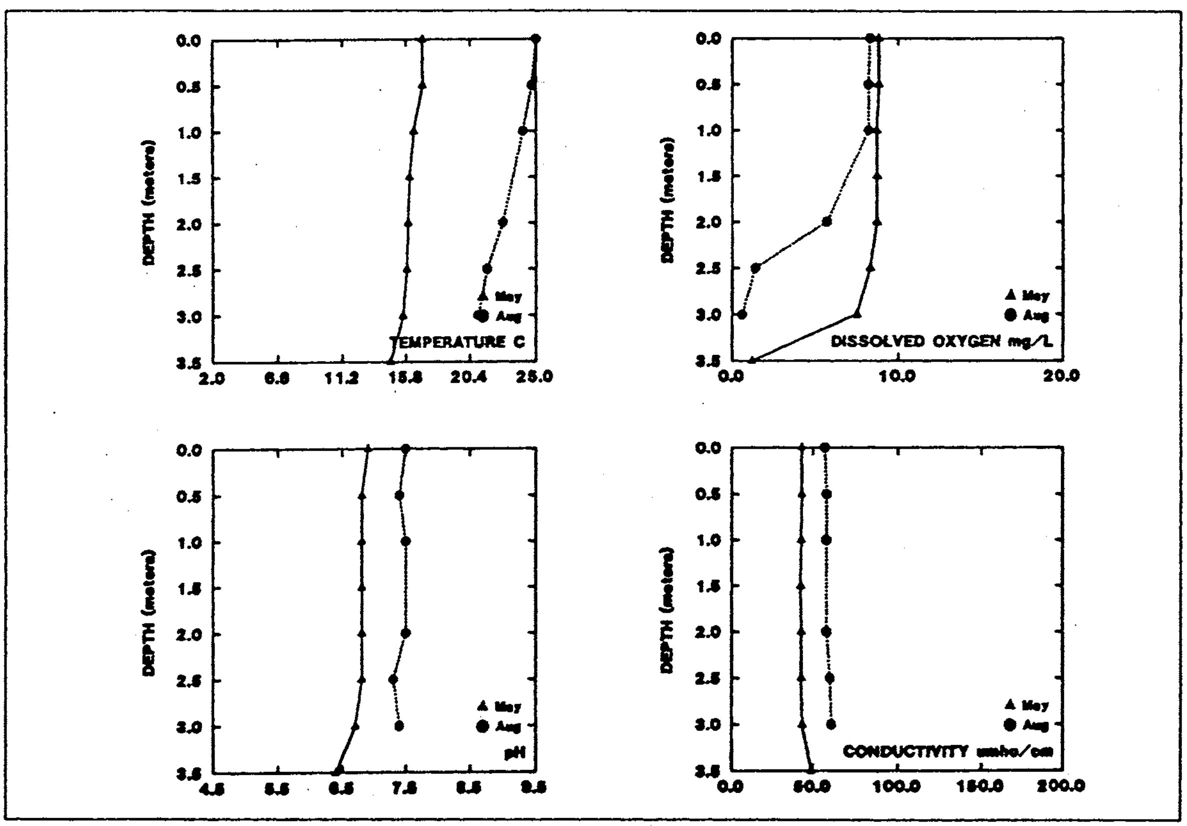
In comparison to other lakes monitored for the program in 1992, only four lakes had higher total phosphorus than Lake Killarney. Lake Alice and Lake Sawyer were the only other King County lakes monitored for the program. Lake Killarney had higher total phosphorus and chlorophyll, and lower Secchi depths, than these lakes.

Acknowledgement

I thank Paul DesJardin for volunteering his time to monitor Lake Killarney during 1989-1992.

LAKE KILLARNEY (KING COUNTY)



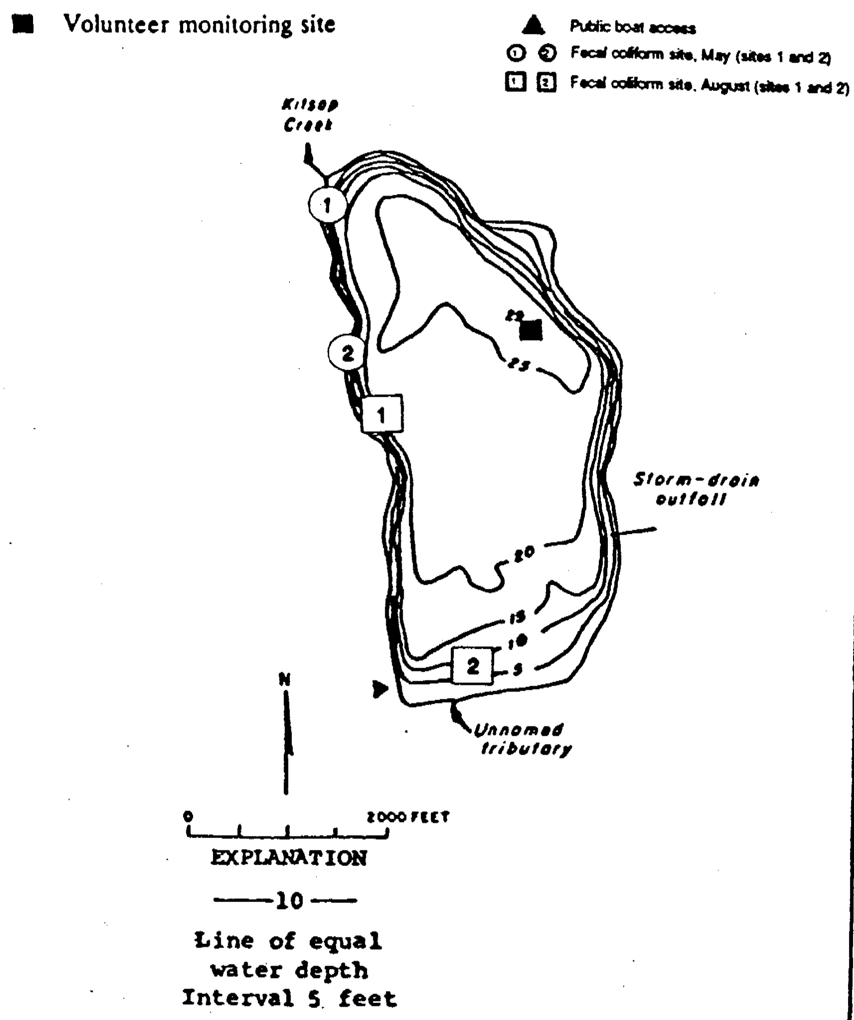


Kitsap Lake -- Kitsap County

Kitsap Lake is located in an urban area, three miles west from Bremerton. It is fed by an intermittent unnamed tributary, and drains via Kitsap Creek to Dyes Inlet. The lake level is stabilized by a dam.

Size (acres)	250
Maximum Depth (feet)	29
Mean Depth (feet)	18
Lake Volume (acre-feet)	4,500
Drainage Area (miles^2)	2.7
Altitude (feet)	156
Shoreline Length (miles)	2.7

Data From Bortleson *et al.* (1976)



Kitsap Lake, Kitsap County. From Washington Department of Game, June 7, 1950.

Kitsap Lake -- Kitsap County

1992 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	42
Mean Trophic State Index (Total Phosphorus):	46
Mean Trophic State Index (Chlorophyll *a*):	37

Volunteer-Collected Data

Date 1992	Time	Temperature (°C) (°F)	Secchi (ft)	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
16-Jun	1030	17.5 63.5	12.5	25.00	Yellow-Gr	100	None	Light	Water color yellow-green. Using a different point from which to measure lake height than used in 1990.
02-Jul	1200	22.8 73.0	10.0	25.50	Pea Green	50	Trace	Light	
15-Jul	1230	21.7 71.1	9.0	25.50	Pea Green	10	None	Light	Algae bloom noted during last two weeks.
31-Jul	1400	23.9 75.0	9.3	26.75	Pea Green	0	None	Strong	Continued algae bloom - sent sample in last week. Purple loosestrife noted last week also.
14-Aug	1015	24.4 76.0	15.3	27.75	Pea Green	10	Trace	Calm	
19-Aug			14.0						Onsite visit
27-Aug	1130	22.8 73.0	12.5	30.00	Pea Green	100	None	Light	
09-Sep	1300	20.0 68.0	10.0	31.25		0	Trace	Light	Water color pea green/green-brown. Rainfall 0.1" last 2 days.
25-Sep	1025	17.8 64.0	17.0	30.50	Pea Green	75	Moderate	Calm	
08-Oct	1020	16.1 61.0	8.7	30.25	Pea Green	90	Light	Light	Blue-green algae bloom occurred last week. Identified by Kitsap Co. Health Dept. as Anabaena.
23-Oct	1100	14.4 58.0	15.0	29.00	Pea Green	25	Moderate	Breezy	

[1] Trophic State Indices calculated from Carlson (1977)

Kitsap Lake -- Kitsap County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/27	0.0	19.5	7.6	10.2	85
	1.0	19.5	7.6	9.9	85
	2.0	19.4	7.6	9.9	85
	3.0	19.4	7.6	9.8	85
	4.0	19.3	7.6	9.8	85
	5.0	17.5	7.3	6.2	88
	6.0	16.6	7.2	3.5	89
	7.0	16.1	7.1	1.5	92
08/19	0.0	24.0	7.8	9.7	98
	1.0	23.9	7.9	9.5	98
	2.0	23.8	8.0	9.5	98
	3.0	23.7	8.1	9.4	98
	4.0	22.4	8.0	8.3	99
	5.0	21.5	7.8	6.5	98
	6.0	20.9	7.7	0.7	101
	6.5	20.3	7.5	0.1	112

1992 Onsite Visit Data - Water Chemistry

Date	05/27/92		08/19/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	6, 7	1, 2, 3	6
Total Phosphorus (μg/L)	18	15	19	67
Total Nitrogen (mg/L)	0.23	0.23	--	0.28
Chlorophyll *a* (μg/L)	1.23	--	2.46	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	<1	--	<1	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	<1	--	4	--
Total Suspended Solids (mg/L)	2	--	1	--
Total Nonvolatile Suspended Solids (mg/L)	<1	--	<1	--
Color (Pt-Co units)	20	--	10	--

Kitsap Lake -- Kitsap County

Historical Data From Ecology

Date	06/30/71[a]	07/21/81[b]	05/23/90[c]	06/13/90[d]	09/04/90[c]	09/12/90[d]
Secchi (ft)	7	15	--	16.4	9.3	6.2
Total Phosphorus, epilimnion (μg/L)	20	30	18	--	35	32
Total Nitrogen, epilimnion (mg/L)	--	0.68	0.23	0.19	0.44	0.35
Chlorophyll *a* (μg/L)	--	2.50	--	3.5	--	7.9
Dissolved Oxygen, surface (mg/L)	10.5	8.5	8.7	9.7	9.4	8.5
Dissolved Oxygen, bottom (mg/L)	8.9	3.6	7.2	8.1	4.5	8.3

a. Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Coots (1991)

Kitsap Lake -- Kitsap County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was fairly good, as indicated by Secchi depths which ranged from 8.8 to 17.0 feet. The mean Secchi depth was 12.1 feet. Secchi depths were much more variable in 1992 than in 1989.

Total Phosphorus
Total phosphorus in the epilimnion was moderately high (18 and 19 μg/L) , and indicated that the lake was mesotrophic. The concentrations measured were similar to those measured in June 1971 (20 μg/L; Bortleson *et al.*, 1976) and May 1990 (15 μg/L; Rector, 1991). During August, the high total phosphorus concentration from the hypolimnion suggests that internal loading from the sediments may have occurred.

Total Nitrogen
Total nitrogen in the epilimnion was low during May (0.23 mg/L). There was some analytical problem with the epilimnion sample from August, so the result is not reported here.

Fecal Coliform Bacteria
Fecal coliforms were detected in only one of four samples. The result from this one sample, which was collected near the wetland at the south end of the lake, was very low and and was within state standards.

Solids and Color
Results for both solids and color were low, indicating that the lake did not have much suspended material in the water at the time of sampling, and that there did not appear to be much natural color in the lake. These results indicate that Secchi depth was most likely affected by algal growth, as opposed to suspended sediments or natural color, at the time of sampling.

Profile Data
In comparison to most other lakes sampled for the program, Kitsap Lake had high surface and bottom water temperatures. There was less than four degrees difference between the surface and bottom temperatures on both sampling dates. The warm water temperatures, particularly during August, are stressful to salmonids, if they are present in the lake.

Plants
Despite moderately high total phosphorus concentrations, algal growth (as indicated by concentrations of chlorophyll *a*) was not very high on either sampling date. Because algal blooms (as indicated by Secchi depth) occurred before and after the lake was sampled for chlorophyll, it appears that phosphorus and Secchi depth may be better indicators of trophic status than chlorophyll *a*. An algae sample collected by the volunteer on July 28, 1992 consisted primarily of clumped coils of *Anabaena*, possibly *A. circinalis*. Detritus (possibly insect exoskeletons) were also present in the sample. In October, the volunteer collected an algae bloom sample and sent it to the Kitsap County Health Department for identification. The sample also consisted of *Anabaena* spp.

Kitsap Lake -- Kitsap County

During the May 27, 1992 onsite visit with the volunteer, largeleaf pondweed (*Potamogeton amplifolius*) was the dominant plant along some nearshore areas of the south end of the lake. Other plants observed included coontail (*Ceratophyllum demersum*), waterweed (*Elodea* spp.), another pondweed (possibly *Potamogeton pectinatus*), yellow-flowering lily (*Nuphar*), and iris (*Iris pseudacorus*). Plants collected during the August 1992 onsite visit were waterweed (*Elodea canadensis*), and several pondweeds, including leafy pondweed (*Potamogeton foliosus*; but it was heavily encrusted with epiphytic algae), largeleaf pondweed, flatstem pondweed (*P. zosteriformis*), and one unidentified pondweed.

Summary of Questionnaire Results and Information From the Volunteer

The 1992 questionnaire on lake and watershed uses was not returned. The following is a summary of the volunteers' responses and remarks to the 1989-1990 questionnaires.

> Kitsap Lake is used for fishing, boating, swimming, rowing, jet skiing, and seaplanes. There is a county park and picnic area on the lakeshore, and two public boat ramps. There is a speed restriction of 45 mph for motorboats, and a no wake zone within 200 feet of shore. Rainbow trout were stocked in the lake. Currently, the watershed is used for industry, and animal feeding/grazing, and the lakeshore is being developed further for residences. In the past, the watershed was used for logging, crop agriculture, and mining, and the shoreline was altered.
>
> There are about 109 houses on the lakeshore, and about 50% of the lakeshore is sewered. There are 15 stormdrains which drain into the lake. There is a neighborhood association and an environmental association for the lake.
>
> The worst problems in the lake in 1990 were ranked as 1) occasional high fecal coliform bacteria counts, 2) aquatic plants, 3) sediment, 4) algae, and 5) floating debris. Overall, the volunteer found the Kitsap Lake had good recreational water quality. Possible sources of problems may be failing septic systems and heavy boat traffic.

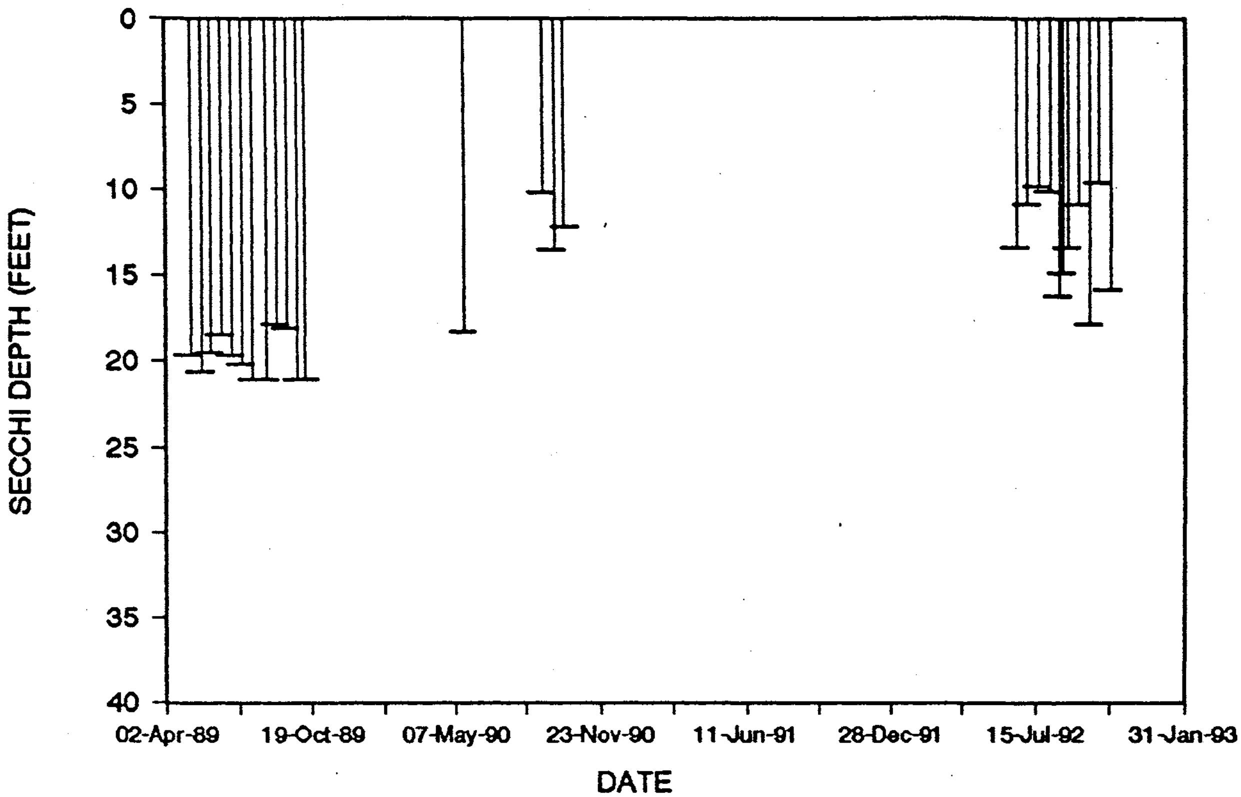
Comments

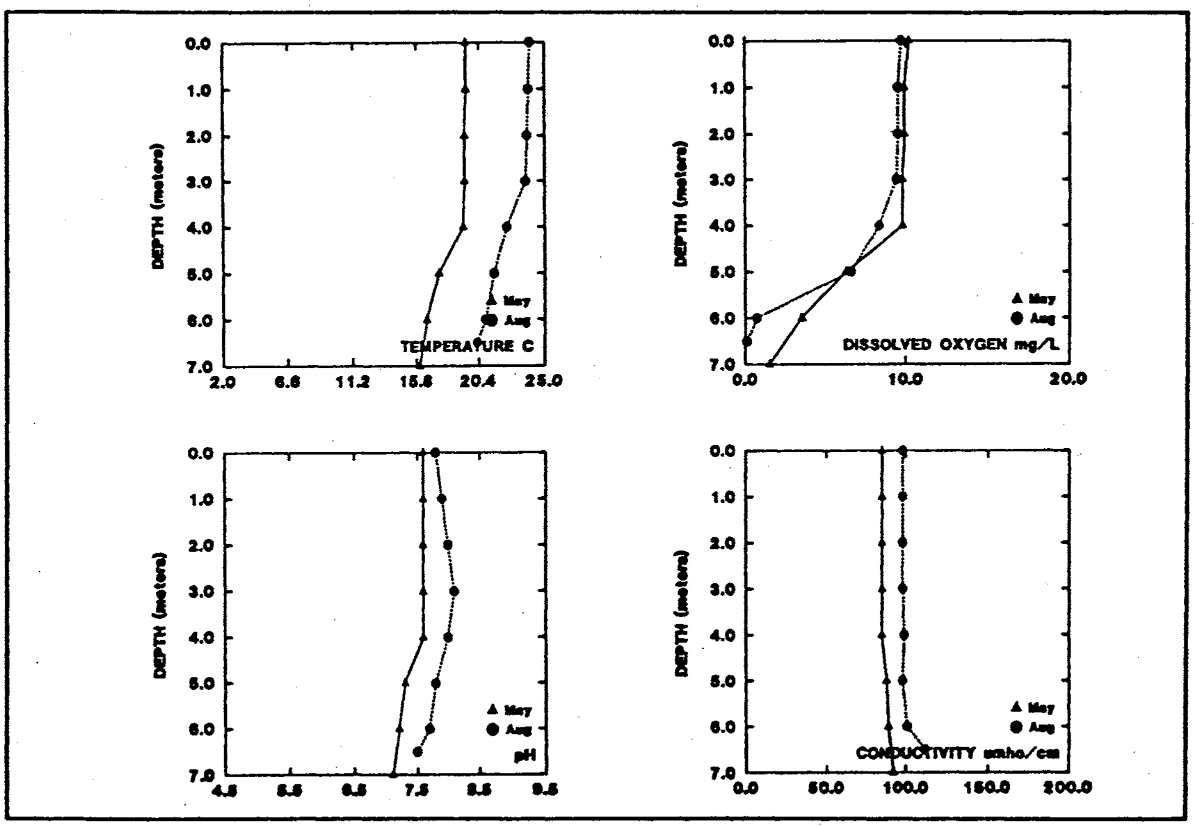
The mesotrophic trophic status was based on the moderate mean Secchi depth, the moderately high concentrations of total phosphorus, the prolific submerged aquatic plant growth in areas of the lake, and the two blooms of blue-green algae that occurred during the monitoring season.

Acknowledgement

I thank Randena Schaap for volunteering her time to monitor Kitsap Lake in 1992 and 1990.

KITSAP LAKE (KITSAP COUNTY)



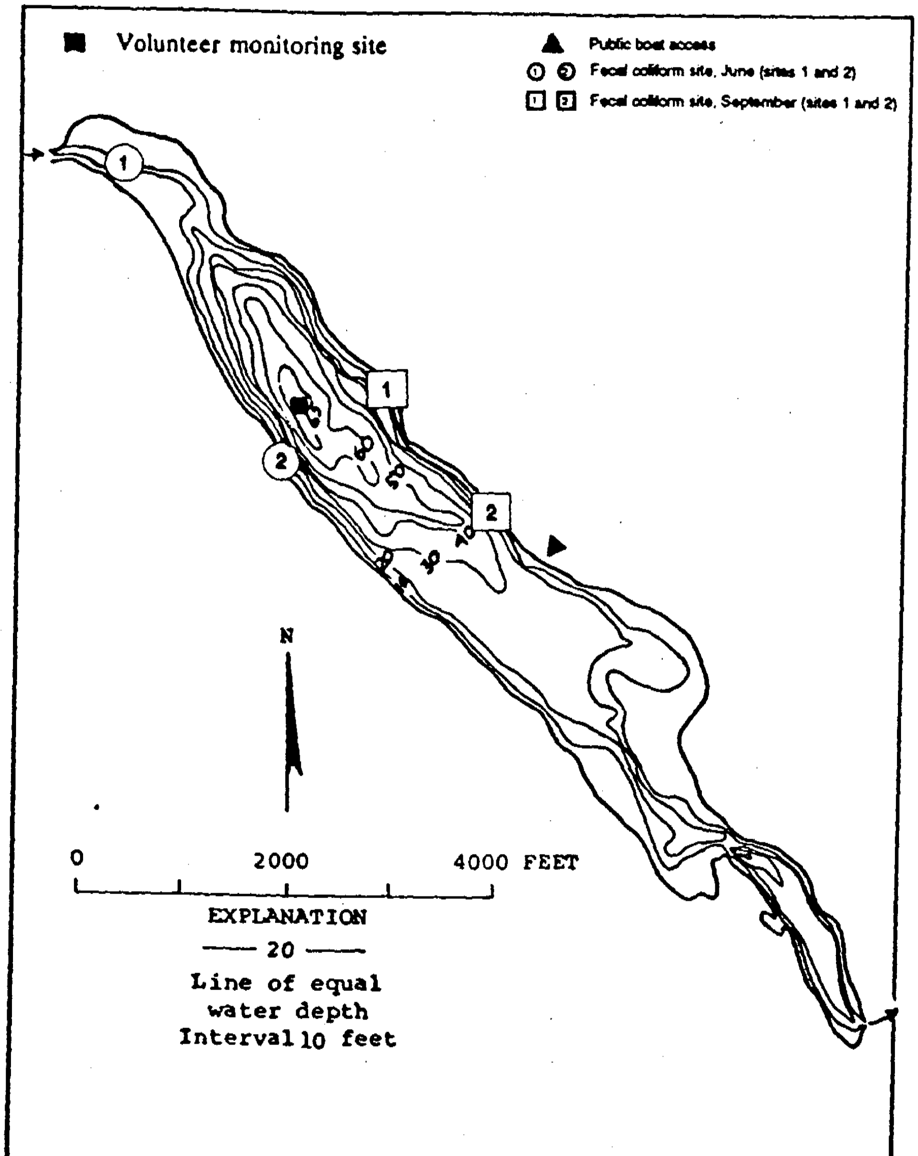


Lacamas Lake -- Clark County

Lacamas Lake is located one mile north of Camas, and is connected to Round Lake. It is formed by two dams in Lacamas Creek. Lacamas Lake is fed by Lacamas Creek, and drains via Round Lake to Lacamas Creek and the Washougal River.

Size (acres)	315
Maximum Depth (feet)	65
Mean Depth (feet)	24
Lake Volume (acre-feet)	7,489
Drainage Area (miles^2)	64.3
Altitude (feet)	179
Shoreline Length (miles)	5.3

Data From Bortleson *et al.* (1976)



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

Lacamas Lake -- Clark County

1992 Trophic Status[1]

Estimated Trophic State:	Eutrophic
Mean Trophic State Index (Secchi):	54
Mean Trophic State Index (Total Phosphorus):	54
Mean Trophic State Index (Chlorophyll *a*):	51

Volunteer-Collected Data

Date 1992	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
30-May	1400	22.2	72.0	7.0		Gr-Brown	0	None	Strong	Weed and algae growing well. Lake starting to smell.
08-Jun				8.0						Onsite visit.
28-Jun	1230	24.4	76.0	6.5		Gr-Brown	50	None	Calm	
15-Jul	1330	24.4	76.0	4.2		Pea Green	0	None	Breezy	Smells wonderful.
26-Jul	1500	27.8	82.0	3.5	18.00	Pea Green	0	None	Breezy	Getting greener.
12-Aug	1205	25.6	78.0	4.0	12.00	Pea Green	10	None	Calm	Green scum floating on surface -- algae seem to be forming small globs about the size of a match head.
27-Aug	1230	24.4	76.0	4.5		Pea Green	0	None	Light	Blue-green balls floating in water -- about 1/8 - 1/4" in diameter.
15-Sep	1230	23.3	74.0	5.0		Pea Green	0	None	Breezy	Blue-green balls, some mats floating out in water.
27-Sep	1300	17.8	64.0	3.5		Green	0	Moderate	Breezy	No blue-green balls. Mats are not visible in open water. Notice considerable amount of new weed growth.
11-Oct	1430	16.7	62.0	4.5		Pea Green	0	None	Light	Green scum on top -- smelly. Lots of algae.

[1] Trophic State Indices calculated from Carlson (1977)

Lacamas Lake -- Clark County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
06/08	0.0	22.0	8.5	10.3	76
	1.0	22.0	8.5	10.3	76
	2.0	21.5	8.5	10.4	77
	3.0	20.5	8.5	10.5	77
	4.0	18.7	7.9	10.0	82
	5.0	16.0	7.6	5.8	76
	6.0	14.6	7.1	3.3	68
	7.0	13.3	7.0	2.4	65
	8.0	12.9	6.9	2.1	65
	9.0	12.7	6.9	3.1	65
	10.0	12.4	6.8	2.5	65
	12.0	12.1	6.7	1.5	66
	14.0	11.8	6.7	0.8	66
	16.0	11.6	6.6	0.2	69
	18.0	11.5	6.6	0.1	71
09/09	0.0	19.2	7.2	7.4	97
	1.0	19.0	7.3	7.5	97
	2.0	18.9	7.4	7.6	97
	3.0	18.9	7.4	7.5	97
	4.0	18.9	7.4	7.4	97
	5.0	18.9	7.5	7.2	97
	6.0	18.0	7.4	2.5	101
	7.0	16.6	7.3	0.2	105
	8.0	14.4	7.2	0.1	98
	9.0	13.3	6.9	0.1	89
	10.0	12.9	6.9	0.1	85
	11.0	12.3	6.9	0.1	86
	12.0	11.9	6.8	0.1	90
	13.0	11.7	6.7	0.1	96
	14.0	11.5	6.7	0.1	103

Lacamas Lake -- Clark County

1992 Onsite Visit Data - Water Chemistry

Date	06/08/92		09/09/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	8, 12, 16	1, 2, 4	11, 12, 13
Total Phosphorus (μg/L)	22	62	39	132
Total Nitrogen (mg/L)	0.85	0.99	0.73	0.75
Chlorophyll *a* (μg/L)	3.53	--	12.14	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	32	--	<1	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	4	--	<1	--
Total Suspended Solids (mg/L)	2	--	4	--
Total Nonvolatile Suspended Solids (mg/L)	<1	--	1	--
Color (Pt-Co units)	20	--	20	--

Historical Data From Ecology

Date	06/26/74[a]	06/16/81[b]	05/26/90[c]	08/20/90[c]	06/21/91[d]
Secchi (ft)	8	4	3.0	4.6	7.3
Total Phosphorus, epilimnion (μg/L)	47	100	37	32	--
Total Nitrogen, epilimnion (mg/L)	--	1.2	3.29	0.78	0.64
Chlorophyll *a* (μg/L)	--	4.98	--	--	--
Dissolved Oxygen, surface (mg/L)	8.9	9.1	13.3	9.7	10.3
Dissolved Oxygen, bottom (mg/L)	0.2	0.2	0.2	0.0	0.2

a. Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)

Lacamas Lake -- Clark County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was poor, as indicated by Secchi depths which ranged from only 3.5 to 8.0 feet, with shallowest depths measured during July and October. Deepest Secchi depths were measured during May and June, before the volunteer started reporting problems with algal blooms. Mean Secchi depth in 1992 (5.1 feet) was similar to that from 1990.

Total Phosphorus
Total phosphorus in the epilimnion was moderately high during June (22 μg/L), and high during September (39 μg/L). Historical data listed on page 4 show that the lake has had high concentrations of total phosphorus since at least 1974.

Total Nitrogen
Total nitrogen was high on both sampling dates (0.85 mg/L in June, and 0.73 mg/L in September), but higher concentrations were measured in May 1990 (3.29 mg/L; Rector, 1991) and June 1981 (1.2 mg/L; Sumioka and Dion, 1985).

Fecal Coliform Bacteria
Results for all fecal coliform samples were below water quality standards (the standard is a geometric mean of 50 colonies/100 mL). The higher result for sample #1 collected during June (32 colonies/100 mL) was collected near the inlet of the lake. This area of the lake was shallow and had prolific growth of lily pads, submerged aquatic plants, and mats of algae.

Solids and Color
Results from solids samples indicate that water clarity (and hence, Secchi depths) was most likely affected by algal growth, as opposed to suspended sediments or natural color, at the time of sampling. The higher solids value during September probably resulted from the high amount of algal growth.

Profile Data
The lake was stratified with respect to temperature on both sampling dates. However, it appears that in September the lake was starting to destratify; epilimnion temperatures were lower, and there was a smaller difference between surface and bottom temperatures. This was a bit unusual because most other lakes sampled for the program were considerably warmer during the late summer sampling.

The dissolved oxygen profiles were similar to those from 1990 and 1991. Very low, or depleted, oxygen in the hypolimnion occurred on both sampling dates. During the September sampling, hydrogen sulfide ("rotten-egg" smell) was noticed in all three water samples from the hypolimnion; hydrogen sulfide is present only in the absence of oxygen; its presence confirms that oxygen was depleted in the hypolimnion. The depletion of dissolved oxygen usually occurs from the bacterial decomposition of algae and aquatic plants in the bottom water and sediments.

Lacamas Lake -- Clark County

The conductivity profiles were a bit unusual because of the slight increase in conductivity at the metalimnion; although the cause of these increases is not clear, the increases also occurred when the lake was sampled for the program in May 1990 and August 1991.

Plants

Algae growth, as indicated by concentrations of chlorophyll *a*, was moderately high during June. An algae sample collected during the June onsite visit consisted of numerous diatoms (primarily *Synedra* and *Asterionella*), and some filaments, possibly *Oscillatoria*, were also present in the sample. An algae attached to the waterweed sample was *Spirogyra*. During September, chlorophyll was very high, indicating eutrophic conditions.

Plants identified by Ecology staff during the June 8, 1992 onsite visit included waterweed (*Elodea canadensis*), largeleaf pondweed (*Potamogeton amplifolius*), and yellow-flowering lily (*Nuphar polysepalum*). During the September onsite visit, pieces of Brazilian elodea (*Egeria densa*) were observed floating near the public boat access. Ecology's Water Quality Financial Assistance Program was notified that this non-native, aggressive species was observed in the lake.

During the June 21, 1991 onsite visit with the volunteer, large beds of largeleaf pondweed covered with periphyton grew along areas of the west shore, extending out 200 - 300 feet.

Other Available Information

From Intergovernmental Resource Center (1988): Data from a Phase I study of Lacamas Lake, Round Lake, and the surrounding watershed indicated that both lakes were eutrophic. The lakes were mainly affected by phosphorus loading from failing septic systems and agricultural operations within the watershed. A Phase IIa drainage basin inventory showed that approximately 94% of the phosphorus entering Lacamas Lake came from animal wastes, and less than 2.5% was from septic systems. Three locations within the watershed had concentrated areas with failing or dysfunctional septic systems; these areas were recommended by the Southwest Washington Health District for sewering. Following an agricultural site survey within the watershed, 42 Best Management Practices (BMPs) for 437 sites were recommended for implementation. Goals of lake restoration are to reduce total phosphorus loading to the lakes by 84%, improve the water quality, enhance recreation, and encourage public interest and involvement in the restoration of the lakes.

From Beak Consultants Incorporated and Scientific Resources Incorporated (1985): Lacamas Lake, Round Lake, and their watersheds and tributaries were monitored from 1983 to 1984. Macrophytes identified in Lacamas Lake during 1983-1984 were *Ceratophyllum demersum*, *Chara*, *Elodea canadensis*, *Elodea densa* (also called *Egeria densa*), *Nuphar polysepalum*, *Potamogeton amplifolius*, and *P. robbinsii*. Secchi depths ranged from 0.6 to 2.0 meters, and the mean value was 1.3 meters. Lower Secchi depths were found during April, early June and early July.

Lacamas Lake -- Clark County

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

Lacamas Lake is used for fishing, boating, swimming, rowing, jet skiing, waterfowl hunting, sailing, and occasional sea plane use. Recreational facilities on the lakeshore include a picnic area and four boat ramps. There are no restrictions for motorboat use on the lake. About 40 percent of the shoreline is publicly-owned. Brown trout were stocked in the lake. Currently the watershed is used for logging, animal grazing and crop agriculture, and the lakeshore is being developed further for residences. In the past the watershed was used for logging, animal grazing and crop agriculture, and the shoreline was altered.

There are 43 houses on the lakeshore, and about 90% of the lakeshore is sewered. There are storm drains that empty into the lake. There is a lake association for the lake. Currently, the minimum setback for lakeshore development is 100 feet. Lake water is withdrawn for industrial use.

Overall, the volunteer finds that Lacamas Lake had poor water quality. Problems in the lake in 1992 were ranked as 1) algae, 2) odor from decaying algae, 3) bacteria, 4) excessive aquatic plant growth, 5) degraded aesthetics, 6) decaying plants, and 7) shoreline erosion. Possible sources of problems are animal wastes entering the lake from its inlets. Algae growth and smell from rotting algae was worse in 1992 than in previous years. Aquatic plants, algae, and odor have been among the worst problems listed in the questionnaires every year since 1989.

The volunteer also noted that a 400-4000 head dairy with 1-acre liquid manure holding pond may be constructed in a flood plain on Lacamas Creek, about 1 mile from the lake.

Plant growth in the lake was heavy in all shallow water, especially at the inlet. In 1990, the shoreline was completely covered with submerged plants to a water depth of ten feet. There are wetland areas on each end of the lake; lily pads cover much of the area near the southern wetland.

Comments

Lacamas Lake was estimated as eutrophic based on shallow Secchi depths, high total phosphorus and chlorophyll *a*, and reports of algal blooms and mats. Mean Secchi and total phosphorus were very similar in 1992 and 1990.

Lacamas Lake -- Clark County

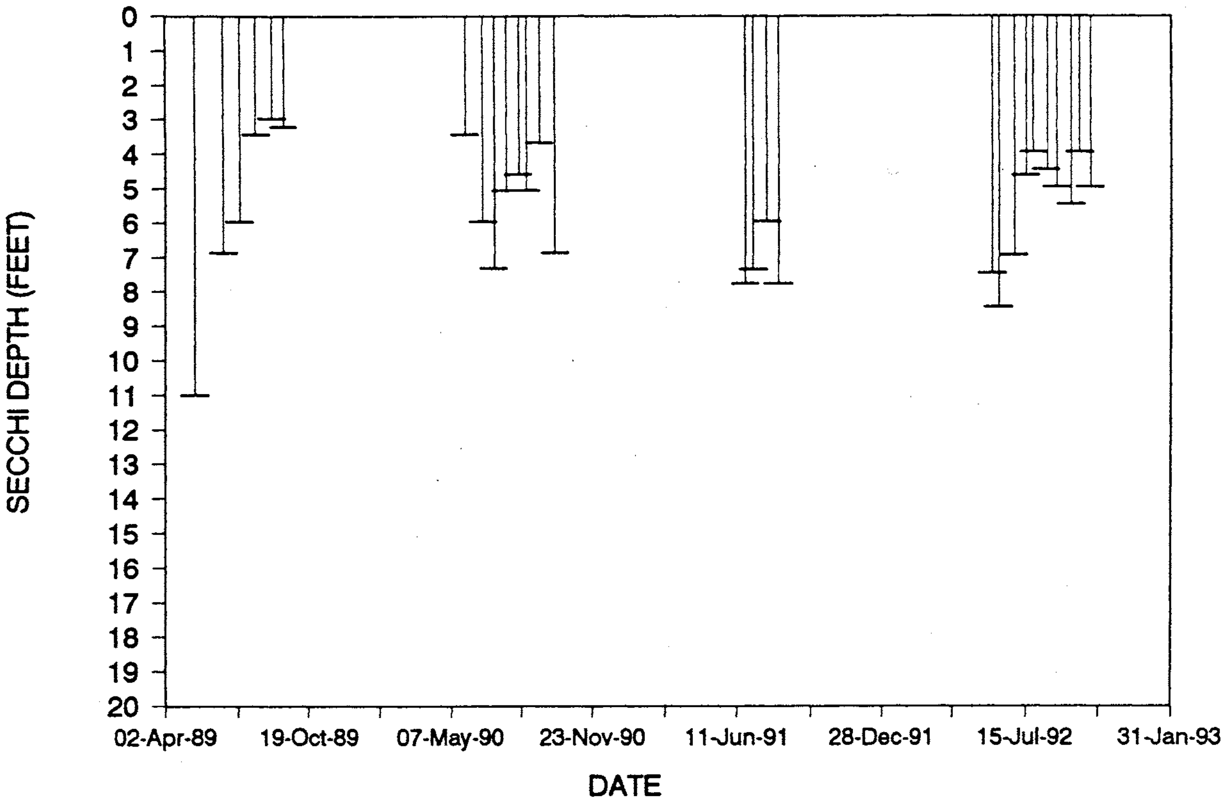
Lacamas Lake water quality was poor. The historical enrichment from watershed runoff containing animal wastes has resulted in large growths of plants and algae. Continued lake monitoring will show how the lake responds to implementation of the Best Management Practices.

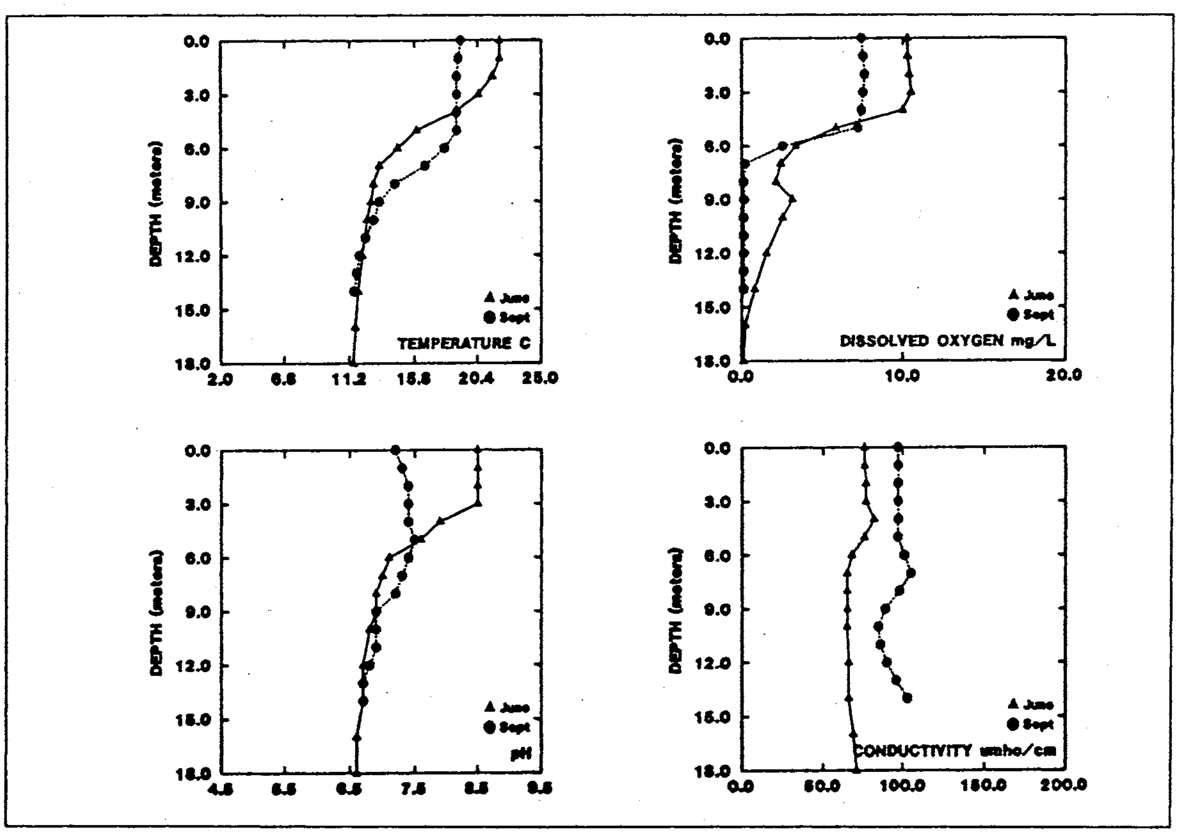
Lacamas Lake was the only Clark County lake monitored for the program in 1992. In comparison to other lakes monitored for the program, 12 lakes had higher total phosphorus, but Lacamas Lake had very poor water clarity.

Acknowledgements

I thank Judy and Jan Baldwin for volunteering their time to monitor Lacamas Lake during 1989-1992.

LACAMAS LAKE (CLARK COUNTY)



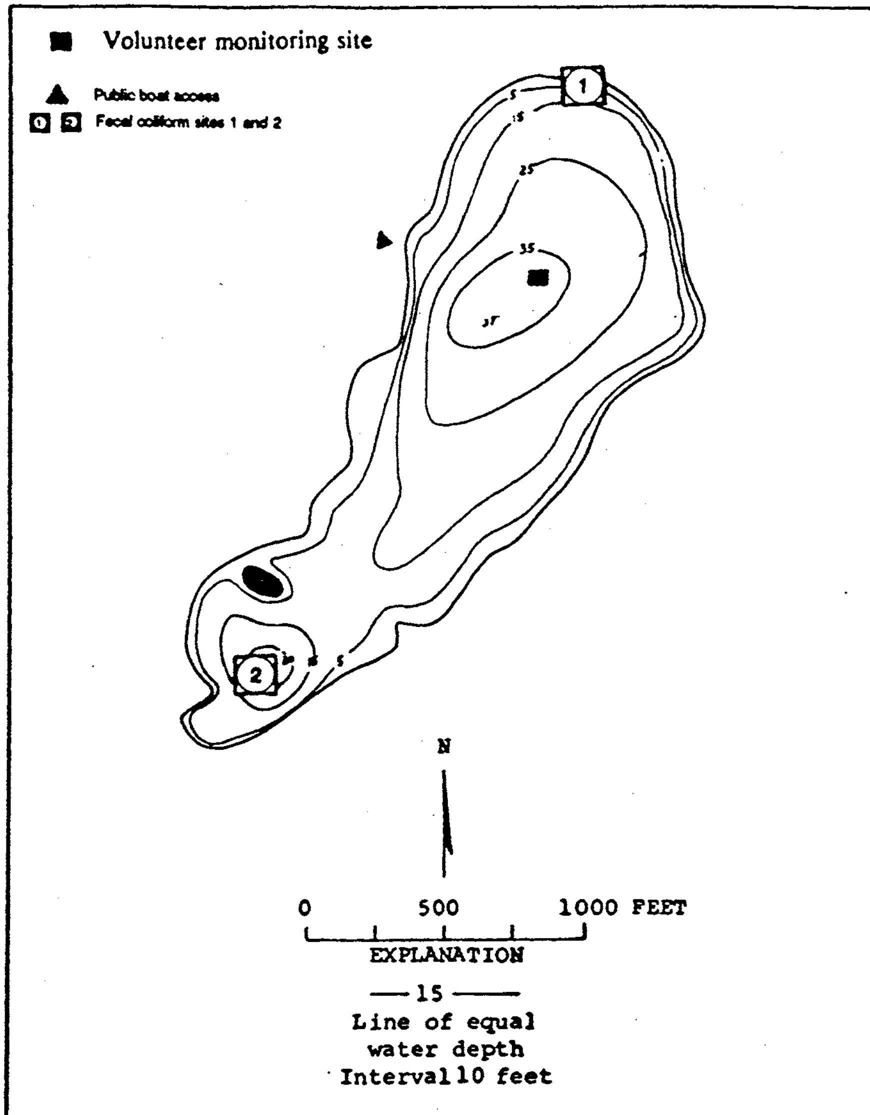


Lake Leo -- Pend Oreille County

Lake Leo is located about seven miles southwest of Ione and 0.8 miles northeast of Heritage Lake. It has an intermittent inflow, and drains via a 2.5 acre pond to Heritage Lake and the Little Pend Oreille River.

Size (acre)	43
Maximum Depth (feet)	37
Mean Depth (feet)	17
Lake Volume (acre-feet)	740
Drainage Area (miles^2)	2.9
Altitude (feet)	3,290
Shoreline Length (miles)	1.3

Data From Dion *et al.* (1976)



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

Lake Leo -- Pend Oreille County

1992 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic[2]
Mean Trophic State Index (Secchi):	35
Mean Trophic State Index (Total Phosphorus):	40
Mean Trophic State Index (Chlorophyll *a*):	36

Volunteer-Collected Data

Date 1992	Time	Temperature (°C) (°F)	Secchi (ft)	pH	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
11-May	1415	13.3 56.0	16.5	7.2	0.00		90	None	Breezy	Water color light greenish brown. pH 7.2.
28-May	1315	17.8 64.0	17.3	7.4	0.00		75	Trace	Breezy	Water color light greenish brown. Ambient temp 61 degrees. Lake height unchanged.
10-Jun	1314	20.0 68.0	21.5	7.4	-4.00	Lt-Green	10	None	Light	pH also 7.4 using phenol red test.
22-Jun	1300	22.8 73.0	23.5	7.6	-6.00	Lt-Green	0	None	Light	
06-Jul	1200	20.0 68.0	16.3	7.5	-6.00	Lt-Green	100	Moderate	Breezy	Took several Secchi readings because change was over 6' from June 22.
20-Jul	1230	22.2 72.0	17.0	8.2	-9.00	Lt-Green	10	None	Light	Highest pH reading in 2.5 years. Double-checked with instrument and phenol red test.
04-Aug	1300	23.3 74.0	19.5	8.2	-10.00	Lt-Green	10	None	Breezy	
17-Aug	1206	22.8 73.0	16.5	8.2		Lt-Green	50	None	Light	
31-Aug	1245	18.3 65.0	19.5	7.6	-12.00	Lt-Green	25	None	Calm	Water color very light green.
15-Sep	1250	13.9 57.0	20.5	7.2	-13.00	Lt-Green	90	Trace	Light	Water color light, light green.
29-Sep	1315	12.8 55.0	21.3	7.2	-13.00	Lt-Green	0	None	Breezy	
13-Oct	1345	11.1 52.0	17.0	7.0	-13.00	Lt-Green	0	Light	Light	

[1] Trophic State Indices calculated from Carlson (1977)

[2] see Comments section

Lake Leo -- Pend Oreille County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/11	0.0	13.7	7.1	9.5	61
	1.0	13.7	7.1	9.4	60
	2.0	13.7	7.1	9.3	60
	3.0	13.7	7.2	9.3	61
	4.0	12.2	7.2	9.0	61
	5.0	9.5	7.0	6.4	66
	6.0	8.3	6.9	1.1	73
	7.0	7.3	6.8	0.2	77
	8.0	7.0	6.8	0.1	79
08/27	0.0	18.2	7.8	8.0	63
	1.0	18.2	7.7	8.0	63
	2.0	18.2	7.6	7.9	63
	3.0	18.2	7.6	7.9	63
	4.0	17.9	7.5	7.0	63
	5.0	17.3	7.2	3.2	68
	6.0	14.3	6.9	0.1	80
	7.0	11.6	6.8	0.1	90
	8.0	10.2	6.7	0.0	125

1992 Onsite Visit Data - Water Chemistry

Date	05/11/92		08/27/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	6, 7, 8	1, 2.5, 4	6, 7, 7.5
Total Phosphorus (μg/L)	11	36	13	82
Total Nitrogen (mg/L)	0.30	0.43	0.26	0.64
Chlorophyll *a* (μg/L)	0.79	--	2.83	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	--	--	1	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	--	--	1	--

Lake Leo -- Pend Oreille County

Historical Data From Ecology

Date	08/16/72[a]	05/25/90[b]	09/11/90[b]	06/13/91[c]
Secchi (ft)	11	10.5	17.8	15
Total Phosphorus, epilimnion (μg/L)	25	12	13	--
Total Nitrogen, epilimnion (mg/L)	--	0.27	0.29	0.21
Chlorophyll *a* (μg/L)	2.6	--	--	--
Dissolved Oxygen, surface (mg/L)	8.5	10.5	8.3	8.7
Dissolved Oxygen, bottom (mg/L)	0.2	0.2	1.1	0.2

a. Bortleson *et al.* (1976), Dion *et al.* (1976)
b. Rector (1991)
c. Rector (1992)

Lake Leo -- Pend Oreille County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was very good, as indicated by deep Secchi readings which ranged from 16.3 to 23.5 feet. There was no pattern in Secchi depths in 1992, like there was in 1989.

Total Phosphorus
Total phosphorus in the epilimnion was low to moderate (11 μg/L in May, and 13 μg/L in August). Concentrations measured in 1992 were very similar to those measured in 1990 (12 and 13 μg/L; Rector, 1991), but were lower than in 1972 (25 μg/L; Dion *et al.*, 1976). Higher concentrations of total phosphorus in the hypolimnion on both sampling dates suggests that phosphorus may be coming from internal loading from the sediments. Internal loading may occur when dissolved oxygen is depleted near the lake bottom, creating an environment that favors releasing phosphorus and other elements from sediments into the water column.

Total Nitrogen
Total nitrogen was low on both sampling dates (0.30 mg/L in May, and 0.26 mg/L in August). These concentrations were similar to those measured in 1991 (0.21 mg/L; Rector, 1992) and 1990 (0.27 and 0.29 mg/L; Rector, 1991).

Fecal Coliform Bacteria
Fecal coliform bacteria samples were collected during August only, and results for both samples were very low and within state standards.

Profile Data
The lake was stratified on both sampling dates, and with the exception of the conductivity data, were very similar to profile data collected in 1990 and 1991. The decrease in dissolved oxygen with depth most likely resulted from the bacterial decomposition of algae and aquatic plants in the bottom water and sediments. Some other chemical or biological process may be occurring in the water, though, because during the August 27, 1992 onsite visit, water samples from the hypolimnion (at depths of 6, 7, and 7.5 meters) appeared greenish. The increase in conductivity near the lake bottom probably resulted from the release of elements from the sediments in the absence of oxygen (see Total Phosphorus, above). Conductivity also increased from surface to bottom during the 1990 and 1991 onsite visits.

Plants
Algal growth, as indicated by concentrations of chlorophyll *a*, was low during May, but was moderately high during August. The May value for chlorophyll *a* was lower than would be expected, given the concentration of total phosphorus. Most other eastern Washington lakes monitored for the program had low algal growth in May; algal growth may have been inhibited during May by cool water temperatures found at the higher elevation eastern Washington lakes.

Lake Leo -- Pend Oreille County

During the September 1990 onsite visit with the volunteer, plant growth in the lake was dominated by the pondweed *Potamogeton robbinsii*. Other plants present were waterweed (*Elodea canadensis*), yellow-flowering lily (*Nuphar polysepalum)*, and water buttercup (*Ranunculus* spp).

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

> Lake Leo is used for fishing, swimming, motor boating, and lakeshore camping. Public recreational facilities on the lakeshore include 8 campsites. 100 percent of the shoreline is publicly-owned National Forest. There are no houses on the lakeshore, and there is no lake association for the lake. There is one public boat ramp, and there are no restrictions for motorboating. Cutthroat trout were stocked in the lake. Currently, the watershed is used for logging and animal grazing/feeding. No plant or algae management occurred in 1992, although the volunteer reported that the lake has been chemically treated in the past to control undesirable fish species.
>
> Overall, the volunteer finds that Lake Leo had excellent water quality. No water quality problems were reported in 1992, and there were no changes in the lake since the 1991 monitoring season.
>
> The lake was not used as much in 1992. Also, fish were stocked late, and fish were fingerlings (instead of catachables) so fishing was not as good as in previous years.
>
> There are wetland areas near the public access, along the east shore of the lake, and near the island. Yellow-flowering lilypads (*Nuphar*) grow all along the wetland areas. So far, no algae blooms have been observed. Although small amounts of submerged weeds grow along the entire shoreline, the growth is sparse. The volunteer noted that the lake depth appears to have decreased over time; the 1950 Department of Game map shows the lake is 35-37 feet deep, whereas now the lake is about 30-32 feet deep.

Comments

In 1991 and 1990, Lake Leo was characterized as oligo-mesotrophic because of Secchi depths or total phosphorus that were borderline between oligotrophy and mesotrophy. During both years, low dissolved oxygen in the hypolimnion was cited as another mesotrophic characteristic of the lake.

Lake Leo -- Pend Oreille County

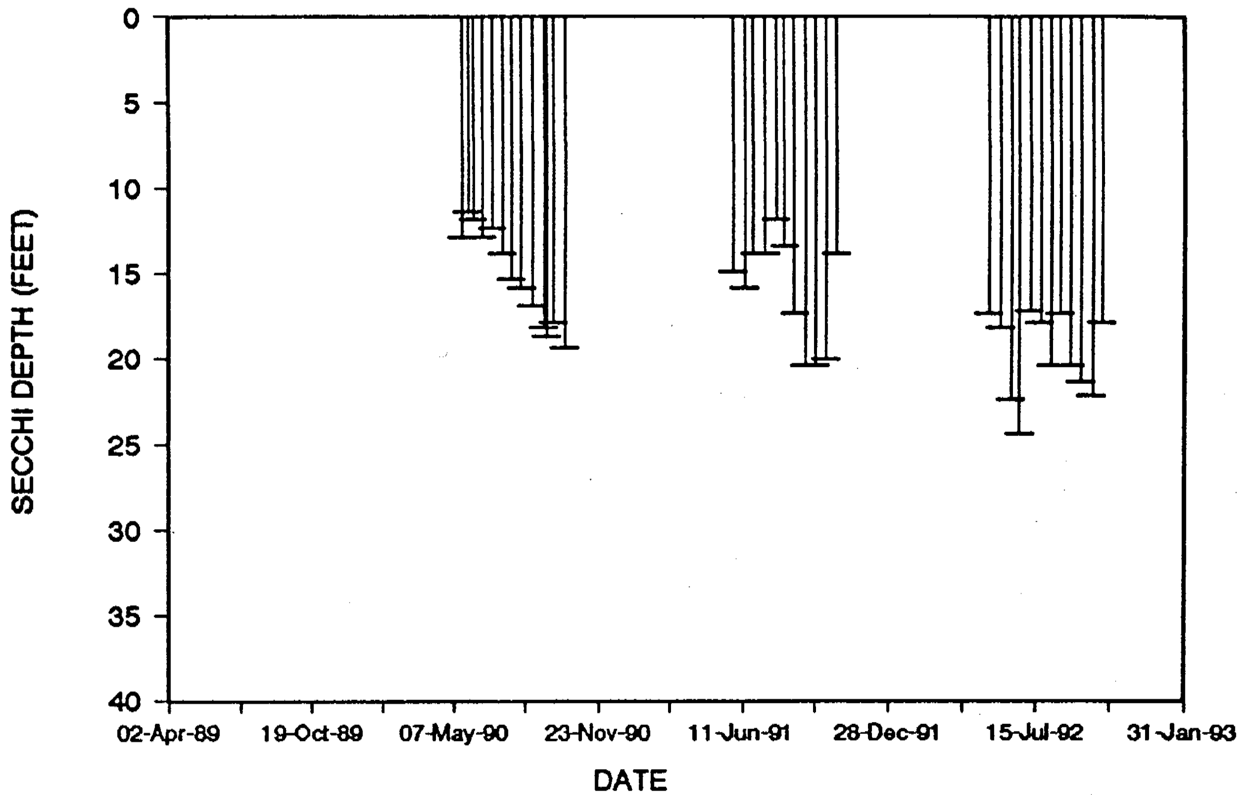
In 1992, both Secchi depth, and chlorophyll *a* indicated that the lake was oligotrophic, whereas total phosphorus was borderline between oligotrophy and mesotrophy. Dissolved oxygen was still low in the hypolimnion, and it is possible that internal loading of phosphorus from the sediments was occurring. Based on the borderline concentration of phosphorus and the low hypolimnetic dissolved oxygen, the lake was again characterized as oligo-mesotrophic.

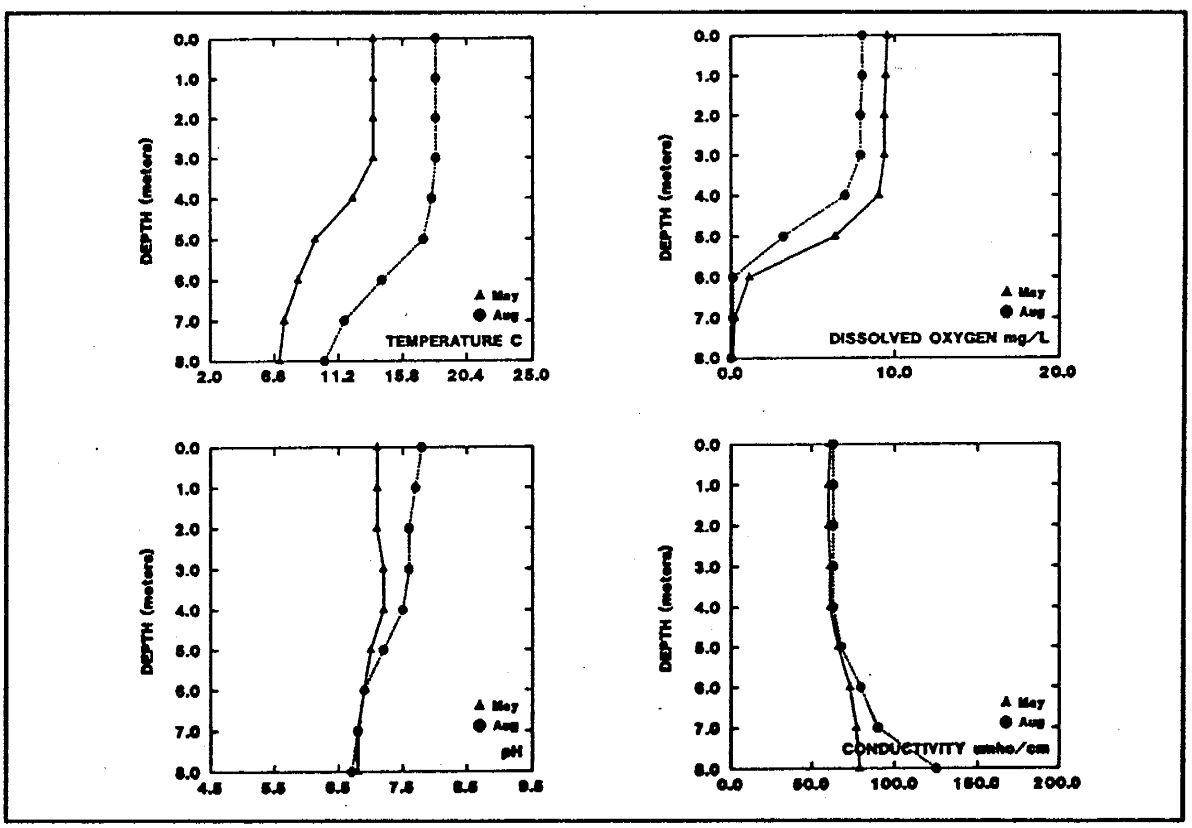
Lake Leo and Lake Thomas are both in the Little Pend Oreille chain of lakes, and both have been monitored for the program since 1990 (Lake Thomas has been monitored for the program since 1989). As in 1990, in 1992 both lakes had similar profile data although total phosphorus was higher in Lake Leo. Eurasian watermilfoil was discovered in Lake Thomas in 1990, but it has not yet been reported in Lake Leo.

Acknowledgement

I thank Earl W. Robinson for volunteering his time to monitor Lake Leo during 1990 - 1992.

LAKE LEO (PEND OREILLE COUNTY)



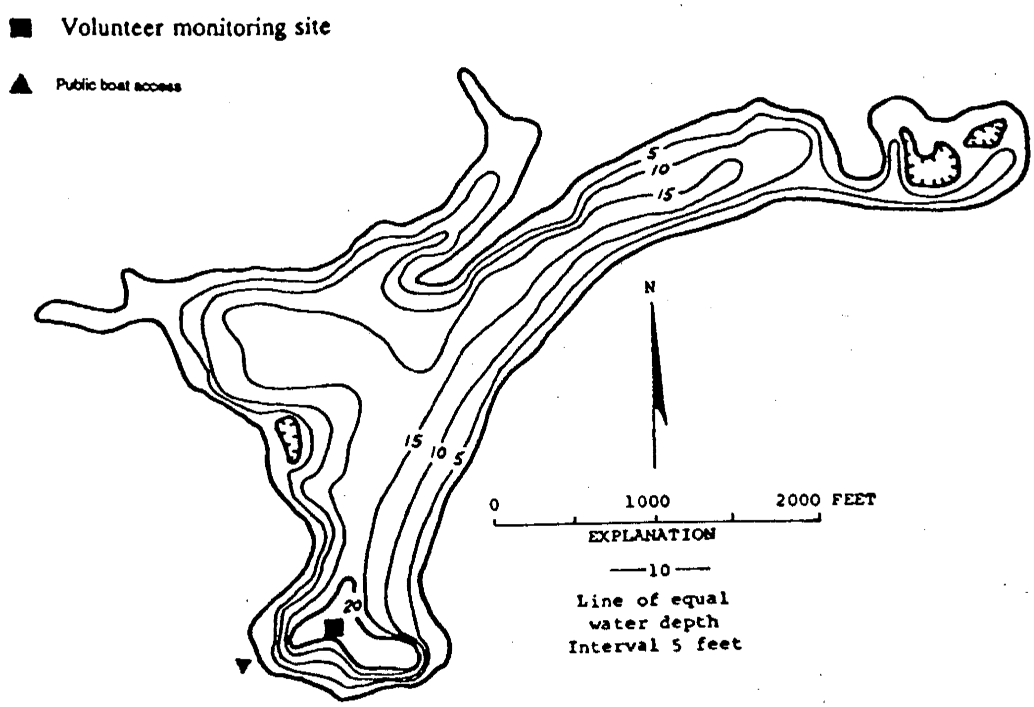


Lake Limerick – Mason County

Lake Limerick is located about 5 miles northeast of Shelton. It was formed in 1966 by impoundment of Cranberry Creek, which is the main inlet to the lake. There are three other minor inlets to the lake.

Size (acre)	129
Maximum Depth (feet)	24
Mean Depth (feet)	9
Lake Volume (acre-feet)	1,210
Drainage Area (miles^2)	13
Altitude (feet)	220
Shoreline Length (miles)	4.4

Data From Bortleson *et al.* (1976)



Limerick Lake, Mason County. From U.S. Geological Survey, December 4, 1973.

Lake Limerick -- Mason County

1992 Trophic Status[1]

Estimated Trophic State:	Mesotrophic[2]
Mean Trophic State Index (Secchi):	43
Mean Trophic State Index (Total Phosphorus):	40
Mean Trophic State Index (Chlorophyll *a*):	29

Volunteer-Collected Data

Date 1992	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
11-Jun	1100	20.0	68.0	10.0		Yellow	75	Moderate	Light	
25-Jun	1110	23.3	74.0	10.2	5.75	Yellow	0	None	Breezy	
09-Jul	1010	21.1	70.0	10.0	6.25	Yellow	90	Moderate	Calm	
23-Jul	1015	20.8	69.5	9.5	0.00	Yellow	100	Trace	Breezy	Lake height 5 feet 1/2".
08-Aug	0915	20.6	69.0	9.0	5.75	Yellow	10	Trace	Calm	
20-Aug	1015	22.2	72.0	10.2	4.75	Yellow	0	None	Breezy	
03-Sep	0925	20.0	68.0	10.2	4.25	Yellow	100	None	Calm	
17-Sep	1000	17.2	63.0	13.5	0.75	Lt-Yellow	0	None	Calm	Water color light yellow.
01-Oct	0945	17.8	64.0	10.3	5.25	Lt-Yellow	0	None	Breezy	
15-Oct	0945	14.4	58.0	11.5	-2.00	Lt-Yellow	0	None	Calm	Lake level fluctuations were to help road crew and new bridge.

[1] Trophic State Indices calculated from Carlson (1977)

[2] see Comments section

Lake Limerick -- Mason County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/29	0.0	19.9	7.7	9.2	45
	1.0	19.7	7.5	9.2	44
	2.0	19.6	7.5	9.1	45
	3.0	19.4	7.4	8.8	45
	4.0	17.4	7.0	3.4	47
	5.0	14.8	6.5	0.1	57
08/26	0.0	22.1	7.5	8.7	58
	1.0	21.6	7.5	8.6	58
	2.0	21.3	7.6	8.5	58
	3.0	20.9	7.5	6.7	58
	4.0	20.6	7.5	4.3	59
	5.0	19.1	7.4	0.2	65

1992 Onsite Visit Data - Water Chemistry

Date	05/29/92		08/26/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	4, 5	1, 2	5
Total Phosphorus (µg/L)	12	37	12	36
Total Nitrogen (mg/L)	0.27	0.33	0.29	0.54
Chlorophyll *a* (µg/L)	1.19	--	0.51	--

Lake Limerick -- Mason County

Historical Data From Ecology

Date	08/16/74[a]	05/24/90[b]	08/15/90[b]	05/15/91[c]
Secchi (ft)	11	--	--	13.5
Total Phosphorus, epilimnion (μg/L)	8	17	15	--
Total Nitrogen, epilimnion (mg/L)	--	0.24	0.49	0.15
Chlorophyll *a* (μg/L)	--	--	--	--
Dissolved Oxygen, surface (mg/L)	8.2	10.1	8.7	10.1
Dissolved Oxygen, bottom (mg/L)	7.3	0.3	0.1	3.3

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)

Lake Limerick -- Mason County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was good, as indicated by Secchi depths which ranged from 9.0 feet to 13.5 feet. All Secchi depths were in the mesotrophic range. There was very little variation in Secchi depths in 1992, compared to data collected in 1991 and 1990.

Total Phosphorus
Total phosphorus in the epilimnion was 12 μg/L on both sampling dates. This concentration is borderline between low and moderate, which is borderline between oligotrophy and mesotrophy. Values from 1992 were somewhat lower than values measured in 1990. Those 1990 values (17 μg/L in May, 15 μg/L in August; Rector, 1991) were also moderately high, but were clearly in the mesotrophic range.

Total Nitrogen
Total nitrogen concentrations were low on both sampling dates (0.27 and 0.29 mg/L).

Profile Data
Although the lake was not clearly stratified on either sampling date, temperature, dissolved oxygen, and pH decreased with depth. Similar profile data were collected in 1990 and 1991.

Plants
Chlorophyll *a* was low and in the oligotrophic range on both sampling dates, indicating that there was little algae at the time of sampling. Algae appear to be more in localized areas of the lake (and often attached to aquatic plants in the lake), and not near the deep site where samples were collected. As a result, chlorophyll collected at the deep site is not a good indicator of trophic status.

Aquatic plants identified by Ecology staff during the May 29, 1992 onsite visit included largeleaf pondweed (*Potamogeton amplifolius*), Brazilian elodea (*Egeria densa*), and waterweed (*Elodea candensis*). The volunteer noted that the largeleaf pondweed was the main nuisance species in the lake, since the Brazilian elodea was chemically treated in 1991. The volunteer also noted that the lake has watershield, duckweed, and tapegrass.

During the May 15, 1991 onsite visit with the volunteer, not much shoreline vegetation was observed; about 75% of the shoreline was cleared for beaches and filled with sand or gravel. At the time of sampling, a harvester was cutting plants in the lake. Near the Lake Limerick clubhouse, there were large beds of largeleaf pondweed, and clumps of the filamentous green alga *Mougeotia* were suspended in the water and/or floating on the surface. Several other aquatic plants including waterweed and pondweed were growing in the cove near the volunteer's home. Aquatic plant growth in the lake during 1974 was described as occurring "in both thinly scattered and dense patches" (Bortleson *et al.*, 1976).

Lake Limerick -- Mason County

Other Available Information

WATER Environmental Sciences conducted a survey of Lake Limerick during 1991 and will propose an aquatic plant management plan for the lake. During the study, Brazilian elodea growth was noted to be especially thick during February 1991 (M. Gibbons, WATER, pers. comm.).

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

> Lake Limerick is used for fishing, swimming, and motor boating. There are four boat ramps on the lakeshore, although only one is for public access. There are motorboating speed limits of 3, 8, and 30 mph. None of the lakeshore is publicly-owned, except for the public boat access. Rainbow and coho trout were stocked in the lake. Currently, the watershed is used for crop agriculture, and the lakeshore is being developed further for residences. In the past, the watershed was used for logging.
>
> There are about 180 houses on the lakeshore, and none of the houses are connected to a sewer. There are culverts that drain into the lake. Lake water is withdrawn for irrigation and for firefighting. There is a community association for the lake. Currently, the minimum setback for lakeshore development is 50 feet, minimum lot lengths are 200 feet, and residential density is restricted to 1 house per lot.
>
> Overall, the volunteer finds that Lake Limerick had good water quality. Problems in the lake in 1992 were ranked as 1) aquatic plants, 2) algae, 3) odor from decaying algae, and 4) swimmer's itch. In comparison to the 1991 monitoring season, watershield showed up and spread rapidly, whereas other weeds have receded below the water surface. The lake was treated with chemicals in 1992 to control both weeds and algae.
>
> In 1991, there were more aquatic plants visible on the lake surface compared with the 1990 monitoring season. In 1990, management activities on the lake included mechanical aquatic plant removal, dredging and lake level drawdown. Weed growth was heavy in about 90% of the lake, and a weed harvester was used on the entire lake. Lilies grew in the lake, mostly near the island.

Lake Limerick -- Mason County

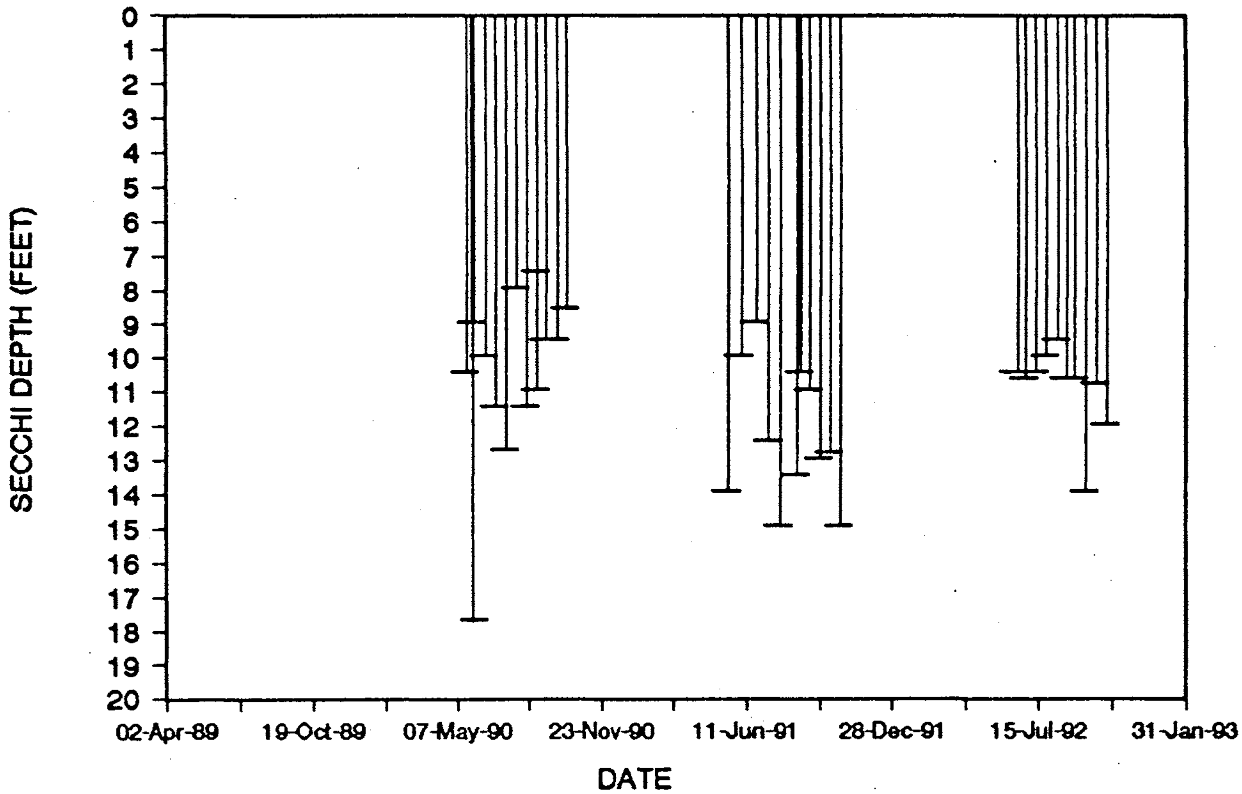
Comments

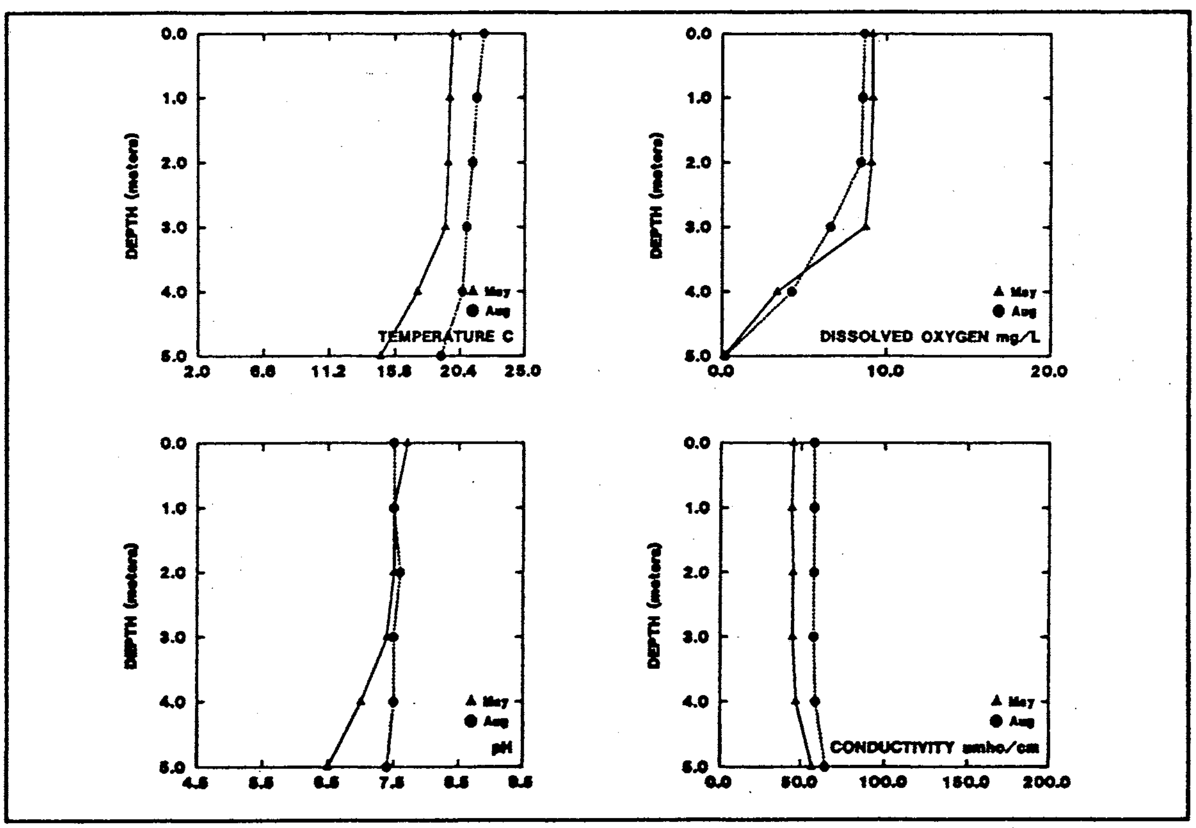
Lake Limerick has been monitored for the program since 1990. Although mean Secchi depths have remained similar, total phosphorus was lower in 1992 than in 1990. The 1992 trophic state estimation was based primarily on Secchi depths and very prolific plant growth which both indicated that the lake was mesotrophic. As noted above, algae appeared to be localized in the lake, so chlorophyll was not a good indicator of trophic status. This may be because of the location of the monitoring site.

Acknowledgement

I thank David Best, Bob King and Bill Weston for volunteering their time to monitor Lake Limerick during 1992, and David Best and Bob King for monitoring the lake during 1990-1991.

LAKE LIMERICK (MASON COUNTY)





Long Lake -- Kitsap County

Long Lake is located 3.5 miles southeast of Port Orchard. It is two miles long. It is fed principally by Salmonberry Creek, and drains via Curley Creek to Yukon Harbor.

Size (acres)	339
Maximum Depth (feet)	12
Mean Depth (feet)	6
Lake Volume (acre-feet)	2,180
Drainage Area (miles^2)	9.4
Altitude (feet)	118
Shoreline Length (miles)	5.1

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	55

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and responses to the 1991 questionnaire. Submerged plants grow in the south end of the lake in about 6 feet of water. According to the volunteer, the lake was treated in 1991 to control algae and aquatic plants. No mechanical weed harvesting occurred in 1991. Fish were not reported as being stocked in the lake. The worst problems in the lake, in the opinion of the volunteer, are aquatic plants, algae, lake level, and suspended sediments. Overall, the volunteer finds that Long Lake has fair water quality, and the volunteer is concerned about water quality effects from housing development in the watershed. The volunteer observed that in some areas there was more plant growth around docks than in past years, and that the water quality of the lake appeared better than in 1990. During the 1991 onsite visit, the volunteer noted that in 1991 the University of Washington will harvest Brazilian elodea (*Egeria densa*) and place it in pens in order to study "fermentation" (presumably, decomposition and nutrient release) in the lake. An alum treatment was scheduled for September, with harvesting occurring from June through August. Dr. Eugene Welch from the Univeristy of Washington told the homeowners that Brazilian elodea was probably introduced into the lake from a fish bowl.

The following are from the volunteer's responses to the 1990 questionnaire. Long Lake is used for fishing, boating, swimming, rowing, jet skiing, and camping. Recreational facilities on the lakeshore include a park, a picnic area, a camping area, a beach and one boat ramp. There is a speed restriction of 8 mph for motorboats within 300 feet of the shore, docks, and the swimming area. Currently the watershed is used for logging and animal grazing, and the lakeshore is being developed further for residences. Lake water is withdrawn for drinking and other domestic uses. Grazing animals have direct access to the lakeshore or inlet tributaries.

Long Lake -- Kitsap County

In the past, the watershed was used for logging and crop agriculture. There are 300 houses on the lakeshore; all are occupied year-round, and the lakeshore is not sewered. There is a community association for the lake. Kitsap County and the University of Washington have also been active in Long Lake issues. The lake was chemically treated in the past to control weeds and algae. Management activities on the lake in 1990 included mechanical aquatic plant removal.

The volunteer noted that The Bremerton Sun reported swimmer's itch in 1990; however, according to the volunteer, the lake has always had swimmers itch but that it was possibly worse that year. There is residential development along approximately 95% of the lakeshore; the south quarter of the lake (at the south inlet) is especially thick with submerged weeds, lilies, and algae. Algae and submerged macrophytes are also thick in the cove near the west inlet. There is a small wetland at the north end near the outlet. The volunteer mentioned that the lake has seven inlets (although some are very small), and the lake is also spring-fed. Salmonberry Creek is the main inlet and has a large drainage area. Olalla Creek (at the south end of the lake) is another main creek.

In the 1989 questionnaire, the volunteer responded that alum was applied to the lake in 1975, 1976 and 1980. The volunteer was concerned that the lake does not flush completely, and that the County does not have very strict controls on either storm or surface runoff, or development.

Monitoring Results/Summary of Other Available Information

The volunteer has monitored Long Lake for the program since 1989. Data from 1989 are reported in Rector (1990) and data from 1990 are reported in Rector (1991).

Volunteer-collected data show that in 1991 Secchi depth ranged from 3.7 to 11.3 feet. Secchi depth was lowest on July 30 and highest on October 10. The deep Secchi depth on October 10, 1991 was much deeper than any of the readings collected from May 1989 through October 1991. Although mean summer water clarity was better in 1991 than in 1990 and 1989, fewer Secchi readings were collected in 1991. Also, algae was heaviest during June and September in 1990 and 1989; this period was not monitored in 1991.

Ecology staff collected water samples and profile data during the May 31 onsite visit with the volunteer. The profile data show that the lake was not thermally stratified, and dissolved oxygen was fairly constant from surface to bottom (8.6 to 8.3 mg/L). These profile data were very similar to data collected during May 1990. Although data from August 1990 show that there was low dissolved oxygen, lower pH, and higher conductivity in the bottom meter of the lake, this was attributed to the probe entering the sediment/water interface.

Total nitrogen in 1991 (0.36 mg/L) was much lower than concentrations measured in 1990 (0.63 mg/L in May and 0.94 mg/L in August).

Long Lake -- Kitsap County

Samples for total phosphorus and chlorophyll *a* were collected in 1991, but the data could not be used due to analytical problems. The 1990 concentrations of total phosphorus were very high (0.057 mg/L in May and 0.070 mg/L in August) and in the eutrophic range. In 1973, total phosphorus was lower (0.041 mg/L) but also in the eutrophic range.

From Welch *et al.* (1988): The lake was drawn down 2 meters during the summer of 1979 to reduce aquatic plant populations, and was treated with alum in 1980 to inactivate phosphorus in the sediments. The effectiveness of the alum, resulting in a 50% reduction in mean chlorophyll *a* and total phosphorus, and a 50% increase in transparency, lasted four years. In 1985, the lake returned to pre-treatment Secchi disk transparency and chlorophyll *a* concentrations, and by 1988 it was concluded that "alum is no longer controlling internal phosphorus loading and lake trophic status in Long Lake."

From Welch and Kelly (1990): In 1990, researchers at the University of Washington proposed that the dense cover of plants (primarily *Elodea densa*) in Long Lake decreases the release of phosphorus from lake sediments by protecting sediments from wind mixing. Rooted aquatic plants can be an important source of internal phosphorus loading because plant roots can retrieve phosphorus from lake sediments, and this phosphorus is released into the water column when the plants die and decay. However, by shielding the bottom layers of water from mixing with upper layers of water, the plant beds may trap phosphorus in bottom waters and may have prolonged the effectiveness of previous alum treatments.

Comments

Long Lake was characterized as eutrophic based on low Secchi depths measured since 1989, and high total phosphorus measured in 1990. Of the 41 lakes monitored by volunteers in 1991, only two lakes (Long Lake in Thurston County, and Horseshoe Lake in Cowlitz County) had lower mean summer Secchi depths than Long Lake.

Long Lake -- Kitsap County

Volunteer-Collected Data

Date 1991	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
31-May								5.5		Onsite visit.
12-Jul	22.2	72.0	7.5	Gr-Brown	0	None	Calm	4.1	12.5	A very light sediment floating. No weed cutting this summer. No algae bloom yet.
30-Jul	23.3	74.0	6.5	Gr-Brown	0	None	Calm	3.7	52.0	Weeds at my dock starting to bloom. Very light sediment. UW put weeds in pens to decay, will do alum treatment in Sept.
14-Aug	23.3	74.0	7.0	Gr-Brown	0	None	Calm	4.0		Sediment size is smaller and very light this year, I think due to no weed harvesting! No algae bloom that I know of. Lake depth 12'7".
03-Sep	18.9	66.0	7.0	Gr-Brown	0	None	Light	5.6		Very light particles floating in water 1-2 feet deep. I feel the lake has been better this year due to no weed harvesting. County put ski line buoys on lake 2 weeks ago. Lake depth 13'.
10-Oct	16.7	62.0	6.5	Lt Gr-Blue	0	None	Calm	11.3		Lake depth 12'7". Last week UW treated lake with alum - really cleared up the water!

Onsite Visit Data

Date 1991	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Composite Sample Depths (m)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Phosphorus (mg/L)
05/31	0.0	15.0	7.3	8.6	72	0.5, 1.5, 2.5	0.36	ND	ND
	0.5	15.0	7.2	8.6	72				
	1.0	15.0	7.2	8.6	72				
	1.5	15.0	7.1	8.5	72				
	2.0	15.0	7.1	8.5	72				
	2.5	15.0	7.1	8.5	72				
	3.0	15.0	7.1	8.3	72				

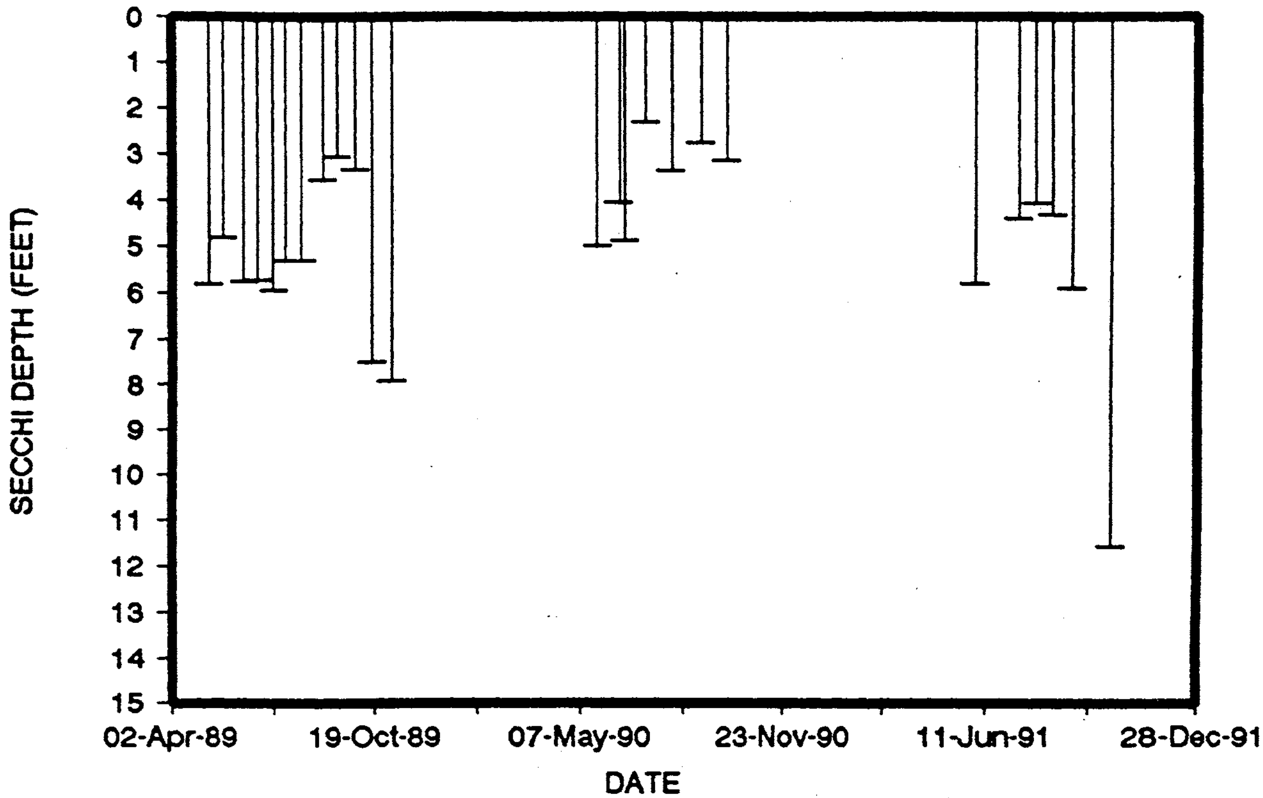
ND No data; data lost due to analytical problems

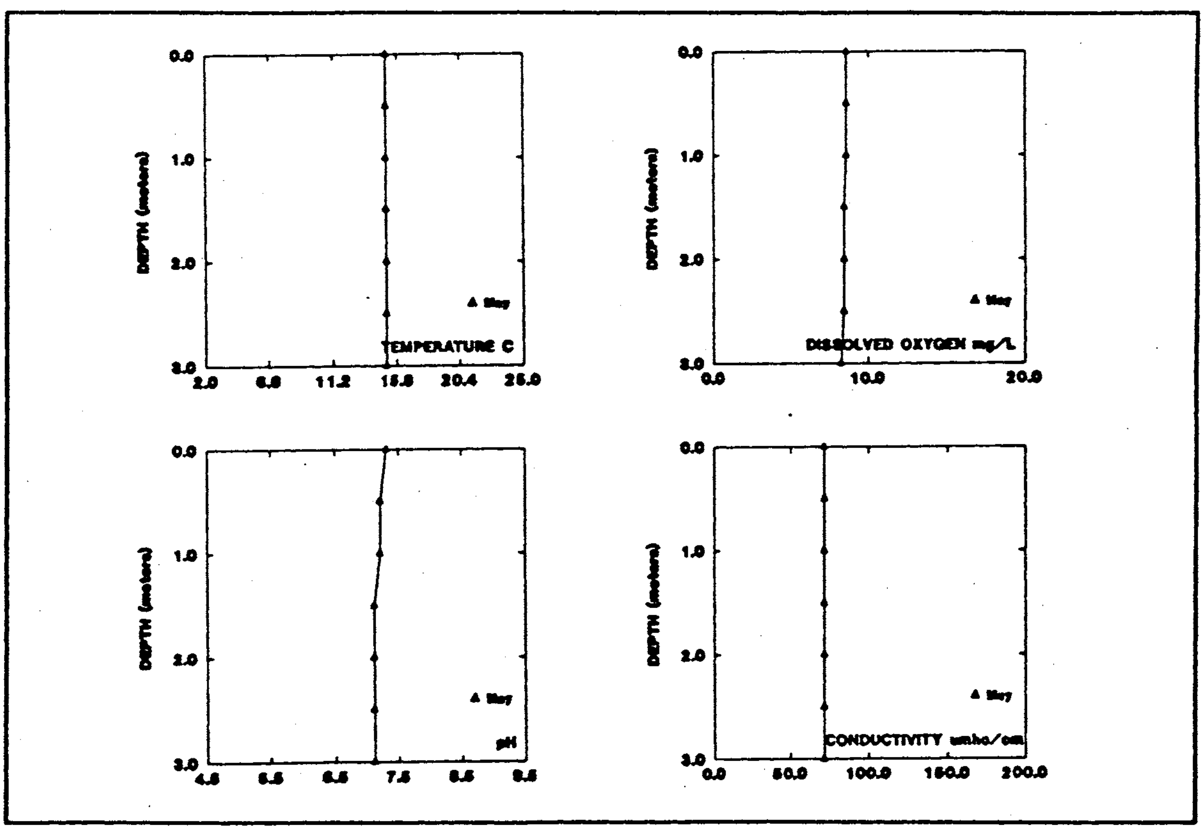
Data From Bortleson *et al.* (1976)

Date	06/22/73
Secchi (meters)	5
Total Phosphorus (mg/L)	0.041

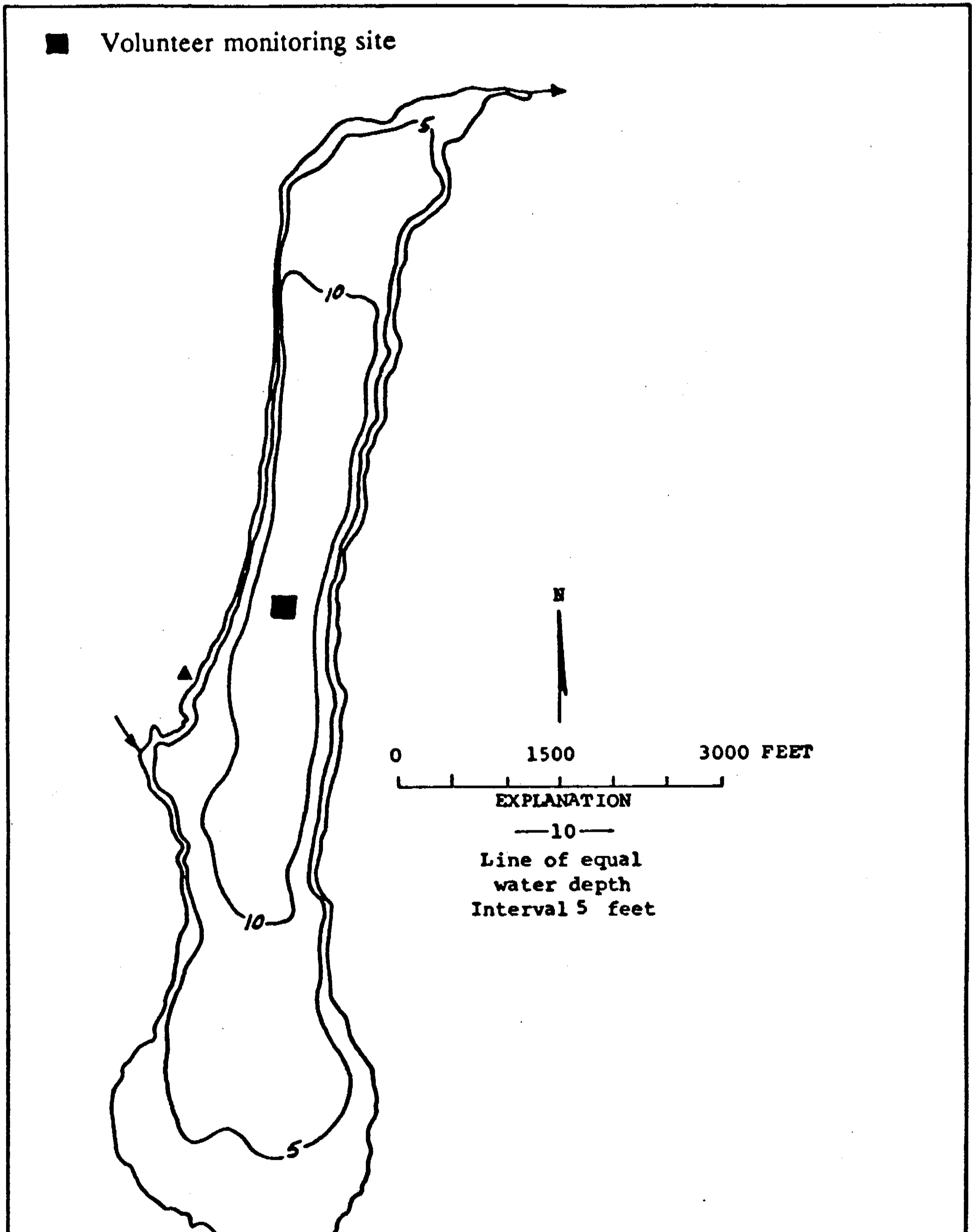
Remarks A NARROW LAKE THAT STRETCHES TWO MILES IN LENGTH. MOST OF THE EMERSED AND SUBMERSED PLANTS WERE ON THE NORTH AND SOUTH ENDS OF THE LAKE. AN ALGAL BLOOM WAS OBSERVED. IN 1973 THE U.S. GEOLOGICAL SURVEY SAMPLED THE LAKE FOUR TIMES. THE PLANT SURVEY WAS MADE ON AUGUST 14, 1973.

LONG LAKE (KITSAP COUNTY)





Profile and Secchi Data Graphs



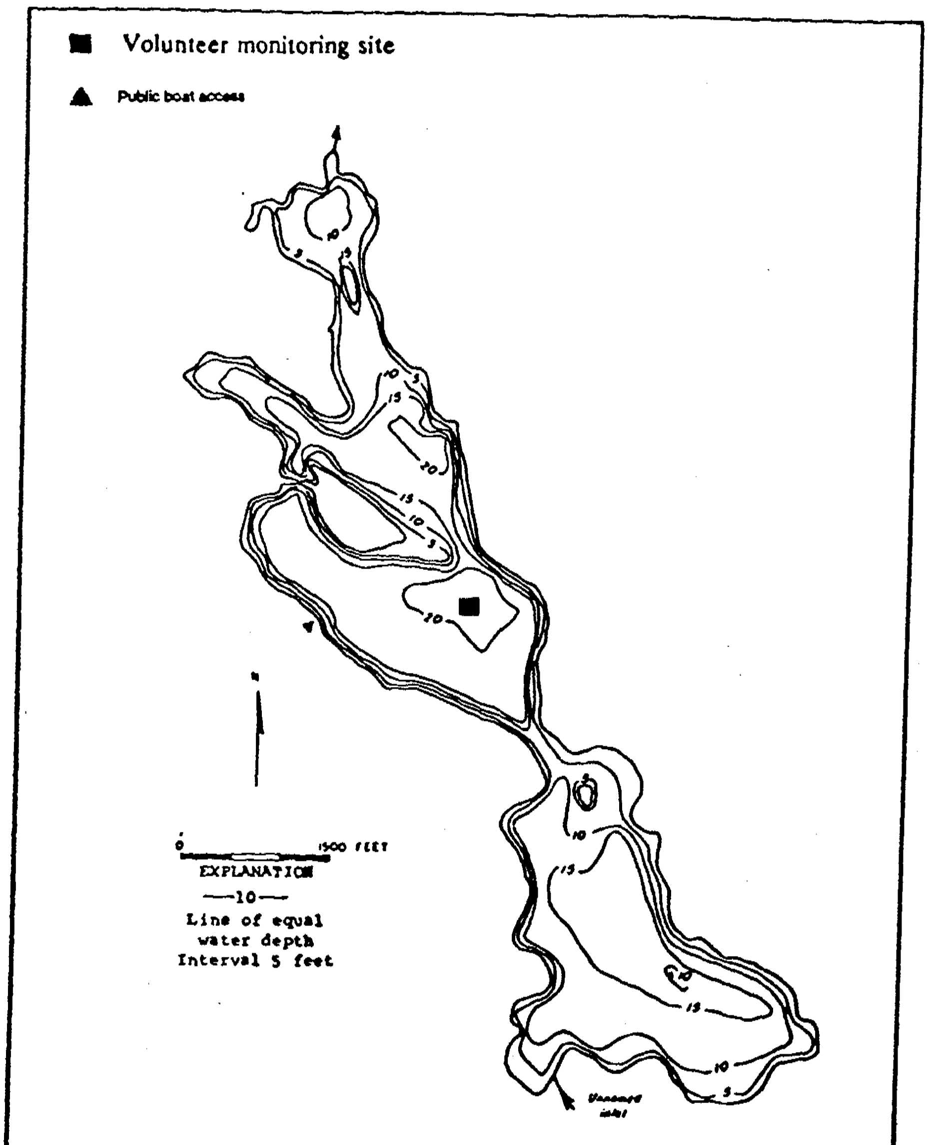
Long Lake, Kitsap County. From U.S. Geological Survey, September 13, 1973.

Long Lake -- Thurston County

Long Lake is located 5.5 miles east of Olympia. It consists of two basins, which are connected by a narrow neck. It is two miles long and has two islands, Holmes Island (13 acres) and Kirby Island (2.4 acres). Long Lake is fed by Pattison Lake and drains via Himes/Woodland Creek and Lois Lake to Henderson Inlet.

Size (acres)	330
Maximum Depth (feet)	21
Mean Depth (feet)	12
Lake Volume (acre-feet)	3,900
Drainage Area (miles^2)	8.3
Altitude (feet)	153
Shoreline Length (miles)	7.1

Data From Bortleson *et al.* (1976)



Long Lake, Thurston County. From Soil Conservation Service, September 20, 1971.

Long Lake -- Thurston County

1992 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	47
Mean Trophic State Index (Total Phosphorus):	55
Mean Trophic State Index (Chlorophyll *a*):	46

Volunteer-Collected Data

Date 1992	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht(in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
11-May	1100	15.6	60.0	6.0	14.75	Gr-Brown	40	Light	Breezy	Onsite visit. Filamentous algae surfacing in areas where breeze pushes mats to confined areas.
22-May	1530	16.9	62.5	7.5	16.50	Gr-Brown	40	None	Breezy	Nitella and filamentous algae.
14-Jun	1730	18.9	66.0	8.0		Gr-Brown	75	Trace	Breezy	
12-Jul	1715	22.2	72.0	10.0	20.00	Gr-Brown		None		
26-Jul	1845			8.0	21.50	Gr-Brown	0	None	Breezy	
15-Aug	1715	23.3	74.0	7.0	23.00	Gr-Brown	50	None	Breezy	
30-Aug	1130	20.0	68.0	6.0	24.50	Gr-Brown	75	None	Breezy	
02-Sep				7.5						Onsite visit.
18-Sep	1245	18.3	65.0	5.0	26.00	Pea Green	100	Light	Strong	
04-Oct	1415	17.8	64.0	5.5	27.00	Pea Green	100	Light	Breezy	

[1] Trophic State Indices calculated from Carlson (1977)

Long Lake -- Thurston County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/11	0.0	16.8	8.4	10.5	102
	1.0	16.6	8.5	10.3	102
	2.0	16.5	8.4	10.3	102
	3.0	16.4	8.3	10.1	102
	3.5	14.5	7.4	7.3	104
	4.0	13.9	7.5	1.1	107
	5.0	12.1	7.1	0.1	123
09/02	0.0	22.2	7.9	9.1	130
	1.0	22.2	7.9	9.1	130
	2.0	22.1	7.9	9.1	131
	3.0	22.1	7.9	8.9	130
	4.0	21.9	7.8	4.5	131
	4.5	21.8	7.7	3.8	131

1992 Onsite Visit Data - Water Chemistry

Date	05/11/92		09/02/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	0.5, 1, 2	3.5, 4, 4.5	1, 2, 4	--
Total Phosphorus (μg/L)	31	54	36	--
Total Nitrogen (mg/L)	0.44	0.45	0.43	--
Chlorophyll *a* (μg/L)	3.23	--	6.25	--

Long Lake -- Thurston County

Historical Data From Ecology

Date	08/20/74[a]	05/29/90[b]	08/21/90[b]	06/04/91[c]
Secchi (ft)	10	7.6	6.4	7
Total Phosphorus, epilimnion (μg/L)	10	20	28	--
Total Nitrogen, epilimnion (mg/L)	--	0.41	0.54	0.40
Chlorophyll *a* (μg/L)	--	--	--	--
Dissolved Oxygen, surface (mg/L)	9.9	10.9	10.1	11.7
Dissolved Oxygen, bottom (mg/L)	0.4	6.3	0.1	0.2

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)

Long Lake -- Thurston County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was fair, indicated by Secchi depths which ranged from 5.0 to 10.0 feet. All Secchi depths were in the mesotrophic range. Although the pattern of Secchi depths was similar to the pattern seen in 1991 (with the shallowest Secchi depths occurring at the beginning and the end of the monitoring season), Secchi depths were not as deep in 1992.

Total Phosphorus

Total phosphorus in the epilimnion was high and in the eutrophic range on both sampling dates (31 μg/L in May and 36 μg/L in September). The concentrations were higher than those measured for the program in 1990 (28 and 20 μg/L; Rector, 1991).

Total phosphorus concentrations vary considerably between surveys conducted on Long Lake. In July 1971 total phosphorus was low (10 μg/L; Bortleson *et al.*, 1976), in 1973 total phosphorus was high (ranging from 27 μg/L to 41 μg/L; McConnell *et al.*, 1976). From 1976-1977 total phosphorus was much higher, and exceeded 80 μg/L during October and November (Entranco Engineers, 1987). Following alum treatment in 1983, total phosphorus was still high, although it did not exceed 50 μg/L in the north basin (Entranco Engineers, 1987).

Total Nitrogen

Total nitrogen was moderately high, but was similar to concentrations measured for the program in 1991 and 1990.

Profile Data

The lake was barely stratified during May, and was unstratified during September. Despite the lack of stratification, dissolved oxygen decreased with depth on both sampling dates, and probably resulted from bacterial decomposition of aquatic plants and algae in the water and sediments. The profile data were very similar to data collected for the program in 1991 and 1990.

Plants

Chlorophyll *a* was moderately high on both sampling dates, indicating that there was a moderate amount of algal growth at the time of sampling. Given the high concentrations of total phosphorus in the water, algal growth (as indicated by chlorophyll concentrations) was not as high as would be expected.

The lake was treated with Sonar® (fluridone) during summer 1991 to control Eurasian watermilfoil (*Myriophyllum spicatum*; see Summary of Questionnaire Results, below). As a result, aquatic plant growth in the lake was reduced, and even emergent plants (such as cattails) and floating-leaved plants (such as lily pads) were brownish.

Long Lake -- Thurston County

Aquatic plants observed by Ecology staff during the May 11, 1992 onsite visit were sago pondweed (*Potamogeton pectinatus*) and an alga (possibly *Nitella*). Iris and cattails along the shore (*Iris pseudacorus* and *Typha* spp.) were brownish to brown near the water surface, indicating that the plants were probably taking up fluridone from the sediments.

During the June 4, 1991 onsite visit with the volunteer, curly-leaf pondweed (*Potamogeton crispus*) and large-leaved pondweed (*Potamogeton amplifolius*) were present near the volunteer's dock. The large-leaf pondweed was in bloom at the time of sampling. In 1990, the volunteer sent an algae sample which was identified as *Oscillatoria*, a filamentous blue-green alga. The volunteer noted that this alga was most prevalent during June and July.

Other Available Information
Long Lake has a history of heavy algal growth, even before Eurasian watermilfoil was introduced into the lake. In 1968, algal blooms and Secchi disk transparency of only four feet were reported by Lee (1969).

From Entranco Engineers (1987): Restoration activities were initiated to address blue-green algal blooms and prolific aquatic plant growth in Long Lake and Pattison Lake. In 1976-1977, Phase I Diagnostic/Feasibility monitoring indicated that total phosphorus concentrations were very high, and exceeded 80 μg/L during October and November. Conclusions and recommendations from the study included whole-lake alum treatments to precipitate phosphorus from the water column, and mechanical harvesting of plants. In 1983, both Long and Pattison Lakes were treated with alum. In Long Lake, mechanical harvesting of plants began in 1983.

From Welch *et al.* (1988): Alum was added to Long Lake in fall, 1983 to inactivate phosphorus in the sediments. This treatment achieved a 55% reduction in water column phosphorus, and an increase of 1.7 meters in Secchi disk transparency. Internal phosphorus loading from macrophytes was addressed by mechanical harvesting. The effectiveness of the treatment lasted about two years.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

> Long Lake is used for fishing, boating, swimming, rowing, jet skiing and camping. Recreational facilities on the lakeshore include a park, a picnic area, a camping area, a beach, a resort and eight boat ramps. There is a speed restriction of 45 mph for motorboats. Less than 1 percent of the shoreline is publicly-owned. Brown trout were stocked in the lake. Currently the watershed is used for light industry, animal grazing and crop agriculture, and the lakeshore is being developed further for residences. In the past, the watershed was used for logging and animal grazing, the lake was dredged, and the shoreline was altered.

Long Lake -- Thurston County

There are about 300 houses on the lakeshore, and none of the houses are connected to a sewer. There is a lake association, lake management district, and a community association for the lake. Currently, the minimum setback for residential development is 50 feet. Lake water is withdrawn for irrigation.

Overall, the volunteer finds that Long Lake had good water quality. Problems in the lake in 1992 were ranked as 1) algae, 2) low water level, 3) degraded aesthetics, and 4) swimmer's itch. Changes in the lake since 1991 included significantly reduced milfoil growth (resulting in improved recreational use of the lake), reduced density of other aquatic vegetation, and reduced water clarity. Possible sources of problems are nutrients from Pattison Lake, stormwater, and septic systems, the shallow lake bed, and decreasing riparian buffer. No plant or algae control occurred in 1992, but plant surveys were conducted as part of the milfoil control program. The milfoil management strategy for next year will not be established by the lake management district until the extent of milfoil eradication is determined.

In 1990, Eurasian watermilfoil grew along most of the shoreline, in water less than 10 feet deep, and covered about 167 acres. Emergent vegetation included both white and yellow-flowering waterlily, cattails, reed canary grass, bulrush, and water iris. Submerged vegetation included (in order of abundance) Eurasian watermilfoil, pondweed (three varieties), waterweed, northern watermilfoil, bladderwort, wild celery (also known as tapegrass), and water silk (an alga). *Chara* (an alga) and bryozoans (invertebrates) were also found.

Long Lake was treated with fluridone on July 2 and August 17, 1991 with the intent of eradicating Eurasian watermilfoil growth in the lake. Although algal growth following the fluridone treatments was not at nuisance levels, it was greater in late summer and fall than in recent years. Because of the fluridone application, the Thurston County Board of Health closed the lake to contact recreation from July 2 through August 24, 1991. A survey conducted in October 1991 found that about 90% of the Eurasian watermilfoil was killed by the fluridone applications. Milfoil was still growing in the inlet channel and a few scattered areas around the lake.

Comments

The mesotrophic estimation of Long Lake was based on the moderate Secchi depths, chlorophyll *a*, and aquatic plant growth, and the high concentrations of total phosphorus.

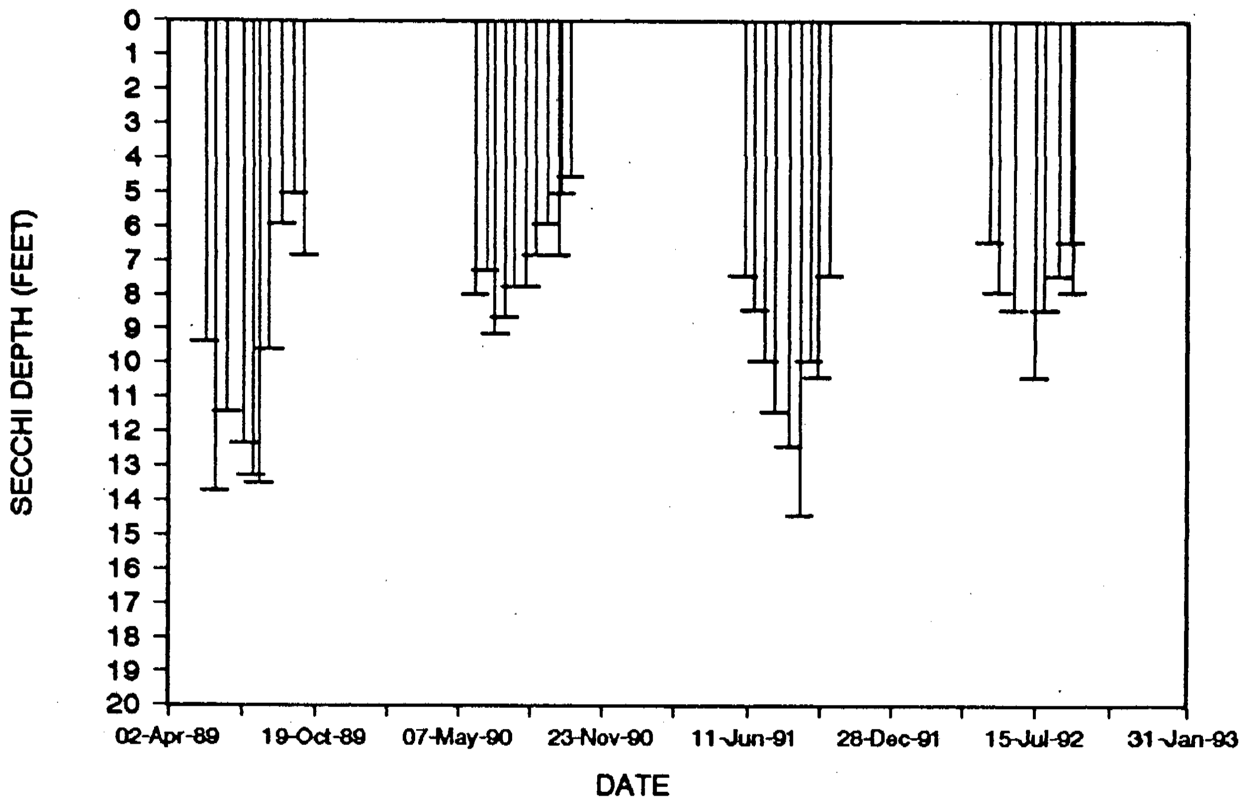
Long Lake -- Thurston County

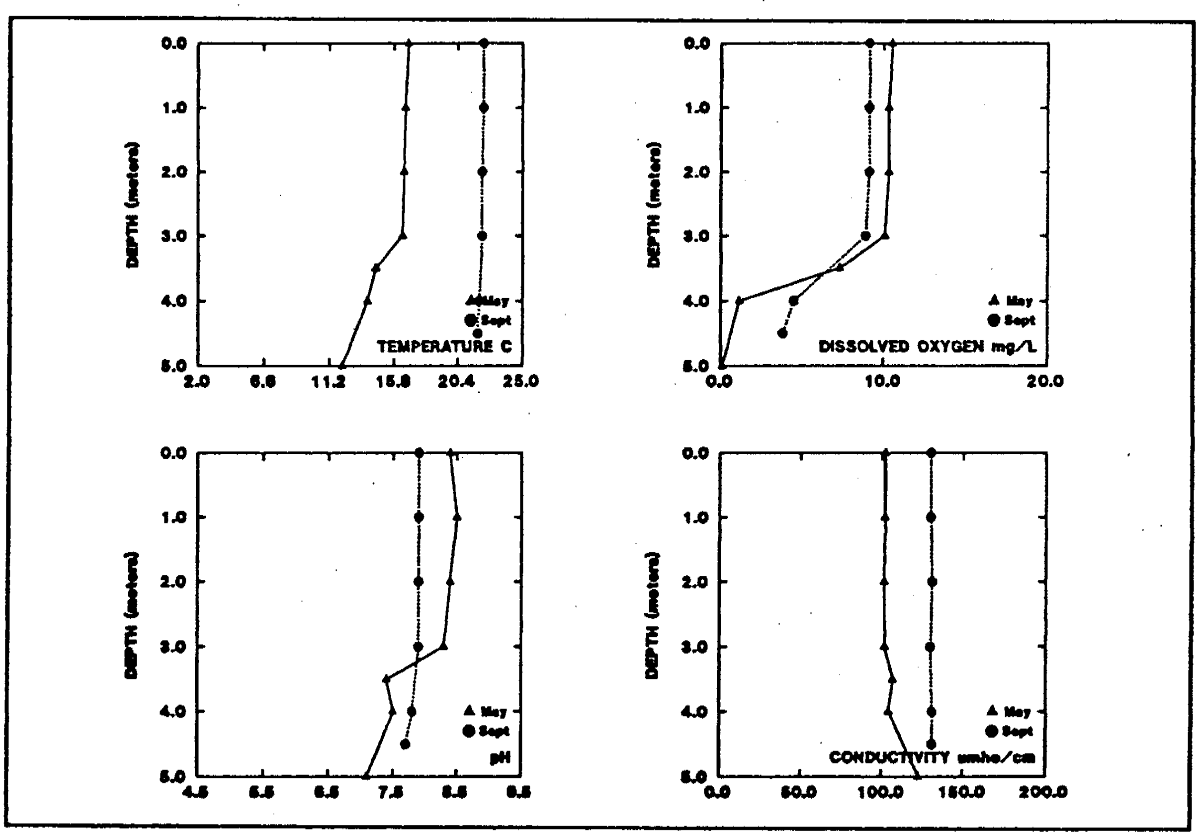
Acknowledgement

I thank Sue Mauermann for volunteering her time to be the primary monitor at Long Lake during 1992, and Kathey Adams for monitoring the lake during 1989-1992.

Other Thurston County lakes monitored for the program in 1992 are North Pattison, War, and St,. Clair. Mean summer Secchi depth and total phosphorus was very similar in Long Lake and Lake St. Clair. North Pattison had lower total phosphorus (23 μg/L in August) and deeper Secchi depths (ranging from 5.3 to 17.5 feet) than Long Lake.

LONG LAKE (THURSTON COUNTY)



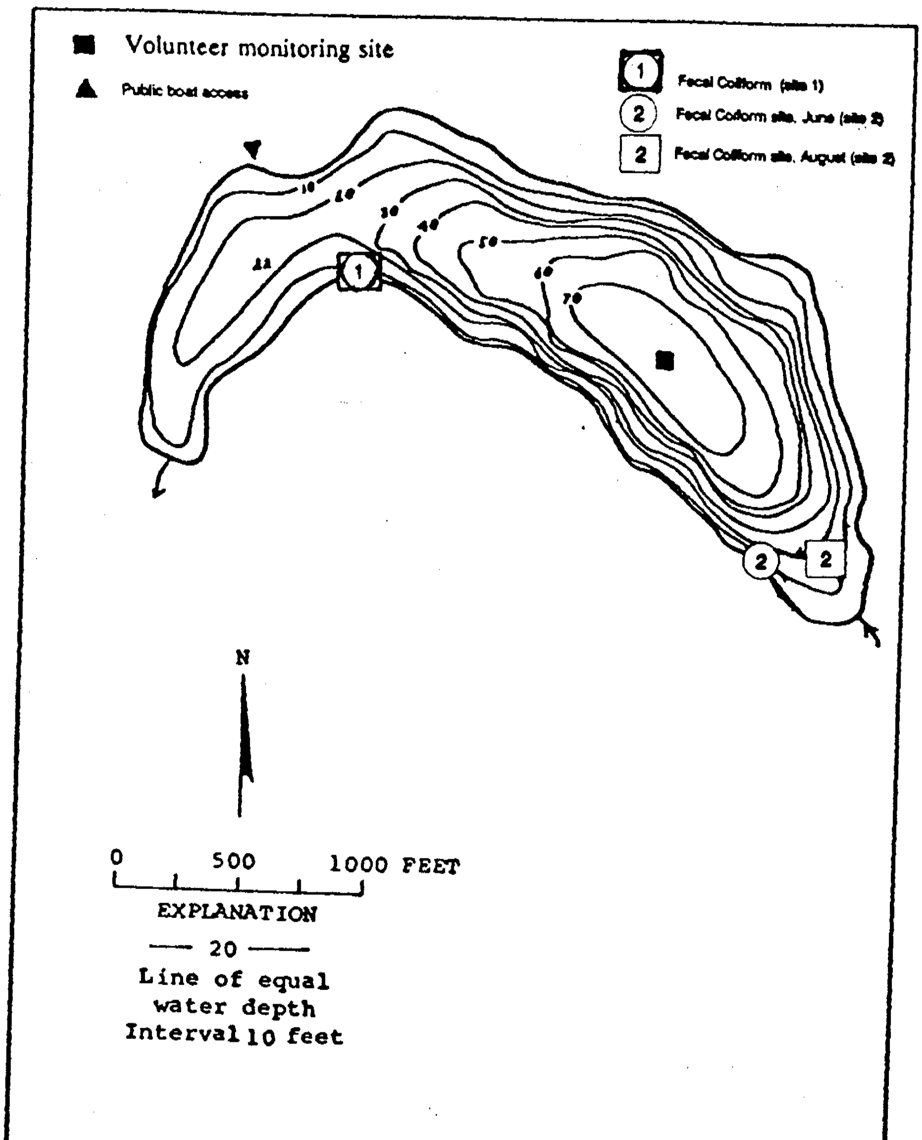


Lake Martha (near Warm Beach) -- Snohomish County

Lake Martha is located 10.5 miles northwest of Marysville, and one mile east of Warm Beach. It is fed by Howard Lake and drains to Port Susan. Lake Martha is different from Martha Lake, which is located near Alderwood Manor.

Size (acres)	62
Maximum Depth (feet)	70
Mean Depth (feet)	33
Lake Volume (acre-feet)	2,034
Drainage Area (miles^2)	1.6
Altitude (feet)	186
Shoreline Length (miles)	1.8

Data From Bortleson *et al.* (1976)



Martha (31N-4E-18) Lake, Snohomish County. June 2, 1970.
Approx. scale 1:12,000.

Lake Martha (near Warm Beach) -- Snohomish County

1992 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	36
Mean Trophic State Index (Total Phosphorus):	40
Mean Trophic State Index (Chlorophyll *a*):	33

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
01-Jun	1050	20.6	69.0	11.9	-15.00	Yellow	100	None	Breezy	
18-Jun	1205	20.6	69.0	14.3	-20.25	Yellow	90	Trace	Light	Lots of greenish-yellow specs in water but white of Secchi disk appeared yellow at 7.5 feet.
07-Jul	1045	20.0	68.0	13.6	-17.25	Yellow	100	Heavy	Calm	Yellow-green specs cloud the water - sent in a sample.
28-Jul	1115	23.3	74.0	17.2	-17.00	Yellow	10	Trace	Light	Weeds not nearly as abundant near dock as before. Thick specs in water - pollen?
15-Aug	1145	23.3	74.0	18.7	-20.50	Yellow	10	None	Breezy	Unusual sighting: green-backed herons feeding and resting on our dock and lawn! Weeds seem much less.
25-Aug	1345	22.2	72.0	19.5	-21.75	Yellow	10	None	Light	Weeds shorter, sparser.
12-Sep	1315	18.9	66.0	19.9	-24.50	Yellow	75	Moderate	Breezy	Nothing to report - things look normal.
21-Sep	1340	17.8	64.0	19.7	-25.00	Yellow	10	Heavy	Light	Weeds less abundant. Hooded mergansers catching crawfish among weeds!
07-Oct	1145	15.0	59.0	19.1	-26.50	Yellow	100	None		Weeds at east end and inlet seem thicker again but not tall enough to reach water surface. Need more feeding ducks?

[1] Trophic State Indices calculated from Carlson (1977)

Lake Martha (near Warm Beach) -- Snohomish County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
06/01	0.0	20.9	8.1	10.1	87
	1.0	21.0	8.0	9.9	88
	2.0	20.9	8.0	9.9	88
	3.0	19.3	7.9	9.7	88
	4.0	15.6	7.7	9.6	87
	5.0	12.2	7.4	6.9	88
	6.0	10.1	7.3	6.7	87
	7.0	8.9	7.2	6.8	85
	8.0	8.1	7.2	6.8	85
	10.0	7.3	7.1	6.5	86
	12.0	7.1	7.0	5.8	85
	14.0	7.0	7.0	5.4	85
	16.0	6.9	6.9	4.6	86
	18.0	6.8	6.8	1.6	87
	20.0	6.7	6.7	0.2	99
08/25	0.0	22.6	8.0	9.0	94
	1.0	21.9	8.0	8.9	94
	2.0	21.7	8.0	8.9	93
	3.0	21.7	8.0	8.8	93
	4.0	21.0	8.0	8.4	92
	5.0	17.1	8.0	10.6	92
	6.0	13.7	8.0	6.1	93
	7.0	10.5	7.8	2.5	92
	8.0	8.8	7.4	2.5	90
	9.0	8.0	7.4	2.6	91
	10.0	7.7	7.4	2.9	90
	12.0	7.1	7.3	2.6	90
	14.0	7.1	7.3	2.3	90
	16.0	7.0	7.3	1.2	90
	18.0	6.8	7.2	0.3	96
	18.5	6.7	6.9	0.1	103

Lake Martha (near Warm Beach) -- Snohomish County

1992 Onsite Visit Data - Water Chemistry

Date	06/01/92		08/25/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2	12, 14, 16	1, 2, 3	12, 14, 16
Total Phosphorus ($\mu g/L$)	12	12	12	17
Total Nitrogen (mg/L)	0.46	0.66	0.38	0.63
Chlorophyll *a* ($\mu g/L$)	1.90	--	0.59	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	9	--	4	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	5	--	<1	--
Total Suspended Solids (mg/L)	2	--	2	--
Total Nonvolatile Suspended Solids (mg/L)	<1	--	<1	--
Color (Pt-Co units)	30	--	20	--

Historical Data

Date	06/20/74[a]	06/30/81[b]	06/05/90[c]	08/28/90[c]	06/18/91[d]
Secchi (ft)	9	10	10.5	14.5	11.7
Total Phosphorus, epilimnion ($\mu g/L$)	17	10	8	12	--
Total Nitrogen, epilimnion (mg/L)	--	--	0.62	0.46	0.61
Chlorophyll *a* ($\mu g/L$)	3.5	6.02	--	--	--
Dissolved Oxygen, surface (mg/L)	9.2	10.5	10.1	9.0	10.3
Dissolved Oxygen, bottom (mg/L)	0.4	0.3	2.0	0.8	4.1

a. Bortleson *et al.* (1976); Dion *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)

Lake Martha (near Warm Beach) -- Snohomish County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good, as indicated by Secchi depths which ranged from 11.9 to 19.9 feet and tended to increase throughout the monitoring season. This same pattern was also evident in 1991 and 1990. Tree pollen in the water may have affected Secchi depths during May and June, 1992.

Total Phosphorus

On both sampling dates, total phosphorus in the epilimnion was 12 μg/L. This concentration is considered low to moderate, and borderline between oligotrophy and mesotrophy. With the exception of the phosphorus concentration measured in 1974, phosphorus concentrations measured in Lake Martha have not been high.

Total Nitrogen

Nitrogen concentrations in the epilimnion were moderate (0.46 mg/L in June, and 0.38 mg/L in August), but in comparison to earlier data collected from the lake, were among the lowest measured.

Fecal Coliform Bacteria

Results from fecal coliform samples were all low, and were within state standards. Sampling sites are indicated on the map.

Solids and Color

Results for both total suspended solids and total nonvolatile suspended solids were low. Results from the color tests, though, indicate that the lake is slightly colored. Natural color can occur from organic-rich soils in the lake bottom and/or the watershed. This may explain the volunteer's observations of a yellow color in the water throughout the monitoring season. While natural color is not a problem in lakes (in fact, color can at times inhibit algal growth by shading algae), color may affect Secchi depths. Because data from this year suggest that mean Secchi depth and total phosphorus indicate similar trophic state, the color in Lake Martha does not seem to greatly affect the use of Secchi depth to estimate trophic status.

Profile Data

On both sampling dates, the lake was stratified with respect to temperature, and dissolved oxygen decreased from surface to bottom. During August, dissolved oxygen was very low in the hypolimnion, but metalimnetic waters appeared to have high enough oxygen and low enough temperatures to support fish. During onsite visits in 1990 and 1991, dissolved oxygen was low at the top of the metalimnion, increased through the metalimnion, and then decreased with depth below the hypolimnion. This pattern was not evident in 1992, and suggests that algal productivity may have been lower in 1992 than in 1990 or 1991. Secchi depths were deeper in 1992, suggesting there was less algal growth.

Lake Martha (near Warm Beach) -- Snohomish County

Plants

Chlorophyll was low and in the oligotrophic range on both sampling dates, indicating that algal density was low at the time of sampling.

Aquatic plants identified by Ecology staff during the June 1, 1992 onsite visit were waterweed (*Elodea canadensis*), muskgrass (*Chara*), iris (*Iris pseudacorus*), and yellow-flowering lily (*Nuphar* spp.). In August 1992, waterweed, (both *Elodea canadensis* and *Elodea nutalli*), largeleaf pondweed (*Potamogeton amplifolius*), muskgrass, flatleaf pondweed (*Potamogeton robbinsii*), lilies, iris, and coontail were observed. Largeleaf pondweed was the dominant plant in deeper water, whereas waterweed was the dominant plant nearshore. Waterweed was the dominant plant in the lake in 1990. Some emergent plants, including sedge and cattails, were also observed.

A water sample was collected by the volunteer on May 23, 1990 because the lake turned a green-brown color. The sample contained pollen, dark-colored cladocerans (a pinhead-sized crustacean) and a lot of algal cells, possibly the blue-green alga *Microcystis*. Another sample collected on July 22, 1990 consisted of the blue-green filamentous algae *Oscillatoria*. Detritus clumps were also examined, and contained *Gomphonema*, *Scenedesmus*, *Stephanodiscus*, a lot of *Aphanocapsa*, and "little green balls" that may have been *Sphaerocystis*.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

> Lake Martha is used for fishing, swimming, motor boating, non-motorized boating, lakeshore camping, and birdwatching. There is one public boat ramp on the lakeshore, and the only restriction for motorboating is a speed limit of 8 mph. About 1 percent of the is shoreline publicly-owned. Trout were stocked in the lake. Currently, the watershed is used for logging, animal grazing/feeding, and lakeshore development for residences. In the past, the watershed was used for logging, crop agriculture, and animal grazing/feeding. In 1969, the lake was dredged on the east end near the inlet to create a U-shaped embayment and to extend the shoreline. Lots on this property were developed.
>
> There are 79 houses on the lakeshore, and none of the houses are connected to a sewer. There is a lake association and a sewer district for the lake. Currently, the minimum setback for development is 26 feet.
>
> Overall, the volunteer finds that Lake Martha had good water quality. Problems in the lake in 1992 were listed as aquatic plants, shoreline erosion, and shoreline construction

with permit violations. No changes occurred in the lake since the 1991 monitoring season. No management activities were taken on the lake in 1992. The lake supports a variety of waterfowl, including green-backed heron and common loon.

Waterweed growth in the lake was not as tall in 1991 as in 1990, although plant growth in the lake was essentially the same during both years. Possibly there were a few more lilies in shallow water near the inlet. In the summer of 1989, waterweed in the lake grew thick and tall, especially at the east end. Only a few mats of waterweed were noted in 1990.

The volunteer measured lake level during a severe storm in fall 1991, and the level rose 5.5 inches in 24 hours.

Comments

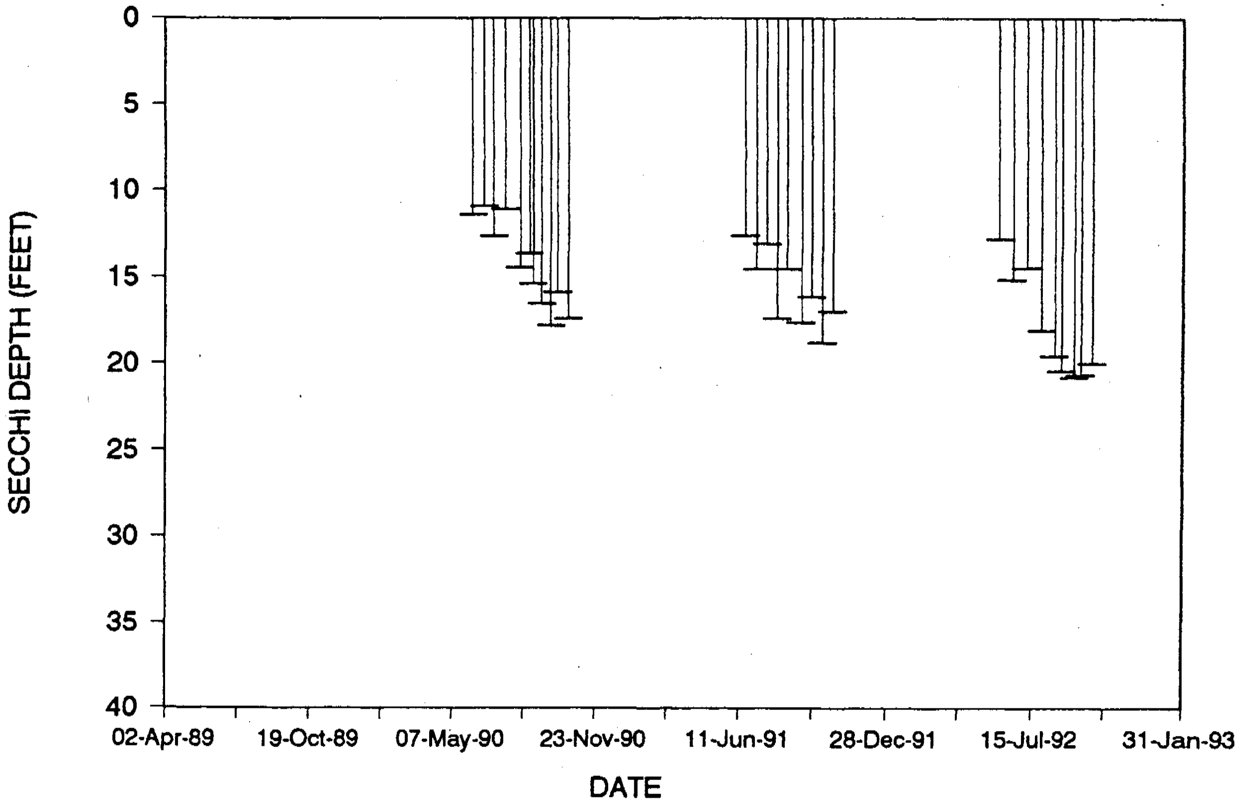
All three trophic parameters (Secchi depth, total phosphorus, and chlorophyll *a*) indicated that Lake Martha was oligotrophic. The volunteer's descriptions of wildlife around the lake indicate that the lake enjoys a nice amount of diversity.

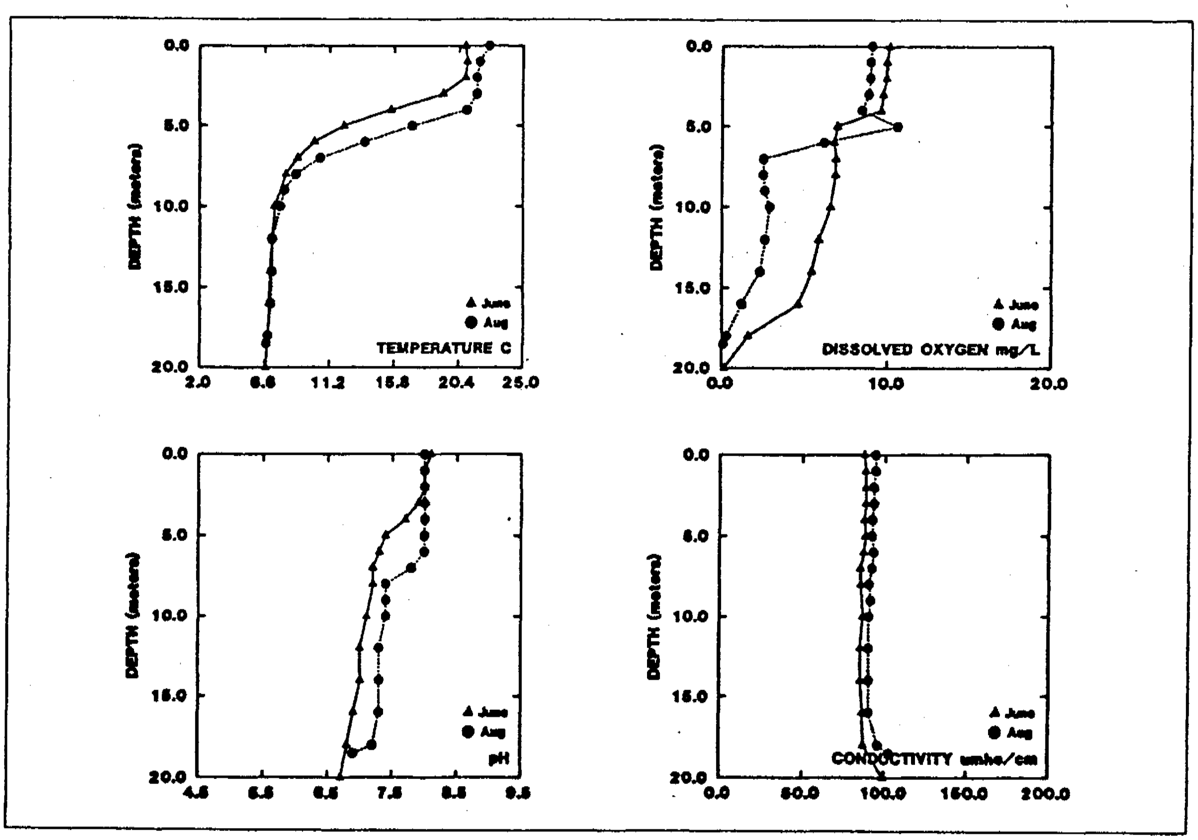
Other Snohomish County lakes monitored for the program in 1991 are Bosworth, Ketchum, Martha Lake, Roesiger, Stevens and Sunday. Lake Martha had very good water clarity, similar to that found in Lake Roesiger and Lake Stevens. Lake Roesiger, Lake Bosworth and Lake Stevens all had lower total phosphorus than Lake Martha. Secchi depths and total phosphorus in Lake Martha were very similar to results from Martha Lake near Alderwood.

Acknowledgement

I thank Joan Lucas for volunteering her time to monitor Lake Martha during 1990 - 1992.

LAKE MARTHA (SNOHOMISH COUNTY)



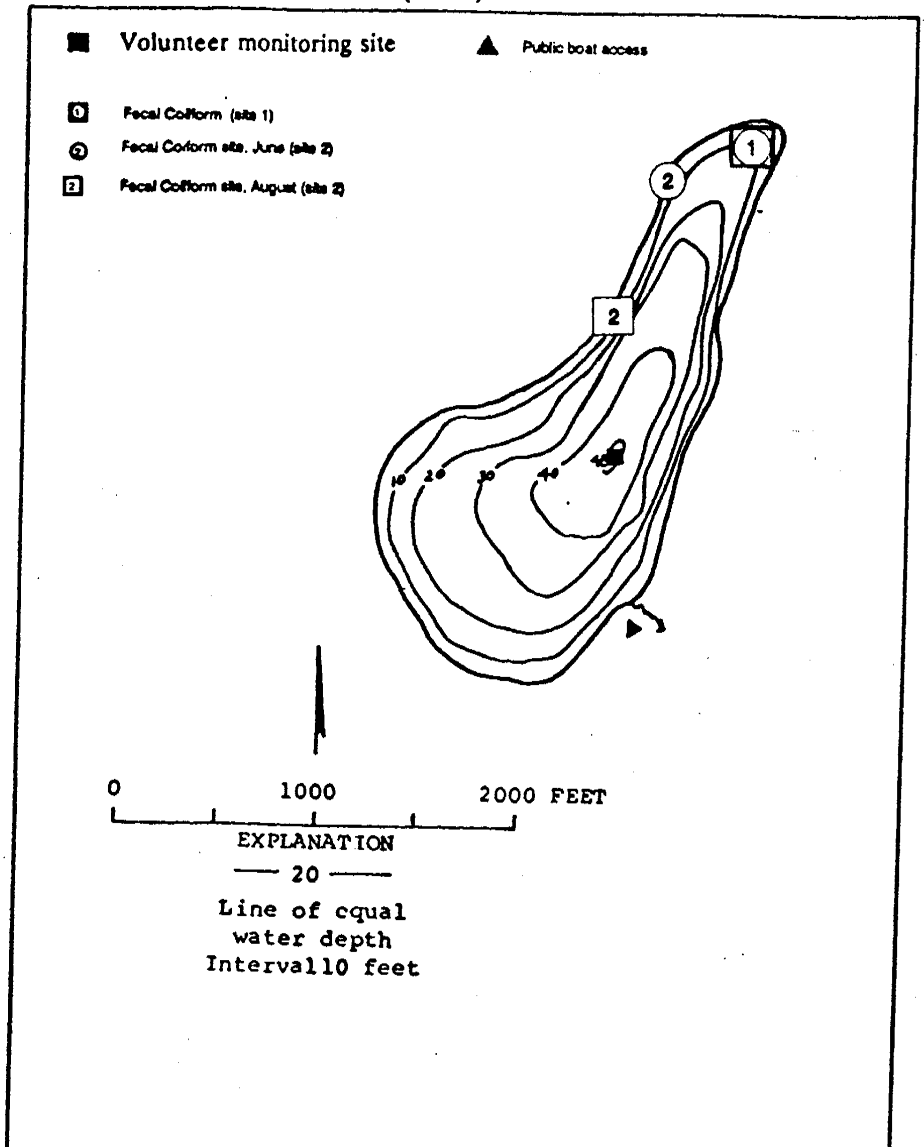


Martha Lake (near Alderwood Manor) -- Snohomish County

Martha Lake is located 2.5 miles northeast of Alderwood Manor. It was originally called Manor Lake. It has an intermittent inlet, and drains via a marsh to Swamp Creek and the Sammamish River.

Size (acres)	57
Maximum Depth (feet)	48
Mean Depth (feet)	24
Lake Volume (acre-feet)	1,346
Drainage Area (miles^2)	0.8
Altitude (feet)	450
Shoreline Length (miles)	1.4

Data From Bortleson *et al.* (1976)



Martha (27N-4E-1) Lake, Snohomish County.
From Washington Department of Game, January 2, 1948.

Martha Lake (near Alderwood Manor) -- Snohomish County

1992 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic[2]
Mean Trophic State Index (Secchi):	37
Mean Trophic State Index (Total Phosphorus):	42
Mean Trophic State Index (Chlorophyll *a*):	28

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
14-May	1430	15.0	59.0	18.0	-16.00	Lt-Green	0	Trace	Light	Very slight algae.
28-May	1530	17.8	64.0	17.0	-19.00	Lt-Green	50	None	Strong	
24-Jun	1100	20.6	69.0	18.0	-20.00	Lt-Green	0	None	Light	
08-Jul	1100	17.8	64.0	14.0	-19.00	Lt-Green	90	Light	Light	
24-Jul	1330	18.3	65.0	14.0	-20.75	Lt-Green	75	Light	Light	
07-Aug	1230	17.2	63.0	15.0	-22.00	Lt-Green	100	Moderate	Light	
26-Aug	1300	18.9	66.0	15.0	-25.50	Lt-Green	10	None	Light	
31-Aug	1045	21.0	70.0	15.0	-26.00	Lt-Green	90	Trace	Light	Onsite visit.
14-Sep	1145	17.2	63.0	14.0	-26.75	Lt-Green	75	Trace	Breezy	Temp using Snoh. Co. thermometer.
29-Sep	1415	17.8	64.0	19.0	-26.50	Lt-Green	10	Trace	Light	

[1] Trophic State Indices calculated from Carlson (1977)

[2] see Comments section

Martha Lake (near Alderwood Manor) -- Snohomish County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/18	0.0	18.7	7.6	10.3	85
	1.0	18.7	7.6	10.3	85
	2.0	18.7	7.7	10.2	84
	3.0	18.6	7.7	9.8	84
	4.0	16.3	7.9	10.9	84
	5.0	12.8	7.6	10.0	83
	6.0	11.0	7.3	4.5	84
	7.0	10.0	7.1	2.3	84
	8.0	9.3	6.9	1.2	85
	9.0	9.0	6.9	0.5	86
	10.0	8.7	6.8	0.3	86
	11.0	8.3	6.7	0.1	89
08/31	0.0	21.0	7.6	8.9	98
	1.0	21.1	7.6	7.6	99
	2.0	21.1	7.6	8.5	99
	3.0	21.1	7.6	6.7	99
	4.0	21.1	7.6	7.0	99
	5.0	20.9	7.6	7.4	99
	6.0	17.1	7.5	0.5	103
	7.0	13.8	7.4	0.3	102
	8.0	11.4	7.3	0.1	104
	9.0	9.9	7.3	0.1	108
	10.0	9.3	7.1	0.1	119
	10.5	9.0	6.9	0.1	122

Martha Lake (near Alderwood Manor) -- Snohomish County

1992 Onsite Visit Data - Water Chemistry

Date	05/18/92		08/31/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	8, 9, 10	1, 2, 4	9, 9.5
Total Phosphorus (μg/L)	16	13	11	40
Total Nitrogen (mg/L)	0.66	0.62	0.41	0.55
Chlorophyll *a* (μg/L)	0.40	--	1.14	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	430	--	160	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	7	--	71	--
Total Suspended Solids (mg/L)	2	--	<1	--
Total Nonvolatile Suspended Solids (mg/L)	1	--	<1	--
Color (Pt-Co units)	20	--	10	--

Historical Data From Ecology

Date	07/25/73[a]	08/28/90[b]	05/30/91[c]
Secchi (ft)	13	16	17
Total Phosphorus, epilimnion (μg/L)	3	15	--
Total Nitrogen, epilimnion (mg/L)	--	0.53	0.81
Chlorophyll *a* (μg/L)	--	--	--
Dissolved Oxygen, surface (mg/L)	9.1	9.4	10.6
Dissolved Oxygen, bottom (mg/L)	0.2	0.1	0.2

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)

Martha Lake (near Alderwood Manor) -- Snohomish County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was good, as indicated by Secchi depths which ranged from 14.0 to 19.0 feet. Although mean Secchi depth (and the Secchi-based TSI) remained very similar from 1990-1992, Secchi depths were more variable in 1992. All Secchi depths from 1992 were in the oligotrophic range.

Total Phosphorus
Total phosphorus in the epilimnion was moderately high during May (16 μg/L), but was lower during August (11 μg/L). The concentration of phosphorus in May was similar to that measured in August 1990 (15 μg/L; Rector, 1991).

Total Nitrogen
Total nitrogen was moderately high (0.66 and 0.41 mg/L), but was lower than the concentration measured in 1991 (0.81 mg/L; Rector, 1992).

Fecal Coliform Bacteria
Fecal coliform bacteria samples were collected at the north end of the lake, near the intermittent inlet, during both onsite visits (site #1 on map). Bacteria counts were high on both sampling dates; results for this site were 430 colonies/100 mL during May, and 71 colonies/100 mL during August. Site #2 in August also had a high result for fecal coliforms (160 colonies/100 mL; see map for location). The Lake Class water quality standard for fecal coliform bacteria is a geometric mean of 50 colonies/100 mL, and no more than 10% of the samples may exceed 100 colonies/100 mL. High bacteria levels in Martha Lake have been documented previously, with sources identified as stormwater and waterfowl (Entranco, 1991; see Other Available Information, below).

Solids and Color
Results for solids and color were very low. These results indicated that Secchi depths were affected most by algal density at the time of sampling, rather than suspended sediments or color.

Profile Data
On both sampling dates, the lake was stratified with respect to temperature, and dissolved oxygen decreased considerably below the thermocline. In May, the increase in dissolved oxygen at four meters may have resulted from an increase in algal growth at this depth. During August, dissolved oxygen was particularly low in the hypolimnion, where oxygen was 0.5 mg/L or lower in the bottom 4.5 meters of the lake. The low oxygen concentrations probably resulted from bacterial decomposition of algae and aquatic plants in the water and sediments. Profile data from 1992 were very similar to profile data collected in 1990 and 1991.

Martha Lake (near Alderwood Manor) -- Snohomish County

Plants

Algal density was low on both smapling dates, as indicated by low concentrations of chlorophyll *a*. During May, though, algal density in the epilimnion was lower than would be expected, because at the time there was a moderately high concentration of total phosphorus. It is possible that algal density was actually higher in May than the chlorophyll data suggest, but the algae were located below the epilimnion (only epilimnion samples were analyzed for chlorophyll). Increased algae below the epilimnion is indicated by an increase in dissolved oxygen at 4 meters (see Profile Data). Increases in dissolved oxygen with depth, which are not explained by temperature changes or the presence of many aquatic plants, can indicate an area of increased algae growth.

Aquatic plants identified by Ecology staff during the May 18, 1992 onsite visit were white-flowering lily (*Nymphaea odorata*), yellow-flowering lily (*Nuphar* spp.), and iris (*Iris pseudacorus*). These plants were also present during the May 1991 onsite visit,

Other Available Information

Martha Lake was monitored by the same volunteer for Snohomish County's Citizen Lake Monitoring Program, from August through October 1992. The volunteer collected Secchi depth and surface water temperature data on the same days for both programs. In addition, the volunteer measured dissolved oxygen (LaMotte kit), pH (Hannah pH pen) and temperature at discrete depths (surface, 1 meter, 3 meters, 6 meters, and 1 meter from the bottom) once each month during August, September, and October. The August profile data were very similar to those collected for Ecology's program during August. In September, the lake was beginning to destratify, and in October the lake was almost completely destratified. Dissolved oxygen was depleted near the lake bottom during both September and October. pH ranged from about 7.5 at the surface to about 6.5 at the bottom during all three months.

From Entranco (1991): A Phase I Restoration study was conducted from December 1989 - November 1990. The purpose of the analysis was to determine the water quality of the lake and its tributaries, determine the sources and extent of water quality problems, and to recommend options for future management of the lake. The lake had low dissolved oxygen at the lake bottom during stratification (April through November). Despite relatively high phosphorus loading from runoff, particularly in winter, concentrations in the water column were relatively low and resulted in low algal productivity. There was no significant internal loading of nutrients from the sediments. The only problem in the lake was high nearshore fecal coliform bacteria levels which exceeded the Washington State standard (geometric mean of 50 organisms/100mL); the geometric mean of fecal coliform at the outlet was 95 colonies/100 mL. Bacterial loading was thought to be mainly from stormwater runoff and waterfowl; loading from septic systems was estimated to be small. Overall, the lake had good water quality and was determined to be oligo-mesotrophic. Recommendations for controlling further loading to the lake included regulatory controls, public education and best management practices.

Martha Lake (near Alderwood Manor) -- Snohomish County

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

> Martha Lake is used for fishing, swimming, non-motorized boating, and lakeshore camping. There is a park on the lakeshore, and about 8 percent of the shoreline is publicly-owned. There is one public boat ramp, but no motorboats are allowed on the lake. Trout were stocked in the lake. Currently, the watershed is used for lakeshore development for residences. In the past, the watershed was used for logging.
>
> There are about 102 houses on the lakeshore, and homes along about 40% of the lakeshore are connected to a sewer. About 3 culverts/stormdrains drain into the lake. Lake water is withdrawn for irrigation. There is a lake association, lake management district, sewer district, and community association for the lake. Currently, the minimum setback for lakeshore development is 25 feet for buildings, and 100 feet for drainfields. Minimum lot lengths are 65 feet, and residential density is restricted to 4 houses per acre.
>
> Overall, the volunteer finds that Martha Lake had good water quality. Problems in the lake in 1992 were ranked as 1) erosion, and 2) excessive aquatic plant growth. Possible sources of problems are runoff in the west end of the lake from Interstate 5, and increased numbers of water lilies. In 1992, Snohomish County purchased the Martha Lake Tavern site, and will convert it to a county park.
>
> The lake is surrounded by residential homes except for areas near the former tavern site and the public access. Lily pads grow along the southwest shoreline and along the north tip of the lake. Reeds grow around the north tip and also near the public access. The lake was treated with chemicals in the past to control undesirable fish species.

Comments

In 1992, Martha Lake exhibited both oligotrophic and mesotrophic characteristics. Oligotrophic characteristics were the good water clarity, and low concentrations of chlorophyll *a* (which indicate low algal density). Mesotrophic characteristics were the moderately high concentrations of total phosphorus, very low dissolved oxygen in the hypolimnion, and moderate amounts of aquatic plant growth. Martha Lake was characterized as oligo-mesotrophic because both oligotrophic and mesotrophic characteristics were documented.

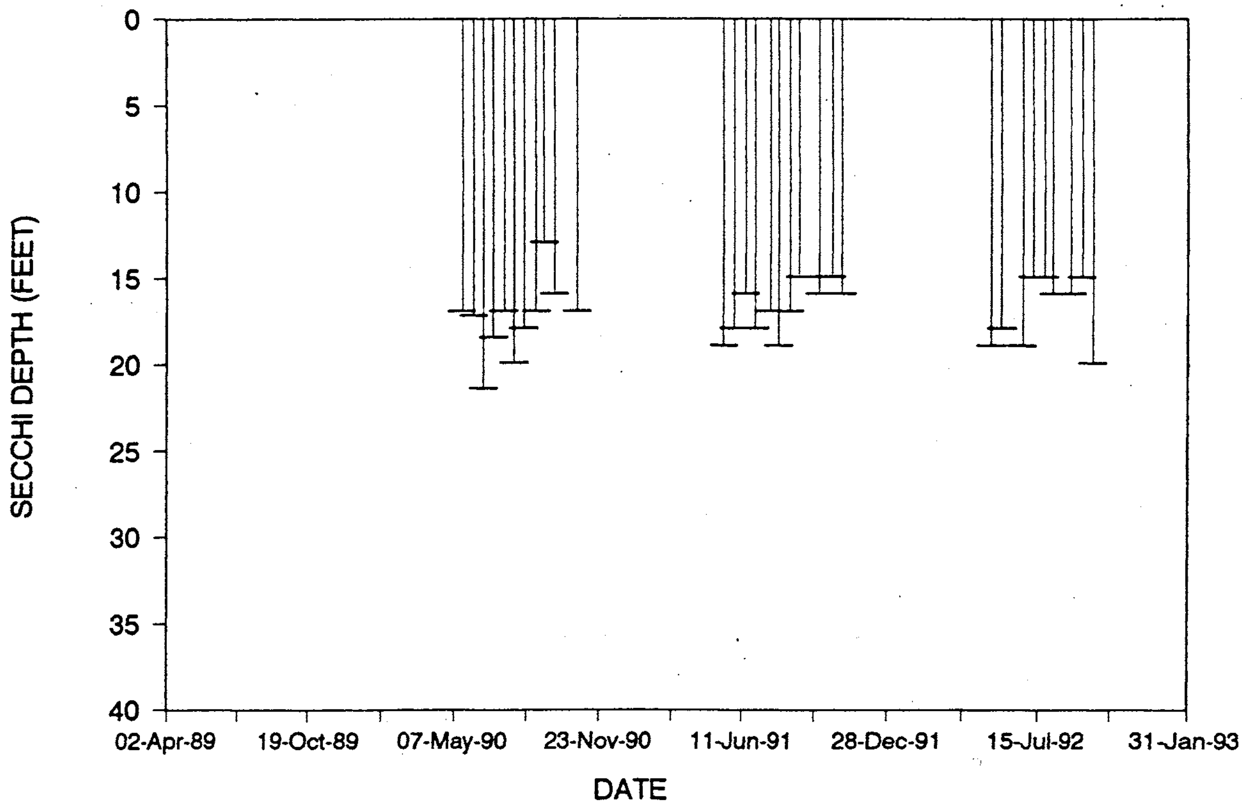
Six other Snohomish County lakes were monitored for the program in 1991; these were Bosworth, Ketchum, Lake Martha, Roesiger, Stevens and Sunday Lakes. Martha Lake and Lake Martha both had very similar Secchi depths and concentrations of total phosphorus.

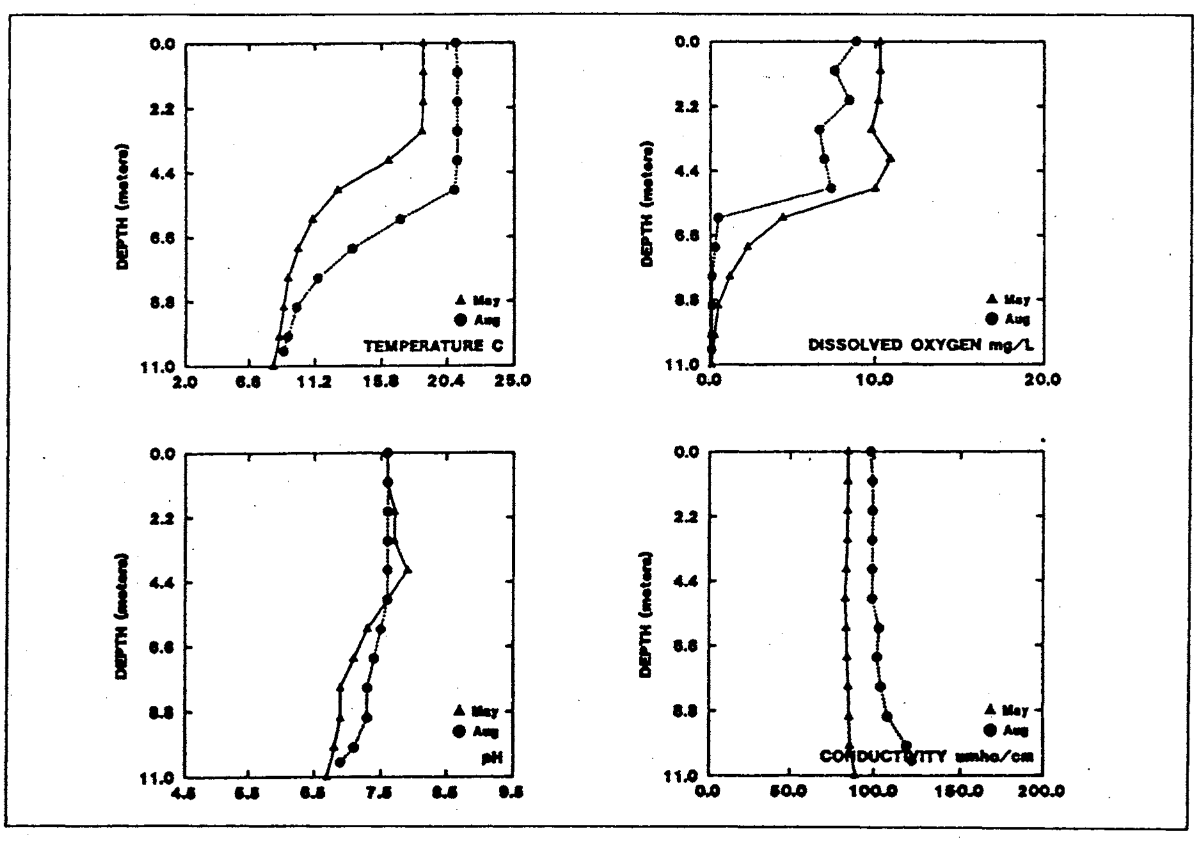
Martha Lake (near Alderwood Manor) -- Snohomish County

Acknowledgement

I thank John W. Moore for volunteering his time to monitor Martha Lake during 1990 - 1992.

MARTHA LAKE (SNOHOMISH COUNTY)



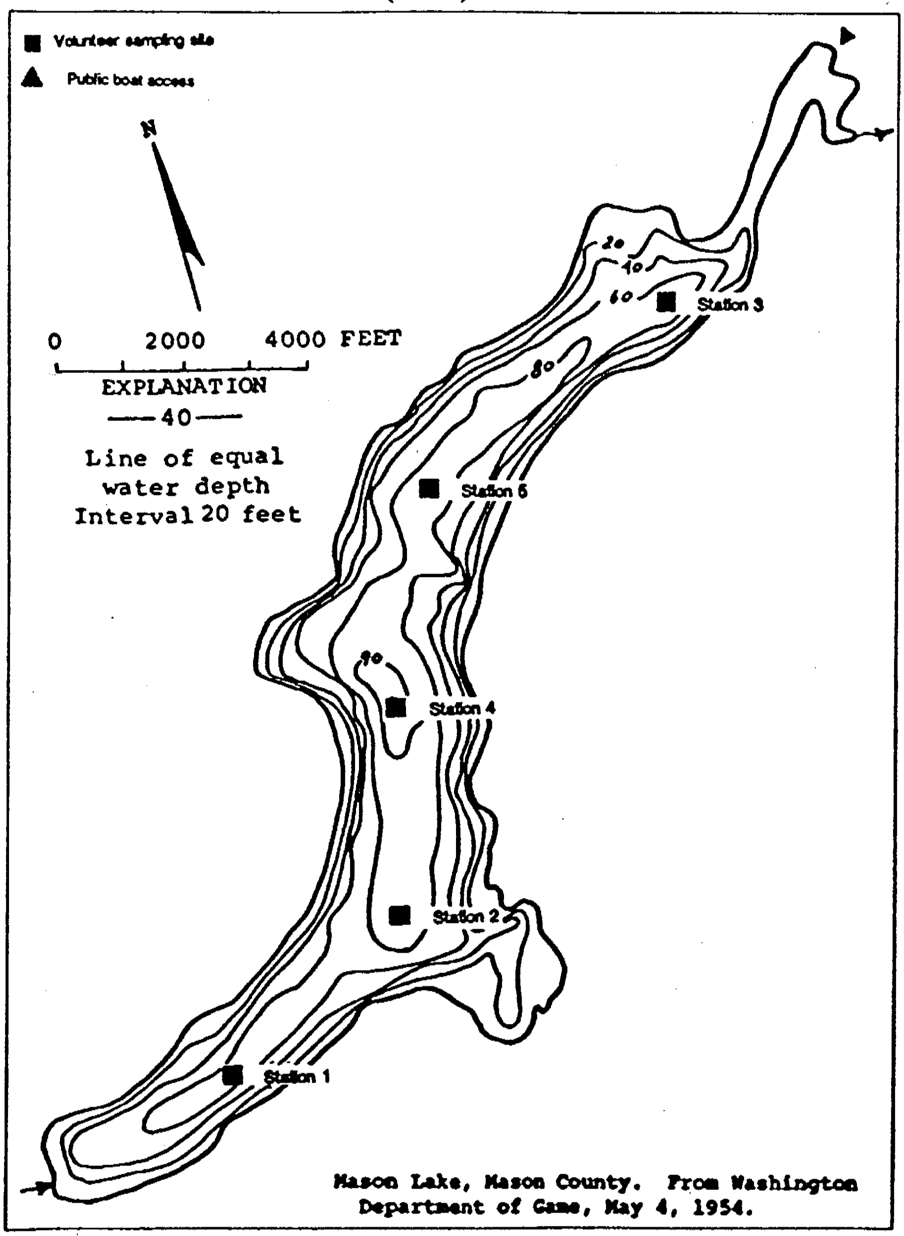


Mason Lake -- Mason County

Mason Lake is located eight miles southwest of Belfair. It is four miles long and is fed by Shumocher Creek. Mason Lake drains via Sherwood Creek to North Bay and Case Inlet. It is the largest and deepest lake in Mason County. Macrophytes are dense around the shoreline and are concentrated near residential development in the northern arm of the lake.

Size (acres)	1,000
Maximum Depth (feet)	90
Mean Depth (feet)	48
Lake Volume (acre-feet)	49,000
Drainage Area (miles^2)	20.2
Altitude (feet)	194
Shoreline Length (miles)	10.9

Data From Bortleson *et al.* (1976)



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

Mason Lake -- Mason County

1992 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi, Station 4):	32
Mean Trophic State Index (Total Phosphorus, Station 4):	26
Mean Trophic State Index (Chlorophyll *a*, Station 4):	32

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	pH	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
Station 2											
05-Jun	1000	20.0	68.0	24.0	7.5		Clear	0	None	Calm	pH strip in water 10 minutes.
17-Jun	1000	17.8	64.0	19.0	6.5		Lt-Green	100	Trace	Calm	pH strip in water 10 minutes.
01-Jul	1030	20.6	69.0	22.0	7.5		Lt-Green	50	Trace	Breezy	Part sun. Water was choppy.
15-Jul	1230	21.1	70.0	23.0	6.5			0	Trace	Breezy	Water light milky-green and choppy.
27-Jul	1030	21.1	70.0	24.0	7.5		Clear	0	None	Calm	No wind.
09-Sep	1100	19.4	67.0	21.0	7.5		Lt-Green	0	Moderate	Breezy	Some weeds on surface.
27-Sep	1630	17.8	64.0	20.0			Green	25	Trace	Calm	
23-Oct	1200	15.6	60.0	19.0			Green	0	Moderate	Calm	
Station 3											
10-Jun	1400	20.0	68.0	20.0	6.5		Lt-Green	100	Trace	Light	
28-Jun	1415	20.0	68.0	22.0		32.00	Lt-Green	10	Light	Light	
14-Jul	1400	21.1	70.0	26.0	6.5		Lt-Green	50	None	Light	
24-Jul	1300	21.1	70.0	21.0	6.5	24.00	Green	50	Trace		
08-Aug	1200	20.6	69.0	17.0	6.5		Green	75	Heavy	Breezy	
22-Aug	1000	21.1	70.0	25.0	6.5	29.00	Green	75	None	Light	
19-Sep	1740	19.4	67.0	24.0		30.00	Lt-Green	0	Light		
27-Sep	1530	17.8	64.0	21.0			Green	0	Light	Light	
23-Oct	1300	15.6	60.0	23.0			Green	0	Moderate	Light	
05-Sep	1510	21.1	70.0	25.0	6.5		Lt-Green	0	None		
Station 4											
10-May	1345	19.4	67.0	20.0	6.5	31.00	Clear	100	Trace	Calm	
29-May				17.0							Onsite visit.
23-Jun	1330	24.4	76.0	24.0	6.5	28.50	Lt-Green	0	None	Calm	
07-Jul	1000	20.0	68.0	21.0	6.5	26.25	Dk-Green	100	Light	Calm	Water color dark green.
18-Jul	1630	24.4	76.0	23.0			Clear	0	None	Calm	Choppy water.
04-Aug	1100	21.1	70.0	23.0	6.5	32.50	Clear	100	None	Breezy	
14-Aug	1000			22.0		33.50	Clear	100	None	Calm	
27-Aug				28.0							Onsite visit.
14-Sep	1400	18.9	66.0	21.0	6.5		Clear	100	None	Calm	
27-Sep	1600	17.8	64.0	21.0			Green	10	Light	Light	
10-Oct	1230	16.1	61.0	22.0	7.0		Lt-Green	50	None	Light	
23-Oct	1230	15.6	60.0	22.0			Green	0	Moderate	Calm	

[1] Trophic State Indices calculated from Carlson (1977)

Mason Lake -- Mason County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/19	0.0	19.6	7.8	9.9	44
	1.0	18.8	7.6	9.7	44
	2.0	18.6	7.6	9.7	44
	3.0	18.5	7.6	9.6	44
	4.0	18.5	7.6	9.6	44
	5.0	18.3	7.6	9.7	44
	6.0	17.9	7.6	9.8	44
	7.0	16.5	7.4	10.1	44
	8.0	15.1	7.4	10.1	43
	9.0	14.4	7.3	10.1	42
	10.0	12.9	7.3	9.6	42
	12.0	11.7	7.2	9.2	42
	14.0	10.8	7.1	9.0	41
	16.0	10.3	7.1	8.1	41
	18.0	10.0	7.0	7.8	41
	20.0	9.3	6.9	6.5	41
	22.0	9.2	6.9	5.8	41
08/27	0.0	22.3	7.9	9.2	50
	1.0	22.2	7.9	9.1	50
	2.0	22.2	7.9	9.1	50
	3.0	21.7	7.8	9.2	49
	4.0	21.6	7.8	9.1	50
	6.0	21.4	7.8	9.1	50
	8.0	21.3	7.8	9.2	50
	10.0	18.1	7.9	9.9	48
	12.0	14.2	7.8	8.8	46
	14.0	11.6	7.7	5.6	46
	16.0	10.9	7.7	4.5	46
	18.0	10.3	7.6	3.2	46
	20.0	10.1	7.6	2.9	46
	22.0	9.8	7.5	1.2	47
	24.0	9.6	7.5	0.1	47

1992 Onsite Visit Data - Water Chemistry

Date	05/19/92		08/27/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 4	14, 16, 18	1, 4, 8	18, 22
Total Phosphorus (μg/L)	5	6	4	37
Total Nitrogen (mg/L)	0.16	0.18	0.14	0.14
Chlorophyll *a* (μg/L)	1.15	--	1.07	--

Mason Lake -- Mason County

Historical Data From Ecology

Date	06/29/72[a]	06/12/81[b]	06/28/89[c]	09/27/89[c]	05/25/90[d]	08/16/90[d]	05/21/91[e]
Secchi (ft)	14	16	24.3	21.7	22.9	--	21
Total Phosphorus, epilimnion (μg/L)	12	20	8	9	7	7	--
Total Nitrogen, epilimnion (mg/L)	--	--	0.14	0.19	0.23	0.23	0.10
Chlorophyll *a* (μg/L)	3.0	1.52	0.7	1.0	--	--	--
Dissolved Oxygen, surface (mg/L)	9.9	9.6	10.4	9.6	10.8	9.1	10.4
Dissolved Oxygen, bottom (mg/L)	6.5	6.0	6.5	0.4	7.6	0.8	8.1

a. Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Brower and Kendra (1990)
d. Rector (1991)
e. Rector (1992)

Mason Lake -- Mason County

Monitoring Results/Summary of Other Available Information

Although volunteers monitored three lake stations in 1992, profile data and water samples were collected from Station 4 only. This station is located at the deepest site of the lake.

Secchi Depths

Water clarity was very good, indicated by Secchi depths which ranged from 17.0 to 28.0 feet. All Secchi depths collected for the program since 1989 have been in the oligotrophic range. In general, measured Secchi depths were deepest in 1990, and were in the same range in 1989, 1991, and 1992.

Volunteers have collected data from three lake stations (see map for station numbers and locations) since 1989. Two deep water stations (stations 2 and 4) and one station located in water about 60 feet deep (station 3) were monitored in 1992. In 1990, five lake stations were monitored by volunteers.

Secchi data collected from Mason Lake in 1970, 1972, 1981, and 1989 also indicate that the lake was oligotrophic (Funk *et al.*, 1972; Bortleson *et al.*, 1976 ; Sumioka and Dion, 1985; Brower and Kendra, 1990).

Total Phosphorus

Total phosphorus in the epilimnion was very low (5 and 4 μg/L) on both sampling dates. The concentrations were similar to concentrations measured in 1990 (7 μg/L; Rector, 1991) and 1989 (8 and 9 μg/L; Brower and Kendra, 1990).

Total Nitrogen

Total nitrogen was very low on both sampling dates (0.16 and 0.14 mg/L).

Profile Data

On both sampling dates, the lake was stratified with respect to temperature, and dissolved oxygen decreased gradually below the thermocline. Lower dissolved oxygen near the lake bottom was also reported in 1968, when dissolved oxygen concentrations were less than 1 mg/L below 75 feet (Lee, 1969). Lower dissolved oxygen in the hypolimnion usually results from bacterial decomposition of aquatic plants and algae in the water and sediments.

Plants

Algal densities were low on both sampling dates, as indicated by low concentrations of chlorophyll *a*.

Plants collected near Little Hoquiam during the May 29, 1992 onsite visit were identified by Ecology staff as flatleaf pondweed (*Potamogeton robbinsii*), largeleaf pondweed (*P. amplifolius*), Illinois pondweed (*P. illinoensis*), waterweed (*Elodea canadensis*), and the alga *Nitella*.

Mason Lake -- Mason County

Plant samples collected by the volunteer during November 1990 were identified as largeleaf pondweed and flatleaf pondweed. Both plants grow mostly submerged in water.

In September 1983, Allied Aquatics identified and mapped the following aquatic plants in Mason Lake: largeleaf pondweed (*Potamogeton amplifolius*), white-flowering waterlily (*Nyphaea odorata*), watershield (*Brasenia schreberi*), waterweed, wild celery (*Vallisneria americana*), and small pondweed (*Potamogeton pusillus*). These plants were located mostly on the north and northwest shore of the lake.

Plants identified in the lake in 1972 included watershield, three species of pondweed, waterweed, yellow waterlily, sedge (*Cyperaceae*), muskgrass, and wild celery (Bortleson *et al.*, 1976a). Watershield and waterweed were noted to be the dominant species.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteers' remarks and responses to questionnaires from 1989 to 1991. The 1992 questionnaire on lake and watershed uses was not returned.

> Mason Lake is used for fishing, boating, swimming, rowing, jet skiing and camping. Recreational facilities on the lakeshore include a park, and a picnic area. There is one public boat ramp, and there are some restrictions for motor boating within 100 feet of shore. Currently the watershed is used for logging, animal grazing, and crop agriculture, and the lakeshore is being developed further for residences. In the past the watershed was used for logging, animal grazing and crop agriculture.
>
> There are approximately 670 houses on the lakeshore; of these, 350 are occupied year-round. About 90% of the shoreline has been developed for residences. The lakeshore is not sewered, and there are 47 culverts all along the shore that empty into the lake. Most of the culverts are located along the southeast end and the shallow northeast end. Lake water is withdrawn for drinking and other domestic uses. There is a community association for the lake.
>
> In 1991, the worst potential problems in the lake were ranked as 1) aquatic plants and 2) algae. In contrast, in 1990 the volunteer ranked problems as 1) aquatic plants, 2) algae, 3) water level, and 4) water odors (like fresh fish on warm days). Overall, the volunteer found that Mason Lake had excellent water quality.
>
> At the south end of the lake, submerged plants grew in water up to about 20 feet deep. Growth of tall weeds in the lake during spring seemed to be thicker in 1991 than in 1990. After the marina closed in 1991, there was less boat traffic on the lake.

Mason Lake -- Mason County

Comments

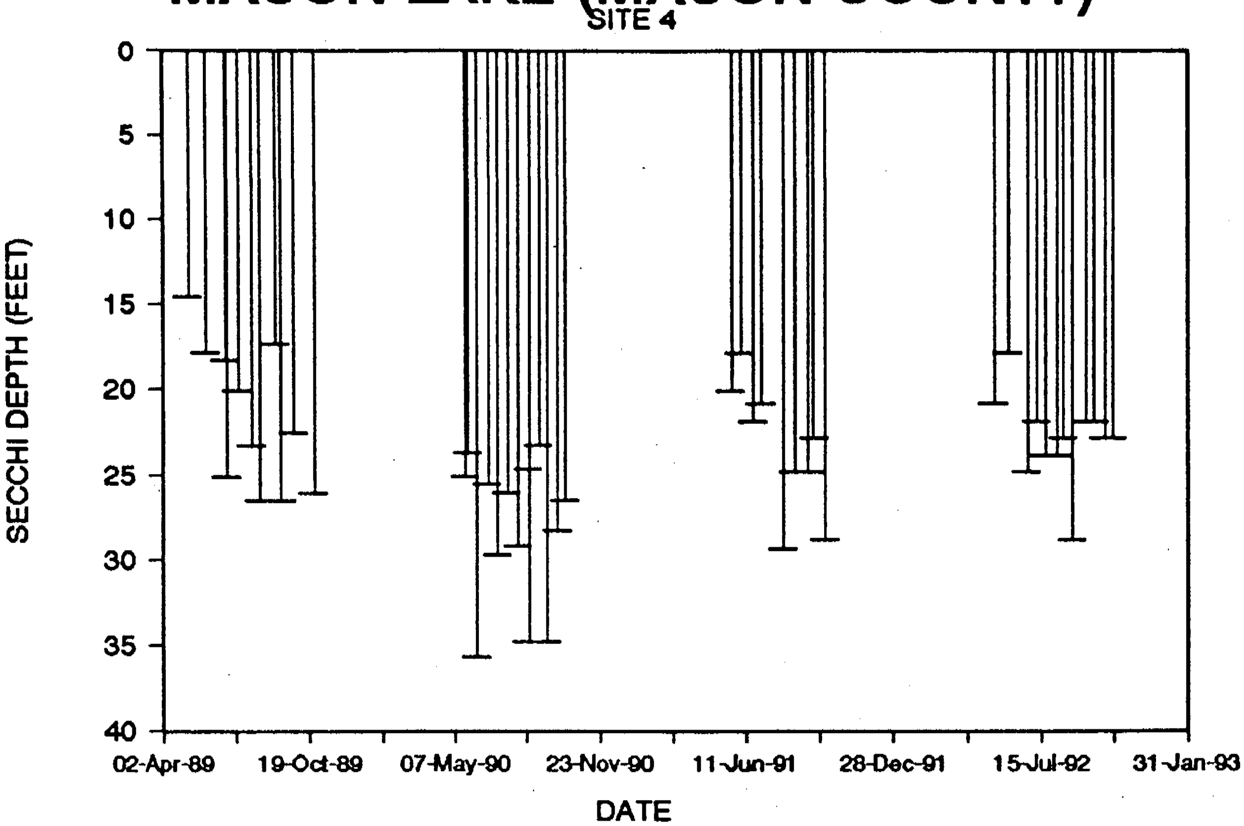
Mason Lake has very good water quality, particularly considering the amount of development along the shoreline and the high amount of recreational use. All trophic state parameters (Secchi depth, total phosphorus, and chlorophyll *a*) indicate that the lake was oligotrophic.

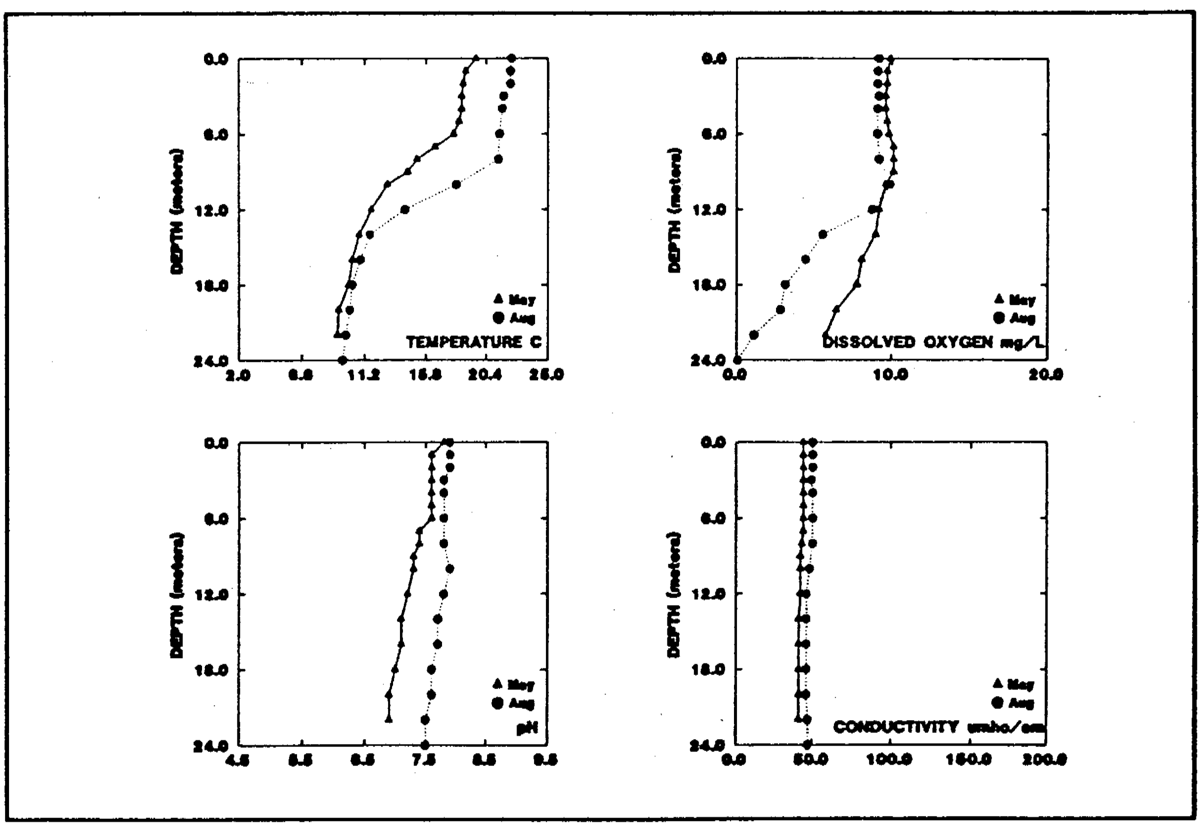
Other Mason County lakes monitored for the program were Limerick, Nahwatzel, Phillips, Spencer, and Wooten. In 1992, Mason Lake had better water clarity and lower total phosphorus concentrations than these lakes. Only one other lake monitored for the program in 1992, Lake Wenatchee, had lower total phosphorus concentrations than Mason Lake. Mason Lake had the lowest total nitrogen concentrations of all the lakes monitored in 1992.

Acknowledgements

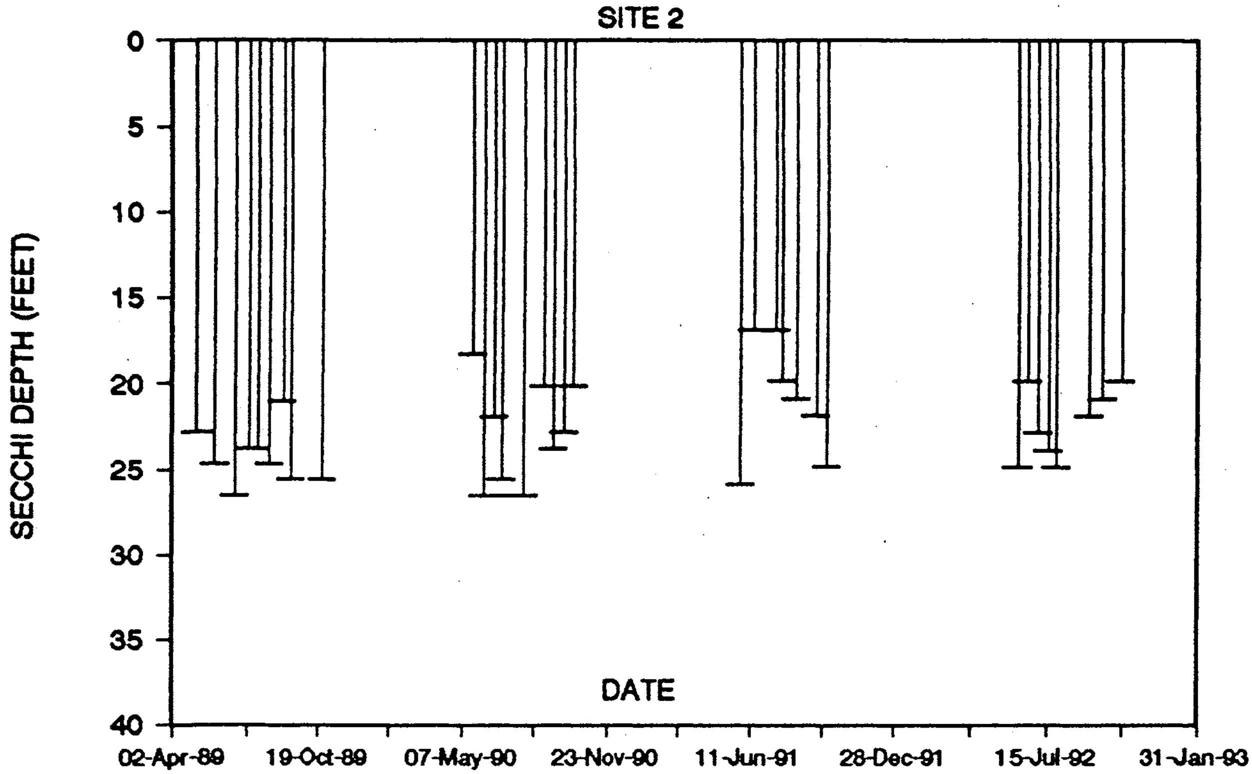
I thank the following volunteers who have collected data for the program: Tom Black (1989-1990; 1992), Jerry Nelson (1989-1992), Al Bernhard (1991-1992), Dick Bowers (1989-1992), Bob Groves (1989-1991), Harold Holm (1991-1992), Ray Hussey (1989-1990), Clay Johnson (1989-1991), Don Lamberto (1989-1990), Roy Magnussen (1989-1992), Jack Richmond (1991-1992), and John Smith (1989-1992).

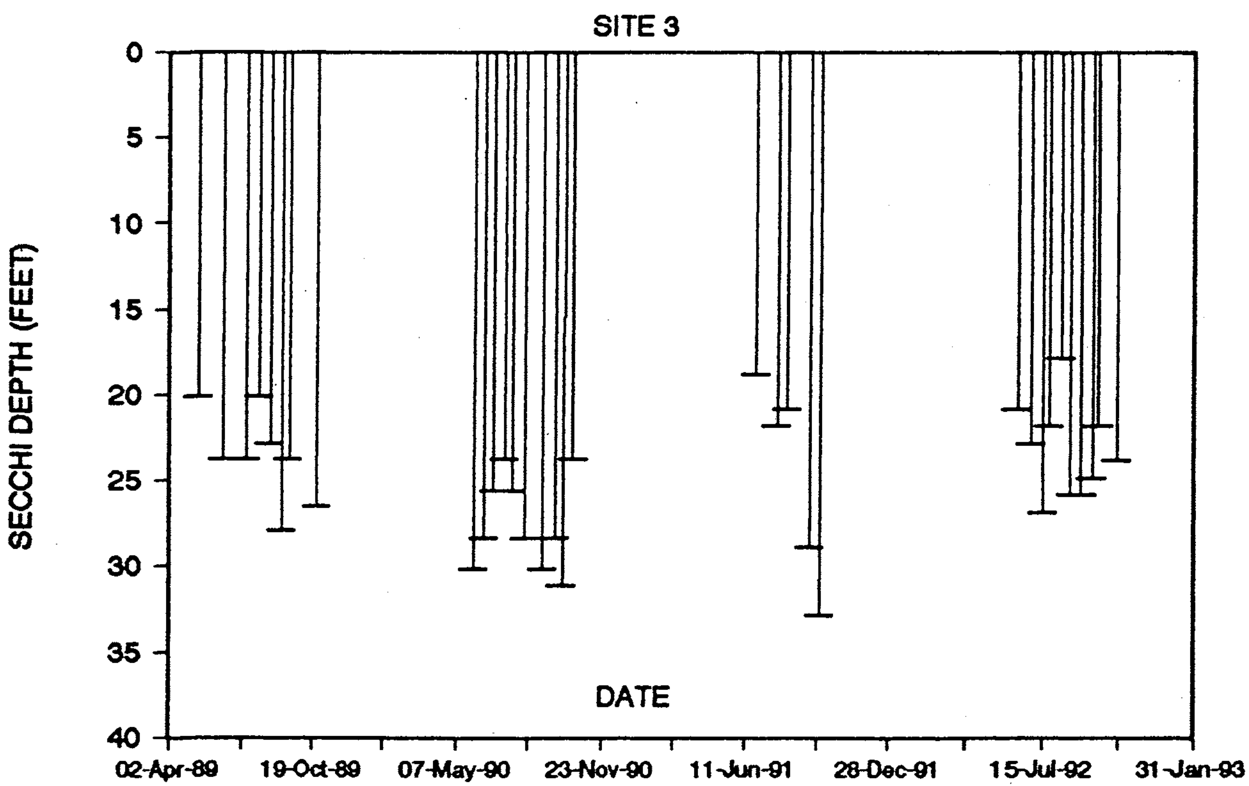
MASON LAKE (MASON COUNTY)





MASON LAKE (MASON COUNTY)





Mill Lake -- Pend Oreille County

Mill Lake is located 3.2 miles east of Metaline Falls. It is an artificial reservoir in Sullivan Creek. It is fed from Sullivan Lake by Sullivan Creek and Harvey Creek, and drains via Sullivan Creek to the Pend Oreille River. The reservoir is used for water storage by Pend Oreille County PUD 1.

Size (acres)	66
Maximum Depth (feet)	51
Mean Depth (feet)	21
Lake Volume (acre-feet)	1,400
Drainage Area (miles^2)	129
Altitude (feet)	2,514
Shoreline Length (miles)	1.6

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	38

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and responses to the 1991 questionnaire. There are no houses on the lakeshore. There is thick submerged plant growth on the north and east ends of the lake. In parts of these areas, plant growth reaches the surface. Scums and underwater plant growth were reported just south of the dam on the west shore, and near the boat ramp. Fish are not reported as being stocked in the lake.

The worst problems in the lake, in the opinion of the volunteer, are ranked as: 1) suspended sediments, 2) aquatic plants, 3) garbage and debris, 4) undesirable fish species, 5) fish kill, 6) odor, 7) algae, and 8) lake level. Overall, the volunteer finds that Mill Lake has good water quality. The volunteer suggested that silt entering the lake from runoff during spring and early summer, and past logging in the Sullivan Creek drainage, may affect the water quality of the lake.

The lake receives only light swimming use, and boating is mainly for fishing. Electric motors under 5 HP only are permitted on the lake.

Monitoring Results/Summary of Other Available Information

Mill Lake was added to the lake monitoring program in 1991. In 1991, volunteer-collected Secchi depths ranged from 7.5 - 26.0 feet. Secchi depth was lowest on May 27 and highest on

Mill Lake -- Pend Oreille County

October 5. The milky-green water color and remarks from the volunteer from May 27 through July 8 indicate that during these times, water clarity was affected mostly by siltation and not by algal growth. Algal growth may have been affecting water clarity during August and September, when the water color was more green and water temperatures were warmer.

Ecology staff collected profile data and water samples from Mill Lake on June 12, 1991. There was very heavy rainfall just prior to sampling. At the time of sampling, the water color was milky green and a lot of wood debris was observed in the water. Secchi depth was only 5.5 feet. Profile data show that the lake was not stratified, and as a result, values for all the profile parameters were constant from surface to bottom. Total nitrogen was very low (0.059 mg/L). Samples for total phosphorus and chlorophyll *a* were also collected, but the data could not be used due to analytical problems.

Mill Lake was also sampled in July 1971 (Dion *et al.*, 1976). At the time of sampling, numerous floating and submerged logs were observed along the shoreline, and the water was turbid. Very few submerged plants were observed. Dissolved oxygen increased slightly from surface to bottom (9.6 to 9.8 mg/L) and Secchi depth was 4 feet. The concentration of total phosphorus was low to moderate, at 0.011 mg/L.

Comments

Except for reports of extensive aquatic plant growth and "scum accumulation" in areas during 1991, the lake was very similar to descriptions and data from 1971.

Acknowledgements

I thank Dick Vogel for volunteering his time to monitor Mill Pond during 1991.

Mill Lake -- Pend Oreille County

Volunteer-Collected Data

Date 1991	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(ft)	Abbreviated Comments
27-May	8.6	47.5	6.5	Milky-Gr	50	Moderate	Light	7.5	50.0	Seems to be a lot of silt from spring runoff.
08-Jun	8.6	47.5	6.5	Milky-Gr	100	Heavy	Calm	8.5	51.0	Lots of rain this week. Lots of snowmelt runoff. Lake much higher.
22-Jun	9.4	49.0	6.5	Milky-Gr	50	Heavy	Calm	15.0	49.5	Vehicles at north end (dam). Lake down 1.5 feet.
08-Jul	15.0	59.0	6.5	Milky-Gr	10	None	Calm	15.5	48.5	Lake dropped 1 ft. Sorry test taken so late in day. Temp rose from 49 to 59 degrees in 2 weeks.
21-Jul	15.0	59.0	6.5	Clear	50			20.5	48.0	Vehicle at north dam end. Fisherman at south end. Lake height dropped 1/2 foot.
02-Aug	16.7	62.1	7.0	Milky-Gr	75	Heavy	Light	18.5	47.8	No vehicles either end of lake. 6 people on shore.
18-Aug	17.8	64.0	0.0	Green	25	Trace		18.0	47.5	Two vehicles at N end lake. One vehicle at S end.
07-Sep	15.0	59.0	6.5	Green	75	None	Light	16.0	47.2	Lake height 47'2". Aquatic plant growth in all shallow (<5') areas. Some reaching to water level.
05-Oct	14.4	57.9	0.0	Clear	0	None	Calm	26.0	48.7	Lake height 48'9". Sullivan Lake spillway is open as of Oct 1. One vehicle (8 people) at south end of lake.

Onsite Visit Data

Date 1991	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)	Composite Sample Depths (m)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Phosphorus (mg/L)
06/12	0.0	8.4	7.3	11.7	92	1, 3, 5	0.059	ND	ND
	0.5	8.4	7.3	11.4	91				
	1.0	8.4	7.3	11.3	91				
	1.5	8.3	7.3	11.2	91				
	2.0	8.3	7.3	11.1	91				
	2.5	8.2	7.3	11.1	91				
	3.0	8.2	7.3	11.1	91				
	3.5	8.2	7.3	11.1	91				
	4.0	8.2	7.3	11.1	92				
	4.5	8.2	7.3	11.1	91				
	5.0	8.2	7.3	11.1	90				
	5.5	8.2	7.3	11.0	90				

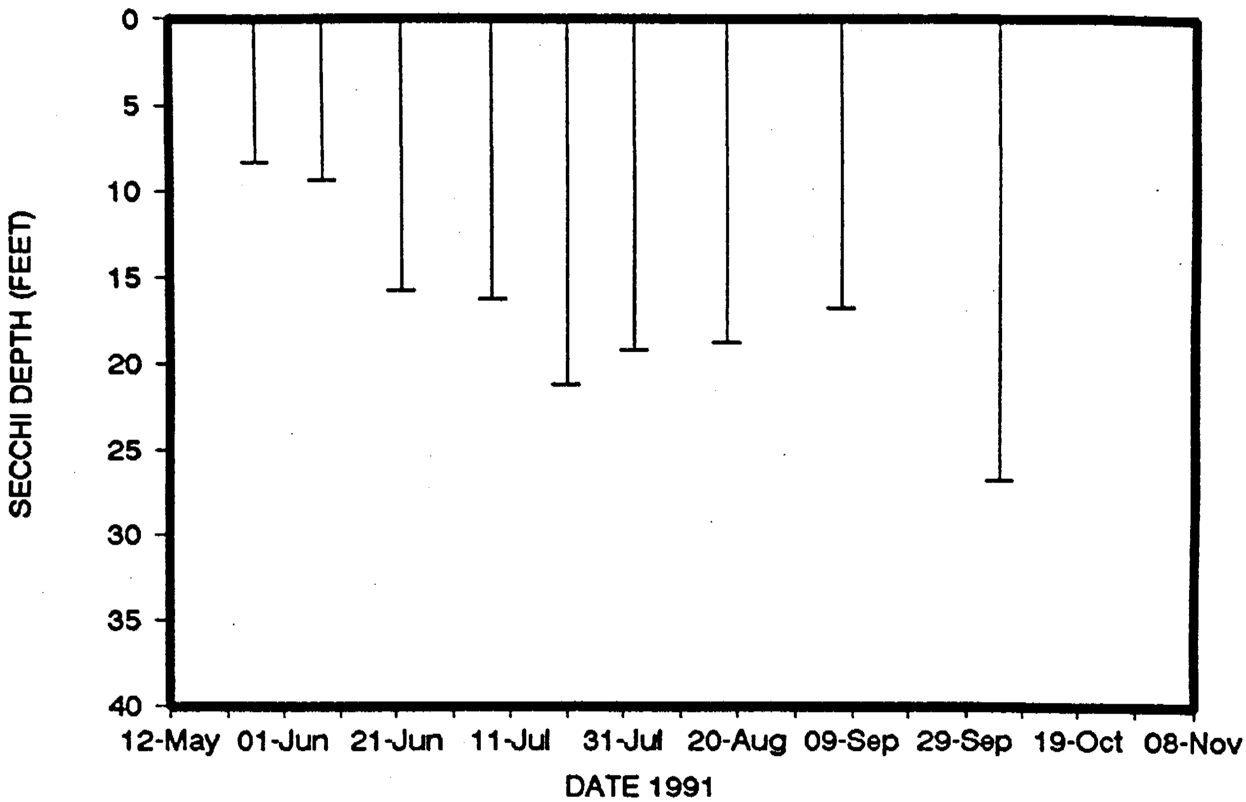
ND No Data; data lost due to analytical problems

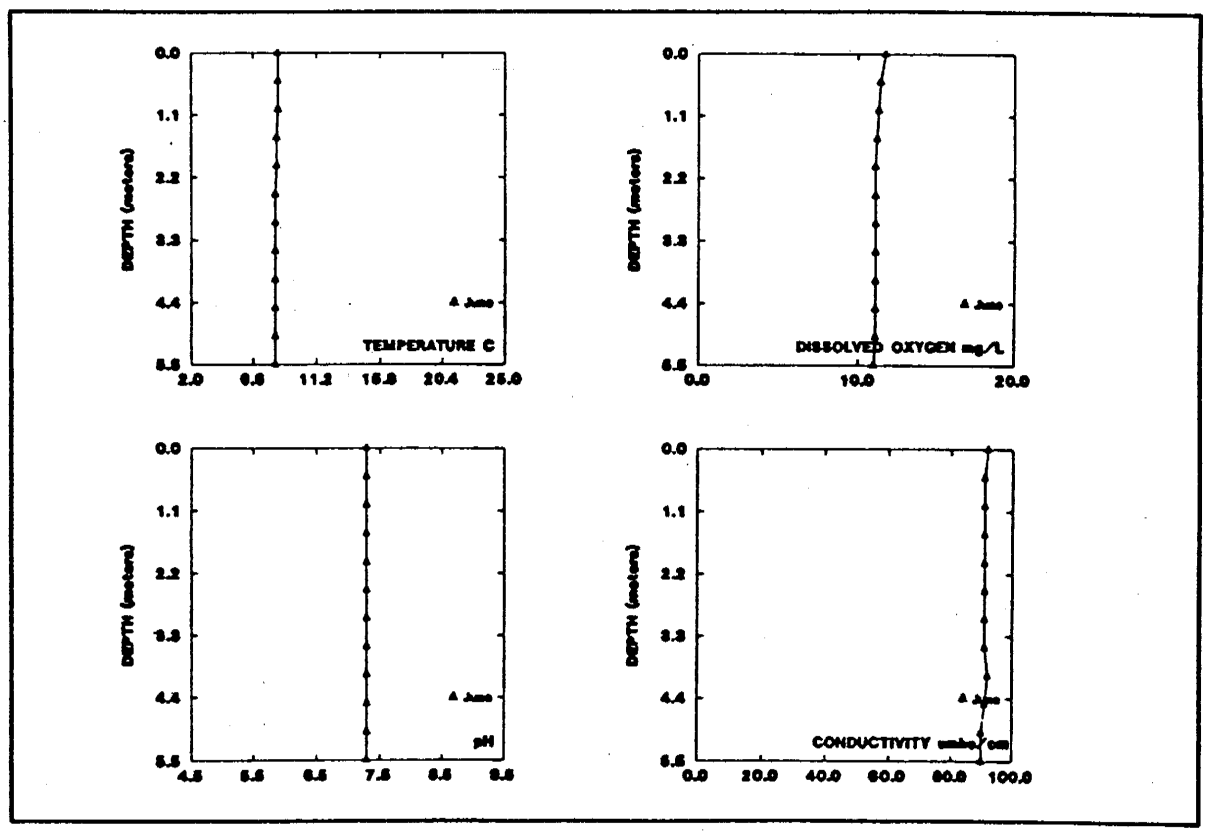
Data From Dion *et al.* (1976)

Date	07/11/74
Secchi (feet)	4
Total Phosphorus (mg/L)	0.011

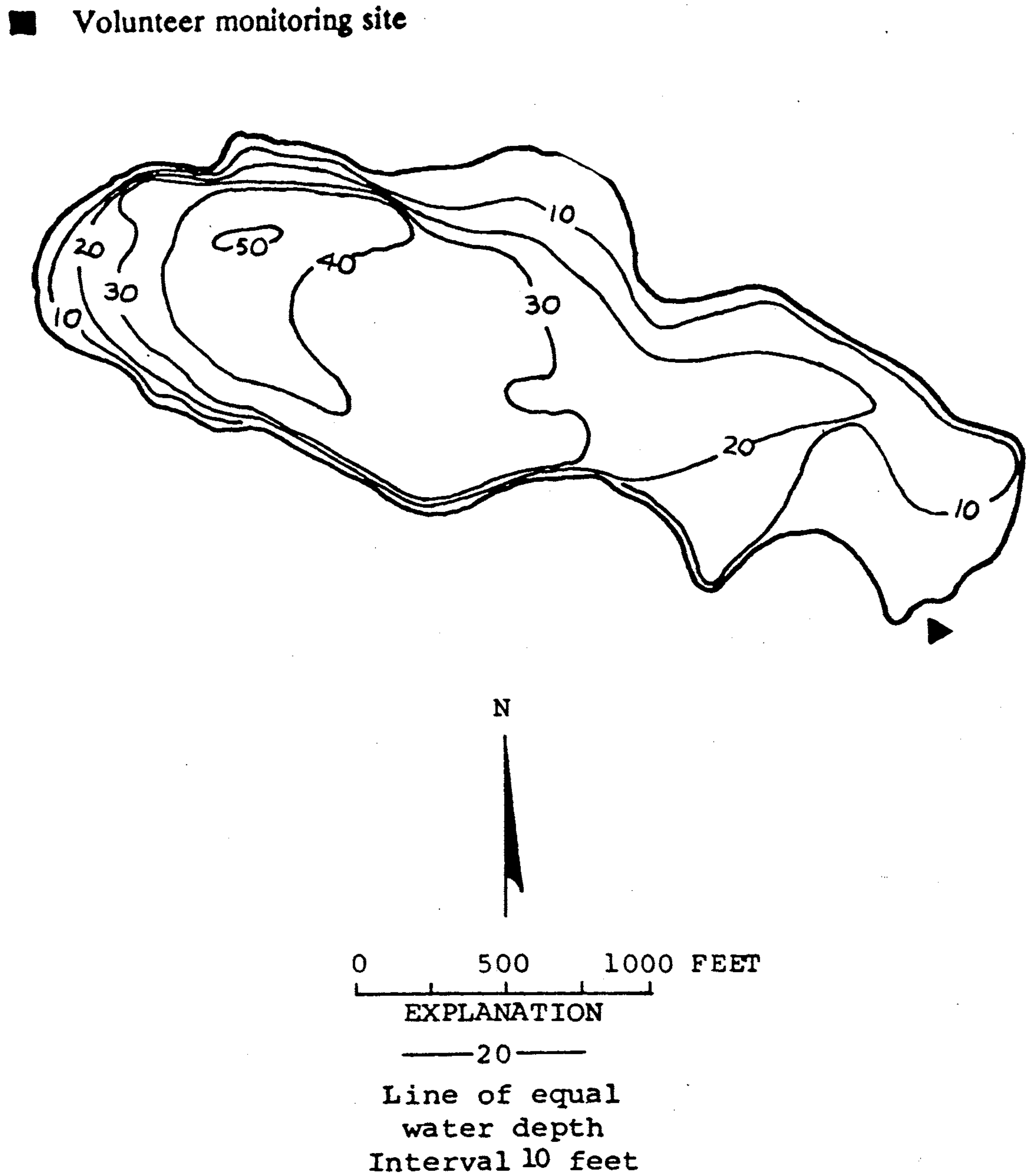
Remarks THE LAKE IS AN ARTIFICIAL PUBLIC-SUPPLY RESERVOIR ON SULLIVAN CREEK AND IS OPERATED BY THE PEND OREILLE COUNTY P.U.D. NUMEROUS FLOATING AND SUBMERGED LOGS WERE OBSERVED ALONG THE SHORELINE. THE LITTORAL BOTTOM IS SILT AND MUCK AND THE WATER WAS TURBID. VERY FEW SUBMERSED AQUATIC PLANTS WERE OBSERVED.

MILL LAKE (PEND OREILLE COUNTY)





Profile and Secchi Data Graphs



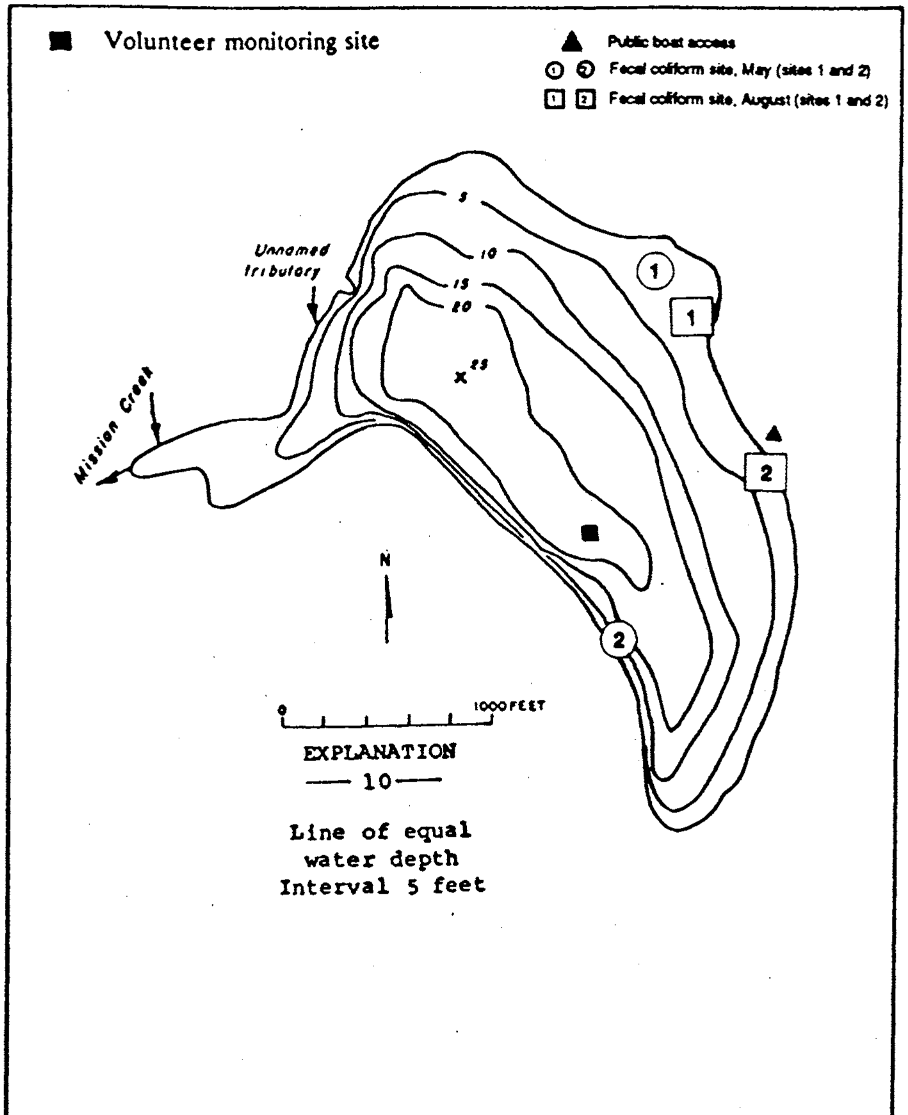
Mill Lake, Pend Oreille County. From U.S. Geological Survey, June 18, 1974.

Mission Lake -- Kitsap County

Mission Lake is located nine miles west of Bremerton. It is fed by Mission Creek and an unnamed tributary, and drains via Mission Creek to Hood Canal.

Size (acres)	88.3
Maximum Depth (feet)	25
Mean Depth (feet)	12
Lake Volume (acre-feet)	1,000
Drainage Area (miles^2)	1.8
Altitude (feet)	516
Shoreline Length (miles)	1.9

Data From Bortleson *et al.* (1976)



Mission Lake, Kitsap County. From Washington Department of Game, June 8, 1946.

Mission Lake -- Kitsap County

1992 Trophic Status[1]

Estimated Trophic State:	Mesotrophic[2]
Trophic State Index (Mean Secchi):	43
Trophic State Index (Mean Total Phosphorus):	39
Trophic State Index (Mean Chlorophyll *a*):	32

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	Temp (°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
13-May				10.8						Onsite visit.
26-May	1000	20.0	68.0	15.0	12.50	Lt-Green	90		Light	pH is 6.5 (using Merck strips). New location for lake height measure; checked and adjusted to 1991 level.
08-Jun	1010	20.0	68.0	14.0	11.50	Lt-Green	25	None	Light	pH is 6.5. Reading taken at 20' depth.
25-Jun	1400	26.7	80.0	14.3	11.25	Lt-Green	0	None	Light	pH is 6.5. Fixed marker is bottom of lake to surface - only way to go.
13-Jul	1030	21.1	70.0	7.5	12.25	Lt-Green	90	Trace	Strong	pH is 6.5. Weed growth tall and abundant.
27-Jul	1400	25.6	78.0	10.7	11.50	Lt-Green	0	None	Calm	pH is 6.5.
12-Aug	1035	25.6	78.0	10.3 W	10.75	Lt-Brown	10	None	Light	pH is 6.5. Strong winds for four days.
20-Aug				16.0						Onsite visit.
03-Sep	1230	21.1	70.0	14.5	7.75	Green	10	None	Light	pH is 6.5.
17-Sep	1200			7.7	7.00	Pea Green	0	None	Light	pH is 6.5. Water very cloudy. Lake sediment heavy - Secchi reading almost impossible.
29-Sep	1000	18.9	66.0	5.0	7.25	Lt-Brown	0	Trace	Calm	pH is 6.5. Sediment extensive - lake is big puddle of mud.
25-Oct	1400	14.4	58.0	4.0	9.75	Lt-Brown	25	Light	Breezy	pH is 6.0. Today we had some calm. Wind and rain constant the past 3 weeks.

W Secchi disk in weeds

[1] Trophic State Indices calculated from Carlson (1977)

[2] see Comments section

Mission Lake -- Kitsap County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/13	0.0	17.0	7.7	10.0	55
	1.0	17.0	7.6	9.8	55
	2.0	16.8	7.6	9.8	55
	3.0	16.5	7.6	9.8	55
	4.0	16.4	7.6	9.8	55
	5.0	16.3	7.6	9.9	55
	5.5	16.2	7.6	9.9	55
08/20	0.0	22.9	7.3	.	74
	1.0	22.9	7.4	.	74
	2.0	22.9	7.4	.	74
	3.0	22.9	7.5	.	75
	4.0	22.4	7.5	.	74
	5.0	22.0	7.4	.	78

1992 Onsite Visit Data - Water Chemistry

Date	5/13/92		08/20/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 3, 5	--	1, 2, 3	4.5
Total Phosphorus (μg/L)	9	--	13	16
Total Nitrogen (mg/L)	0.20	--	0.25	0.23
Chlorophyll *a* (μg/L)	1.15	--	1.14	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	31	--	92	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	<1	--	27	--
Total Suspended Solids (mg/L)	1	--	<1	--
Total Nonvolatile Suspended Solids (mg/L)	<1	--	<1	--
Color (Pt-Co units)	25	--	15	--

Mission Lake -- Kitsap County

Historical Data From Ecology

Date	09/05/74[a]	05/23/90[b]	08/14/90[b]	05/20/91[c]
Secchi (ft)	17	18[d]	13.5[d]	17.3[d]
Total Phosphorus, epilimnion (μg/L)	6	14	14	--
Total Nitrogen, epilimnion (mg/L)	--	0.22	0.23	0.16
Chlorophyll *a* (μg/L)	--	--	--	--
Dissolved Oxygen, surface (mg/L)	10.3	9.7	8.5	8.9
Dissolved Oxygen, bottom (mg/L)	9.8	8.9	0.1	8.1

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Secchi disk hit bottom

Mission Lake -- Kitsap County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity varied considerably from good to poor, as indicated by Secchi depths which ranged from 16 feet to 4 feet. Secchi depths in Mission Lake generally were shallower in 1992 than in 1991 or 1990. However, the method used by the volunteer for reporting Secchi depths was corrected in 1992 to make the readings more reliable, and as a result, it is difficult to compare Secchi readings from 1992 with data from 1991 and 1990.

The mud noted by the volunteer in September and October 1992 was not reported earlier, and may have been from heavy winds and rain during this period (see commments with Volunteer-Collected Data). "Mud" in the lake may have been sediments stirred up from the bottom during periods of heavy winds; the lake has very soft sediments which, during the onsite visits, were easily stirred by the Secchi disk and by attempts to retrieve aquatic plant samples from the lake bottom. This was particularly apparent during the May 1991 onsite visit with the volunteer, when the Secchi disk disappeared very abruptly when it entered the sediment. After the sediments were disturbed with the Secchi disk, water near the bottom was very cloudy.

Total Phosphorus

Total phosphorus in the epilimnion was low to moderate on both sampling dates (9 μg/L in May, and 13 μg/L in August). Results from 1990 were slightly higher (14 μg/L in both May and August; Rector, 1991) than those from 1992.

Total Nitrogen

Total nitrogen was very low on both sampling dates (0.20 mg/L in May, and 0.25 mg/L in August). Values were very similar to concentrations measured in 1990 (0.22 mg/L and 0.23 mg/L; Rector, 1991).

Fecal Coliform Bacteria

Of four samples collected from Mission Lake, results ranged from <1 to 92 colonies/100 mL. The high value was from a sample collected on the northeast end of the lake, near a large patch of lily pads, during the August onsite visit (see map, site #1). A sample collected at this same site during May had a lower result of 31 colonies/100 mL. Site #2 during May was on the south end of the lake, and no bacteria were detected. Site #2 during August was located near the public boat access, where there were 27 colonies/100 mL. Whereas bacteria levels in the lake were not high enough to warrant concern about public health, and were within state water quality standards, it is clear that there are sources of bacteria to the lake. Possible sources are waterfowl (which, according to the volunteer, are abundant at the lake), malfunctioning nearshore septic tanks, or intermittent streams which the volunteer noted are located on the north shore of the lake.

Mission Lake -- Kitsap County

Solids and Color

Suspended solids results were all very low, confirming that the "mud" noted by the volunteer was not present until after August. There was also very little color in the lake at the time of sampling. These parameters were tested to determine if suspended sediments or natural color in the lake water could interfere with the Secchi depth measurements at the time of sampling.

Profile Data

The lake was not stratified on either sampling date. As a result, data for temperature, pH, dissolved oxygen and conductivity did not change from surface to bottom. These data were similar to data collected in 1991 and 1990. There are no dissolved oxygen data for August 1992 because the quality assurance evaluation indicated that the data were not of acceptable quality.

In August 1990, as well as February and June 1970, dissolved oxygen decreased considerably to less than 1.0 mg/L in the bottom 2 - 5 feet of the lake (Rector, 1991; Collings, 1973), so it is likely that very low oxygen near the lake bottom has been occurring for many years. Decreases in dissolved oxygen near the lake bottom are most likely related to bacterial decomposition of organic material (such as algae, aquatic plants and woody debris) in the water and sediments.

Plants

Algal density was low on both sampling dates, as indicated by low concentrations of chlorophyll *a*. Algae problems were reported by the volunteer in 1990 and 1991, but not in 1992.

Aquatic plants identified by Ecology staff during the May 13, 1992 onsite visit were largeleaf pondweed (*Potamogeton amplifolius*), yellow-flowering lily (*Nuphar polysepalum*), waterweed (*Elodea canadensis*), white-flowering lily (*Nymphaea odorata*), and cattails (*Typha* spp.). Iris (*Iris pseudacorus*) was abundant, and according to the volunteer, is spreading along the shore.

On the May 20, 1991 onsite visit with the volunteer, a lot of pondweed (possibly *Potamogeton amplifolius*, although identification was not verified) was observed near the shore. Water lily was growing south of the public access; the volunteer mentioned the lily was planted by a homeowner and was spreading. Large cladocerans (invertebrates which eat algae and are eaten by fish) were visible in the composite samples collected. In 1970, the following plants were reported in Mission Lake: pondweed (*Potamogeton* spp.), watershield (*Brasenia*), waterweed (*Elodea*), waterlily (*Nuphar*), bulrushes (*Scirpus*), sedge (*Cyperus*), and cattail (*Typha*; Collings, 1973).

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

Mission Lake -- Kitsap County

Mission Lake is used for fishing, swimming, and non-motorized boating. There is one public boat ramp; there is a speed restriction of 7 mph for motorboating, and water skiing is not allowed. Rainbow trout were stocked in the lake. Currently, the watershed is used for logging, crop agriculture, animal grazing/feeding, and lakeshore development for residences. In comparison to the 1991 monitoring season, there were many new residences in 1992. In the past, the watershed was used for logging, and crop agriculture. In the past, the shoreline was altered when an island at the north end was connected to the shore by dirt fill.

There are about 60 houses on the lakeshore, and none of the houses are connected to a sewer. There is a lake association for the lake. Lake water is not withdrawn for any uses.

Overall, the volunteer finds that Mission Lake had fair water quality. Problems in the lake in 1992 were ranked as 1) swimmer's itch, 2) eye/skin problems after swimming, 3) excessive aquatic plant growth, 4) recently degraded water quality, 5) bacteria, 6) seagulls, 7) gradually degrading water quality over the years, 8) decaying plants, 9) odor from decaying algae, 10) degraded aesthetics, 11) algae and impaired fisheries, 12) fish kills, and 13) suspended sediments. Possible sources of problems are excessive growths of aquatic plants, and the large numbers of seagulls. In comparison to the 1991 monitoring season, in 1992 there was more weed growth, and there were more seagulls which may have contributed to the swimmers itch. Plant management was limited to hand pulling.

In 1990, the volunteer reported that the worst problems were 1) aquatic plants, 2) large flocks of seagulls, 3) algae, 4) suspended sediments, 5) garbage and debris, 6) fish kill, and 7) lake level. There was a fish kill during 1991 caused by a parasite carried by seagulls. This parasite was first reported in 1990, and was identified by the Department of Wildlife.

Submerged plants grow throughout the lake; these and water lilies are especially thick on the east side of the lake. The volunteer first noticed plants in the lake in 1953.

Comments

Although the low chlorophyll concentrations indicate that Mission Lake may be oligotrophic, the lake also exhibits some characteristics which do not indicate oligotrophy. Mesotrophic characteristics of the lake include the moderately shallow Secchi depths, total phosphorus which is borderline between oligotrophy and mesotrophy, and the prolific aquatic plant growth (lily pads, in particular) in areas of the lake. Based on these, the lake was characterized as mesotrophic.

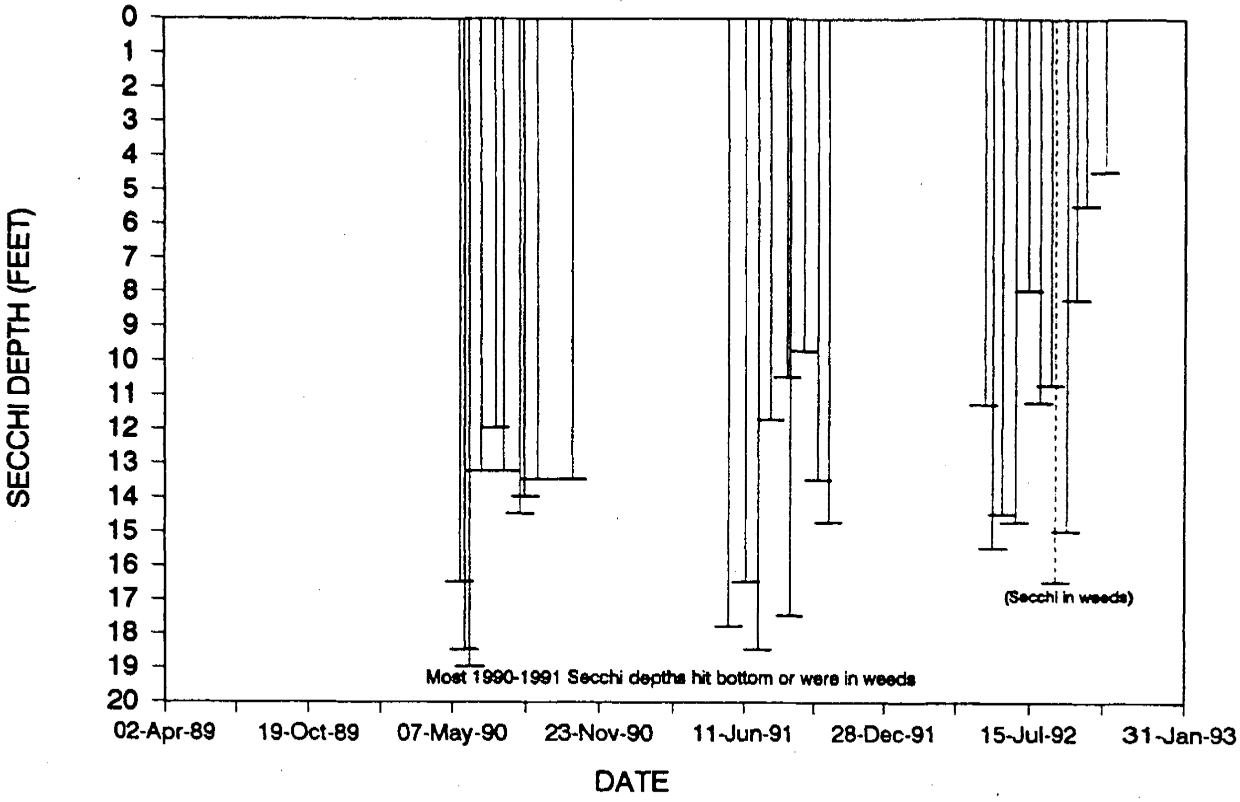
Mission Lake -- Kitsap County

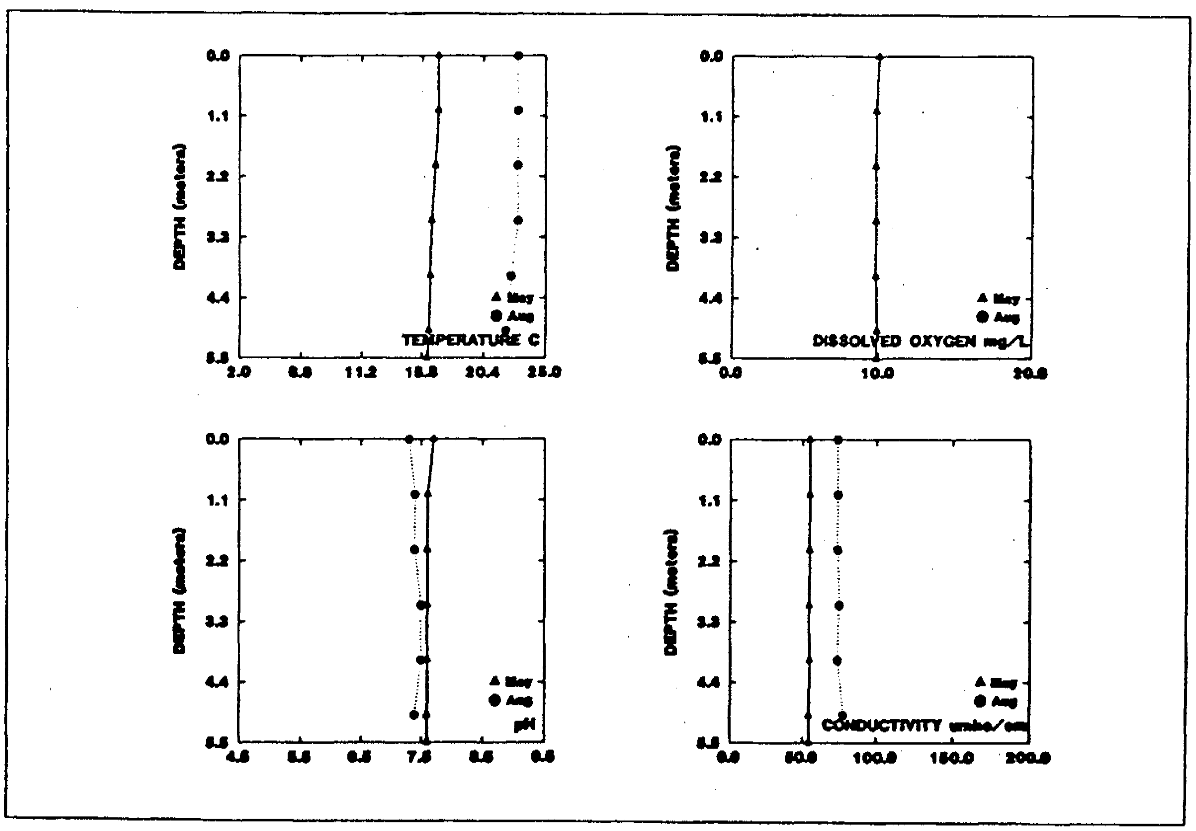
The method used to report Secchi depths in 1991 and 1990 was different from the method used in 1992, and from methods used in other lakes in the program. As a result, data for those two years will not be included in comparisons with data collected from other lakes in the program.

Acknowledgement

I thank Eleanora Fedenk for volunteering her time to monitor Mission Lake during 1990 - 1992.

MISSION LAKE (KITSAP COUNTY)



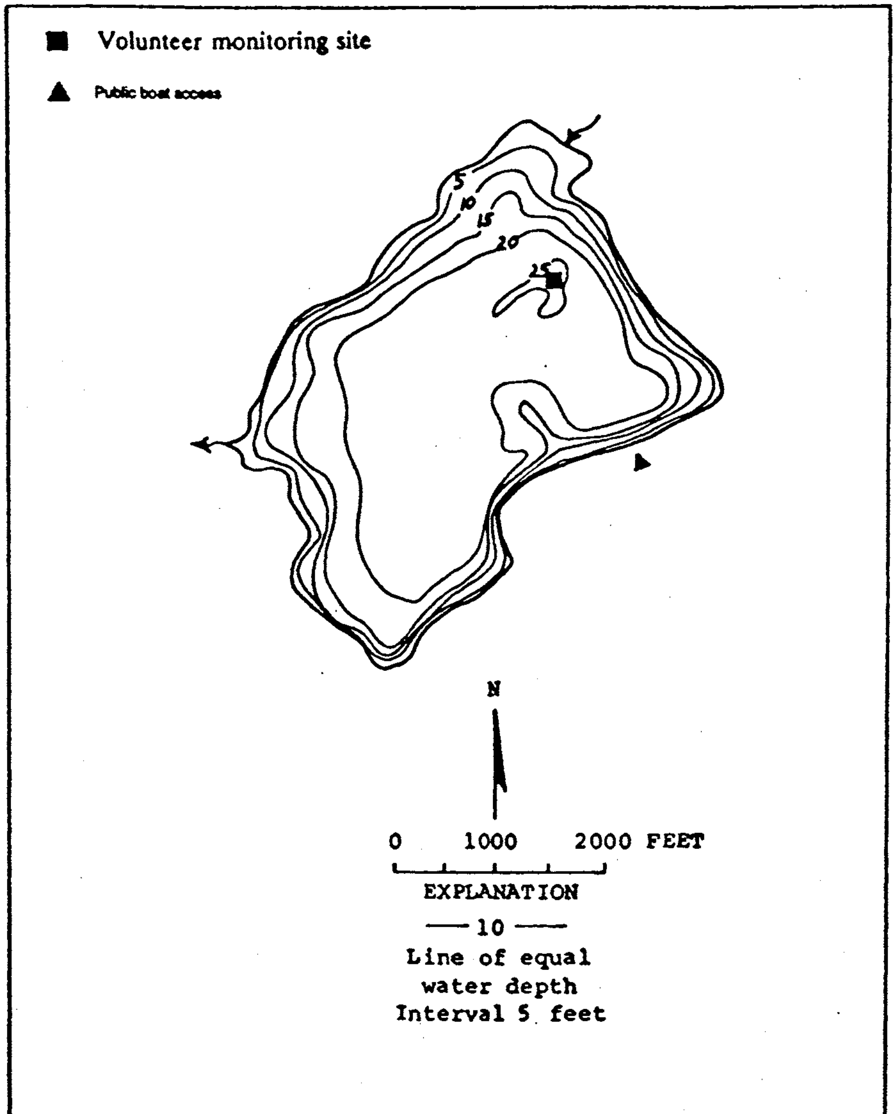


Lake Nahwatzel -- Mason County

Lake Nahwatzel is located 11 miles west of Shelton. It has two inlets, and drains via Outlet Creek to the East Fork of the Satsop River. The outlet seeps through a swampy area.

Size (acres)	269
Maximum Depth (feet)	25
Mean Depth (feet)	17
Lake Volume (acre-feet)	4,642
Drainage Area (miles^2)	6.2
Altitude (feet)	440
Shoreline Length (miles)	2.9

Data From Bortleson *et al.* (1976)



Nahwatzel Lake, Mason County. From Washington Department of Game, June 7, 1949.

Lake Nahwatzel -- Mason County

1992 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	38
Mean Trophic State Index (Total Phosphorus):	35
Mean Trophic State Index (Chlorophyll *a*):	27

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
14-Jun	1150	20.0	68.0	17.0	-1.50	Lt-Green	90	Moderate	Calm	
20-Jun	1010	21.7	71.0	16.0	-4.00	Lt-Green	100	Trace	Calm	Lake height 36" base.
12-Jul	1530	21.7	71.0	14.0		Green	50		Strong	Osprey fishing overhead. Saw bald eagle 7/11/92.
26-Jul	1330	22.2	72.0	16.5	-6.00	Lt-Green	10	None	Calm	
08-Aug	1530	21.7	71.0	14.5	-8.50	Lt-Green	0	Moderate	Light	
26-Aug	1000			16.2						Onsite visit.
06-Sep	1300	18.9	66.0	15.0		Green	25	None	Calm	
20-Sep	1300	17.8	64.0	11.5	-14.00	Green		None	Breezy	
04-Oct	1000	17.2	63.0	18.0	-13.75	Lt-Green	50		Calm	Last monitoring for this year - pulling boat out.

[1] Trophic State Indices calculated from Carlson (1977)

Lake Nahwatzel -- Mason County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/19	0.0	18.3	7.5	10.3	16
	1.0	18.3	7.3	9.8	16
	2.0	18.3	7.2	9.6	16
	3.0	18.3	7.1	9.7	16
	4.0	18.3	7.1	9.7	16
	5.0	18.2	7.1	9.7	16
	6.0	18.1	7.0	9.4	16
	7.0	16.3	6.8	8.0	17
08/26	0.0	23.2	7.9	8.5	26
	1.0	22.1	7.9	8.4	26
	2.0	21.6	7.9	8.5	26
	3.0	21.3	7.8	8.5	26
	4.0	21.2	7.8	8.5	26
	5.0	20.9	7.8	8.3	25
	5.5	20.9	7.8	8.3	25

1992 Onsite Visit Data - Water Chemistry

Date	05/19/92		08/26/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 3, 6	--	1, 3, 5	--
Total Phosphorus (μg/L)	9	--	8	--
Total Nitrogen (mg/L)	0.23	--	0.32	--
Chlorophyll *a* (μg/L)	1.18	--	0.25	--

Lake Nahwatzel -- Mason County

Historical Data From Ecology

Date	08/15/74[a]	06/10/81[b]	06/13/90[c]	09/12/90[c]	05/24/90[d]	08/15/90[d]	06/12/91[e]
Secchi (ft)	18	13	13.8	14.1	--	14.3	20
Total Phosphorus, epilimnion (μg/L)	7	40	--	--	12	12	--
Total Nitrogen, epilimnion (mg/L)	--	--	0.15	0.21	0.27	0.24	0.16
Chlorophyll *a* (μg/L)	--	1.52	2.2	2.2	--	--	--
Dissolved Oxygen, surface (mg/L)	8.7	10.2	9.8	8.9	8.8	9.6	9.8
Dissolved Oxygen, bottom (mg/L)	8.6	9.5	9.7	8.9	9.8	8.7	9.5

a. Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Coots (1991)
d. Rector (1991)
e. Rector (1992)

Lake Nahwatzel -- Mason County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was good, as indicated by Secchi depths which ranged from 11.5 to 18.0 feet. Except for one shallow Secchi depth measured on September 20 (which may have been affected by the breezy conditions at the time; see Volunteer-Collected Data), all Secchi depths were deep and in the oligotrophic range.

Total Phosphorus
Total phosphorus was low on both sampling dates. Results from 1992 onsite visits (9 μg/L in May, and 8 μg/L in August) were lower than results from 1990 (12 μg/L on both sampling dates; Rector, 1991) and 1981 (40 μg/L; Sumioka and Dion, 1985).

Total Nitrogen
Although both total nitrogen results were low (0.23 and 0.32 mg/L) on both sampling dates, the August value was higher than values from earlier studies (see Historical Data From Ecology).

Profile Data
Because there was very little change in profiled parameters from surface to bottom on both sampling dates, it was apparent that the lake was not stratified. As a result, only one set of water samples were collected on each sampling date. In comparison to other lakes monitored for the program, Lake Nahwatzel had very low conductivity. Low conductivity results from low ion content of water.

Plants
Algal density was very low at the time of sampling, particularly during August, as indicated by the low concentrations of chlorophyll *a*.

On the June 12, 1991 onsite visit with the volunteer, waterweed (*Elodea canadensis*), Berchtold's pondweed (*Potamogeton berchtoldii*) and another macrophyte, possibly *Lobelia*, were observed in the lake. The latter plant was also observed during the 1990 onsite visit, and at the time was tentatively identified as *Lobelia dortmanna*. During the 1990 survey, sedge (*Scirpus*) grew along about 40% of the shoreline (Coots, 1991). Muskgrass (*Chara*; actually an alga) was found growing in deep water areas of the lake in 1974 (Bortleson *et al.*, 1976).

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

> Lake Nahwatzel is used for fishing, swimming, motor boating, non-motorized boating, jet skiing, and lakeshore camping. There is one resort on the lakeshore.

Lake Nahwatzel -- Mason County

There is one public boat ramp, and there is a no wake restriction for motorboating within 100 feet of shore. About one percent of the shoreline publicly-owned. Trout were stocked in the lake. Currently, the watershed is used for logging and lakeshore development for residences. In the past, the watershed was used for logging. In the 1930s, the watershed was logged and there was a sawmill on the lakeshore. There are numerous old pilings in the lake which are safety hazards for boating.

There are 113 houses on the lakeshore, and none of the houses are connected to a sewer. There are no culverts or stormdrains which drain into the lake. There is no lake association for the lake. Currently, the minimum setback for lakeshore development is 25 feet (years earlier, the minimum setback was 15 feet), and there is no restriction for residential density.

Overall, the volunteer finds that Lake Nahwatzel had good water quality. Problems in the lake in 1992 were ranked as 1) aquatic plants, and 2) gradually degrading water quality over the years. Pondweeds were among the problem plants in the lake. No plant or algae management occurred in the lake in 1992. There were no changes in the lake since the 1991 monitoring season.

The volunteer noted that the lake is primarily fed by springs, and that despite maps which show there are inlets, none are apparent.

Most aquatic plants in the lake grow near the railroad trestle on the north end of the lake. There is a wetland near the outlet. The southwest shore is also marshy.

In 1990, the volunteer took pictures of foam on the lakeshore. The volunteer reported that the foam is found periodically. This foam is likely from organic material on the lake which is whipped up by winds. The foam sample collected by the volunteer on April 21, 1990 contained chironomid exoskeletons. Another sample collected by the volunteer during August contained a lot of detritus, zooplankton (microscopic animal) parts, bryozoan spores, exuvia (skins or coverings shed off by larvae, animals or insects), some filamentous algae, and a few live insects.

Comments

All three trophic state parameters (Secchi depth, total phosphorus, and chlorophyll *a*), indicate that Lake Nahwatzel was oligotrophic.

Lake Nahwatzel -- Mason County

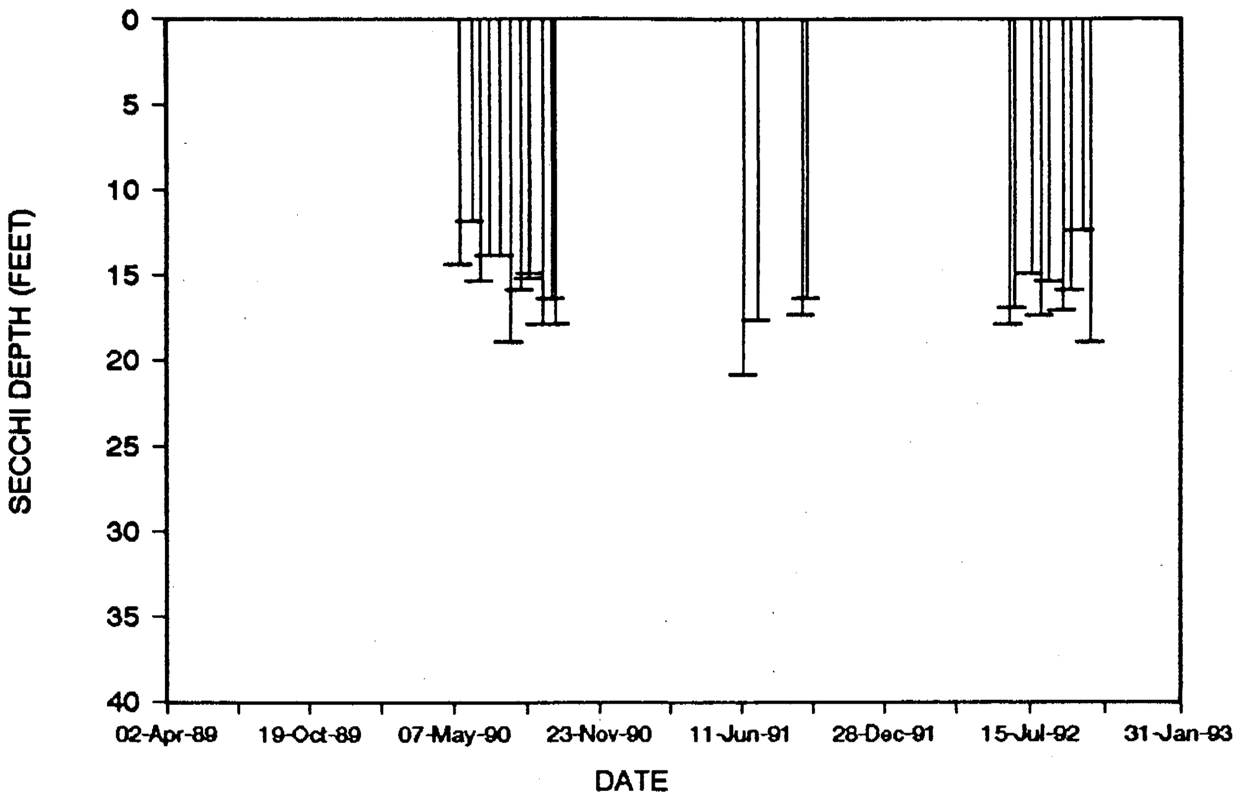
The relatively shallow depth of Lake Nahwatzel probably makes it more susceptible to mixing from winds. This would explain the lack of stratification and no changes in dissolved oxygen from surface to bottom.

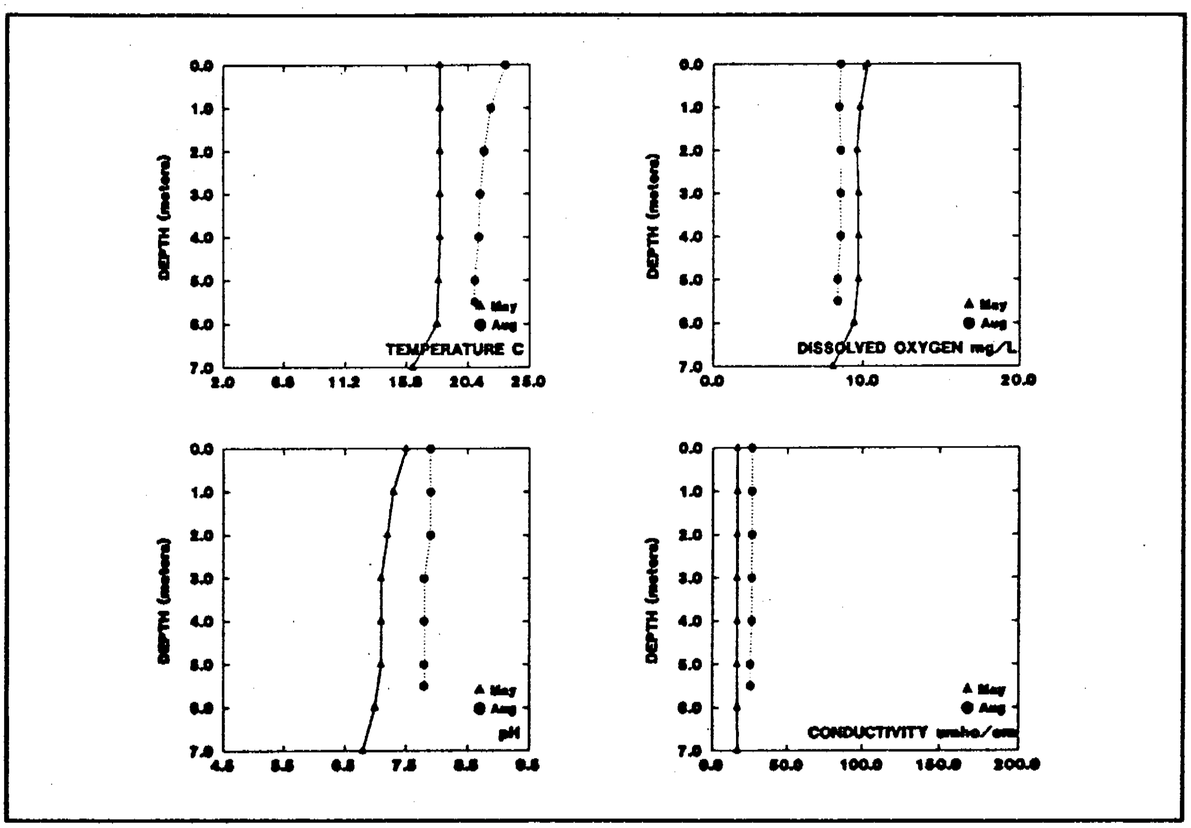
Five other Mason County lakes were monitored for the program in 1991. These lakes were Limerick, Mason, Phillips, Spencer and Wooten Lakes. Lake Nahwatzel had better mean summer water clarity than Lake Limerick and Phillips Lake.

Acknowledgement

I thank Dave Fowble for volunteering his time to monitor Lake Nahwatzel during 1990 - 1992.

LAKE NAHWATZEL (MASON COUNTY)



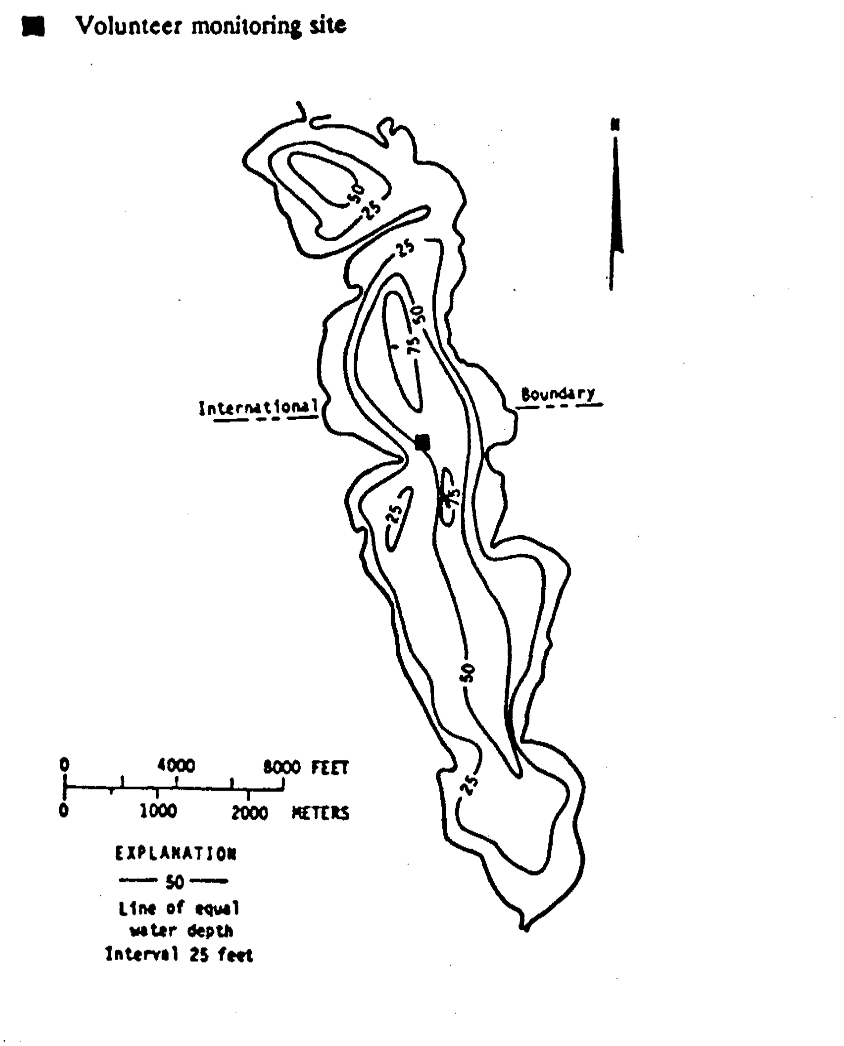


Lake Osoyoos -- Okanogan County

Lake Osoyoos is located one mile north of Oroville. It is ten miles long and extends north into Canada. The total size of the lake is 5,729 acres; 3,693 acres lie in British Columbia, Canada, and 2,036 acres lie in the U.S. Lake Osoyoos is fed principally by the Okanogan River in Canada and drains south via the Okanogan River in the U.S. to the Columbia River.

Size (acres)	5,729
Maximum Depth (feet)	208
Mean Depth (feet)	46
Lake Volume (acre-feet)	266,000
Drainage Area (miles^2)	3,150
Altitude (feet)	911
Shoreline Length (miles)	29.7

Data From Dion *et al.* (1976)



Osoyoos Lake, Okanogan County.
from Washington Department of Game, August 10, 1966.

Lake Osoyoos -- Okanogan County

1992 Trophic Status[1]

Estimated Trophic State:	Mesotrophic[2]
Trophic State Index (Mean Secchi):	44
Trophic State Index (Mean Total Phosphorus):	40
Trophic State Index (Mean Chlorophyll *a*):	31

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (ft)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
18-May	0930	16.7	62.0	17.0	911.20	Lt-Green	90	None	Light	Onsite visit. Lake height reported in feet.
03-Jun	1535	21.1	70.0	15.0	911.00	Lt-Green	0	None	Calm	Lake height in feet, from state park.
24-Jun	1430	30.0	86.0	12.0	911.80	Green	0	None	Calm	Thought all of US side max 50'.
13-Jul	1349	23.3	74.0	7.0	912.90	Lt-Green	90	Trace	Calm	Heavy rains last two weeks brought lake level up to 913 - now down to 912.9.
01-Aug	1445	27.8	82.0	7.0	912.90	Lt-Green	0	None	Calm	Temp 100 degrees.
25-Aug	1515	20.0	68.0	10.0	912.70	Lt-Green	0	None	Breezy	
31-Aug				10.5						Onsite visit.
15-Sep	1530	16.1	61.0	6.0	912.60	Green	75	None	Breezy	
30-Sep	1415	17.8	64.0	6.0	911.40	Pea Green	10	None	Calm	Much heavy green algae floating nearshore. Sent you a sample.

[1] Trophic State Indices calculated from Carlson (1977)

[2] see Comments section

Lake Osoyoos -- Okanogan County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/18	0.0	16.3	8.7	10.5	268
	1.0	16.3	8.7	10.4	270
	2.0	16.3	8.7	10.4	270
	3.0	16.3	8.7	10.4	269
	4.0	16.3	8.7	10.3	270
	5.0	16.3	8.7	10.3	270
	6.0	16.3	8.7	10.3	270
	7.0	16.3	8.7	10.3	269
	8.0	16.0	8.7	10.2	269
	9.0	13.9	8.5	8.5	272
	10.0	12.5	8.2	6.3	274
	11.0	11.0	8.0	5.7	274
	12.0	10.6	7.9	5.0	275
	13.0	10.4	7.9	4.8	275
	14.0	10.2	7.8	4.2	274
	15.0	10.1	7.8	3.9	276
	16.0	10.0	7.7	3.7	277
	17.0	10.0	7.7	3.7	277
08/31	0.0	20.1	8.3	8.8	266
	1.0	20.1	8.3	8.8	267
	2.0	20.1	8.4	8.7	267
	3.0	20.1	8.4	8.7	267
	4.0	20.1	8.4	8.7	267
	5.0	19.9	8.4	8.1	267
	6.0	19.9	8.4	8.1	267
	7.0	19.8	8.3	7.3	269
	8.0	19.7	8.3	6.7	270
	9.0	19.5	8.3	6.1	272
	10.0	19.4	8.3	5.6	273
	12.0	17.7	8.0	0.1	295
	14.0	15.2	7.8	0.1	302
	16.0	14.7	7.8	0.1	304
	18.0	14.4	7.8	0.1	302
	20.0	14.1	7.8	0.1	306
	22.0	18.6	7.8	0.0	308

Lake Osoyoos -- Okanogan County

1992 Onsite Visit Data - Water Chemistry

Date	05/18/92		08/31/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	2, 4, 6	11, 13, 15	3, 6, 9	14, 16, 18
Total Phosphorus (μg/L)	12	23	12	32
Total Nitrogen (mg/L)	0.34	0.40	0.24	0.54
Chlorophyll *a* (μg/L)	0.82	--	1.29	--

Historical Data From Ecology

Date	07/22/74[a]	07/15/81[b]	06/06/89[c]	09/06/89[c]	06/27/91[d]
Secchi (ft)	7	9	11.8	6.9	--
Total Phosphorus, epilimnion (μg/L)	12	20	16	21	--
Total Nitrogen, epilimnion (mg/L)	--	0.71	0.36	0.31	0.21
Chlorophyll *a* (μg/L)	--	3.28	2.3	6.0	--
Dissolved Oxygen, surface (mg/L)	9.4	8.8	10.4	10.8	9.6
Dissolved Oxygen, bottom (mg/L)	0.9	0.4	2.6	0.4	0.2

a. Dion *et al.* (1976)
b. Sumioka and Dion (1985)
c. Brower and Kendra (1990)
d. Rector (1992)

Lake Osoyoos -- Okanogan County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good to fair, as indicated by Secchi depths which ranged from 17 feet in May, to 6 feet in September. The general decrease in Secchi depths over the course of the monitoring season has been documented each year since 1989. Secchi depths in May and June 1992 were much deeper than those from earlier years for the program.

Total Phosphorus

Total phosphorus in the epilimnion was moderate (12 μg/L on both sampling dates). This concentration was lower than concentrations measured in 1989 and 1981. In 1989 total phosphorus was 16 μg/L in June and 21 μg/L in September (Brower and Kendra, 1990), and in 1981 it was 20 μg/L (Sumioka and Dion, 1985).

Total Nitrogen

Total nitrogen was low on both sampling dates. Concentrations measured were very similar to those measured in 1991 and 1989.

Profile Data

On both sampling dates, the lake was stratified with respect to temperature, and pH and dissolved oxygen decreased with depth below the thermocline. During August, dissolved oxygen was very low (0.1 mg/L) in the bottom 10 meters of the lake. In July 1974, dissolved oxygen also decreased from 9.4 mg/L at the surface to 0.9 mg/L at 49 feet (Dion *et al.*, 1976), so it is likely that low hypolimnetic dissolved oxygen has been occurring in the lake for many years. Dissolved oxygen is usually depleted by bacterial decomposition of aquatic plants and algae in the water and sediments.

Fish in the lake are probably restricted to the metalimnion of the lake, because of warm temperatures in the epilimnion and low oxygen in the hypolimnion, particularly during August. Temperature increased about 4 degrees at the very bottom of the lake in August; reasons for this increase are not known, but it may be a recording error.

Plants

Algal density was low on both sampling dates, as indicated by the low concentrations of chlorophyll *a*. During the May 18, 1992 onsite visit with the volunteer, both the volunteer and a neighbor noted that Eurasian milfoil growth was reduced since 1991. Aquatic plants identified by Ecology staff were Eurasian milfoil (*Myriophyllum spicatum*), curlyleaf pondweed (*Potamogeton crispus*), and waterweed (*Elodea canadensis*). None of the plants identified were very abundant. During the August onsite visit, Eurasian milfoil was not very abundant; some floating sprigs were seen, but no surface mats.

Lake Osoyoos -- Okanogan County

Other Available Information

Ambient monitoring data from the Okanogan River at Oroville from 1977 through 1992 were analyzed for possible trends in total phosphorus related to time, seasons, or flow. The data source was Washington State Department of Ecology Freshwater Ambient Moniotoring Program, and trend analysis was conducted using WQHYDRO (Aroner, 1990). No significant trend was detected.

From Ryder *et al.* (1991): Researchers from Okanagan College in British Columbia, Canada, sampled Lake Osoyoos six times from May through August, 1991. Fifty-nine lake stations were located along transects on the Canadian side of the lake, and were measured for temperature, pH, dissolved oxygen, turbidity, Secchi disk transparency, orthophosphate, nitrate-nitrogen, and total dissolved solids. The researchers concluded that nutrient concentrations in the lake were high, not only with respect to the eutrophication of the lake, but also in comparison to other lakes in the region. Orthophosphate values from the study ranged from 10 - 170 μg/L, and Secchi depths ranged from 1.6 to 13.8 feet. Several recommendations were made for improving the water quality of Lake Osoyoos; these included improving the wastewater treatment and sewer collection systems in the town of Osoyoos, minimizing impacts from septic systems, continuing milfoil harvesting in the lake, monitoring nitrates in groundwater, and continuing the monitoring of nutrients in the lake.

From Johnson and Norton (1990): As part of a toxics monitoring portion of the Lake Monitoring Program, sediment and largemouth bass samples were collected from Lake Osoyoos in 1989. No unusual concentrations of metals or organics were detected from bottom sediments. Compared to the other eight lakes sampled, largemouth bass tissues in Lake Osoyoos contained higher concentrations of selenium (0.95 mg/Kg) and total DDT compounds (210 μg/Kg), primarily in the form of degradation by-products. The concentrations of DDT compounds suggest that there was significant historical use of DDT in the drainage basin. Concentrations of DDT and selenium were both within levels considered acceptable for human consumption.

Eurasian water milfoil was introduced into Lake Osoyoos, and was first reported in 1975 (Gibbons *et al.*, 1984). Mechanical harvesting of milfoil was proposed but not permitted by the Departments of Fisheries and Game (K. Hamel, Ecology, pers. comm.). Chemical treatment of milfoil has been tried in experimental test plots, but local and international concern about the use of herbicides has preempted chemical control of the water milfoil. Efforts to control milfoil in lake Osoyoos are now at a standstill on the U.S. side, although populations of chironomids and caddisfly larvae appear to eat milfoil in noticeable quantities (K. Hamel, Ecology, pers. comm., 1991).

From Coulthard and Stein (1969): Algal growth in Lake Osoyoos was studied by the University of British Columbia in 1968-69 because there were concerns that Lake Osoyoos, which is used for domestic water supply, had the potential to exhibit water quality problems similar to those observed in Skaha Lake (such as severe blue-green algal blooms). Lake Osoyoos receives water from Skaha Lake via the Okanogan River, and secondary sewage effluent from the town of Oliver is pumped into the Okanogan River about 3 miles north of Lake Osoyoos. The Osoyoos stations located just north of the International Border did not exhibit the extent of blue-green algal growth as did Lake Skaha and the northern Lake Osoyoos stations. Point source discharges from primary and secondary wastewater treatment facilities, and cannery and packing house wastes, as well as runoff from agricultural lands, were cited as nutrient sources to be studied further.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

> Lake Osoyoos is used for fishing, boating, swimming, rowing, jet skiing and camping. Recreational facilities on the lakeshore include a city park, a state park, a beach and two boat ramps. Currently the watershed is used for mainly for crop agriculture, although lakeshore development for residences is also occurring. Lake water is withdrawn for municipal, industrial and agricultural uses. In the past the watershed was used for animal grazing and crop agriculture.
>
> There are approximately 300 houses on the lakeshore; of these, most are occupied year-round. The lakeshore is not sewered on the U.S. side, although most homes on the Canadian side are sewered. There is a lake association for the lake.
>
> Overall, the volunteer thought that Lake Osoyoos had good water quality. The worst problem in the lake in 1992 was the fluctuating water level. Moderate problems were shoreline erosion, suspended sediments, and algae. Lesser problems were aquatic plants, degraded aesthetics, gradually degrading water quality over the years, odor from decaying algae, decaying plants, beach closure, recently degraded water quality, fish kills, and impaired fisheries. There were no changes in the lake since the 1991 monitoring season.
>
> Lake level was also a problem in 1991. In contrast, in 1990 the volunteer believed that aquatic weeds presented the worst problems, possibly because the volunteer reported that there was more watermilfoil in Lake Osoyoos in 1990 than in any past year. Algae growth was also reported to be heavy in 1990. In 1990, aquatic plants were removed with a mechanical harvester on the Canadian side of the lake, but not on the U.S. side.

Lake Osoyoos -- Okanogan County

Comments

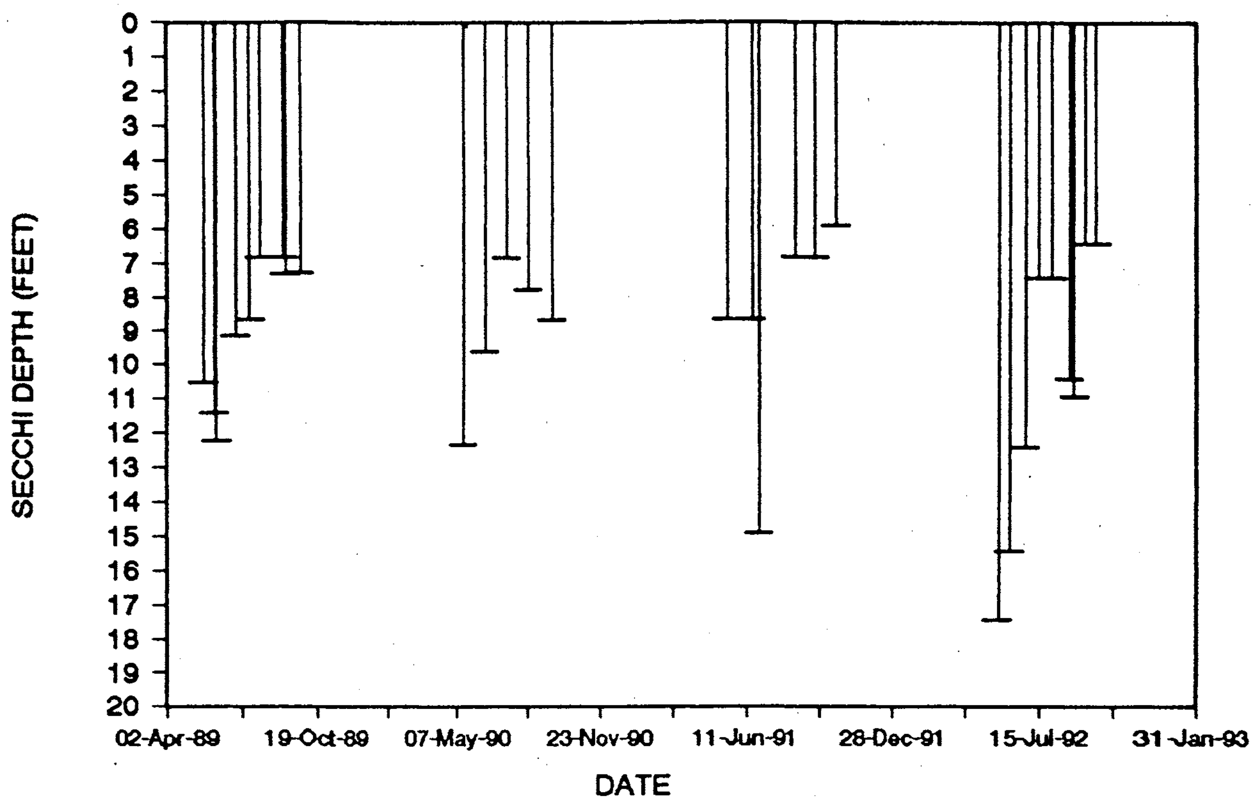
Secchi depths in Lake Osoyoos appear to have improved somewhat over the four years the lake has been monitored for the program. In addition, chlorophyll was in the oligotrophic range and total phosphorus was borderline between oligotrophy and mesotrophy, yet both parameters were clearly in the mesotrophic range when the lake was sampled for the program during 1989. Despite apparent improvements in water quality, Lake Osoyoos was characterized as mesotrophic because the Secchi depths were moderately shallow, and because of the very low oxygen in the hypolimnion.

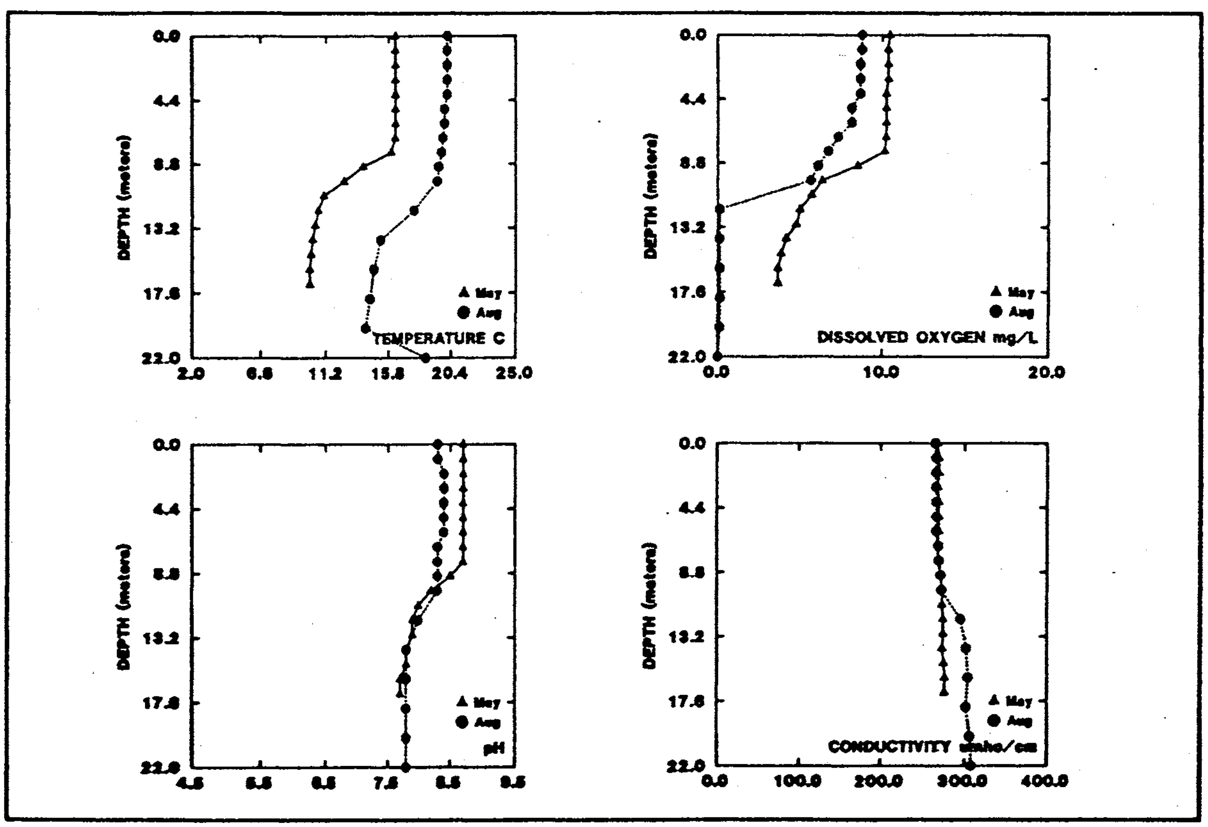
Mean trophic state index values (Secchi) for 1991 and 1990 were very similar and in the mesotrophic range. Long Lake in Thurston County, Lake Thomas in Stevens County, and Lake Sawyer in King County also have Eurasian watermilfoil. Lake Killarney, in King County, is also monitored for the program and had Eurasian milfoil successfully eradicated using Sonar® (fluridone). Long Lake was treated with Sonar in July 1991.

Acknowledgements

I thank Walter Ullrich for volunteering his time to monitor Lake Osoyoos during 1990-1992, and Kathy Jones for monitoring the lake during 1989.

LAKE OSOYOOS (OKANOGAN COUNTY)



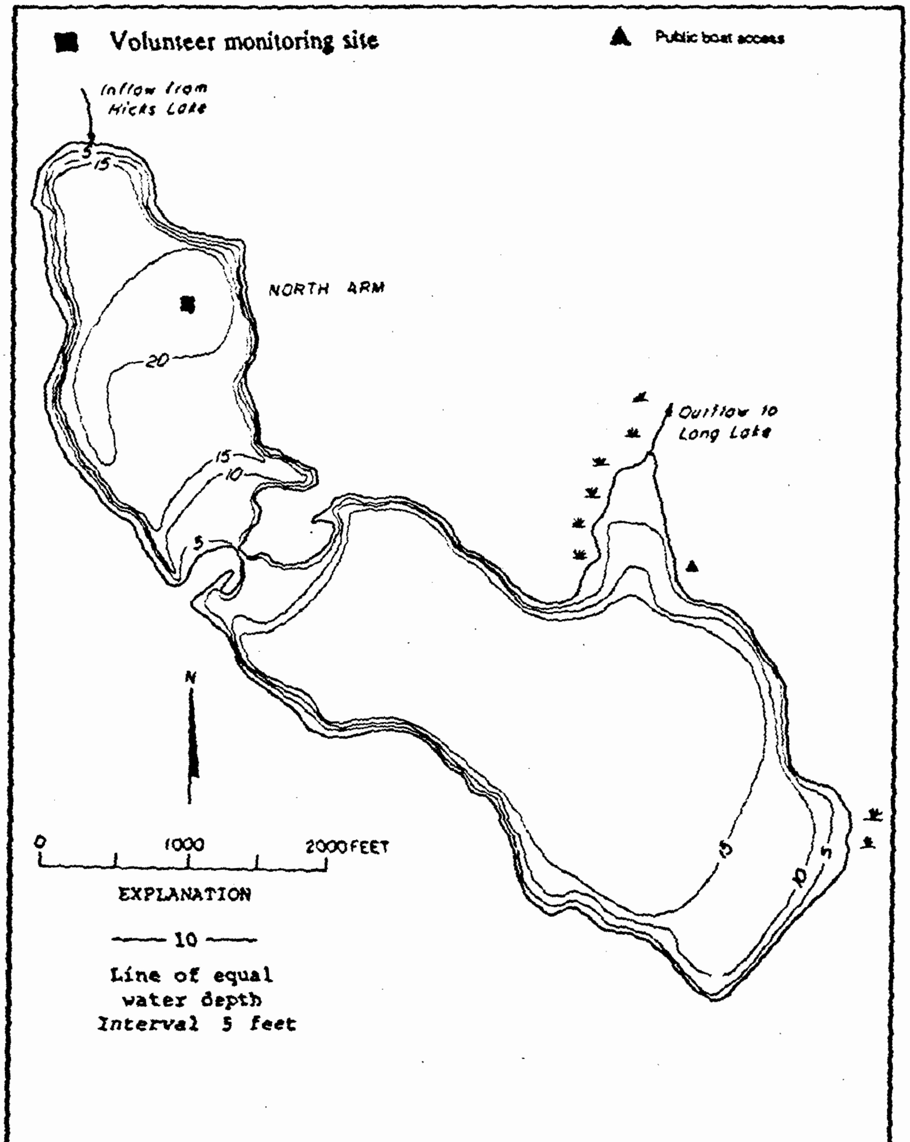


North Pattison Lake – Thurston County

Pattison Lake is located six miles southeast of Olympia. It consists of two basins separated by a narrow channel. The north basin covers 75 acres and the south basin covers 182 acres. The lake is fed by Hicks Lake and drains to Long Lake and ultimately to Henderson Inlet via Himes/Woodland Creek. Pattison Lake is also listed in references as Patterson Lake.

Size (acres)	257
Maximum Depth (feet)	19
Mean Depth (feet)	13
Lake Volume (acre-feet)	2,500
Drainage Area (miles^2)	3.8
Altitude (feet)	154
Shoreline Length (miles)	4.6

Data From Bortleson *et al.* (1976)



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

North Pattison Lake -- Thurston County

1992 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	41
Mean Trophic State Index (Total Phosphorus):	49
Mean Trophic State Index (Chlorophyll *a*):	44

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
05-Jul	1542	22.0	71.6	16.0	27.00	Lt-Green	0	Moderate	Light	
18-Jul	1420	24.5	76.1	17.5	25.00	Lt-Green	25	None	Light	Lake height marker same one used in '91.
17-Aug	1407	25.5	77.9	13.3	23.00	Green	25			
01-Aug	1315	24.5	76.1	14.5	24.00	Lt-Green	0	None	Light	
02-Sep	1222	22.0	71.6	13.3	22.00	Lt-Green	0	None	Calm	
19-Sep	1223	19.5	67.1	8.8	21.00	Green	50	Light	Light	
06-Oct	1345	17.0	62.6	6.0	22.50	Yellow-green	0	None	Calm	Algae bloom with lots of large multi-celled algae.
17-Oct	1543	15.0	59.0	5.3	24.00	Pea Green	100	Light	Calm	Lots of green algae floating on surface, accumulates in heavy drifts downwind along shore.

[1] Trophic State Indices calculated from Carlson (1977)

North Pattison Lake -- Thurston County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
08/17	0.0	24.9	9.5	11.2	128
	1.0	24.3	9.5	11.3	129
	2.0	24.1	9.5	11.4	128
	3.0	23.9	9.6	15.3	128
	4.0	22.5	9.6	14.2	127
	5.0	21.0	9.1	10.7	130

1992 Onsite Visit Data - Water Chemistry

Date	08/17/92	
	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 4	--
Total Phosphorus (μg/L)	23	--
Total Nitrogen (mg/L)	0.61	--
Chlorophyll *a* (μg/L)	3.96	--

North Pattison Lake -- Thurston County

Historical Data From Ecology

Date	06/19/74[a]	07/21/81[b]	05/30/90[c]	08/22/90[c]	6/04/91[d]
Secchi (ft)	7	14	14.7	14.7	12
Total Phosphorus, epilimnion (μg/L)	14	--	20	15	--
Total Nitrogen, epilimnion (mg/L)	--	1.5	0.65	0.95	1.27
Chlorophyll *a* (μg/L)	10.0	2.86	--	--	--
Dissolved Oxygen, surface (mg/L)	8.7	9.2	10.4	10.6	10.3
Dissolved Oxygen, bottom (mg/L)	0.4	0.4	0.6	1.5	0.2

a. Bortleson *et al.* (1976), Dion *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)

North Pattison Lake -- Thurston County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity varied from good to fair, as indicated by Secchi depths which ranged from 17.5 feet in July to 5.3 feet in October. Secchi depths decreased throughout the duration of the monitoring season; this pattern was not evident in either 1991 or 1990. Mean Secchi depth (which was used to calculate the trophic state index and determine the trophic state of the lake) was better in 1990 than in 1992 or 1991. Earlier data from 1985-1990 (see Other Available Information) also indicated that water clarity was unusually good in 1990.

Total Phosphorus

The lake was not stratified at the time of sampling, so water samples were composited from surface to bottom. Total phosphorus in the water column was moderately high (23 μg/L) when the lake was sampled during August. This concentration was higher than concentrations measured for the program in 1990 (20 μg/L in May, and 15 μg/L in August; Rector, 1991).

Total Nitrogen

Total nitrogen was also moderately high (0.61 mg/L), but was lower than results from 1991, 1990 and 1981. Total nitrogen was 1.27 mg/L in June 1991 (Rector, 1992), 0.65 mg/L in May 1990 and 0.95 mg/L in August 1990 (Rector, 1991), and 1.5 mg/L in July 1981 (Sumioka and Dion, 1985).

Profile Data

The lake was not stratified with respect to temperature, and as a result, there was little change in pH and conductivity from surface to bottom. The increase in dissolved oxygen at 3 and 4 meters was probably from aquatic plants, and possibly algae, photosynthesizing at these depths. Plants use carbon dioxide and release oxygen into water as part of the photosynthesis process.

In contrast, in June 1974 the lake was stratified and dissolved oxygen decreased from 8.7 mg/L at the surface to 0.4 mg/L at 16 feet (Bortleson *et al.*, 1976). The decrease in dissolved oxygen may have been due to bacterial decomposition of aquatic plants and algae in the water and sediments, and may not have been offset by high aquatic plant or algal productivity.

Plants

During August, algal density was moderately high at the time of sampling, as indicated by the moderately high concentration of chlorophyll *a*.

Aquatic plants identified by Ecology staff during the August 17, 1992 onsite visit with the volunteer were sago pondweed (*Potamogeton pectinatus*), Illinois pondweed (*Potamogeton illinoensis*), waterweed (*Elodea canadensis* and possibly *E. Nutallii*), coontail (*Ceratophyllum demersum*), largeleaf pondweed (*Potamogeton amplifolius*) and curlyleaf pondweed (*Potamogeton crispus*). Several of the plants were collected from the bed of the mechanical harvester, which was operating at the time of sampling.

During the June 4, 1991 onsite visit with the volunteer, two types of algae were observed in the water. One type appeared to be filaments of the blue-green alga *Aphanizomenon*. In addition, iris (*Iris pseudacorus*) were in bloom and cattails (*Typha*) were observed on the shore.

Other Available Information

The North Pattison Lakes Management District has sponsored County monitoring efforts on the lake. Water clarity, phosphorus, dissolved oxygen and chlorophyll data have been collected by the county. Data from 1991 indicate that the basin was stratified from May thorough September. During stratification, dissolved oxygen was depleted near the lake bottom, although during July and August dissolved oxygen was supersaturated in the metalimnion. Water clarity data collected monthly from June through October since 1985 indicate that water clarity was lowest during 1988 and 1989, and highest during 1990.

In October 1992, the term of the North Pattison Lake Management District was due to expire and renewal of the district was put to the vote of lakeshore property owners. Based on results of the vote, the lake management district was not renewed.

From Entranco Engineers (1987): A Phase I Diagnostic/Feasibility Study of Pattison Lake was conducted in response to increasing blue-green algal blooms and prolific aquatic plant growth in Pattison Lake. Data collected during 1984-1985 as part of the restoration plan indicated that concentrations of total phosphorus in both the north and the south basins varied considerably, although highest concentrations were found during late fall and winter. Following an alum treatment of 382 tons during September 1983, the concentration of total phosphorus was lower during the fall and winter of 1984 than prior to treatment. Mechanical harvesting in the north basin occurred from 1983-1984. Harvesting was stopped because of pressure from lakeshore residents. During a survey of aquatic plant growth in North Pattison during August 1985, plant growth was mainly concentrated at the south end near the channel leading to the south basin. Populations of yellow and white-flowering lilies (*Nuphar* and *Nymphaea odorata*, respectively) were nearest to the channel. The submerged species coontail (*Ceratophyllum demersum*) and waterweed (*Elodea canadensis*) extended towards the mid-basin and along the shoreline. Curlyleaf pondweed (*Potamogeton crispus*) was in deeper water near the center of the lake, and along the north shore. Compared to the south basin, the north basin had less of the bottom surface covered with submerged species of plants and less of the shoreline supported emergent plants (except for an area surrounding the public access area, the entire shoreline of the south basin is ringed with aquatic plants). The water of the north basin was dark and humic-colored; however, following alum treatment, the color changed to aquamarine in the treated basins and was particularly noticeable in North Pattison.

Severe algal growth and other water quality problems in Pattison Lake have been documented during earlier surveys. A 1968 survey reported that Secchi disk transparency in Pattison Lake was only 4.75 feet, and the lake was described as a "moderately eutrophic lake which supports algal blooms from midsummer to early fall" (Lee, 1969). This report, though, does not indicate whether one or both basins were surveyed. Moderate to heavy blooms of blue-green algae, low Secchi disk transparency and very low concentrations of dissolved oxygen near the bottom of the north basin were reported in 1974 (Dion *et al.*, 1976).

South Pattison Lake was monitored for the program from 1989-1990. Monitoring results were reported in the 1989 and 1990 data summaries for Pattison Lake (Rector, 1990; 1991).

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 and 1992.

> North Pattison Lake is used for fishing, and swimming. The public access to the lake is located on the south basin, and there is a speed restriction of 5 mph for motor boats. About 1 percent of the north basin shoreline is publicly-owned. Rainbow trout were stocked in the lake: about 8,000 legal size, and 20,000 fingerlings. This year, the main watershed activity was clearing land for a large housing development. In the past, the watershed was logged, and the shoreline was altered with fill for a railroad bridge which separates the two lake basins.
>
> There are 75 houses on the lakeshore, and none of the houses are connected to a sewer. About 2 culverts/stormdrains drain into the lake. There is a tri-lakes association for the lake. Currently, the minimum setback for lakeshore development is 50 feet, and residential density is restricted to two houses per acre on the north and east shores, and two to eight houses per acre on the west shore.
>
> Overall, the volunteer finds that North Pattison Lake had good water quality. Problems in the lake in 1992 were ranked as 1) aquatic plants, 2) algae, and 3) low water level. Possible sources of problems are chronic nonpoint source pollution loading, which lead to abundant macrophytes and seasonal algae blooms. In 1990, the worst problem was algae, particularly during August on the west end of the lake, and it was raked off the lake by lakefront property owners. In 1992, plants were managed by mechanical harvesting. In comparison to the 1991 monitoring season, the maximum Secchi depth increased from about 14 feet in 1991, to 17.5 feet in 1992. Also, an extensive housing development is being constructed on the southwest corner of the north basin. This development will add about 500 additional housing units with access to the lake.
>
> There are conservancy areas on each side of the railroad bridge between the two basins, and thick growths of surface weeds extend out beyond these conservancy areas.

North Pattison Lake -- Thurston County

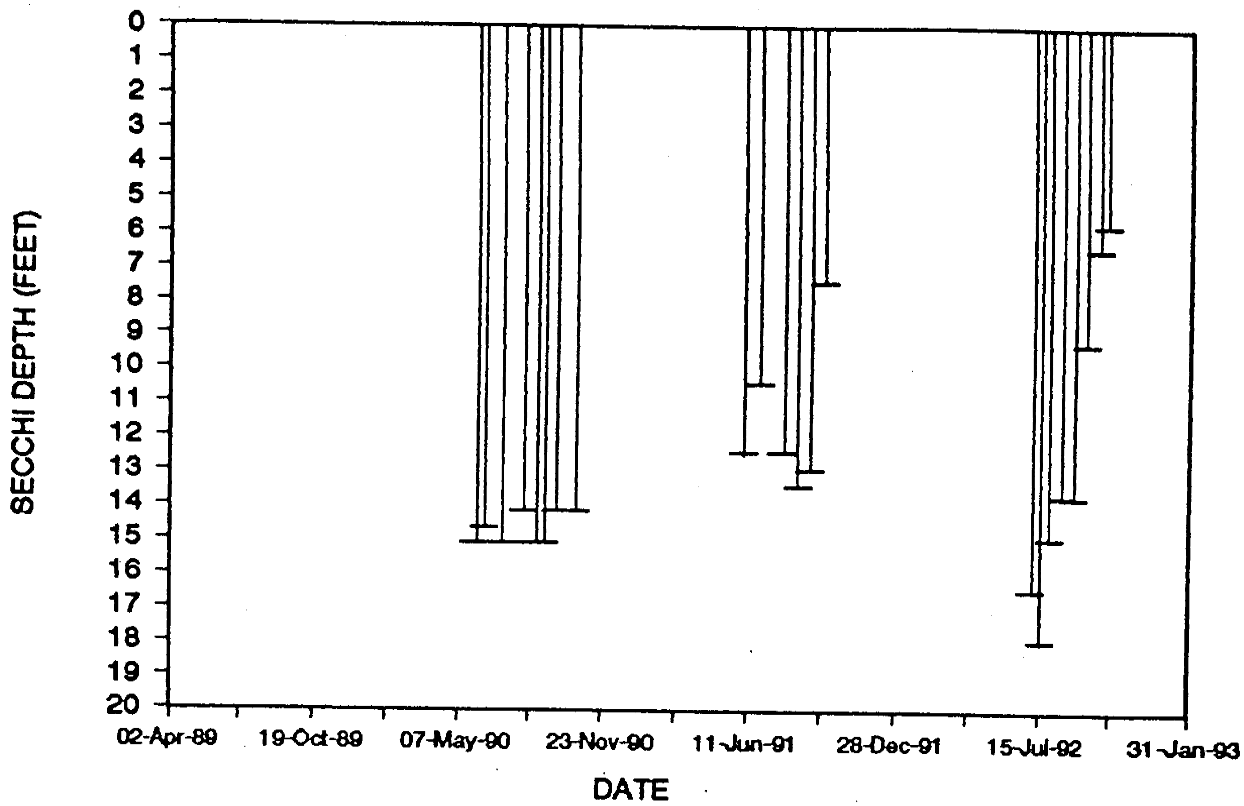
Comments

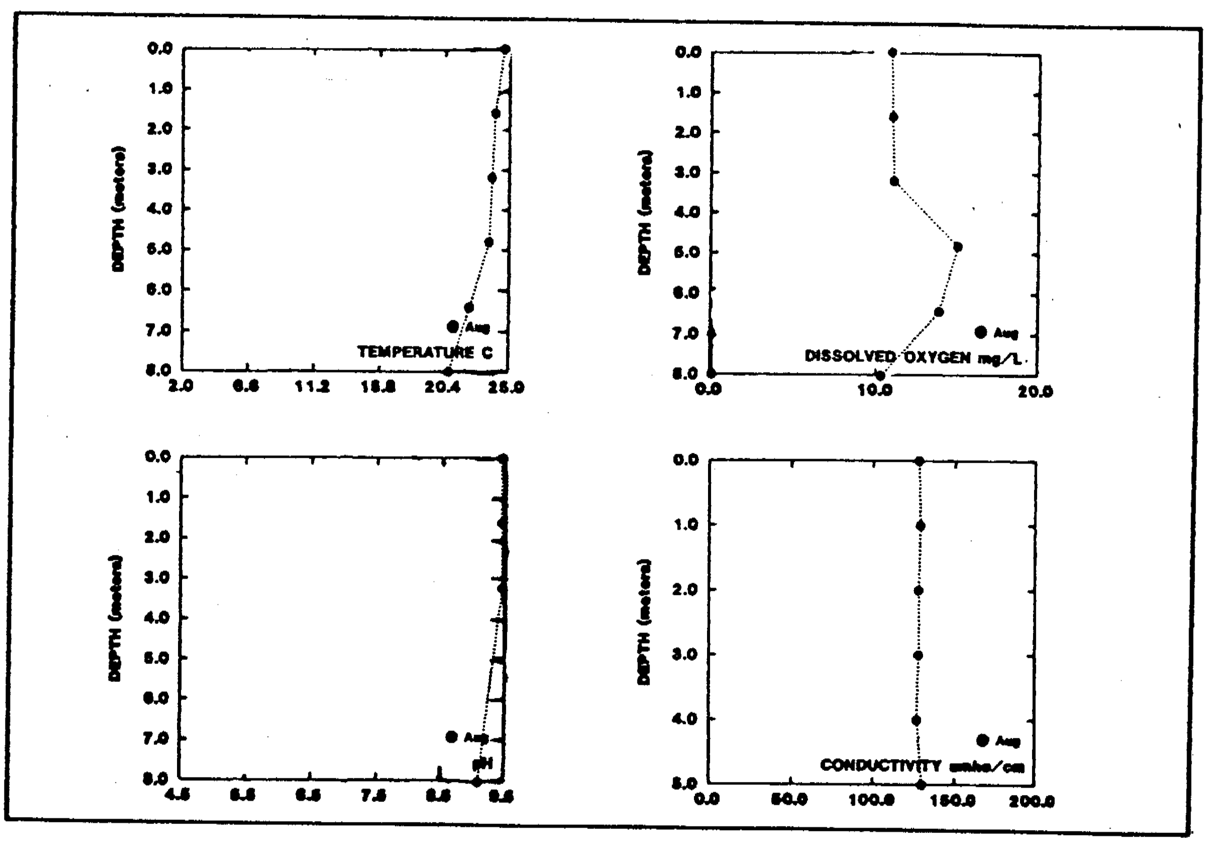
All trophic state parameters (Secchi depth, total phosphorus, and chlorophyll) indicate that North Pattison Lake was mesotrophic. Other Thurston County lakes monitored for the program in 1992 are Long, St. Clair, and Ward. Long and St. Clair both had higher total phosphorus and more algal growth, and shallower Secchi depths, than North Pattison. Of Thurston County lakes which were monitored for the program, Ward was the only oligotrophic lake.

Acknowledgements

I thank Russ McMillan for volunteering his time to monitor north Pattison Lake during 1991-1992, and Peg Eisenmann for monitoring the north basin during 1990.

NORTH PATTISON LAKE (THURSTON COUNTY)



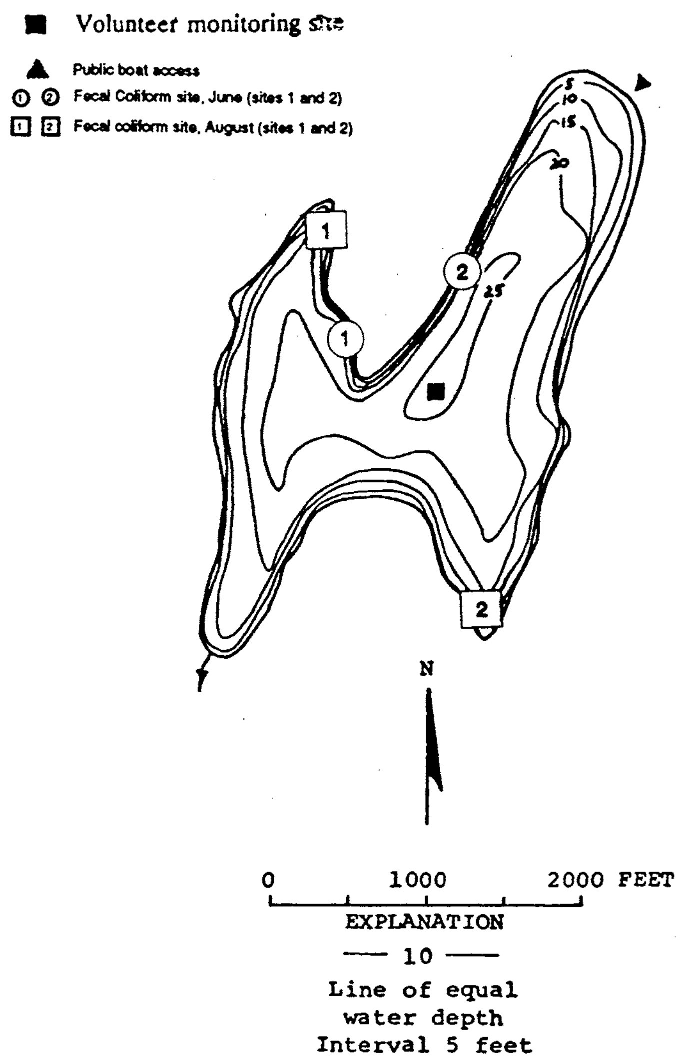


Phillips Lake -- Mason County

Phillips Lake is located seven miles north of Shelton. It has no surface inlets, and drains via Campbell Creek through a marshy area to Oakland Bay.

Size (acres)	110
Maximum Depth (feet)	25
Mean Depth (feet)	16
Lake Volume (acre-feet)	1,800
Drainage Area (miles^2)	0.5
Altitude (feet)	188
Shoreline Length (miles)	2.6

Data From Bortleson *et al.* (1976)



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

Phillips Lake -- Mason County

1992 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic[2]
Mean Trophic State Index (Secchi):	42
Mean Trophic State Index (Total Phosphorus):	37
Mean Trophic State Index (Chlorophyll *a*):	30

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
01-May	1030	15.0	59.0	14.5	10.00	Lt-Green	90	None		
28-May	1230	19.4	67.0	12.5	12.00	Pea Green	75	None		
18-Jun	1230	19.4	67.0	11.0	15.00	Pea Green	75	Trace	Light	Water color pea-green and milky green.
02-Jul	1200	18.9	66.0	10.5	17.00	Pea Green	75	Light	Light	
16-Jul	1200	18.9	66.0	13.0	18.00	Lt-Green	0	Trace	Light	Lots of boating waves.
31-Jul	1130	23.3	74.0	13.0	21.00	Lt-Green	0	None	Light	
17-Aug	1130	25.0	77.0	10.5	24.00	Lt-Green	0	None	Light	Lots of boats out.
01-Sep		21.1	70.0	11.0	26.50	Milky-Gr	25	Trace	Light	
15-Sep	1030	16.1	61.0	10.5	28.50	Milky-Gr	10	None	Light	
01-Oct	1100	17.2	63.0	10.0	29.00	Milky-Gr	25	None	Breezy	
17-Oct	1130	13.9	57.0	10.0	29.50		90	Light	Light	Water color milky pea-green.

[1] Trophic State Indices calculated from Carlson (1977)

[2] see Comments section

Phillips Lake -- Mason County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
06/02	0.0	21.8	8.0	9.5	28
	1.0	21.3	7.7	9.3	26
	2.0	21.0	7.6	9.2	26
	3.0	20.9	7.5	9.2	26
	4.0	20.5	7.5	9.3	26
	5.0	20.1	7.5	9.2	28
	5.5	19.5	7.4	8.8	27
08/26	0.0	23.4	7.8	8.2	31
	1.0	22.7	7.8	8.2	32
	2.0	22.4	7.7	8.1	31
	3.0	22.3	7.7	8.1	31
	4.0	22.2	7.7	8.1	31
	5.0	22.1	7.7	8.0	31
	5.5	22.1	7.7	7.9	31

1992 Onsite Visit Data - Water Chemistry

Date	06/02/92		08/26/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 4	5.5	1, 3, 5	--
Total Phosphorus (µg/L)	8	15	11	--
Total Nitrogen (mg/L)	0.30	0.32	0.38	--
Chlorophyll *a* (µg/L)	0.82	--	1.15	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	<1	--	<1	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	<1	--	35	--
Total Suspended Solids (mg/L)	2	--	4	--
Total Nonvolatile Suspended Solids (mg/L)	<1	--	1	--
Color (Pt-Co units)	20	--	10	--

Phillips Lake -- Mason County

Historical Data From Ecology

Date	6/29/72[a]	05/24/90[b]	08/15/90[b]	5/21/91[c]
Secchi (ft)	16	--	19	--
Total Phosphorus, epilimnion (μg/L)	15	13	13	--
Total Nitrogen, epilimnion (mg/L)	--	0.30	0.49	0.27
Chlorophyll *a* (μg/L)	2.2	--	--	--
Dissolved Oxygen, surface (mg/L)	9.1	10.3	8.4	9.7
Dissolved Oxygen, bottom (mg/L)	8.5	9.9	8.2	9.2

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)

Phillips Lake -- Mason County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was good, as indicated by Secchi depths which ranged from 10.0 to 14.5 feet. Most Secchi depths were in the mesotrophic range, and the pattern in Secchi depths was very similar to that seen in 1990. Secchi depths in 1990 were much deeper, though the reason for this is unknown.

A 1970 survey of Phillips Lake showed Secchi depths ranged from 10 to 20 feet, with lowest Secchi depths occurring during May, June and November (Funk *et al.*, 1972). A blue-green algal bloom was observed on the October 1970 sampling date.

Total Phosphorus
Total phosphorus in the epilimnion was low on both sampling dates (8 and 11 μg/L). The concentrations measured in 1992 were slightly lower than those from 1990 and 1972.

Total Nitrogen
Total nitrogen in the epilimnion was low on both sampling dates (0.30 and 0.38 mg/L), and was similar to concentrations measured in 1991 (0.27 mg/L; Rector, 1992) and 1990 (0.30 and 0.49 mg/L; Rector, 1991).

Fecal Coliform Bacteria
Of four samples collected from Phillips Lake, only one sample contained fecal coliforms. The result from this sample (35 colonies/100 mL) was within state standards. This sample was collected nearshore at the southeast tip of the lake during August.

Solids and Color
Results for suspended solids and color were low on both sampling dates. These results indicate that Secchi depths were most likely affected by algal density, rather than suspended sediments or natural color, at the time of sampling.

Profile Data
The lake was not stratified with respect to temperature on either sampling date. As a result, profile data were very similar from surface to bottom. The lake was not stratified when it was monitored for the program in 1990 and 1991.

Plants
Algal density was low on both sampling dates, as indicated by low concentrations of chlorophyll *a*. Although nuisance algae have been reported by lakeshore residents on Phillips Lake, the sampling periods did not appear to catch a bloom in progress. An algae sample collected by one volunteer during early September, 1992 was identified by Ecology staff to be the blue-green alga *Anabaena flos-aquae*.

Phillips Lake -- Mason County

In both June and November, 1991, algal blooms in Phillips Lake were reported by residents. Both blooms consisted of the blue-green alga *Anabaena flos-aquae* (Dave Hallock, Dept. of Ecology, pers. comm.; Carol Spaulding, Mason County Water Quality Department, pers. comm.). This species of algae is capable of producing natural toxins, but only when environmental conditions are favorable. Mouse bioassays conducted at Pacific Lutheran University determined that neither bloom produced these toxins (The Olympian June 21, 1991; Carol Spaulding, Mason County Water Quality Dept., pers. comm.).

During the May 21, 1991 onsite visit with the volunteer, irises (*Iris pseudacorus*) were growing in what appeared to be planted and controlled areas. In 1972, few rooted aquatic plants were reported growing on the lake bottom (Bortleson *et al.*, 1976).

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989, 1990, and 1992.

> Phillips Lake is used for fishing, swimming, boating, jet skiing, and rowing. Recreational facilities on the lakeshore include a picnic area, a beach and one boat ramp. There are no restrictions on motor boat use on the lake. About 1 percent of the shoreline is publicly-owned. Rainbow trout were stocked in the lake. Currently the watershed is used for logging, and the lakeshore is being developed further for residences. In the past, the watershed was used for logging, and the shoreline was altered during bulkhead construction. The lake has been chemically treated in the past to control undesirable fish species.
>
> There are about 150 houses on the lakeshore, and none of the houses are connected to a sewer. There is a lake association for the lake. There are five culverts that drain into the lake. Lake water is withdrawn for drinking and other domestic uses. Currently, the minimum setback for lakeshore development is 15 feet, and minimum lot size is 12,500 square feet size (zoning for lot sizes depends on soil type).
>
> Overall, the volunteer finds that Phillips Lake had good water quality. Problems in the lake in 1992 were ranked as 1) algae, 2) gradually degrading water quality over the years, and 3) low water level. In 1992, the lake level was lower (than in 1991), several lots were cleared, and algae blooms seemed to be more frequent.

Phillips Lake -- Mason County

Comments

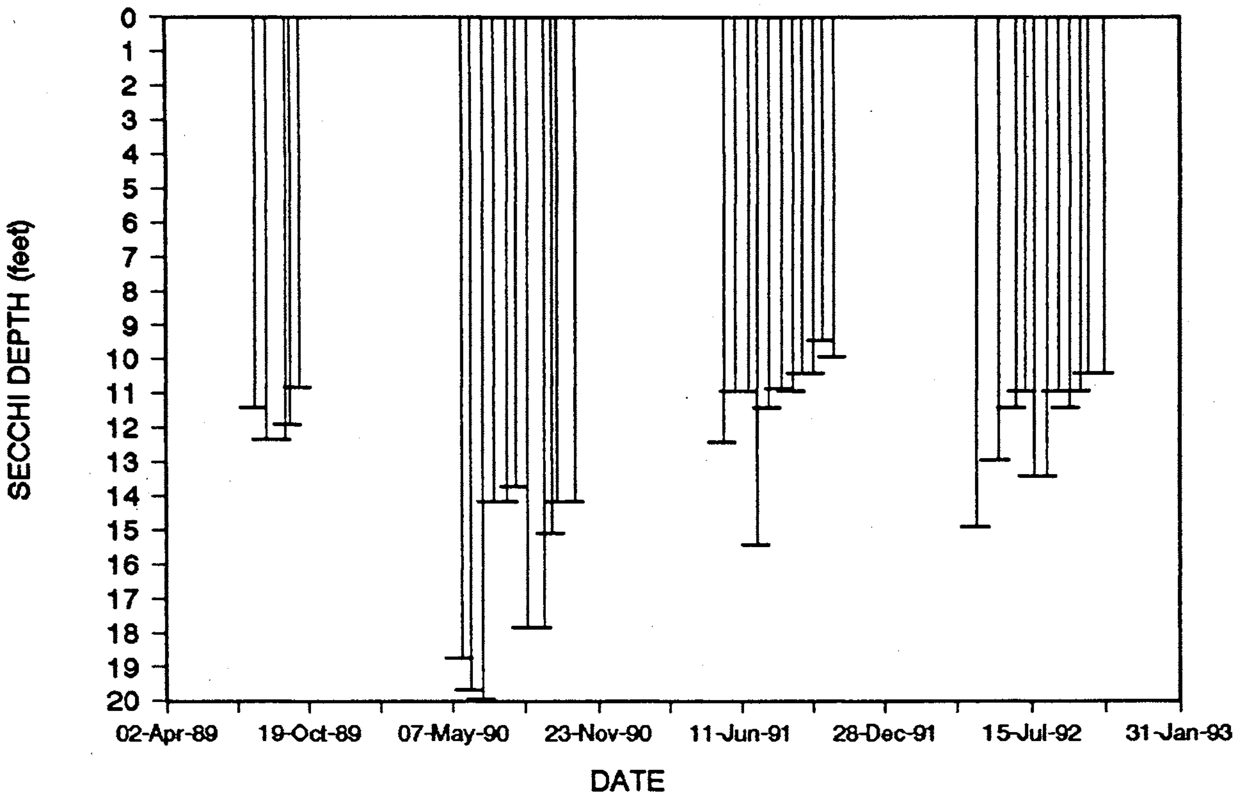
Only Secchi depths indicated that Phillips Lake was mesotrophic. The other trophic state parameters, total phosphorus and chlorophyll *a*, indicated that the lake also had some oligotrophic qualities. Because Phillips Lake experiences some algal blooms during the year which would indicate that the lake is not oligotrophic, the lake was characterized as oligo-mesotrophic for 1992.

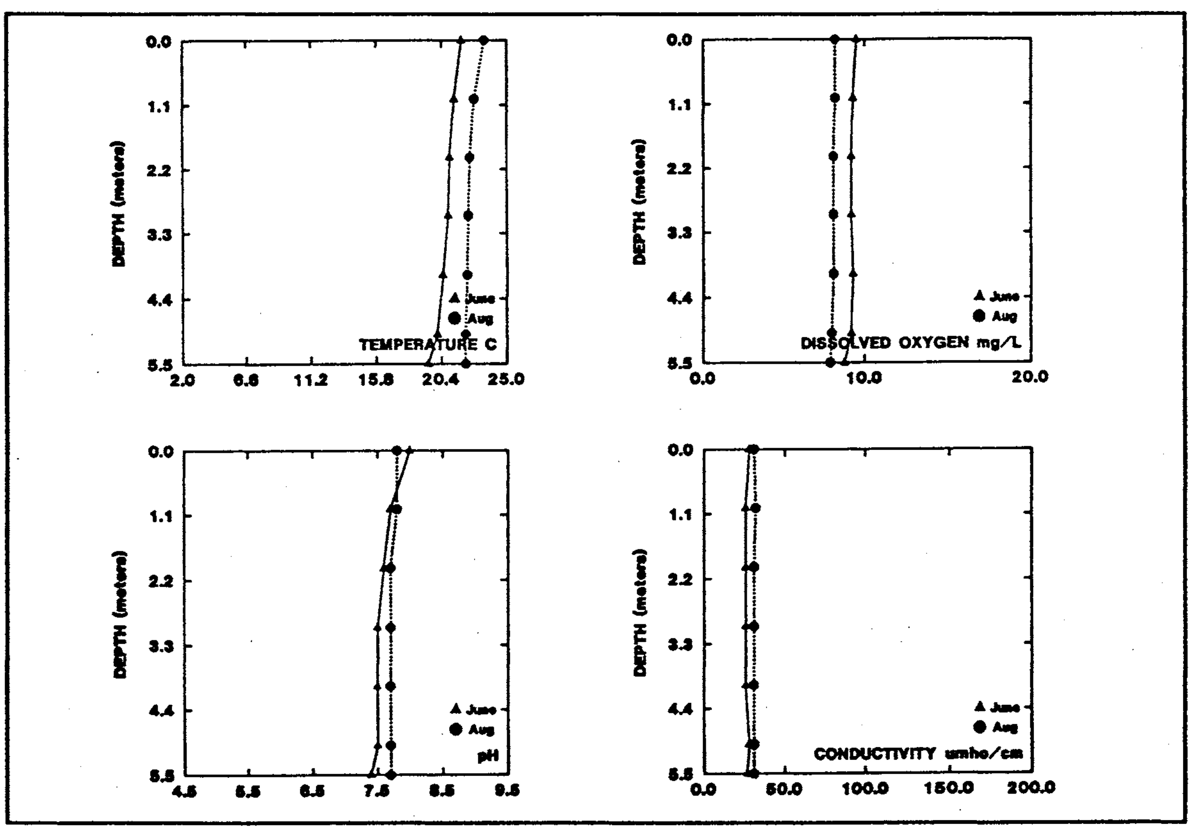
Other Mason County lakes monitored for the program in 1992 are Limerick, Mason, Nahwatzel, Spencer, and Wooten. Of these lakes, only Lake Limerick had higher total phosphorus and shallower Secchi depths than Phillips Lake.

Acknowledgement

I thank James Keeley for volunteering his time to monitor Phillips Lake during 1989-1992.

PHILLIPS LAKE (MASON COUNTY)

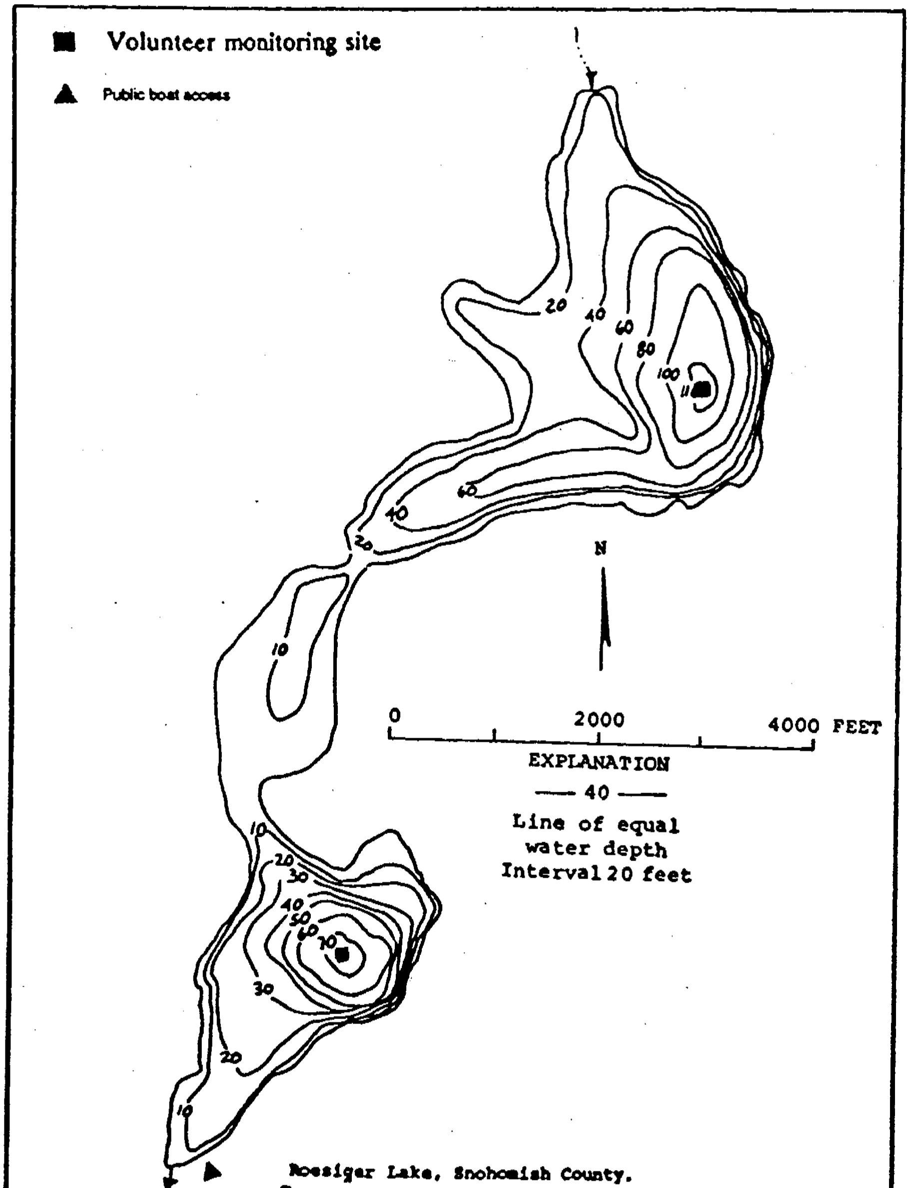




Lake Roesiger -- Snohomish County

Lake Roesiger is located 8.5 miles northeast of Monroe. The north and south basins of the lake are separated by a shallow connecting basin. The volunteer monitored both north and south basins of the lake. The north basin of Lake Roesiger is fed by an intermittent stream, and drains southeast through the south basin of the lake via Roesiger Creek to Woods Creek and the Skykomish River. Data From Bortleson *et al.* (1976)

	North Basin	South Basin
Size (acres)	200	140
Maximum Depth (feet)	110	70
Mean Depth (feet)	48	22
Lake Volume (acre-feet)	9,600	3,000
Drainage Area (miles^2)	1.9	3.6
Altitude (feet)	570	570
Shoreline Length (miles)	2.9	3.0



Roesiger Lake, Snohomish County.
From Washington Department of Game, February 5, 1952.

Lake Roesiger -- Snohomish County

1992 Trophic Status[1]	North Basin	South Basin
Estimated Trophic State:	Oligo-mesotrophic[2]	Oligo-mesotrophic[2]
Mean Trophic State Index (Secchi):	36	40
Mean Trophic State Index (Total Phosphorus):	30	34
Mean Trophic State Index (Chlorophyll *a*):	--	38

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	Temp (°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
North Basin, Deep Site										
09-Feb	1030	7.9	46.2	15.0	4.25	Lt-Green	10	Light	Light	
25-Feb	1015	8.5	47.3	14.0	1.00	Lt-Green	0	Moderate	Light	Lake height rose 3.5"
24-Mar	0930	12.0	53.6	15.0	7.50	Lt-Green	10	Moderate	Light	Lake height dropped 6.5"
22-Apr	1030	13.0	55.4	17.0	6.50	Lt-Green	100	Light	Light	Lake height rose 1"
12-May	1025	15.1	59.2	20.5	6.25	Lt-Green	10	Moderate	Light	Lake height rose 0.25"
24-May	0915	19.2	66.6	19.5	9.50	Lt-Green	0	None	Calm	Lake height dropped 3.25"
13-Jun	0700	19.5	67.1	19.0	9.50	Lt-Green	100	Heavy	Calm	No change in lake height.
26-Jun	0900	24.5	76.1	18.0	10.50	Lt-Green	100	None	Calm	Lake height dropped 1"
17-Jul	1045	23.1	73.6	19.0	11.00	Green-Blue	0	None		Lake height dropped 1". Strong sulfur odor in 28m water sample.
31-Jul	0920	24.5	76.1	19.0	12.00	Green-Blue	0	None	Calm	Lake height dropped 1". 18 m water sample had sulfur odor.
16-Aug	0800	23.8	74.8	18.0	13.00	Green-Blue	0	None	Calm	Lake height dropped 1". Very strong sulfur odor in 28m water sample.
South Basin, Deep Site										
17-Jul	1300	24.2	75.6	12.0		Green	0	None	Light	South basin site A.
31-Jul	1138	25.0	77.0	12.0		Green	0	None	Calm	Light sulfur odor from 21m water sample.
11-Sep	1040	19.8	67.6	12.0		Lt-Green	90	None	Light	Sulfur odor in 16m and 20m water samples.
25-Sep	1230	17.9	64.2	14.0			50	Heavy	Calm	Water color greenish-yellow. Sulfur odor in 18m and 21m water samples.
07-Oct	1630	16.8	62.2	15.0		Lt-Green	100	None	Calm	
23-Oct	1210	14.2	57.6	17.0			50	Lt-Brown	Breezy	Water color brownish to yellowish. Sulfur odor in 16m and 20m water samples.

[1] Trophic State Indices calculated from Carlson (1977)

[2] see Comments section

Lake Roesiger -- Snohomish County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
North Basin					
05/15	0.0	17.1	7.7	10.8	24
	1.0	16.8	7.5	10.7	24
	2.0	16.5	7.4	10.7	23
	3.0	16.2	7.4	11.0	23
	4.0	14.9	7.7	11.7	23
	5.0	12.2	8.1	13.6	23
	6.0	10.9	8.0	13.6	23
	7.0	9.3	7.8	13.3	23
	8.0	8.2	7.6	12.7	23
	9.0	7.8	7.5	11.6	23
	10.0	7.3	7.3	10.0	23
	12.0	6.5	7.1	7.3	23
	15.0	6.2	6.9	5.7	23
	20.0	5.9	6.7	3.9	23
	23.0	5.8	6.6	1.9	24
South Basin					
08/21	0.0	23.3	7.4	9.2	37
	1.0	23.5	7.4	9.0	37
	2.0	23.5	7.4	8.8	36
	3.0	23.5	7.4	8.8	36
	4.0	21.9	7.4	9.5	35
	5.0	19.3	7.5	11.9	36
	6.0	16.0	7.5	13.0	34
	7.0	12.7	7.4	7.1	37
	8.0	10.8	7.3	4.6	36
	9.0	9.4	7.2	2.2	37
	10.0	7.8	7.0	0.8	36
	12.0	6.8	7.0	0.1	35
	14.0	6.3	6.9	0.1	36
	16.0	6.1	6.7	0.1	39
	18.0	6.1	6.6	0.1	45
	20.0	5.9	6.4	0.1	50
	20.5	5.9	6.3	0.1	52

1992 Onsite Visit Data - Water Chemistry

Date	05/15/92		08/21/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
North Basin				
Composite Depths (m)	0.5, 1, 2	--	1,2,3	
Total Phosphorus (µg/L)	5	--	6	--
Total Nitrogen (mg/L)	0.48	--	0.19	--
Chlorophyll *a* (µg/L)	0.46	--	--	--
South Basin				
Composite Depths (m)	--	--	1,2,3	14,16,18
Total Phosphorus (µg/L)	--	--	8	17
Total Nitrogen (mg/L)	--	--	0.24	0.47
Chlorophyll *a* (µg/L)	--	--	2.18	--

Lake Roesiger -- Snohomish County

Historical Data From Ecology (North Basin)

Date	07/25/72[a]	07/06/81[c]
Secchi (ft)	10	17
Total Phosphorus, epilimnion (μg/L)	29	10
Total Nitrogen, epilimnion (mg/L)	--	1.0
Chlorophyll *a* (μg/L)	2.3	2.3
Dissolved Oxygen, surface (mg/L)	8.7	9.3
Dissolved Oxygen, bottom (mg/L)	3.9	0.2

a. Bortleson *et al.* (1976);
b. Sumioka and Dion (1985)

Historical Data From Ecology (South Basin)

Date	07/25/72[a]	06/06/90[b]
Secchi (ft)	10	
Total Phosphorus, epilimnion (μg/L)	5	7
Total Nitrogen, epilimnion (mg/L)	--	0.40
Chlorophyll *a* (μg/L)	3.1	--
Dissolved Oxygen, surface (mg/L)	9.0	12.1
Dissolved Oxygen, bottom (mg/L)	0.2	3.8

a. Bortleson *et al.* (1976)
b. Rector (1992)

Lake Roesiger -- Snohomish County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was very good in the north basin, as indicated by Secchi depths which ranged from 18.0 to 20.5 feet during the monitoring season (May through October). Although water clarity was shallower in the south basin (Secchi depths ranged from 12.0 to 17.0 feet), both basins were oligotrophic.

Total Phosphorus

Epilimnetic total phosphorus was low in both basins. In 1990, the epilimnion concentration of the south basin (7 μg/L; Rector, 1991) was very similar to the concentration measured in 1992. Data were collected from both basins so that results could be compared with data collected by the Association of Lake Roesiger Homeowners. Their results are not yet available.

Total Nitrogen

Total nitrogen in both basins was low during August (0.19 mg/L in the north basin, and 0.24 mg/L in the south basin). During May, total nitrogen in the north basin was higher (0.48 mg/L) and similar to the concentration measured in June 1990 (0.40 mg/L; Rector, 1991).

Profile Data

On both sampling dates, each monitored basin was stratified, and both pH and dissolved oxygen decreased below the thermocline. The decrease in dissolved oxygen probably resulted from bacterial decomposition of organic material, such as algae and aquatic plants, in the water and sediments. The metalimnion of each basin was at about 4 to 10 meters. At depths of 4 to 6 meters in the metalimnion, dissolved oxygen increased considerably. This increase most likely occurred from the corresponding decrease in water temperature at these depths, but could also result from increased algal growth.

A similar increase of dissolved oxygen in the metalimnion was documented in July 1972, when dissolved oxygen increased to almost 13 mg/L between 15 and 25 feet, and decreased to 3.9 mg/L at 95 feet (Bortleson *et al.*, 1976).

Although not listed with other profile data collected during the onsite visits, oxidation-reduction potential ("redox") was also measured during both onsite visits. Redox was measured because it indicates whether reducing conditions exist in water. When these conditions exist, sulphate can be reduced to hydrogen sulfide, and ferrous phosphate (from sediments) can be reduced to phosphate in water. Reduction can occur when redox is less than 0 volts. During May, all redox readings were over 100 v in the north basin. In August, though, redox readings from the south basin ranged from 137 volts at the surface to 104 volts at 16 meters, and from -30 volts at 18 meters to -85 volts at 20.5 meters (bottom). No redox readings were collected from the north basin during August. Despite very low oxygen (0.1 mg/L or less) from 12 meters to the bottom, reducing conditions only existed in the bottom 2.5 meters of the lake. This is supported by field notes which described hydrogen sulfide as being detected in the 18 meter sample, but not from the 16 meter sample. Elevated phosphorus in the hypolimnion of the south basin during August (17 μg/L) probably resulted from internal loading of phosphorus from the sediments.

Hydrogen sulfide was produced in the hypolimnion of both basins. Water samples collected by the volunteer during the course of the monitoring season (see Abbreviated Comments in the table listing volunteer-collected data), as well as an 18 meter sample collected from the south basin during August onsite visit, smelled of hydrogen sulfide. Hydrogen sulfide can be toxic to some species, but since it was not detected above 16 meters, it is likely that fish habitat is not affected much by the presence of hydrogen sulfide. The volunteer was collecting water samples for the Association of Lake Roesiger Homeowners, to establish baseline data for Lake Roesiger.

Plants

Chlorophyll *a* was only collected from the north basin during May, and from the south basin during August. Both results were low, and given the low concentrations of total phosphorus, were in a range of expected values from the trophic state index model. Values from 1972 and 1981 (both 2.3 μg/L; Bortleson *et al.* (1976), Sumioka and Dion (1985)) were higher.

During the August 21, 1992 onsite visit with the volunteer, plant samples were not collected. Milfoil was reported by some residents, though. At the time of sampling, divers were collecting samples near the boat launch so that identification could be verified.

Other Available Information

From KCM (1989): A Phase I lake restoration study of Lake Roesiger was conducted from May 1988-May 1989. Objectives of the study were to characterize the existing water quality of the lake, identify sources of nutrient loading to the lake, and recommend approaches for lake restoration. The study consisted of aerial shoreline analysis, and monitoring of inlets, outlet, and both lake basins. The researchers concluded that Lake Roesiger was mesotrophic and phosphorus-limited. The majority of phosphorus loading to the lake (61%) was from nonpoint sources that enter the lake via the inlets, runoff, ground water, and precipitation. Internal loading from lake sediments contributed 39% of the phosphorus loading to the lake. Low dissolved oxygen in the hypolimnion was also found. Recommendations for improving water quality include controlling nutrient loading from the watershed through public education, revisions to county ordinances and policies regarding development, forest practices and roadside ditch maintenance, and improving on-site wastewater disposal in the Lake Roesiger watershed. The researchers also recommended hypolimnetic aeration of the north and south basins of the lake, and partial dredging of the middle basin.

A Centennial Clean Water Fund Phase II grant to implement alum treatment and hypolimnetic aeration in both basins of the lake is currently on hold because of questions regarding whether the large expense of the project will have appreciable benefits to the lake. The decision on whether the grant will be awarded may depend on additional monitoring of the lake.

Lake Roesiger -- Snohomish County

The Association of Lake Roesiger Homeowners initiated baseline monitoring of the north and south basins of the lake in March 1992. Two staions in each basin are monitored each month. Composite samples from the epilimnion are analyzed for total phosphorus, chlorophyll *a*, and pheophytin. Composited samples from the hypolimnion are analyzed for total phosphorus only. In addition, temperature and dissolved oxygen profile data are collected using a YSI meter. Results from February through April 1992 indicated that the lake was thermally stratified in March and April (but not during February), and during all three months dissolved oxygen was very low (0.2 to 2.0 mg/L) near the lake bottom.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires from 1990 - 1992.

> Lake Roesiger is used for fishing, boating, swimming, rowing, jet skiing, camping, and bird watching. Public recreational facilities on the lake include a county park, a picnic area, and a beach. There is one public boat ramp, and there is a speed restriction of 8 mph for motorboating and "no wake" allowed before 10:30 a.m. and after 5:30 p.m., or in the middle basin. Water skiing is restricted between September 26 and May 24. Rainbow, cutthroat, and brown trout were stocked in the lake. Less than 5 percent of the shoreline is publicly-owned. The watershed is used for logging, horse grazing, and the lakeshore is being developed further for residences. In the past, the watershed was logged, and the shoreline was altered (prior to 1960, trees and fallen timber in the Gemmer Road area were pushed into the lake during lot clearing). Also, prior to 1960, a wetland on the east side of the middle basin was filled in.
>
> There are about 345 houses on the lakeshore. Except for the county park area, there are residences all along the south basin shore. The lakeshore is not sewered. Currently, the minimum setback for lakeshore development is 25 feet, and residential density is restricted to 2 houses per acre. Lake water is withdrawn for drinking, irrigation, and to fill fire district tankers. There are 48 culverts which drain into the lake. There is a a community association, and a lake association for the lake. A water conservation and wastewater control program was initiated by the county PUD. Residents initiated information programs about yard fertilizers and using no-phosphorus detergents.
>
> Lakeshore residents also collect data from the Lake Roesiger water shed for the Adopt-A-Stream program.
>
> Blue heron, beaver, otter, osprey, eagle and muskrat have been seen on and near the lake. In the north basin, there are wetlands near the north inlet, the western cove, and near an inlet stream on the south end of the basin. Most of the entire shoreline is ringed with aquatic plants, including bulrush, water plantain, iris, and white-flowering water

lily. There are several springs along the shore. No algae blooms occur, but there are large areas of submerged water plantain extending up to 20 feet from shore. In 1991, the shallow middle basin, there was waterweed, yellow-flowering water lily, and water plantain in the shallow middle basin, and water plantain growth was thick in a northern cove, and at the south end of the south basin. At the south end there was also iris and heavy growths of waterweed. The lake was treated with chemicals in the past to control weeds and undesirable fish species.

Overall, the volunteer finds that Lake Roesiger had good water quality. The worst problems in the lake in 1992 were ranked as 1) shoreline erosion, and 2) suspended sediments. Possible sources of problems were newly cleared lots. The volunteer noted that there was a wider range of Secchi depths in the lake (from 2 to 23 feet) than in 1991.

Comments

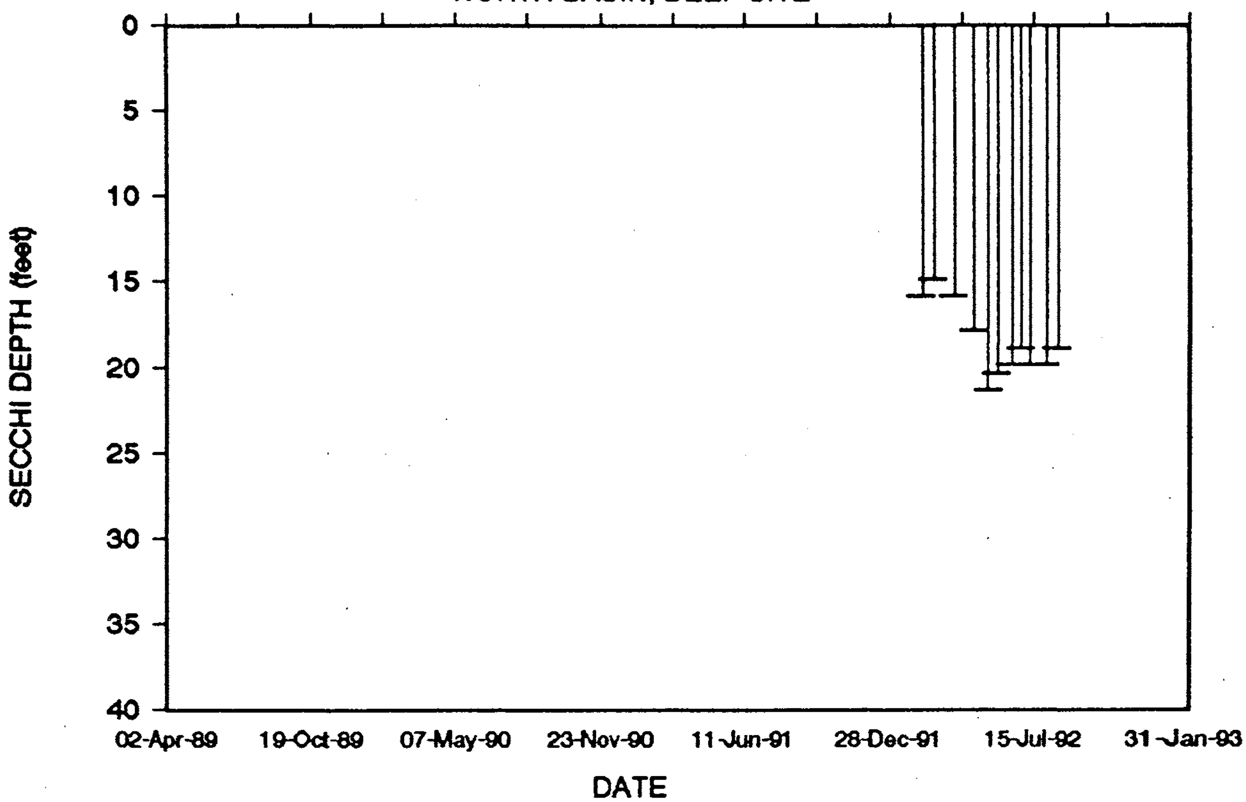
All trophic state parameters (Secchi depth, total phosphorus, and chlorophyll *a*) indicate that both basins of Lake Roesiger were oligotrophic. However, low dissolved oxygen and reducing conditions in the hypolimnion, resulting in hydrogen sulfide and internal loading of phosphorus, do not indicate oligotrophy. As a result, the lake was characterized as oligo-mesotrophic in 1992. The trophic state estimation for 1991, which was based primarily on 1991 Secchi depth data and one set of profile data and epilimnetic water samples from June 1990, indicated oligotrophy. It is apparent that hypolimnion samples and/or late summer profile data are needed for a more reliable estimate of Lake Roesiger's trophic status.

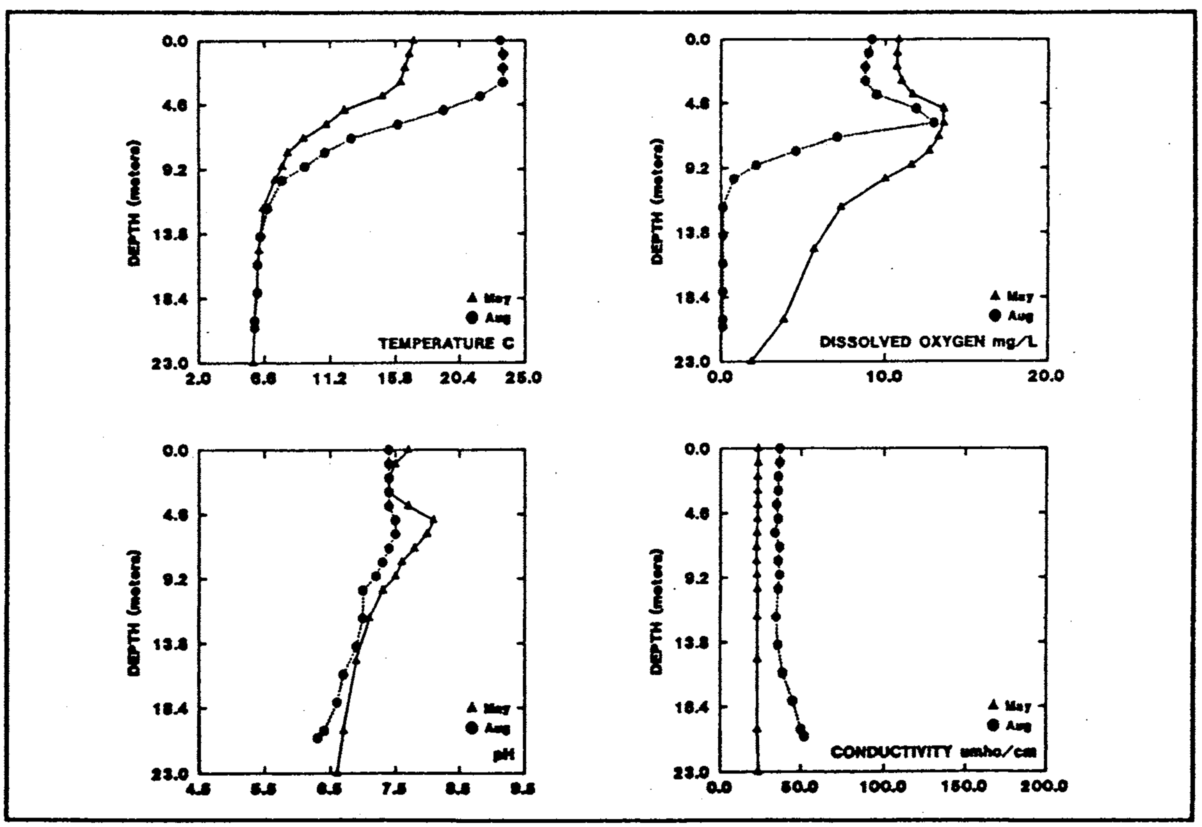
Acknowledgement

I thank Andy Loch for volunteering his time to monitor both basins of Lake Roesiger during 1992, and Elsie Sorgenfrei and Frank Stegmeier for monitoring the south basin of the lake during 1991.

LAKE ROESIGER (SNOHOMISH COUNTY)

NORTH BASIN, DEEP SITE



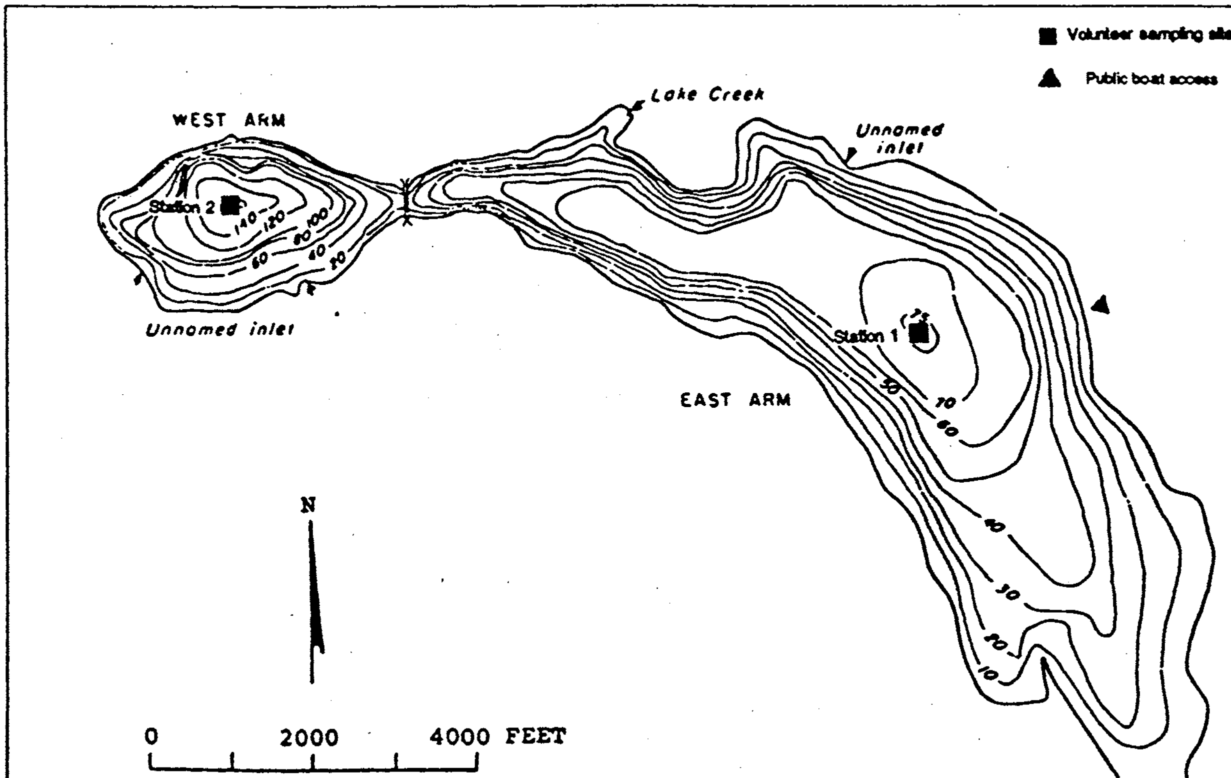


Lake Samish -- Whatcom County

Lake Samish is located 6.5 miles southeast of Bellingham. It is comprised of two basins which are connected by a narrow strait. The west arm is a small deep bay, and the east arm is a larger shallow bay. There are several small inlets that flow into the lake, including Lake Creek and Barnes Creek. Lake Samish drains via Friday Creek to the Samish River.

	East Arm	West Arm
Size (acres)	680	130
Maximum Depth (feet)	75	140
Mean Depth (feet)	31	71
Lake Volume (acre-feet)	24,000	9,100
Drainage Area (miles^2)	9.2	3.7
Altitude (feet)	273	273
Shoreline Length (miles)	6.3	1.8

Data From Bortleson *et al.* (1976)



Lake Samish, Whatcom County

From Washington Department of Game, 1956.

Lake Samish -- Whatcom County

1992 Trophic Status[1]

	East Arm	West Arm
Estimated Trophic State:	Oligo-mesotrophic	Oligo-mestrophic
Mean Trophic State Index (Secchi):	41	40
Mean Trophic State Index (Total Phosphorus):	32	--
Mean Trophic State Index (Chlorophyll *a*):	33	--

Volunteer-Collected Data

Date 1992	Time	Temp (°C) (°F)	Secchi (ft)	pH	Lake Ht (ft)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
East Basin										
21-May			19.3							Onsite visit.
04-Jun	0925	19.0 66.2	17.3		268.30	Lt-Green	10	None	Light	
19-Jun	1415	20.0 68.0	17.0	7.6	268.30	Lt-Green	10	None	Breezy	Lake height in feet above sea level.
02-Jul	1330	21.0 69.8	12.0	8.5		Lt-Green	100	None	Breezy	
16-Jul	0945	21.0 69.8	13.0	8.3	268.00	Lt-Green	0	None	Calm	
29-Jul	0945	22.0 71.6	13.5	9.4	268.62	Lt-Green	0	None	Calm	
13-Aug	1345	23.0 73.4	11.0	8.5	267.82	Lt-Green	0	None	Calm	
24-Aug			9.0							Onsite visit.
02-Sep	0930	17.0 62.6	9.5	10.3	267.61	Lt-Green	100	None	Light	
17-Sep	1420	17.8 64.0	8.0	8.8	267.57	Lt-Green	0	None	Breezy	
01-Oct	1300	15.0 59.0	8.0	6.6	271.74	Lt-Green	0	None	Breezy	
23-Oct	1330	13.0 55.4	9.0	6.5	268.27	Lt-Green	100	Light	Light	
West Basin										
25-Feb		9.0 48.2	12.0		269.51	Lt-Green	10		Light	For your info.
04-Jun	0955	19.0 66.2	18.5	8.1	268.30	Lt-Green	0	None	Light	Lake height in feet above sea level.
19-Jun	1445	20.0 68.0	20.0	8.1	268.30	Lt-Green	10		Breezy	
02-Jul	1400	21.0 69.8	15.0	8.2	268.08	Lt-Green	100	None	Breezy	
16-Jul	1030	21.0 69.8	16.0	8.5	268.03	Lt-Green	0	None	Light	
29-Jul	1033	22.0 71.6	20.0	8.9	268.63	Lt-Green	0	None	Breezy	Second pH reading was 9.0.
13-Aug	1400	20.0 68.0	14.0	6.8	267.82	Lt-Green	0	None	Calm	
02-Sep	1000	17.0 62.6	10.0	10.3	267.61	Lt-Green	100		Light	pH ranged 10.2 - 10.3
17-Sep	1430	13.5 56.3	8.5	9.6	267.56	Lt-Green	0	None	Breezy	
01-Oct	1330	15.0 59.0	8.0	7.6	271.74	Lt-Green	0	None	Breezy	
23-Oct	1400	13.0 55.4	10.0	7.6	268.27	Lt-Green	100	Light		

[1] Trophic State Indices calculated from Carlson's model (1977)

Lake Samish -- Whatcom County

1992 Onsite Visit Data - East Basin Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/21	0.0	16.9	7.8	10.9	55
	1.0	16.8	7.9	10.7	55
	2.0	16.8	7.9	10.7	55
	3.0	16.7	7.9	10.7	55
	4.0	16.7	7.9	10.7	55
	5.0	16.6	8.0	10.7	55
	6.0	14.8	8.1	11.5	55
	7.0	13.8	8.0	11.5	54
	8.0	12.4	7.8	11.0	54
	9.0	11.7	7.6	10.0	54
	10.0	10.7	7.2	8.4	54
	12.0	9.5	7.1	6.4	54
	14.0	8.5	7.0	5.4	53
	16.0	8.1	6.9	4.8	53
08/24	0.0	21.8	8.8	10.1	71
	1.0	21.8	9.1	10.0	72
	2.0	21.8	9.2	10.0	72
	3.0	21.8	9.3	10.0	72
	4.0	21.8	9.4	10.0	71
	5.0	21.7	9.4	9.8	71
	6.0	20.9	9.3	9.5	70
	7.0	19.5	8.6	6.9	68
	8.0	17.1	8.5	3.9	70
	9.0	15.7	8.3	2.9	69
	10.0	13.9	8.2	0.7	70
	12.0	11.4	8.1	0.1	70
	14.0	9.3	7.9	0.1	69
	15.0	9.0	7.9	0.1	68

Lake Samish -- Whatcom County

1992 Onsite Visit Data - East Basin Water Chemistry

Date	05/21/92		08/24/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 4	12, 14, 16	1, 2, 4	12, 14
Total Phosphorus (µg/L)	4	12	10	12
Total Nitrogen (mg/L)	0.66	0.69	0.25	0.53
Chlorophyll *a* (µg/L)	1.17	--	1.27	--

Historical Data From Ecology -- East Arm

Date	08/24/74[a]	06/27/89[b]	09/26/89[b]	06/04/90[c]	08/15/90[c]	05/28/91[d]
Secchi (ft)	10	13.8	11.8	--	9.6	17.0
Total Phosphorus, epilimnion (µg/L)	0.0	6	12	13	10	--
Total Nitrogen, epilimnion (mg/L)	--	0.62	0.40	--	0.36	0.58
Chlorophyll *a* (µg/L)	--	2.7	6.3	--	--	--
Dissolved Oxygen, surface (mg/L)	10.4	11.0	10.4	10.6	9.8	11.1
Dissolved Oxygen, bottom (mg/L)	1.1	4.5	0.1	4.7	0.2	0.4

a. Bortleson *et al.* (1976)
b. Brower and Kendra (1990)
c. Rector (1991)
d. Rector (1992)

Lake Samish -- Whatcom County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good in both basins, particularly from May through July. Secchi depths decreased considerably from August through October; this pattern in water clarity was very similar to the pattern from data collected in 1989.

Total Phosphorus

Total phosphorus in the epilimnion was very low on both sampling dates. Except for the sample collected in June 1990 (13 μg/L; Brower and Kendra, 1990), all total phosphorus data from Lake Samish were low and characteristic of an oligotrophic lake.

Total Nitrogen

Although total nitrogen concentrations were low to moderate in comparison to other lakes monitored for the program, total nitrogen was higher during May (0.66 mg/L) than in August (0.25 mg/L). Data from 1989-1991 also indicate that total nitrogen tends to be lower in late summer.

Profile Data

The lake was stratified on both sampling dates, and both dissolved oxygen and pH decreased below the thermocline. Profile data from 1992 were very similar to data collected in 1991, 1990, and 1989. In 1992, the pH of the lake was rather high, particularly during August, when pH increased from 8.8 at the surface to 9.4 at 4 meters. When profile data were collected in 1990, pH was also much higher during August (around 8.5) than during May (Rector, 1991). Higher pH probably resulted from increased algal growth in the epilimnion. Data collected by the volunteers also indicate that high pH values occurred in late summer, with the highest value on September 2, 1992.

Dissolved oxygen in the hypolimnion was particularly low during August, when values were less than 1.0 mg/L in the bottom 5 meters of the lake. Similar values near the lake bottom were also measured for the program in 1989-1990. (In 1991, profile data were collected only during spring.) Low values in late summer were also reported in 1971 (0.0 mg/L at the bottom in September; Bortleson *et al.*, 1976) and 1968 (1.5 mg/L in October; Lee, 1969). Lower dissolved oxygen in the hypolimnion most likely results from bacterial decomposition of aquatic plants and algae in the water and sediments.

On the August 1990 and September 1989 sampling dates, dissolved oxygen decreased considerably below the thermocline (down to 0.2 mg/L at 19 meters in August 1990, and less than 0.5 mg/L from 14.0 to 20.0 meters in September 1989; Brower and Kendra, 1990). Profile data collected on May 24, July 14 and September 23, 1971 showed that dissolved oxygen at the lake bottom was approximately 6 mg/L on the May sampling date, 4 mg/L in July, and 0.0 mg/L in September (Bortleson *et al.*, 1974). In 1968, dissolved oxygen was 1.5 mg/L near the lake bottom, and the lake was described as oligotrophic (Lee, 1969).

Lake Samish -- Whatcom County

Plants

Algal growth was low on both sampling dates, as indicated by low concentrations of chlorophyll *a*.

Aquatic plants identified by Ecology staff during the August 24, 1992 onsite visit were tapegrass (also known as wild celery; *Vallisneria americana*), coontail (*Ceratophyllum demersum*), watershield (*Brasenia schreberi*), duckweed (*Lemna minor*), waterweed (*Elodea nuttali*), and white-flowering lily (*Nymphaea odorata*). A lot of pollen from the tapegrass was on the water surface near the south end of the lake. The volunteers noted that watershield was not as abundant this year compared to earlier years. Tapegrass was identified in the lake in 1971, when about 26-50% of the shoreline was covered by submerged plants (Bortleson *et al.*, 1974). In 1989, tapegrass was growing along approximately 90% of the shore of the east basin (Brower and Kendra, 1990).

Other Available Information

From Johnson and Norton (1990): In 1989, Ecology staff collected sediment and largemouth bass samples from both basins, and analyzed the samples for selected heavy metals and organic pollutants. No unusual concentrations of metals, and no organochlorine pesticides or PCBs, were detected in the fish samples. Sediments contained arsenic (21.0 μg/Kg), 4-methylphenol (1500 μg/kg), and polyaromatic hydrocarbons (PAH; 81-110 μg/Kg). The concentrations found were not high enough to warrant further study. Possible sources of the 4-methylphenol are natural degradation of biological material, auto exhaust, asphalt, and domestic sewage. The most likely sources of PAH are urban runoff and combustion of fossil fuels.

From Larson (1990): Approximately 440 residences withdrew Lake Samish water for drinking and domestic use, and new construction of homes is expected to increase demand for water withdrawal. However, very low streamflow down the outlet (Friday Creek) during late summer affects fish habitat and has raised concern about additional water withdrawal from the lake. At present, the lake level is affected primarily by beaver dams along Friday Creek, which are periodically broken down to allow flow through the creek. To investigate the possible effects from additional water withdrawal from Lake Samish, computer models using lake stage and creek flow data were used. Results indicated that a control dam for storing additional water and supplementing creek flow, or pumping lake water to maintain streamflow (which would reduce the lake stage below the natural levels), may remedy the situation.

From A. Larson (Ecology, pers. comm.): In addition to the concern over limiting the amount of development around the lake by limiting the number of water withdrawal permits, Whatcom County Health Department generally does not encourage direct withdrawal from lakes for drinking water purposes. As a result, negotiations between the county (to permit direct withdrawal despite health concerns), Ecology (to allow additional water resource permits for direct withdrawal) and Department of Wildlife (to determine the amount of water needed in Friday Creek to provide adequate fish habitat) were initiated in 1990, following the findings reported in Larson (1990).

Lake Samish -- Whatcom County

Summary of Questionnaire Results and Information From the Volunteers

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

Lake Samish is used for fishing, boating, water skiing, swimming, rowing and jet skiing. Public recreational facilities on the lakeshore include a park, a picnic area, a beach, and one boat ramp. About 5 percent of the shoreline is publicly-owned. Currently the watershed is used for logging, and the lakeshore is being developed further for residences. In the past, the watershed was used for logging and animal grazing, and the lake was dredged. In 1990 there were about 60 culverts or stormdrains that drained into the lake.

There are 529 residences in the Lake Samish basin; 295 of these are on the lakeshore, and 11 of the 15 residences under construction in the basin are also located on the lakeshore. Lake water is withdrawn for drinking and other domestic uses. The lakeshore is fully sewered and Water District #12 is responsible for sewage collection, and is currently gathering information about a community water system that will be voted on by residents in 1993. There is a lake management district and a community association for the lake.

Overall, the volunteer finds that Lake Samish had excellent water quality. Problems in the lake in 1992 were ranked as 1) excessive aquatic plant growth, and 2) algae. Possible sources of problems are weeds, sediment from streams, and algae. In comparison to 1991, weeds were spreading rapidly in 1992, especially along the shore in water up to 10 feet deep.

From 1990 to 1992, the predominant plants in the lake were tapegrass, watershield, and northern watermilfoil (*Myriophyllum exalbescens*). All three plants were reported to be growing or spreading rapidly in the lake. There is a wetland at the south end of the east basin, at the lake's outlet. Beaver dams at the outlet are periodically torn down; in 1990 the dams were torn down three times.

Comments

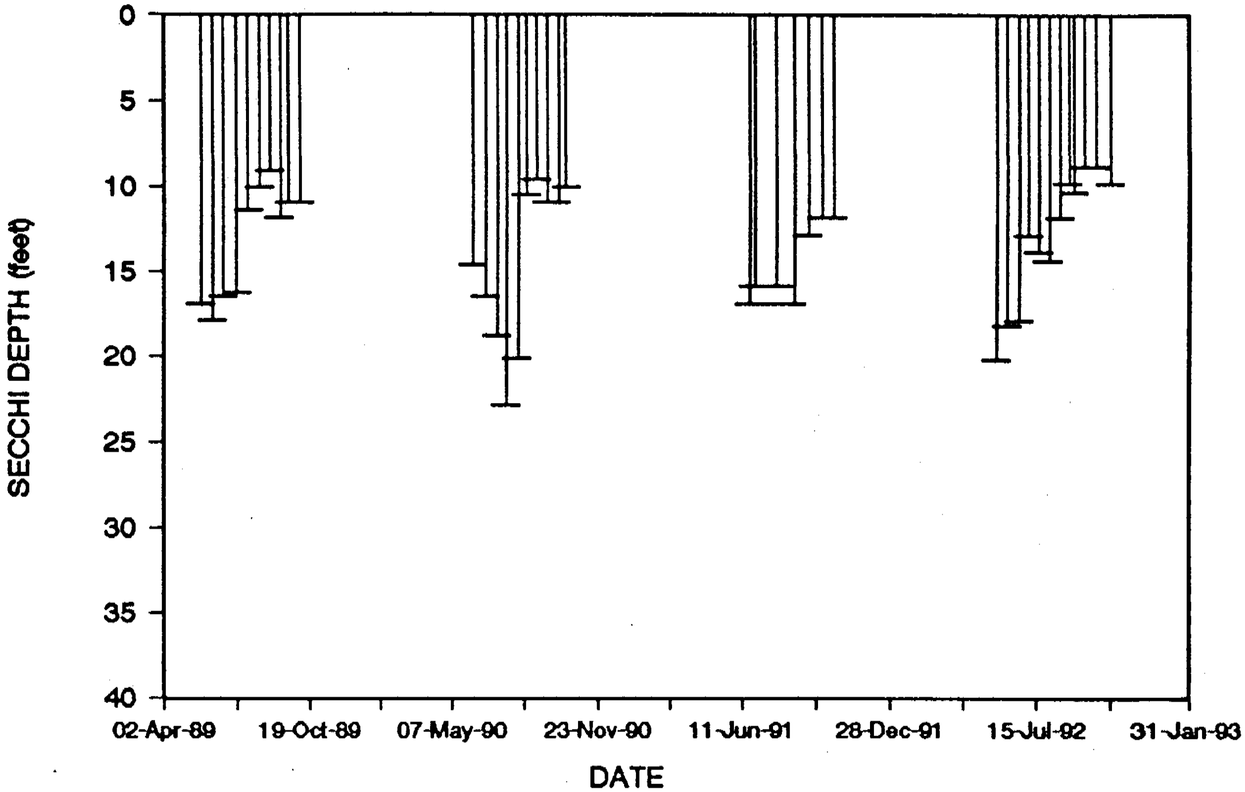
All trophic state parameters (Secchi depth, total phosphorus, and chlorophyll *a*) indicated that Lake Samish was oligotrophic. In addition, concentrations of total phosphorus and chlorophyll *a* were lower than those measured during earlier surveys. Although the volunteers noted that algal growth was very bad this year, water clarity was not much worse in 1992 than in 1991-1989. Plant growth in areas of the lake remained heavy, and there was very low dissolved oxygen in the hypolimnion during August. Because the lake still exhibits both oligotrophic and mesotrophic characteristics, the lake was characterized as oligo-mesotrophic.

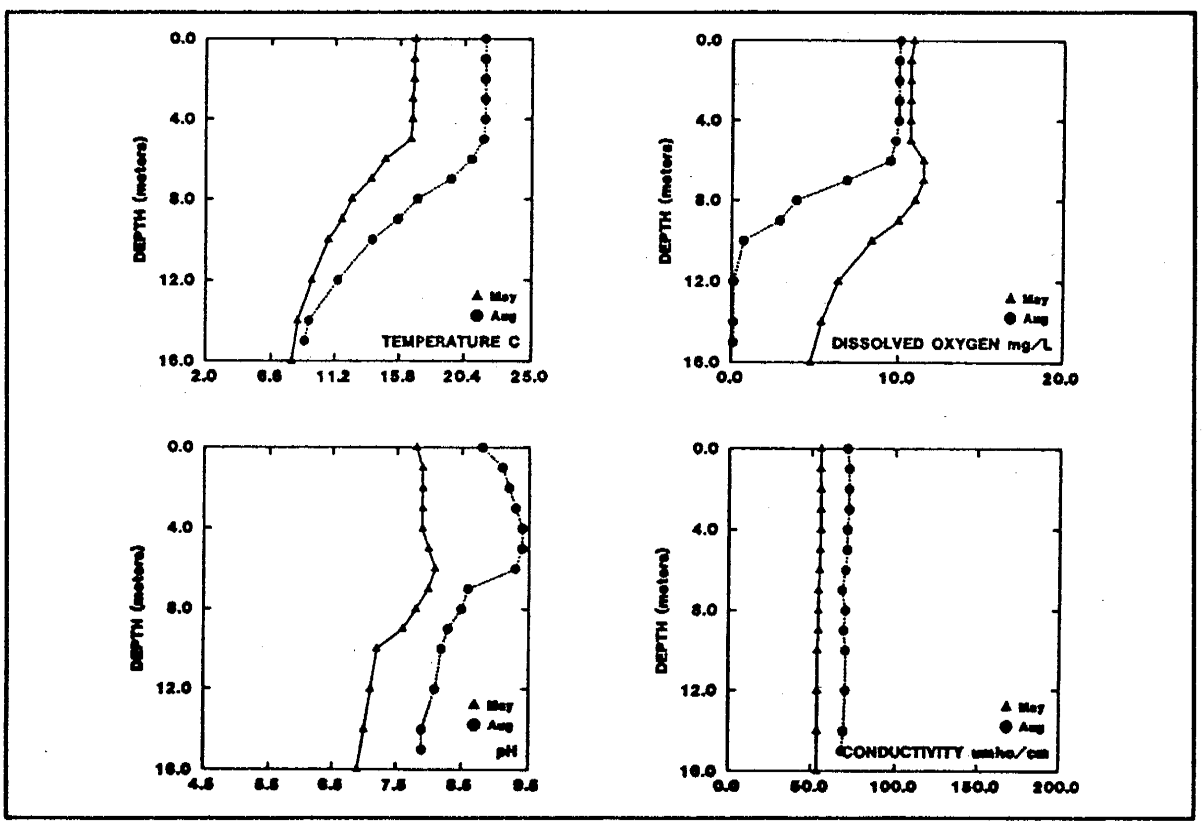
Acknowledgements

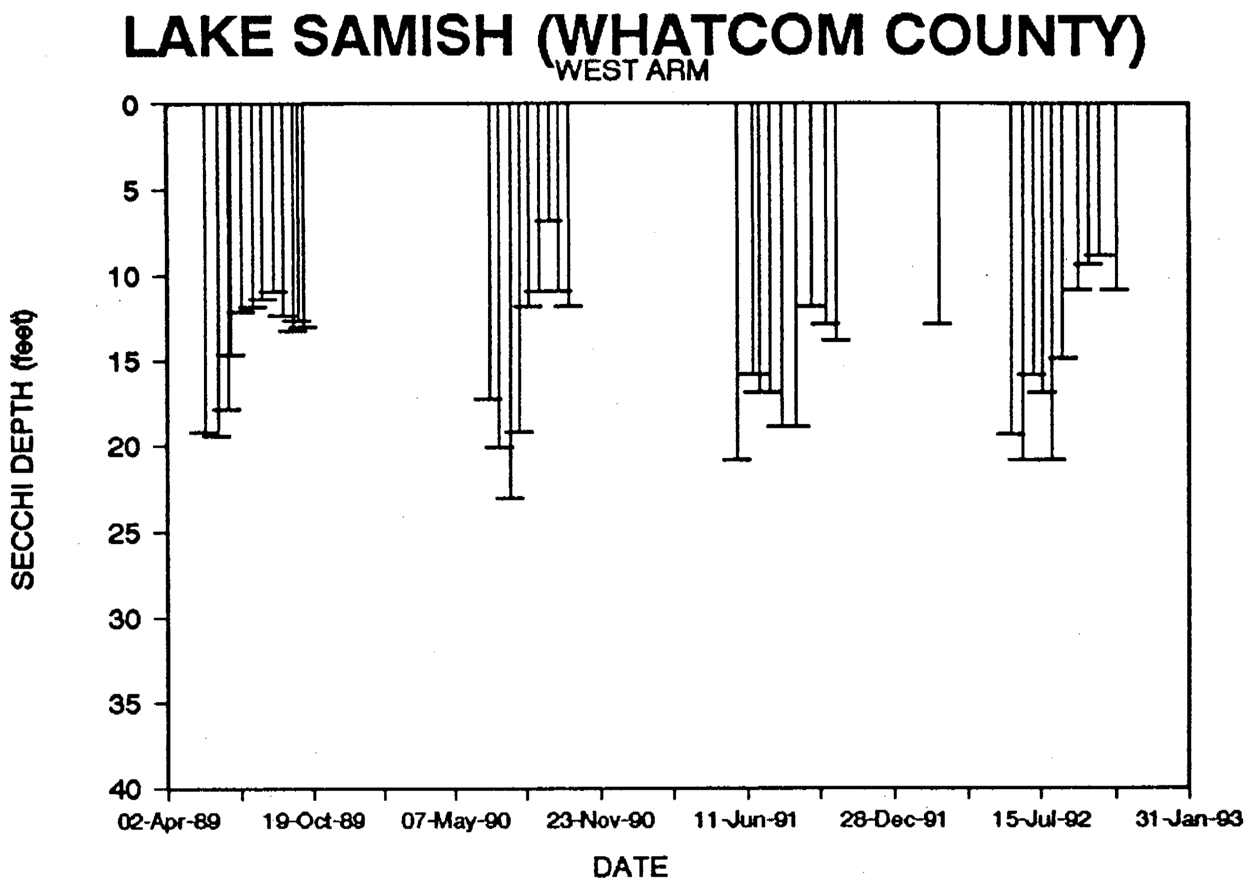
I thank A.B. Davis and J. David Jenkins for volunteering their time to monitor the east and west basins of Lake Samish, respectively, during 1989-1992.

LAKE SAMISH (WHATCOM COUNTY)

EAST ARM







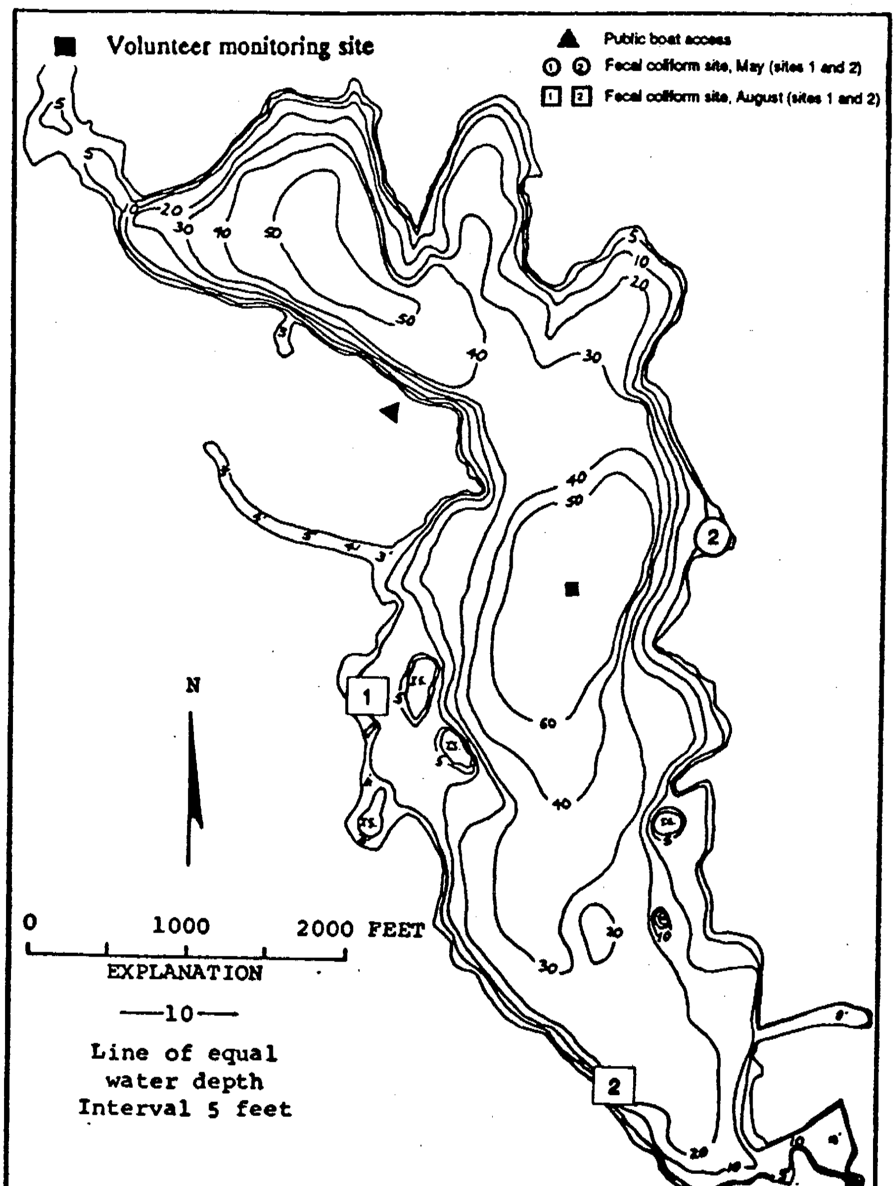
LAKE SAMISH (WHATCOM COUNTY)
WEST ARM
SECCHI DEPTH (feet)
0
5
10
15
20
25
30
35
40
02-Apr-89
19-Oct-89
07-May-90
23-Nov-90
11-Jun-91
28-Dec-91
15-Jul-92
31-Jan-93
DATE

Lake Sawyer -- King County

Lake Sawyer is located 2 miles northwest of Black Diamond. It has four small islands. It is fed at the south end of the lake by Rock Creek, Ravensdale Creek, and an extensive wetland. The lake drains via Covington Creek to the Green River. Lake level is controlled by a concrete weir which was constructed in 1952. Wastewater effluent from the City of Black Diamond has been discharged to a natural wetland that drains to Lake Sawyer since 1983.

Size (acres)	300
Maximum Depth (feet)	58
Mean Depth (feet)	26
Lake Volume (acre-feet)	7,700
Drainage Area (miles^2)	13.0
Altitude (feet)	512
Shoreline Length (miles)	7.0

Data From Bortleson *et al.* (1976)



Sawyer Lake, King County. From U.S. Geological Survey, June 6, 1973.

Lake Sawyer -- King County

1992 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	39
Mean Trophic State Index (Total Phosphorus):	45
Mean Trophic State Index (Chlorophyll *a*):	39

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
12-May				10.0						Onsite visit.
26-May	1645	20.0	68.0	13.0		Lt-Green	75	Light	Light	Sampled day after 3-day, hot weekend that had lots of boat activity.
14-Jun	1220	18.9	66.0	11.0		Lt-Green	75	Heavy	Light	
05-Jul	1500	21.7	71.0	17.0	-10.00	Lt-Green	100	Heavy	Breezy	Started lake height this time.
20-Jul	1630	23.9	75.0	17.0		Green	75	None	Calm	
18-Aug	1730	25.0	77.0	16.0	-22.00	Lt-Green	0	None	Light	Hot weekend preceding - lots of boating activity.
24-Aug				16.0						Onsite visit.
13-Sep	1630	17.8	64.0	17.5	-32.50	Lt-Green	90	Trace	Breezy	Heavy winds (40 mph) yesterday.
26-Sep	1140	16.7	62.0	13.0	-34.50	Lt-Green	100	Heavy	Breezy	Foggy day - hard rains last week.
22-Oct	1800	13.9	57.0	10.0	-39.50	Lt-Green	75	Moderate	Calm	Very low water level for beach, dock, and bulkhead improvements.

[1] Trophic State Indices calculated from Carlson (1977)

Lake Sawyer -- King County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/12	0.0	16.8	8.3	11.0	126
	1.0	16.7	8.3	11.0	126
	2.0	16.1	8.4	11.2	126
	3.0	15.8	8.3	11.1	127
	4.0	13.5	7.8	9.0	133
	5.0	12.0	7.3	6.5	129
	6.0	10.5	7.1	4.1	128
	7.0	9.2	7.0	3.2	127
	8.0	8.3	7.0	3.2	125
	9.0	7.9	6.9	3.0	125
	10.0	7.7	6.9	2.8	124
	12.0	7.5	6.9	2.4	124
	14.0	7.3	6.9	2.3	125
	16.0	7.3	6.8	1.9	125
	17.0	7.2	6.8	1.0	125
08/24	0.0	22.7	8.1	9.5	143
	1.0	22.7	8.2	9.4	143
	2.0	22.6	8.2	9.4	143
	3.0	22.4	8.2	9.3	143
	4.0	21.9	8.4	9.7	142
	5.0	19.6	8.1	9.1	146
	6.0	14.5	7.9	0.5	147
	7.0	11.5	7.9	0.3	145
	8.0	10.0	7.8	0.2	143
	9.0	8.9	7.9	0.3	143
	10.0	8.4	7.8	0.2	143
	12.0	8.1	7.7	0.1	143
	14.0	7.8	7.6	0.1	151
	16.0	7.7	7.4	0.1	162

Lake Sawyer -- King County

1992 Onsite Visit Data - Water Chemistry

Date	05/12/92		08/24/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	10, 12, 14	1, 2, 3	12, 14
Total Phosphorus (μg/L)	19	30	14	272
Total Nitrogen (mg/L)	0.32	0.56	0.27	0.57
Chlorophyll *a* (μg/L)	3.23	--	1.47	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	1	--	1	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	2	--	1	--
Total Suspended Solids (mg/L)	--	--	3	--
Total Nonvolatile Suspended Solids (mg/L)	--	--	1	--
Color (Pt-Co units)	--	--	15	--

Historical Data From Ecology

Date	06/18/73[a]	6/11/81[b]
Secchi (ft)	8	22
Total Phosphorus, epilimnion (μg/L)	28	--
Total Nitrogen, epilimnion (mg/L)	--	--
Chlorophyll *a* (μg/L)	7.3	1.6
Dissolved Oxygen, surface (mg/L)	10.4	9.0
Dissolved Oxygen, bottom (mg/L)	11.1	0.2

a. Bortleson *et al.* (1976), McConnell *et al.* (1976)
b. Sumioka and Dion (1985)

Lake Sawyer -- King County

Monitoring Results/Summary of Other Available Information

Secchi Depths
All Secchi depths, except for the first and last collected in 1992, were better than would be expected given the moderately high concentrations of total phosphorus. Deepest Secchi depths (16.0 to 17.5 feet) were measured from July through mid-September.

Total Phosphorus
Total phosphorus in the epilimnion was 19 μg/L in May, and 14 μg/L in August. These concentrations indicate mesotrophy. During August, total phosphorus was very high (272 μg/L) in the hypolimnion and probably resulted, in part, from internal loading from the sediments (see Other Available Information, below). In 1973, total phosphorus was 28 μg/L (Bortleson *et al.*, 1976), which indicates that the lake had high total phosphorus concentrations even before the discharge of wastewater into the lake.

Total Nitrogen
Total nitrogen was low on both sampling dates (0.32 mg/L in May, and 0.27 mg/L in August). It is difficult to compare results from this program with those from earlier studies, because water samples were composited for this program, and samples from other surveys were collected at discrete depths.

Fecal Coliform Bacteria
Results for all four samples were very low (1-2 colonies/100 mL) and were within state standards.

Solids and Color
Solids and color samples were collected during the August onsite visit only. Results were all low, and indicate that Secchi depths were most likely affected by algal growth at the time of sampling, rather than by suspended sediments or natural color.

Profile Data
On both sampling dates, the lake was thermally stratified. Below the thermocline, both dissolved oxygen and pH decreased with depth. During August, dissolved oxygen was particularly low (less than 0.5 mg/L) in the bottom 9 meters of the lake. Very low dissolved oxygen in the hypolimnion results from bacterial decomposition of aquatic plants and algae in the water and sediments. Earlier studies (see Other Available Information, below) have shown that the lake has a history of low dissolved oxygen in the hypolimnion.

Plants
Algal growth was moderately high during May, but low during August, as indicated by the concentrations of chlorophyll *a*. Chlorophyll measured in 1973 (7.3 μg/L; McConnell *et al.*, 1976) was very high and in the eutrophic range, but chlorophyll from 1981 (1.6 μg/L; sumioka and Dion, 1985) was low.

Lake Sawyer -- King County

Aquatic plants identified by Ecology staff during the May 12, 1992 onsite visit were yellow-flowering lily (*Nuphar polysepalum*), duckweed (*Lemna* spp.), cattails (*Typha* spp.), coontail (*Ceratophyllum demersum*), and Eurasian milfoil (*Myriophyllum spicatum*). There was a filamentous algae growing on the milfoil. During the August 1992 onsite visit, largeleaf pondweed (*Potamogeton amplifolius*), curlyleaf pondweed (*Potamogeton crispus*), flatstem pondweed (*P. zosteriformis*), another pondweed (possibly *P. gramineas*), and white-flowering lily (*Nymphaea odorata*) were also observed.

Other Available Information

From Pelletier and Joy (1989): A wasteload allocation evaluation of data determined that continued discharge from the wastewater treatment facility into Lake Sawyer would cause the lake to become eutrophic as a result of excessive phosphorus loading. If the effluent is diverted, Lake Sawyer would be expected to return to a mesotrophic condition (pre-effluent conditions), provided that nonpoint sources of phosphorus to the lake do not cause in-lake concentrations of phosphorus to exceed 25 μg phosphorus/liter.

From Carroll and Pelletier (1991): A Phase I Diagnostic Study of Lake Sawyer was conducted by Ecology from February 1989 to March 1990. The majority of the nutrient loading was from the Black Diamond wastewater treatment plant, which contributed about 50% of the external total phosphorus load, and 12% of the external total nitrogen load. Septic systems contributed less than 1% of the total nutrient loads. Less than 20% of the total phosphorus and total nitrogen loads came from internal loading from the sediments. Because the lake has a rapid flushing rate (about 4.2 months), wastewater diversion is expected to revert the lake back to a mesotrophic condition from its eutrophic condition in 1989-1990, providing that nonpoint source pollution does not increase. Best management practices are recommended to minimize nonpoint loading of phosphorus to the lake from future development within the watershed. Aquatic macrophytes, which are a nuisance in the lake, are expected to worsen after wastewater diversion causes reduced algal growth and subsequent improvements in water clarity.

From Hart Crowser (1990): A hydrological survey of Lake Sawyer conducted in August 1989 - May 1990, and evaluation of other existing data for the Lake Sawyer basin, determined that estimated groundwater inflow to the lake averaged about 0.1 cfs, entering mainly along the eastern shore of the lake, with greatest inflow during winter. Estimated outflow was about 3 cfs, with highest outflow occurring during summer and fall. Nutrient loading from groundwater was estimated as 50 kg total nitrogen/yr and 0.8 kg total phosphorus/yr. These inputs were small relative to nutrient loading from the Black Diamond Wastewater Treatment Plant and nonpoint sources.

Lake Sawyer -- King County

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1992 questionnaire.

> Lake Sawyer is used for fishing, swimming, motor boating, non-motorized boating, and jet skiing. Public recreational facilities on the lakeshore include a city/county park, and one resort. There is one public boat ramp, and motorboating is restricted to specific hours when higher speeds are allowed (30 mph); otherwise, speed is restricted to 8 mph. There is also a restriction on wakes within 200 feet of shore, and no exhaust noise above 74 db. About 1 percent of the shoreline publicly-owned. No fish were stocked in the lake. Currently, the watershed is used for logging, animal grazing/feeding, industry (mining for coal and silica sand), and lakeshore development for residences. In 1992, 32 acres of the watershed were cleared for development. In the past, the watershed was used for logging, animal grazing/feeding, and mining (coal). The lake was also dredged in the past.
>
> There are 312 houses on the lakeshore, and none of the houses are connected to a sewer. There are no culverts which drain into the lake. There is a sewer district and a community association for the lake. Currently, the minimum setback for development on the shoreline is 20 feet, minimum lot lengths are 200 feet, and residential density is restricted to 1 house per acre. However, most development on the lakefront occurred before this zoning, so most lots are 50 feet wide.
>
> Overall, the volunteer finds that Lake Sawyer had fair water quality. Problems in the lake in 1992 were ranked as 1) degraded aesthetics, 2) aquatic plants, 3) algae, 4) suspended sediments, 5) fish kills, 6) decaying plants, 7) odor from decaying algae, 8) high water level, 9) low water level, and 10) fluctuating water level. Possible sources of problems are the Black Diamond sewage treatment plant, internal loading of nutrients from the sediments, and silting from upstream mining operations. Aquatic plants were mechanically harvested in 1992.

Comments

The trophic state characterization was based primarily on the moderately high concentrations of total phosphorus, low dissolved oxygen in the hypolimnion, and moderately high aquatic plant growth in 1992. The methods used for estimating lake trophic state for this program (including sampling and data analysis) differ from the methods used for the more intensive studies conducted from 1989 - 1991.

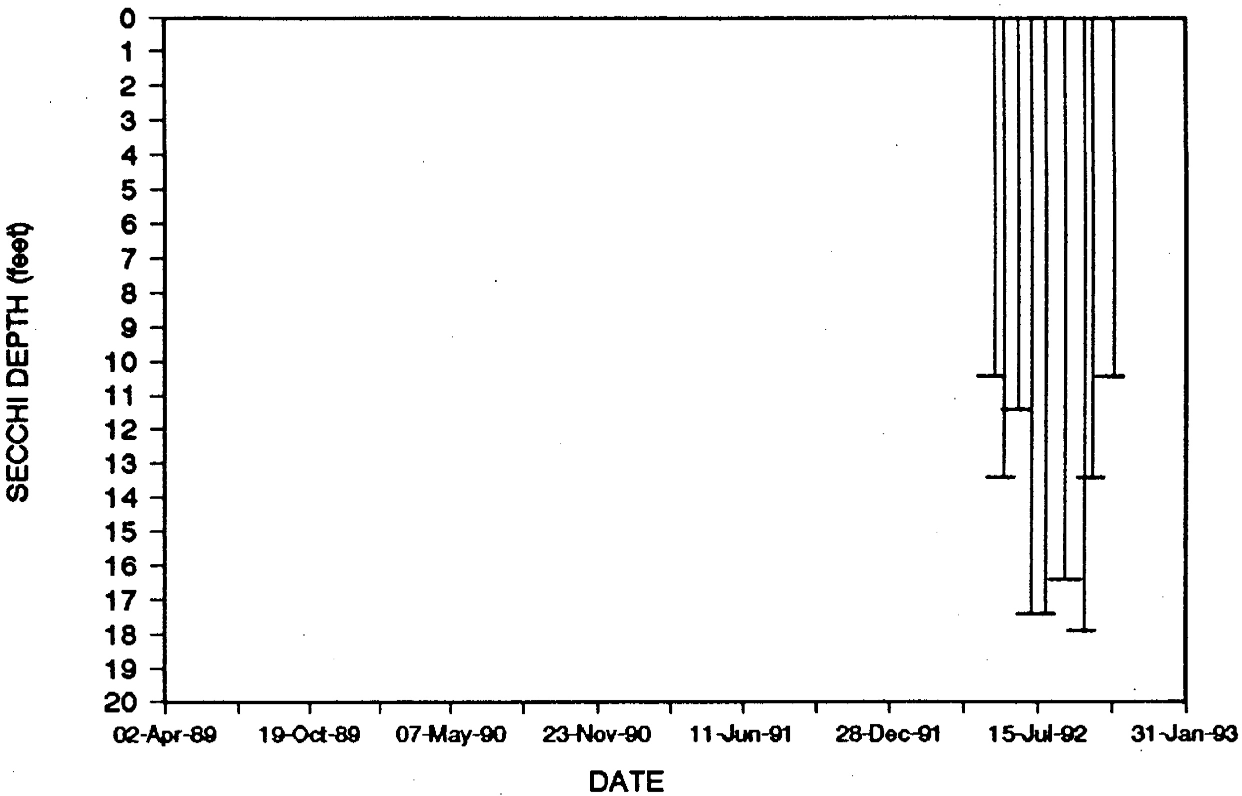
Lake Sawyer -- King County

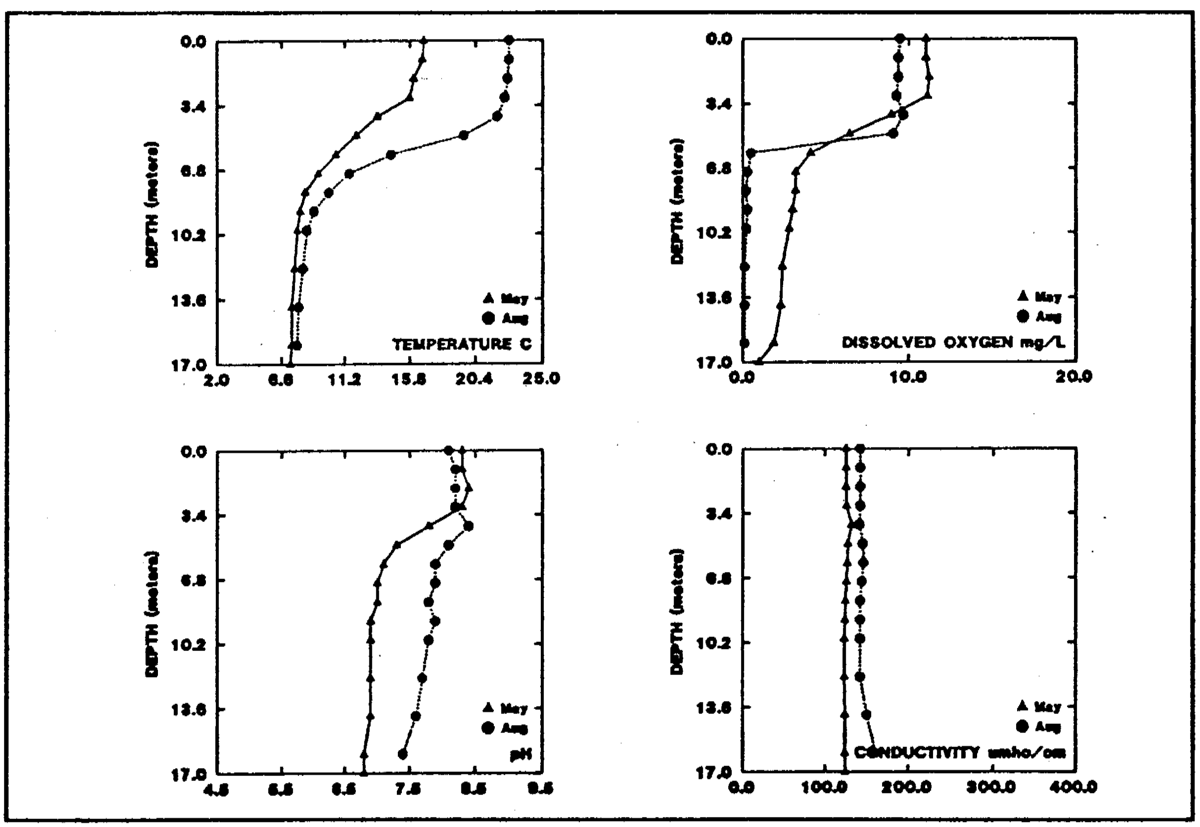
Other King County lakes monitored for the program in 1992 were Lake Alice and Lake Killarney. Lake Alice was characterized as oligo-mestrophic, and Lake Killarney was eutrophic. Both lakes are considerably smaller than Lake Sawyer. Lake Thomas (Stevens County), Lake Osoyoos (Okanogan County), and Long Lake (Thurston County) also have milfoil.

Acknowledgement

I thank Doug Geiger for volunteering his time to monitor Lake Sawyer during 1992.

LAKE SAWYER (KING COUNTY)



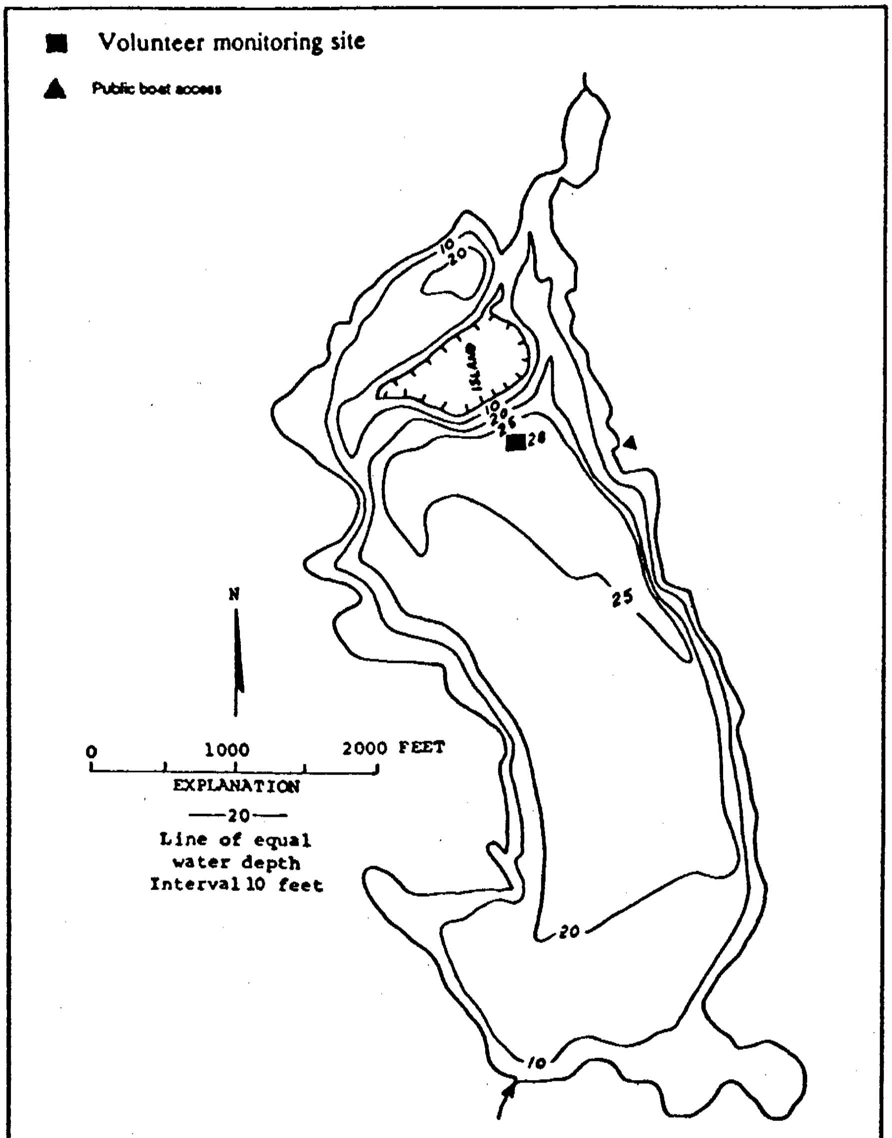


Lake Spanaway -- Pierce County

Lake Spanaway is located ten miles south of Tacoma, and 0.5 mile west of Spanaway. It is fed by drainage from a swampy area, and drains via Spanaway Creek to Clover Creek and Lake Steilacoom. Daron Island lies in the north portion of the lake.

Size (acres)	280
Maximum Depth (feet)	28
Mean Depth (feet)	16
Lake Volume (acre-feet)	4,600
Drainage Area (miles^2)	17.0
Altitude (feet)	320
Shoreline Length (miles)	4.4

Data From Bortleson *et al.* (1976)



Spanaway Lake, Pierce County. From Washington Department of Game, February 2, 1950.

Lake Spanaway -- Pierce County

1992 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	42
Mean Trophic State Index (Total Phosphorus):	41
Mean Trophic State Index (Chlorophyll *a*):	38

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	pH	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
16-May	1330	18.9	66.0	16.5		-0.75	Lt-Green	25	None	Calm	Busy recreational activities due to nice, warm weather.
22-May				18.0							Onsite visit.
29-May	1030	18.9	66.0	18.5	8.1	-1.25	Lt-Green	100	Trace	Calm	Water is fairly clear.
12-Jun	1130	19.7	67.5	16.5	8.3	-2.00	Lt-Green	100	Trace	Breezy	Water color light to moderate green.
27-Jun	1330	24.4	76.0	8.5	8.8	-3.00		10	None		Lake is extremely warm with a lot of weed growth. A lot of recreational use in past 2 weeks.
11-Jul	1230	20.6	69.0	8.5	9.3	-2.25	Gr-Brown	100	Light	Calm	Weeds abundant and everywhere; most I've seen in 5 years.
26-Jul	1030	21.1	70.0	9.5	9.1	-3.50	Green				
09-Aug	1030	21.1	70.0	10.5	9.0	-3.50	Lt-Green	0	Trace	Calm	Very little recreational activity the past week.
22-Aug	1020	22.2	72.0	10.5	8.8	-4.50	Lt-Green	100	Trace	Light	A lot more weeds, algae and snails in lake this year; more frequent swimmers itch.
04-Sep	1030	20.6	69.0	17.5	7.9	-4.75	Lt-Green	100	Trace	Breezy	Onsite visit.
19-Sep	1100	17.8	64.0	9.0	7.8	-4.75	Green	100	Light	Strong	
04-Oct	1100	16.4	61.5	5.5	8.0	-5.00	Pea Green	25		Light	Water has pea-soup green layer on top; a lot of algae.
17-Oct	1358	13.9	58.0	7.0	7.4	-5.50	Pea Green	100	Moderate	Calm	Pea-soup color on top layer only.

[1] Trophic State Indices calculated from Carlson (1977)

Lake Spanaway -- Pierce County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/22	0.0	17.1	7.6	11.4	104
	1.0	17.2	7.6	11.3	104
	2.0	17.2	7.6	11.3	104
	3.0	17.2	7.7	11.2	104
	4.0	17.1	7.6	11.0	104
	5.0	14.9	7.2	7.8	107
	6.0	13.9	7.0	4.0	112
	7.0	13.0	6.8	0.4	120
09/04	0.0	21.3	8.2	10.1	117
	1.0	21.3	8.3	10.0	117
	2.0	21.3	8.3	10.0	117
	3.0	21.3	8.4	10.0	117
	4.0	21.2	8.4	9.7	117
	5.0	20.7	8.2	1.9	125
	6.0	17.6	7.7	0.2	154
	7.0	15.7	7.3	0.1	242
	8.0	14.6	7.2	0.1	298

1992 Onsite Visit Data - Water Chemistry

Date	05/22/92		09/04/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	6, 7	1, 2, 3	7, 8
Total Phosphorus (µg/L)	8	27	17	--
Total Nitrogen (mg/L)	1.17	0.96	0.30	3.66
Chlorophyll *a* (µg/L)	1.20	--	3.25	--

Lake Spanaway -- Pierce County

Historical Data From Ecology

Date	06/18/73[a]	06/11/81[b]	06/01/90[c]	08/24/90[c]	05/24/91[d]
Secchi (ft)	8	22	11.8	--	14.0
Total Phosphorus, epilimnion (μg/L)	28	0.00	22	15	--
Total Nitrogen, epilimnion (mg/L)	--	--	1.01	0.68	1.21
Chlorophyll *a* (μg/L)	7.3	1.6	--	--	--
Dissolved Oxygen, surface (mg/L)	10.4	9.0	12.4	10.7	11.1
Dissolved Oxygen, bottom (mg/L)	11.1	0.2	0.1	0.1	0.4

a. Bortleson *et al.* (1976), McConnell *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)

Lake Spanaway -- Pierce County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was fair to good, as indicated by Secchi depths which ranged from 5.5 to 18.5 feet. The pattern of Secchi depths, showing reduced water clarity during June-July and October, was also evident in 1991 and 1990.

Total Phosphorus
Total phosphorus in the epilimnion was low during May (8 μg/L), but was moderately high during August (17 μg/L). The May concentration was much lower than those measured in 1990 (22 and 15 μg/L; Rector, 1991) and 1973 (28 μg/L; Bortleson *et al.*, 1976). There is no result for the hypolimnion in August, because the sample was not analyzed by the lab.

Total Nitrogen
Total nitrogen was very high during May (1.17 mg/L). High concentrations were also measured during May 1991 (1.21 mg/L; Rector, 1992) and May 1990 (1.01 mg/L; Rector, 1991).

In September 1992, the concentration of nitrogen in the epilimnion decreased to 0.30 mg/L, yet the concentration in the hypolimnion was very high (3.66 mg/L). Total nitrogen probably decreased in the epilimnion because algae take up nitrogen, and when they die, they sink through to the hypolimnion, where they decompose. Because the epilimnion and hypolimnion layers do not mix during stratification, the nitrogen is trapped in the hypolimnion until the lake turns over. During May, the epilimnion and hypolimnion concentrations were very similar, yet during September the hypolimnion concentration was considerably higher than the epilimnion concentration.

Profile Data
On both sampling dates, the lake was stratified and both pH and dissolved oxygen decreased below the thermocline. In September, dissolved oxygen was low (less than 2.0 mg/L) throughout the hypolimnion. Decreased dissolved oxygen results from bacterial decomposition of aquatic plants and algae in the bottom water and sediments.

Plants
Algal growth was low during May, as indicated by a low concentration of chlorophyll *a,* but was moderately high during August. Apparently the August sample was collected at the onset of an algal bloom, because the volunteer noted that algae growth was severe from August through October.

Aquatic plants observed during the September 1992 onsite visit included Richardson pondweed (*Potamogeton richardsonii*; dominant plant present), Berchtold's pondweed (*Potamogeton berchtoldii*), coontail (*Ceratophyllum demersum*), waterweed (*Elodea* spp.), and the alga *Nitella*.

Lake Spanaway -- Pierce County

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

Lake Spanaway is used for fishing, swimming, motor boating, non-motorized boating, and jet skiing. Public recreational facilities on the lakeshore include a city/county park, and one public boat ramp. Motorboating is restricted to no wake within 200 feet of shore. Brook, brown, rainbow, cutthroat, steelhead, kokanee and coho trout were stocked in the lake. Currently, the main activity in the watershed is lakeshore development for residences. In the past, the watershed was used for logging and animal grazing/feeding, the lake was dredged, and the shoreline was altered by vegetation removal and fill.

There are about 177 houses on the lakeshore, and none of the houses are connected to a sewer. About 3 culverts/stormdrains drain into the lake, and there is a possibility that these may be diverted from the lake. There is no lake association for the lake. Currently, the minimum setback for lakeshore development is 100 feet.

Overall, the volunteer finds that Spanaway Lake had fair water quality. Problems in the lake in 1992 were ranked as 1) swimmer's itch, 2) excessive aquatic plant growth, 3) excessive numbers of resident waterfowl, 4) eye/skin problems after swimming, 5) algae, 6) bacteria, 7) decaying plants, 8) odor from decaying algae, 9) degraded aesthetics, 10) suspended sediments, 11) gradually degrading water quality over the years, 12) recently degraded water quality, 13) shoreline erosion, 14) low water level, 15) fluctuating water level, and 16) high water level. Possible sources of problems are old septic systems, road runoff, and a large year-round waterfowl population. In comparison to 1991, there was a big increase in the frequency and numbers of people affected by swimmers itch reported in 1992. Swimmer's itch was not reported to be a problem in the lake in 1991. Both aquatic plants and algae were the worst problems in the lake in 1990 and 1991.

The entire lakeshore is developed for residences, including the island. There are two wetland areas on the west shore. Cattails grow along most of the shoreline, particularly at the north and south ends of the lake. Lily pads grow in cove areas at the south, west, and north areas of the lake. In 1991, submerged plants and algae growth were especially heavy at the south end of the lake, where weeds come to the surface in the middle of the basin. In 1991, parts of the lake were treated with chemicals to control algae and aquatic plants. The lake has also been chemically treated in the past to control undesirable fish species.

Lake Spanaway -- Pierce County

Comments

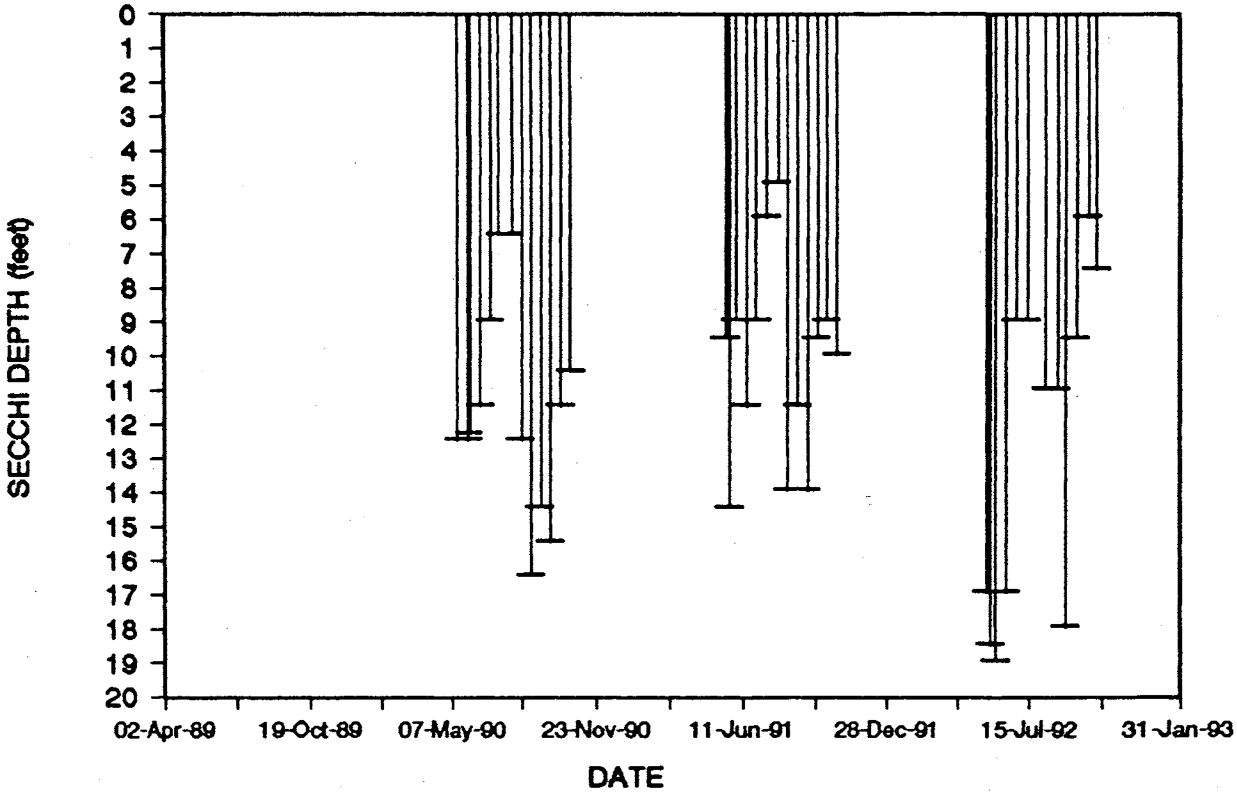
Lake Spanaway exhibited several mesotrophic characteristics which were the basis of the assessment in this report. Although both mean total phosphorus and mean chlorophyll *a* were borderline between oligotrophy and mesotrophy, concentrations for these parameters were clearly in the mesotrophic range during September. Other mesotrophic characteristics of the lake include the very low dissolved oxygen in the hypolimnion, and the prolific plant growth in areas of the lake.

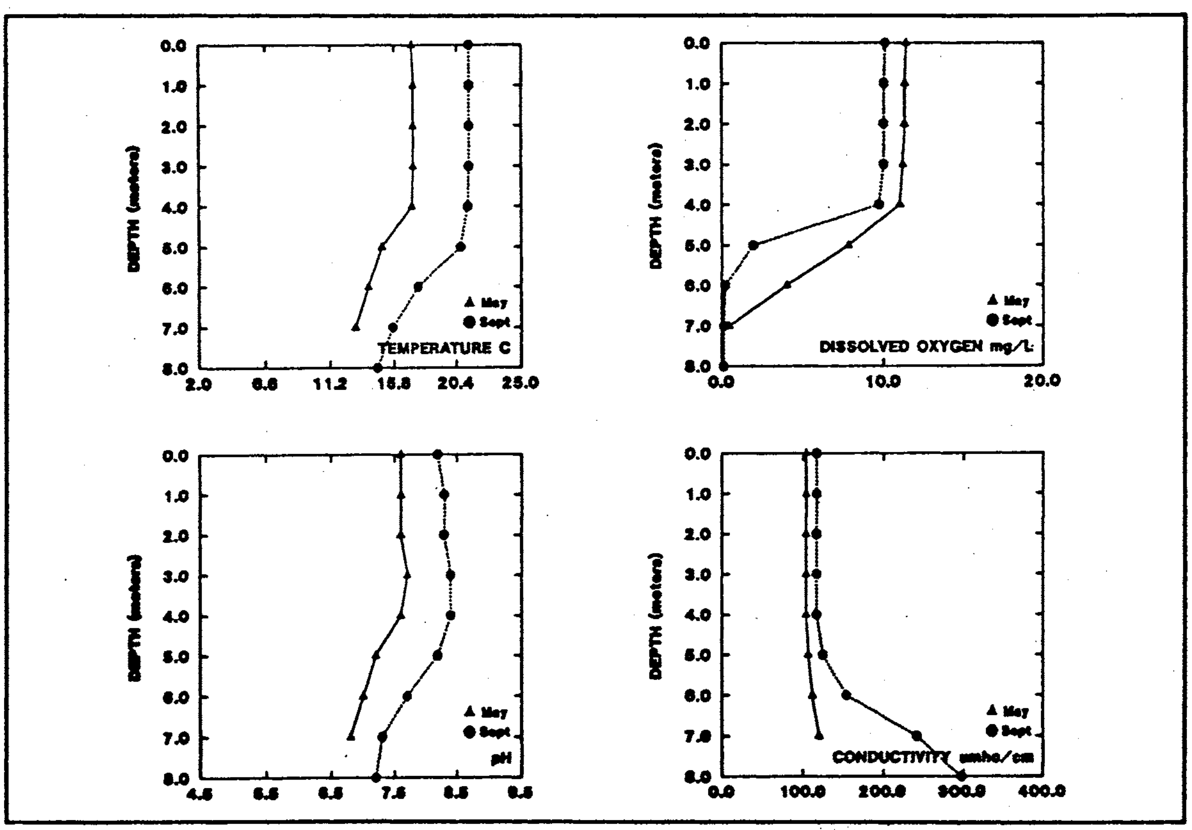
Lake Spanaway and Tanwax Lake were the only Pierce County lakes monitored for the program in 1992. Despite the urban setting, heavy residential development, and heavy recreational use, Lake Spanaway had better mean summer water clarity than the more rural Lake Tanwax.

Acknowledgement

I thank Sue Thompson for volunteering her time to monitor Lake Spanaway during 1990 - 1992.

LAKE SPANAWAY (PIERCE COUNTY)



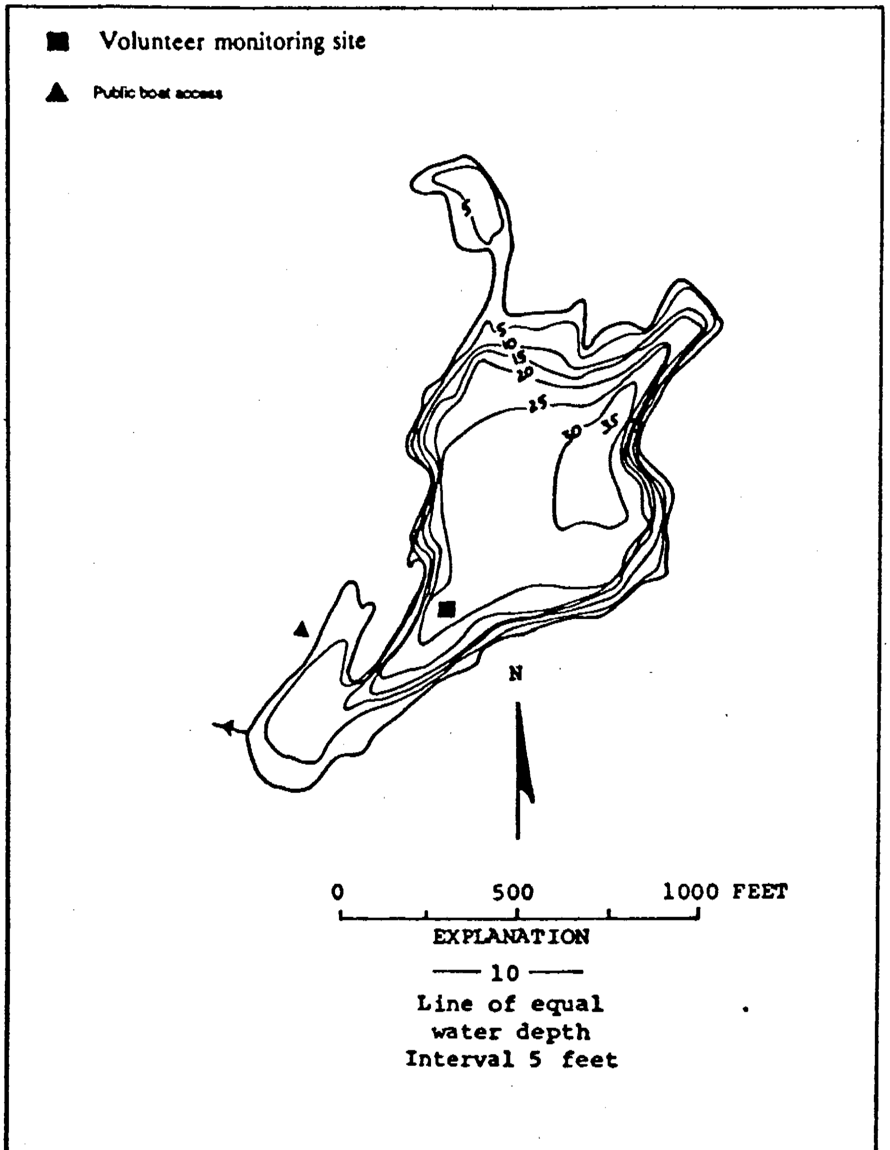


Spencer Lake -- Mason County

Spencer Lake is located seven miles northeast of Shelton. It has no inlets, and drains via Malaney Creek to Oakland Bay.

Size (acres)	230
Maximum Depth (feet)	36
Mean Depth (feet)	22
Lake Volume (acre-feet)	5,152
Drainage Area (miles^2)	1.7
Altitude (feet)	170
Shoreline Length (miles)	4.3

Data From Bortleson *et al.* (1976)



Spencer Lake, Mason County. From Washington Department of Game, July 30, 1947.

Spencer Lake -- Mason County

1992 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	40
Mean Trophic State Index (Total Phosphorus):	35
Mean Trophic State Index (Chlorophyll *a*):	32

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
19-May				13.0						Onsite visit.
01-Jun	1100	18.9	66.0	13.5	14.00	Lt-Green	25	None	Light	Lake height 14" below winter high.
16-Jun	1045	17.8	64.0	13.0	15.50	Lt-Green	50	Trace	Calm	Water level below 15.5" below winter high.
01-Jul	1030	18.9	66.0	13.0	16.50	Lt-Green	25	Light	Light	Lake height 16.5" below winter high.
16-Jul	1000	21.1	70.0	15.5	18.00	Lt-Green	0	None	Calm	
28-Jul	1030	22.2	72.0	14.0	20.00	Lt-Green	0	None	Calm	
14-Aug	1100	23.3	73.9	12.0	23.00	Lt-Green	0	None	Calm	
26-Aug	1030	21.1	70.0	14.5	24.00	Lt-Green	0	None	Calm	Water color light green-yellow.
14-Sep	1130	16.7	62.0	10.5	26.50		10	None	Light	Water color light green-yellow.
29-Sep	1300	20.0	68.0	10.0	26.50		0	None	Calm	Water color light yellow-green. Algae bloom scattered all around lake; noted along access area and on other side of "island".
13-Oct	1300	15.6	60.0	9.0	28.00		25	Light	Light	Water color light yellow green. A few small algae pieces between access and point.

[1] Trophic State Indices calculated from Carlson (1977)

Spencer Lake -- Mason County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/19	0.0	17.8	7.5	10.5	29
	1.0	17.9	7.3	10.0	29
	2.0	17.8	7.3	9.9	29
	3.0	17.7	7.2	9.8	29
	4.0	16.3	7.2	9.5	29
	5.0	15.1	7.1	9.2	28
	6.0	14.2	6.9	7.0	29
	7.0	12.4	6.7	2.8	31
	7.5	11.9	6.5	1.0	34
08/26	0.0	21.5	7.5	8.8	41
	1.0	21.4	7.5	8.7	42
	2.0	21.4	7.5	8.6	41
	3.0	21.3	7.5	8.5	41
	4.0	21.3	7.5	8.4	41
	5.0	21.2	7.5	8.3	41
	6.0	21.1	7.5	7.8	41
	7.0	17.6	7.5	0.7	44

1992 Onsite Visit Data - Water Chemistry

Date	05/19/92		08/26/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	5, 6, 7	1, 3, 5	7
Total Phosphorus (µg/L)	10	21	7	6
Total Nitrogen (mg/L)	0.29	0.33	0.33	0.30
Chlorophyll *a* (µg/L)	1.32	--	1.09	--

Spencer Lake -- Mason County

Historical Data From Ecology

Date	08/20/74[a]	05/24/90[b]	08/15/90[b]	5/21/91[c]
Secchi (ft)	10	--	13	11
Total Phosphorus, epilimnion (μg/L)	9	9	13	--
Total Nitrogen, epilimnion (mg/L)	--	0.27	0.35	0.22
Chlorophyll *a* (μg/L)	--	--	--	--
Dissolved Oxygen, surface (mg/L)	9.0	10.3	8.7	10.3
Dissolved Oxygen, bottom (mg/L)	0.5	1.9	0.2	3.3

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)

Spencer Lake -- Mason County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was generally very good, as indicated by Secchi depths which ranged from 9.0 to 15.5 feet. Secchi depths were shallower only during September and October when an algae bloom occurred. Secchi depth data collected from 1990 - 1992 indicate that water clarity was best in 1991, and data from 1990 and 1992 were similar.

Total Phosphorus

Total phosphorus in the epilimnion was low on both sampling dates (10 μg/L and 7 μg/L). Concentrations measured during 1992 were very similar to those measured in 1990 (9 μg/L and 13 μg/L; Rector, 1991) and 1974 (9 μg/L; Bortleson *et al.*, 1976).

Total Nitrogen

Total nitrogen was also low (0.29 and 0.33 mg/L), and similar to concentrations measured in 1990 and 1991.

Profile Data

During May, the lake was barely stratified, and both pH and dissolved oxygen decreased with depth below the thermocline. These decreases are probably related to the decomposition of aquatic plants and algae in bottom water and sediments. During August, the lake was not stratified, and lower oxygen and temperature were only measured at the very bottom of the lake. There was nothing unusual about the profile data.

Plants

Algal growth was low on both samping dates, as indicated by low concentrations of chlorophyll *a*. Although small patches of floating scum from decaying algae were visible during the August onsite visit, chlorophyll *a* only measures algae that are actively growing, not dead algae. During August, there were complaints to the Mason County Office of Water Quality about a severe algae bloom in Spencer Lake. When samples of the algae were collected for this program within a few days of the complaints, it appeared that the algae were localized at the north end of the lake, since only clumps of dying algae were noticed at the sampling site on the south end. The algae was identified as the blue-green filamentous alga *Oscillatoria*.

On the May 21, 1991 onsite visit with the volunteer, thick patches of algae were observed in shallow water near the public access. A sample contained the filamentous green species *Mougeotia* (primarily) and *Spirogyra*. The volunteer noted that algae growth was worse in 1991 than in previous years, and was especially bad during February and March.

Aquatic plants identified by Ecology staff during the May 19, 1992 onsite visit with the volunteer were yellow-flowering lily (*Nuphar polysepalum*), iris (*Iris pseudacorus*), and an unidentified rush. During the August 1990 onsite visit with the volunteer, large-leaved pondweed (*Potamogeton amplifolius*).

Spencer Lake -- Mason County

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

> Spencer Lake is used for fishing, swimming, motor boating, non-motorized boating, jet skiing, lakeshore camping, and waterfowl hunting. Many springs feed the lake. There is one resort on the lakeshore, and two public boat ramps. About 1 percent of the shoreline is publicly-owned. Rainbow trout were stocked in the lake. Restrictions for motorboating are set by general county regulations. Currently, the watershed is used for crop agriculture, animal grazing/feeding, and lakeshore development for residences. In the past, the watershed was used for logging, crop agriculture, and animal grazing/feeding. The lake was also used as a log storage pond 50-60 years ago. The shoreline was altered in the past when beaches were cleaned at individual residences. A dike was built in 1950, and the weir was taken out around 1988. Wildlife in the area include raccoon, otter, mink, muskrat, and geese (both wild and domestic).
>
> There are 93 houses on the lakeshore, and none of the houses are connected to a sewer. One culvert drains into the lake. There is no lake association for the lake. Currently, the minimum setback for lakeshore development is 15 feet, and minimum lot lengths are 50 feet. Septic systems are restricted within 100 feet of individual wells, and there is a minimum lot size of 12,500 square feet per residence which use community wells.
>
> Overall, the volunteer finds that Spencer Lake had good water quality. Problems in the lake in 1992 were ranked as 1) algae, and 2) recently degraded water quality. The hot dry summer weather may have contributed to the appearance of the algae.
>
> In 1990, submerged plant growth was particularly heavy in the northernmost cove and the south basin near the outlet. Lily pads, mostly pink and white-flowering and some yellow-flowering grew in the south basin. Reeds grew along isolated areas of the north and south shores. There is "swamp land" around the outlet area. In 1991, aquatic plants were listed as the worst problem in the lake, although plants in the lake have not changed much in the last 50 years. The volunteer has been coming to the lake for the past 65 years.

Spencer Lake -- Mason County

Comments

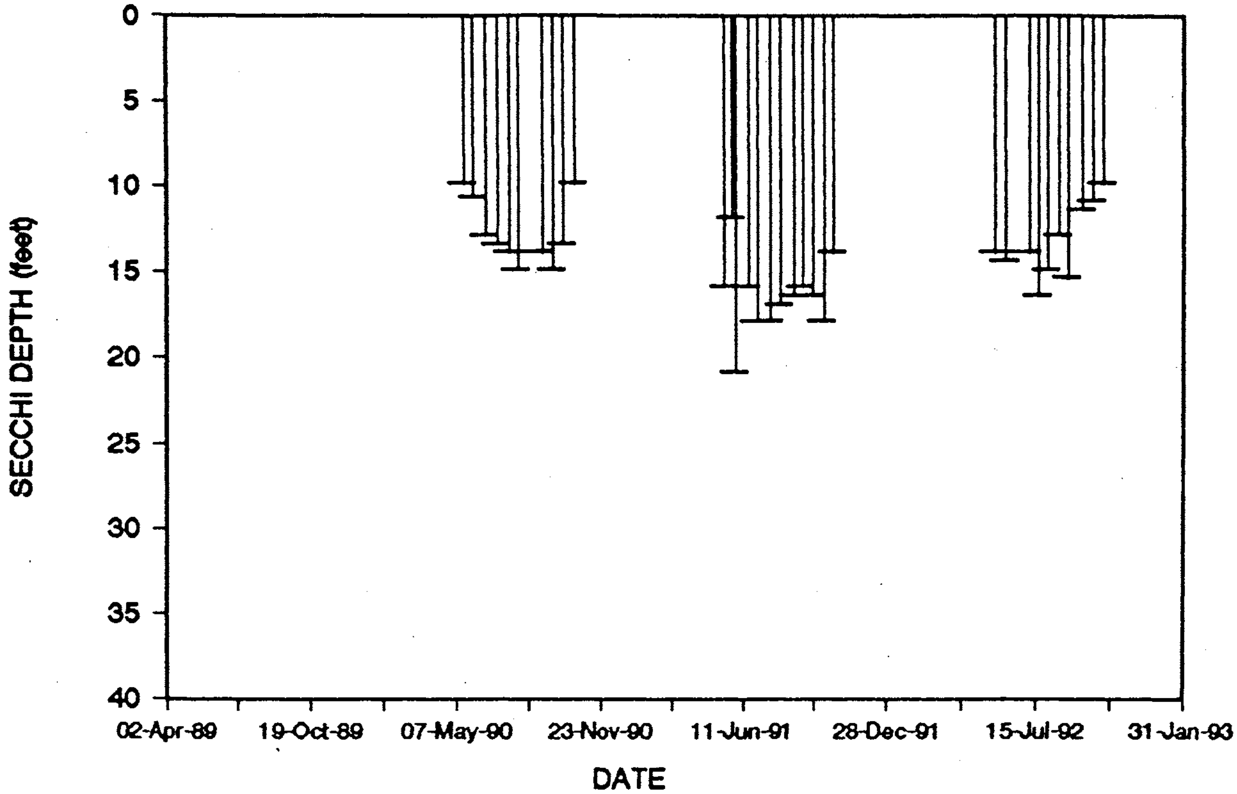
Despite the localized algae bloom reported in the lake during August 1992, all three trophic state parameters (Secchi depth, total phosphorus, and chlorophyll *a*) indicated that the lake was oligotrophic.

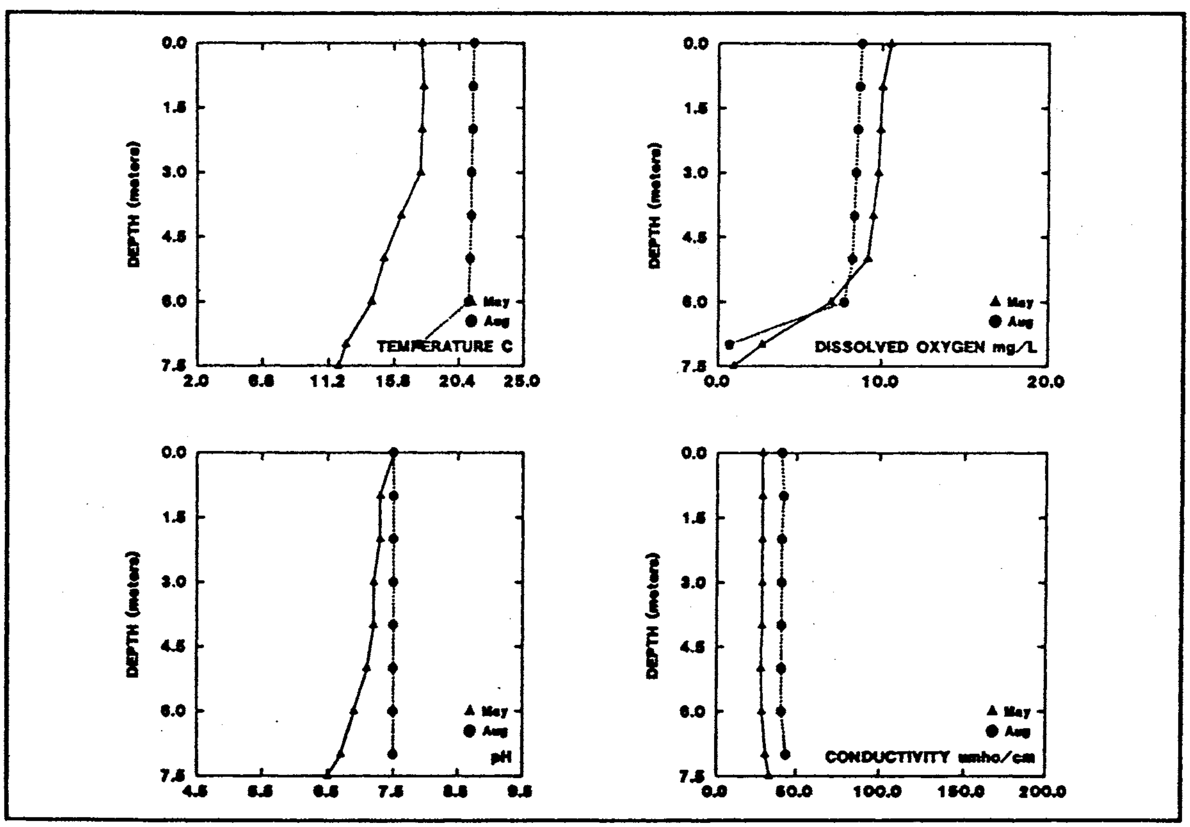
Spencer Lake was one of six Mason County lakes monitored for the program in 1991. The other lakes were Limerick, Mason, Nahwatzel, Phillips, and Wooten. The best mean summer water clarity was at Mason Lake and Lake Wooten (23 feet), and the worst at Phillips Lake (10.7 feet), compared with a mean of 16 feet at Spencer Lake.

Acknowledgement

I thank Virginia Charrier for volunteering her time to monitor Spencer Lake during 1991-1992, and both Virginia and Larry Charrier for monitoring the lake during 1990.

SPENCER LAKE (MASON COUNTY)



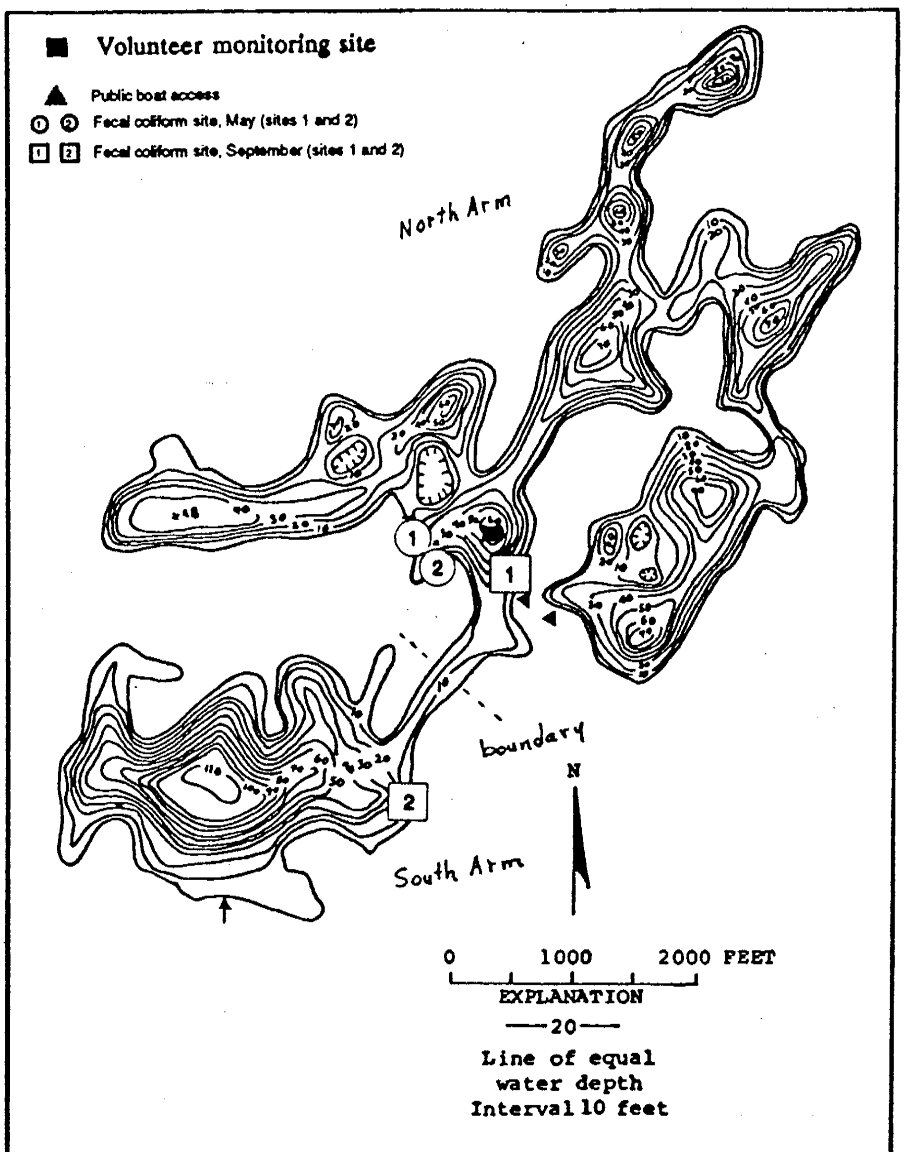


Lake St. Clair -- Thurston County

Lake St. Clair is located 6.5 miles northwest of Yelm. It is an irregularly shaped lake with steep sides, numerous narrow arms and four small islands. The lake is fed by Eaton Creek, drains to the Nisqually River, and seeps to McAllister Springs. The south arm of Lake St. Clair is a deep conical-shaped depression.

	North Arm	South Arm
Size (acres)	180	88
Maximum Depth (feet)	70	110
Mean Depth (feet)	28	40
Lake Volume (acre-feet)	5,100	3,600
Drainage Area (miles^2)	6.4	14.5
Altitude (feet)	73	73
Shoreline Length (miles)	7.5	2.9

Data From Bortleson *et al.* (1976)



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

Lake St. Clair -- Thurston County

1992 Trophic Status[1]

Estimated Trophic State:	Eutrophic[2]
Mean Trophic State Index (Secchi):	47
Mean Trophic State Index (Total Phosphorus):	53
Mean Trophic State Index (Chlorophyll *a*):	43

Volunteer-Collected Data

Date 1992	Time	Temp (°C) (°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
13-May	1100	18.0 64.4	5.0	-3.00	Red-Brown	0	Light	Breezy	A greenish algae cut distance on the Secchi disk. Sample forwarded. Lake height dropped 3" since high water mark 5/1/92.
30-May	1400	22.0 71.6	6.0	-8.50	Red-Brown	0	None	Light	Algae seems to have cleared up - sent sample 5/15/92.
16-Jun	1600	23.0 73.4	6.5	-14.50	Red-Brown	10	Light	Breezy	Lake level dropped 14.5" from May 1. Cloudy weather delayed sampling this time.
03-Jul	1400	25.0 77.0	7.5	-17.00	Red-Brown	10	Trace		17" drop in water level since May 1.
16-Jul	1400	27.0 80.6	6.5	-18.00	Red-Brown	0	None	Breezy	Lake height dropped 1" in 2 weeks. Water not as clear as 2 weeks ago; small particles.
29-Jul	1400	28.0 82.4	7.0	-20.50	Red-Brown	0	None	Breezy	Lake dropped 2.5" since last reading. Hot dry weather.
16-Aug	1430	28.0 82.4	9.0	-22.50	Red-Brown	0	None	Breezy	Boating activity increased noticeably this year. Lake level dropped 2"; total drop since May 1 is 22.5". Water cleared up a lot.
02-Sep		23.0 73.4	10.0	-26.25	Red-Brown	0	None	Light	Sharp drop in lake height.
17-Sep	1400	19.0 66.2	10.0	-28.00	Red-Brown	0	None	Breezy	Water looks good - no algae.
03-Oct	1130	18.0 64.4	9.0	-28.00	Red-Brown	25	Light	Breezy	Some sign of algae in a few areas.
13-Oct	1400	15.0 59.0	7.5	-27.50	Red-Brown	25	Trace	Breezy	Water looked clear, no sign of algae.

[1] Trophic State Indices calculated from Carlson (1977)

[2] see Comments section

Lake St. Clair -- Thurston County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/11	0.0	16.3	7.8	9.8	82
	1.0	15.4	7.6	9.3	81
	2.0	13.4	7.3	5.1	81
	3.0	10.3	7.1	3.8	80
	4.0	9.2	7.1	3.6	80
	5.0	7.8	7.0	4.1	79
	6.0	7.6	7.0	4.2	80
	7.0	7.3	7.0	4.4	80
	8.0	7.0	6.9	4.0	81
	9.0	6.6	6.9	3.4	82
	10.0	6.3	6.9	2.0	83
	12.0	6.1	6.8	0.6	84
	14.0	5.9	6.8	0.1	85
	16.0	5.8	6.8	0.1	87
	17.5	5.8	6.7	0.1	89
09/02	0.0	21.8	8.0	8.2	106
	1.0	21.1	7.9	7.9	106
	2.0	21.0	7.9	7.4	105
	3.0	19.3	7.8	1.6	102
	4.0	15.1	7.8	0.3	99
	5.0	11.2	7.7	0.1	97
	6.0	8.9	7.7	0.2	96
	7.0	7.9	7.6	0.9	95
	8.0	7.4	7.6	0.4	96
	9.0	7.0	7.5	0.1	96
	10.0	6.8	7.5	0.1	100
	12.0	6.5	7.4	0.1	105
	14.0	6.3	7.3	0.1	111

Lake St. Clair -- Thurston County

1992 Onsite Visit Data - Water Chemistry

Date	05/11/92		09/02/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	0.5, 1	10, 12, 16	1, 2	9, 10, 12
Total Phosphorus (μg/L)	32	59	25	114
Total Nitrogen (mg/L)	0.61	0.81	0.38	0.62
Chlorophyll *a* (μg/L)	5.89	--	1.02	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	5	--	1	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	3	--	<1	--
Total Suspended Solids (mg/L)	5	--	<1	--
Total Nonvolatile Suspended Solids (mg/L)	1	--	<1	--
Color (Pt-Co units)	250	--	50	--

Lake St. Clair -- Thurston County

Historical Data From Ecology -- North Arm

Date	06/28/72[a]	05/30/90[b]	08/22/90[b]	05/31/91[c]
Secchi (ft)	9	6.4	6.9	4.6
Total Phosphorus, epilimnion (μg/L)	20	35	24	–
Total Nitrogen, epilimnion (mg/L)	--	0.53	0.53	0.63
Chlorophyll *a* (μg/L)	4.6	--	–	--
Dissolved Oxygen, surface (mg/L)	11.2	10.1	8.1	10.5
Dissolved Oxygen, bottom (mg/L)	7.3	3.6	0.1	1.0

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)

Historical Data From Ecology -- South Arm

Date	06/28/72[a]	06/09/81[b]	06/11/90[c]	09/19/90[c]
Secchi (ft)	6	3.5	4.9	5.6
Total Phosphorus, epilimnion (μg/L)	30	80	--	25
Total Nitrogen, epilimnion (mg/L)	--	2.0	0.63	0.66
Chlorophyll *a* (μg/L)	11.0	54.2	11.6	10.1
Dissolved Oxygen, surface (mg/L)	11.4	13.4	9.7	11.3
Dissolved Oxygen, bottom (mg/L)	0.2	0.2	0.1	0.3

a. Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Coots (1991)

Lake St. Clair -- Thurston County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was fair, as indicated by Secchi depths which ranged from 5.0 to 10.0 feet. Secchi depths generally increased throughout the monitoring season. This pattern has been documented since 1989.

Total Phosphorus

Total phosphorus in the epilimnion was high on both sampling dates (32 μg/L and 25 μg/L). Although the concentration was lower during September, the value was still high and indicates that the lake was eutrophic. Concentrations measured in 1992 were similar to those measured at the same site in 1990 (35 μg/L and 24 μg/L in June and September, respectively; Rector, 1991).

During August, the concentration in the hypolimnion was very high (114 μg/L). Because dissolved oxygen in the hypoimnion was very low (see Profile Data, below), it is likely that phosphorus was being released from the sediments.

Total Nitrogen

Total nitrogen was moderately high during May (0.61 mg/L), but low during September (0.38 mg/L). Total nitrogen and total phosphorus data indicate that algal growth was limited by the amount of phosphorus in the water.

Fecal Coliform Bacteria

Results from four fecal coliform samples were all very low, and were within state standards.

Solids and Color

Although results from solids samples were low, the total suspended solids concentration was higher during May than during September. The higher value in May was probably due to the high amount of algal growth at the time of sampling (see Plants, below). Solids results indicate that Secchi depths were most likely affected by algal growth, rather than by suspended sediments.

Results for color were expected to be high because the volunteer has consistently reported the lake to be a reddish brown color since 1989. An earlier report also described the lake as "highly colored from natural sources" (Bortleson *et al.*, 1976). During May, a sample for color did indicate that the lake was highly colored. Although the September result for color was lower, this was still a high value for color. It is possible that water color reduces light penetration and inhibits algal growth in the lake; algal growth was lower (and as a result, Secchi depths were deeper) than would be expected, given the high concentrations of total phosphorus.

Lake St. Clair -- Thurston County

Profile Data

On both sampling dates, the lake was strongly stratified with respect to temperature, and pH decreased steadily with depth below the thermocline. As noted in earlier studies, Lake St. Clair exhibits unusual dissolved oxygen profile data in comparison to most other lakes monitored for the program. Dissolved oxygen decreases at the base of the epilimnion/top of the metalimnion, as well as at the lake bottom (see graph). Similar oxygen profiles were measured in 1991, 1990, and 1968.

It is possible that the strong thermocline in the lake creates a strong density gradient that can trap sinking algae at the base of the epilimnion. Rather than sinking to the bottom of the lake to decompose, the algae may be decomposing at the base of the epilimnion. Dissolved oxygen usually decreases in water because of bacterial decomposition of organic material (such as algae, aquatic plants, and woody debris) in the water and sediments.

The very low dissolved oxygen in the hypolimnion, particularly during September, probably affects fish habitat. During late summer, it is likely that cold water fish such as trout had to migrate between areas of lower water temperature and higher dissolved oxygen. Hydrogen sulfide was evident, from the smell, in the 12 meter sample collected during September. Hydrogen sulfide is produced when oxygen concentrations are very low.

Plants

Algal growth was very high during May, as indicated by the high concentration of chlorophyll *a*. During August, chlorophyll was low and there was less algae visible in the water, as noted in observations from the volunteer (see Volunteer-Collected Data). An algae sample collected by the volunteer in May contained *Anabaena*, possibly *A. flos-aquae*. On November 10, 1991, the volunteer brought in a sample of algae found nearshore in an embayment of the north arm. The alga was the filamentous blue-green alga *Oscillatoria*, which is a fairly common nuisance algae.

Aquatic plants observed in the lake in 1992 included naiad (*Najas* spp.), watershield (*Brasenia schreberi*), tapegrass (*Vallisneria americana*), flatleaf pondweed (*Potamogeton robbinsii*), white-flowering lily (*Nymphaea odorata*), and the alga *Nitella*. In 1990, aquatic plants observed in Lake St. Clair included cattail (*Typha latifolia*), white-flowering water lily, iris (*Iris pseudacorus*), waterweed (*Elodea canadensis*), tapegrass, large-leaf pondweed (*Potamogeton amplifolius*), flatstem pondweed (*P. zosteriformis*), sedge (*Scirpus*), coontail (*Ceratophyllum demersum*), and the alga *Nitella* (Coots, 1991).

Other Available Information

From Davis (1993): The Lake St. Clair Organization began a volunteer monitoring program at five lake stations in 1992. Temperature, dissolved oxygen, pH, Secchi disk transparency, turbidity, total phosphorus, and nitrate were measured from April through October 1992. Data collected indicated that the lake was stratified throughout the monitoring season, and that dissolved oxygen was very low near the lake bottom. Secchi depths tended to increase from April through October. The average Secchi depth for the whole monitoring season and all five lake stations was 7.4 feet. (Although surface total phosphorus data were reported, they may not be reliable; S. Davis, pers. comm.)

Secchi depth data collected by the Lake St. Clair Organization were very similar to data collected by Ecology's volunteer. The average Secchi depth from data collected for Ecology was 7.6 feet. Dissolved oyxgen data collected by Ecology also indicated that dissolved oxygen was very low near the bottom of the lake.

The lake's level decreases considerably each summer; in 1990, the level dropped 23 inches from May 30 to September 30. In 1991, it dropped 25 inches from May 21 to September 20. In 1992, the level dropped 28 inches from May 13 to September 17. Low water level is a concern of lakeshore homeowners (see Summary of Questionnaire Results, below).

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

> Lake St. Clair is used for fishing, boating, swimming, rowing and jet skiing. There are two boat ramps on the lakeshore, and with the exception of the deep basin in the south arm, there is a speed restriction of 5 mph for motorboats. About 2 percent of the shoreline is publicly-owned. Trout were stocked in the lake. Currently the watershed is used for logging, animal grazing, and crop agriculture, and the lakeshore is being developed further for residences. In the past the watershed was used for logging, animal grazing, and crop agriculture. The channel under the bridge was dredged in 1990 (in the 1989 questionnaire, the volunteer noted that the passage under the bridge was too shallow for some boats to navigate through).
>
> There are 313 houses on the lakeshore, and none of the houses are connected to a sewer. Two storm drains empty into the lake. Lake water is withdrawn for drinking and other domestic uses. There is a community association and a volunteer lake monitoring group for the lake. Currently, the minimum setback for lakeshore development is 30 feet.
>
> Overall, the volunteer finds that Lake St. Clair had good water quality. Problems in the lake in 1992 were ranked as 1) algae, 2) low water level, 3) excessive aquatic plant growth, and 4) decaying plants. Possible sources of problems are water runoff from yards, houses, and possibly farm runoff into one of the lake's inlets, and outboard motors. There were no noticeable changes in the lake since

the 1991 monitoring season. Algae and low lake level have been problems in the lake since the volunteer started with the program. The lake was treated with chemicals in the past to control undesirable fish species.

Lilies, mostly white and pink-flowering (most likely *Nymphaea odorata*) and a very few yellow-flowering (*Nuphar* spp.), reeds, and wild iris (*Iris pseudacorus*) grew in the coves and near the islands. There is a wetland in the south arm of the lake near the creek.

Comments

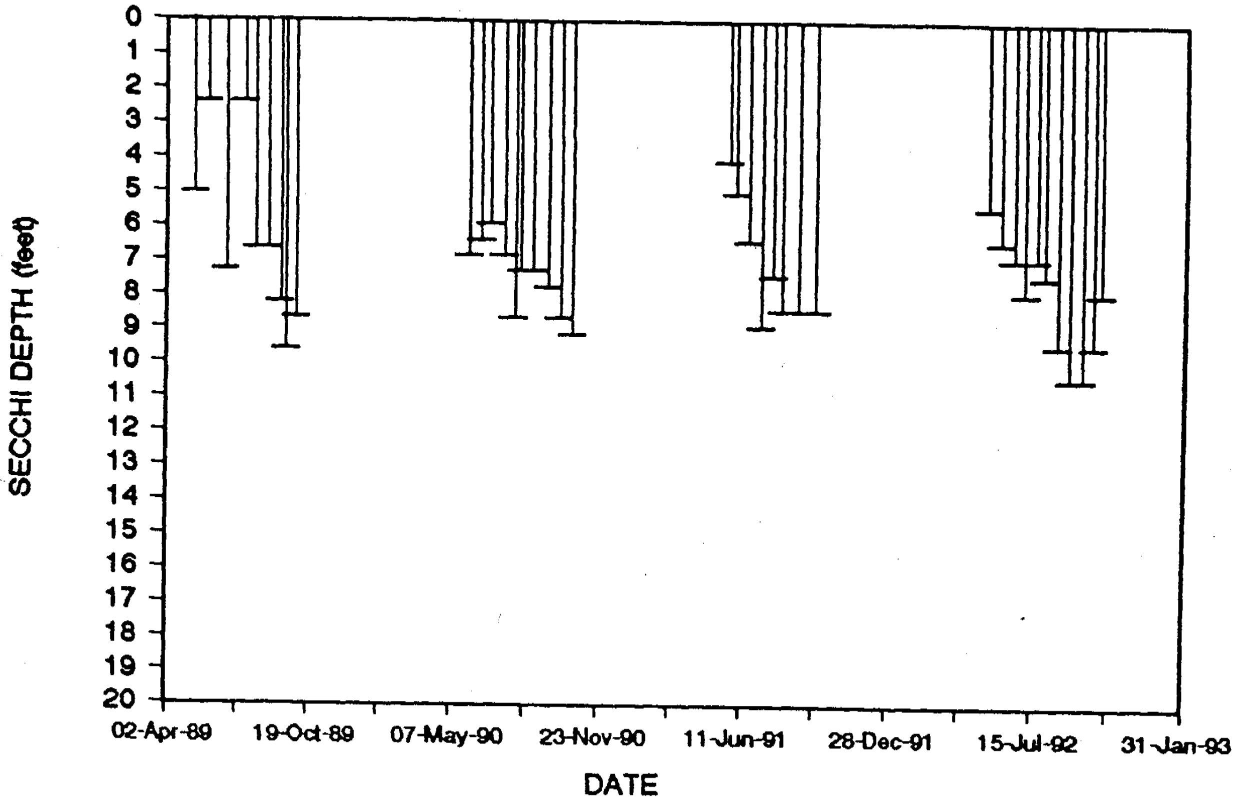
Lake St. Clair exhibited both mesotrophic and eutrophic characteristics during 1992. Both Secchi depths and chlorophyll were in the range that would indicate the lake was mesotrophic. However, the lake had very high total phosphorus and very low dissolved oxygen throughout most of the hypolimnion, and a couple periods of heavy blue-green algal growth. The latter indicate that Lake St. Clair was still eutrophic.

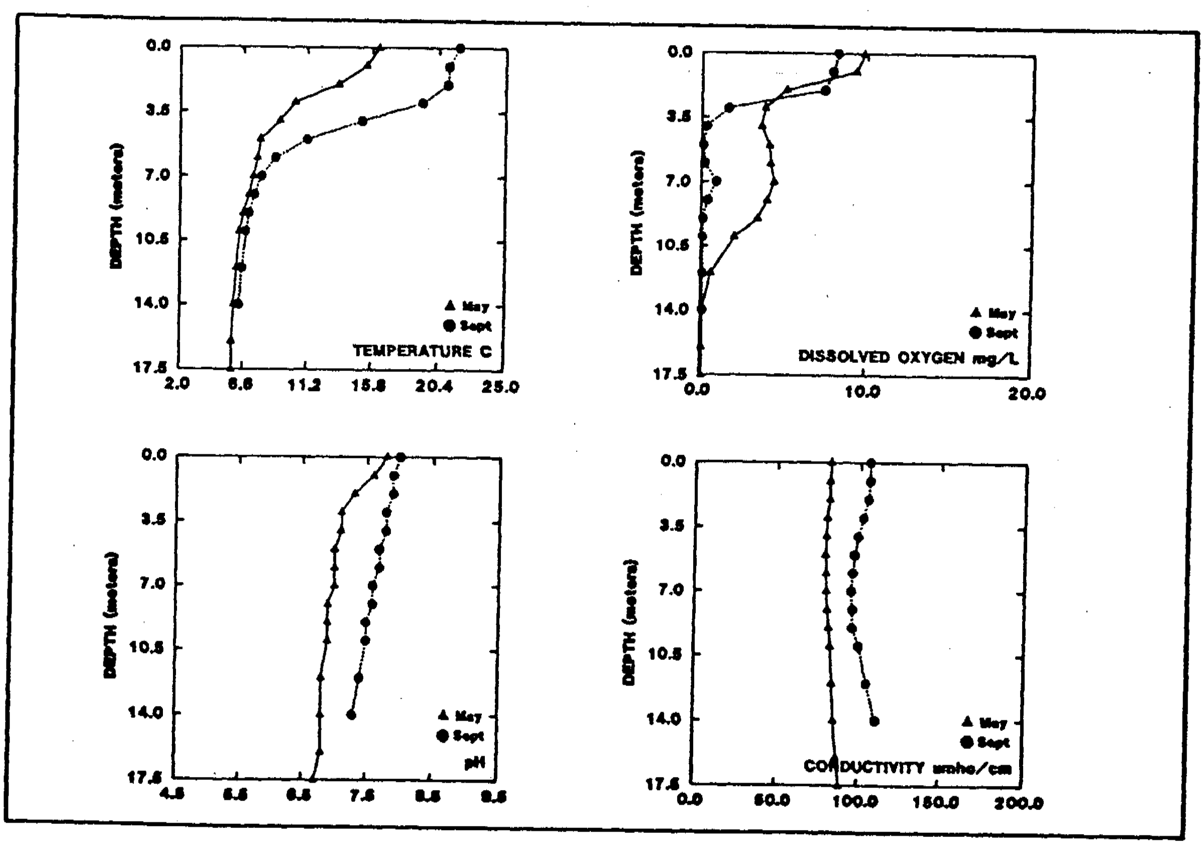
Other Thurston County lakes monitored for the program in 1992 are Long, North Pattison, and Ward. Of these, Long had the highest total phosphorus concentrations, although water clarity in both Long and St. Clair was very similar.

Acknowledgement

I thank M.E. Christopherson for volunteering his time to monitor Lake St. Clair from 1989-1992.

LAKE ST. CLAIR (THURSTON COUNTY)



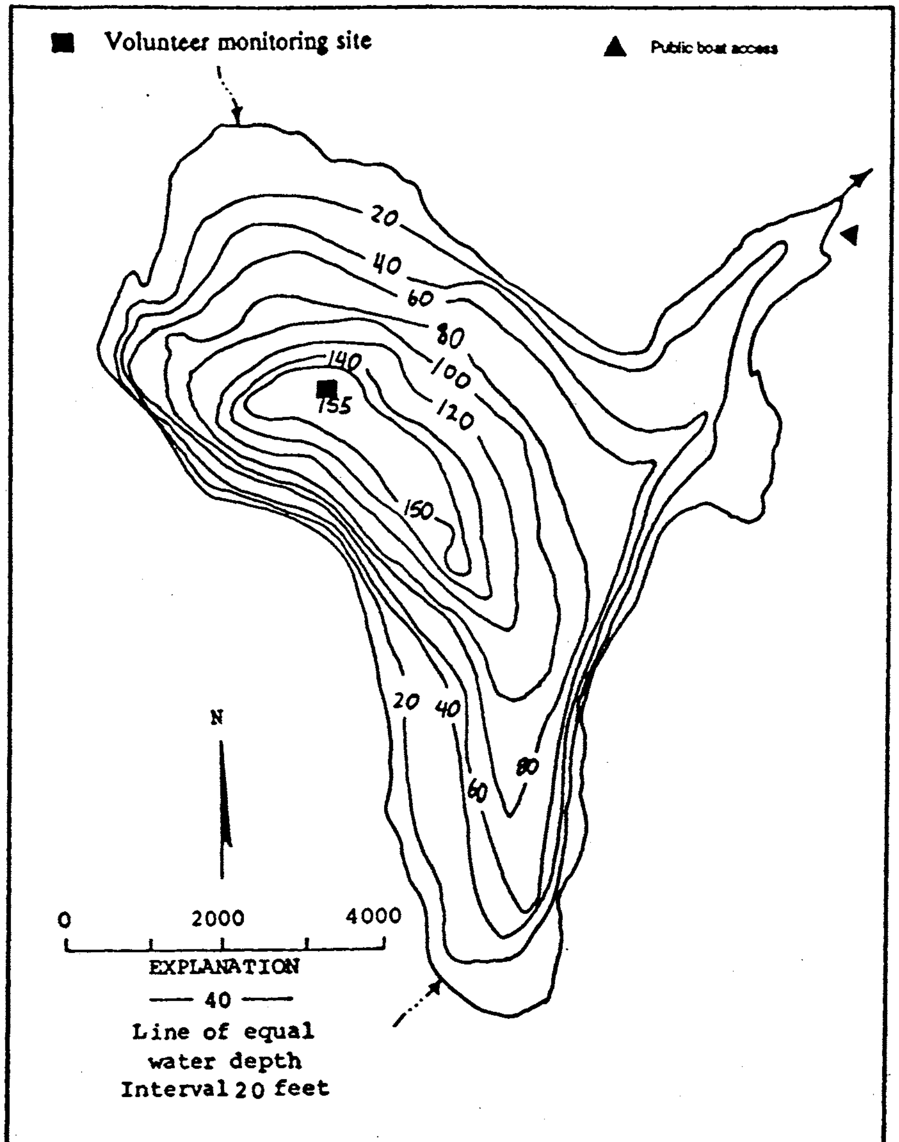


Lake Stevens – Snohomish County

Lake Stevens is located 5.5 miles east of Everett. It has several small inlets and drains via Lake Stevens Creek to Little Pilchuk Creek and the Pilchuk River.

Size (acres)	1,000
Maximum Depth (feet)	155
Mean Depth (feet)	63
Lake Volume (acre-feet)	65,000
Drainage Area (miles^2)	6.8
Altitude (feet)	210
Shoreline Length (miles)	7.1

Data From Bortleson *et al.* (1976)



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

Lake Stevens -- Snohomish County

1992 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	36
Mean Trophic State Index (Total Phosphorus):	40
Mean Trophic State Index (Chlorophyll *a*):	38

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
17-Jun	1820	21.0	69.8	12.5	-20.00	Green	10	None	Breezy	Lake is extremely low for this time of year. Green clumps of fine slimy patches floating.
05-Jul	1850	22.0	71.6	16.5		Gr-Brown	0	Light	Breezy	Free floating algae. Water improved since last sample.
26-Jul	1800	24.0	75.2	17.5	-26.00	Green	10	None	Breezy	Lake is extremely low. South end of lake is full of free floating algae, causing water to appear in spots.
10-Aug	1245	24.0	75.2	16.5	-26.00	Pea Green	0	None	Calm	Lots of brown algae floating on surface in big patches. Lake is extremely low.
18-Aug	1750	24.0	75.2	17.5	-27.00	Green	0		Calm	Lake is improving -- brown floating algae is slowly disappearing.
27-Aug	1730	22.5	72.5	20.5	-27.00	Green	0	None	Calm	Lake seems to be improving.
31-Aug				20.5						Onsite visit.
13-Sep	1100	18.0	64.4	20.5	-27.00	Green	50	Trace	Calm	
27-Sep	1620	17.0	62.6	15.5	-25.00	Gr-Brown	10	Moderate	Calm	Water was much cloudier than normal after the rains.
11-Oct	1545	16.0	60.8	20.5		Green	75	None	Calm	

[1] Trophic State Indices calculated from Carlson (1977)

Lake Stevens -- Snohomish County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
08/31	0.0	22.3	8.0	9.1	89
	1.0	21.9	8.0	9.2	88
	2.0	21.9	8.1	9.2	88
	3.0	21.8	8.1	9.2	89
	4.0	21.8	8.1	9.2	89
	5.0	21.8	8.1	9.2	88
	6.0	21.0	8.1	9.2	88
	7.0	18.9	8.1	9.6	86
	8.0	14.9	8.0	6.9	88
	9.0	13.0	8.0	6.0	87
	10.0	11.2	7.9	4.8	86
	14.0	8.5	7.8	3.5	86
	18.0	7.8	7.8	3.9	84
	22.0	7.6	7.7	4.3	84
	26.0	7.3	7.7	4.2	86
	30.0	7.3	7.6	3.6	84
	34.0	7.2	7.5	2.8	83
	38.0	7.1	7.5	1.4	83
	42.0	7.1	7.4	0.2	89
	44.0	7.0	7.3	0.1	96

1992 Onsite Visit Data - Water Chemistry

Date	08/31/92	
	Epilimnion	Hypolimnion
Composite Depths (m)	1, 3, 6	22, 26
Total Phosphorus (µg/L)	12	45
Total Nitrogen (mg/L)	0.33	0.60
Chlorophyll *a* (µg/L)	2.22	--

Lake Stevens -- Snohomish County

Historical Data From Ecology

Date	7/27/72[a]	06/06/90[b]	08/30/90[b]	06/18/91[c]
Secchi (ft)	17	23.5	21	17.5
Total Phosphorus, epilimnion (μg/L)	5	9	12	--
Total Nitrogen, epilimnion (mg/L)	--	0.36	0.35	0.37
Chlorophyll *a* (μg/L)	--	--	--	--
Dissolved Oxygen, surface (mg/L)	9.7	--	9.6	10.6
Dissolved Oxygen, bottom (mg/L)	3.5	--	3.7	3.8

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)

Lake Stevens -- Snohomish County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good in 1992, as indicated by Secchi depths which ranged from 12.5 to 20.5 feet. Although Secchi depths from 1992 were generally not as deep as those measured in 1991 and 1990, they were still deep and indicate that the lake was oligotrophic.

Total Phosphorus

Water samples were collected from Lake Stevens during August only. Total phosphorus in the epilimnion was low to moderate (12 μg/L), but was similar to concentrations measured for the program in 1990 (9 μg/L and 12 μg/L; Rector, 1991). Higher total phosphorus in the hypolimnion indicates that internal loading from the sediments was occurring.

Total Nitrogen

Total nitrogen in the lake was low (0.33 mg/L), and very similar to concentrations measured for the program in 1991 (0.37 mg/L; Rector, 1992) and 1990 (0.36 and 0.35 mg/L; Rector, 1991).

Profile Data

The lake was strongly stratified at the time of sampling. The slight increase in dissolved oxygen at seven meters (the start of the thermocline) probably resulted from increased solubility of oxygen in cooler water, but may have also been affected by increased algae growth at this depth. Below the thermocline, both pH and dissolved oxygen decreased with depth to the bottom of the lake. Low dissolved oxygen, and lower pH, probably resulted from the bacterial decomposition of aquatic plants and algae in the water and sediments.

Profile data from August 1990 were very similar to the August 1992 data.

Plants

Algal growth was low, as indicated by a low concentration of chlorophyll *a*. However, the volunteer commented throughout the monitoring season that algae were frequently visible in the water (see Volunteer-Collected Data). Despite localized algae growth throughout most of the summer, water clarity was very good.

Other Available Information

From Snohomish County Public Works (1991): Lake Stevens has had high nutrient concentrations, low water clarity, high growth of algae, and in deeper water, low concentrations of dissolved oxygen. The primary problem identified was the high concentrations of phosphorus in the water. The main source of the phosphorus was internal loading from the sediments, although runoff and groundwater were major outside sources. Studies of the lake were conducted in 1983 (Phase I) and 1987 (Phase IIa). In 1989 a watershed management plan was completed. The Final Environmental Impact Statement proposes to manage nutrient and sediment loading to the lake with nine capital improvement structures (to enhance water quality and habitat "by reducing erosion, providing sediment traps, promoting biofiltration and controlling the energy of streamflows"); a whole-lake alum treatment (to bind phosphorus in the sediments and prevent internal loading of phosphorus; and hypolimnetic aeration (to increase oxygen concentrations in deep water and help keep phosphorus in the sediments).

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

> Lake Stevens is used for fishing, swimming, motor boating, non-motorized boating, and jet skiing. There is a park on the lakeshore, and about 3 percent of the shoreline is publicly-owned. There are two public boat ramps, and there is a speed limit of 35 mph for motorboating. Currently, the watershed is used for logging, crop agriculture, animal grazing/feeding, and industry. The lakeshore is being developed further for residences. In the past, the watershed was used for logging, crop agriculture, and animal grazing/feeding. The lake was also dredged, and the shoreline altered (filled wetlands), in the past.
>
> There are 283 houses on the lakeshore, and about 100 of the houses are connected to a sewer. About 6 culverts/stormdrains drain into the lake. There is a lake management district for the lake.
>
> Overall, the volunteer finds that Lake Stevens had excellent water quality. Problems in the lake in 1992 were ranked as 1) algae, and 2) low water level. Possible sources of problems are runoff from farms and residential areas, and logging. In comparison to 1991, the lake level was extremely low in 1992. Also, plant growth seemed reduced compared to prior years; plants were listed as a problem in 1990 and 1991, but not in 1992.
>
> Wetlands are located at the north end of the lake, near the city boat launch, near a small cove on the east side, and at the south end. Submerged weeds are thick near these wetland areas. At the south end of the lake near the bridge, there are lily pads, and thick weeds and brush grow on the bank. Algae blooms are common in the south end of the lake during summer. Except for the wetland areas, the entire lakeshore is developed for residences.

Comments

Based on data collected for this program, all trophic state parameters (Secchi depth, total phosphorus, and chlorophyll *a*) indicate that Lake Stevens was oligotrophic. However, Lake Stevens exhibited some characteristics that are not indicative of oligotrophy. As noted in the

Lake Stevens -- Snohomish County

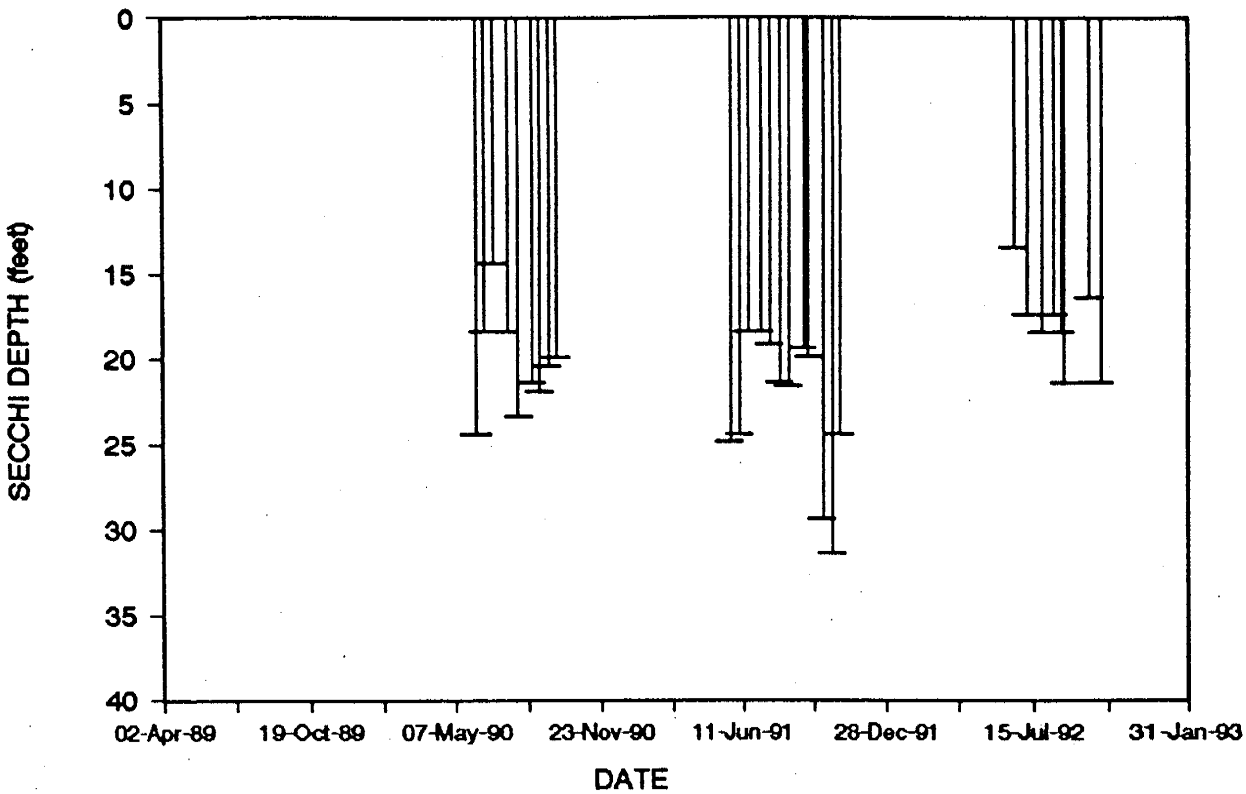
1991 data assessment, Lake Stevens has a history of very low dissolved oxygen during late summer/early fall, right before the lake turns over. At the time of sampling in late August 1992, oxygen was low throughout the hypolimnion (less than 5 μg/L). The higher total phosphorus in the hypolimnion indicates that oxygen was depleted from the sediments, which lead to the internal loading of phosphorus. These characteristics in the hypolimnion, and the algae growth reported by the volunteer from June through early August, suggest that Lake Stevens was more eutrophic than indicated by data collected for this program. This lake should be watched closely for changes in water quality, such as further deterioration, or improvements that may result from restoration efforts.

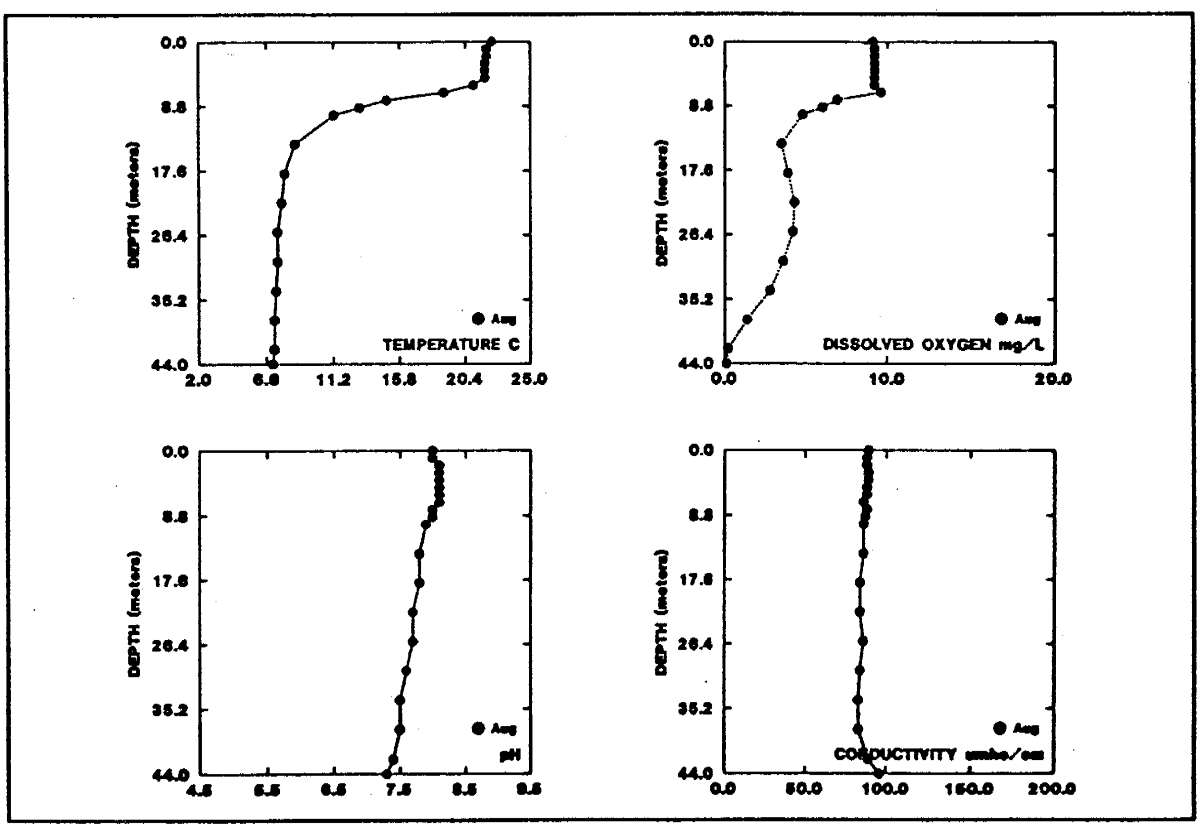
Lake Stevens is one of seven Snohomish County lakes monitored for the program in 1992. The other monitored lakes were Bosworth, Ketchum, Lake Martha, Martha Lake, Roesiger and Sunday. Of these, Lake Stevens had the best overall water clarity and Lake Roesiger had the lowest concentrations of total phosphorus. Lake Ketchum was characterized as eutrophic because of its extremeley high concentrations of total phosphorus and very prolific aquatic plant growth.

Acknowledgement

I thank Mark McCullough for volunteering his time to monitor Lake Stevens during 1990 - 1992.

LAKE STEVENS (SNOHOMISH COUNTY)





Sunday Lake -- Snohomish County

Sunday Lake is located five miles east of Stanwood. It drains southeast to the lower Stillaguamish River via Jackson Gulch. It has a marshy shoreline.

Size (acres)	46
Maximum Depth (feet)	20
Mean Depth (feet)	8
Lake Volume (acre-feet)	365
Drainage Area (miles²)	1.7
Altitude (feet)	211
Shoreline Length (miles)	1.3

Data From Bortleson *et al.* (1976)

Sunday Lake, Snohomish County. Bathymetric map from U.S. Geological Survey, July 27, 1973. Aerial photo, July 14, 1973.

Sunday Lake -- Snohomish County

1992 Trophic Status[1]

Estimated Trophic State:	Eutrophic
Mean Trophic State Index (Secchi):	48
Mean Trophic State Index (Total Phosphorus):	60
Mean Trophic State Index (Chlorophyll *a*):	48

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
06-May	0930	20.0	68.0	1.5	19.00	Pea Green	0	None	Calm	Numerous weeds.
21-Jun	0945	20.6	69.0	5.0		Gr-Brown	0	None	Calm	pH 7.0.
15-Jul	1000	18.3	65.0	9.5	19.50	Clear	0	Trace	Calm	pH 6.5.
27-Jul	1600	22.2	72.0	9.5	10.00	Clear	0	None	Breezy	Weeds abundant. pH 7.0.
30-Aug	1000	21.1	70.0	9.0	8.00	Lt-Brown	10	None	Light	Floating algae abundant.
12-Sep	1030	15.6	60.0	9.5	6.00	Lt-Green	25	Light	Light	Very low water.
27-Sep	1030	15.6	60.0	9.5	6.00	Lt-Brown	50	Light	Light	Beaver affecting water height.
11-Oct	1000	12.8	55.0	9.5	9.00	Lt-Brown	50	Trace	Light	Still very low water.

[1] Trophic State Indices calculated from Carlson (1977)

Sunday Lake -- Snohomish County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/18	0.0	21.5	9.6	13.2	82
	1.0	18.5	9.7	15.3	81
	2.0	16.2	8.7	9.7	75
	3.0	14.9	8.0	4.1	75
	4.0	13.8	7.7	0.6	79
	5.0	12.7	7.4	0.1	87
08/25	0.0	22.4	7.8	8.5	92
	1.0	21.5	7.7	8.0	91
	2.0	21.3	7.7	8.1	92
	3.0	20.4	7.6	3.6	94
	4.0	14.6	7.1	0.1	112
	4.5	14.9	6.8	0.1	144

1992 Onsite Visit Data - Water Chemistry

Date	05/18/92		08/25/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 1	4, 4	1, 2	4
Total Phosphorus (μg/L)	54	51	44	189
Total Nitrogen (mg/L)	0.96	0.78	0.74	1.20
Chlorophyll *a* (μg/L)	7.80	--	4.32	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	<1	--	<1	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	<1	--	<1	--
Total Suspended Solids (mg/L)	7	--	4	--
Total Nonvolatile Suspended Solids (mg/L)	1	--	1	--
Color (Pt-Co units)	60	--	40	--

Sunday Lake -- Snohomish County

Historical Data From Ecology

Date	7/26/73[a]	06/06/90[b]	08/28/90[b]	5/29/91[c]
Secchi (ft)	10	11	7	6.5
Total Phosphorus, epilimnion (μg/L)	18	151	71	--
Total Nitrogen, epilimnion (mg/L)	--	--	0.93	0.61
Chlorophyll *a* (μg/L)	--	--	--	--
Dissolved Oxygen, surface (mg/L)	8.8	10.1	10.6	10.6
Dissolved Oxygen, bottom (mg/L)	2.2	0.1	0.2	0.2

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)

Sunday Lake -- Snohomish County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was poor to fair, as indicated by Secchi depths which ranged from 1.5 to 9.5 feet. Secchi depths were in the same range from 1990-1992, with shallowest depths measured during May and June.

Total Phosphorus
Total phosphorus was high during both May (54 μg/L) and August (44 μg/L), and indicate that the lake was eutrophic. However, concentrations measured in 1992 were much lower than those measured in 1990 (151 μg/L in June and 71 μg/L in August; Rector, 1991). If the total phosphorus of 18 μg/L in 1973 (Bortleson *et al.*, 1976) was accurate and representative, it is likely that the eutrophication of the lake was accelerated by human activities.

Total Nitrogen
Total nitrogen was also high on both sampling dates (0.96 and 0.74 mg/L), but total nitrogen concentrations were high enough that algal growth was limited by the amount of phosphorus in the water.

Fecal Coliform Bacteria
No fecal coliforms were detected from the four samples collected from the lake.

Solids and Color
There was a lot of suspended material in the water on both sampling dates, particularly during May. Most of the suspended matter was likely due to algae (as opposed to sediments), which is confirmed by the low total nonvolatile suspended solids and very high chlorophyll values from both dates. The lake is also colored, and color appears to have increased since 1973, when color was 20 platinum-cobalt units (Bortleson *et al.*, 1976). The color of the lake may inhibit algal growth by reducing light penetration, which would explain why Secchi depths and chlorophyll *a* were better than would be expected given the high concentrations of total phosphorus.

Profile Data
Although the lake was not stratified with respect to temperature on either sampling date, water samples were collected from the bottom of the lake (called the "hypolimnion" sample in the table above) because pH and dissolved oxygen were very different at the surface in comparison to the bottom of the lake. The decreases in these parameters with depth, and the increase in conductivity with depth, most likely result from the bacterial decomposition of aquatic plants and algae in the water and sediments.

During May, the very high pH in the top two meters of water, and the spike in dissolved oxygen at one meter, were probably caused by prolific algae growth in the lake at the time of sampling.

Actively photosynthesizing algae will release oxygen into the water while taking carbon dioxide out of the water.

Plants

On both sampling dates, algal growth was moderately high to high, as indicated by the high concentrations of chlorophyll *a*.

Aquatic plants identified by Ecology staff during the May 18, 1992 onsite visit with the volunteer were yellow-flowering lily (*Nuphar polysepalum*), sedge (*Scirpus* spp.), cattails (*Typha* spp.), largeleaf pondweed (*Potamogeton amplifolius*), waterweed (*Elodea canadensis*), and coontail (*Ceratophyllum demersum*). The volunteer noted that there were more plants for the time of year, compared with earlier years. During the August 1992 onsite visit, algae were very abundant and ropey, and the yellow-flowering lily was starting to die off.

During the May 29, 1991 onsite visit with the volunteer, several macrophytes were observed in the lake, including yellow-flowering lily, sedge, cattails, waterweed, and coontail. Pieces of decomposing large-leaved pondweed were also observed near the dock. Small filaments of the blue-green alga *Aphanizomenon* were observed in open water. These filaments look like blue-green eyelashes or small grass blades. In 1973, there was a heavy cover of emergent plants (watershield, water lilies, and sedge) and submerged plants (*Chara* and *Elodea*; Bortleson *et al.*, 1976).

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

> Sunday Lake is used for fishing, boating, swimming and rowing. There is one boat ramp on the lakeshore, and electric motors only are allowed on the lake. About 5 percent of the shoreline is publicly-owned. Fish were not stocked in the lake. Currently the watershed is used for logging and crop agriculture, and the lakeshore is being developed further for residences. In the past the watershed was used for logging and animal grazing, and parts of the lake were dredged.
>
> There are 20 houses on the lakeshore, and none of the houses are connected to a sewer. There is one storm drain that empties into the lake. There is a community association for the lake. Currently, the minimum setback for development is 100 feet, and residential density is restricted to 1 house per 3 acres.
>
> Overall, the volunteer finds that Sunday Lake had poor water quality. Problems in the lake in 1992 were ranked as 1) gradually degrading water quality over the

years, 2) excessive aquatic plant growth, 3) algae, 4) decaying plants, 5) odor from decaying algae, 6) degraded aesthetics, 7) impaired fisheries, 8) suspended sediments, 9) recently degraded water quality, 10) fluctuating water level, 11) fish kills, 12) hazardous substances, 13) bacteria, 14) eye/skin problems after swimming, 15) swimmer's itch, 16) beach closure, and 17) shoreline erosion. Possible sources of problems are failing septic systems.

There are lots of lilies on the north shore in up to ten feet of water. There are wetlands on the east side of the lake near the outlet. Weed growth is heavy over the entire lake. The lake did not have algae blooms until the late 1970s. The lake has been chemically treated in the past to control weeds. The volunteer noted that the lake currently needs some sort of weed control.

Comments

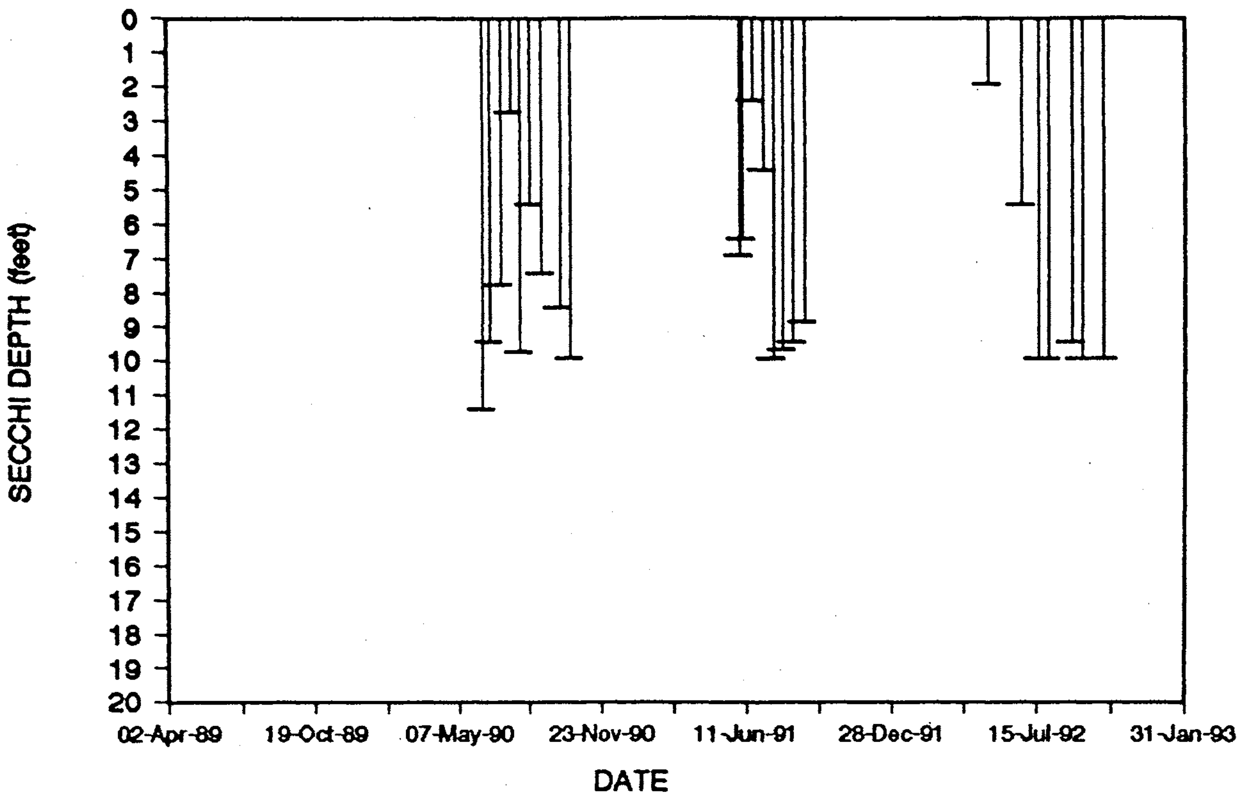
Although total phosphorus was lower in Sunday Lake during 1992 than in 1990, the lake was still eutrophic based on high nutrient concentrations, prolific plant and algal growth, and very low dissolved oxygen at the bottom of the lake.

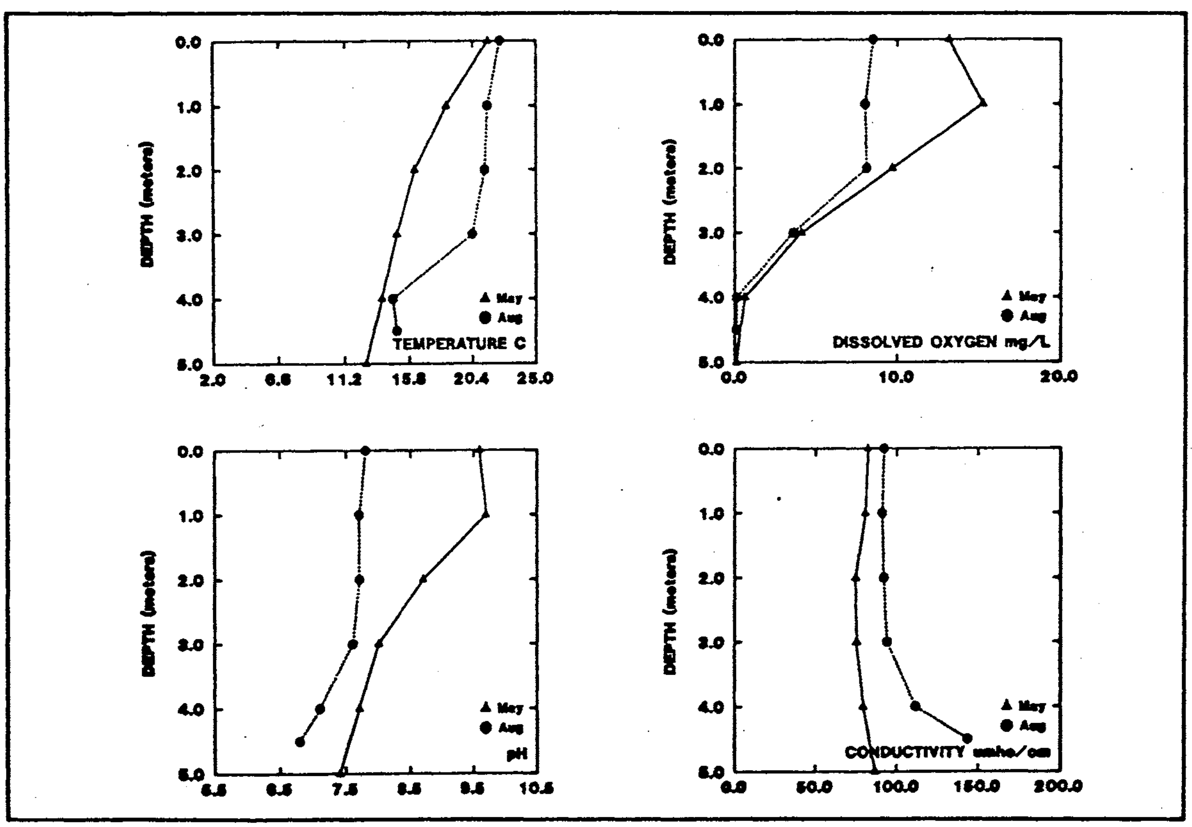
Other monitored Snohomish County lakes were Bosworth, Ketchum, Lake Martha, Martha Lake, Roesiger and Stevens. Of these, Lake Ketchum had the highest total phosphorus concentrations, the lowest water clarity, and the highest amount of algal growth (as indicated by chlorophyll *a* concentrations).

Acknowledgement

I thank Darryl Johnson for volunteering his time to monitor Sunday Lake during 1990 - 1992.

SUNDAY LAKE (SNOHOMISH COUNTY)



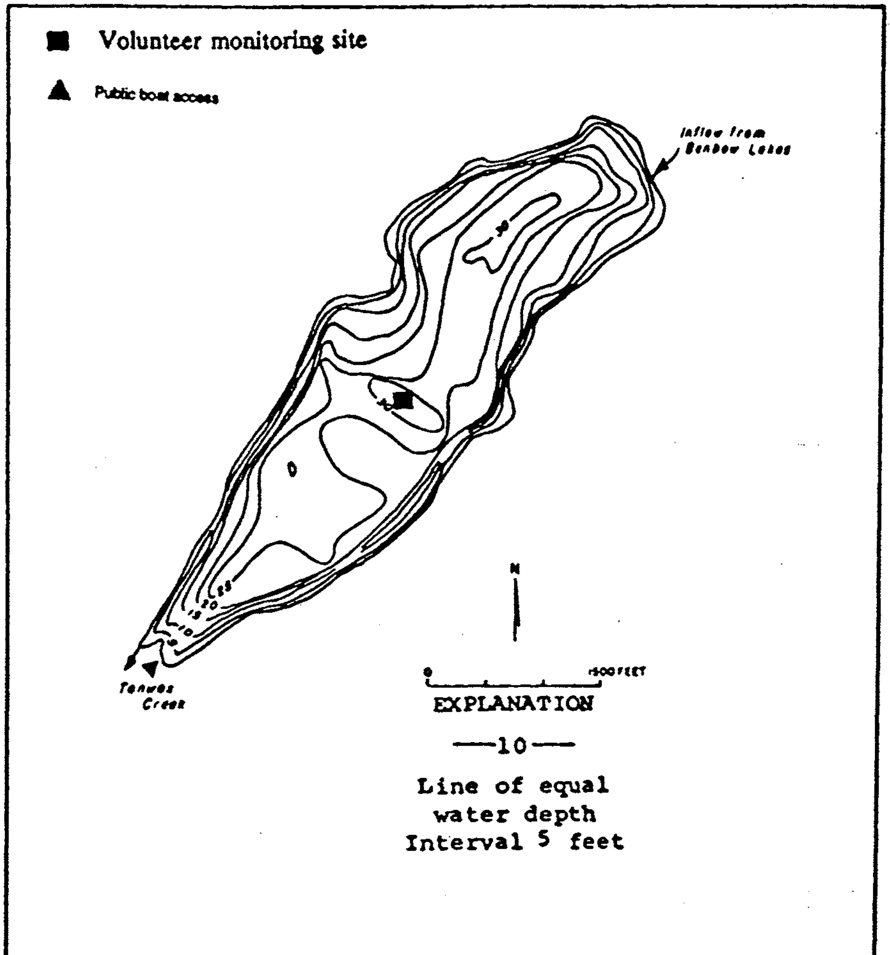


Tanwax Lake -- Pierce County

Tanwax Lake is located 5.5 miles north of Eatonville. It is fed by Byron Creek and Stidham Creek, and drains via Tanwax Creek to the Nisqually River.

Size (acres)	170
Maximum Depth (feet)	30
Mean Depth (feet)	20
Lake Volume (acre-feet)	3,300
Drainage Area (miles^2)	4.1
Altitude (feet)	600
Shoreline Length (miles)	2.8

Data From Bortleson *et al.* (1976)



Tanwax Lake, Pierce County. From Washington Department of Game, June 26, 1952.

Tanwax Lake -- Pierce County

1992 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	48
Mean Trophic State Index (Total Phosphorus):	52
Mean Trophic State Index (Chlorophyll *a*):	44

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
02-May				5.0						Onsite visit.
13-Jun	1600	16.7	62.0	5.6	-11.00	Gr-Brown	90	Moderate	Breezy	Lake height -- 0 is 18 inches from bottom.
12-Jun	1000	21.1	70.0	6.0	-11.00	Gr-Brown	0		Calm	Heavy skiing.
05-Jul	1100	22.2	72.0	6.0	-11.00	Gr-Brown	90	Heavy	Light	
27-Jul	1815	25.6	78.0	7.0	-11.00	Gr-Brown	0	None	Calm	Heavy skiing.
10-Aug	1155	22.2	72.0	7.0	-11.00	Gr-Brown	10	Moderate	Breezy	
12-Sep	1500	16.7	62.0	11.5		Gr-Brown	25	Light	Breezy	Water color brown and clear.
10-Oct	1525	17.8	64.0	8.0	-11.00	Gr-Brown	10	None	Calm	

[1] Trophic State Indices calculated from Carlson (1977)

Tanwax Lake -- Pierce County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/22	0.0	19.3	7.6	9.4	65
	1.0	18.3	7.5	9.7	65
	2.0	16.9	7.4	9.7	64
	3.0	16.2	7.3	9.3	64
	4.0	13.1	6.9	2.5	64
	5.0	11.5	6.8	0.4	70
09/04	0.0	20.8	8.0	7.8	81
	1.0	20.8	7.9	7.7	81
	2.0	20.8	7.8	7.6	81
	3.0	20.7	7.8	7.0	81
	4.0	16.9	7.5	0.1	94
	5.0	13.3	7.3	0.1	142
	5.5	12.5	7.2	0.1	156

1992 Onsite Visit Data - Water Chemistry

Date	05/22/92		09/04/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	0.5, 1	4, 4.5	1, 2	4.5
Total Phosphorus (μg/L)	30	30	26	37
Total Nitrogen (mg/L)	0.57	0.72	0.50	0.52
Chlorophyll *a* (μg/L)	1.65	--	6.46	--

Tanwax Lake -- Pierce County

Historical Data From Ecology

Date	08/26/74[a]	6/23/81[b]	06/11/90[c]	09/10/90[c]	06/02/90[d]	08/17/90[d]	05/19/91[e]
Secchi (ft)	7	4	4.3	4.6	5.5	7	4
Total Phosphorus, epilimnion (μg/L)	20	30	--	32	38	30	--
Total Nitrogen, epilimnion (mg/L)	--	--	0.56	0.87	0.61	0.64	0.85
Chlorophyll *a* (μg/L)	--	17.6	--	15.4	18.1	--	--
Dissolved Oxygen, surface (mg/L)	9.7	9.0	9.3	10.6	10.2	8.7	11.4
Dissolved Oxygen, bottom (mg/L)	0.3	0.3	8.1	0.2	0.1	0.1	2.7

a. Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Coots (1991)
d. Rector (1991)
e. Rector (1992)

Tanwax Lake -- Pierce County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was fair, as indicated by Secchi depths which ranged from 5.0 to 11.5 feet. The range of readings was similar to ranges from 1991 and 1990.

Total Phosphorus
Total phosphorus in the epilimnion was high on both sampling dates (30 μg/L in May, and 26 μg/L in September). These values were similar to those from samples collected by the Tacoma-Pierce County Health Department in April 1991 (27 μg/L; Tacoma-Pierce County Health Department, 1991a), as well as historical values from Ecology. All values reported since 1981 were in the eutrophic range.

Total Nitrogen
Total nitrogen was moderately high on both sampling dates (0.50 and 0.57 mg/L), but values were somewhat lower than concentrations measured in 1990 (0.61 mg/L in June and 0.64 mg/L in September; Rector, 1991) and May 1991 (0.85 mg/L; Rector, 1992). Values from 1992 and 1991 were lower than those measured by Tacoma-Pierce County Health Department in April 1991 (see Other Available Information, below).

Profile Data
On both sampling dates, the lake was weakly stratified with respect to temperature, and both pH and dissolved oxygen decreased with depth below the thermocline. Decreases in pH and dissolved oxygen probably resulted from bacterial decomposition of aquatic plants and algae in the water and sediments.

Plants
Algal growth was low during May, as indicated by the low concentration of chlorophyll *a* (1.65 μg/L). During September, though, chlorophyll was considerably higher (6.46 μg/L), though not nearly as high as values reported from 1990 (15.4 in June and 18.1 μg/L in September; Coots, 1991).

During the May 19, 1991 onsite visit with the volunteer, small suspended filaments of the blue-green alga *Aphanizomenon* were present in the water. Iris (*Iris pseudacorus*), water lilies (just emerging; species not readily evident) and cattails (*Typha* spp.) were also observed.

Other Available Information
From Tacoma-Pierce County Health Department (1990, 1991a, 1991b): The Tacoma-Pierce County Health Department collected samples from Lake Tanwax, its two inlets, and its outlet, in April and August 1990, and April and September 1991. Sample analysis was paid for by the Tanwax Lake Homeowners Association. Samples from April 1990 indicated that fecal coliforms ranged from 0 - 100 colonies/100 mL, with higher values in the tributaries. Samples from

August 22, 1990 indicated much higher values for fecal coliform bacteria (ranging from 25-1510 colonies/100 mL); the high value was from Tanwax Lake, at the mouth of Stidham Creek. Although the geometric mean of the lake samples did not violate the water quality standard for Lake Class waters, two of the six lake samples (33%) exceeded 100 colonies/100 mL. Water quality standards for Lake Class states that fecal coliforms shall not exceed a geometric mean of 50 colonies/100 mL, with not more than 10% of samples exceeding 100 colonies/100 mL. (This standard, though, is intended to apply to five or more samples collected within a one-month period.)

In 1991, nutrient samples and profile data were collected in addition to the fecal coliform bacteria samples. Although values were lower than those found in August 1990, higher values were still observed in the creeks and in the lake at the mouths of Stidham and Byron Creeks. Nutrient samples collected from mid-lake during April 1991 indicated that total phosphorus and total nitrogen were very high at the surface (65 μg/L total phosphorus and 1.3 mg/L total nitrogen), indicating that the lake was eutrophic. Stream data (collected from inlets only) also showed high values for total phosphorus (27 μg/L in both Stidham and Byron Creeks) and total nitrogen (0.74 mg/L in Byron Creek, and 0.99 mg/L in Stidham Creek). Samples from September indicated that fecal coliform bacteria ranged from 0-100 colonies/100 mL; the highest value was at the mouth of Byron Creek. Profile data from the open water site indicated that the lake was stratified, and dissolved oxygen was low ($<$2.0 mg/L) in the bottom 3 meters of the lake.

Summary of Questionnaire Results and Information From the Volunteer

The 1992 questionnaire on lake and watershed uses was not returned. The following are from the volunteer's remarks and responses to the 1990 questionnaire.

> Lake Tanwax is used for fishing, boating, swimming, rowing, jet skiing, camping, and waterfowl hunting. Recreational facilities on the lakeshore include a picnic area, a camping area, three resorts, and two boat ramps. There is a speed restriction of 8 mph for motorboats within 200 feet of shore. Currently the watershed is used for animal grazing and lakeshore development. In the past the watershed was used for logging and crop agriculture, and the shoreline was altered.
>
> There are 72 houses on the lakeshore; of these, 33 are occupied year-round. The lakeshore is not sewered, and there are storm drains that empty into the lake. A lake association was being formed. Fish were stocked in the lake. The lake has been chemically treated in the past to control undesirable fish species.
>
> In 1990, the worst problems in the lake were ranked as 1) water level, and 2) aquatic plants. Overall, the volunteer found that Lake Tanwax had excellent

recreational water quality, and suggested that septic systems, development, animals grazing in the watershed, burning of the hillside to clear land, fertilizers, and too many waterfowl may have affected water quality.

Resorts on the lake raise German brown trout and rainbow trout in pens. The lake receives heavy recreational use by water skiers and anglers. Stidham Creek drains from Stidham Lake into the northwest side of Lake Tanwax. There are wetlands near the main inlet and the outlet, where submerged plants are especially thick. Among the aquatic plants in the lake are cattails, water lilies (white, yellow and pink-flowering), and irises.

Comments

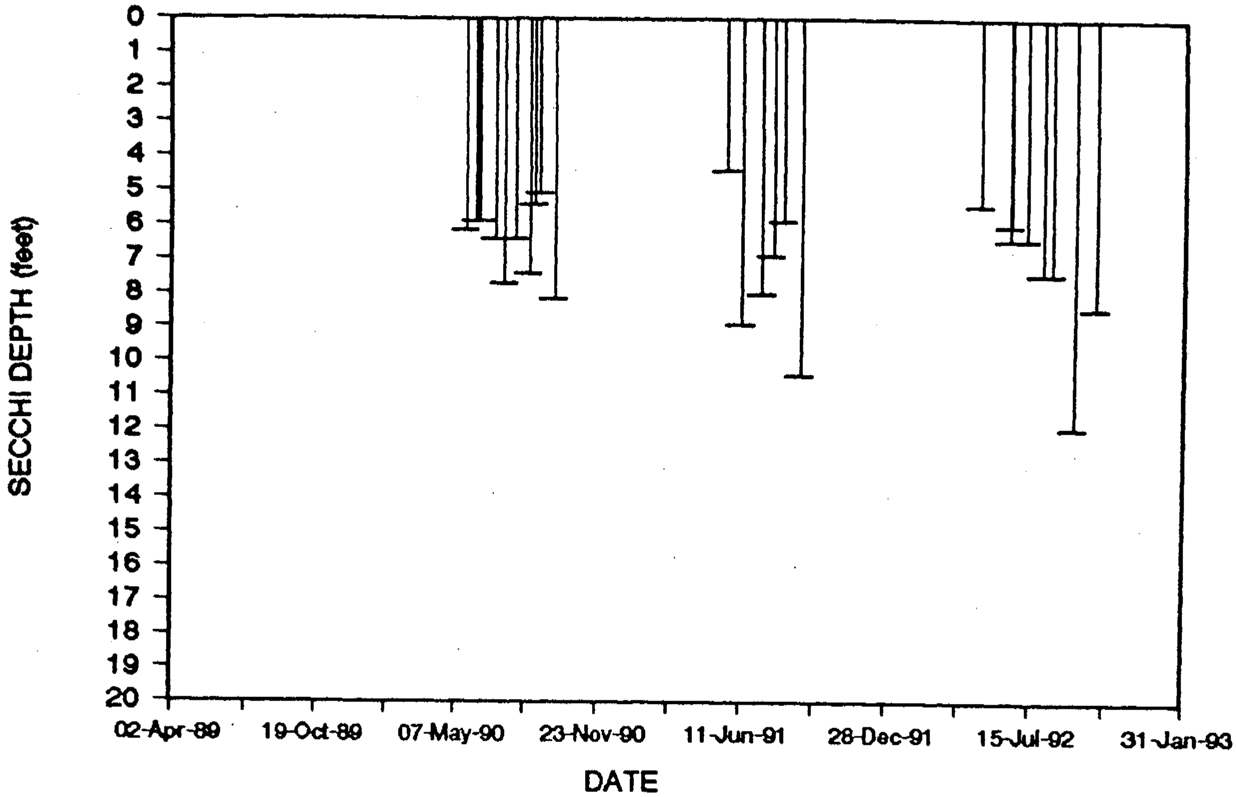
Tanwax Lake exhibited both mesotrophic and eutrophic characteristics. Mesotrophic characteristics were the low to moderate Secchi depths and the moderate amount of aquatic plant growth in the lake. Eutrophic characteristics were the high concentrations of total phosphorus on both sampling dates, the high chlorophyll *a* concentration in September, and the very low dissolved oxygen in the hypolimnion.

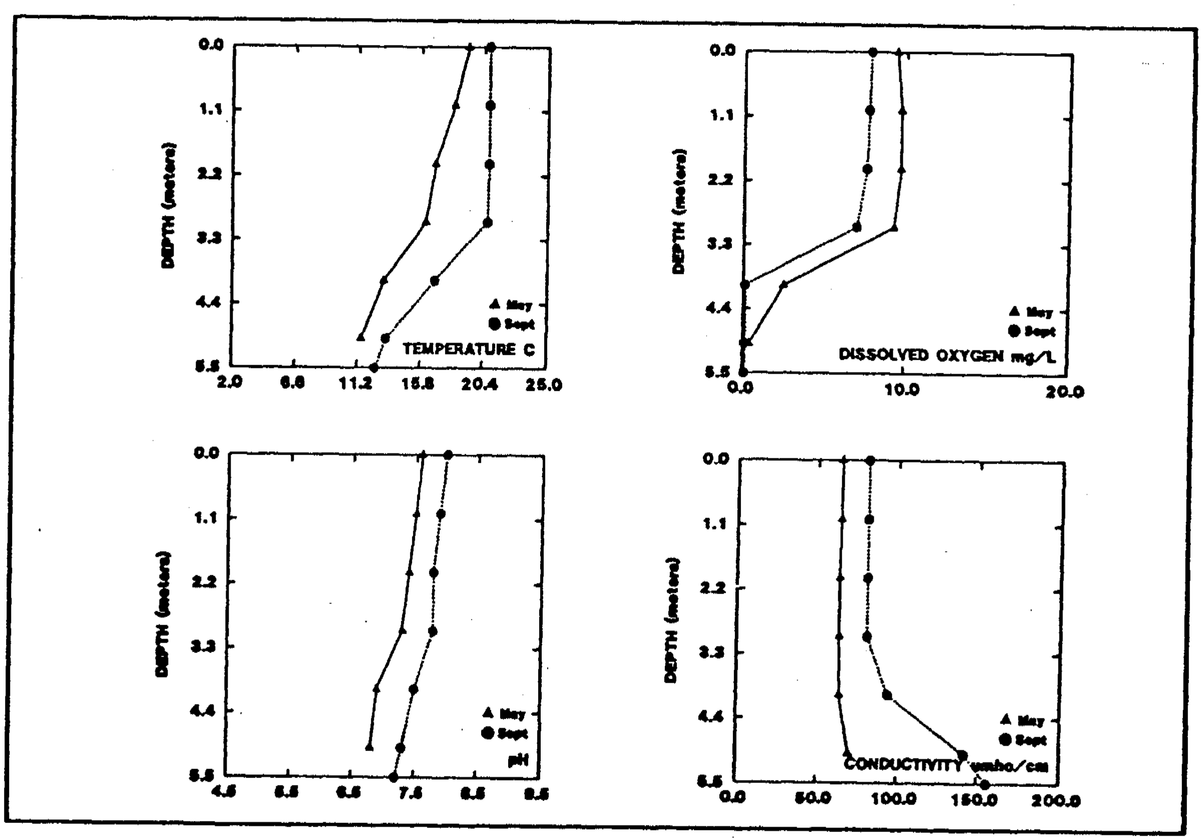
Lake Spanaway was the only other Pierce County lake monitored for the program in 1992. In comparison with Lake Spanaway, Lake Tanwax had higher total phosphorus, more algal growth, and lower water clarity.

Acknowledgement

I thank Marsha Erickson for volunteering her time to monitor Lake Tanwax during 1990 - 1992.

TANWAX LAKE (PIERCE COUNTY)



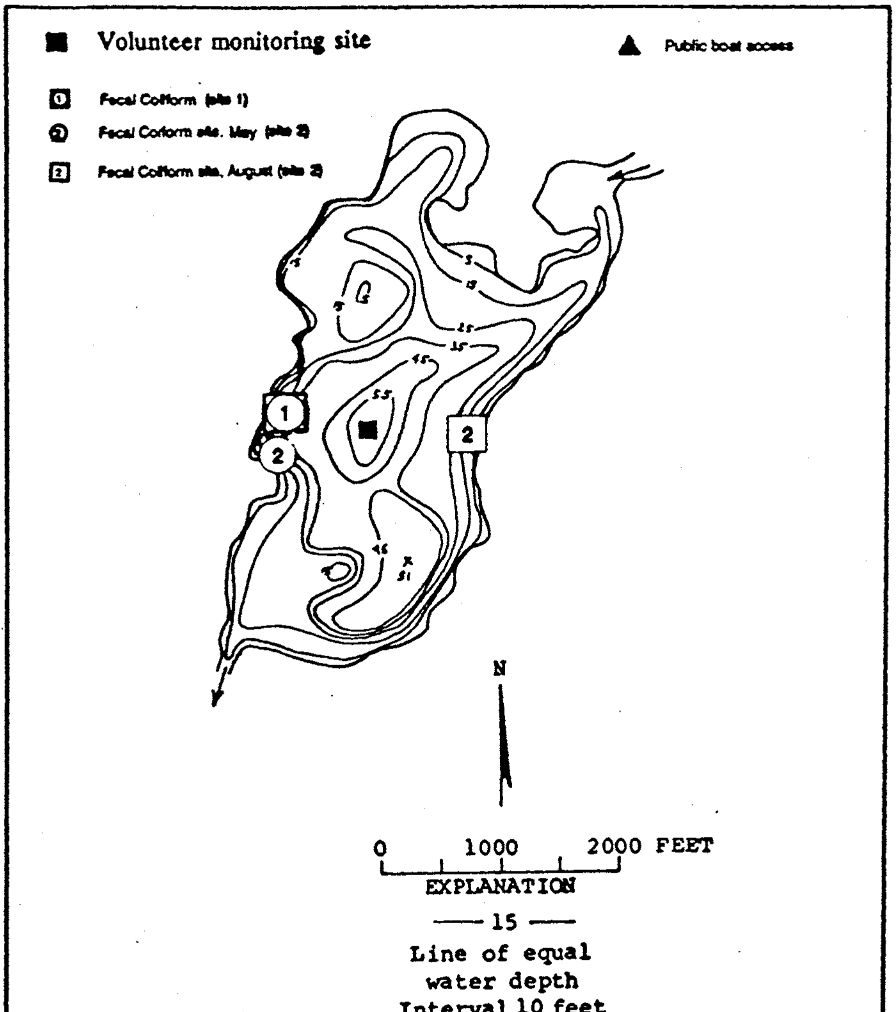


Lake Thomas -- Stevens County

Lake Thomas is located 17 miles northeast of Colville. Lake Thomas is in the Little Pend Oreille chain of lakes. It is fed by Heritage Lake via a narrow channel, and drains south to Gillette Lake and ultimately to the Little Pend Oreille River. There is no boat ramp on the lake, but it is accessible from the other lakes in the Little Pend Oreille chain.

Size (acres)	170
Maximum Depth (feet)	55
Mean Depth (feet)	23
Lake Volume (acre-feet)	4,000
Drainage Area (miles^2)	12.7
Altitude (feet)	3,147
Shoreline Length (miles)	3.3

Data From Dion *et al.* (1976)



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

Lake Thomas -- Stevens County

1992 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic[2]
Mean Trophic State Index (Secchi):	37
Mean Trophic State Index (Total Phosphorus):	36
Mean Trophic State Index (Chlorophyll *a*):	38

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
11-May	1215	13.4	56.1	14.0	0.00	Yellow-Gr	90	None	Light	Lake height 4" below 1991 base level. Start at 0 this year. Preshrunk line put on Secchi disk. Snow quail sighted.
30-May	1055	17.8	64.0	14.3	-0.75	Yellow-Gr	25		Breezy	
10-Jun	1015	17.8	64.0	16.0	-3.50	Yellow-Gr	0	Trace	Breezy	
30-Jun	1030	22.2	72.0	14.5	-2.50	Yellow-Gr	50	Heavy	Calm	Extremely hot weather followed by 24h heavy rains.
14-Jul	1230	19.4	67.0	15.0		Yellow-Gr	75	Trace	Breezy	
28-Jul	1010	21.7	70.0	15.0	0.0	Yellow-Gr	100	None	Light	Overcast.
11-Aug	1354	23.3	74.0	15.5	-10.63	Yellow-Gr	0	None	Light	Water color light yellow-green. Vandalism on dam - reported 8/5/92.
25-Aug	1231	17.8	64.0	18.3	-13.13	Yellow-Gr	0	Light	Breezy	Water color light yellow-green. Heavy rain on Saturday with minimum temp of 35 degrees.
27-Aug				17.0						Onsite visit.
09-Sep	1336	16.1	61.0	15.0	-14.88	Yellow-Gr	0	None	Light	Forgot to note that leeches apparent before 8/25/92.
22-Sep	1223	15.6	60.0	22.0	-16.00	Lt-Yellow	0	None	Calm	Water color light yellow. Note lake height; more vandalism at the dam!

[1] Trophic State Indices calculated from Carlson (1977)

[2] see Comments section

Lake Thomas -- Stevens County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/11	0.0	13.4	7.0	9.7	58
	1.0	13.4	7.2	9.6	58
	2.0	13.4	7.3	9.6	58
	3.0	13.4	7.4	9.6	58
	4.0	10.5	7.3	9.8	58
	5.0	8.7	7.2	6.8	59
	6.0	7.5	7.0	4.2	60
	8.0	6.9	6.9	3.0	60
	10.0	6.3	6.9	2.2	61
	12.0	6.1	6.8	1.7	61
	14.0	6.1	6.8	1.4	62
	15.5	7.0	6.8	1.3	62
08/27	0.0	18.2	7.7	8.2	60
	1.0	18.2	7.7	8.0	59
	2.0	18.1	7.6	8.0	60
	3.0	18.1	7.6	8.0	59
	4.0	18.0	7.5	7.8	59
	5.0	17.4	7.4	6.2	60
	6.0	13.9	7.0	0.2	62
	7.0	11.2	7.0	0.1	63
	8.0	9.0	6.9	0.1	62
	9.0	7.9	6.9	0.1	63
	10.0	7.4	6.9	0.0	69
	12.0	7.1	6.9	0.0	74

Lake Thomas -- Stevens County

1992 Onsite Visit Data - Water Chemistry

Date	05/11/92		08/27/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	6, 10, 14	1, 2.5, 4	7, 8.5, 10
Total Phosphorus (μg/L)	13	16	5	36
Total Nitrogen (mg/L)	0.33	0.30	0.28	0.33
Chlorophyll *a* (μg/L)	3.10	--	1.10	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	1	--	1	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	<1	--	<1	--
Total Suspended Solids (mg/L)	2	--	1	--
Total Nonvolatile Suspended Solids (mg/L)	<1	--	--	--
Color (Pt-Co units)	25	--	20	--

Historical Data From Ecology

Date	08/16/72[a]	07/15/81[b]	05/25/90[c]	09/10/90[c]	06/13/91[d]
Secchi (ft)	14	12	--	13.7	--
Total Phosphorus, epilimnion (μg/L)	27	20	11	7	--
Total Nitrogen, epilimnion (mg/L)	--	0.69	0.29	0.27	0.21
Chlorophyll *a* (μg/L)	2.1	3.0	--	--	--
Dissolved Oxygen, surface (mg/L)	8.1	8.6	11.1	8.1	8.9
Dissolved Oxygen, bottom (mg/L)	0.2	0.2	0.4	0.0	0.1

a. Dion *et al.* (1976), Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)

Lake Thomas -- Stevens County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Secchi depths ranged from 14.0 to 22.0 feet. In general, Secchi depths gradually increased throughout the course of the monitoring season. This same pattern in Secchi depths has been documented since 1989. Water clarity in Lake Thomas was good, and was better in 1992 than in 1989-1991.

Total Phosphorus
Total phosphorus in the epilimnion was moderate during May (13 μg/L), and low during August (5 μg/L). These values were very similar to results from 1990 (11 μg/L in May and 7 μg/L in September; Rector, 1991). Data from 1981 and 1972, though, indicate that the lake has had moderately high concentrations of total phosphorus. Total phosphorus was 20 μg/L in July 1981 (Sumioka and Dion, 1985), and 27 μg/L in August 1972 (Dion *et al.*, 1976).

Total Nitrogen
Total nitrogen was very low on both sampling dates (0.33 mg/L in May, and 0.28 mg/L in August). Although results were higher than the concentration measured in June 1991 (0.21 mg/L; Rector, 1992), the values were similar to results from 1990 (0.29 mg/L in May and 0.27 mg/L in September; Rector, 1991). These slight variations are not likely to affect water quality.

Fecal Coliform Bacteria
Results from four samples were very low and within state standards; in fact, no fecal coliforms were detected from two of the samples collected.

Solids and Color
Solids and color samples were collected to evaluate whether suspended sediments or natural color were affecting Secchi depths. Results indicate that suspended solids in the water were very low on both sampling dates, but the lake has some natural color. Despite some water color, Secchi values were in the range expected, given the nutrient concentrations in the lake.

Profile Data
On both sampling dates, the lake was stratified with respect to temperature. Below the thermocline, dissolved oxygen decreased considerably with depth. This was particularly apparent during August, when oxygen was very low (0.2 mg/L or less) in the bottom 6 meters of the lake. Oxygen can be depleted from the hypolimnion by bacteria which decompose aquatic plants and algae in the water and sediments. Very low dissolved oxygen in the hypolimnion also occurred in 1972, so this was not a recent phenomena.

Plants
Algal density was moderately high during May, as indicated by a moderately high concentration of chlorophyll *a*. During August, algal density/chlorophyll was very low.

Lake Thomas -- Stevens County

Aquatic plants identified by Ecology staff during the May 11, 1992 onsite visit with the volunteers were yellow-flowering lily (*Nuphar polysepalum*) and muskgrass (*Chara*). During the June 13, 1991 onsite visit with the volunteers, yellow-flowering lily was budding, and cattails were observed along the shoreline. During the September 1990 onsite visit with the volunteer, pondweed (*Potamogeton praelongus*), Eurasian watermilfoil (*Myriophyllum spicatum*), and white-flowering lily (*Nymphaea* spp.) were identified during the visit. Also, the alga *Nitella* was identified.

During the August 1992 onsite visit, a few freshwater jellyfish (*Craspedacusta sowerbii*) were seen. Freshwater jellyfish were also observed by the volunteer during September 1991, and during the September 1990 onsite visit. Freshwater jellyfish are relatively rare, and Lake Thomas was the only volunteer-monitored lake in which they were observed.

In 1972, watershield (*Brasenia schreberi*) was the dominant aquatic plant in the lake (Bortleson *et al.*, 1976). Other plant species identified in 1972 included burreed (*Sparganium* sp.), white water lily, yellow water lily, muskgrass, nitella, and five species of pondweed. About 26 to 50% of the shoreline was covered with aquatic plants.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

> Lake Thomas is used for fishing, boating, swimming, rowing, jet skiing, and camping. There is a U.S. Forest Service campground on the lakeshore. There are no restrictions for motorboat use on the lake. About 3 percent of the shoreline is publicly-owned. Cutthroat trout were stocked in the lake. Stevens County passed a phosphorus ban for detergents in 1991.
>
> There are 72 houses on the lakeshore, and none of the houses are connected to a sewer. There is no lake association for the lake. Currently the watershed is being logged, and the lakeshore is being developed further for residences. In the past, logging and mining were occurring in the watershed, and the shoreline was altered. The lake was treated with chemicals in the past to control undesirable fish species.
>
> Overall, the volunteer finds that Thomas Lake had good water quality. The worst problem in the lake in 1992 was low water level. Possible sources of potential problems are pollutants from boat engines, and garbage from boats. There were no changes in the water quality of the lake since the 1991 monitoring season. However, the volunteers noted that the outlet weir to the lake was vandalized on (or around) August 5, 1992, and as a result, the lake level decreased 10 inches from July 28 to August 11 (see lake levels reported by the volunteers).

Lake Thomas -- Stevens County

Water lilies and submerged plants grow along the majority of the western and northern shores of the lake. Reeds and partially submerged plants grow in shallow areas of the northwest end of the lake. Submerged plants are especially thick near the inlet and outlet. There is a wetland at the northwest cove of the lake.

Comments

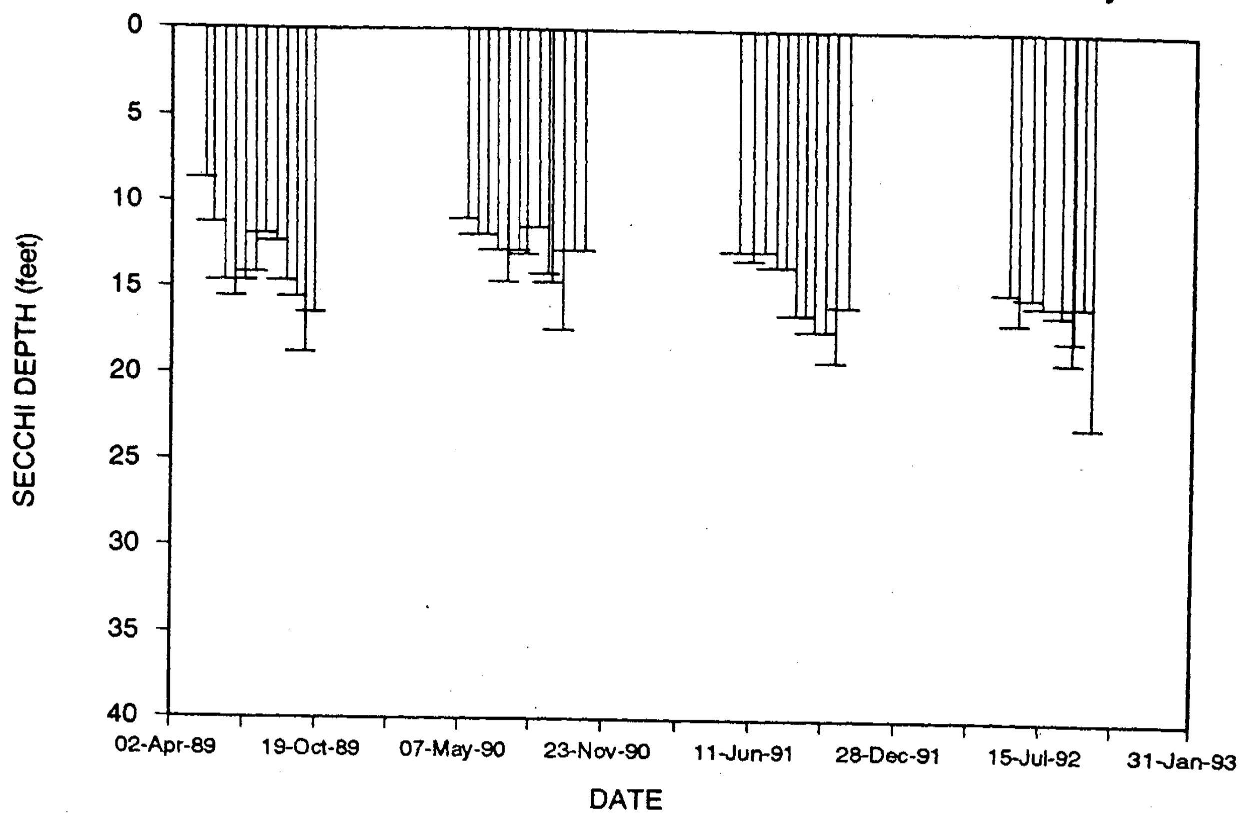
Although all three trophic state parameters (Secchi depth, total phosphorus, and chlorophyll *a*) indicate that Lake Thomas was oligotrophic, the lake had other characteristics which suggest that the lake was in a more advanced trophic state. These characteristics were the very low dissolved oxygen in the hypolimnion, and the presence of Eurasian watermilfoil. Based on these, the lake was again characterized as oligo-mesotrophic.

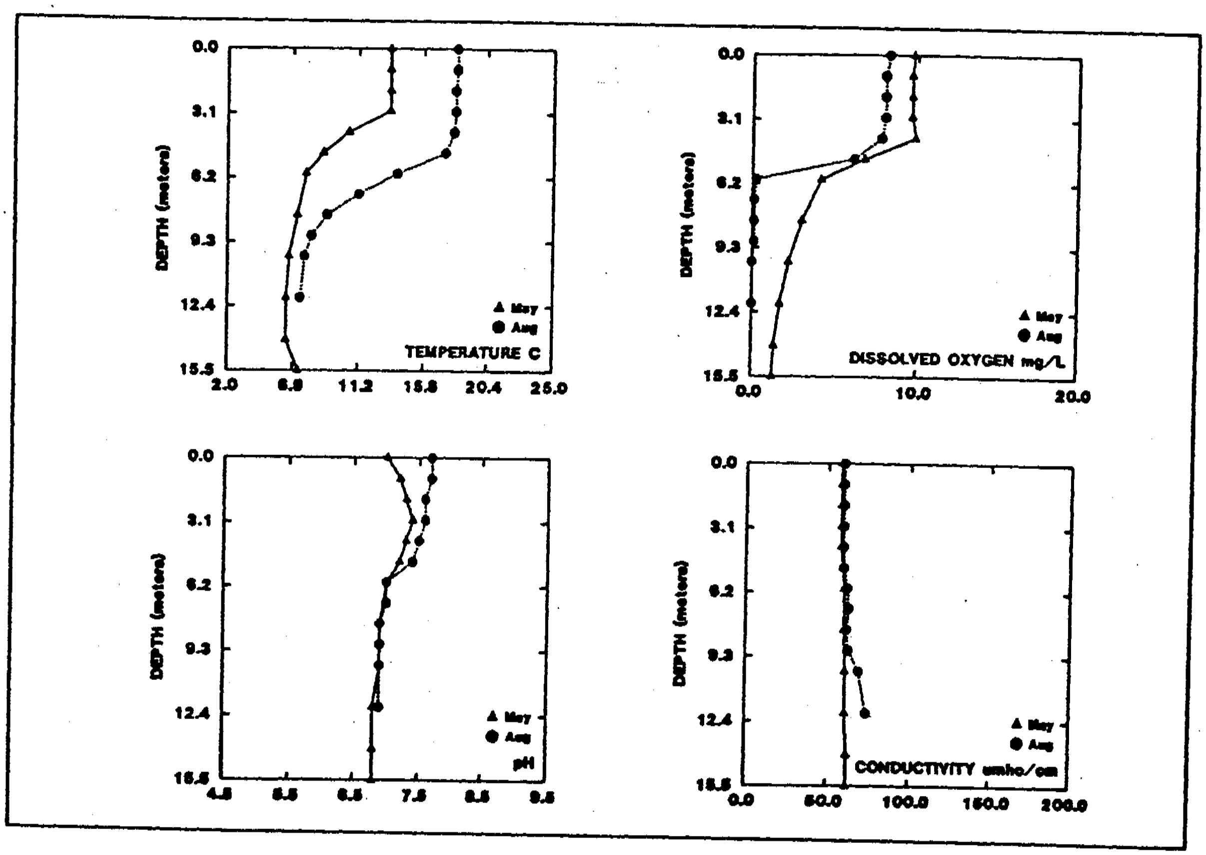
Although milfoil is not abundant in Lake Thomas, it is abundant near the boat ramp on Lake Gillette, the lake immediately downstream in the chain of lakes. Lake Leo, which is upstream of Lake Thomas in the chain of lakes and was also monitored for the program, did not appear to have milfoil in 1991 or 1992.

Acknowledgements

I thank Ray Hawk and Robert Strauss for volunteering their time to monitor Lake Thomas during 1989-1992.

LAKE THOMAS (STEVENS COUNTY)



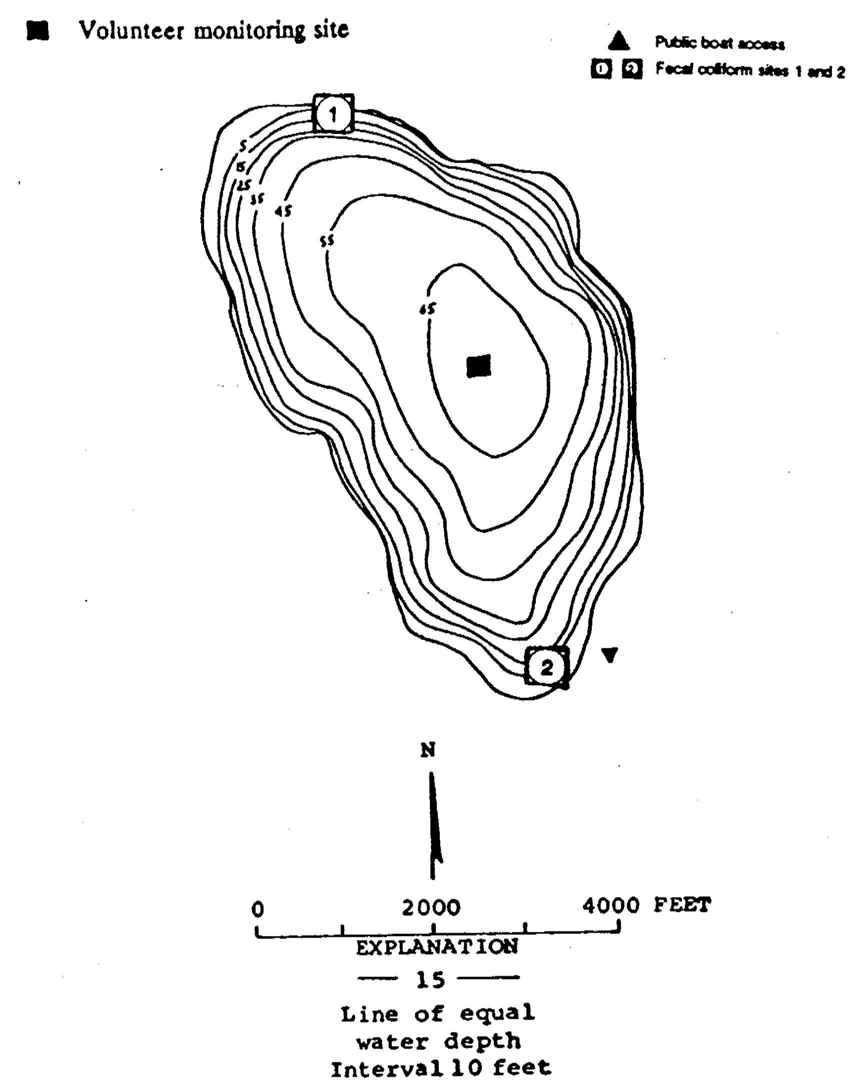


Waitts Lake -- Stevens County

Waitts Lake is located seven miles south of Chewelah, and 2.5 miles west of Valley. It is a reservoir stabilized by a low dam built in 1927. It is fed by two creeks and drains east via an unnamed creek about two miles to the Colville River.

Size (acres)	472
Maximum Depth (feet)	68
Mean Depth (feet)	40
Lake Volume (acre-feet)	18,784
Drainage Area (miles²)	11.7
Altitude (feet)	1,946
Shoreline Length (miles)	3.3

Data From Dion *et al.* (1976)



Waitts Lake, Stevens County. From Washington Department of Game, February 9, 1954.

Waitts Lake -- Stevens County

Waitts Lake is located seven miles south of Chewelah, and 2.5 miles west of Valley. It is a reservoir stabilized by a low dam built in 1927. It is fed by two creeks and drains east via an unnamed creek about two miles to the Colville River.

Size (acres)	472
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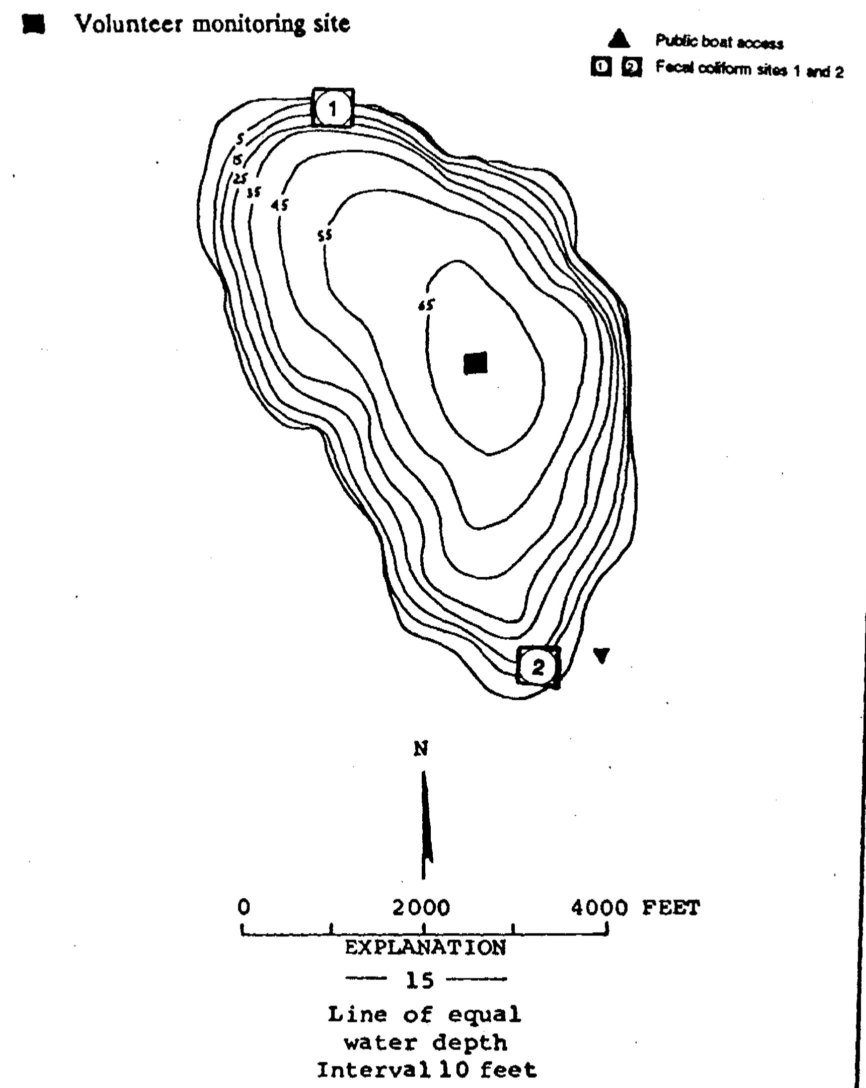


Waitts Lake, Stevens County. From Washington Department of Game, February 9, 1954.

Waitts Lake -- Stevens County

1992 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	35
Mean Trophic State Index (Total Phosphorus):	41
Mean Trophic State Index (Chlorophyll *a*):	34

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
02-Mar	0923	1.1	34.0	8.0		Green	100	Moderate	Calm	
14-Mar	1034	4.4	40.0	13.0	16.00	Lt-Green	10	None	Calm	
12-May		14.2	57.6	20.0	25.25	Lt-Green	10	Light	Calm	Onsite visit. Second reading 22' with view tube.
19-May	0930	13.3	56.0	22.0	26.00	Lt-Green	0		Light	
02-Jun	0845	17.8	64.0	14.0	27.00	Green	10	None	Breezy	Lots of floaties. Algae?
16-Jun	1619	18.9	66.0	10.0	27.37	Lt-Green	25	Heavy	Breezy	
30-Jun	0900	22.2	72.0	18.0	27.19	Gr-Brown	0	Heavy	Calm	Light lake turnover last week.
14-Jul	0848	20.0	68.0	23.5	28.00	Lt-Green	0	Trace	Light	Heavy rains in past two weeks.
28-Jul	0821	21.1	70.0	22.0	28.75	Gr-Brown	10	None	Calm	
18-Aug	0845	22.2	72.0	18.0	32.50	Milky-Gr	0	None	Calm	
25-Aug				17.0						Onsite visit.
08-Sep	0925	16.1	61.0	19.1	36.06		10	Trace	Calm	Water color moderately green/black. Lake height is lowest I've ever seen.

[1] Trophic State Indices calculated from Carlson (1977)

Waitts Lake -- Stevens County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/12	0.0	14.2	8.2	10.9	256
	1.0	14.3	8.6	10.8	258
	2.0	14.3	8.7	10.8	259
	3.0	14.1	8.7	10.8	258
	4.0	13.9	8.8	10.5	258
	5.0	11.5	8.7	11.0	259
	6.0	8.8	8.3	9.2	262
	7.0	7.5	8.1	7.8	262
	8.0	7.1	8.0	6.3	263
	10.0	6.0	7.8	1.8	261
	12.0	5.2	7.7	0.3	261
	14.0	4.8	7.7	0.1	263
	16.0	4.7	7.6	0.1	264
08/25	0.0	19.9	8.4	8.5	258
	1.0	20.0	8.4	8.4	258
	2.0	20.0	8.5	8.4	258
	3.0	20.0	8.5	8.4	258
	4.0	20.0	8.5	8.4	258
	5.0	20.1	8.5	8.4	258
	6.0	20.1	8.5	8.3	258
	7.0	20.0	8.5	7.5	259
	8.0	11.9	8.0	3.2	285
	9.0	10.0	7.8	0.6	285
	10.0	8.9	7.7	0.2	282
	11.0	7.7	7.7	0.2	277
	12.0	6.8	7.7	0.1	275
	14.0	5.5	7.7	0.1	275
	16.0	5.2	7.6	0.1	282

Waitts Lake -- Stevens County

1992 Onsite Visit Data - Water Chemistry

Date	05/12/92		08/25/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	8, 10, 12	2, 4, 6	10, 12, 14
Total Phosphorus (μg/L)	16	28	10	34
Total Nitrogen (mg/L)	0.48	0.48	0.46	0.65
Chlorophyll *a* (μg/L)	0.77	--	2.08	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	<1	--	1	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	<1	--	2	--
Total Suspended Solids (mg/L)	2	--	2	--
Total Nonvolatile Suspended Solids (mg/L)	1	--	<1	--
Color (Pt-Co units)	20	--	10	--

Historical Data From Ecology

Date	07/08/74[a]	07/14/81[b]	06/26/90[c]	09/25/90[c]	08/09/90[d]	6/10/91[e]
Secchi (ft)	15	17	13.8	24.6	19	11
Total Phosphorus, epilimnion (μg/L)	17	20	10	8	16	--
Total Nitrogen, epilimnion (mg/L)	--	0.70	0.41	0.40	0.47	0.40
Chlorophyll *a* (μg/L)	--	1.5	1.7	7.5	--	--
Dissolved Oxygen, surface (mg/L)	8.9	9.6	10.2	9.6	8.9	10.1
Dissolved Oxygen, bottom (mg/L)	0.0	0.2	0.1	0.2	0.2	0.1

a. Dion *et al.* (1976)
b. Sumioka and Dion (1985)
c. Coots (1991)
d. Rector (1991)
e. Rector (1992)

Waitts Lake -- Stevens County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Secchi depths were deep throughout most of the monitoring season, ranging from 10.0 to 23.5 feet, but did not exhibit the same general pattern that was documented in 1991 and 1990. During those two years, Secchi depths gradually increased from May through October. In 1992, though, Secchi depths during May were better than they were the previous two years.

Total Phosphorus

Total phosphorus in the epilimnion was moderately high during May (16 μg/L), and low during August (10 μg/L). Values were very close to those measured in 1990 (10 μg/L in June and 16 μg/L in August; Rector, 1991).

Total Nitrogen

Total nitrogen was low to moderate on both sampling dates (0.48 and 0.46 mg/L). Values were very similar to those measured in 1990 and 1991.

Fecal Coliform Bacteria

Results from all samples were very low and within state standards.

Solids and Color

Results indicated that there were very few suspended solids at the time of sampling. This indicates that Secchi depths were most likely related to algal density at the time of sampling, as opposed to suspended sediments. Although the lake has some natural color, it does not appear that color was affecting water clarity, because Secchi depths were in the range expected given the concentrations of nutrients.

Profile Data

On both sampling dates, the lake was stratified with respect to temperature. Below the thermocline, dissolved oxygen decreased considerably with depth. Dissolved oxygen was particularly low in the hypolimnion during August, when oxygen was 0.2 mg/L or less in the bottom 6 meters of the lake. Oxygen can be depleted by bacterial decomposition of aquatic plants and algae in the water and sediments.

Plants

Algal density was low on both sampling dates, as indicated by low concentrations of chlorophyll *a*. Lower Secchi depths and the volunteer's comments of suspended solids in the water ("floaties") indicate that algal density probably increased during early June.

During the May 1992 onsite visit, muskgrass (*Chara*), Illinois pondweed (*Potamogeton illinoinsis*), and milfoil (not the aggressive Eurasian species) were observed. During the August 1990 onsite visit with the volunteer, Illinois pondweed, and nitella (an alga; *Nitella*) were observed.

Waitts Lake -- Stevens County

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

> Waitts Lake is used for fishing, swimming, boating, jet skiing, and waterfowl hunting. There is one public boat ramp, and there are no restrictions for motorboating in the lake. About 2 percent of the shoreline is publicly-owned. Rainbow and German brown trout were stocked in the lake. Currently, the watershed is used for logging and animal grazing/feeding. In the past, the watershed was used for logging, crop agriculture, and animal grazing/feeding. The shoreline has been altered, and the southeast end of the lake was filled in the 1950's for a housing development.
>
> There are about 60 houses on the lakeshore, and none of the houses are connected to a sewer. There are no culverts or stormdrains which drain into the lake. There is a community association for the lake.
>
> Overall, the volunteer finds that Waitts Lake had good water quality. The worst problems in the lake in 1992 were swimmer's itch and low water level. In comparison to the 1991 monitoring season, in 1992 there was a dramatic drop in water level. There was no management of plants or algae in the lake in 1992, but the lake was treated with chemicals in the past to control undesirable fish species.
>
> There are wetlands on the northwest and south ends of the lake. Plants and lily pads grow in the south end of the lake in water up to about 30 feet deep. Plants also grow in water near the north wetlands and near the outlet. There is heavy residential development along the north and east shores.

Comments

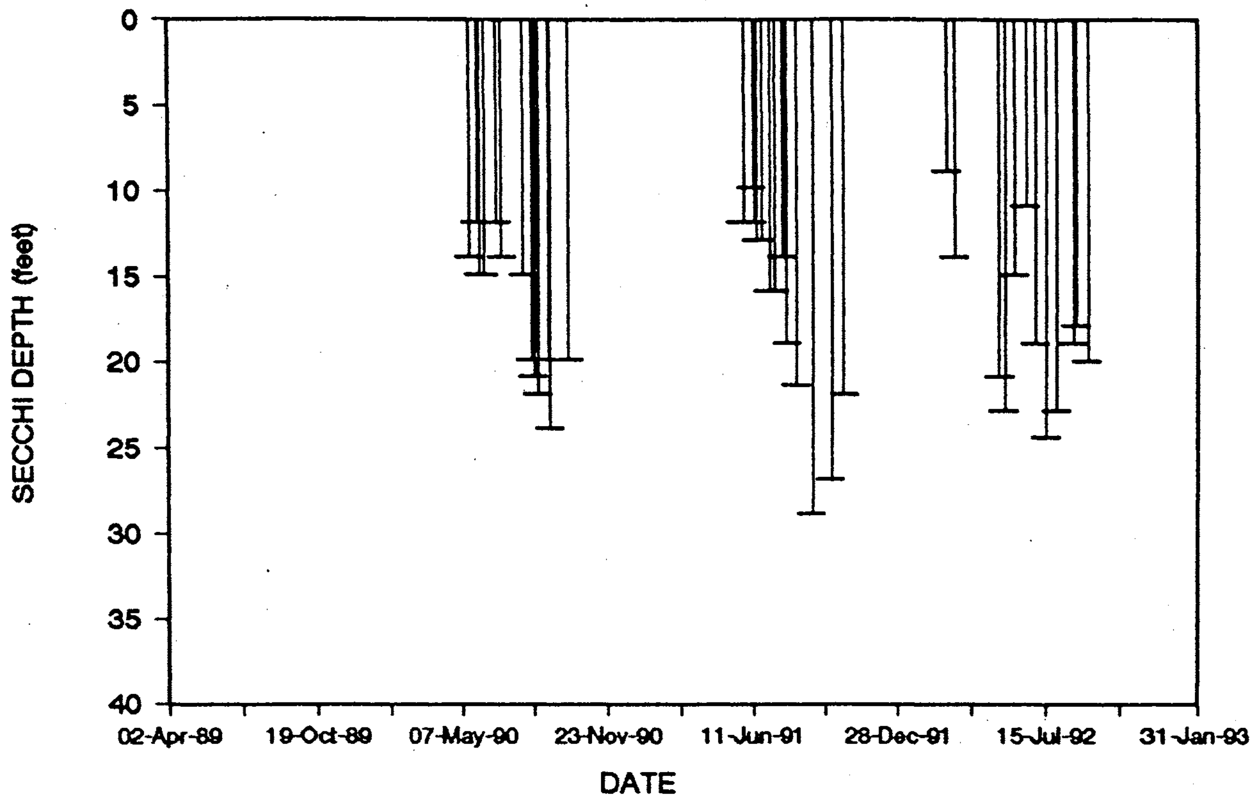
As in 1991, Waitts Lake exhibited both oligotrophic and mesotrophic characteristics. Water clarity of the lake was good, and chlorophyll *a* indicated that algal density was not excessive. However, there was very low dissolved oxygen in the hypolimnion of the lake, and total phosphorus during May was moderately high. Based on these characteristics, Waitts Lake was described as oligo-mesotrophic.

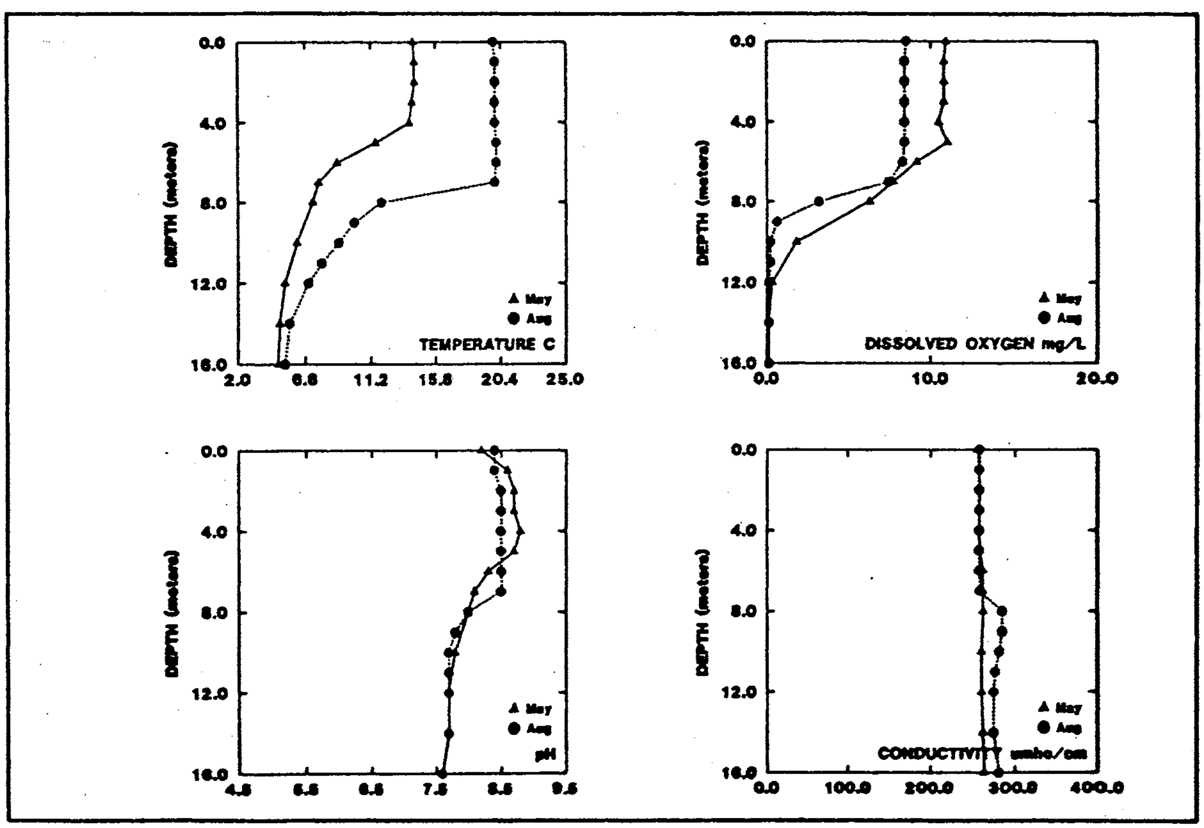
Other Stevens County lakes monitored for the program were Black, Deer, Jumpoff Joe, Leo and Thomas Lakes. Of these lakes, Deer Lake had the lowest total phosphorus and the best water clarity.

Acknowledgement

I thank Beth Pulliam for volunteering her time to monitor Waitts Lake during 1990 - 1992.

WAITTS LAKE (STEVENS COUNTY)



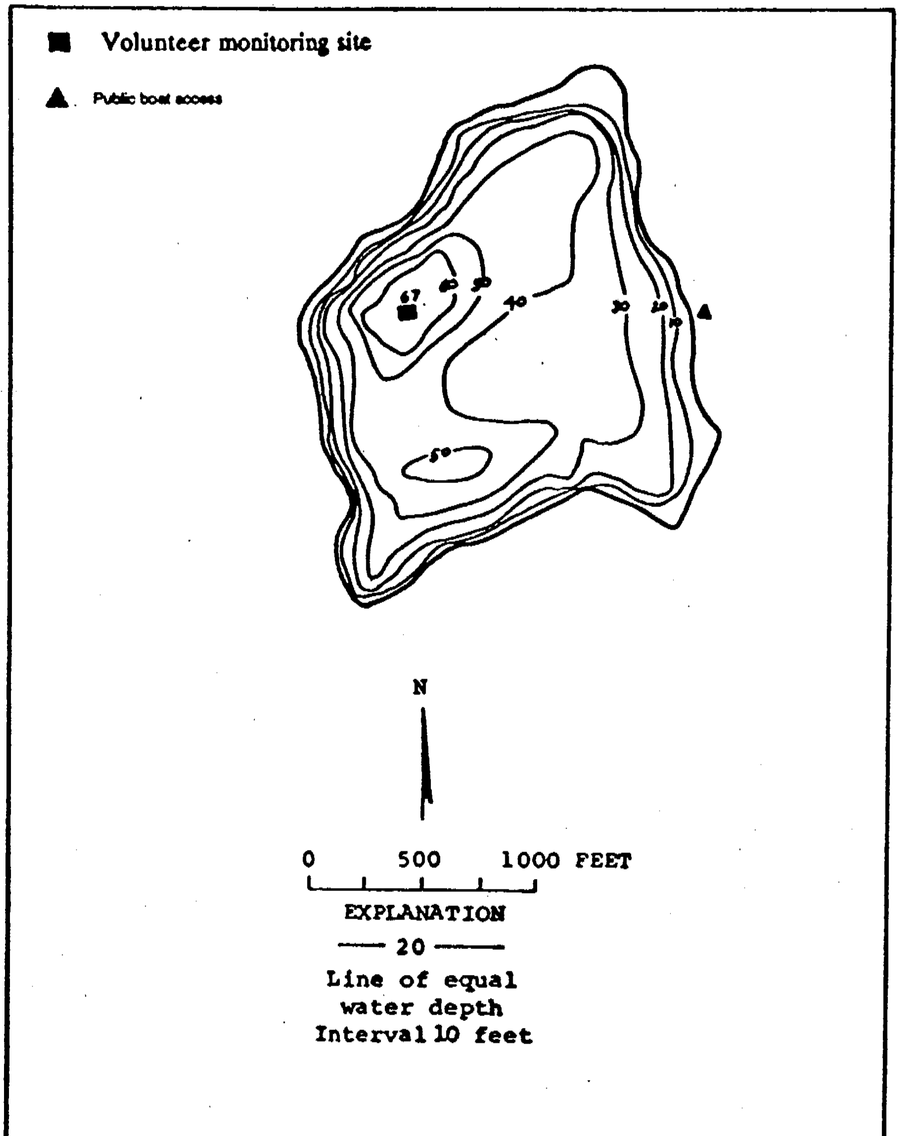


Ward Lake -- Thurston County

Ward Lake is located 2.5 miles south of Olympia, in a kettle depression. It is spring-fed, and has no surface outlets. It is within the Deschutes River watershed.

Size (acres)	65
Maximum Depth (feet)	67
Mean Depth (feet)	33
Lake Volume (acre-feet)	2,100
Drainage Area (miles^2)	1.0
Altitude (feet)	123
Shoreline Length (miles)	1.4

Data From Bortleson *et al.* (1976)



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

Ward Lake -- Thurston County

1992 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	35
Mean Trophic State Index (Total Phosphorus):	37
Mean Trophic State Index (Chlorophyll *a*):	18

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
01-Apr	1200	13.3	56.0	21.0	51.50	Lt-Green	0	None	Breezy	Lake is dropping fast. Only gained 3.5" since 1/17.
01-May	1200	15.6	60.0	17.0	55.00	Milky-Gr	25	Light	Light	Lake has come up 7" since 1/17; half in April. Lots of boat traffic.
11-May				19.0						Onsite visit.
15-May	1245	17.8	64.0	20.5	51.00	Milky-Gr	0	None	Light	Logging for new construction in SE corner of lake.
01-Jun	1145	18.3	65.0	20.0	47.00	Green	100	None	Calm	Heavy boat and swimmer traffic.
15-Jun	1245	21.1	70.0	17.0	42.50	Pea Green	75	Trace	Calm	Water color cloudy green. Noted that we did not sample at deepest part of lake during onsite visit.
07-Jul	1300	23.3	74.0	17.5	42.00	Pea Green	10	None	Breezy	4" waves at time of measuring lake height; 40" is close.
14-Jul	1230	22.2	72.0	18.0	39.50		75	None	Light	Water color light cloudy green. 3/4 acre +- mineral earth clearing to 15' of shoreline. Hard rain would cause silting.
02-Aug	1245	23.3	74.0	18.0	36.00	Pea Green	50	Light		300 plus geese on lake at night; come in after dark and leave at dawn. Many swimmers.
17-Aug	1030	23.3	74.0	17.0	33.50	Pea Green	0	None	Breezy	Julie read 18.5' on Secchi.
02-Sep	1315	22.2	72.0	21.0	30.00	Lt-Green	0	None	Light	No fishing - few swimmers. Feathers, lots of geese debris. Oil.
15-Sep	1300	18.9	66.0	19.0	27.00	Lt-Green	0		Breezy	The lake has turned over. Too cold to swim.
05-Oct	1230	16.7	62.0	17.0	25.50	Lt-Green	90	Trace	Gusty	
19-Oct	1230	15.6	60.0	15.0	25.00	Lt-Green	100	Moderate	Breezy	

[1] Trophic State Indices calculated from Carlson (1977)

Ward Lake -- Thurston County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/11	0.0	16.8	8.0	10.4	15
	1.0	16.8	7.6	9.9	15
	2.0	16.7	7.5	9.8	15
	3.0	16.7	7.3	9.9	15
	4.0	16.5	7.3	9.8	15
	5.0	13.7	7.3	11.4	15
	6.0	11.8	7.3	11.6	15
	7.0	10.4	7.2	11.0	15
	8.0	9.5	7.1	9.9	15
	9.0	8.7	6.8	6.5	15
	10.0	8.2	6.5	2.2	16
	12.0	7.7	6.3	0.4	17
	15.0	7.5	6.1	0.1	17
	18.5	7.4	6.1	0.1	20
09/09	0.0	21.0	7.6	8.8	24
	1.0	21.0	7.4	8.8	24
	2.0	21.0	7.3	8.8	23
	3.0	20.9	7.3	8.8	22
	4.0	20.6	7.3	8.8	23
	5.0	20.5	7.3	8.8	23
	6.0	20.4	7.3	8.8	22
	7.0	20.3	7.2	8.8	22
	8.0	15.4	6.9	4.6	25
	9.0	13.3	6.6	2.6	26
	10.0	12.0	6.5	0.2	26
	12.0	9.5	6.4	0.1	27
	14.0	8.5	6.2	0.1	37
	16.0	8.1	6.1	0.1	38

1992 Onsite Visit Data - Water Chemistry

Date	05/11/92		09/09/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 3	9, 10, 12	1, 3, 6	12, 14, 16
Total Phosphorus (µg/L)	12	40	8	207
Total Nitrogen (mg/L)	0.28	0.39	0.27	0.60
Chlorophyll *a* (µg/L)	0.00	--	0.58	--

Ward Lake -- Thurston County

Historical Data From Ecology

Date	6/27/72[a]	05/29/90[b]	08/21/90[b]	6/19/91[c]
Secchi (ft)	12	22	25.5	24
Total Phosphorus, epilimnion (μg/L)	10	10	12	--
Total Nitrogen, epilimnion (mg/L)	--	0.26	0.27	0.19
Chlorophyll *a* (μg/L)	7.8	--	--	--
Dissolved Oxygen, surface (mg/L)	9.9	10.3	8.9	10.1
Dissolved Oxygen, bottom (mg/L)	1.8	1.9	0.1	0.4

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)

Ward Lake -- Thurston County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good throughout the monitoring season, as indicated by Secchi depths which ranged from 15.0 to 21.0 feet. There does not appear to be any pattern in Secchi depths from Ward Lake; the variations in Secchi depths were very different from 1990 to 1992.

Total Phosphorus

Total phosphorus in the epilimnion was low on both sampling dates (12 μg/L in May and 8 μg/L in September). Values were similar to those measured in 1990 (10 μg/L in May and 12 μg/L in August; Rector, 1991) and June 1972 (10 μg/L; Bortleson *et al.*, 1976). However, total phosphorus in the hypolimnion was very high in September 1992, indicating release of phoshporus from the sediments into the water column.

Total Nitrogen

Total nitrogen was very low on both sampling dates (0.28 and 0.27 mg/L). Values were similar to those measured in 1990 and 1991.

Profile Data

Although profile data were collected during the August onsite visit with the volunteer, water samples could not be collected at the time (due to equipment problems). Ecology staff returned to the lake in September to collect both water samples and profile data; those data from September are reported here. On both sampling dates, the lake was stratified with respect to temperature. Below the thermocline, dissolved oxygen decreased considerably with depth. Although oxygen can be depleted by bacteria which use oxygen to decompose aquatic plants and algae in the water and sediments, plant and algae growth in Ward Lake was very low. Because Ward Lake is fed by springs, it is possible that the low dissolved oxygen in the hypolimnion is due, in part, to the fact that spring water is very low in oxygen.

Conductivity of the lake water was very low in comparison to other lakes monitored for the program. Conductivity measures the ability of water to conduct an electrical current, and is an indicator of the amount of ions in the water. Low conductivity indicates low ion content.

Plants

Algal growth was very low on both sampling dates, as indicated by low concentrations of chlorophyll *a*.

Aquatic plants identified by Ecology staff during the May 11, 1992 onsite visit with the volunteer were white-flowering water lily (*Nymphaea odorata*) and cattails (*Typha* spp.). Only about 50% of the shoreline had emergent plants, likely due to the many bulkheads, docks, and artificial beaches put in by lakeshore residents.

Ward Lake -- Thurston County

During the June 1991 and August 1990 onsite visits with volunteers, white-flowering water lily was observed on the shoreline. In 1991, a submerged macrophyte was tentatively identified as water-starwort (*Callitriche* spp.). The same plant was sampled in 1990, but during both years the samples did not include flowers, which are useful for positive identification. In 1990, the plant grew along a narrow band in water about three feet deep, and the volunteer noted that the plant recently appeared in the lake.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1990 to 1992.

> Ward Lake is used for fishing, swimming, and boating. There is one public boat ramp, making about 2 percent of the shoreline publicly-owned. Sometimes it is difficult to use the public boat launch due to heavy use of the area by swimmers. Rainbow, silver, and cutthroat trout were stocked in the lake. Currently, the watershed is used for crop agriculture, animal grazing/feeding, and the lakeshore is being developed further for residences. In the past, the watershed was used for logging, crop agriculture, and animal grazing/feeding. The lake has been dredged, and the shoreline was altered with dredging and fill. (The Game Department filled about 1 acre in 1949 when access was built, and old sawdust and shavings from the north end were dredged in the 1960's for landscaping at Holiday Hills.) There was a sawmill on the lakeshore prior to 1900, so the lake is full of sunken logs.
>
> There are 35 houses on the lakeshore, and about 20% of the houses are connected to a sewer. At least 5 culverts/stormdrains drain into the lake. There is a no lake association for the lake.
>
> Overall, the volunteer finds that Ward Lake had excellent water quality, and believes that Ward Lake is the cleanest lake in the county. The lake had no water quality problems in 1992. Possible sources of potential problems include resident geese and storm drains. In 1992, there was a large population of Canada geese during summer, but during winter there were fewer geese at the lake (about 40-50) than during previous years (around 100-200). The volunteer also noted that the sewer at Holiday Hills failed once, and may again.
>
> Waterlilies grow all around the lake, except where property owners pull them. White-flowering lilies were introduced into the lake at Holiday Hills, between 1920-1930, and have since spread. Perch, bluegill and largemouth bass are present in the lake, but are not stocked by the Department of Wildlife. The volunteer noted that fishing in the lake was not great, because the lake is too cold

for bass, and the bluegill are small. There are some ponds in the watershed, down-gradient from Briggs Nursery, that are about 50-75 feet in diameter and have heavy growths of green scum on them.

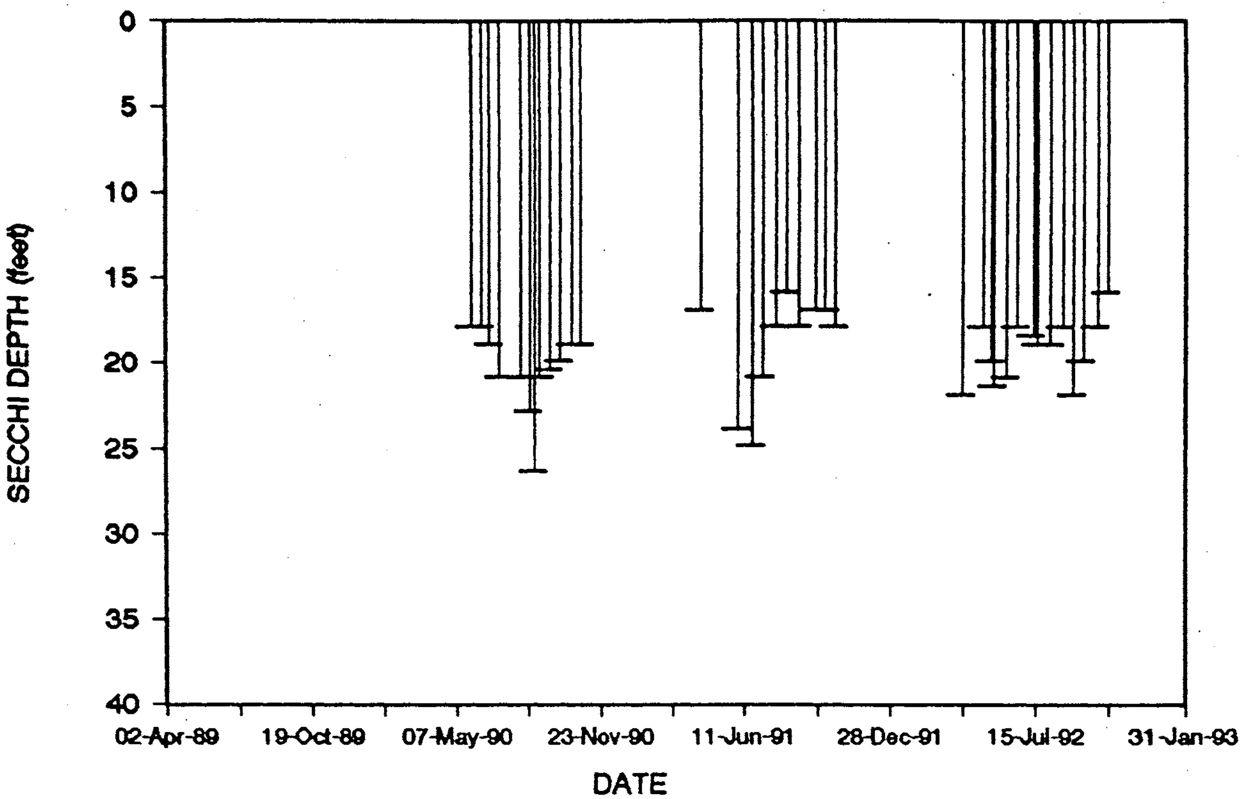
Comments

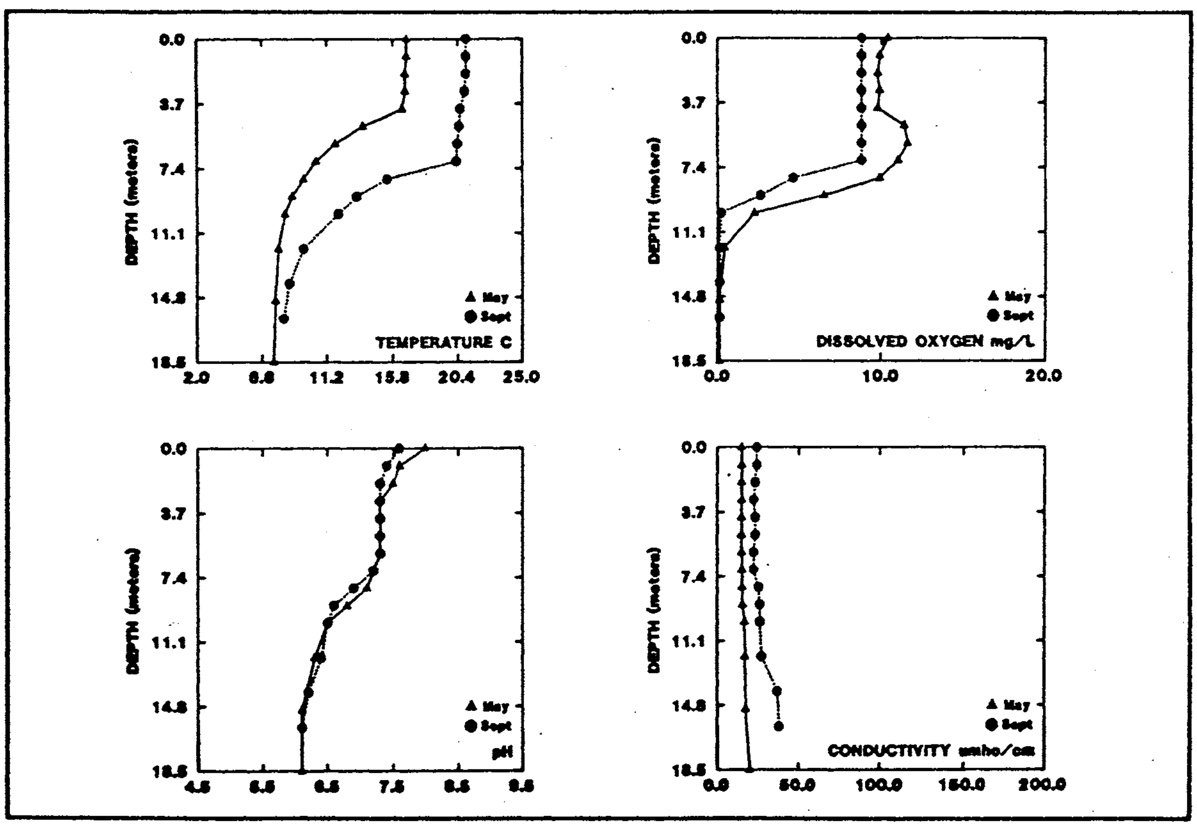
Ward Lake was characterized as oligotrophic because of its good water clarity and its low nutrient concentrations. Long Lake, North Pattison Lake and Lake St. Clair were also monitored for the program in 1991. Of the monitored Thurston County lakes, Ward Lake had the best mean summer water clarity and the lowest nutrient concentrations.

Acknowledgements

I thank Kit Weaver for volunteering his time to monitor Ward Lake during 1990 - 1992.

WARD LAKE (THURSTON COUNTY)



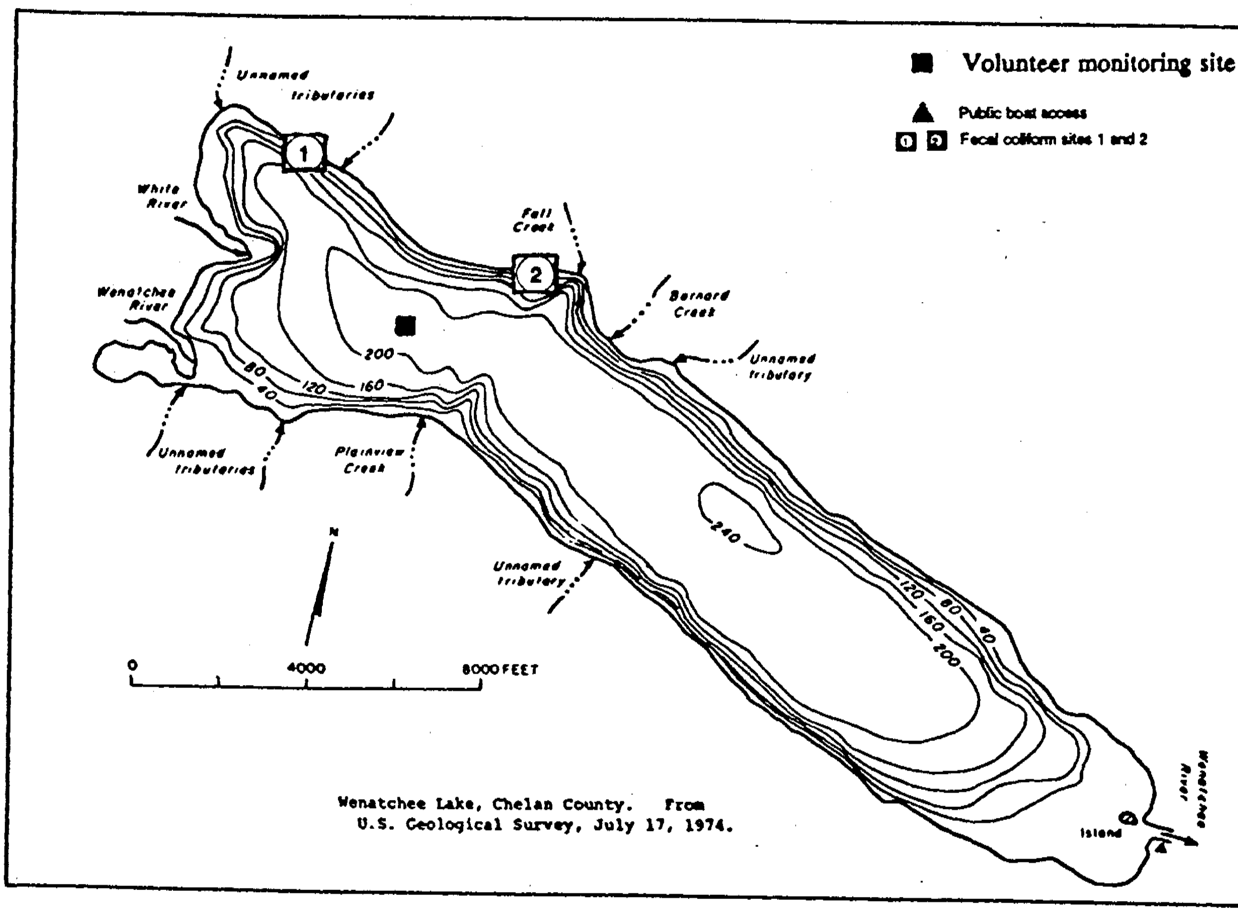


Lake Wenatchee -- Chelan County

Lake Wenatchee is a large, steep-sided lake located 15 miles north of Leavenworth in the Wenatchee National Forest. It is fed principally by the Little Wenatchee River and the White River, and drains to the Wenatchee River. There is a large wetland at the northeast end of the lake.

Size (acres)	2,480
Maximum Depth (feet)	244
Mean Depth (feet)	147
Lake Volume (acre-feet)	360,000
Drainage Area (miles²)	273
Altitude (feet)	1,875
Shoreline Length (miles)	13.3

Data From Dion *et al.* (1976b)



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

Lake Wenatchee -- Chelan County

1992 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	35
Mean Trophic State Index (Total Phosphorus):	20
Mean Trophic State Index (Chlorophyll *a*):	27

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
25-May	1000	11.1	52.0	24.0		Lt-Green	0	None	Calm	Calm, clear for 4 days.
08-Jun	1000	10.0	50.0	24.5		Lt-Green	0	None	Light	Windy for past 2 days. Windy early morning, calming by 10 am.
24-Jun	1220	17.8	64.0	21.5		Lt-Green	0	None	Calm	Water has some glacial melt due to warm conditions. Calm only today - previous 2 days windy. Water temp rose from 60 degrees at 8 a.m. to 64 degrees at 12 p.m.
15-Jul	1300	17.2	63.0	19.0			0	None	Calm	Water color light green-light brown. Heavy windy conditions for past 4 days. Not much glacial melt yet.
30-Jul	1130	18.3	65.0	17.0		Milky-Gr	0	None	Calm	Warm days, glacial melt in water.
16-Aug	1130					Lt-Green	0	None	Calm	Heavy wind conditions previous 2 days. Heavy glacial melt - warm conditions.
22-Sep	1300	17.8	64.0	24.5		Lt-Green	10		Light	Weather cooler, and windy. Lake temp dropping.

[1] Trophic State Indices calculated from Carlson (1977)

Lake Wenatchee -- Chelan County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/21	0.0	7.9	7.6	11.2	29
	1.0	7.8	7.4	11.1	28
	2.0	7.8	7.3	11.1	28
	3.0	7.7	7.3	11.1	28
	4.0	7.5	7.3	11.0	28
	5.0	6.7	7.2	11.1	27
	6.0	6.6	7.2	11.1	27
	7.0	6.6	7.2	11.1	27
	8.0	6.6	7.2	11.1	27
	10.0	6.5	7.2	11.1	27
	12.0	6.5	7.2	11.1	27
	14.0	6.5	7.1	11.0	27
	16.0	6.4	7.1	11.1	27
	18.0	6.4	7.1	11.0	27
	20.0	6.4	7.1	11.0	26
	25.0	6.3	7.1	11.0	27
	30.0	6.1	7.1	11.0	26
	35.0	6.1	7.1	11.0	26
	40.0	6.1	7.1	10.9	27
	45.0	6.1	7.1	10.9	27
09/03	0.0	16.9	7.8	9.0	23
	1.0	16.9	7.7	8.9	23
	2.0	16.9	7.6	8.9	23
	3.0	16.8	7.6	8.9	23
	4.0	16.8	7.5	8.9	23
	5.0	16.8	7.5	8.9	23
	6.0	16.8	7.5	8.9	23
	7.0	16.7	7.5	8.9	23
	8.0	16.7	7.4	8.9	23
	9.0	16.7	7.4	8.9	23
	10.0	16.7	7.4	8.9	23
	11.0	16.7	7.4	8.9	23
	12.0	16.6	7.4	8.9	23
	14.0	16.6	7.5	8.9	23
	16.0	16.2	7.5	8.7	23
	18.0	15.8	7.5	8.6	23
	20.0	14.9	7.6	8.2	22
	22.0	12.9	7.7	8.2	21
	24.0	11.3	7.7	8.6	21
	26.0	13.4	7.8	8.7	21
	28.0	9.8	7.8	8.8	21
	30.0	9.3	7.9	8.8	21
	35.0	8.6	8.1	9.0	21
	40.0	8.1	8.2	8.9	21

Lake Wenatchee -- Chelan County

1992 Onsite Visit Data - Water Chemistry

Date	05/21/92		09/03/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 4	10, 20, 30	5, 10, 15	25, 30, 35
Total Phosphorus (μg/L)	3	3	3	3
Total Nitrogen (mg/L)	0.21	0.13	0.07	0.11
Chlorophyll *a* (μg/L)	0.20	--	1.23	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	<1	--	<1	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	<1	--	<1	--
Total Suspended Solids (mg/L)	1	--	1	--
Total Nonvolatile Suspended Solids (mg/L)	1	--	1	--
Color (Pt-Co units)	10	--	5	--

Historical Data From Ecology

Date	07/18/74[a]	06/06/89[b]	09/06/89[b]	06/04/90[c]	08/20/90[c]	06/06/91[d]
Secchi (ft)	20	11.5	22.6	17	--	17.4
Total Phosphorus, epilimnion (μg/L)	4	6	7	8	12	--
Total Nitrogen, epilimnion (mg/L)	--	0.16	0.07	0.11	0.17	0.11
Chlorophyll *a* (μg/L)	1.0	0.7	6.9	--	--	--
Dissolved Oxygen, surface (mg/L)	10.8	11.6	12.2	--	7.0	11.4
Dissolved Oxygen, bottom (mg/L)	10.4	11.5	12.0	--	6.5	11.8

a. Dion *et al.* (1976)
b. Brower and Kendra (1985)
c. Rector (1991)
d. Rector (1992)

Lake Wenatchee -- Chelan County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity in Lake Wenatchee was very good, as indicated by Secchi depths which ranged from 17.0 to 24.5 feet. Given the very low nutrient concentrations and chlorophyll *a* (which indicates the amount of algal density in the water), Secchi depths were not as deep as would be expected, although the water clarity was still very good. As noted in the volunteer's comments, it is likely that water clarity was affected by glacial meltwater in July. Secchi depths were somewhat deeper in 1992 than in 1989 - 1991.

Total Phosphorus
Total phosphorus in the epilimnion was very low (3 μg/L) on both sampling dates. Lake Wenatchee had the lowest phosphorus concentrations of all lakes monitored for the program in 1992.

Total Nitrogen
Total nitrogen was also very low, although the concentration during May (0.21 mg/L) was somewhat higher than those measured in June 1989 (0.16 mg/L; Brower and Kendra, 1990), 1990 (0.11 mg/L in June and 0.17 mg/L in August; Rector, 1991), and June 1991 (0.11 mg/L; Rector, 1992).

Fecal Coliform Bacteria
No fecal coliforms were detected in any of the four samples collected.

Solids and Color
There were very few suspended solids in the samples, possibly because there was no glacial meltwater present at the time of sampling (there was no mention of meltwater in the field notes). Color in the lake was low, also. These data indicate that at the time of sampling, Secchi depths were most likely related to algal density, as opposed to suspended sediments or natural color.

Profile Data
On both sampling dates, the lake was stratified with respect to temperature. Temperature differences between the surface and bottom were much greater during September than during May; very cool water temperature in May probably contributed to the high dissolved oxygen throughout the water column and very low algal growth.

Lake Wenatchee was one of the few lakes sampled in 1992 that exhibited truly oligotrophic profile data; dissolved oxygen did not decrease appreciably with depth, even when the lake was strongly stratified during late summer.

Lake Wenatchee -- Chelan County

In August 1990, the lake was stratified, but the other measured parameters (dissolved oxygen, pH and conductivity) were fairly constant from surface to bottom. These data were similar to profile data collected during 1990, 1989 (Brower and Kendra, 1990), 1974 (Dion *et al.*, 1976) and 1968 (Lee, 1969).

Plants

Algal density was very low on both sampling dates, as indicated by low concentrations of chlorophyll *a*.

During the May 21, 1992 onsite visit with the volunteer, pieces of milfoil (*Myriophyllum* spp., but not the aggressive Eurasian variety) were seen floating at the monitoring site. Other aquatic plants observed were spikerush (*Eleocharis* spp.), waterweed (*Elodea* spp.), quillwort (*Isoetes* spp.), and nitella (actually an alga; *Nitella*). During the August 1992 onsite visit, Robbins pondweed (*Potamogeton robbinsii*), water buttercup (*Ranunculus aquatilus*), and milfoil were observed. During the June 5, 1991 onsite visit with the volunteer, a filamentous periphyton was observed on the dock and shore. During August 1990, milfoil, water buttercup, and waterweed (*Elodea nuttalli*) were identified in the west end of the lake.

Other Available Information

Ambient monitoring data from the Wenatchee River near Leavenworth (RM 35.6) from 1979 through 1992 were analyzed for possible trends in total phosphorus associated with time, season, and flow. Trend analysis was conducted using WQHYDRO (Aroner, 1990; data source: Washington State Department of Ecology Freshwater Ambient Monitoring Program). No significant trends were detected.

From Johnson and Norton (1990): Fish and sediment samples collected in 1989 for toxics analyses indicated no significant levels of the chemicals tested. Sediment analysis detected low concentrations of 4-methylphenol (74 μg/Kg). This chemical is commonly detected in sediments and is generally considered to have low toxicity to aquatic organisms. Low concentrations of DDT compounds (24 μg/Kg) were detected in lake white fish tissues. These fish samples were well within levels considered acceptable for human consumption.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

> Lake Wenatchee is used for fishing, boating, swimming, rowing, jet skiing and camping. Recreational facilities on the lakeshore include a park, a picnic area, a state park, a camping area, a beach and one resort. About 50 percent of the shoreline is publicly-owned Natural Forest. There are two boat ramps on the lakeshore, and there are no restrictions for motorboat use on the lake. Salmon

were stocked in the lake. Currently the watershed is used for logging and animal grazing, and the lakeshore is being developed further for residences. In the past the watershed was used for logging and crop agriculture.

There are about 155 houses on the lakeshore; of these, 10 are occupied year-round. The lakeshore is not sewered (although some facilities provide their own wastewater collection and treatment), and there are culverts that empty into the lake. There is a sewer district for the lake. Currently, the minimum setback for lakeshore development is 20 feet, minimum lot lengths are 100 feet, and residential density is restricted to a 50 foot frontage minimum. Lake water is withdrawn for drinking and other domestic uses.

Overall, the volunteer finds that Lake Wenatchee had excellent water quality. The worst problem in the lake in 1992 was algae. Possible sources of problems are fish pens. There were no changes in the lake since the 1991 monitoring season, although sewers are being installed this year.

Runoff, containing glacial silt from Glacier Peak, enters the lake via the White River. The "plume" where the silt enters the lake is very distinct because the water color is milky. This plume area is near the volunteers' monitoring site, so he avoids taking Secchi readings in the silt "plume". Two fish pens are still located on the west end of the lake just north of where the White River enters the lake; one is a holding pond for brood stock and the other is a rearing pond. Reeds and waterlilies grow in the cove just south of the Wenatchee River outlet. Algae blooms have also occurred in this area.

Comments

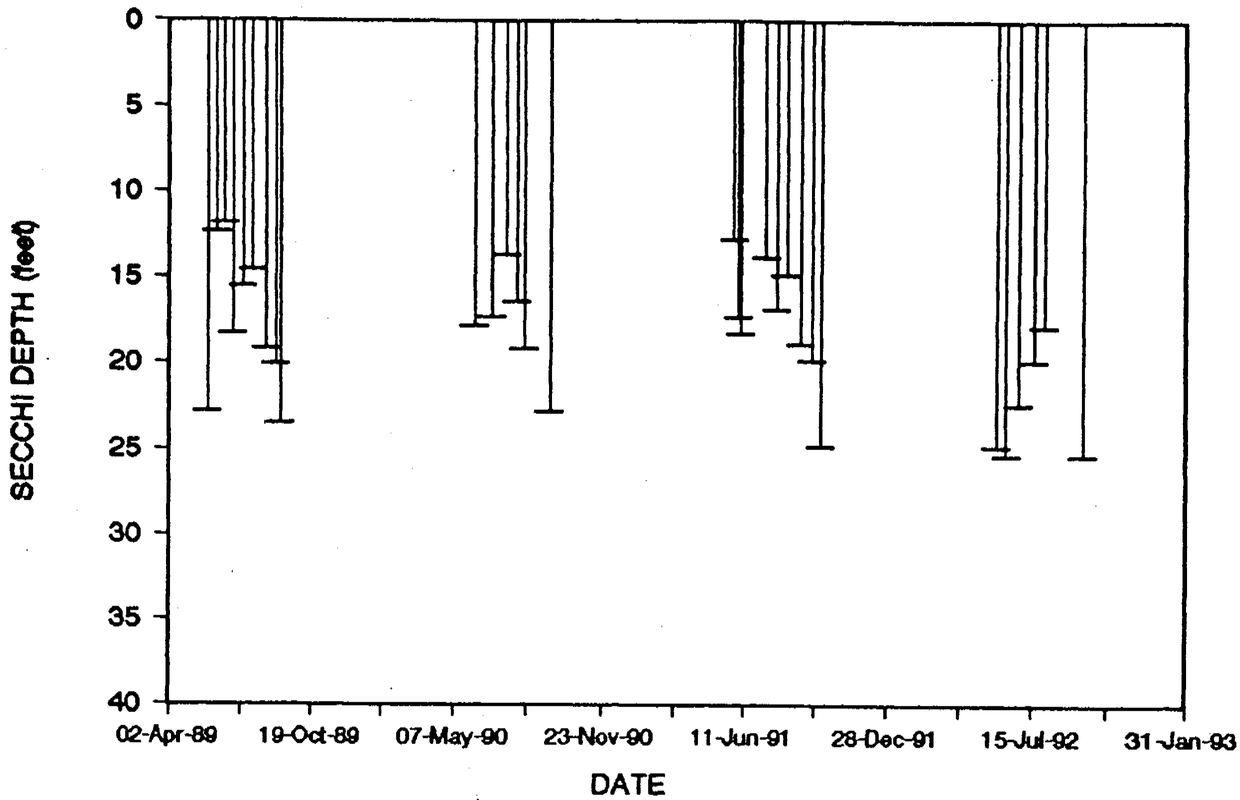
Lake Wenatchee had very low nutrient concentrations, good water clarity, and low algal growth (as indicated by chlorophyll *a*). Based on these, the lake was characterized as oligotrophic.

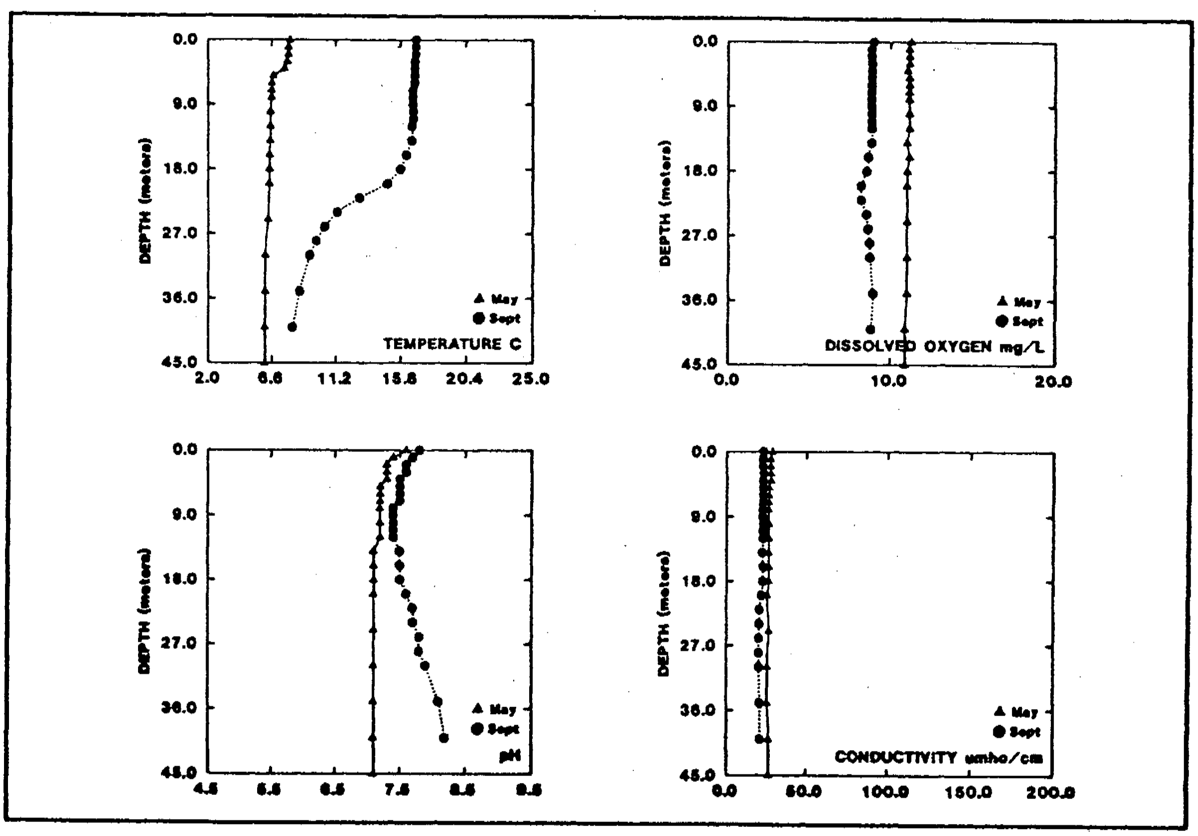
In comparison with other lakes monitored for the program in 1992, Lake Wenatchee had the lowest concentrations of total phosphorus.

Acknowledgement

I thank Gary Craig for volunteering his time to monitor Lake Wenatchee during 1989-1992.

LAKE WENTACHEE (CHELAN COUNTY)





Lake Whatcom -- Whatcom County

Lake Whatcom is located three miles east of Bellingham. It is a natural lake stabilized by a dam. It is 12 miles long. Inlets include Carpenter, Olson, Smith, Fir, Brannian and Austin Creeks. It drains via Whatcom Creek to Bellingham Bay. Acreage does not include Reveille Island (12 acres). It is the water supply for the City of Bellingham.

Size (acres)	5,000
Maximum Depth (feet)	330
Mean Depth (feet)	154
Lake Volume (acre-feet)	767,700
Drainage Area (miles^2)	55.9
Altitude (feet)	315
Shoreline Length (miles)	26.5

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	35

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The 1991 questionnaire on lake and watershed uses was not returned by the volunteer. The following are from the volunteer's responses to the 1990 questionnaire. Lake Whatcom is used for fishing, boating, swimming, rowing, jet skiing, camping and waterfowl hunting. Recreational facilities on the lakeshore include a park, a picnic area, a camping area, a beach, and three resorts. These are five boat ramps on the lakeshore. Lake water is withdrawn for municipal and industrial uses, irrigation, and for drinking and other domestic uses. Currently the watershed is used for logging, industry, animal grazing, and crop agriculture, and the lakeshore is being developed further for residences. In the past the watershed was used for logging, animal grazing, crop agriculture and mining, and the shoreline was altered. The lakeshore is partially sewered, and there are storm drains that empty into the lake. Fish were not reported as being stocked in the lake. There are two grassroots organizations for the lake: Lake Whatcom Watershed Defense Coalition, and Friends of Lake Whatcom. The worst problems in the lake, in the opinion of the volunteer, were ranked as 1) sediments suspended in the water column, and 2) debris torrents. The volunteer is concerned about possible water quality effects from urban runoff, sediment, nonpoint pollution, and bacteria.

Monitoring Results/Summary of Other Available Information

Volunteers have monitored Lake Whatcom for the program since 1990. Data from 1990 are reported in Rector (1991). In 1991, only station 2 was monitored. Both stations 1 and 2 were monitored in 1990.

Lake Whatcom -- Whatcom County

In 1991, volunteer-collected Secchi depths ranged from 16.0 to 21.0 feet. There were not enough data collected to evaluate patterns in water clarity, but the Secchi depths were in the same range as Secchi depths collected in 1990.

Water samples and profile data were not collected from Lake Whatcom in 1991. In 1990, water samples and profile data were collected from station 1. Total phosphorus in these samples was very low (0.006 mg/L in June and 0.007 mg/L in August), although total nitrogen was moderately high (0.50 mg/L and 0.41 mg/L). These concentrations are somewhat lower than those found in 1981, when total phosphorus was 0.010 mg/L and total nitrogen was 0.57 mg/L (Sumioka and Dion, 1985). The 1981 total phosphorus data were also in the oligotrophic range. Total phosphorus data from 1974 ranged from 0.003 to 0.006 mg/L (Bortleson *et al.*, 1976), and were only slightly lower than the 1990 data.

The lake has been studied since the 1960s by Western Washington University. Data collected by University researchers show that concentrations of total phosphorus in the lake were low (0.005 to 0.015 mg/L in 1985; Creahan *et al.*, 1986) and concentrations of nitrogen (especially nitrate/nitrite-nitrogen) were moderate (0.004 - 0.513 mg/L in 1986; Rector and Matthews, 1987). The concentration of nitrogen in the lake water was high relative to the concentration of phosphorus; researchers concluded that the productivity of algae in the lake was limited by the amount of phosphorus in the water (Creahan *et al.*, 1986).

Water quality in the lake has varied with location. The lake is divided into three subbasins, which flow from the deepest, cleanest basin to the the shallow, mesotrophic basin. The smaller, shallow basin is heavily developed in some areas, and has the heaviest recreational use (Creahan *et al.*, 1986). Dissolved oxygen concentrations in this basin are depleted near the bottom, and algal productivity is greater in this basin than in the other two basins (Rector and Matthews, 1987). The volunteers' monitoring stations in 1990 were located in the larger and deeper of the three basins. This basin contains considerable woody debris in some areas, from past use of the lake as a log storage pond for sawmills and from past debris torrents (Rector and Matthews, 1987).

Several debris torrents have occurred in the tributaries of Lake Whatcom, carrying logs, sediments and assorted other debris into the lake (Weden and Associates, 1983). Debris torrents, which are short duration, high intensity, high volume surges of debris-laden water that occur in stream channels, have been reported in Lake Whatcom as far back as 1917 (Syverson, 1984). Of the documented debris torrents, the most severe debris torrent occurred in the Smith Creek drainage on January 10, 1983 (Syverson, 1984). The actual volume of debris washed into the lake from these debris torrents is unknown.

Residential development of the lakeshore has increased over the years; there were 348 nearshore homes in 1974 (Bortleson *et al.*, 1976), and 500 nearshore homes were reported in 1981 (Sumioka and Dion, 1985).

Lake Whatcom -- Whatcom County

Comments

The trophic state estimation applies only to the basin monitored by the volunteers, and is based on the very good water clarity measured in the lake.

Acknowledgements

I thank Robin Bigelow for volunteering her time to monitor station 2 in Lake Whatcom during 1990 -1991, and Wendy Hand for monitoring station 1 during 1990.

Lake Whatcom -- Whatcom County

Volunteer-Collected Data -- Station 2

Date 1991	Temperature (°C)	(°F)	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
12-Jul	19.4	67.0			None	Light	16.0		
23-Jul	20.0	68.0	Lt-Green	0	None	Calm	21.0		
13-Aug	18.9	66.0	Lt-Green	10	Moderate	Breezy	21.0		

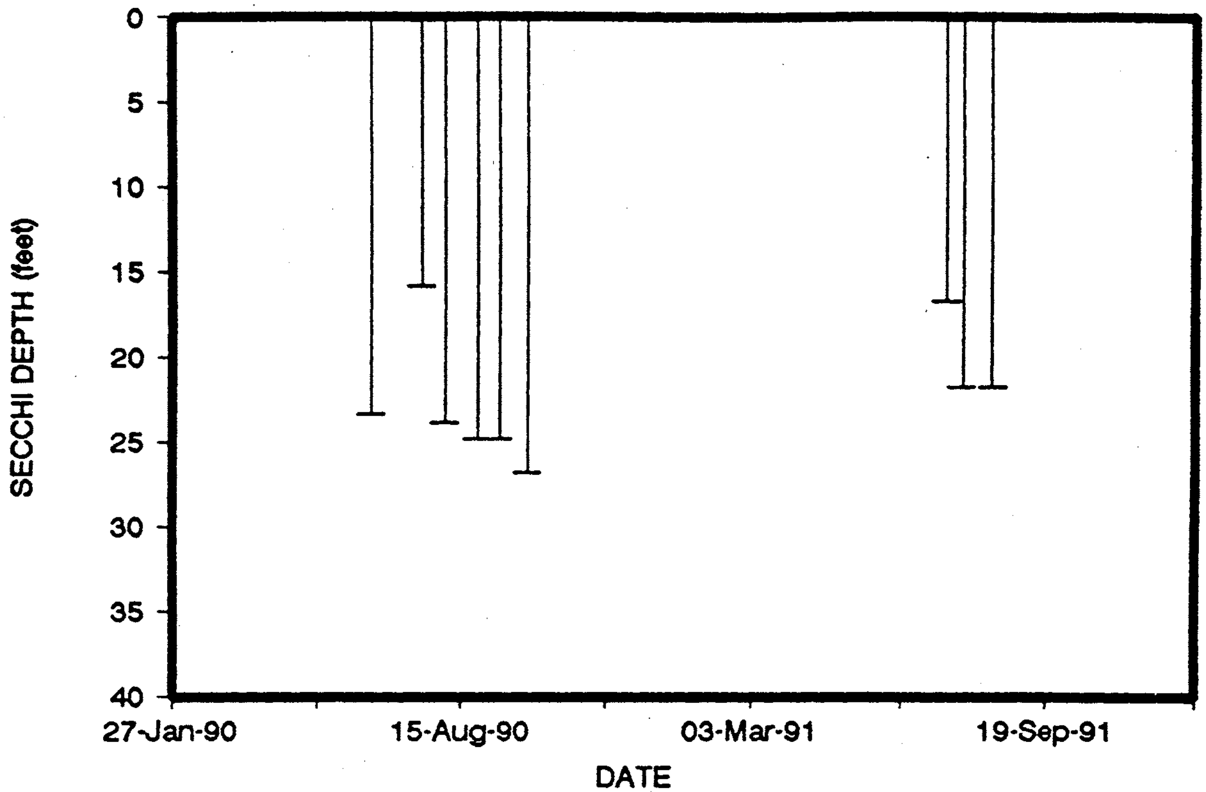
Data From Bortleson *et al.* (1976) and Sumioka and Dion (1985)

Date	08/09/74
Secchi (feet)	21
Total Phosphorus (mg/L)	0.003

Remarks A LARGE NATURAL LAKE STABILIZED BY A DAM. MOST OF THE EMERSED PLANTS WERE OBSERVED ONLY IN THE SHELTERED BAY AREAS. AT ALL THREE SAMPLING STATIONS DO REMAINED NEAR SATURATION THROUGHOUT THE WATER COLUMN. THE STATE TROUT HATCHERY DISCHARGES .65 MGD WATER INTO BRANNIAN CREEK HATCHING AND REARING PONDS. NO DATA ARE AVAILABLE ON THE CONTENT OF THE WASTEWATER (STATE OF WASHINGTON DEPARTMENT OF ECOLOGY WASTEWATER-DISCHARGE MASTER INVENTORY). ADDITIONAL STUDIES ON LAKE WHATCOM HAVE BEEN MADE BY WESTERN WASHINGTON STATE COLLEGE.

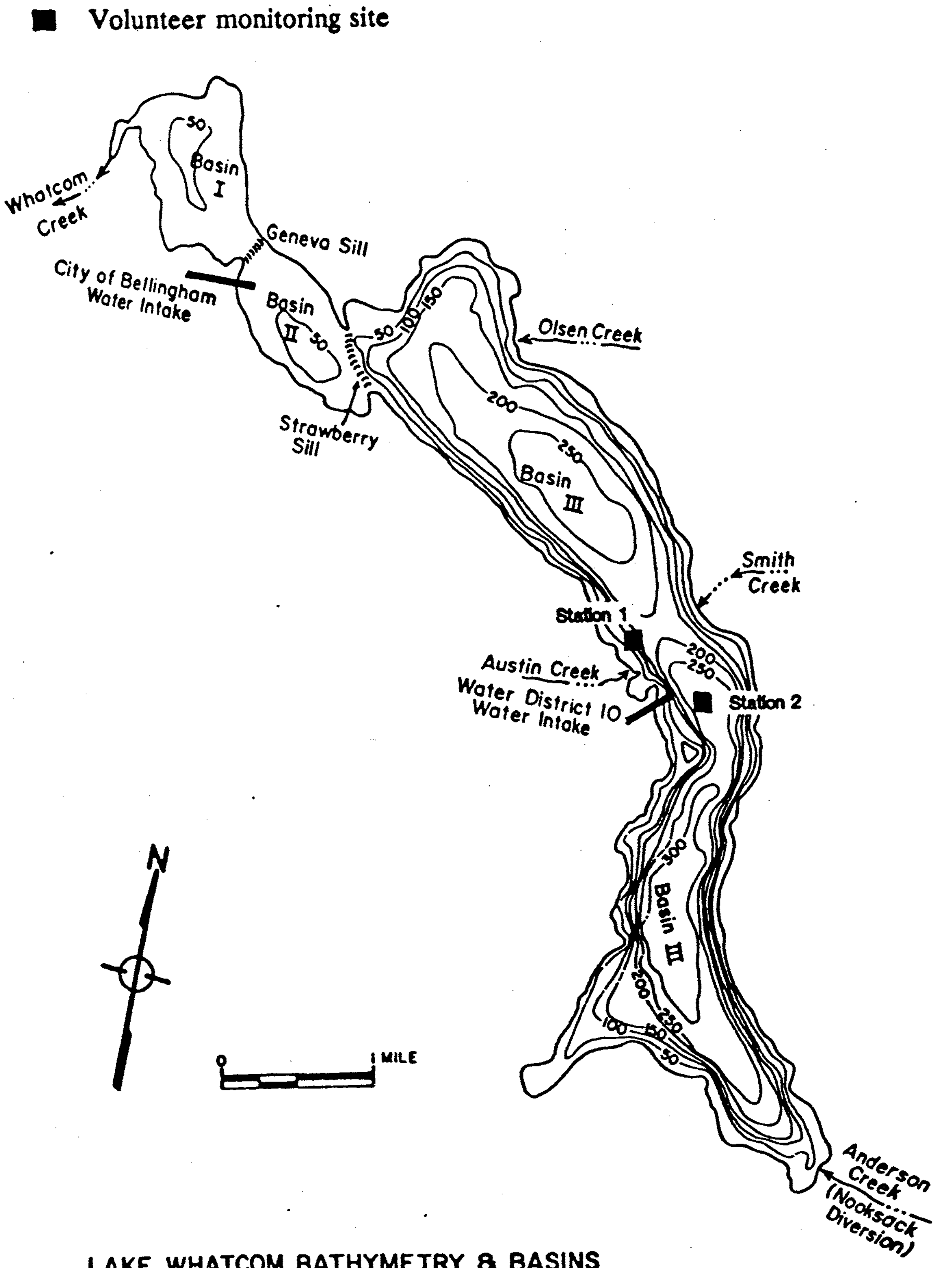
Date	07/08/81
Secchi (feet)	17
Total Phosphorus (mg/L)	0.01
Chlorophyll a (μg/L)	2.70

LAKE WHATCOM (WHATCOM COUNTY)



PROFILE DATA NOT COLLECTED IN 1991

Profile and Secchi Data Graphs



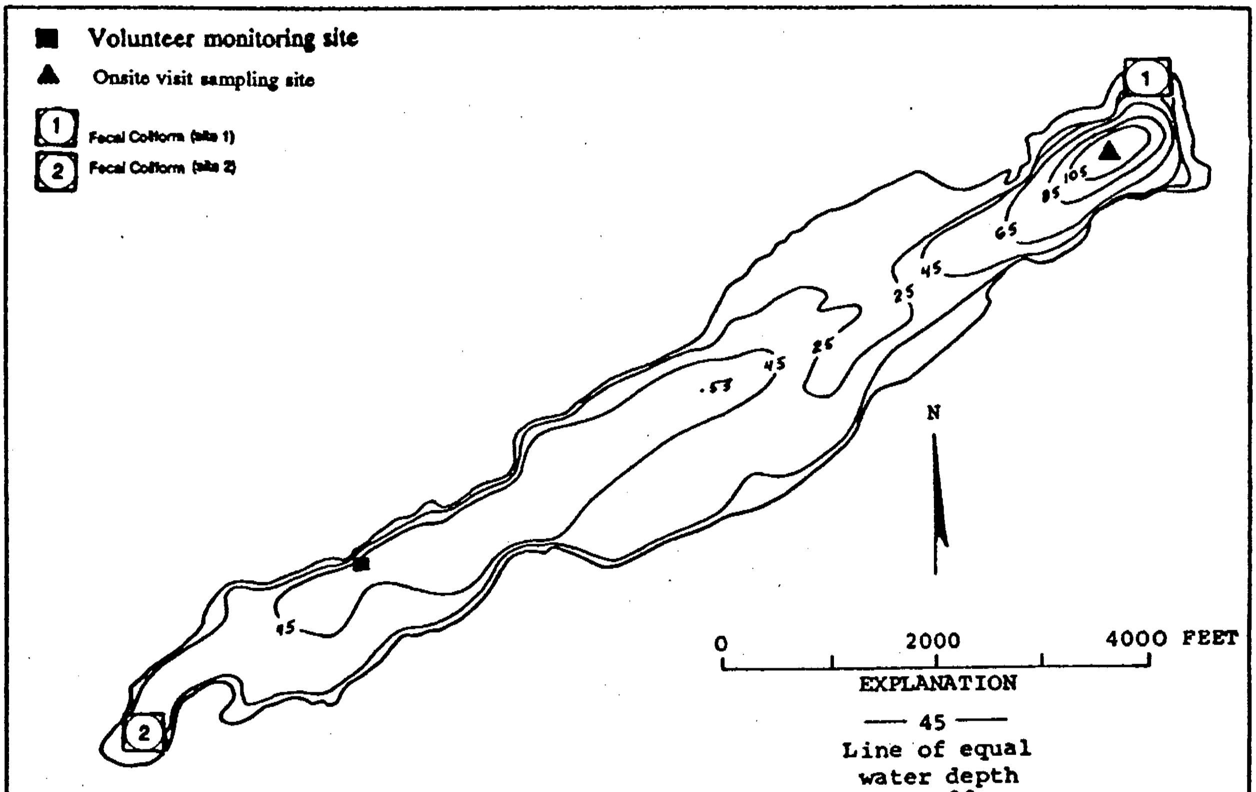
LAKE WHATCOM BATHYMETRY & BASINS

Williams Lake -- Spokane County

Williams Lake is located 11.5 miles southwest of Cheney and 12.5 miles east of Sprague. The inflow is intermittent. The outlet, which flows only during high water, drains to Downs Lake and the Palouse River.

Size (acres)	320
Maximum Depth (feet)	120
Mean Depth (feet)	37
Lake Volume (acre-feet)	12,000
Drainage Area (miles^2)	21.8
Altitude (feet)	2,052
Shoreline Length (miles)	5.3

Data From Dion *et al.* (1976)



Williams Lake, Spokane County. From Washington Department of Game, January 1948.

Williams Lake -- Spokane County

1992 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	45
Mean Trophic State Index (Total Phosphorus):	45
Mean Trophic State Index (Chlorophyll *a*):	37

Volunteer-Collected Data

Date 1992	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
13-May				13.0						Onsite visit.
16-Jun	1200	23.0	73.4	9.0	-2.00	Milky-Gr	0	None	Calm	Due to extreme low water I had to make another lake height gauge. Readings is 0.2". All future readings will be based on this.
05-Jul	1200	20.0	68.0	8.0	-4.50	Milky-Gr	50	None	Breezy	Lake level very low.
22-Jul	1200	21.0	69.8	9.0		Lt-Green	100	Trace	Breezy	Water lowest I've ever seen in 32 years.
02-Aug	1200	22.0	71.6	10.0	-10.00	Milky-Gr	100	None	Light	Lake lowest in history.
19-Aug	1200	23.0	73.4	12.0	-13.00	Milky-Gr	100	None	Calm	Lake lowest in history.
26-Aug				15.0						Onsite visit.
01-Sep	1130	20.0	68.0	9.0	-14.50	Lt-Green	75	None	Calm	Lake still dropping. Hard to launch boats.
25-Sep	0900	15.0	59.0	8.0	-17.00	Green	0	Trace	Breezy	Lake lowest anybody's ever seen.
31-Oct	1200	10.0	50.0	8.0	-26.00	Lt-Green	90	Light	Calm	Lots of dead algae floating. Lowest lake has been in 90 years!

[1] Trophic State Indices calculated from Carlson (1977)

Williams Lake -- Spokane County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/13	0.0	14.9	8.3	10.3	269
	1.0	14.0	8.5	10.4	272
	2.0	13.8	8.5	10.3	271
	3.0	13.7	8.6	10.3	271
	4.0	13.6	8.6	10.3	271
	5.0	13.6	8.6	10.2	272
	6.0	13.6	8.6	10.2	271
	7.0	13.6	8.6	9.8	272
	8.0	13.5	8.6	9.6	272
	9.0	13.4	8.6	9.6	273
	10.0	13.4	8.6	9.5	271
	11.0	13.1	8.5	9.0	272
	12.0	10.9	8.2	7.7	273
	14.0	7.1	8.0	6.4	270
	16.0	5.6	7.9	6.4	268
	18.0	5.0	7.8	6.4	267
	20.0	4.9	7.8	5.9	268
	22.0	4.8	7.7	4.2	270
	24.0	4.7	7.6	0.8	270
	26.0	4.7	7.5	0.3	276
	28.0	4.7	7.5	0.1	276
	30.0	4.7	7.4	0.1	279
	32.0	4.7	7.4	0.1	282
	34.0	4.7	7.3	0.1	285
08/26	0.0	20.4	8.7	8.7	281
	2.0	20.4	8.7	8.6	281
	4.0	20.2	8.7	8.6	280
	6.0	20.1	8.8	8.5	281
	8.0	19.7	8.8	7.1	282
	9.0	17.1	8.1	2.9	296
	10.0	13.4	8.0	0.1	302
	11.0	12.1	8.0	0.1	302
	12.0	10.7	8.0	0.1	296
	14.0	8.4	7.9	0.0	294
	16.0	6.7	7.9	0.0	286
	18.0	6.1	7.9	0.0	285
	20.0	5.7	7.9	0.0	286
	25.0	5.3	8.0	0.0	293
	29.0	5.0	7.8	0.0	298

Williams Lake -- Spokane County

1992 Onsite Visit Data - Water Chemistry

Date	05/13/92 Epilimnion	05/13/92 Hypolimnion	08/26/92 Epilimnion	08/26/92 Hypolimnion
Composite Depths (m)	3, 6, 9	14, 22	2, 4, 6	14, 16, 18
Total Phosphorus ($\mu g/L$)	18	21	15	18
Total Nitrogen (mg/L)	0.57	0.70	0.52	0.54
Chlorophyll *a* ($\mu g/L$)	2.00	--	2.03	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	<1	--	<1	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	<1	--	<1	--
Total Suspended Solids (mg/L)	3	--	4	--
Total Nonvolatile Suspended Solids (mg/L)	1	--	2	--
Color (Pt-Co units)	25	--	--	--

Historical Data From Ecology

Date	07/10/73[a]	06/21/89[b]	09/20/89[b]	05/23/90[c]	08/10/90[c]	6/10/91[d]
Secchi (ft)	6	16.4	18.0	--	--	17
Total Phosphorus, epilimnion ($\mu g/L$)	27	18	15	19	17	--
Total Nitrogen, epilimnion (mg/L)	--	0.45	0.74	0.49	0.52	0.42
Chlorophyll *a* ($\mu g/L$)	3.2	2.4	2.6	--	--	--
Dissolved Oxygen, surface (mg/L)	9.7	9.9	9.0	11.5	9.1	10.8
Dissolved Oxygen, bottom (mg/L)	0.1	0.1	0.0	0.2	0.2	0.2

a. Dion *et al.* (1976), McConnell *et al.* (1976)
b. Brower and Kendra (1990)
c. Rector (1991)
d. Rector (1992)

Williams Lake -- Spokane County

Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity in Williams Lake was fair, as indicated by Secchi depths which ranged from 8.0 to 13.0 feet. The mean Secchi depth in 1992 (10.1 feet) was not as deep as the mean Secchi depths from 1991, 1990, and 1989. Shallower Secchi depths in 1992 may be related to the low water level.

Total Phosphorus
Total phosphorus in the epilimnion was moderately high on both sampling dates (18 μg/L in May and 15 μg/L in August). Concentrations found were very similar to those measured in 1990 (19 μg/L in May and 17 μg/L in August; Rector, 1991).

Total Nitrogen
Total nitrogen was also moderately high on both sampling dates (0.57 mg/L in May and 0.52 mg/L in August), and was similar to concentrations measured in 1990 (0.49 in May and 0.52 mg/L in August; Rector, 1991).

Fecal Coliform Bacteria
No fecal coliforms were detected in any of the four samples collected.

Solids and Color
There were some suspended solids in the water on both sampling dates, but the majority of the solids were organic, probably indicating algae or zooplankton. During May, field notes indicate that there was a lot of zooplankton in the water samples.

Profile Data
On both sampling dates, the lake was stratified with respect to temperature. Below the thermocline, dissolved oxygen decreased considerably with depth. During August, dissolved oxygen was very low (0.1 mg/L or less) in the bottom 19 meters of the lake. It is likely that very low dissolved oxygen has been occurring for many years, since dissolved oxygen was less than 1.0 mg/L throughout the entire hypolimnion in October 1968 (Lee, 1969).

Oxygen is depleted from the hypolimnion by bacteria which decompose aquatic plants and algae in the water and sediments. When decomposition occurs in the absence of oxygen and sulphate is present, hydrogen sulfide (rotten-egg smell) can be produced. Hydrogen sulfide was detected in water samples collected from the bottom of the lake in 1989 and 1973 (Brower and Kendra, 1990; McConnell *et al.*, 1976).

Plants
Algal density was low on both sampling dates, as indicated by low concentrations of chlorophyll *a*. Given the moderately high concentrations of total phosphorus on both dates, low chlorophyll

was not expected. It is possible that algal density was controlled by zooplankton (microscopic animals); during the May onsite visit, there was a lot of zooplankton on the chlorophyll filter compared to other lakes monitored for the program this week.

Aquatic plants identified by Ecology staff during the May 13, 1992 onsite visit with the volunteer were largeleaf pondweed (*Potamogeton amplifolius*), waterweed (*Elodea canadensis*), coontail (*Ceratophyllum demersum*), milfoil (*Myriophyllum verticillatum*), and muskgrass (*Chara*). The alga *Cladophora* was seen at the volunteer's boat ramp. During the August 1990 onsite visit with the volunteer, waterweed, coontail, watermeal (*Wolffia* spp.), and cattails (*Typha*. spp.) were also observed.

Other Available Information

Lake sediments in Williams Lake were analyzed in 1983 to evaluate sedimentation of volcanic ash (Anderson *et al.*, 1984). Discontinuous ash layers in the sediments were found to result from ash layers breaking up and sinking into lower density, uncompacted lake sediment.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

> Williams Lake is used for fishing, boating, swimming, rowing, jet skiing, camping, and waterfowl hunting. There are two resorts on the lakeshore. There is one boat ramp, and there is a speed restriction set by Spokane County of 50 mph for motorboats. About 1 percent of the shoreline is publicly-owned. Rainbow, cutthroat, and kamloop trout were stocked in the lake. Currently the watershed is used primarily for animal grazing and crop agriculture. The lakeshore is being developed further for residences. In the past the watershed was used for animal grazing and crop agriculture.
>
> There are 20 houses on the lakeshore. At the northeast end of the lake there are about 125 permanent trailers which use septic tanks, and 55 lots used seasonally by RVs that all use holding tanks. The resort on the west end of the lake was sewered in 1976 (treatment uses a lagoon system) and serves 75 trailers. There are two culverts that empty into the lake. Lake water is withdrawn for drinking and irrigation. Currently, the minimum setback for lakeshore development is 50 feet.
>
> There are wetlands on the west end of the lake. Weeds come to the surface of the water in the shallow areas. The lake has been treated with rotenone several times for eliminating undesirable fish species; the last time was in 1988.

Williams Lake -- Spokane County

Overall, the volunteer finds that Williams Lake had good water quality. Problems in the lake in 1992 were ranked as 1) low water level, 2) algae, and 3) gradually degrading water quality over the years. A possible source of problems is the lack of a sewer on the north end of the lake. There were no changes in water quality since the 1991 monitoring season, but the volunteer noted that the lake level was the lowest in many years; he reported that the lake dropped 24 inches from June 16 through October 31. Algae and lake level were also the two worst problems in 1991. The volunteer noted that the lake is slowly deteriorating, and something needs to be done about it.

Comments

Williams Lake was characterized as mesotrophic, based on the fair water clarity, the moderately high concentrations of total phosphorus, and the very low dissolved oxygen in the hypolimnion.

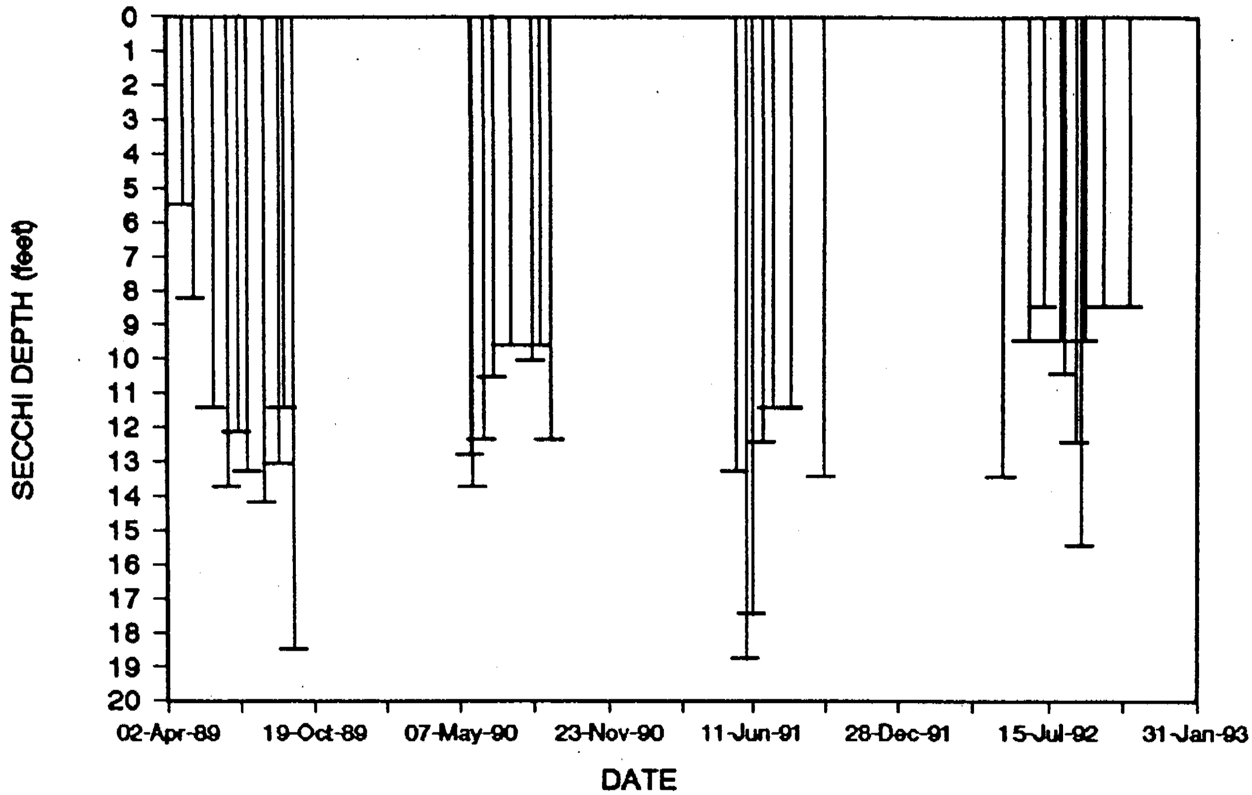
Despite the low water level in the lake, nutrient concentrations and profile data were similar to data collected earlier for the program. Because surface flow to the lake is primarily from an intermittent inlet, it is likely that low precipitation during 1992 considerably restricted inflow to the lake. This is cause for concern, because nutrients and ions were not being flushed naturally from the lake. As a result, if low precipitation continues, nutrients and ions could concentrate in the water. Sidley Lake in Okanogan County is another lake which had an intermittent inflow, and both the inflow and outflow dried up as a result of low surface flow. Concentration of ions in the lake water from no flushing is the likely cause of the very high conductivity in Sidley Lake; when the lake was last monitored in 1990, conductivity was greater than 2,000 μmhos/cm.

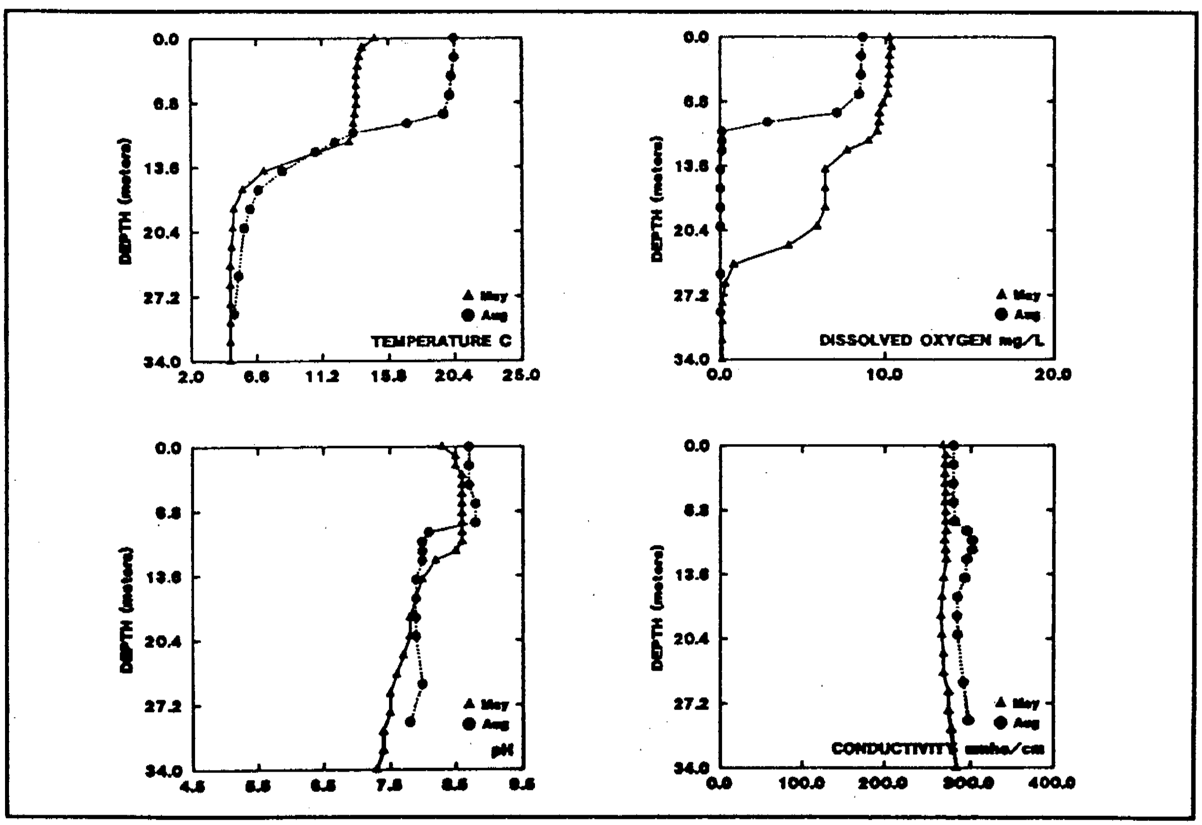
Eloika Lake was the only other Spokane County Lake monitored for the program in 1992. In comparison with Williams Lake, Eloika Lake had lower water clarity and higher concentrations of total phosphorus.

Acknowledgement

I thank Brad McHenry for volunteering his time to monitor Williams Lake during 1989-1992.

WILLIAMS LAKE (SPOKANE COUNTY)



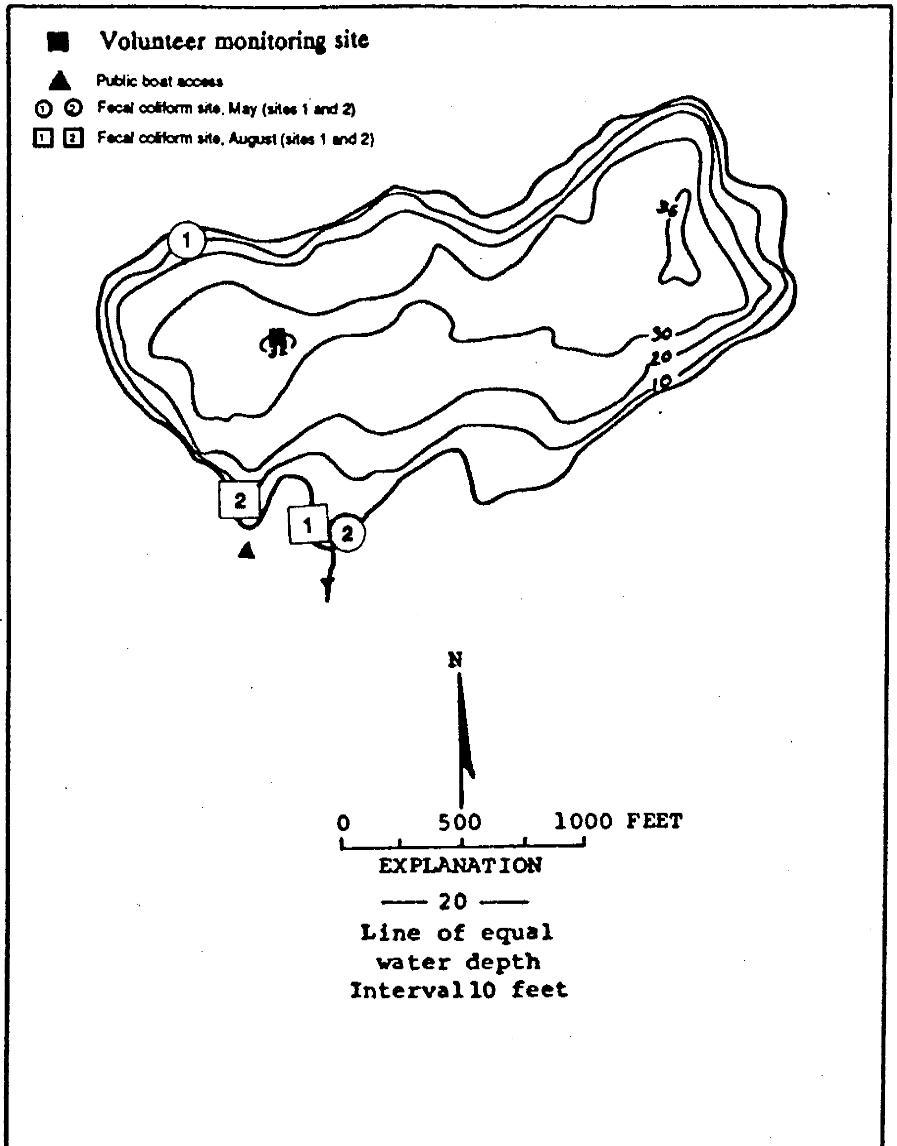


Lake Wooten -- Mason County

Lake Wooten is located seven miles west of Belfair. The lake has no inlet and drains to Haven Lake and the Tahuya River.

Size (acres)	68
Maximum Depth (feet)	36
Mean Depth (feet)	23
Lake Volume (acre-feet)	1,530
Drainage Area ($miles^2$)	0.3
Altitude (feet)	407
Shoreline Length (miles)	1.5

Data From Bortleson *et al.* (1976)



Wooten Lake, Mason County. From Washington Department of Game, July 23, 1948.

Lake Wooten -- Mason County

1992 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	35
Mean Trophic State Index (Total Phosphorus):	32
Mean Trophic State Index (Chlorophyll *a*):	34

Volunteer-Collected Data

Date 1992	Time	Temp (°C) (°F)	Secchi (ft)	Lake Ht (in)	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
13-May			23.0						Onsite visit.
27-May	1130	19.0 66.2	20.3		Lt-Green	90	Trace	Light	pH is 7.8.
11-Jun	1500	20.0 68.0	20.7	33.75	Lt-Green	90	Trace	Breezy	pH is 7.7. New dock so lake height is different from last year.
24-Jun	1500	25.0 77.0	21.3	20.00	Lt-Green	0	None	Light	pH is 7.5
08-Jul	1430	21.0 69.8	20.5	21.00	Lt-Green	100	Light	Calm	The set screw on pH stick is stripped so I cannot adjust it.
29-Jul	1030	23.0 73.4	21.0	18.75	Green	0	None	Calm	Slight amount of algae bloom.
11-Aug	0930	22.0 71.6	20.0	17.75	Green	0	None	Calm	Moderate algae bloom with water a little darker green.
19-Aug			18.2						Onsite visit.
01-Sep	1300	20.0 68.0	18.0	15.50	Green	50	None	Breezy	
14-Sep	1500	18.0 64.4	14.5	12.75	Green	100	None	Breezy	
28-Sep	1300	18.0 64.4	12.7	12.50	Green	25	Trace	Light	Lake clarity has never been this poor. No algae bloom left.
18-Oct	1300	15.0 59.0	12.5	12.00		0	Light	Strong	

[1] Trophic State Indices calculated from Carlson (1977)

Lake Wooten -- Mason County

1992 Onsite Visit Data - Profile Data

Date 1992	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/13	0.0	17.2	7.7	10.2	23
	1.0	17.0	7.5	10.1	23
	2.0	16.9	7.5	10.2	23
	3.0	16.9	7.5	10.1	23
	4.0	16.8	7.5	10.1	23
	5.0	16.8	7.5	10.1	23
	6.0	14.5	7.6	12.1	23
	7.0	12.9	7.6	12.3	23
	8.0	11.6	7.4	9.6	24
08/19	0.0	24.2	7.6	8.7	35
	1.0	24.1	7.6	8.6	35
	2.0	24.1	7.6	8.5	35
	3.0	24.0	7.6	8.5	34
	4.0	23.8	7.6	8.7	34
	5.0	23.0	7.6	9.0	35
	6.0	22.7	7.6	8.9	34
	7.0	21.6	7.6	7.7	35
	8.0	20.0	7.4	0.3	41

1992 Onsite Visit Data - Water Chemistry

Date	05/13/92		08/19/92	
	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Composite Depths (m)	1, 2, 4	7, 8	1, 2, 3	6, 7
Total Phosphorus (µg/L)	6	33	8	12
Total Nitrogen (mg/L)	0.26	0.32	0.21	0.27
Chlorophyll *a* (µg/L)	1.14	--	1.70	--
Fecal Coliform Bacteria Site 1 (colonies/100 mL)	<1	--	4	--
Fecal Coliform Bacteria Site 2 (colonies/100 mL)	<1	--	2	--
Total Suspended Solids (mg/L)	1	--	1	--
Total Nonvolatile Suspended Solids (mg/L)	1	--	<1	--
Color (Pt-Co units)	25	--	5	--

Lake Wooten -- Mason County

Historical Data From Ecology

Date	8/22/74[a]	06/28/89[b]	09/27/89[b]	08/14/90[c]	05/20/91[d]
Secchi (ft)	15	22	14.1	25.4	22.5
Total Phosphorus, epilimnion (μg/L)	5	3	10	15	--
Total Nitrogen, epilimnion (mg/L)	--	0.13	0.20	0.64	0.13
Chlorophyll *a* (μg/L)	--	0.9	9.7	--	--
Dissolved Oxygen, surface (mg/L)	8.8	9.7	9.1	8.7	10.5
Dissolved Oxygen, bottom (mg/L)	8.4	6.1	0.2	9.4	8.7

a. Bortleson *et al.* (1976)
b. Brower and Kendra (1985)
c. Rector (1991)
d. Rector (1992)

Lake Wooten -- Mason County

Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in Lake Wooten was very good, as indicated by Secchi depths which ranged from 12.5 to 23.0 feet. Secchi depths were not as deep in 1992 in comparison to Secchi depths collected from 1989 to 1991. Each year from 1989 to 1992, Secchi depths have typically decreased from May through October.

Total Phosphorus

Total phosphorus in the epilimnion was very low on both sampling dates (6 μg/L in May and 8 μg/L in August), and was similar to concentrations measured in 1989 (3 μg/L in June and 10 μg/L in September; Brower and Kendra, 1990) and August 1974 (5 μg/L; Bortleson *et al.*, 1976). The concentration from August 1990 (15 μg/L; Rector, 1991) was moderately high.

Total Nitrogen

Total nitrogen was also low on both sampling dates (0.26 mg/L and 0.24 mg/L), but was somewhat higher than concentrations found in 1989 and 1991 (0.13 mg/L on both dates; Brower and Kendra, 1990; Rector, 1992). The 1990 concentration, like the phosphorus concentration, was moderately high (0.64 mg/L; Rector, 1991) and may have resulted from some short-term input of nutrients.

Fecal Coliform Bacteria

No fecal coliforms were detected from samples collected in May. Although there were some bacteria present in the August samples, results were very low and were within state standards.

Solids and Color

There were very few suspended solids in the water at the time of sampling. Color results indicate the water had some natural color during May, but there was very little color during August. Results indicate that Secchi depth were most likely related to algal density, rather than suspended sediments or natural color.

Profile Data

On both sampling dates, the lake was weakly stratified with respect to temperature. Dissolved oxygen decreased only at the very bottom of the lake, which often occurs as bacteria use oxygen during decomposition of aquatic plants and algae in the water and sediments. Profile data from 1992 were very similar to profile data collected in 1989, 1990, and 1991.

Plants

Algal density was very low on both sampling dates, as indicated by very low concentrations of chlorophyll *a*.

Lake Wooten -- Mason County

During the May and August 1992 onsite visits with the volunteer, plant samples were collected from the vicinity of the outlet. The only plant identified was *Ludwigia palustris*. No other submerged macrophytes were observed. During August, algal colonies (possibly *Gloeotrichia*) were visible in the water.

Summary of Questionnaire Results and Information From the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed from 1989 to 1992.

> Lake Wooten is used for fishing, boating, swimming, rowing and jet skiing. There are is one public boat ramp, and there are no restrictions for motorboat use on the lake. About 1 percent of the shoreline publicly-owned. Rainbow and cutthroat trout were stocked in the lake. In the past the watershed was logged, and the shoreline was altered.
>
> There are 63 houses on the lakeshore, and none of the houses are connected to a sewer. There are four culverts that drain into the lake. Lake water is withdrawn for drinking and irrigation. There is no citizen's organization for the lake. Currently, the minimum setback for lakeshore development is 15 feet, and there are no minimum lot lengths or restrictions on residential density.
>
> The lake is mostly spring-fed. There was very little aquatic plant growth in the lake, although one plant sampled during both onsite visits in 1992 was not seen earlier. There is a small amount of planted and maintained lily pads on the north shore of the lake, and some reeds grow on the south shore near the outlet and in a southeast cove of the lake. The lake was treated with chemicals in the past to control undesirable fish species. During the May 1992 onsite visit, the volunteer noted that Western Pond Turtle were spotted in the lake by another resident.
>
> Overall, the volunteer finds that Lake Wooten had excellent water quality. Problems in the lake in 1992 were ranked as 1) gradually degrading water quality over the years, and 2) algae. Possible sources of problems in the lake are old septic systems, and the county giving variances for new septic systems. There were no changes in the lake since the 1991 monitoring season.

Comments

Lake Wooten had very good water clarity, low nutrient concentrations, and low algal growth (as indicated by chlorophyll *a*). Based on these, the lake was characterized as oligotrophic.

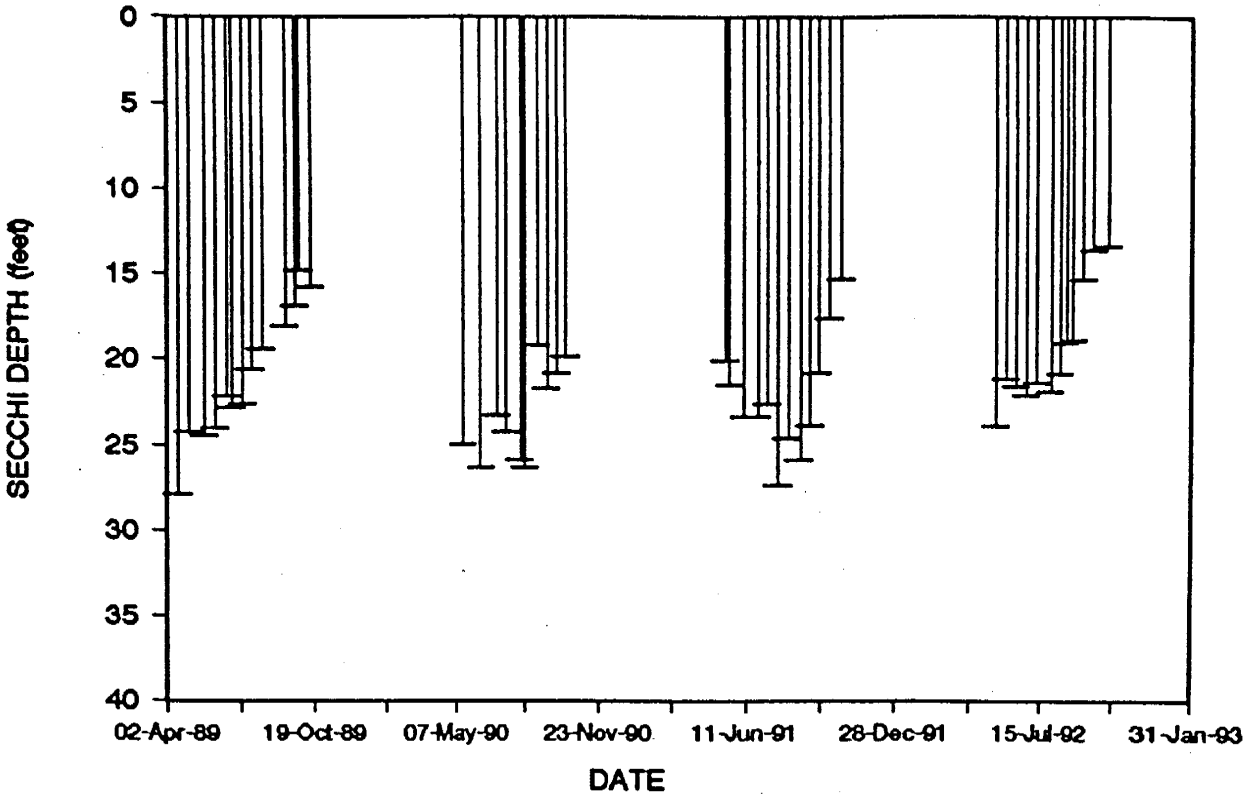
Lake Wooten -- Mason County

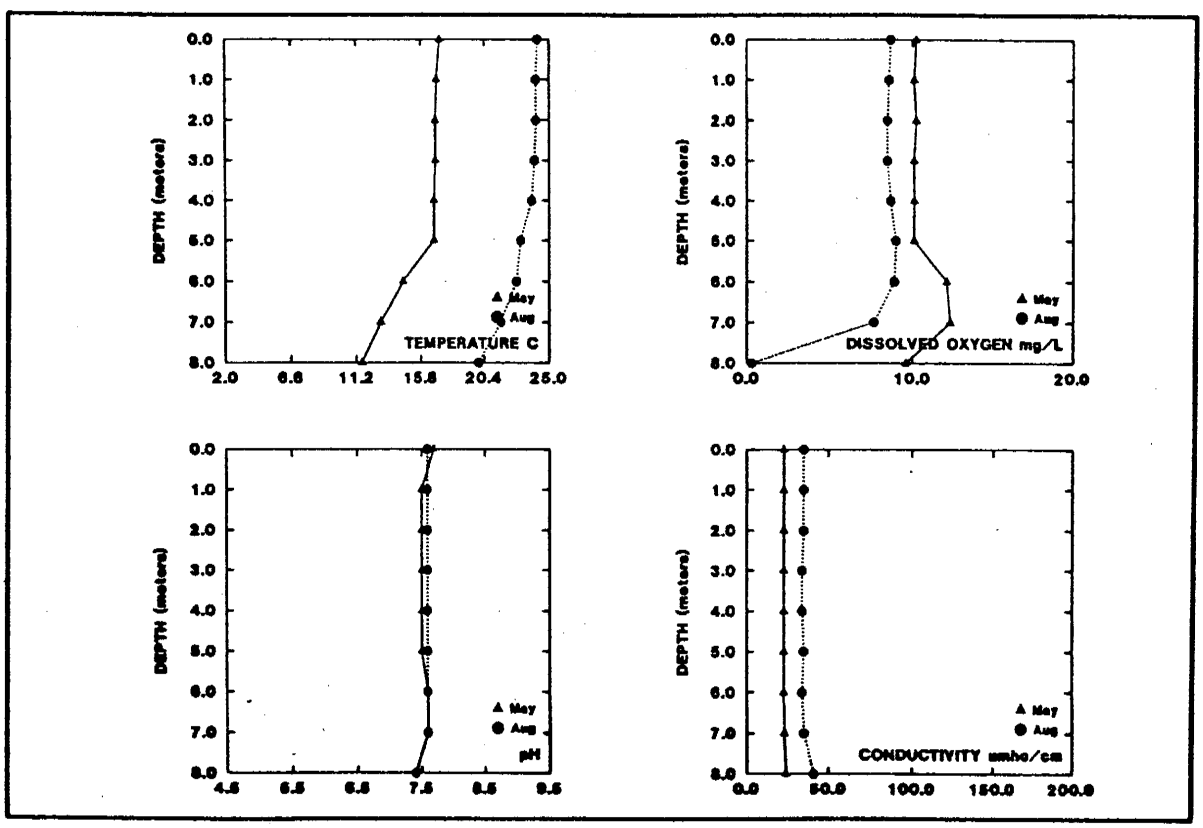
Other Mason County Lakes monitored for the program in 1992 were Limerick, Mason, Nahwatzel, Phillips, and Spencer. Of these, Mason, Spencer and Nahwatzel were oligotrophic, Phillips was oligo-mesotrophic, and Limerick was mesotrophic.

Acknowledgement

I thank Rusty Kidrick for volunteering her time to monitor Lake Wooten during 1989-1992.

LAKE WOOTEN (MASON COUNTY)





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APPENDIX A

Questionnaire on Lake and Watershed Uses

WASHINGTON'S CITIZEN LAKE MONITORING PROJECT
1992 QUESTIONNAIRE

Your Name ______________________ Date ______________
Lake/County ______________________

- o Please complete and return this questionnaire by October 30, 1992
- o Remember to continue collecting Secchi data, every two weeks, until mid-Ocotober
- o Contact Julie at (206) 586-5496 if you aren't sure how to answer a question
- o **Thanks for your time spent on this!**

<u>General Lake Information</u>

1. How many houses are there on the shoreline? (The exact number is best; please estimate the number if you are monitoring a very large lake.)
   - ☐ Exactly ______________________
   - ☐ Estimated ______________________

2. Some counties use zoning to establish minimum setbacks from lakeshores, minimum lot lengths along shorelines, and the maximum number of houses/acre. This information may be obtained from the county Master Plan or your County Planner.
   - ☐ Setbacks are currently ____________feet from the shoreline
   - ☐ Minimim lot lengths are currently ____________feet
   - ☐ Residential density is currently restricted to ____________houses per acre
   - ☐ Don't Know

3. Approximately what percent of the shoreline is publicly-owned? (Publicly-owned shoreline includes city, county or State parks, National Forest lands, and land managed by the Department of Natural Resources, Bureau of Land Management, Deparment of Wildlife, Department of Game, etc.)
   - ☐ ________percent
   - ☐ Don't Know

4. Will the lake be treated with any chemicals this year?
   - ☐ Yes, for weed control
   - ☐ Yes, for algae control
   - ☐ Yes, for eliminating non-game fish
   - ☐ No
   - ☐ Don't Know

5. Are any lake management activities occurring on your lake this year?
   - ☐ Yes, a mechanical harvester has been used
   - ☐ Yes, the lake will be/has been chemically treated
   - ☐ Yes, the lake will be/has been dredged this year
   - ☐ Yes, the lake will be drawn down next winter
   - ☐ No management activities will be pursued this year

6. Were fish stocked in the lake this year?
   - ☐ Yes (What species? ______________________________________)
   - ☐ No
   - ☐ Don't know

Lake Water Quality

7. Were there days when you would not swim in your lake because of poor water quality?
   - ☐ Yes (About how many days out of the year? ________________)
     Was the lake officially closed for swimming? ☐ Yes ☐ No
   - ☐ No

8. Were there days when fishing was difficult because of poor water quality (for example, because of excessive plants or algae)?
   - ☐ Yes (About how many days out of the year? ________________)
     Was the lake officially closed to fishing? ☐ Yes ☐ No
   - ☐ No

9. Were there days when the lake had poor aesthetics?
   - ☐ Yes (About how many days out of the year? ________________)
   - ☐ No

10. Overall, how would you evaluate the recreational quality on your lake with respect to swimming, fishing, and boating?
    - ☐ Excellent
    - ☐ Good--no uses are restricted because of poor water quality
    - ☐ Fair--some uses are restricted because of water quality or excessive plant growth
    - ☐ Poor--would not swim in this lake most days of the year, even when the temperature was warm enough

11. What have been the worst water quality problems on your lake in 1992? Please rank the problems in order of their importance, with No. 1 being the worst problem and No. 2 being the next worse problem, etc.

____ Algae bloom	____ High water level
____ Odor from decaying algae	____ Low water level
____ Aesthetics degraded	____ Fluctuating water level
____ Excessive aquatic plant growth	____ Suspended sediments
____ Decaying plants	____ Shoreline erosion
____ Bacteria	____ Water quality gradually degraded over years
____ Hazardous substance	____ Recently degraded water quality
____ Eye/skin problems after swimming	____ Fish kill
____ Swimmer's itch	____ Impaired fisheries
____ Beach closure	

____ Other ____

12. What do you see as the predominant source(s) of water quality problems in your lake (if a problem exists)? Use the back of Page 3 if you need more room.

____
____
____

13. Have there been any changes in your lake since last year's monitoring season?

____
____
____

14. Is there any other information that you would like to pass on about your lake?

____
____
____

Lake Organizations

15. Are there any lake groups for your lake?
- ☐ Lake Association
- ☐ Lake Management District
- ☐ Sewer District
- ☐ Community Association
- ☐ Other(s) ______________________________

Monitoring/Training

16. How many times did you take a Secchi reading? ______________
(This is to make sure we've received as many data cards as you've mailed)

17. Do you have any comments on the report which was prepared from earlier data you've collected (if you monitored your lake prior to 1992)?

____
____

18. Did you enjoy participating in this project? (Please comment.)

____
____

19. Would you volunteer again for next summer?
- ☐ Yes
- ☐ No, I'll return the disk and thermometer at the end of the sampling season so another volunteer can use them next year.
- ☐ No, but I know someone who may want to monitor next year:
  Name ______________________________
  Address ______________________________
  Phone ______________________________

20. Suggestions for improving the program for the 1993 sampling season:

____
____
____

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE!

VOLUNTEERS WHO ENTERED THE PROGRAM PRIOR TO 1990 HAVE ALREADY ANSWERED THE FOLLOWING QUESTIONS WHICH APPEAR ON BOTH SIDES OF THIS PAGE. PLEASE MARK ALL THAT APPLY. Thank You!

Watershed and Lake Uses

1. What are the recreational uses of the lake?
   - ☐ Swimming
   - ☐ Fishing
   - ☐ Motor Boating (including water skiing)
   - ☐ Non-motorized boating (rowing, sailing, wind surfing)
   - ☐ Jet skiing
   - ☐ Lakeshore camping
   - ☐ Waterfowl hunting
   - ☐ Other ______________________________

2. What public recreational facilities are there on the lakeshore?
   - ☐ Day use area (picnic area, beach...)
   - ☐ State Park
   - ☐ County/City Park
   - ☐ Resorts (How many? __________)
   - ☐ Boat Ramps (How many? ________________)
   - ☐ Other ______________________________

3. Are there restrictions for motor boat use on the lake?
   - ☐ No motor boating allowed
   - ☐ Speed limits for motor boats ______________mph
   - ☐ No wake zones within _____________feet of lakeshore
   - ☐ Other restrictions (please list ______________________________)
   - ☐ No restrctions on motor boat use

4. What are the uses of the lake water?
   - ☐ Direct withdrawal -- drinking and other domestic uses
   - ☐ Municipal water supply
   - ☐ Industrial water supply
   - ☐ Irrigation
   - ☐ Other ______________________________
   - ☐ Don't Know

Lake/Watershed Activities and Development

5. **Currently**, what kinds of activities are there within the watershed? (A watershed is all land that drains eventually into a lake, and includes land that drains into streams that flow into the lake.) Please note if one activity is especially dominant.
   - ☐ Logging
   - ☐ Agriculture -- crops, orchards, tree farms...
   - ☐ Agriculture -- animal grazing and animal feeding operations
     Do livestock have direct access to the lakeshore or inlet tributaries? ☐ Yes ☐ No
   - ☐ Industrial development
   - ☐ Lakeshore development for residences
   - ☐ Other ______________________________

6. **Historically**, what kinds of activities occurred within the watershed?
   - ☐ Logging
   - ☐ Agriculture -- crops
   - ☐ Agriculture -- animal grazing
   - ☐ Mining
   - ☐ Dredging (lake or wetlands? ______________________)
   - ☐ Shoreline alteration (such as vegetation removal or filling in the shoreline. Please explain.)
     ____
   - ☐ Other ______________________________

8. Is the lakeshore area sewered?
   - ☐ Yes -- Fully
   - ☐ Yes -- Partially (_____ % of the shoreline, or _____% of the homes served)
   - ☐ No
   - ☐ Don't Know

9. Are there any storm drains that drain into the lake? (Storm drains usually appear as concrete or metal pipes that drain into a lake from ditches or under roads.)
   ☐ Yes (How many? ________) ☐ No

APPENDIX B

Data Quality Objectives for Total Phosphorus

monitoring data is used by Ecology staff in making management decisions, designing more intensive studies, etc, as well as by private consulting firms, EPA, universities, private individuals, and others.

4) A trend analysis will be conducted after data has been collected for a sufficient number of years. The length of time required to identify a given trend depends on the variance in the data and the magnitude of the trend.

5) Nutrient limitation of primary productivity will be evaluated. The ratio of total nitrogen (TN) to total phosphorus (TP) is indicative of whether TN or TP is limiting which in turn can explain observed relationships between water quality variables. Nutrient limitation can also affect management decisions.

6) Hypolimnetic phosphorus concentration will be used to assess, in a general way, internal loading.

Project Design for Total Phosphorus

One depth-composited sample will be collected from the epilimnion and one from the hypolimnion of each lake. Samples will be collected in either a van Dorn or a Kemmerer sampler which will be rinsed in lake water several times prior to collecting the sample. Samples will be collected from three depths and composited directly in the sample bottle. Preservative will be added (if not already contained in the bottle), the bottle shaken to distribute the preservative, labeled, and placed on ice for shipment to the lab.

DATA QUALITY OBJECTIVES

Precision and Limit of Detection

In order to meet the objectives for the total phosphorus data, the total precision for results between 5 and 15 $\mu g/L$ should be $\leq$ 15% at the 95% confidence level. This will require a total RSD for results in this range of $\leq$ 7.5%. The limit of detection should be $\leq$ 5 $\mu g/L$ and preferably 2.5 $\mu g/L$ or less, so as to be below the lowest concentration expected (5 $\mu g/L$ in both 1989 and 1990).

Bias

The total relative bias for results above 5 $\mu g/L$ should not exceed 5%.

The overall accuracy of any given result should then be $\leq$ 20% at the 95% confidence level or $\pm$ 2 $\mu g/L$ at 10 $\mu g/L$.

Representativeness

The objectives of this survey will be achieved by collecting a depth-composited sample from the epilimnion and one from the hypolimnion. The epilimnion is generally well-mixed; a single sample collected in this way should be representative of open-water conditions. Because the hypolimnion is not as well mixed, this data will provide only a general assessment of internal phosphorus loading.

Because interpretations will be based on a single sample, it is important that the aliquot being analyzed from that sample also be representative. For this reason and because the analysis will be performed on unfiltered samples, the larger the volume used in the analysis, particularly prior to digestion, the more representative the result.

Completeness

Except for ten lakes (which will be sampled in duplicate), only one sample each from the epilimnion and the hypolimnion will be collected at each lake. If that sample is lost, no data will be available. If the specified holding time is exceeded, the project manager should be contacted for a determination as to whether or not to analyze the sample. No samples over holding times should be analyzed without prior approval of the project manager.

Comparability

For future trend analysis, comparability of the results is very important. Carefully documented standard sampling procedures will be used. The analytical method will be selected to provide results with minimum bias and good precision and the data quality will be carefully documented.

ANALYTICAL PROCEDURES

The results from the 1990 Lakes Survey indicate that EPA Method 365.3 (modified by the use of a 10 cm cell) is capable of meeting the data quality objectives for this project. Matrix spike and check standard recoveries averaged 99%, the RPDs for two pairs of duplicates averaged 5% and the Limit of Detection was estimated to be about 4 μg/L based on the results for three blanks.

QC results from four labs were compared in April, 1992. The four labs were Manchester, Aquatic Research, the Institute for Watershed Studies at Western Washington University (WWU), and the limnology lab at Eastern Washington University (EWU). Because Aquatic Research uses the same method as Manchester (365.1) and had similar QC results, it was not considered further. QC results from Manchester, WWU, and EWU are shown in the table below:

QUALITY CONTROL PROCEDURES

Field QC

Duplicate samples will be collected at 10 lakes, 7 of which will have expected concentrations ≤ 15 μg/L. In order to assess total variability, including in-lake variability, duplicates will be collected from a different open-water location than the original sample. The exact location will depend on lake morphometry.

One transfer blank will be prepared by each sample team each week of the sampling survey by rinsing (to simulate lowering the sampler through the water column) and then filling the sampler with deionized water. This water will then be transfered to sample containers.

EPA reference standards will be diluted to 7.5 and 15.0 μg/L and submitted to the lab during each sampling season (spring and fall). All field QC samples will be submitted as blind samples.

Analytical QC

One out of each pair of field duplicates will be analyzed in duplicate.

Check standards at 3.0, 12.5, and 25.0 μg/L will be prepared from EPA's WP022 Conc. #3 PE sample for total phosphorus. One check standard at each level will be analyzed with each batch of samples.

Two method blanks will be analyzed with each batch of samples.

Two samples in each batch will be spiked with WP022 Conc. 3 at 25.0 μg/L.

DATA ASSESSMENT PROCEDURES

Precision

Within-batch analytical precision will be estimated as the pooled standard deviation of the results of all pairs of laboratory duplicates analyzed with the batch of samples.

$$s_p = \sqrt{\frac{\Sigma D_i^2}{2m}}$$

where D_i is the difference between the ith pair of duplicate results and m is the number of pairs of results.

Between-batch analytical precision will be estimated as the pooled standard deviation of the results of the 10 pairs of laboratory duplicates.

Total precision will be estimated as the pooled standard deviation of the results of the 10 pairs of field duplicates.

The Limit of detection is calculated as

$$LOD = 2\sqrt{2}\,t_{n-1,0.1}S$$

where t is the value of Student's t statistic and S is the standard deviation (or pooled standard deviation for pairs) of blanks.

Bias

Analytical bias will be estimated as the mean of the recoveries of the analytical check standards.

The recoveries of the matrix spikes will be used to indicate the presence of excessive bias due to matrix effects. The precision of the matrix spike recoveries will be about ± 10% at the 95% confidence interval. Therefore, recoveries of > 120% or < 80% indicate the presence of matrix interference.

APPENDIX C

Hydrolab Postcalibration Data

Appendix C. Hydrolab Postcalibration Data for Quality Assurance.

Date 1991	Parameter	Comparison Value	Hydrolab Value	Postcalibration for the following lakes
05/15	D.O.	9.7 mg/L	9.4 mg/L	Limerick
05/19	D.O.	10.0 mg/L	10.3 mg/L	Limerick
	pH	7.0	7.1	
	pH	10.0	10.0	
05/20	D.O.	9.5 mg/L	9.3 mg/L	Tanwax, Wooten, Mission
	pH	7.0	7.0	
	pH	10.0	10.1	
	D.O.[f]	10.2 mg/L	10.1 mg/L	Wooten, surface
05/23	D.O.	10.0 mg/L	9.9 mg/L	Summit, Killarney
	pH	7.0	7.0	
	pH	10.0	10.1	
	cond	147. µmho/cm	152. µmho/cm	
05/24	D.O.[f]	9.4 mg/L	9.3 mg/L	
	pH	7.0	7.0	
05/28	D.O.	10.2 mg/L	9.6 mg/L*	
	D.O.[f]	11.0 mg/L	10.2 mg/L	
	pH	7.0	7.0	
	pH	10.0	10.0	Alice, Sawyer
05/29	D.O.	9.9 mg/L	9.7 mg/L	Samish, Cranberry, Goss, Bosworth,
	pH	7.0	7.0	Flowing
	pH	10.0	10.0	
05/30	D.O.[f]	10.4 mg/L	10.3 mg/L	
05/31	D.O.	10.1 mg/L	9.8 mg/L	
	pH	7.0	7.0	
06/04	D.O.	10.2 mg/L	10.1 mg/L	Long, Pattison
	pH	7.0	7.1	
	pH	10.0	10.0	
	D.O.[f]	11.6 mg/L	11.6 mg/L	
06/10	D.O.	10.4 mg/L	10.6 mg/L	Wenatchee
	pH	7.0	6.8	
	pH	10.0	10.0	
	D.O.[f]	10.3 mg/L	10.3 mg/L	
06/11	D.O.	8.4 mg/L	8.4 mg/L	Williams, Eloika, Waitts
	pH	7.0	7.1	
	pH	10.0	10.0	
	D.O.[f]	9.6 mg/L	10.3 mg/L	
06/12	pH	7.0	7.0	Big Meadow, Mill precal
	pH	10.0	10.0	
06/13	D.O.	8.7 mg/L	9.2 mg/L	Big Meadow, Mill (pH only)
	pH	7.0	7.0	
	pH	10.0	10.1	
	D.O.[f]	10.5 mg/L	11.1 mg/L*	Mill, surface

Methods:

D.O.	Azide-modified dissolved oxygen titration
D.O.[f]	Azide-modified dissolved oxygen titration of field sample
pH 7	standard pH 7 buffer
pH 10	standard pH 10 buffer
cond	standard 0.02N KCl conductivity solution, 147 µmho/cm
	Postcalibration data exceeded acceptable QA limits. Data for this parameter are flagged.

Appendix C. Continued.

Date 1991	Parameter	Comparison Value	Hydrolab Value	Postcalibration for the following lakes
06/14	D.O.	10.6 mg/L	10.3 mg/L	Leo, Thomas, Black
	pH	7.0	7.0	
	pH	10.0	10.0	
	cond	141.µmho/cm	142.µmho/cm	
	D.O.[f]	8.5 mg/L	mg/L	
06/15	D.O.	9.7 mg/L	9.7 mg/L	Deep
	pH	7.0	7.1	
	pH	10.0	10.2	
06/18	D.O.	9.8 mg/L	9.7 mg/L	Martha, Stevens
	pH	7.0	7.0	
	pH	10.0	10.1	
	cond	141. µmho/cm	142. µmho/cm	
06/19	D.O.	9.2 mg/L	8.9 mg/L	Martha, Stevens, Ward
	pH	7.0	7.2	
	pH	10.0	10.0	
	cond	141. µmho/cm	144. µmho/cm	
	D.O.[f]	9.5 mg/L	9.6 mg/L	
06/21	D.O.[f]	9.5 mg/L	9.4 mg/L	
06/26	D.O.	9.2 mg/L	9.5 mg/L	Lacamas, Horseshoe
	pH	7.0	7.2	
	pH	10.0	10.0	
	D.O.[f]	10.5 mg/L	10.4 mg/L	
06/27	D.O.	10.0 mg/L	10.2 mg/L	Twin, Curlew
	pH	7.0	7.0	
	pH	10.0	10.1	
	D.O.[f]	8.9 mg/L	9.0 mg/L	
06/28	D.O.[f]	8.6 mg/L	8.3 mg/L	Osoyoos, Sidley, Crawfish

Methods:

D.O. Azide-modified dissolved oxygen titration
D.O.[f] Azide-modified dissolved oxygen titration of field sample
Ph 7 standard pH 7 buffer
pH 10 standard pH 10 buffer
pH 4 standard pH 4 buffer
cond standard KCL conductivity solution, 107 µmho/cm
* Postcalibration data exceeded acceptable QA limits. Data for this parameter or flagged, or not reported

Appendix C. Continued.

Date 1992	Parameter	Comparison Value	Hydrolab Value	Postcalibration for the following lakes
5/11	D.O.	9.0 mg/L	9.3 mg/L	Leech, Kahlotus
	D.O.[f]	9.2 mg/L	9.5 mg/L	Leo, 2 m
	pH 7	7.0	6.8	
	pH 10	10.1	10.3	
	cond	109. μmho/cm	113. μmho/cm	
5/12	D.O.	10.2 mg/L	9.8 mg/L	Black, Thomas, Leo
	pH 7	7.1	7.1	
	pH 10	10.1	10.1	
5/13	D.O.	10.8 mg/L	11.0 mg/L	Waitts, Jumpoff Joe, Deer
	D.O.[f]	10.3 mg/L	10.1 mg/L	Williams Lake, 3 m
	pH 7	7.0	7.2	
	pH 10	10.1	10.1	
5/14	D.O.	9.5 mg/L	9.5 mg/L	Williams, Eloika
	pH 7	7.0	7.2	
	pH 10	10.1	10.2	
5/18	D.O.	9.5 mg/L	9.7 mg/L	Osoyoos, Conconully
	D.O.[f]	9.9 mg/L	10.1 mg/L	Conconully Lake, 1 m
	pH 7	7.0	7.1	
	pH 10	10.1	10.0	
5/19	D.O.	10.7 mg/L	10.9 mg/L	Big Meadow, Deep
	D.O.[f]	9.3 mg/L	9.3 mg/L	Big Meadow Lake, __m
	pH 7	7.0	7.1	
	pH 10	10.1	10.1	
5/20	D.O.	10.6 mg/L	10.7 mg/L	Curlew, Crawfish
	D.O.[f]	9.0 mg/L	9.0 mg/L	Crawfish Lake, __ m
	pH 7	7.1	7.1	
	pH 10	10.1	10.1	
5/21	D.O.	9.6 mg/L	9.5 mg/L	Wenatchee
	pH 7	7.0	7.1	
5/12	D.O.	10.0 mg/L	9.7 mg/L	Long (Thurston), St. Clair, Ward, Killarney,
	pH	7.0	7.0	Alice, Sawyer
	pH	10.1	10.0	
5/13	D.O.	9.8 mg/L	9.7 mg/L	Mission, Wooten
	D.O.[f]	10.3 mg/L	10.2 mg/L	Wooten, 0 m
	pH 7	7.0	7.1	
	pH	10.1 mg/L	10.0 mg/L	Clear, Patterson, St. Clair
5/17	D.O.	9.1 mg/L	9.3 mg/L	Bosworth, Roesiger
	pH	7.0	6.9	
	pH	10.0	10.0	
5/19	D.O.	9.2 mg/L	9.3 mg/L	Martha L., Ketchum, Sunday
	pH	7.0	7.0	
	pH	10.0	10.1	
5/22	D.O.	9.8 mg/L	9.6 mg/L	Samish, Spanaway, Tanwax
	D.O.[f]	10.9 mg/L	10.9 mg/L	Samish, 0 m
	pH	7.0	7.0	
	pH	10.1	10.0	

Methods:

D.O. Azide-modified dissolved oxygen titration
D.O.[f] Azide-modified dissolved oxygen titration of field sample
Ph 7 standard pH 7 buffer
pH 10 standard pH 10 buffer
pH 4 standard pH 4 buffer
cond standard KCL conductivity solution, 107 μmho/cm
* Postcalibration data exceeded acceptable QA limits. Data for this parameter or flagged, or not reported

Appendix C. Continued.

Date 1992	Parameter	Comparison Value	Hydrolab Value	Postcalibration for the following lakes
5/29	D.O.	9.4 mg/L	9.6 mg/L	Kitsap, Mud, Horseshoe, Lacamas
	D.O.[f]	9.9 mg/L	9.8 mg/L	Mason, 0 m
	pH	7.0	7.0	
	pH	10.1	10.1	
6/02	D.O.	9.3 mg/L	9.5 mg/L	Mason, Limerick, L. Martha
	pH 7	7.0	7.1	
	pH 10	10.1	10.0	
6/05	D.O.	9.4 mg/L	9.3 mg/L	Phillips, American
	D.O.[f]	0.4 mg/L	0.1 mg/L	American, 20 m
	pH	7.0	7.0	
	pH	10.1	10.0	
6/09	D.O.			Lacamas
	D.O.[f]	0.4 mg/L	0.2 mg/L	Lacamas, 16 m
	pH			
	pH			
8/18	D.O.	8.4 mg/L	8.2 mg/L	Patterson
	pH	7.0	7.1	
	pH	4.1	4.1	
8/18	D.O.	8.7 mg/L	8.7 mg/L	Killarney
	pH 7	7.0	7.1	
	pH 4	4.1	4.0	
8/19	D.O.	8.1 mg/L	8.2 mg/L	Kitsap, Wooten
	pH 7	7.0	7.0	
	pH 4	4.1	4.1	
8/20	D.O.	8.8 mg/L	8.4 mg/L	Mission
	D.O.[f]	8.8 mg/L	8.7 mg/L	Mission, 0m
	pH	7.0	7.0	
	pH	4.1	4.1	
8/24	D.O.[f]	0.3 mg/l	0.1 mg/L	Sawyer, 14m
8/24	D.O.[f]	8.9 mg/L	8.5 mg/L	Sunday, 0m
8/26	D.O.	8.5 mg/L	8.9 mg/L	Bosworth, Roesiger, Samish, Alice, Sawyer
	pH	7.0	7.0	
	pH	10.0	10.0	
	cond	109. µmho/cm	113. µmho/cm	
8/24	D.O.	7.8 mg/L	8.0 mg/L	Leech, Kahlotus, Black, Thomas, Leo
	pH	7.0	7.0	
	pH	10.1	10.1	
8/26	D.O.	9.8 mg/L	9.9 mg/L	Waitts, Jumpoff Joe, Deer
	D.O.[f]	8.3 mg/L	8.2 mg/L	Williams, 2m
	pH 7	7.0	7.0	
	pH 10	10.1	10.1	

Methods:

D.O. Azide-modified dissolved oxygen titration
D.O.[f] Azide-modified dissolved oxygen titration of field sample
Ph 7 standard pH 7 buffer
pH 10 standard pH 10 buffer
pH 4 standard pH 4 buffer
cond standard KCL conductivity solution, 107 µmho/cm
* Postcalibration data exceeded acceptable QA limits. Data for this parameter or flagged, or not reported

Appendix C. Continued.

Date 1992	Parameter	Comparison Value	Hydrolab Value	Postcalibration for the following lakes
8/27	D.O.	8.5 mg/L	8.2 mg/L	Limerick, Nahwatzel, Phillips, Spencer
	D.O.[f]	8.7 mg/L	8.5 mg/L	Nahwatzel, 0m
	pH	7.0	7.2	
	pH	10.0	10.2	
	pH	4.1	4.2	
8/30	D.O.	8.8 mg/L	8.8 mg/L	Long (Kitsap), Mason
	pH	7.0	7.0	
9/02	D.O.	8.9 mg/L	8.9 mg/L	Martha L., Ketchum, Stevens
	pH 7	7.0	7.1	
	pH 10	10.0	9.9	
8/27	D.O.	8.8 mg/L	8.7 mg/L	Eloika, Williams
	D.O.[f]	7.7 mg/L	7.7 mg/L	Thomas, 1m
	pH	7.0	7.0	
	pH	10.0	10.1	
8/31	D.O.	8.4 mg/L	8.4 mg/L	Osoyoos, Conconully
	D.O.[f]	9.6 mg/L	9.6 mg/L	Conconully, 2m
	pH	7.0	6.9	
	pH	10.1	10.1	
9/01	D.O.	9.4 mg/L	9.4 mg/L	Deep, Big Meadow
	D.O.[f]	8.1 mg/L	8.2 mg/L	Big Meadow, 1m
	pH 7	7.0	7.0	
	pH 10	10.1	10.1	
9/02	D.O.	8.3 mg/L	8.3 mg/L	Crawfish, Curlew
	D.O.[f]	7.5 mg/L	7.5 mg/L	Crawfish, 1m
	pH	7.0	7.0	
	pH	10.1	10.1	
9/03	D.O.	9.0 mg/L	9.0 mg/L	Long (Thurston), St. Clair
	pH 7	7.0	7.1	
	pH 10	10.0	9.9	
	temp	21.3	21.1	
9/04	D.O.	9.1 mg/L	9.3 mg/L	Tanwax, Spanaway
	D.O.[f]	7.7 mg/L	7.8 mg/L	Tanwax, 0m
	pH	7.0	7.1	
	pH	10.0	10.0	
9/03	D.O.	8.3 mg/L	8.3 mg/L	Wenatchee
	pH 7	7.0	7.0	
	pH 10	10.1	10.1	
9/10	D.O.	9.1 mg/L	9.1 mg/L	Lacamas, Ward
	pH	7.0	6.9	
	pH	10.1	10.1	
	cond	109. μmho/cm	113. μmho/cm	

APPENDIX D

Laboratory Quality Assurance/Quality Control Data for 1991-1992

Appendix D. Laboratory Quality Assurance/Quality Control Data for 1991-1992

1991 Total Phosphorus Data

Lab Duplicates

Lab No.	Result 1 (μg/L)	Duplicate (μg/L)	CV (%)	RMS (%)
228414	5.8	3.1	42.9	
238171	5.8	5.8	0	
238423	8.3	9.4	8.8	
248025	4.2	7.7	41.6	
248431	2.3	1.1	49.9	
258012	4.6	1.6	68.4	
268024	0.8	0.7	9.4	
				39.5

Field Duplicates

Lake	Result 1 (μg/L)	Duplicate (μg/L)	CV (%)	RMS (%)
Big Meadow	4.6	5.2	8.7	
Sidley	16.6	18.3	6.9	
Pattison	8.3	7.7	5.3	
Samish	3.3	0.9	80.8	
Summmit	4.8	3.7	18.3	
				37.5

Lab Check Standards

Standard Value (μg/L)	Result (μg/L)
75	74
	74
	71
500	504
	515
	490

Matrix Spikes

Spike concentration was 100 μg/L. Recoveries for four samples were 75%, 79%, 85%, and 100%. Mean recovery was 85%.

1991 Total Persulfate Nitrogen Data

Field Duplicates

Lake	Result 1 (mg/L)	Duplicate (mg/L)	CV (%)	RMS (%)
Summit	0.123	0.130	3.9	
Samish	0.579	0.580	0.1	
Pattison	1.27	1.28	0.6	
Big Meadow	0.343	0.331	2.5	
Sidley	1.11	1.12	0.9	
				2.1

No laboratory quality control data (lab dulicates, lab check standards or matrix spikes) were provided.

1991 Chlorophyll *a* Data

Field Duplicates

Lake	Result 1 (μg/L)	Duplicate (μg/L)	CV (%)	RMS (%)
Summit	0.7	1.5	51.4	
Samish	1.7	1.2	21.2	
Pattison	1.1	0.8	24.1	
Big Meadow	1.3	1.7	19.4	
Sidley	2.7	1.8	28.5	
				31

1992 Total Phosphorus Data

Lab Duplicates

	Lab No.	Result 1 (µg/L)	Duplicate (µg/L)	CV (%)	RMS (%)
Spring	208408	12	14	11	
	208432	7	7	0	
	208470	12	13	6	
	208472	14	14	0	
	208473	9	10	7	
	218417	18	17	4	
	218422	13	12	6	
	218466	3U	3U	--	
	228402	83	83	0	
	228424	5	5	0	
	238510	9	8	8	
					5.7
Fall	358497	7	6	11	
	358798	10	9	7	
	358799	13	15	10	
	368497	1	2	47	
	368798	16	14	9	
	368499	3	4	20	
				(22.3 for n = 6)	

Field Duplicates

	Lake	Result 1 ($\mu g/L$)	Duplicate ($\mu g/L$)	CV (%)	RMS (%)
Spring	Ward	12	12	0	
	Bosworth	10	7	25	
	Black	23	12	44	
	Waitts	16	14	9	
	Deer	7	9	18	
	Spencer	10	18	40	
	Nahwatzel	9	13	26	
	Samish	4	8	47	
	Wenatchee	3	2	28	
	Mason	5	5	0	
	Phillips	8	9	8	
					27.6
Fall	Wooten	8	6	20	
	Roesiger	8	6	20	
	Samish	10	10	0	
	Nahwatzel	7	6	11	
	Mason	4	5	16	
	Black	10	7	25	
	Waitts	10	10	0	
	Williams	15	13	10	
	Stevens	12	9	20	
	St. Clair	25	21	12	
	Spanaway	17	22	18	
	Deep	14	16	9	
	Wenatchee	3	3	0	
	Lacamas	39	32	14	
					14.8

Lab Check Standards

	Standard Value ($\mu g/L$)	Result ($\mu g/L$)	Standard Value ($\mu g/L$)	Result ($\mu g/L$)
Spring	3	3	13	13
	3	3	13	13
	3	3	13	13
	3	3	13	13
	3	3	13	13
	24.5	24		
	24.5	24		
	24.5	25		
	24.5	24		
	24.5	24		
Fall	3	3	13	13
	3	3	13	12
	3	3	13	12
	3	3	13	13
	3	3	13	14
	3	3	13	14
	24.5	25		
	24.5	25		
	24.5	24		
	24.5	24		
	24.5	24		
	24.5	25		

Matrix Spikes -- Spring 1992

Spike concentration was 26 $\mu g/L$. Recoveries for ten samples were 102%, 100%, 103%, 104%, 100%, 98%, 103%, 105%, 100%, and 100%. Mean recovery was 102%.

Matrix Spikes -- Fall 1992

Spike concentration was 26 $\mu g/L$. Recoveries for ten samples were 100%, 97%, 100%, 94%, 97%, 91%, 92%, 92%, 96%, and 92%. Mean recovery was 95%.

Blanks

All blanks (10/survey) were 0 $\mu g/L$.

1992 Total Persulfate Nitrogen Data

Lab Duplicates

	Lab No.	Result 1 (mg/L)	Duplicate (mg/L)	CV (%)	RMS (%)
Spring	208403	0.814	0.810	0.4	
	208416	0.323	0.331	1.8	
	208450	0.169	0.162	3.2	
	208460	0.477	0.464	1.9	
	218409	0.616	0.652	4.0	
	218423	0.664	0.677	0.9	
	218451	0.396	0.398	0.5	
	228400	0.635	0.629	0.7	
	228408	0.225	0.224	0.2	
	238507	0.329	0.323	1.3	
	238505	0.301	0.318	3.9	
	248081	0.389	0.419	5.2	
					2.6
Fall	348403	0.274	0.241	9.0	
	348409	0.227	0.228	0.2	
	358403	0.377	0.364	2.4	
	358409	0.740	0.771	3.0	
	358418	0.542	0.510	4.3	
	358452	0.303	0.334	6.8	
	358459	0.334	0.327	1.5	
	358466	0.277	0.264	3.2	
	368404	0.603	0.565	4.7	
	368411	0.621	0.637	1.8	
	368453	0.399	0.417	4.9	
	378044	0.649	0.617	3.6	
					4.4

Field Duplicates

	Lake	Result 1 (mg/L)	Duplicate (mg/L)	CV (%)	RMS (%)
Spring	St. Clair	0.61	0.84	22	
	Black	0.30	0.01U	--	
	L. Martha	0.66	0.73	7	
	Tanwax	0.57	0.65	9	
	Conconully	0.31	0.25	15	
	Wenatchee	0.20	0.01U	--	
	Kitsap	0.23	0.20	10	
	Phillips	0.30	0.33	7	
					13.0
					4.4
Fall	Wooten	0.21	0.20	4	
	Samish	0.25	0.23	6	
	Nahwatzel	0.32	0.23	23	
	Black	0.30	0.27	7	
	Waitts	0.46	0.47	2	
	Williams	0.52	0.51	1	
	Stevens	0.33	0.31	4	
	St. Clair	0.38	0.32	12	
	Spanaway	0.30	0.34	9	
	Deep	0.18	0.17	4	
	Lacamas	0.75	0.65	10	
					9.5

Lab Check Standards

	Standard Value (mg/L)	Result (mg/L)	Standard Value (mg/L)	Result (mg/L)
Spring	0.2	0.206	1.2	1.19
		0.168		1.20
		0.168		1.20
		0.206		1.20
		0.207		1.20
		0.168		1.12
		0.205		
		0.203		
		0.218		
Fall				
	0.15	0.146	1.0	1.07
		0.151		0.99
		0.166		0.98
		0.162		1.05
		0.161		1.09
		0.160		
		0.163		

Matrix Spikes -- Spring

Spike concentration varied. Recoveries for three samples were 83%, 121%, and 112%. Mean recovery was 105%.

Matrix Spikes -- Fall.

Spike concentration varied. Recoveries for seven samples were 97%, 91%, 96%, 98%, 101%, 83%, and 112%. mean recovery was 97%.

1992 Chlorophyll *a* Data

Field Duplicates

	Lake	Result 1 (μg/L)	Duplicate (μg/L)	CV (%)	RMS (%)
Spring		5.49	5.89	5.0	
		1.51	1.17	17.9	
		1.21	1.23	1.2	
		1.54	0.82	43.1	
		0.45	0.77	37.1	
		0.39	0.79	48.0	
					31.3
Fall		1.85	1.70	6.0	
		1.12	1.07	3.2	
		2.31	2.08	7.4	
		2.47	20.3	13.8	
		0.78	1.47	43.3	
		1.82	1.02	39.8	
					25.0

1992 Fecal Coliform Bacteria Data

Lab Duplicates

	Lab No.	Result 1 (colony/ 100 mL)	Duplicate (colony/ 100 mL)	CV (%)	RMS (%)
Spring	208470	0	0	0	
	208463	0	0	0	
	208469	1	1U	--	
	218462	0	0	0	
	218411	71	72	1	
	218458	0	0	0	
	228405	0	0	0	
	238504	6	5	13	
	238509	0	0	0	
	248087	4	3	20	
Fall	348402	6	9	28	
	348401	3	1	71	
	348409	27	15	40	
	358467	1U	0	--	
	358413	0	0	0	
	358497	0	0	0	
	358410	0	0	0	
	358451	1	0	41	
	368499	0	0	0	
	368400	160	160	0	
	378661	0	0	0	
					30

Field Duplicates

Lake	Result 1 (colony/ 100 mL)	Duplicate (colony/ 100 mL)
Black	1U	1U
Martha L.	430	280
Martha L.	7	12
Kitsap	1U	1U
Kitsap	1U	2
Eloika	1	1
Martha L.	71	53
Wenatchee	1U	1U

1992 TSS and TNVSS Data

Lab Duplicates

	Lab No.	TSS (mg/L)	Dup TSS (mg/L)	TNVSS (mg/L)	dup TNVSS (mg/L)
Spring	208454	1	1	1U	1U
	208470	1	1	1U	1U
	208462	2	2	1	1
	208468	2	2	1	1
	218418	7	5	1	1
	218466	1U	1	1	1
	228408	1	1	1U	1U
	238510	2	2	1U	1U
	248084	2	3	1U	1U
Fall	348407	2	1	2	1
	348401	4	3	2	1
	348466	1	1	1U	1U
	358497	2	1	1	1U
	358409	4	4		
	368400	4	4	1U	1U
	368499	1	1	1	1
	378060			1	2
	378061	4	4		

Field Duplicates

	Lake	TSS (mg/L)	Dup TSS (mg/L)	TNVSS (mg/L)	dup TNVSS (mg/L)
Spring	St Clair	5	4	1	1
	Black	1	1	1U	1U
	Martha L.	2	2	1	1
	Wenatchee	1	1	1	1
	Kitsap	2	1	1U	1
	Phillips	2	2	1U	1U
Fall	Wooten	1	2	1U	1U
	Black	2	2	1	1
	Martha L.	1U	1U	1U	1U
	Wenatchee	1	1	1	1
	Phillips			1	1U

1992 Color Data

Lab Duplicates

	Lab No.	Result 1 (Pt-Co Unit)	Duplicate (Pt-Co unit)
Spring	208456	25	25
	208462	20	20
	208466	25	25
	218466	5	10
	218408	20	20
	228408	20	20
	238500	30	30
	238510	20	20
	248084	20	20
	248401	35	35
Fall	348408	15	15
	348403	10	10
	358407	20	20
	358497	15	15
	358411	10	10
	358466	20	20
	368410	50	50
	368462	5	5
	368406	60	60
	378060	20	20

Field Duplicates

Lake	Result 1 (Pt-Co Unit)	Duplicate (Pt-Co unit)
St. Clair	250	250
Black	25	25
Wenatchee	10	5
Kitsap	20	20
Phillips	20	20
Wooten	5	5
Black	20	15
Phillips	10	15ISJ*
Waitts	10	10ISJ*
Martha L.	10	156

* Estimated value, because the sample was filtered

APPENDIX E

Materials Accompanying Individual Lake Assessments Mailed to Volunteers in 1992

SECTIONS IN THIS REPORT

Estimated Trophic State -- Oligotrophic means the lake has low nutrient concentrations, a low amount of aquatic plant and algae growth, and very good water clarity. Mesotrophic means that the lake has a moderate amount of nutrients and plant and algae growth. Eutrophic means the lake has a high amount of nutrients, prolific plant and algae growth, and poor water clarity. Lakes that were in between two trophic states were estimated as oligo-mesotrophic or meso-eutrophic. See the Data Evaluation and Glossary sections at the end of this report for more characteristics of each trophic state.

Mean Trophic State Index -- when data were available, a Trophic State Index was calculated for Secchi depth, total phosphorus, and chlorophyll *a* data. The Trophic State Index rates a lake on a scale of 1 to 100; the higher the Trophic State Index, the more eutrophic a lake is. If the index values did not correspond to the estimated trophic state, there will be an explanation in the Monitoring Results or Comments section.

Volunteer-Collected Data -- data collected by volunteers are listed in this table.

1992 Onsite Visit Data -- twice each summer, Ecology staff met with each volunteer to collect profile data (measurements made from surface to bottom) and water samples. Profile data were collected using a Hydrolab Surveyor II. Water samples were collected from the epilimnion and hypolimnion of each lake. Results from these onsite visits are listed in two tables.

Historical Data From Ecology -- many of the monitored lakes have been sampled previously, most at the same sites, by Ecology. Results from available data are listed in this table. Results from specialized or more detailed studies conducted by Ecology are summarized in the Monitoring Results/Summary of Other Available Information section.

Monitoring Results/Summary of Other Available Information -- Secchi data collected by the volunteers, and nutrient and profile data collected by Ecology staff during the onsite visits with the volunteers, are summarized and interpreted. If data from earlier studies were available, they were also summarized and referenced in this section.

Summary of Questionnaire Results and Information From the Volunteer -- each volunteer was asked to complete a questionnaire on lake and watershed uses. Other information provided by the volunteer were also included in this section. Unless stated otherwise, volunteer-provided information were not verified by Ecology.

Comments -- comments vary between the monitored lakes. Most Comments include a discussion of what the trophic state characterization was based on, but may also include comparisons between monitored lakes.

Graphs -- the upper graph shows all Secchi data collected by the volunteer(s), including data collected prior to 1992. The lower graph shows profile data collected during the onsite visits in 1992.

Data Evaluation

One of the main objectives of the Citizen Lake Monitoring Project is to use volunteer-collected data to estimate the trophic state of each monitored lake. The trophic state describes a lake with respect to a lake's capacity to support plant and algal growth.

To determine each lake's trophic state, trophic state index values were calculated using Secchi depth, total phosphorus, and chlorophyll *a* data collected from each lake. The trophic state index (calculated from Carlson, 1977) rates each parameter from a lake on a scale from 1 to 100. Generally, low trophic state index values (41 or less) indicate a lake was oligotrophic, whereas high trophic state index values (51 or higher) indicate that a lake was eutrophic. Trophic state index values between 41 and 51 generally indicate that a lake was mesotrophic.

When trophic state index values for a lake varied by more than 10 units or did not indicate one clear trophic state, it was necessary to use additional information to determine the lake's trophic state. Additional information usually consisted of profile data collected during the onsite visits (particularly dissolved oxygen profile data), or observations made by Ecology staff at the time of collecting water samples. If a lake exhibited characteristics of more than one trophic state, it may have been described as oligo-mesotrophic or meso-eutrophic (see Glossary for definitions of these terms). The basis for a lake's trophic state is discussed in the Comments section of this report.

Typical Secchi depths and trophic state indices for each trophic state category are listed below.

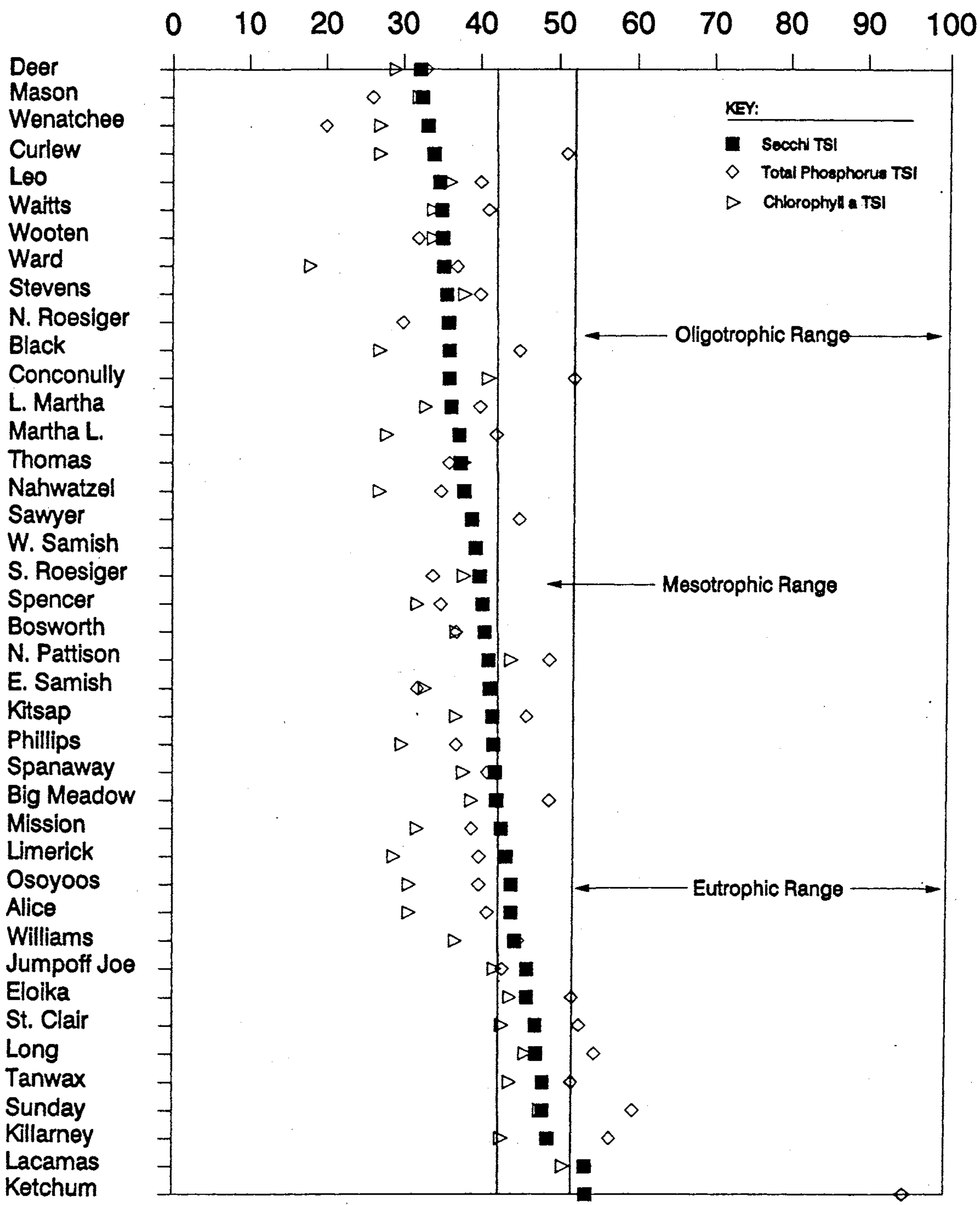
General Physical and Chemical Parameters Associated with Trophic State

Trophic State	Trophic State Index	Secchi Depth (ft)	Total Phosphorus (μg/L)	Chlorophyll *a* (μg/L)
Oligotrophic	0 - 41	13.1 +	0 - 12	0 - 2.6
Mesotrophic	41 - 51	6.5 - 13.1	12 - 24	2.6 - 6.4
Eutrophic	51+	0 - 6.5	24 +	6.4+

(Information Source: Carlson, 1977; 1979)

1992 Trophic State Indices (TSI)

Ordered by Secchi TSI



TSI Differences ≤ 3 units between lakes should not be considered significant.

Glossary

Algae Bloom - abundant growth of algae that results in mats, scums, or otherwise dense growths forming in or on the water. Not all types of algae form blooms.

Ambient Water Quality Monitoring - monitoring to collect baseline information on a water resource, which can therefore be used to determine if a water quality problem exists and how water quality is changing.

Bathymetric Map - a contour map of a lake's depth.

Blue-Green Algae - a type of algae that, when found in bloom concentrations, is usually associated with polluted or eutrophic water bodies. Most blue-green algae are considered to be nuisance species, because they may develop unpleasant scums and odors.

Chlorophyll *a* - a pigment found in the cells of photosynthetic plants. The quantity of chlorophyll *a* in a water sample indicates the amount of photosynthesizing algae per volume of water. In this report, chlorophyll *a* concentrations are reported in μg/L.

Clean Water Act (Federal Clean Water Act) - this law requires water quality to be kept at an acceptable level to support both swimming and fishing in all surface waters. The authority to enforce this law is with the EPA, but this authority can be delegated to individual states; it has been delegated to Washington.

Color - a test used to measure the color of water from which suspended matter has been removed. Color in water may result from natural metals, humus and peat materials, algae, and aquatic plants.

Conductivity - a measure of the ability of a solution to conduct electrical current. As ion content of water increases, conductivity will increase. The unit for expressing conductivity is μmhos/cm.

Cultural Eutrophication - eutrophication caused or accelerated by human activities.

Dissolved Oxygen - oxygen content in water that comes from being in contact with the atmosphere, from agitation (as in streams), or from being released by photosynthesizing aquatic plants. Oxygen is depleted by bacteria that decompose vegetation or other organic material, and from respiration by plants and animals. The unit for expressing dissolved oxygen is mg/L.

Epilimnion - the "top" (closest to the surface), warmer layer of water in a thermally stratified lake. See metalimnion, hypolimnion.

Eutrophic - describes a lake that has high nutrient concentrations, abundant plant and algae growth, and low water clarity. Eutrophication can occur naturally over time, or can be accelerated by human activities (see Cultural Eutrophication).

Fecal Coliform Bacteria - bacteria that are associated with mammal and bird feces. Fecal coliform bacteria results determine whether feces have entered and contaminated a water body. Fecal coliform bacteria results are reported in this report in colonies/100 mL.

Hydrolab® - the brand name of an instrument used to measure temperature, pH, dissolved oxygen and conductivity at various depths in water.

Hypereutrophic - describes a lake in advanced eutrophication which has very high nutrient concentrations, and very abundant plant and algae growth. In this report, hypereutrophic lakes will have a trophic state index value greater than 70.

Hypolimnion - when a lake is thermally stratified, the hypolimnion is the cooler layer of water at the bottom of the lake. See Epilimnion.

Lake Height - volunteers for this program measured the distance from a fixed point (usually on a stationary dock or piling) to the water surface. For most lakes the fixed point was above the water surface, so the greater the lake height value, the lower the water level.

Limnology - the science of lakes and streams, including the factors that influence the biology and chemistry of inland waters. (From the Greek *Limne*, which means "lake").

Macrophyte - any aquatic plant larger than algae that grows on, or in, water.

Meso-eutrophic - a trophic state that is borderline between mesotrophic and eutrophic.

Mesotrophic - describes a lake that has moderate concentrations of nutrients, a moderate amount of plant and algae growth, and moderate water clarity (generally 7 to 13 feet, as measured with a Secchi disk).

Metalimnion - the middle layer of water between the epilimnion and hypolimnion of a thermally stratified lake. The metalimnion is located at the thermocline.

mg/L - milligrams per liter. A unit used to describe the concentration of a substance in solution. One mg/L is equivalent to one part per million (ppm).

Nitrogen - an essential plant nutrient that can be present in water in various forms. Common forms are nitrate, nitrite, ammonia, and dissolved nitrogen gas. Nitrogen concentrations are reported in mg/L.

Nutrients - substances, especially nitrogen and phosphorus compounds, that fertilize the growth of aquatic plants and algae. The amount of nutrients in water will affect the amount of plants and algae that can grow.

Oligotrophic - describes a lake that has low nutrient concentrations, little plant or algae growth, and very clear water.

Oligo-mesotrophic - a trophic state that is borderline between oligotrophic and mesotrophic.

Oxidation-Reduction Potential - "Redox"- the oxidizing or reducing intensity in water, measured in volts. In chemical reactions, electrons flow between constituents in a solution until equilibrium is reached; constituents which have gained electrons are reduced, and constituents which have lost electrons are oxidized.

pH - represents on a scale of 0 to 14 the acidity of a solution. A pH of 7 is neutral; acid solutions such as vinegar have a pH of less than 7, and basic solutions have a pH greater than 7.

Phase I Study - lake water quality monitoring (called a diagnostic/feasibility study) funded through the Centennial Clean Water Fund program. Phase I must be completed before Phase II (implementation of the lake restoration plan) can begin. For Phase I, twelve months of water quality data are collected and interpreted, and available restoration approaches are evaluated to determine the feasibility of implementing each approach.

Phosphorus - an important, often critical, plant nutrient that can be present in water in various forms. Phosphorus can be dissolved in water (orthophosphorus), adsorbed onto particles, or taken up by plants. Phosphorus concentrations are reported in $\mu g/L$.

Profile Data - data collected at various depths of a lake to characterize a sampling site from surface to bottom. In this report, profiled parameters are temperature, pH, dissolved oxygen, and conductivity.

Runoff - water that washes over a ground surface or within the soil column as groundwater. Runoff can pick up suspended and dissolved substances from areas it has washed, and carry the substances to streams and lakes.

Secchi disk - a black and white, 20 cm diameter disk that is attached to a rope. The disk is used to measure water transparency in open water. See Transparency.

Stratification (Thermal Stratification) - the state in which a lake forms distinct layers (the epilimnion and hypolimnion), usually because of the temperature differences between the surface and bottom of the lake. These layers do not mix while the lake is completely stratified.

Thermocline - when measuring temperature from the surface to bottom of a lake, the thermocline is characterized by a considerable change in temperature with little change in depth. It is the transition area between the epilimnion and hypolimnion.

Total Suspended Solids - measures the amount of suspended matter that is filtered out of a sample of water, and dried at a specified temperature. Nonvolatile solids are the residue remaining after the sample is ignited at a specified temperature. The units for expressing solids results are mg/L. Suspended solids do not include dissolved solids (such as salts).

Transparency - generally, water clarity of open water measured by a Secchi disk is called Secchi disk transparency. Secchi disk transparency is a measurement of the depth that sunlight can penetrate water and then reflect back up to the surface.

Trophic State - characterizes a lake according to the amount of plants that grow in a lake. Trophic state also characterizes the water clarity and the amount of nutrients in the water. See Oligotrophic, Mesotrophic, and Eutrophic.

Trophic State Index - a number that rates a lake according to the extent of eutrophication. In this report, oligotrophic lakes have lower trophic state values, and eutrophic lakes have a higher trophic state index value.

Turbidity - a measurement of the effects of light-absorbing and light-scattering substances that are suspended in water. Turbidity is determined by passing a light through a sample and measuring the amount of light that is scattered by the suspended particles. Turbidity is not the same as transparency.

Turnover (Lake Turnover) - the seasonal mixing of water layers that occurs when temperature differences lessen between the top and bottom layers of water. Turnover occurs during fall in most lakes. Lakes that freeze over during winter will also turnover after spring thaw.

Water Clarity - another term for Transparency.

Water Quality Standards - criteria established by Washington State for surface waters, cited in Chapter 173-201A WAC (Washington Administrative Code). Water quality standards (for dissolved oxygen, pH, fecal coliform bacteria, temperature, and other parameters) are established for classes of rivers, streams, and marine waters (Class A, AA, etc., depending on their characteristic uses), and lakes (Lake Class).

Watershed - all the area that collects water and drains to a lake via streams, surface runoff, or groundwater.

Winterkill - fish kill in lakes generally caused by the depletion of oxygen in water while the lake is frozen over.

Zooplankton - microscopic animals in water that eat algae and are eaten by fish.

μg/Kg - micrograms per kilogram. A unit of concentration used to describe how many micrograms of a chemical or contaminant are present in one kilogram of the analyzed substance (such as sediment or fish tissue). One μg/Kg is equal to one ppb (parts per billion).

μg/L - micrograms per liter. A unit of concentration used to describe how many micrograms of a substance are in one liter of solution. One μg/L is equal to one milligram per cubic meter (mg/m^3), and to one part per billion (ppb). One thousand μg/L is equal to one mg/L.

μmhos/cm - micromhos per centimeter. A unit used to describe conductivity measured by two electrodes 1 cm^2 in area and 1 cm apart.