WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Lake Water Quality Assessment Program

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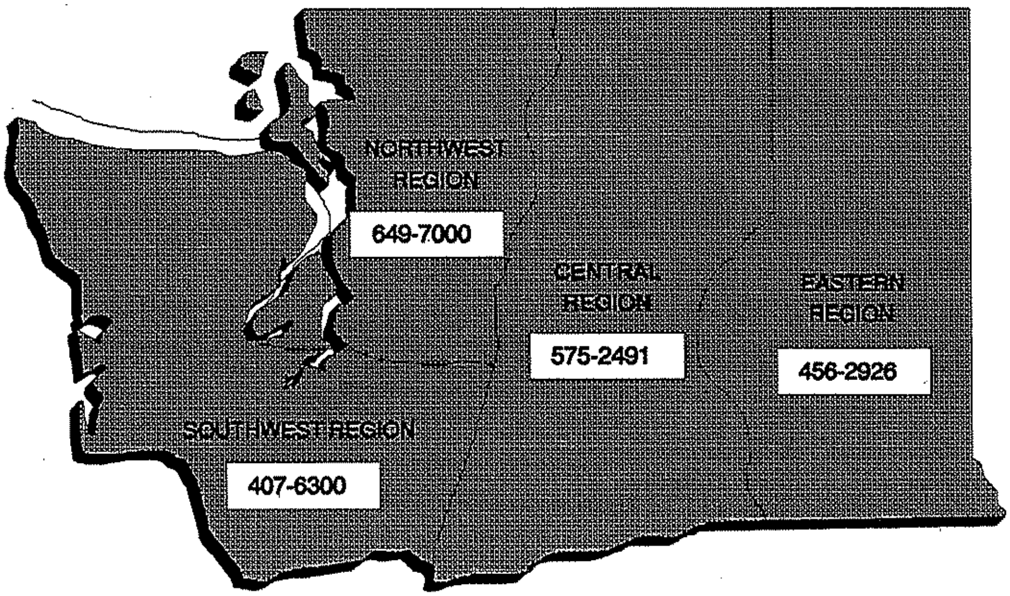

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DEPARTMENT OF
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by
Julie Rector

Environmental Investigations
and Laboratory Services Program
Olympia, Washington 98504-7710

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Acknowledgments

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Washington's Citizen Lake Monitoring Project cost about $112,000 in 1993. 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. Continued federal support of this program is greatly appreciated by Ecology staff, as well as by the volunteers who participate in the program.

Executive Summary

The objectives of the Washington State Department of Ecology's (Ecology) 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 1993, Ecology staff collected water samples and profile data from 86 lakes. Water samples were collected in May and August from both the epilimnion and hypolimnion of stratified lakes, and were analyzed for total phosphorus, total nitrogen, and chlorophyll *a*. Samples for total suspended solids, total nonvolatile suspended solids, and fecal coliform bacteria were also collected from 18 of the 86 sampled lakes. To supplement data collected by Ecology staff, volunteers participating in Washington's Citizen Lake Monitoring Program measured Secchi disk transparency and surface water temperature in 65 of the 86 lakes. Volunteers monitored their lakes bi-monthly from May through October. Most volunteers also completed a questionnaire on lake and watershed uses, and eight volunteers collected and stored water samples as part of an evaluation to determine the feasibility of having volunteers collect water samples.

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 estimations were assigned to a total of 85 lakes: 36 lakes were oligotrophic or oligo-mesotrophic, 33 lakes were mesotrophic or meso-eutrophic, 16 lakes were eutrophic, and one lake was hyper-eutrophic.

Statistical trend in water clarity was evaluated for 17 lakes that were monitored by volunteers from 1989 to 1993. Using the seasonal Kendall test for trend, only three lakes exhibited statistically significant trends in water clarity. Big Meadow Lake (Pend Oreille County) and Lake Thomas (Stevens County) showed improving trends in water clarity ($p < 0.01$ and $p < 0.20$, respectively), and Long Lake (Thurston County) showed a decreasing trend in water clarity ($p < 0.20$).

From comparisons of mean Secchi depth, mean total phosphorus (TP), and mean chlorophyll within ecoregions, Soap Lake in Grant County had exceptionally high TP concentrations not only within its ecoregion, but in comparison to the rest of the lakes monitored in 1993. Soap Lake also did not fit into any of the traditional trophic state classifications, and was the only lake that was not assigned a trophic state. Mean Secchi depths from lakes monitored in the Puget Lowlands and Northern Rockies ecoregions were lower than mean Secchi depths in the Cascades and Columbia Basin ecoregions.

From evaluation of the relationships between Secchi depth, TP, and chlorophyll *a*, it was apparent that chlorophyll *a* data from the Lake Water Quality Assessment Program did not fit the predicted Secchi:TP:chlorophyll relationship. Factors affecting these relationships include non-phosphorus limitation, variability between sampling seasons, climatic variations, and possibly the methods used for storing and analyzing chlorophyll samples.

Recommendations for future monitoring seasons are the following: (1) labs should report all analytical data one decimal place beyond normal reporting limits, to allow for QA/QC analysis (particularly for total phosphorus data); (2) labs should report all QA/QC data along with sample results, to allow for comparisons between field and analytical variability; (3) methods for improving chlorophyll *a* yields should be investigated, including storing filters in acetone, and requesting that the lab use a 10 cm cell path with the spectrophotometer; (4) discontinue the investigation of having volunteers collect surface TP samples; (5) determine an acceptable TP field precision limit for the final program QAPP; and (6) continue the current practice of basing trophic state classifications on all available information and data that indicate trophic status.

This report includes a compilation of the sixty-five individual lake assessments (reports) which were written for volunteers who participated in the program, as well as data collected by Ecology staff from an additional 21 lakes.

Introduction

The purpose of this report is to describe the 1993 Lake Water Quality Assessment Program, and to present data and individual lake assessments from 65 lakes which were monitored by Ecology staff and volunteers in 1993. Also included are data results from 21 lakes which were sampled by Ecology staff only.

Program Objectives

The goals of the Lake Water Quality Assessment (LWQA) Program are to assess the current water quality of publicly-owned lakes in Washington, and to maintain a relationship with volunteers of monitored lakes for data exchange, education, and technical assistance. Specific objectives for the 1993 program 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 lakes into ecoregions (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.

History of LWQA Program

Ecology's Lake Water Quality Assessment Program was established in 1989 to gather general water quality information from significant, publicly-owned lakes. 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. For the purposes of reporting water quality assessments, significant, publicly-owned lakes cover at least 20 acres, have a public access, and support or have the potential to support the fishable-swimmable goals of the Clean Water Act (Ecology, 1992).

The 1989 lake monitoring program was funded from a Federal 314 Water Quality Assessment grant. The program 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 Lake Water Quality Assessment Project, 1989 (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. A supplemental water quality survey was conducted on 15 lakes (Coots, 1991). Results of all data collected from 1990 are discussed in Lake Water Quality Assessment Project, 1990 (Rector and Hallock, 1993).

In 1991, the program was reduced because of insecure funding. A Federal 314 grant maintained the program through 1991. Volunteers collected data from 41 lakes, and Ecology staff collected one set of water samples and vertical profile data from each of the volunteer-monitored lakes. No supplemental surveys were conducted.

In 1992, additional 314 and 205(j) grants were obtained. Volunteers collected data from 41 lakes, and Ecology staff collected two sets of water samples and profile data from these lakes. Five lakes were surveyed for various contaminants in sediment and fish tissues, and five additional lakes were surveyed for copper in sediments (Serdar *et al.*, 1994). Results from the 1991 and 1992 monitoring years are discussed in Lake Water Quality Assessment Program, 1991-1992 (Rector, 1994).

The 1993 program was funded from both federal grants secured in 1992, and is described in this report.

Methods

Methods for lake selection, data collection, sample analysis, and data analysis are described below. Methods for quality assurance and quality control (QA/QC) of data collected for the program are discussed in the "QA/QC Evaluation and Results" section that follows this "Methods" section.

Volunteer Recruitment and Lake Selection

All Washington lakes that cover at least 20 acres and have a public access are eligible for inclusion in the volunteer monitoring program. Approximately 1,000 lakes in Washington meet these criteria, although the exact number is unknown (Rector and Hallock, 1995).

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 by Ecology staff, county offices, or from other volunteers. Potential volunteers were accepted into the program if they indicated that they (1) wanted to monitor an eligible lake, (2) were willing and able to collect monitoring data for the six-month monitoring period, and (3) had access to a boat to use while collecting data.

Ecology coordinated lake selection with local volunteer lake monitoring programs in King County (coordinated by METRO) and Snohomish County (coordinated by Snohomish County Department of Public Works). The Snohomish County program was developed in 1993, so several volunteers who responded to Ecology's press release were referred to the new Snohomish County program. Some lakes were monitored by Ecology as well King County's Small Lakes Program and Snohomish County's Volunteer Lake Monitoring Project; data collected from these lakes may be compared in the future, for QA/QC purposes.

To support the monitoring phase of Ecology's watershed approach to water quality management, 15 lakes were sampled by Ecology staff within the Kitsap, Lower Columbia, Upper Yakima, and Mid-Columbia watersheds.

In summary, each year of monitoring includes a group of lakes which have been monitored by volunteers over a long period (which allows for trend analysis), a group of lakes relatively new to the program whose volunteers may or may not continue over a long period, and a group of lakes monitored by Ecology staff for watershed-based permitting and planning purposes. The latter group of lakes are selected primarily because of a lack of data and geographical considerations.

Field Methods

There were two separate field data collection efforts for the program: (1) volunteers measured Secchi depth and surface water temperature on a relatively frequent basis; and (2) Ecology staff collected water samples, profiles, and qualitative information on algae and macrophytes during two "onsite visits" with the volunteers. In addition, a subset of the volunteers collected total phosphorus (TP) samples from their lakes, as part of a test to determine the feasibility of having volunteers collect and store water samples. Each of these data collection efforts is described below.

Volunteer-Collected Data, Information, and TP Samples

All volunteers measured Secchi disk transparency and surface water temperature from one lake station (the deepest site). Data were collected between 10 a.m. and 2 p.m., approximately every two weeks from mid-May through mid-October. Water clarity was measured by leaning over the shady side of a 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. 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 (Appendix A). The Secchi disks used by volunteers were made by Ecology staff, using methods described in Rector and Hallock (1991).

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.

Each new volunteer was trained by Ecology staff at his or her monitoring site during the May surveys (see discussion below). New volunteers were provided with a summary of monitoring instructions, monitoring equipment (Secchi disk and thermometer), a bathymetric map showing the location of their monitoring site, and business-reply data cards for mailing in data. 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 from an algae bloom. Algae identification was provided by Ecology.

In 1993, most volunteers were provided with viewing tubes, to help reduce the effect of glare and surface ripple. Earlier experience during the field visits with the volunteers showed that most volunteers could not see the Secchi disk as deep as Ecology staff (Rector and Hallock, 1993). This is partly due to differences in eyesight and experience with the Secchi disk. However, it was also apparent that while Ecology staff often measure Secchi depth while leaning over close to the water surface, this is not possible for all of the volunteers. To increase volunteers' readings closer to the range seen by Ecology staff, volunteers were provided with viewing tubes that were made by Ecology staff. The materials and methods used for these tubes is shown in Appendix B. Volunteers were asked to measure Secchi depth without the viewing tube, and then with the tube, on each of their regular monitoring days. Secchi depths measured with, and without, the tubes were also recorded during the onsite visits with Ecology staff, so that a determination could be made whether the volunteers' "accuracy" improved using the viewing tube. Results of these evaluations are in the "QA/QC Evaluation and Results" section of this report.

All volunteers were mailed a questionnaire on lake and watershed uses near the end of each monitoring season (Appendix C). 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.

The final volunteer monitoring effort involved only eight volunteers. This effort was intended to test the feasibility of having volunteers collect and store water samples and was prompted by Greisbach and Peters (1991), who reported that lake samples can be frozen beyond normal holding time constraints without introducing a significant amount of variability into total phosphorus results. Theoretically, this would allow volunteers to collect and freeze surface total phosphorus samples during months when Ecology staff are not normally scheduled to collect water samples. For this evaluation, Ecology staff and the eight selected volunteers collected duplicate surface TP samples in May. The volunteers kept one of the duplicate samples in their freezer, and the other duplicate was analyzed along with other samples collected for the program in May. The volunteers were then provided with two clean sample bottles, and two samples bottles that contained concentrated sulfuric acid as a sample preservative. These were intended for samples to be collected during regular Secchi depth measurement days in mid-June and mid-July. The clean sample bottle was used to scoop surface water, which was poured into a sample bottle that contained the acid preservative. The bottles were then labeled with the lake name and date, and placed in the volunteer's freezer. During the August onsite visit, Ecology staff collected the frozen samples from the volunteers and sent them to the lab for analysis. If results from both samples collected during May were not significantly different, then the results from the samples collected by the volunteers in June and July would be used in calculations of TSI_{TP}.

Data Collected by Ecology Staff

Ecology staff visited most of the volunteers twice in 1993; the first visit occurred during late May or early June, and the second occurred during late August or early September. The purpose of these visits was to (1) observe the volunteer's Secchi disk reading technique and compare to the Ecology staff 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 each field visit, the 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 or Sonde 3/Surveyor III. 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 TP, total persulfate 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). Samples for total suspended solids (TSS) and total nonvolatile suspended solids (TNVSS) were collected from the epilimnion of 18 lakes, at the same sites and sample depths as the nutrient samples. Most lakes sampled for TSS and TNVSS were selected because in the previous year of sampling, they did not exhibit the expected relationship between Secchi depth, TP, and chlorophyll *a*. For some lakes, non-algal turbidity can interfere with these relationships.

Table 1. Analytical methods used for samples collected for the LWQA Program.

Parameter	Strata Sampled[1]	Sample Preservation[2]	Analytical Method	Method Detection Limit	Holding Time	Analytical Lab[3]
Total Phosphorus	epilimnion, hypolimnion	H_2SO_4 to pH < 2	SM 4500-P D	3 µg/L	28 days	EWU
Total Nitrogen	epilimnion, hypolimnion	H2SO4 to pH < 2	EPA 353.2	0.010 mg/L	28 days	MEL
Chlorophyll a4	epilimnion	MgCO35	SM 10200H (2,B)	0.05 mg/L	28 days	EWU
Solids	epilimnion		SM 2540D,E	1 mg/L	7 days	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 Corrected for pheophytin.
5 Approximately 2 mL saturated $MgCO_3$ added with last of filtrate onto filter. Filters were iced, or frozen, until delivered to lab.

Two fecal coliform bacteria samples were collected from 18 lakes during May 1993, and from 19 lakes during August 1993. 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 in small plastic petri dishes, then wrapped in foil, and the lab number and volume of sample filtered were 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).

Methods Used for Estimating Trophic Status

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. In general, TSIs of 40 or less indicate oligotrophy, TSIs greater than 40 indicate mesotrophy, and TSIs greater than 50 indicate eutrophy (Carlson, 1979). To describe lakes which appeared to be between trophic states, the terms "oligo-mesotrophic" and "meso-eutrophic" were used.

TSI_{SD} values were calculated from a time-weighted mean Secchi depth calculated from all Secchi data collected between May and October 1993. The rationale for using a time-weighted TSI_{SD} is discussed in Rector (1994). A minimum of five Secchi depth measurements separated by at least two weeks were used to calculate the TSI_{SD} for each lake. Data invalidated by the QA/QC evaluation (below) were excluded from the TSI_{SD} calculations. TSI_{TP} and TSI_{CHL} values were calculated separately for each of the May and August results.

It is not legitimate to average TSI values from different trophic state parameters, and to use that average to summarize a lake's trophic status. 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." Therefore, a subjective assessment of all data collected during the monitoring season was used to determine which index to use for assigning trophic states. Then monitoring data, other available survey information (short-term lake surveys conducted by Ecology or universities, and consultant reports from Ecology-funded lake restoration activities), and information from the volunteers (e.g., information on aquatic herbicide use), were used to temper the trophic state assessment for some lakes. As a result, the trophic state estimations were not based on TSI alone, and were not necessarily based on the same parameters for all lakes. The basis for each trophic state assessment is discussed in the "Comments" section of the Individual Lakes Assessments at the end of this report.

QA/QC Evaluation and Results

All data collected for the LWQA Program were evaluated to determine whether data quality objectives for the program (Table 2) were met. Methods used for data quality evaluations are described in <u>Lake Water Quality Assessment Program Quality Assurance Project Plan</u> (Hallock, 1995). Laboratory QA/QC results for all parameters are listed in Appendix D.

Table 2. Summary of data quality objectives for the LWQA Program.

Parameter	Detection Limit	Precision	Accuracy (Bias)
Secchi Depth	--	< 10% CV (daily pairs) < 5% RMS (all pairs/lake)	< 10% CV (volunteer/Ecology)
Total Phosphorus	5 µg/L	< 7.5% RMS (10 lab splits)	< 2.5% relative bias (lab check standards)
Total Persulfate Nitrogen	0.050 mg/L	< 5% RMS (lab splits)	< 5% relative bias (lab check standards)
Chlorophyll *a*	0.5 µg/L	< 10% CV (field dups) < 29% CV (May/August)	< 2.5% relative bias (lab check standard)
Profile parameters			
Temp.	--	--	± 0.5°C
pH	--	--	± 0.2 SU
D.O.	--	--	± 0.50 mg/L
spec. cond.	--	--	± 5 µmho/cm
Fecal Coliforms	1 colony/100 mL	< 35% RMS (lab splits)	--
Solids	1 mg/L	± 1 mg/L (field splits)	--

Source of information: Hallock (1995)

Volunteer-Collected Secchi Data

On each sampling date, volunteers measured the Secchi depth two times. The coefficient of variation (CV) was calculated for each pair of Secchi depth readings, to evaluate the volunteers' abilities to reproduce their measurements. Although this is summarized as "precision" in Table 2, it should be apparent that the two sets of readings cannot be collected independently of each other, so the estimation of precision may be biased. Pairs which exceeded the requirements in the data quality objectives were not used in calculations of trophic state indices (TSI_{SD}).

All CVs for each volunteer's data set were pooled using the root mean square (RMS) to determine the overall variability in each volunteers' readings. Of the 63 volunteer-monitored lakes, overall variability in readings was high for Lake Limerick and Offutt Lake. Data from these lakes will not be used in comparisons with other lakes.

During the two field visits with the volunteers, Secchi depth was measured by both Ecology staff and the volunteers. The CV was calculated for Secchi depths measured during these field visits to evaluate the "accuracy" of the volunteers' measurements (assuming the Ecology staff reading was the "standard"). Accuracy limits for Secchi depth (Table 2) were exceeded for volunteers at Mission Lake, Phillips Lake, and Tiger Lake. Although these results indicate that data from these lakes will not be used in comparisons between lakes, the data will be used when evaluating year-to-year changes and trend in water clarity, providing that the same volunteer collects the data for each of these lakes.

Overall it was apparent that the majority of volunteers cannot see the disk as deep as Ecology staff. (This was also documented in 1990; Rector and Hallock, 1993.) In an attempt to improve Secchi depth readings collected by volunteers, viewing tubes were made by Ecology staff and distributed to volunteers in 1993 (see "Field Methods" section of this report). Using the tubes helps to reduce glare and surface ripple. Comparisons between volunteer-measured Secchi depths and Ecology staff-measured Secchi depths were made during the field visits. Based on improved "accuracy" using the viewing tubes, six volunteers were asked to use a viewing tube for all their Secchi disk readings (volunteers at Lakes Alice, Mission, Phillips, Thomas, Tiger, and Osoyoos). Other volunteers use the tube as needed, indicating on the reporting card when the tube was used, or consistently report readings collected with, and without, the tube. Except for those volunteers who need to use the tube to increase "accuracy," most measurements made without tubes were used when both "with" and "without" readings were reported. This allows for readings collected before 1993 (including historical data) to be compared to readings collected for the current program. One exception is Lake Wenatchee, which is frequently choppy due to high winds in the area. The viewing tube has made it much easier for the volunteer to measure Secchi depth at this lake.

Profile Data

The Hydrolabs were pre- and postcalibrated daily for pH and dissolved oxygen. The manufacturer's instructions were followed for pH calibration, using pH 7 (low ionic strength) and pH 10 (regular, *i.e.*, high, ionic strength) standard buffer solutions. Postcalibration readings within 0.2 pH unit of the standard buffer values were considered acceptable. The Hydrolab's dissolved oxygen probe was checked against the mean of three azide-modified Winkler titrations; dissolved oxygen concentrations from the Sonde 3/Surveyor III unit was checked against the theoretical water-saturated air method as well as field samples collected for Winkler titrations. Postcalibration results within 0.3 mg/L of the comparison methods (Winkler or theoretical) were considered acceptable. Specific conductance, 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 within 5 µmhos/cm of the standard value were considered acceptable. Temperature was also checked periodically against a National Bureau of Standards (NBS) mercury thermometer. Values within 0.5°C were considered acceptable.

Hydrolab postcalibration data for dissolved oxygen were outside acceptable ranges for Lake Samish, Toad Lake, and Blackmans Lake during the May survey. These data are not reported here.

All pH and conductivity data from the May and August surveys were within acceptable limits. Hydrolab postcalibration data are compiled in Appendix E.

Total Phosphorus Data

Methods used in this report for evaluating the quality of TP data (Hallock, 1995) were specified after the 1993 samples were collected. As a result, some evaluations are based on a smaller sample size than recommended in Hallock (1995). The following sections discuss laboratory quality control (QC), and total variability determined from results of field duplicates.

Laboratory QC

Results from all lab blanks were reported as 0 µg/L, although absorbances varied between individual blank samples. Based on the reported concentrations, the detection limit would be 0 µg/L. However, using the absorbances reported for each lab blank sample, the calculated detection limit was 3 µg/L for the May survey, and 4 µg/L for the August survey.

These detection limits were acceptable for the program, but also illustrate the need to have the lab report TP data to the nearest 0.1 µg/L (instead of the nearest whole µg/L) for QA/QC purposes. For the LWQA Program, all analytical results should be reported to one decimal place beyond the reporting limits, to allow for thorough (and easier) QA/QC evaluations.

Laboratory precision was calculated by pooling the coefficient of variation (using the root mean square) for all pairs of lab splits. Results were in the acceptable range specified in Table 2 (Appendix D). Bias due to calibration error was estimated from the difference between the results for lab check standards and the true concentration. These results were also within the acceptable range specified in Table 2. Interference effect (bias) due to the sample matrix was calculated as the percent recovery for matrix spikes. Bias due to matrix effects was considered acceptable if mean recoveries of matrix spikes were within 80-120%. Results from matrix spikes from both surveys were acceptable.

An additional check on laboratory quality control was to submit diluted standards as "blind" samples. Results from these blind standards were compared against the 95% confidence intervals provided in the literature with the samples. However, because the standards had to be diluted considerably to be in the expected range of lake samples, the ranges of the extrapolated confidence intervals (calculated from equations provided with the standards) were extremely wide (e.g., 6.9 µg/L to 53.8 µg/L for a known TP concentration of 15 µg/L). Nevertheless, the CVs of the blind standard and its analytical result were < 15%, and results were within the 95% confidence intervals, so the results were considered acceptable.

Field Variability Evaluated from TP Field Duplicates

TP samples were collected at a second site from 12 lakes during each survey. This sampling strategy was applied only to TP samples in 1993, and hereafter in this report, these samples are referred to as field duplicates. These samples were collected to evaluate the representativeness of collecting epilimnetic data from a single lake station. The draft Quality Assurance Project Plan (QAPP) for the LWQA Program (Hallock, 1995) states that total precision of these field duplicates should be evaluated by pooling the CVs for each pair using the RMS.

Results in Table 3 show that RMS values exceeded the draft QAPP's RMS limit of < 14% for field duplicates. As stated in the QAPP, to achieve spatial plus analytical variability within ± 3 TSI units using one sample per lake, the RMS of CVs from 10 duplicate samples must be < 14%. The majority of the total variability in Table 3 was likely due to field variability, because lab variability was relatively small; laboratory precision, which was calculated from results of field duplicate samples which were analyzed by the lab in duplicate, was 2.7% for the May survey, and 6.5% for the August survey (Appendix D).

Table 3. Total precision of field duplicates.

Field Duplicates	n	CV%	RMS
May survey	12	3.7-101	41.5
August survey*	10	5.7-47.1	24.3
both surveys	22	3.7-101	34.2

* results from two lakes were below the detection limit, and were not used in this comparison

Because the main station was located at the deep site, and the field duplicate was collected (from the epilimnion) from a shallower site, a paired t-test was used to determine whether samples collected from the established deep-site stations were significantly different from samples collected from shallower stations. Results showed that the main station mean was not significantly different from the second station mean ($P = 0.19$, $n = 22$). Although the variance of samples collected from the second stations was greater than the variance of samples collected from the main stations, critical values of the F distribution showed that the two variances were not significantly different ($0.50 < P < 1.00$; Table 4).

Further, Table 4 shows that the variances between the May and August samples for all lakes were not significantly different ($P < 0.20$). In addition, differences between seasons, as well as between years, were closer to being significant than differences between stations. Similar results were apparent from data collected in 1994 (Table 4).

Table 4. Tests of significance between variances of TP data for station, season, and year.

Populations	n	F	Probability	Significance
1993				
TP at main station and second site	24	1.25	0.50 < P < 1.00	NS
TP in May and TP in August	48	1.34	0.10 < P < 0.20	NS
1994				
TP at main station and second site	21	1.71	0.20 < P < 0.50	NS
TP in May and TP in August	48	1.41	0.10 < P < 0.20	NS
Between Years				
TP in May 1993 and May 1994	48	1.32	0.10 < P < 0.20	NS
TP in August 1993 and August 1994	48	1.41	0.10 < P < 0.20	NS

These results suggest that the effect of station is not as high as the effect of season or year. However, another important consideration is whether the effect of lake is high, so that a single TP sample can differentiate between lakes. As specified in the QAPP for the LWQA Program, an analysis of variance (Anova) should be used to evaluate variability between lake, station, season, and year. Because only five lakes were sampled at a second station during both seasons in 1993, there were not enough representative data available to estimate the variance component for station. Instead, a nested Anova was used to estimate the magnitude of variance components among years, among lakes, and among seasons (within years). Data were used from 31 lakes which had been sampled for the LWQA Program, during both seasons, from 1992 through 1994. Results of this Anova are in Table 5.

Table 5. Anova table (two-level nested anova) for estimating the significance of variance in TP results among lakes, years, and seasons.

Source of variation	df	SS	MS	F	P
Between years	2	2,694.323	1,347.161	3.793	0.028
Between lakes	30	30,643.463	1,021.449	2.876	0.000
Season (within lakes within years)	93	45,741.200	491.841	1.385	0.089
within lakes (error; variability in TP within each lake over 3 years)	60	21,309.871	355.165		

The sum of squares (SS) component indicates the magnitude of each source of variation. From Table 5, it is apparent that from 1992 through 1994, seasonal variation was greater than variation due to lake or year. However, seasonal variation was not significant (Table 5; also shown in Table 4). Variation between lakes was significant ($P = 0.0$), and as expected, variation due to lake had a higher significance level than variation due to either season ($P = 0.09$) or year ($P = 0.03$).

Overall, variability in TP between stations was high according to the level specified in the QAPP, but was not significant compared to differences between lakes. As noted in Hallock (1995), increasing the number of samples per lake will improve precision (and hence the representativeness of collecting one sample per lake), but is not necessarily within the financial means or the monitoring objectives of the LWQA Program. Variability in TP was even higher between seasons and between years, raising the question whether the precision limit of < 14% between stations is unnecessarily stringent.

The variability between station, season, and year raises other questions about basing assessments on a single TP sample. This is discussed further in the "Results" section.

Other Water Chemistry Data

QA/QC evaluations for total nitrogen, chlorophyll *a*, solids, and fecal coliform bacteria followed most of the methods described in Hallock (1995). All available lab QC data results are listed in Appendix D.

Total Nitrogen

Results from field duplicates were within acceptable ranges specified in Table 2. However, lab QC data were not available to estimate analytical variability, so it was not possible to assess the relative contribution of station to total variance.

Chlorophyll a

Total precision of chlorophyll *a* was reported as the RMS of field duplicates. Results for both surveys were high; the RMS of field duplicates was 26.4% for the May survey, and 18.4% for the August survey. These results are higher than the precision limit in Table 2 (< 10%).

The variability in chlorophyll *a* concentrations between surveys was also evaluated, using the CV between survey results for each lake. Coefficient of variation values ranged from 0 to 127%, and the mean CV was 44.2%. About two thirds of the lakes had CV values that exceeded the limit in Table 2 (< 29%), indicating that overall variability between the May and August surveys was high. This limit is primarily used to determine the utility of chlorophyll data that is collected only twice annually, as opposed to being a true measure of data quality. In fact, assuring the quality of chlorophyll *a* data has been problematic for the LWQA Program. Normal QC procedures are not available for chlorophyll *a* analysis--most labs do not run lab check standards for chlorophyll, relying instead on periodic calibration of the instrument. Also, lab splits are not possible because of the small volume of extracted sample. As shown above, results from field duplicates were highly variable, but information was not available to evaluate how much of that field variability was due to lab procedures or sample processing procedures. Until that information is available, it is premature to evaluate seasonal variation in chlorophyll data.

To evaluate possible effects from field procedures, concentrations of pheophytin *a* (a degradation product of chlorophyll *a*) can be compared to concentrations of chlorophyll *a*. However, roughly half of the calculated pheophytin *a* concentrations were negative (an impossibility); most likely, these calculated values were due to insufficient significant figures. Instead, ratios of absorbances read before acidification (at 664 nm; denoted as 664_b) and after acidification (at 665 nm; denoted as 665_a) were used to characterize the physiological condition of chlorophyll samples (APHA, 1992). A $664_b/665_a$ ratio of 1.7 indicates that no pheophytin *a* is present and the sample is in good physiological condition. A ratio between 1.0 and 1.7 indicates that there is a mixture of chlorophyll *a* and pheophytin *a* (APHA, 1992). Ratios from 1993 sample results ranged from 1.3 to 4.0; ratios greater than 1.7 should not occur, and may also be an artifact of insufficient significant digits. A large number of samples had ratios between 1.4 and 1.6, even when implied limits about the low number of significant figures were considered. And, there is no information to show whether pheophytin *a* was produced before or after the sample was collected. It is possible, though, that degradation of chlorophyll *a* may have occurred after the sample was collected. Eisner (1994) showed that for marine water samples, filters placed in 90% acetone, and stored in a freezer, gave a 22% higher yield in chlorophyll *a* than filters stored "dry" in a freezer. Samples for the LWQA Program have been frozen "dry" since the program began. In the future, samples for the LWQA Program will be stored in acetone.

The problem with significant digits resulted because the method states that pre-acidification absorbances should be between 0.1 and 1.0 (APHA, 1992), yet most of the LWQA samples had pre-acidification absorbances below 0.100 (and post-acidification absorbances between 0.001 and 0.008). As stated in the method, the pre-acidification absorbance can be adjusted by using a longer light path (*i.e.*, using a wider cuvette). For the LWQA Program, the resolution of the test should be improved by increasing the cell path from 1 cm to 10 cm.

Solids and Fecal Coliform Bacteria

With the exception of one TNVSS sample, results from field duplicates of solids samples were within the limits of ± 1 mg/L.

Precision of fecal coliform bacteria data should be evaluated using results from lab duplicates (Table 2). In 1993, results from lab duplicates were not available, to some degree because a larger sample is needed to perform a reliable lab split. However, because samples are collected for the LWQA Program merely to screen lakes for possible public health problems that could affect beneficial uses, high or unusual results from the program are referred to Ecology's regional offices for confirmation, particularly since the water quality standard is based on a geometric mean value. During the 1994 monitoring season, a subset of the bacteria samples were collected in 500 mL bottles (instead of the usual 250 mL), to allow for lab duplicates and QA/QC evaluation.

Results and Discussion

In 1993, 65 lakes were monitored by Ecology and volunteers, and 21 lakes were sampled by Ecology staff only. Locations of the monitored lakes are shown in Figure 1.

Data collected for the program in 1993 were used for trophic state assessments, evaluating trends in monitored lakes, and identifying anomalous water quality in monitored lakes based on evaluations within ecoregions. The following sections discuss each of these. In addition, the relationship between trophic state parameters is discussed, because these relationships are important for evaluating sampling and data analysis methods used for the LWQA Program.

Trophic State Assessments

Trophic states were assigned to 85 lakes (Table 6). The basis for the trophic state assessments for the 65 volunteer-monitored lakes are explained in the "Comments" section for each lake's Individual Lake Assessment (compiled at the end of this report).

Individual Lakes Assessments were written only for lakes which were monitored by volunteers, so there are no Individual Lake Assessments for lakes that were monitored by Ecology staff only. Water quality data for Ecology-monitored lakes are compiled in Appendix F.

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

Oligotrophic	17
Oligo-mesotrophic	19
Mesotrophic	22
Meso-eutrophic	11
Eutrophic	16
Hyper-eutrophic	1

Trend in Water Clarity

Seventeen lakes were monitored by volunteers every year from 1989 through 1993. The software package WQHYDRO (Aroner, 1990) was used to analyze Secchi depth data from these lakes, including analysis for significance of serial correlation. For lakes with significant serial correlation, data were deseasonalized and detrended before analysis. Slopes were also calculated to determine annual changes in Secchi depths from 1989 to 1993 (Table 7).

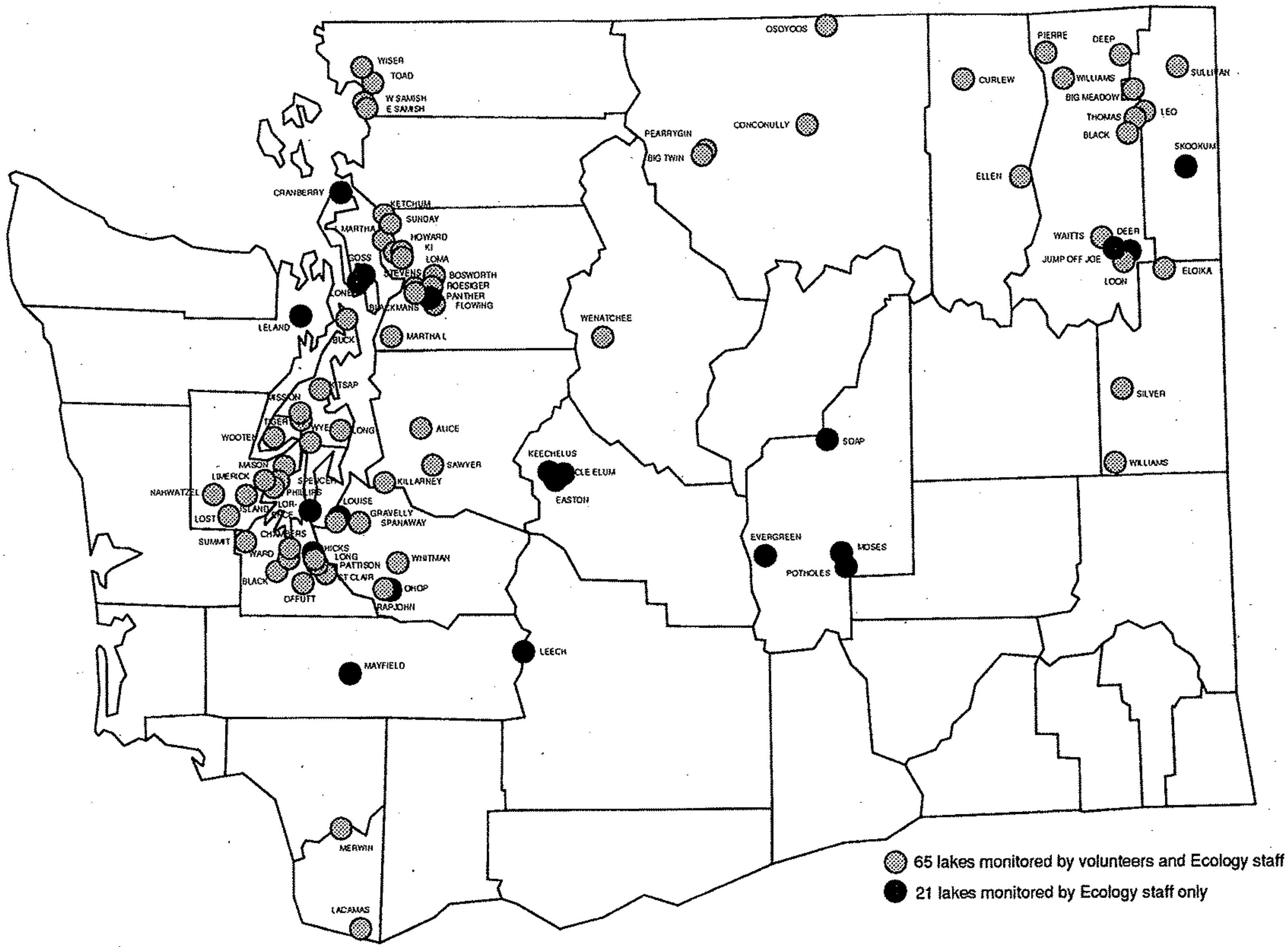


Figure 1. Locations of Lakes Monitored for LWQA Program in 1993

Table 6. Trophic states and trophic state indices for lakes monitored in 1993. The "assessed trophic state" is based on an evaluation of TSIs and other available data.

Lake (County)	Assessed Trophic State	TSI_{SD}	TSI_{TP} May	TSI_{TP} Aug	TSI_{CHL} May	TSI_{CHL} Aug
Alice (King)	Mesotrophic	43	49	37	< 24	42
Big Meadow (Pend Oreille)	Mesotrophic	40	46	44	46	39
Black (Stevens)	Oligo-mesotrophic	36	32	34	38	39
Black (Thurston)	Eutrophic	53	61	62	46	63
Blackmans (Snohomish)	Mesotrophic	43	53	41	41	41
Bosworth (Snohomish)	Oligo-mesotrophic	37	48	40	39	48
Buck (Kitsap)	Meso-eutrophic	43	57	54	53	45
Chambers (Thurston)	Eutrophic	57	65	56	67	49
Cle Elum (Kittitas)	Oligotrophic	--	20	52	44	69
Conconully (Okanogan)	Mesotrophic	34	52	42	44	49
Cranberry (Island)	Eutrophic	--	56	54	53	57
Curlew (Ferry)	Mesotrophic	40	50	59	42	38
Deep (Stevens)	Oligo-mesotrophic	32	48	30	43	35
Deer (Stevens)	Oligotrophic	--	41	32	27	36
Easton (Kittitas)	Oligotrophic	--	< 20	45	25	26
Ellen (Ferry)	Oligotrophic	37	36	30	40	36
Eloika (Spokane)	Meso-eutrophic	47	62	53	36	50
Evergreen (Grant)	Mesotrophic	--	51	49	38	47
Florence (Pierce)	Mesotrophic	--	42	37	39	45
Flowing (Snohomish)	Oligo-mesotrophic	39	42	37	39	45
Goss (Island)	Oligotrophic	--	< 20	49	36	27
Gravelly (Pierce)	Oligo-mesotrophic	28	27	32	33	24
Hicks (Thurston)	Mesotrophic	--	49	47	47	42
Howard (Snohomish)	Oligo-mesotrophic	35	44	52	36	35
Island (Mason)	Oligotrophic	36	32	39	34	38
Jump Off Joe (Stevens)	Mesotrophic		48	48	38	48
Keechelus (Kittitas)	Oligotrophic	--	41	34	36	40
Ketchum (Snohomish)	Hyper-eutrophic	50	--	--	--	--
Ki (Snohomish)	Oligotrophic	32	36	30	41	36
Killarney (King)	Eutrophic	50	52	55	46	50
Kitsap (Kitsap)	Mesotrophic	38	--	44	--	45
Lacamas (Clark)	Eutrophic	52	63	55	58	54
Leech (Yakima)	Mesotrophic	--	41	44	33	44
Leland (Jefferson)	Eutrophic	--	58	--	61	--
Leo (Pend Oreille)	Oligo-mesotrophic	35	46	30	41	33
Limerick (Mason)	Mesotrophic	43*	--	48	--	40
Loma (Snohomish)	Eutrophic	50	49	56	50	72

Table 6. Continued.

Lake (County)	Trophic State	TSI_{SD}	TSI_{TP}		TSI_{CHL}	
			May	Aug	May	Aug
Lone (Island)	Meso-eutrophic	--	53	58	48	45
Long (Kitsap)	Eutrophic	57	64	63	54	63
Long (Thurston)	Meso-eutrophic	48	54	59	46	59
Lost (Mason)	Oligotrophic	34	40	24	25	25
Louise (Pierce)	Oligo-mesotrophic	--	39	41	--	40
Lake Martha (Snohomish)	Mesotrophic	35	58	40	46	42
Martha Lake (Snohomish)	Oligo-mesotrophic	36	44	27	32	31
Mason, Center (Mason)	Oligotrophic	31	39	30	32	30
Mason, NE (Mason)	Oligotrophic	31	--	--	--	--
Mason, SE (Mason)	Oligotrophic	31	--	--	--	--
Mayfield (Lewis)	Oligo-mesotrophic	--	54	27	43	40
Merwin (Clark)	Oligotrophic	32	37	20	37	37
Mission (Kitsap)	Mesotrophic	44*	55	48	42	50
Moses (Grant)	Eutrophic	--	61	60	42	70
Moses (Pelican)	Eutrophic	--	60	71	50	70
Moses (Parker Horn()	Eutrophic	--	60	77	42	70
Nahwatzel (Mason)	Oligotrophic	35	32	32	37	41
Offutt (Thurston)	Eutrophic	47**	51	51	< 24	58
Ohop (Pierce)	Eutrophic	--	55	56	50	58
Osoyoos (Okanogan)	Mesotrophic	45	43	37	46	45
Panther (Snohomish)	Oligotrophic	--	39	39	34	46
S Pattison (Thurston)	Meso-eutrophic	42	67	49	< 24	52
Pearrygin (Okanogan)	Mesotrophic	46	52	44	44	56
Phillips (Mason)	Mesotrophic	40*	48	40	25	30
Pierre (Stevens)	Oligo-mesotrophic	36	43	27	42	34
Potholes (Grant)	Eutrophic	--	57	56	46	59
Rapjohn (Pierce)	Meso-eutrophic	48	58	54	49	50
N Roesiger (Snohomish)	Oligo-mesotrophic	33	72	24	33	39
S Roesiger (Snohomish)	Oligo-mesotrophic	35	--	--	--	--
E Samish (Whatcom)	Oligo-mesotrophic	40	49	34	32	41
W Samish (Whatcom)	Oligo-mesotrophic	38	--	--	--	--
Sawyer (King)	Mesotrophic	42	55	39	52	45
Silver (Spokane)	Meso-eutrophic	47	64	47	46	49
Skookum (Pend Oreille)	Mesotrophic	--	51	52	35	45
Soap (Grant)	(not assessed)	--	94	95	33	28
Spanaway (Pierce)	Meso-eutrophic	45	41	42	51	52
Spencer (Mason)	Oligo-mesotrophic	39	61	34	44	39
St. Clair (Thurston)	Meso-eutrophic	46	53	46	37	45
Stevens (Snohomish)	Oligo-mesotrophic	34	32	37	44	41

Table 6. Continued.

Lake (County)	Trophic State	TSI_{SD}	TSI_{TP} May	TSI_{TP} Aug	TSI_{CHL} May	TSI_{CHL} Aug
Sullivan (Pend Oreille)	Oligotrophic	30	45	32	29	33
Summit (Thurston)	Oligotrophic	32	47	34	42	32
Sunday (Snohomish)	Eutrophic	48	66	59	70	46
Thomas (Stevens)	Oligo-mesotrophic	37	40	39	35	34
Tiger (Kitsap/Mason)	Oligotrophic	41*	34	34	36	31
E Toad (Whatcom)	Meso-eutrophic	41	70	45	54	44
W Toad (Whatcom)	Meso-eutrophic	43	--	--	--	--
Twin, Big (Okanogan)	Oligo-mesotrophic	30	43	40	37	34
Waitts (Stevens)	Oligo-mesotrophic	33	47	37	35	35
Ward (Thurston)	Oligo-mesotrophic	36	48	27	26	< 24
Wenatchee (Chelan)	Oligotrophic	37	61	< 20	26	41
Whitman (Pierce)	Mesotrophic	46	49	46	50	47
Williams (Spokane)	Mesotrophic	44	53	40	46	48
Williams (Stevens)	Mesotrophic	34	59	37	43	40
Wiser (Whatcom)	Eutrophic	--	--	78	--	64
Wooten (Mason)	Oligotrophic	33	24	27	31	36
Wye (Kitsap)	Meso-eutrophic	< 41***	52	43	57	41

* Accuracy limit was exceeded, so Secchi depths should not be compared with other lakes (just within the lake between years).

** Duplicate Secchi readings exceeded the precision limit, so readings should not be compared with other lakes or years

*** Most Secchi readings "hit bottom," so TSI_{SD} underestimates true water clarity

Table 7. Seasonal slopes, percent annual change of Secchi depths, and probability of trend for lakes monitored by volunteers during 1989-1993.

Lake	Seasonal Slope*	Average Percent Annual Change	Probability
Big Meadow (Pend Oreille)	1.2691	12.9	0.0001
Black (Stevens)	-0.3083	-1.8	0.6663
Curlew (Ferry)	0.1667	0.9	0.6427
Eloika (Spokane)	0.3056	4.1	0.2418
Killarney (King)	-0.2475	-3.1	0.4395
Lacamas (Clark)	0.2486	4.3	0.7861
Long (Thurston)	-0.4982	-6.2	0.1824
Mason (Mason)	-0.1241	-0.5	0.8197
Osoyoos (Okanogan)	0.1673	1.9	0.7105
Phillips (Mason)	-0.4762	-3.8	0.4884
E Samish (Whatcom)	-0.2492	-1.9	0.4785
W Samish (Whatcom)	-0.0418	-1.3	0.8166
St. Clair (Thurston)	-0.3133	-0.4	1.000
Thomas (Stevens)	0.4786	3.2	0.1378
Wenatchee (Chelan)	-0.0376	-0.2	0.8844
Williams (Spokane)	-0.7921	-6.7	0.2998
Wooten (Mason)	-0.5192	-2.4	0.3631

* Positive slope values (using Sen's slope estimator, Aroner, 1990) indicate increasing Secchi depths, and negative values indicate decreasing Secchi depths.

Using the seasonal Kendall test for trend, three lakes exhibited statistically significant trends in water clarity (Table 7). Big Meadow Lake and Lake Thomas exhibited statistically significant improving trends in water clarity from 1989 to 1993 (significant at the 99% and 80% levels, respectively). Long Lake in Thurston County exhibited a statistically significant decreasing trend in water clarity (significant at the 80% level).

Because there are gaps in the period of record for total phosphorus data (there are no total phosphorus data for the program in 1991), and because water samples are collected from lakes only two times per year, trend analysis of nutrient data will not have sufficient power to be meaningful until 1996 at the earliest.

Lake Water Quality Within Ecoregions and Within Watersheds (WRIAs)

One of the objectives of the LWQA Program is to separate lakes into ecoregions (Omernik and Gallant, 1986), and identify lakes within ecoregions that exhibit anomalous water quality. Ecoregional analysis for the LWQA Program was last discussed in Rector and Hallock (1993).

In 1993, Ecology began a systemized process for focusing water quality management and planning within four targeted watersheds each year. This process occurs in five-year cycles that consist of scoping, data collection, data analysis, plan production, and plan implementation. Data collected for the LWQA Program are included in the scoping phase of this process, and lakes have been added to the program specifically to support the monitoring phase. Lakes monitored in 1993, and lakes to be considered for the 1995 monitoring season, are described below.

Ecoregion Comparisons

Omernik and Gallant (1986) divided the Pacific Northwest into 15 ecoregions based on similarities in land use, land surface form, potential natural vegetation, and soils. In theory, waterbodies within an ecoregion would have similar water quality or potential water quality.

Among many uses, ecoregions have been used for water quality modeling, water quality management, and identifying waterbodies with unusual water quality in comparison to other waterbodies in the same ecoregion.

There are eight ecoregions in Washington, and lakes from five ecoregions were monitored for the program in 1993. These ecoregions are the Puget Lowlands (54 lakes), Willamette Valley (1 lake), Cascades (6 lakes), Columbia Basin (11 lakes), and the Northern Rockies (15 lakes). Mean Secchi depth, mean TP, and mean chlorophyll *a* data from 1993 were grouped into ecoregions. Ecoregion comparisons were made using box plots (Figures 2-4). Box plots are used to illustrate the distribution of a series of data points from a ranked set of data. In the box plots for each ecoregion, data outliers that are within 1.5 to 3.0 times the interquartile range are indicated with a star (*), and data outliers that are greater than 3.0 times the interquartile range are indicated with a circle (o). Comparisons between ecoregions were made using the interquartile ranges; when interquartile ranges overlap, values from the ecoregions were not significantly different.

Mean Secchi depth data (Figure 2) showed that Big Twin Lake in Okanogan County had very good water clarity in comparison to other lakes monitored within the Columbia Basin ecoregion, despite moderate concentrations of TP on both sampling dates (12 µg/L in May, and 15 µg/L in August) that would predict lower Secchi depths. Box plots (Figure 3) show that unusually high mean TP concentrations were measured in Wiser Lake and South Pattison Lakes within the Puget Lowland ecoregion, Williams Lake (Stevens County) within the Northern Rockies ecoregion, and Soap Lake within the Columbia Basin ecoregion. The mean TP concentration from Soap Lake (536.6 µg/L) was exceptionally high, not only for its ecoregion, but in comparison to the rest of the lakes monitored in 1993. Despite extensive restoration efforts, Moses Lake was an outlier with respect to mean chlorophyll *a* concentration in the Columbia Basin ecoregion (Figure 4). Of the five lakes within the Puget Lowlands ecoregion that had unusually high mean chlorophyll *a* concentrations, three of the five lakes have been studied in the past for lake restoration projects. Both lakes that have not been studied, Sunday Lake and Black Lake, are good candidates for lake restoration.

Figure 2. Box Plots of mean Secchi data, grouped by Ecoregion

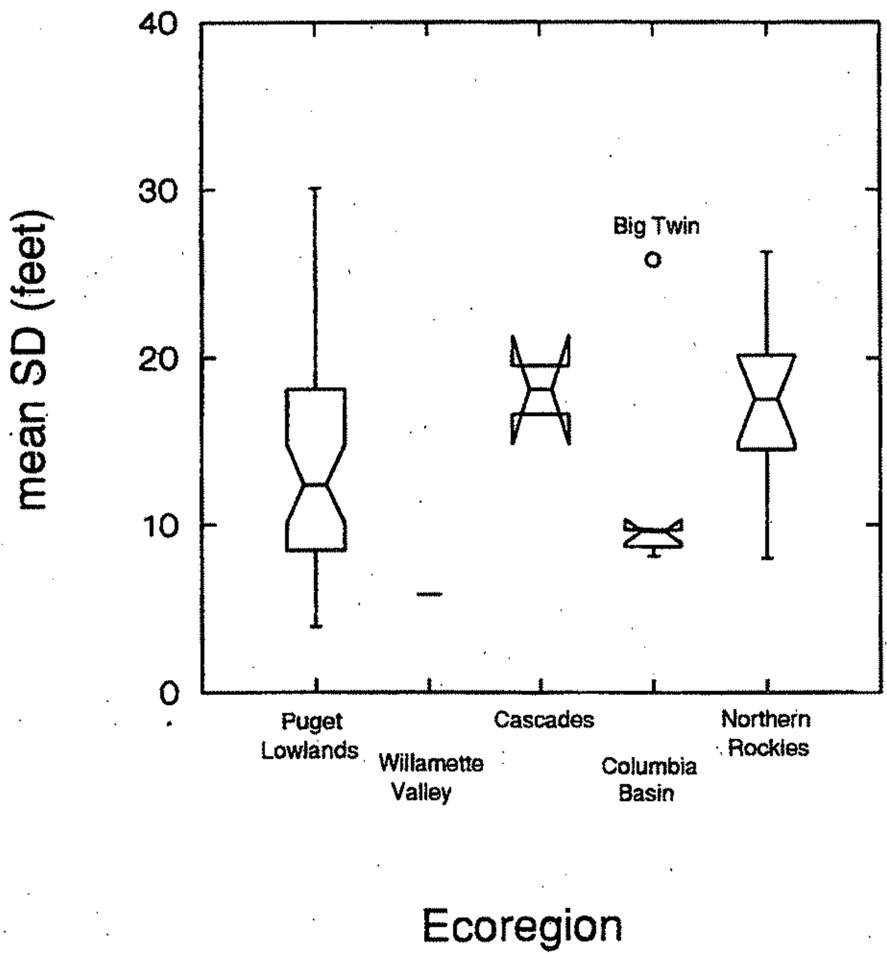


Figure 3. Box Plots of mean TP data, grouped by ecoregion

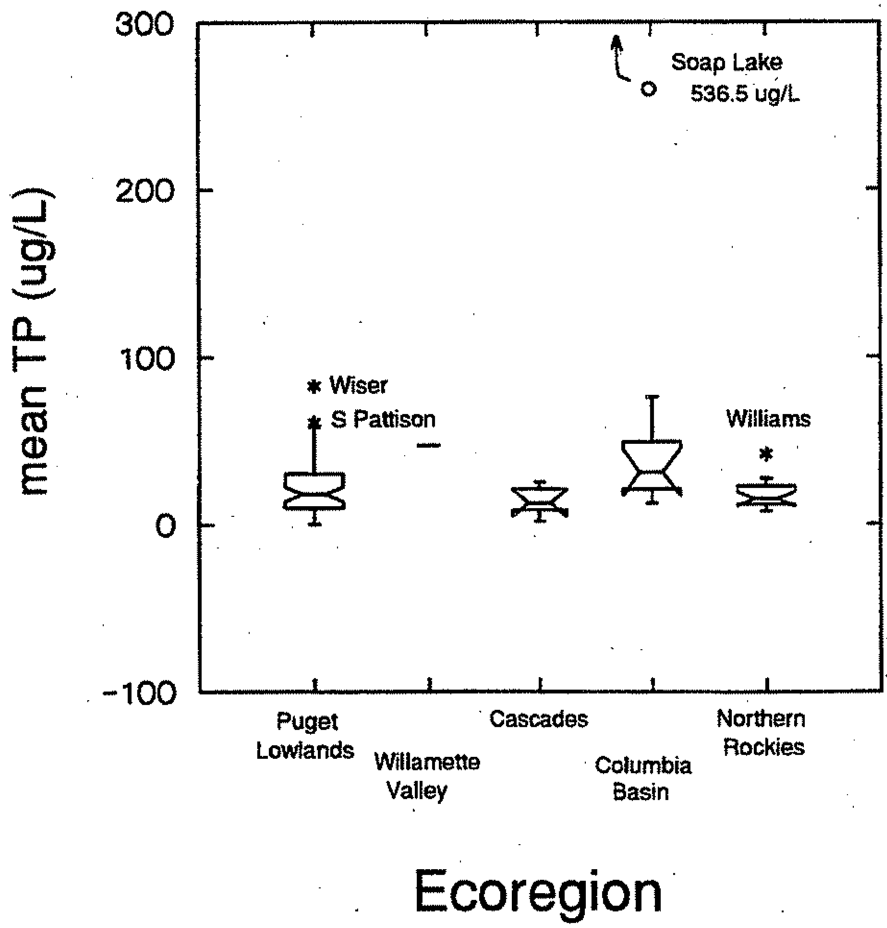
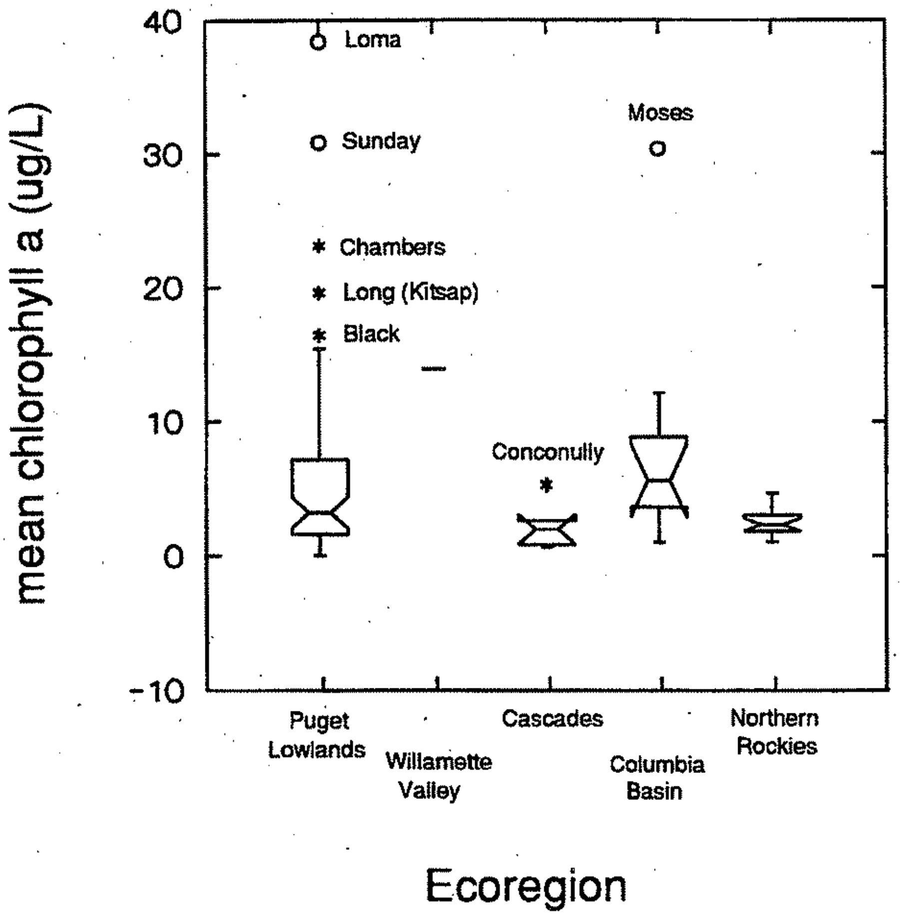


Figure 4. Box Plots of mean chlorophyll a data, grouped by ecoregion



Comparisons between ecoregions show that mean Secchi depths in the Puget Lowlands and the Columbia Basin were lower than mean Secchi depths from lakes monitored in the Cascades and the Northern Rockies ecoregions (Figure 2). Secchi depths from the Columbia Basin were significantly lower than Secchi depths from the Cascades and Northern Rockies ecoregions. For both mean TP and mean chlorophyll *a*, there were wider ranges of results in the Puget Lowlands and Columbia Basin ecoregions than in the Cascades and Northern Rockies ecoregions. However, mean TP and mean chlorophyll *a* concentrations were not significantly different between the four ecoregions.

Lake Monitoring in Support of Watershed-Based Water Quality Management

Each year, Ecology's ambient monitoring programs sample additional stations within basins that are targeted for watershed-based water quality management and planning. Watersheds are comprised of Water Resource Inventory Areas (WRIAs); because the boundaries for these watersheds are not based on the same criteria as the ecoregion boundaries, WRIAs and ecoregions cover different areas.

In 1993, stations were added within the mid-Columbia, Upper Yakima, Kitsap, and Lower Columbia Basins. The LWQA Program sampled 16 lakes in these basins in 1993. The data analysis phase (third year) of the basin planning process has already occurred, and the planning phase (fourth year) is in process. The lakes, and their WRIAs, are listed below.

Lake	County	Basin	WRIA
Buck*	Kitsap	Kitsap	15
Cle Elum	Kittitas	Upper Yakima	39
Easton	Kittitas	Upper Yakima	39
Evergreen	Grant	Mid Columbia	41
Keechelus	Kittitas	Upper Yakima	39
Kitsap*	Kitsap	Kitsap	15
Leech	Yakima	Upper Yakima	39
Long *	Kitsap	Kitsap	15
Mayfield	Lewis	Lower Columbia	26
Mission*	Kitsap	Kitsap	15
Moses--	Grant	Mid Columbia	
Main Basin			41
Parker Horn			41
Pellican Horn			41
Potholes	Grant	Mid Columbia	41
Soap	Grant	Mid Columbia	41
Tiger *	Kitsap/Mason	Kitsap	15
Wooten*	Mason	Kitsap	15
Wye *	Kitsap	Kitsap	15

* Lakes monitored by volunteers, and there is an Individual Lake Assessment at the end of this report.

Results From Volunteer-Collected TP Samples

A paired t-test was used to evaluate the differences between pairs of results from the May field visits. Results from the t-test showed that samples that were held frozen for three months were significantly different from results of samples that were analyzed within holding times. The CV was also calculated for each data pair. The CVs ranged from 4.0% to 54.8%; the mean CV was 29.6%, and the median CV was 26.9%. With one exception, all CVs for data pairs exceeded the draft data quality requirements for precision (which is < 14% CV of field duplicates). Based on poor agreement between the split samples, the results from the samples frozen by the volunteers will not be used. (Although we may attempt to test this method again, we did not continue this type of sampling in 1994.)

Relationships Between Trophic State Parameters

Carlson's (1977) Trophic State Index has been very useful for evaluating data collected for the LWQA Program. Primarily the TSIs have been used for the LWQA Program to assess the trophic status of monitored lakes--TSI values less than 40 are typical of oligotrophic lakes, and TSIs greater than 50 are typical of eutrophic lakes (Carlson, 1979).

However, TSI values for sampled LWQA lakes do not always agree (1993 TSIs are shown in Figure 5), and most trophic state assessments for the LWQA Program are tempered with professional judgment using other data and information that indicate trophic status (*i.e.*, dissolved oxygen concentrations and macrophyte coverage). These disagreements between TSI values for monitored LWQA Program lakes warrant an evaluation of the relationships between trophic state parameters, and how they compare to the relationships used in the development of Carlson's (1977) TSIs.

Comparisons of Regression Equations

Regression equations for data collected from 1989 to 1994 are listed in Table 8. Results from Carlson's regression equations are also listed for comparison.

In Table 8, only the regression equations for Secchi depth against TP are similar. The relationships involving chlorophyll, however, are considerably different. This is disturbing because of the three trophic state parameters measured for the LWQA Program, summer average chlorophyll *a* is the most direct measurement of trophic state (Carlson, 1977). In an exercise to evaluate what concentrations of TP and chlorophyll *a* would be predicted if the LWQA equations were substituted into the TSI equations, the LWQA relationships predict that a lake with a TSI of 100 would have 1,024 µg/L TP and approximately 28,000 µg/L chlorophyll *a*. This predicted chlorophyll concentration is absurd, and indicates further that chlorophyll *a* concentrations measured for the LWQA Program do not relate well with the other two parameters.

1993 Trophic State Indices (TSI)

Ordered by Secchi TSI

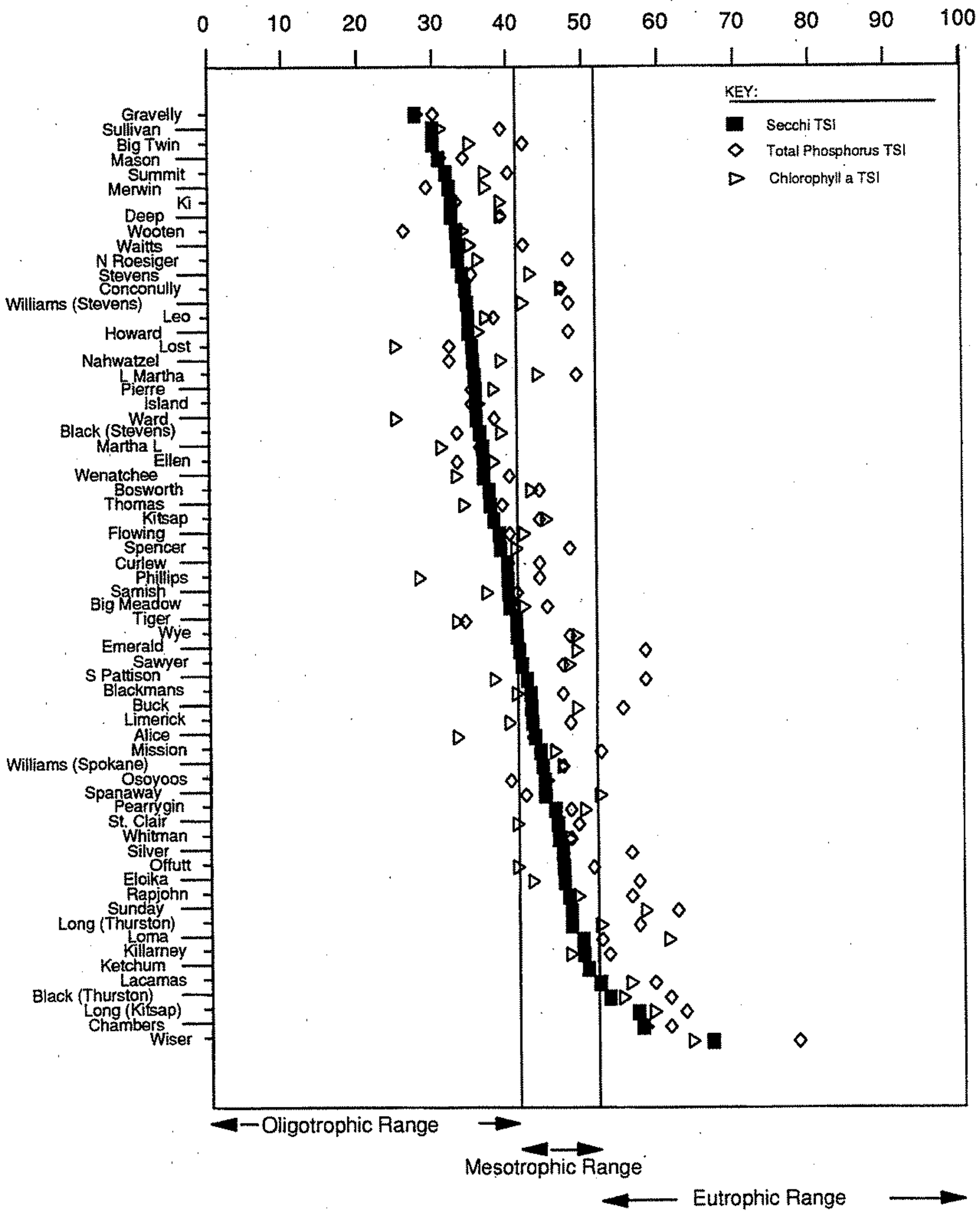


Table 8. Regression equations using LWQA data from 1989-1994, compared to Carlson's (1977) regression equations.

LWQA[1]	Carlson (1977)
$\ln Chl = 1.025 \ln TP - 1.55$ (r^2=0.46, n=141)[2]	$\ln Chl = 1.449 \ln TP - 2.442$ (r^2=0.72,n=43)[3]
$\ln SD = 1.83 - 0.43 \ln Chl$ (r^2=0.65, n=212)[4]	$\ln SD = 2.04 - 0.68 \ln Chl$ (r^2=0.86, n=147)
$\ln SD = 4.09 - 0.98 \ln TP$ (r^2=0.53, n=265)[2,4]	$\ln SD = 3.876 - 0.98 \ln TP$ ([5])

[1] data collected 1989-1994, August survey only
[2] using August survey data for TN:TP≥17
[3] TP data from only July and August were used
[4] Secchi depths from same day as TP and chlorophyll *a* data (*i.e.*, not mean summer values)
[5] Equation developed by combining the two other equations

Factors Affecting Trophic State Relationships

Despite concerns about the methods used to store and analyze chlorophyll *a* samples (discussed in the "QA/QC Evaluation" section of this report), the best relationship between trophic state parameters was between chlorophyll and Secchi depth (Table 8). Both of these parameters are both more direct measures of trophic status than TP, so it is worthwhile to explore other factors that could affect the relationships between chlorophyll *a*, Secchi depth, and TP for LWQA data. Factors that could affect these relationships include non-phosphorus limitation, variability in results between the May and August surveys, or climatological variations. These factors will each be discussed in turn.

Non-Phosphorus Limitation

It is important to assess non-phosphorus limitation because the TSI relationships assume that algal productivity is phosphorus-limited. Although it is difficult to assess non-nutrient limitation in LWQA lakes, nutrient limitation can be evaluated using ratios of total nitrogen to total phosphorus (TN:TP). While this method is commonly used, there is disagreement among researchers regarding the cutoff points that distinguish P-limitation and N-limitation. As part of a literature review on nutrient limitation, Carroll and Pelletier (1991) noted that cutoff points indicating P-limitation range from > 10:1 to > 21:1, although > 17:1 is a commonly reported limit. Using LWQA data, TP explains the most variability in chlorophyll *a* concentration when data only from phosphorus-limited lakes (predicted by a TN:TP ≥17) are used (Table 9).

Table 9. Correlations between in-transformed chlorophyll and in-transformed TP.

LWQA Data	Correlation, r
All LWQA data 1989-1994	0.58 (n=455)
May survey data, 1989-1994	0.55 (n = 224)
August survey data, 1989-1994	0.64 (n = 212)
August survey data, TN:TP≥17	0.68 (n=141)

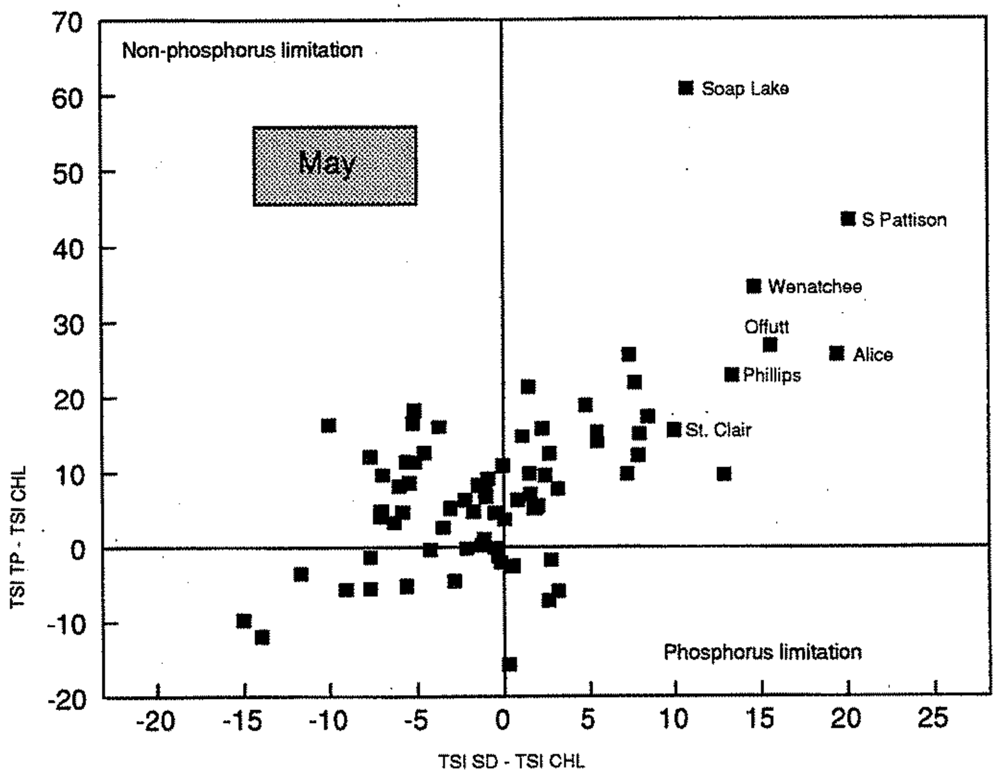
Table 9 also shows that on the basis of TN:TP, 71 data points from August surveys (33% of the data set) were from lakes where phosphorus limitation was questionable. Yet, excluding these data points did not improve the relationship that much. This could suggest that non-nutrient limitation, among other possible factors, affected the relationship between TP and chlorophyll *a*. To evaluate whether LWQA lakes were affected by non-nutrient limitation, TSI residuals were plotted using the method described in Carlson (1991), and are shown in Figure 6. TSI residuals are the difference between TSI_{SD} and TSI_{CHL}, and between TSI_{TP} and TSI_{CHL}. This method is intended to be a tool to identify possible non-nutrient limitation in lakes, which can then be used to identify lakes which may have been assigned erroneous trophic states.

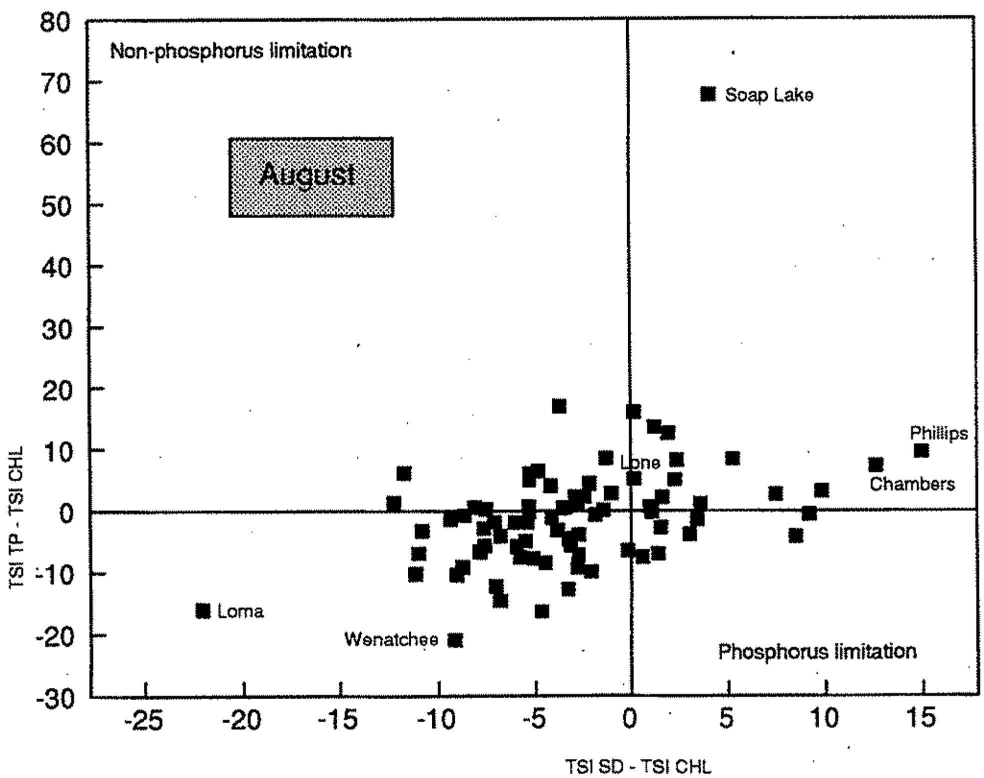
TSI residuals for most LWQA lakes were < 10 (Figure 6). However, residuals differed considerably between surveys. This analysis tool indicates that the majority of lakes were non-phosphorus limited during the May survey, and phosphorus-limited during the August survey. Because each survey is represented by one chlorophyll and one TP result, this tool is probably best used in support of other data.

Results from the May survey gave a wide range of residuals, particularly in the upper right quadrant; several lakes falling into this quadrant had much lower chlorophyll than would be expected given the TP concentration and Secchi depth. Nitrogen limitation may be a major factor because with the exception of Lake St. Clair and Offutt Lake, all of the lakes in this quadrant had a TN:TP ratio ≤17. For lakes in the upper left quadrant for the May survey, chlorophyll *a* was higher than would be predicted given the Secchi depths, and lower than predicted given TP. TN:TP ratios for these lakes ranged from 5.2 to 31.6, which, when considered with TN:TP from the upper right quadrant, agrees with Carlson's conclusion that all lakes plotted above the TSI_{SD} - TSI_{Chl} line will have TN:TP < 33.1. In this quadrant, there was no obvious explanation for the range of TSI residuals, although non-phosphorus limitation appeared to affect productivity.

In the residuals plotted for results from the August survey, many of the lakes are located along the TSI_{TP} - TSI_{CHL} axis, which indicates that algae were the dominate cause of light attenuation (Carlson, 1991). This is a major assumption in the use of the TSI. With the exception of Soap Lake, Phillips Lake, and Lake Wenatchee, outliers (TSI residuals > 10) from the August survey had moderately high to high chlorophyll *a*. As with the May results, most of the lakes in the upper right quadrant had TN:TP≤17. However, Phillips Lake, Chambers Lake, and Lone Lake were all in this quadrant with TN:TP > 20; this suggests that productivity was limited

Figure 6. TSI Residuals





by neither phosphorus nor nitrogen. In Chambers Lake, by late summer most of the lake surface is covered with lily pads (see individual lake assessment at the end of this report) which probably causes light limitation. It is not clear what limited productivity in Lone Lake and Phillips Lake during the August survey.

TSI residuals from Soap Lake indicate that the lake is an obvious outlier with respect to Secchi:TP:chlorophyll relationships. TP concentrations were very high (> 500 µg/L) in the lake, so that TN:TP was very low (< 3.5) on both sampling dates. However, Soap Lake is a unique case, having unusually high epilimentic concentrations of sulfate and chloride, as well as high pH, alkalinity, and specific conductance (Appendix F). In this lake, chemical limitation may affect biomass. Soap Lake is a good example of a lake that would be erroneously classified as eutrophic based on TP concentration alone.

Using TSI residuals, the other obvious outlier lake was Lake Loma during the August survey. This lake is highly colored (Bortleson *et al.*, 1976), which according to Carlson (1991), would affect transparency but not algal biomass. However, TSI residuals for Lake Loma do not agree with this, because chlorophyll was much higher than would be predicted from the Secchi depth. The reason for this is unknown.

Variability Between Sampling Seasons

As discussed in the "QA/QC Evaluation" section, variability in TP between the May and August surveys was not significant in 1993, but five years of monitoring data show that seasonal variability was greater than annual variability (Table 5). Also, Figure 6 shows the considerable difference in the relationship between TP and chlorophyll *a* between the two surveys. Variability between surveys has the potential to affect the trophic state estimations when only two samples are collected, so evaluation of seasonal variability is important to evaluating the monitoring design of the LWQA Program.

In 1993, the relationships between May TP and mean chlorophyll concentration, and May TP and mean Secchi depth, were weak (Table 10). In addition, these relationships were not particularly strong in earlier years of the program, with the exception of the 1990 monitoring season (Table 11). Overall, May TP, which presumably represents the potential for algal productivity (hence, it is an indirect measure of trophic status) explained the least amount of variability between trophic state parameters in 1993.

Considering that May TP exhibited poor relationships with mean chlorophyll *a* and mean Secchi depth, one May TP sample is not as useful as one August TP sample for predicting algal biomass (indicated by two chlorophyll *a* samples), or the effect of algal biomass on transparency (indicated by 5-12 Secchi depth measurements), during the growing season. This could be attributed to several factors.

First, these relationships assume that algal growth is limited primarily by phosphorus. However, phosphorus limitation was questionable for a large number of LWQA Program lakes based on TSI residuals from May 1993 (Figure 6), and on TN:TP ratios of August data from 1989 to 1994 (Table 9).

Table 10. Regression equations for mean volunteer-measured Secchi depth and results from May and August LWQA surveys, 1993.

Equation	Statistics
mean values from both surveys	
$\ln SD_X = 3.05 - 0.40 \ln Chl_X$	($r^2 = 0.61$, $n = 56$)
$\ln SD_X = 4.10 - 0.53 \ln TP_X$	($r^2 = 0.50$, $n = 56$)
$\ln Chl_X = 1.01 - 1.72 \ln TP_X$	($r^2 = 0.47$, $n = 57$)
Separating TP_{May} and TP_{Aug}	
$\ln SD_X = 3.77 - 0.39 \ln TP_{May}$	($r^2 = 0.34$, $n = 56$)
$\ln SD_X = 3.77 - 0.39 \ln TP_{Aug}$	($r^2 = 0.62$, $n = 56$)
$\ln Chl_X = 0.71 - 0.97 \ln TP_{May}$	($r^2 = 0.29$, $n = 58$)
$\ln Chl_X = 1.03 - 1.35 \ln TP_{Aug}$	($r^2 = 0.62$, $n = 57$)

SD_X is from the time-weighted mean for data collected by volunteers from May through October
Chl_x is from the mean value for both May and August surveys.

Table 11. Variability in mean chlorophyll *a* and mean Secchi depth explained by May/June TP.

Variability in mean chlorophyll *a* concentration

Survey year	month	n	r^2
1989[1]	May	25	0.49
1990[2]	June	9	0.69
1993	May	56	0.29

Variability in mean Secchi depth

Survey year	month	n	r^2
1989[1]	June	18	0.66
1990[2]	May/June	45	0.46
1993	May	56	0.34

[1] from Rector and Hallock (1991)
[2] from Rector and Hallock (1993)

Second, it is unknown whether May TP concentrations indicate phosphorus that will be biologically available later in the growing season. For example, highly colored lakes (e.g., Lake Loma and Lake St. Clair) may have some forms of phosphorus which are not biologically available because they are tied up in humic acids (Carlson, 1977). In addition, some of the sampled eastern Washington lakes receive suspended sediments from snowmelt and glacial runoff, and non-biologically available phosphorus could be adsorbed onto suspended sediments. In 1993 and 1992, several lakes were sampled for total suspended solids and total non-volatile suspended solids, and of the lakes with a measurable amount of suspended solids, 20-100% of the solids present were non-volatile. Indirectly, this suggests that a significant amount of the solids could adsorb non-biologically available TP. However, it would be more reliable in future years of the LWQA Program to compare TP and orthophosphorus concentrations, particularly in lakes that are expected to have non-biologically available forms of phosphorus.

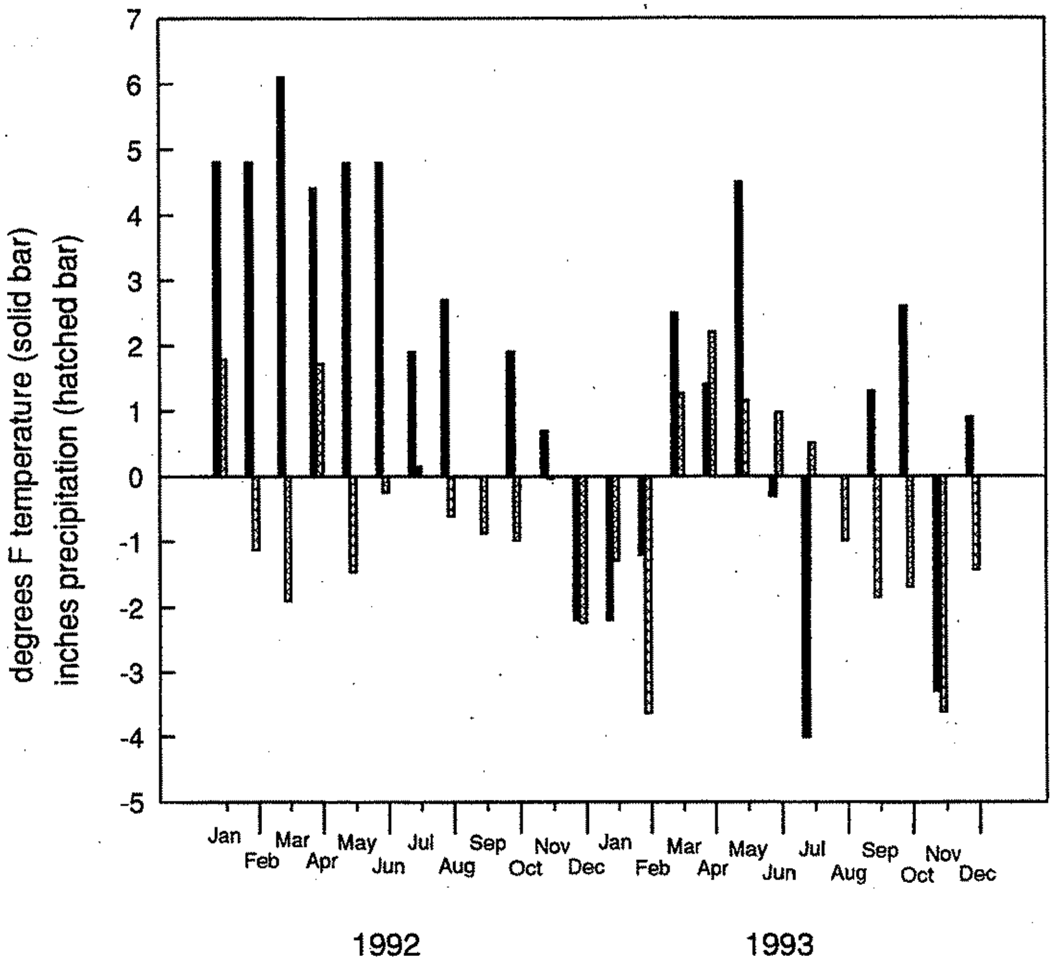
Finally, each year the TSI_{TP}, TSI_{SD}, and TSI_{CHL} values for roughly one third of sampled lakes do not indicate the same trophic state. Professional judgment is then used to decide which trophic state parameter(s), including profile data and observations of macrophyte abundance, will be the basis for the trophic classification. For many of these lakes most trophic state parameters agree--except for a relatively high TP concentration in May. During the May 1993 survey, 18 of the 63 volunteer-monitored lakes had high TSI values for total phosphorus (TSI_{TP}) that, if used alone, would have predicted a more eutrophic trophic state than was ultimately assigned to the lakes (see Table 6). This probably results because the relationships used by Carlson to develop the TSI were based on TP data from only July and August, "to provide the best agreement of total phosphorus with algal parameters during the season when sampling would normally be done." Therefore when agreement between TSIs is important (such as for assessing trophic status), it appears that the index was designed to be used with summer (*i.e.*, July and August) data. For the LWQA Program, it may be appropriate to place more emphasis on August TP results, and less on May TP results, when assessing trophic status.

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 productivity, 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 prompt at least a cursory evaluation of available climatic data.

The departures from normal temperature and precipitation were particularly apparent in western Washington during 1992 and 1993. For a 62-year period of record for climate data in Seattle (1931-1993), mean maximum temperature was highest in 1992 (EarthInfo, 1993). In 1993, precipitation levels were higher than normal from April through July, but lower than normal from August through December (Figure 7). This deviated from normal expectations of Seattle weather: "the dry season [in western Washington] is centered around July and early August with July being the driest month of the year. The rainy season extends from October to March with

Figure 7. Deviation from Normal Temperature and Normal Precipitation at SeaTac Airport, 1992 - 1993



Normal values are derived from data from the previous 30 years
source of data: National Climatic Data Center (1992), (1993)

December normally the wettest month, however, precipitation is rather evenly distributed though the winter and early spring months with more than 75 percent of the yearly precipitation falling during the winter wet season" (National Climatic Data Center, 1992).

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 lake level at many of the monitored lakes is affected by control weirs, beaver dams, or otherwise blocked outlets. 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. In 1993, volunteers noted that low lake levels were not as much of a problem as in 1992.

Recommendations

Quality Assurance

Although quality control data indicated good quality data from the laboratories, more information is needed from the laboratories in order to determine whether data quality objectives for the program are met. Based on data quality review in 1993, the following recommendations were made for the 1994 program:

1. The laboratory should report total phosphorus data to the nearest 0.1 µg/L so that variability in precision, accuracy, and detection limits can be calculated.

2. Quality control data from MEL should be provided for all parameters analyzed by the lab for the LWQA Program. Although MEL has internal data quality requirements, these requirements may not necessarily agree with data quality requirements for the LWQA Program.

3. Representativeness of collecting samples from one lake station needs to be tested further, particularly to reevaluate the RMS limit in the draft QAPP (Hallock, in draft). The stated limit in the QAPP (< 14% RMS of 10 field duplicates) was not met in 1993, although variability between stations was not high compared to variability between lakes, seasons, or years. As a result, the limit may be unnecessarily stringent. The final QAPP for the LWQA Program will address possibilities for changing the limit, or altering the statistical method used for evaluating total precision.

Monitoring Design

Periodic evaluation of monitoring design should be an integral part of any long-term monitoring program. The following conclusions and recommendations on monitoring design resulted from analysis of 1993 data.

1. Methods for storing and analyzing chlorophyll *a* samples should be investigated and improved in future monitoring seasons. In particular, possible degradation of chlorophyll *a* on the filters may be reduced by storing filters in 90% acetone when in a freezer. In addition, the spectrophotometric method can be improved using a 10 cm cuvette, instead of the standard 1 cm cuvette.

2. The program also needs to include measures that will allow for evaluation of field and lab variability of chlorophyll *a*. The most likely method for assessing lab variability is to provide the lab with chlorophyll standards that can be run as lab check standards.

3. Having volunteers collect and freeze TP samples did not work as hoped. Although Greisbach and Peters (1991) found no significant difference between samples analyzed after being frozen beyond holding times, there was a significant difference between split samples collected by volunteers for the LWQA Program. Funding limitations at this time also limit volunteer water sampling, but it was worth investigating the method.

Data Analysis

1. Until lab and field variability in chlorophyll *a* results can be assessed, it is premature to refine Carlson's index using LWQA data. However, this should be considered during future years of the program.

2. Because August TP results have better agreement with mean Secchi depth and mean chlorophyll *a* results, more emphasis should be placed in August TP, and less on May TP, when trophic states are assessed.

Individual Lake Assessments

The 65 individual lake assessments 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. Each volunteer was mailed a draft of the assessment for their lake in June 1994, so that they could review the summaries of their field comments and questionnaire responses. Their comments on these individual assessments are also gratefully acknowledged for this report.

Highlights from the Individual Lake Assessments include the following

- During the field visits by Ecology staff, Eurasian water milfoil (*Myriophyllum spicatum*) was sighted at eight lakes, Brazilian elodea (*Egeria densa*) was sighted at two lakes, and purple loosestrife (*Lythrum salicaria*) was sighted at two lakes. These lakes have been reported to Ecology's Freshwater Aquatic Weeds Program for confirmation, mapping, and possible technical assistance for locally-initiated control efforts.

- Most lakes in the program were not actively managed to control macrophytes or algae. However, four volunteer-monitored lakes (Gravelly Lake, Lake Ketchum, Lake Killarney, and Lake Limerick) were treated with aquatic herbicides in 1993. (Of the Ecology-monitored lakes, Lake Louise, Ohop Lake, and Evergreen Lake were treated with aquatic herbicides in 1993.)

- In 1993, several lakes in western Washington had bryozoans and freshwater sponges. Although one reference suggests that bryozoans are seen primarily in relatively clean, undisturbed water (Prescott), large colonies were seen in Lake St. Clair and Chambers Lake, and smaller colonies were seen at Blackmans Lake. These lakes are not pristine, and receive moderate to heavy recreational use.

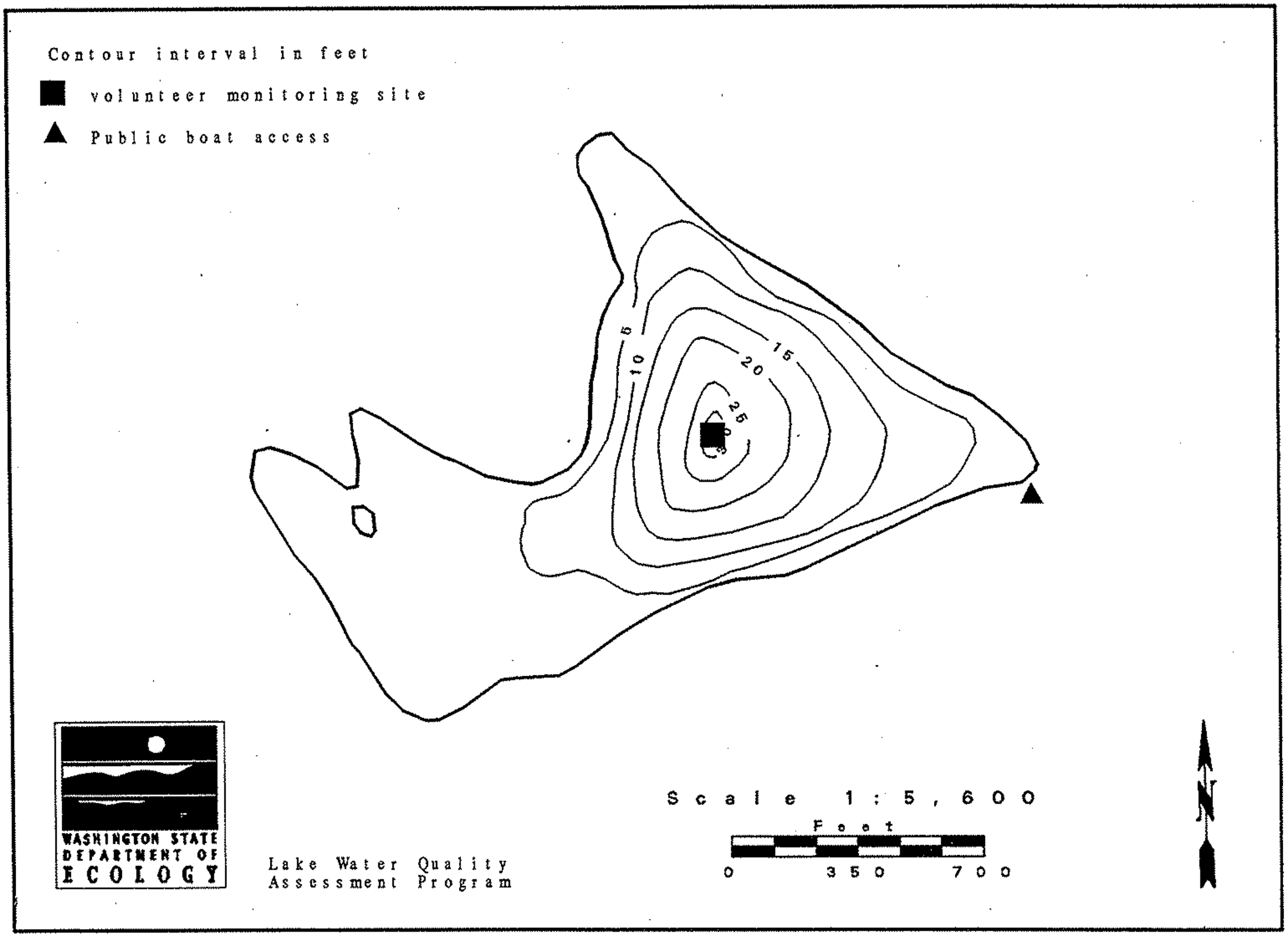
- From questionnaire results, it was apparent many volunteers felt that algae and plants were more of a problem in 1993 than in 1992. However, low water level, which was considered to be a major problem in volunteer-monitored lakes in 1992, was not as much of a problem in 1993. Most changes in apparent water quality were likely due to the unusually cloudy and cool weather in 1993, in comparison to the warm and dry summer in 1992.

Lake Alice -- King County

Lake Alice is located 2.5 miles south of Fall City. It has no surface inlets, and drains intermittently via Icy Creek 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)



Overall Assessment

In 1993, Lake Alice was classified as mesotrophic. This assessment is based on fair water clarity, very low concentrations of dissolved oxygen in the lower layer of water, a moderately high concentration of total phosphorus in May, and a high density of algae in August. (In 1992 and 1991, Lake Alice exhibited both oligotrophic and mesotrophic characteristics, resulting in oligo-mesotrophic lake assessments.)

Water quality in Lake Alice will be affected by its shallow depth and the springwater that feeds it, as well as by lakeshore development, recreational use of the lake, and land uses within its watershed. It may be worthwhile for King County Health Department to follow up on the volunteer's concern that the rising lake level, and subsequently the water table, may enter the drainfields of older septic systems.

Purple loosestrife (*Lythrum salicaria*), an exotic invasive wetland species, was first noticed on the lakeshore in August 1993 and has since been reported to King County Surface Water Management and the noxious weed board.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Secchi depths in 1993 were fair, ranging from 6.5 feet to 10.5 feet. Secchi depths in this range are typical for mesotrophic lakes. In general, Secchi depths were deeper in 1991 and 1992 than in 1993.

Total Phosphorus

In May, the concentration of total phosphorus in the upper layer of water (the epilimnion) was 23 µg/L, which is a moderately high concentration. Suspended sediments in the lake from runoff may be partly responsible for this moderately high value. In August, total phosphorus in the upper layer was 10 µg/L. Total phosphorus concentrations from 12 to 24 µg/L are typical for mesotrophic lakes.

Total Nitrogen

Total nitrogen in the upper layer of water was 0.34 mg/L in May, and 0.33 mg/L in August. These concentrations were low (compared to other lakes monitored for the program) and were similar to concentrations measured in 1992. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae usually use at least 10 times the amount of nitrogen as phosphorus. In August, the ratio of total nitrogen was greater than 17:1, so nitrogen was not limiting algal growth when the lake was sampled. In May, the total nitrogen to total phosphorus ratio was 15:1, so algal growth may have been limited by nitrogen when the lake was sampled in May.

Profile Data

On both sampling dates, the lake thermally 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 and respiration in the water and sediments. The 1993 profile data were very similar to profile data collected in 1991 and 1992.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. In May, the chlorophyll concentration was less than 0.50 µg/L (the detection limit), indicating that there was a very low density of algae when the lake was sampled. In August the chlorophyll *a* concentration was higher (3.1 µg/L), indicating that there was a moderate amount of algae present. The warm and calm conditions during sampling were favorable for algae growth. Algae probably caused the pea-green water color, the lower Secchi depth (6.5 feet) and the slightly higher pH (7.1 units) at the surface when the lake was sampled in August.

During the August 23, 1993, sampling visit, purple loosestrife (*Lythrum salicaria*) was noted on the west shore of the lake. This plant is an aggressive non-native species that can outcompete other wetland plants along the shoreline. This plant should be destroyed or contained, in order to preserve other shoreline plants and habitat areas around Lake Alice.

Aquatic plants identified by Ecology staff during the 1993 sampling visits were iris (*Iris pseudacorus*), white-flowering water lily (*Nymphaea odorata*), watershield (*Brasenia schreberi*), cattails (*Typha* sp.), bulrush (*Scirpus*), quillwort (*Isoetes* sp.), and water star-wort (*Callitriche* sp.). These plants were also present in 1992; additional plants observed in 1992 (but not in 1993) included water-moss (*Fontinalis*), mint (*Labiatae*), yellow-flowering water lily (*Nuphar polysepalum*), and ribbonleaf pondweed (*Potamogeton epihydrus*). Iris continued to spread in the lake from 1991 to 1993.

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 1993.

> Lake Alice is used for fishing, swimming, and non-motorized boating. There is one public boat ramp on the lakeshore, making about one percent of the shoreline

publicly-owned. No motor boats are allowed on the lake. Trout were stocked in the lake in 1993. Currently, the watershed is used only for lakeshore development for residences. In the past, the watershed was logged and the lake was dredged.

There are 76 houses on the lakeshore, and none are connected to a sewer collection system. There are no culverts which drain into the lake. There is no lake association or community association for the lake, and no lake management activities occurred on the lake in 1993. 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 two houses per acre. Lake water is withdrawn for drinking and other domestic uses.

Overall, the volunteer found that Lake Alice had good water quality. Problems in the lake in 1993 were ranked as (1) high water level, and (2) algae. Canada geese may be a possible source of problems in the lake. Drainage from the lake was reduced when fill work was done in the watershed, resulting in higher lake levels. There is concern that the high water level may raise the water table above some of the drainfields around the lake. The water level was higher in 1993 than in 1992, and in 1992 the level was seven inches higher than in 1991, despite the low rainfall.

Acknowledgment

I thank Antony Johnson for volunteering his time to monitor Lake Alice during 1991-1993.

Lake Alice -- King County

1993 Trophic Status[1]

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

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[3]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
20-May	1415	21.7	71.0	10.5	32.00	yellow-gr	50	moderate	light	Water color light yellow-green.
01-Jun	1310	18.9	66.0	9.0	33.50	yellow-gr	75	heavy	light	Water color light yellow-green.
13-Jun	1005	15.6	60.0	9.0	36.50	green-brown	25	light	light	
26-Jun	1230	21.4	70.5	7.0	34.50	yellow-gr	25	none	light	Water color light yellow-green.
13-Jul	1025	17.2	63.0	7.5	33.00	green-brown	90	trace	light	
28-Jul	1320	20.0	68.0	7.0	33.00	lt-green	10	moderate	light	
11-Aug	1320	21.1	70.0	8.0	30.50	yellow-gr	50	none	light	
23-Aug	1420	20.6	69.0	6.5	29.00	pea-green	50	heavy	light	Onsite visit.
06-Sep	1050	20.0	68.0	8.3	27.00		0	none	light	
22-Sep	1145	15.0	59.0	8.5	24.50	lt-green	0	trace	breezy	
07-Oct	1010	15.4	59.5	9.0	23.50	lt-green	100	heavy	calm	Lake level very high for October.
21-Oct	1040	12.2	54.0	7.0	23.00	pea-green	90	trace	light	Viewer reduced water clarity. Much suspended veg. matter.

1 Trophic State Indices calculated from Carlson (1977).

2 The May value was below the detection limit, so a mean value could not be calculated.

3 "Lake height" refers to the change in water level. Based on volunteer-collected data, the level of Lake Alice dropped 9" from May 20 to October 21.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/20	0.0	23.0	6.9	8.5	14
	1.1	21.9	6.8	7.9	14
	2.0	18.8	6.7	7.9	13
	3.0	15.0	6.8	8.1	13
	4.0	12.4	6.7	5.9	14
	5.0	10.6	6.4	2.4	15
	6.1	9.3	6.3	0.9	16
	7.0	9.0	6.2	0.5	17
	8.0	8.9	6.1	0.4	18
	8.5	8.7	6.1	0.3	18
08/23	0.0	21.4	7.1	8.3	13
	1.0	21.3	7.1	8.2	12
	2.0	21.0	7.1	7.9	13
	3.0	19.2	6.9	6.7	13
	4.0	16.0	6.7	1.3	15
	5.0	12.8	6.6	0.3	16
	6.0	11.0	6.4	0.2	18
	7.0	10.1	6.3	0.1	22
	8.0	9.5	6.3	0.1	27
	8.4	9.5	6.3	0.1	28

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 20							
Epilimnion	23	0.34	bdl				
Hypolimnion	42	0.45	--				
August 23							
Epilimnion	10	0.33	3.1				
Hypolimnion	43	0.54	--				

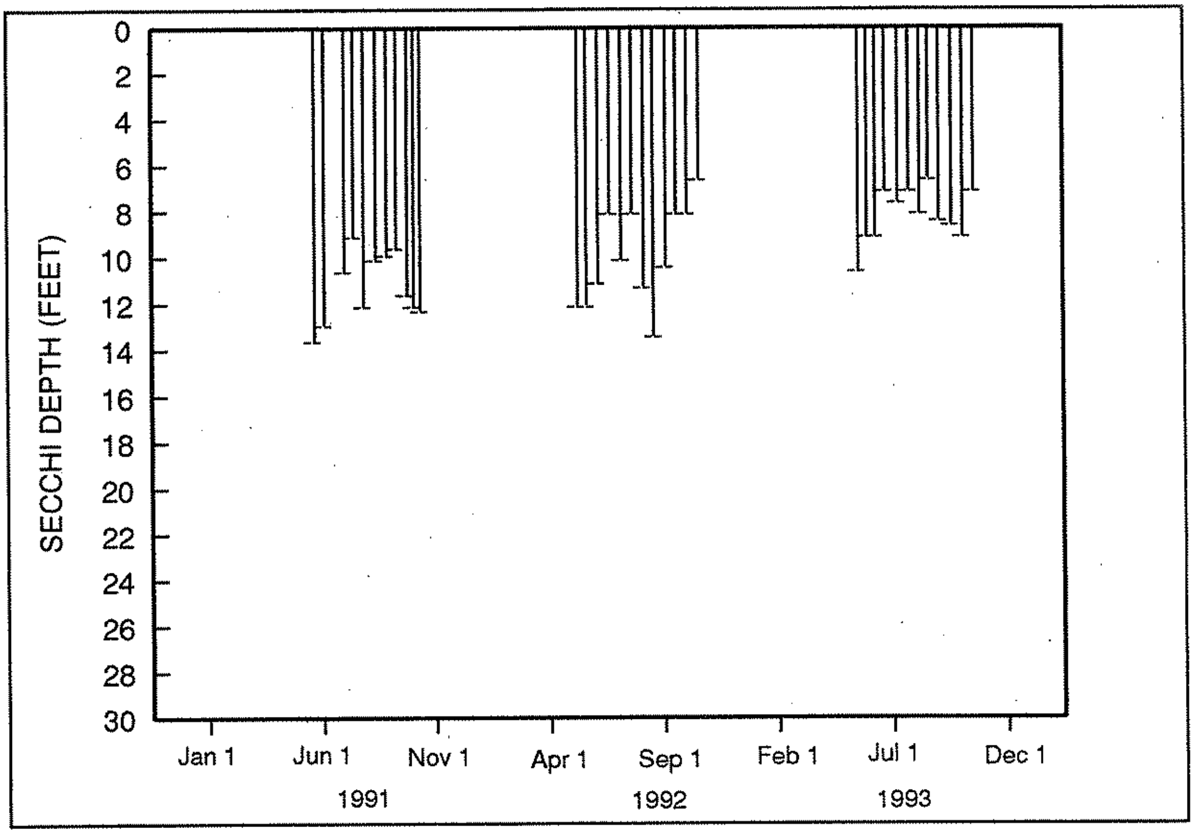
bdl = below analytical detection limit of 0.5 μg/L

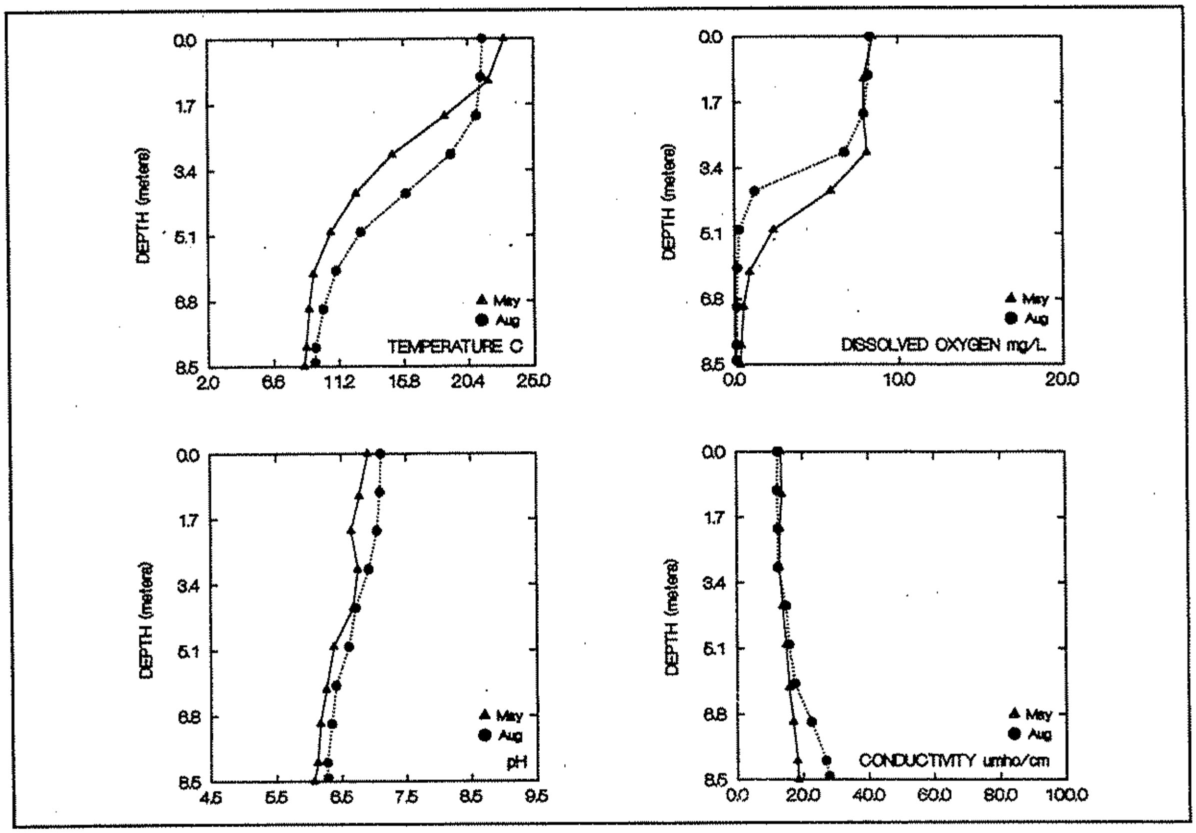
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
6/25/73[a]	11	--	0.8
5/24/91[b]	--	0.23	--
05/12/92[c]	12	0.31	1.6
08/24/92[c]	14	0.38	0.5

a. Bortleson *et al.* (1976)
b. Rector (1992).
c. Rector (1993)

LAKE ALICE (KING COUNTY)



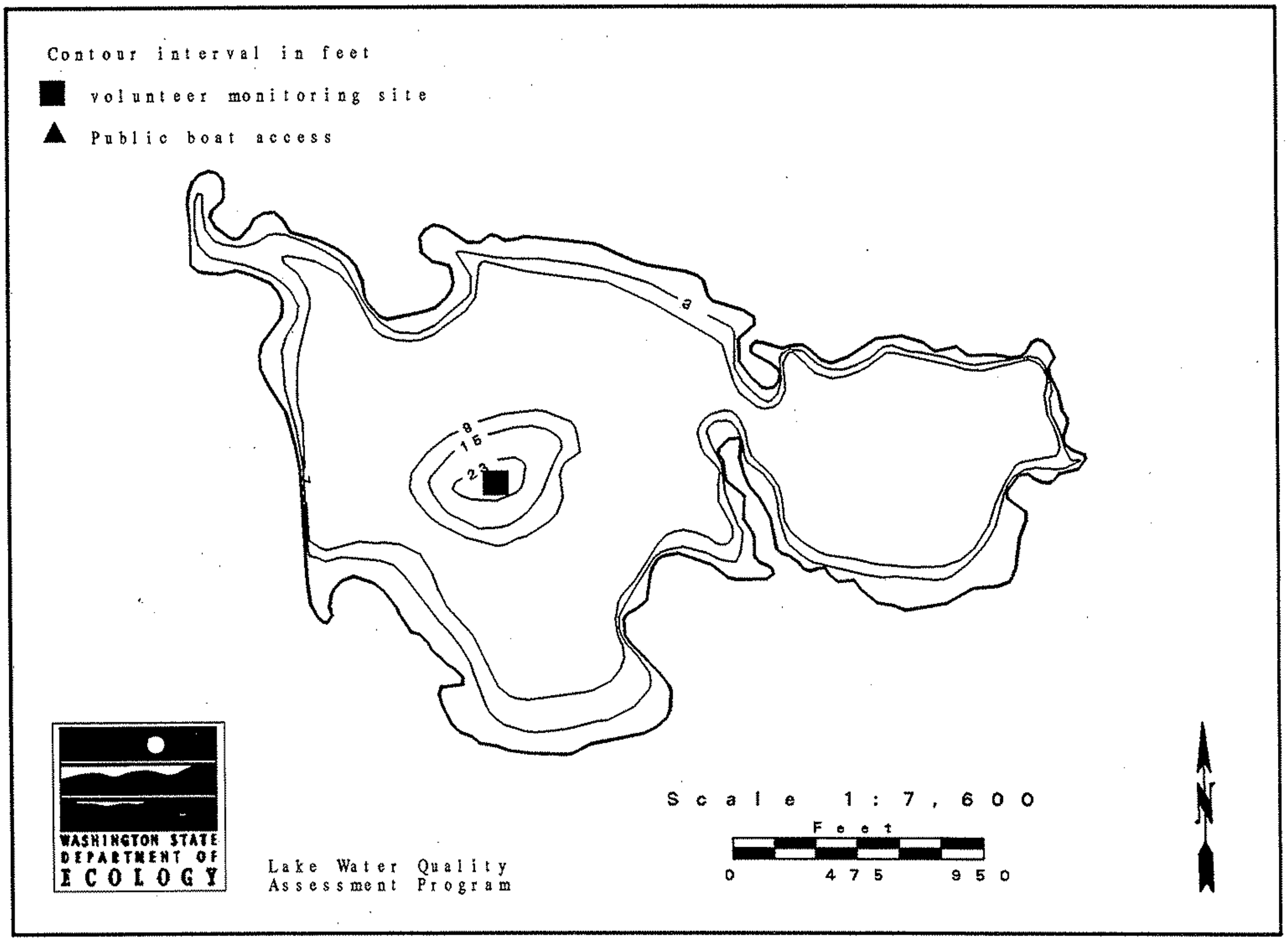


1993 Secchi Depth and Profile Data Graphs

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 four 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



Overall Assessment

Big Meadow Lake was mesotrophic in 1993. This assessment is based on moderately deep Secchi depths, and moderate concentrations of total phosphorus and chlorophyll *a*. However, the water quality of Big Meadow Lake appears to be improving. Secchi depth data collected since 1989 indicated a statistically significant improving trend in water clarity. In addition, total phosphorus concentrations appear to be decreasing in the lake, although there were not enough data available to determine whether this decrease was significant.

Other Pend Oreille County lakes monitored for the program in 1993 were Lake Leo and Sullivan Lake. In comparison to these other two lakes, Big Meadow Lake had lower water clarity, and higher concentrations of phosphorus and chlorophyll *a*. Both Lake Leo and Sullivan Lake were classified as oligotrophic in 1993.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in 1993 ranged from 9.0 feet in May to 18.5 feet in October. The measurements from late September through October were the deepest since monitoring began in 1989. A statistical trend analysis using data from 1989 through 1993 indicated that there was an improving trend in water clarity in Big Meadow Lake ($P<0.01$). This improvement may result from aerating the lake during winter. Although aeration is intended to prevent winterkill, there may also be the incidental benefit of reducing algae growth in the lake by reducing phosphorus concentrations (see below).

Total Phosphorus

Although total phosphorus in the upper layer of water (the epilimnion) was moderately high on both sampling dates, concentrations measured in 1993 (18 µg/L in May and 16 µg/L in August) were lower than concentrations measured in 1992 (23 µg/L and 22 µg/L) and 1990 (31 µg/L and 30 µg/L). Although there were not enough data available to report a statistical trend in phosphorus concentration, the 1990 concentrations were high and suggest the lake was eutrophic, whereas the concentrations in 1992 and 1993 were in the range associated with mesotrophic lakes. Concentrations between 12 µg/L and 24 µg/L are typical for mesotrophic lakes.

Total Nitrogen

Total nitrogen concentrations were high. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 (36:1 in May, and 27:1 in August), algal growth was not limited by the amount of nitrogen when the lake was sampled.

Profile Data

The lake was weakly stratified on both sampling dates. Both dissolved oxygen and pH decreased with depth in the lower layer of water (the hypolimnion), indicating that there was probably some bacterial decomposition and respiration occurring in the bottom water and sediments. This is typical for mesotrophic lakes.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. In May, the chlorophyll concentration in Big Meadow Lake (4.8 µg/L) indicated a moderately high density of algae when the lake was sampled. In August, the chlorophyll *a* concentration was 2.4 µg/L, indicating a moderately low density of algae.

Plants observed during the 1993 monitoring visits included sedge (*Carex* sp.), bulrush (*Scirpus* sp.), white-flowering water lily (*Nymphaea odorata*), muskgrass (*Chara*), and *Nitella*. With the exception of the white-flowering water lily, these were also observed in the lake during 1991 and 1992. Additional plants identified during the 1992 visits were flatleaf pondweed (*Potamogeton robbinsii*), largeleaf pondweed (*Potamogeton amplifolius*), floatingleaf pondweed (*Potamogeton natans*), yellow-flowering lily (*Nuphar polysepalum*), waterweed (*Elodea canadensis*), and bur-reed (*Sparganiaceae* family). Two other unidentified pondweeds were also noted.

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 1993.

> 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 fingerlings were stocked in the lake in 1993.
>
> 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 fish kill. The Department of Wildlife installed an aeration system on August 25, 1989, to prevent the winter fish kills. The lake was aerated throughout winter 1993.

Overall, the volunteer found that Big Meadow Lake had good water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, and (2) decaying plants. "Fish kill" and "water quality gradually degraded over years" were also listed as problems in the lake (but were not ranked). Lack of oxygen during winter contributed to the problems in the lake. There were more aquatic plants in the lake in 1993 in comparison to 1992, and there were more in 1992 than in 1991.

Acknowledgment

I thank Terry Williams for volunteering his time to monitor Big Meadow Lake during 1989-1993.

Big Meadow Lake -- Pend Oreille County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	40
Mean Trophic State Index (Total Phosphorus):	45
Mean Trophic State Index (Chlorophyll *a*):	42

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
17-May				9.0		gr-brown	10		calm	Onsite visit. Aerator turned off for season between 3/30 and 4/18.
03-Jun	1307	19.5	67.0	13.5	1.00	gr-brown	50	heavy	light	
17-Jun	1400	20.8	69.5	12.0	-1.00	gr-brown	50	moderate	breezy	
01-Jul	1255	18.2	65.0	11.0	-1.00	gr-brown	75	light	light	Seems to be a light green algae bloom.
15-Jul	1010	17.0	62.6	10.3	1.00	gr-brown	90	light	light	
29-Jul	1110	19.0	66.0	11.5	1.00	gr-brown	90	light	breezy	
12-Aug	1400	22.0	71.5	12.3	0.00	gr-brown	10	none	light	A very large hatch of 3/4" frogs happening.
18-Aug	1400			13.9	0.00		25	heavy	calm	Onsite visit.
26-Aug	1320	18.6	65.5	13.3	-3.00	gr-brown	25	trace	breezy	
09-Sep	1310	19.8	67.6	14.0	-6.00	gr-brown	0	none	strong	
23-Sep	1330	13.8	56.8	17.5	-4.00	gr-brown	10	light	breezy	
04-Oct	1345	15.3	59.5	18.5	-4.00	gr-brown	0	none	light	Marks on rope getting very hard to read.
19-Oct	1400	10.7	51.3	15.5	-6.00	gr-brown	0	light	breezy	Markings on Secchi disk line are very faint.

1 Trophic State Indices calculated from Carlson (1977)

2 "Lake height" refers to the change in water level. Based on volunteer-collected data, the level of Big Meadow Lake dropped 7" from June 3 to October 19.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/17	0.0	21.3	8.6	9.0	44
	1.0	19.7	8.5	9.3	44
	2.0	15.8	8.4	10.6	41
	3.0	11.8	7.3	11.3	38
	4.0	8.7	7.2	9.7	39
	5.0	8.0	7.2	7.2	40
	5.9	7.6	7.1	4.4	42
08/18	0.0	20.1	8.3	7.4	43
	1.0	18.8	8.1	7.3	43
	2.0	18.5	8.1	7.3	43
	3.0	18.4	8.0	7.2	43
	4.0	15.8	7.7	4.1	46
	5.0	13.5	7.5	0.8	47
	6.0	10.5	7.2	0.1	70

1993 Onsite Visit Data - Water Chemistry

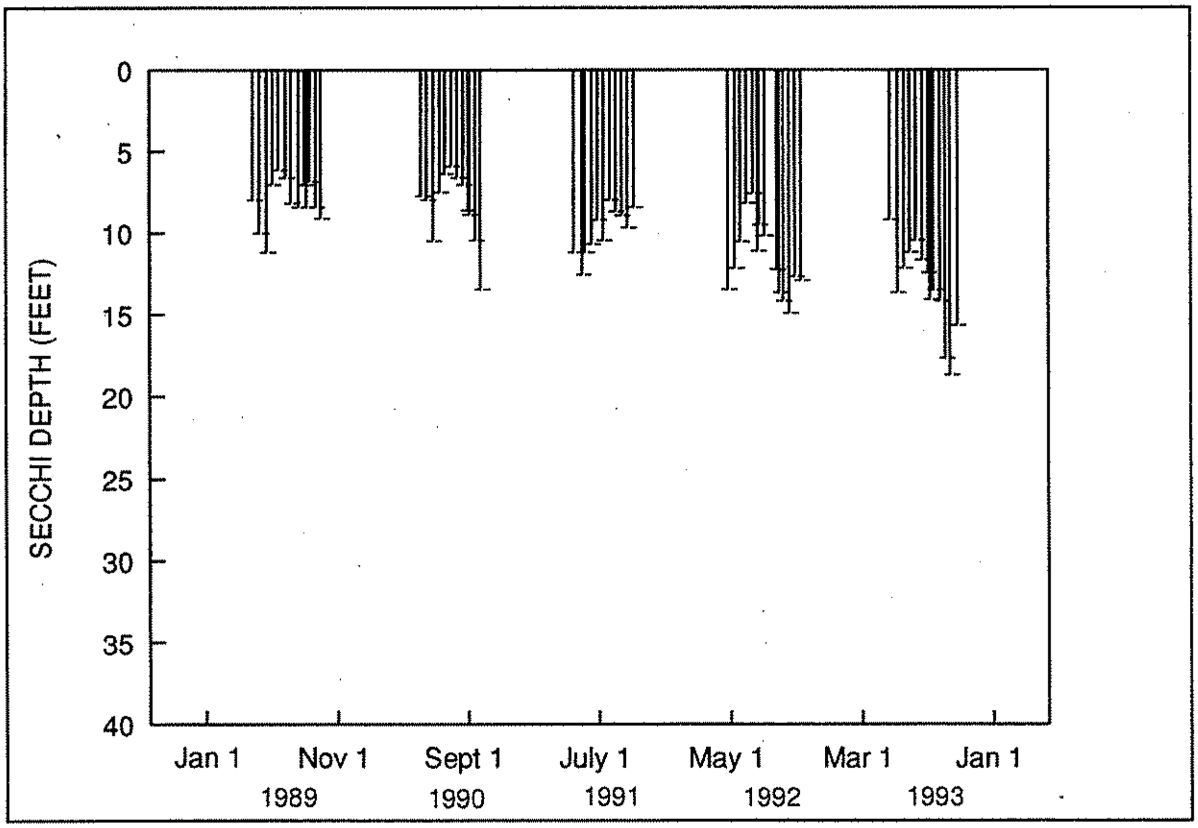
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 17 Epilimnion	18	0.65	4.8	--	--	--	--
Hypolimnion	36	0.44	--	--	--	--	--
August 18 Epilimnion	16	0.43	2.4	--	--	--	--
Hypolimnion	15	0.41	--	--	--	--	--

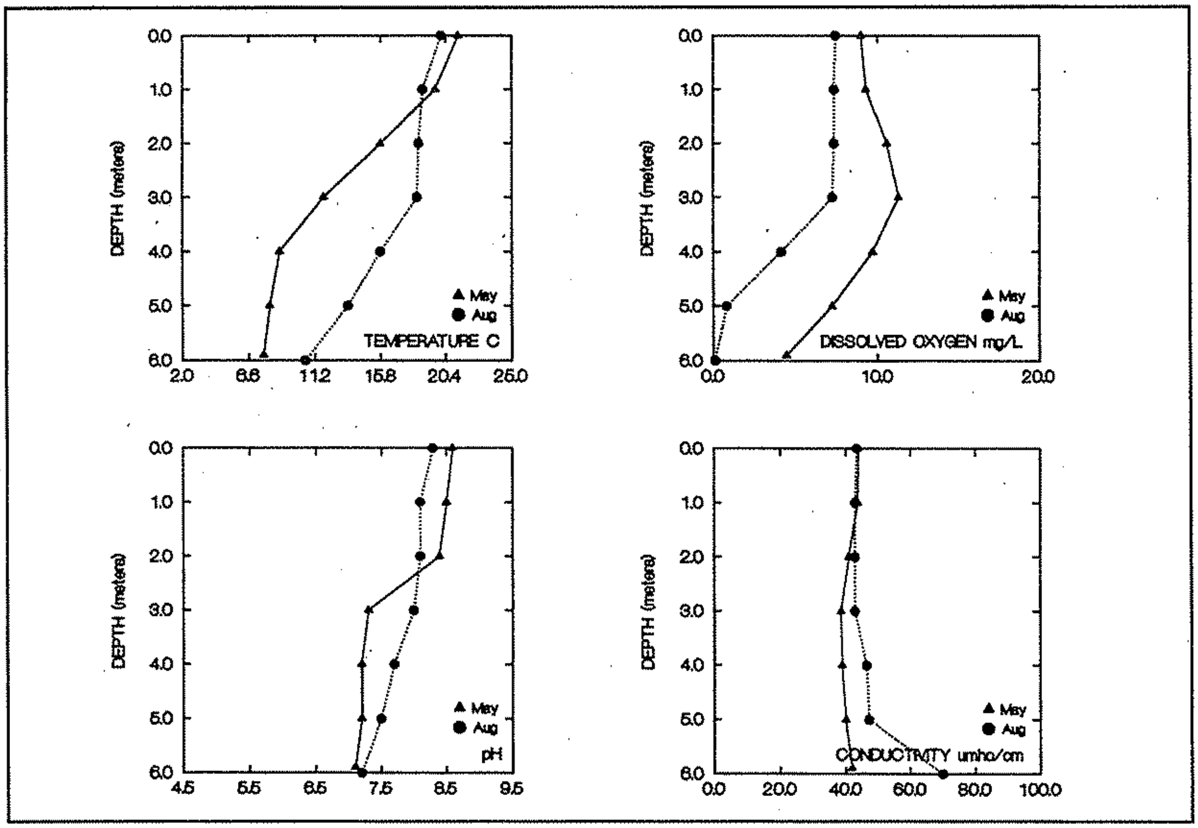
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
05/29/90a	31	0.70	--
09/12/90a	30	0.91	--
06/12/91b	--	0.34	--
05/19/92c	23	0.60	1.6
09/01/92c	22	0.71	3.1

a. Rector (1991)
b. Rector (1992)
c. Rector (1993)

BIG MEADOW LAKE (PEND OREILLE COUNTY)



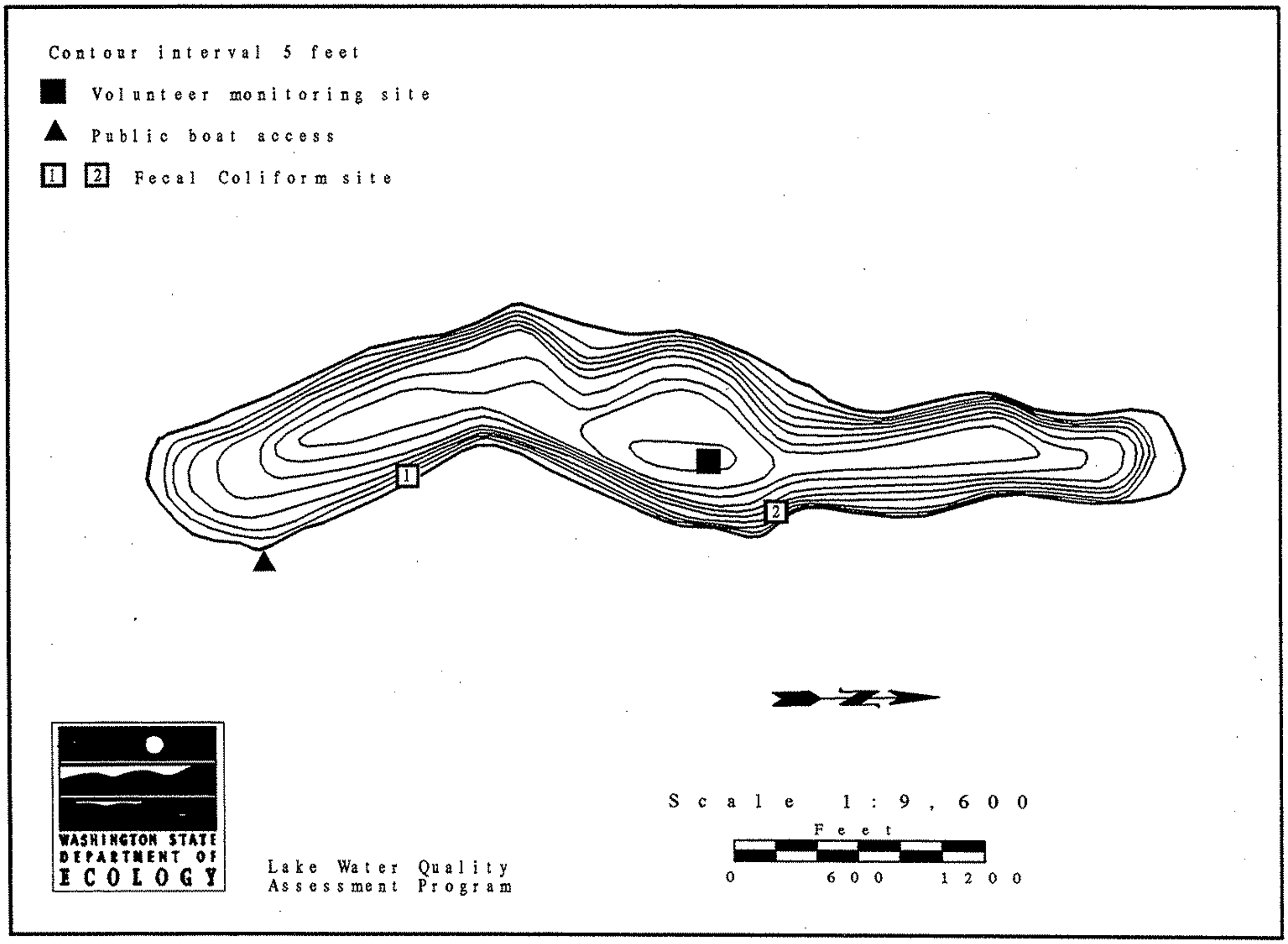


1993 Secchi Depth and Profile Data Graphs

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



Overall Assessment

Because Black Lake exhibited both oligotrophic and mesotrophic characteristics, the lake was described as oligo-mesotrophic in 1993. Oligotrophic characteristics were very good water clarity, very low concentrations of total phosphorus, and low amounts of algae (as indicated by low concentrations of chlorophyll *a* and deep Secchi readings). Mesotrophic characteristics were the prolific aquatic plant growth particularly near the public access, and very low concentrations of dissolved oxygen in the bottom layer of water.

Three other Stevens County lakes (Deep, Thomas, and Waitts) were monitored by volunteers during 1993. Water clarity at Black Lake and Lake Thomas was very similar. Waitts Lake had better water clarity, and lower concentrations of total phosphorus and chlorophyll *a*, than Black Lake. All three lakes had a moderate amount of aquatic plant growth, but most of the plants in Lake Thomas were the aggressive non-native Eurasian watermilfoil. Because of the close proximity of Black Lake to Lake Thomas, there is a high potential for introducing Eurasian watermilfoil into Black Lake. Future sampling at Black Lake for this program will include thorough screening for early signs of milfoil introduction. It would also be beneficial if local lake users learned to identify Eurasian watermilfoil, so that early infestations can be reported. Suspected milfoil sightings should be reported to the Department of Ecology (Kathy Hamel at (206) 407-6562, or Jenifer Parsons (206) 407-6679).

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
Secchi depths in 1993 ranged from 12.0 to 22.0 feet. These depths were very similar to the range of values measured in 1992. Although water clarity has improved each year since 1990, there was not a statistically significant trend in Secchi depth from 1989 to 1993.

Total Phosphorus
Concentrations of total phosphorus on both sampling dates were much lower than concentrations previously measured for this program. Also, the concentration in May 1993 was not high, as it was in both May 1992 and May 1990. Concentrations less than 12 µg/L are typical for oligotrophic lakes.

Total Nitrogen
The concentrations of total nitrogen were high on both sampling dates, and were similar to concentrations measured during previous years. Also, the concentrations of total nitrogen were high relative to the concentrations of total phosphorus, indicating that algae growth in Black Lake as not limited by nitrogen when the lake was sampled. Although total nitrogen concentrations varied between sampling dates, small variations in nitrogen concentrations are not as critical to overall lake condition as changes in phosphorus concentration.

Fecal Coliform Bacteria

Samples for fecal coliform bacteria were collected at sites on the east side of the lake during the May 18 sampling visit. One sample was collected near the resort, and the other was collected in a cove about 500' north of the volunteer's sampling site. Results for both samples were very low and below the detection limit for the test. These results were within the State's water quality standards for lakes.

Solids

Three of the four solids samples collected in 1993 were below the detection limit of 1 mg/L. Total suspended solids in the water during May (1 mg/L) may have come from lake turn over following lake thaw. The volunteer reported that ice was off the lake by April 23, 1993.

Profile Data

The lake was thermally stratified on both sampling dates. In May, there was a slight increase in dissolved oxygen from two to four meters, which probably resulted from the sharp decrease in water temperatures at these depths (because dissolved gases are more soluble in cold water than in warm water). On both dates, dissolved oxygen decreased with depth in the lower layer of water (the hypolimnion), indicating that bacterial decomposition and respiration were occurring in the bottom water and sediments. In August, dissolved oxygen was very low in the bottom five meters of water. Data from Dion *et al.* (1976), and this program indicate that low dissolved oxygen concentrations in the hypolimnion occur during late summer. Trout generally prefer water that has at least 4.5 mg/L dissolved oxygen. Concentrations were above 4.5 mg/L from the surface to a depth of about six meters.

The pH data from May could not be used because of a problem with the instrument probe. The pH data from August decreased with depth, also indicating that bacterial decomposition and respiration were occurring in the bottom water and sediments.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Chlorophyll *a* concentrations in Black Lake indicated that there were low to moderate amounts of algae in the water on both sampling dates. The concentrations measured in 1993 were higher than those measured in 1992 and 1989, although all values (except the May 1992 value) were in the range associated with oligotrophic lakes.

Plants identified by Ecology staff during the 1993 sampling visits included largeleaf pondweed (*Potamogeton amplifolius*), waterweed (*Elodea canadensis*), yellow-flowering water lily (*Nuphar* sp.), ribbonleaf pondweed (*Potamogeton epihydrus*), Berchtold's pondweed (*Potamogeton berchtoldii*), muskgrass (*Chara*), water buttercup (*Ranunculus subrigidus*), and slender naiad (*Najas flexilis*). Two other plants, cinquefoil (possibly *Potentilla palustris*), and bur-reed (possibly *Sparganium minumum*), were also observed in 1993.

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.

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 1993.

> 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, and one resort. There is one public boat ramp. About four percent of the shoreline is publicly-owned. Rainbow and eastern brook trout were stocked in the lake in 1993. Current watershed uses include lakeshore development for residences. In the past, the watershed was also logged and used for 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. No lake management activities occurred in 1993, although the lake has been chemically treated in the past to control undesirable fish species. Lake water is withdrawn for drinking and other domestic uses.
>
> Overall, the volunteer found that Black Lake had excellent water quality. In 1993, the worst problem in the lake was excessive aquatic plant growth, which is getting worse every year. Largeleaf pondweed in particular created problems for fishing and swimming. (In 1992, there were no reported problems in the lake, although in 1991 aquatic plants and fish species were identified as problems.) There were no apparent sources of water quality problems. There were no changes in the lake since the 1992 monitoring season.

Acknowledgment

I thank Norman S. LaVigne for volunteering his time to monitor Black Lake during 1989-1993.

Black Lake -- Stevens County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	36
Mean Trophic State Index (Total Phosphorus):	33
Mean Trophic State Index (Chlorophyll *a*):	39

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	pH	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
18-May				12.0				10		calm	Onsite visit. Ice off April 23.
13-Jun	1100	15.6	60.0	14.0		-2.00		100	light	light	Water color clear-brownish.
01-Jul	1030	17.2	63.0	15.0				50	trace	light	Water color clear-brownish.
13-Jul	1430	17.2	63.0	15.0		-5.00		75	heavy	light	Water color clear-brownish.
11-Aug	0930	20.0	68.0	21.0		-9.50	clear	0	none	light	Heavy rain during July kept water murky--no rain in August has let it settle and water is clear.
19-Aug	0905			20.5			gr-brown	0	heavy	calm	Onsite visit.
06-Sep	1230	18.9	66.0	20.0		-10.75	clear	10	none	calm	Indian summer.
03-Oct	1145	14.4	58.0	22.0		-12.50		0	none	calm	Water color clear-brownish.

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

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Black Lake dropped 10.5" from June 13 to October 3.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/18	0.0	20.8	.	8.5	33
	1.0	19.0	.	8.5	33
	2.0	17.0	.	9.5	32
	3.0	11.1	.	10.7	31
	4.0	8.9	.	10.4	32
	6.0	7.2	.	8.0	32
	8.0	6.7	.	6.7	32
	10.0	6.5	.	6.1	32
	12.0	6.4	.	5.8	32
08/19	0.0	18.8	8.2	8.3	34
	1.0	18.7	8.1	8.2	34
	2.0	18.5	8.0	8.1	34
	3.0	18.4	8.0	8.1	34
	4.0	18.0	7.9	8.4	34
	5.0	14.0	7.7	6.4	34
	6.0	10.9	7.5	2.8	35
	7.0	9.5	7.3	0.7	36
	8.0	8.2	7.2	0.2	38
	9.0	7.5	7.0	0.2	43
	10.0	7.4	7.0	0.1	44
	11.0	7.4	6.9	0.1	45
	12.0	7.3	6.9	0.1	45

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 18 Epilimnion	7	0.39	2.2	1	dl	bdl	bdl
Hypolimnion	19	0.28	–	–	–	–	–
August 19 Epilimnion	8	0.24	2.4	bdl	bdl	–	–
Hypolimnion	25	0.24	–	–	–	–	–

bdl = below the analytical detection limit of 1 mg/L, or 1 colony/100 mL

Black Lake -- Stevens County

Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/08/74[a]	9	--	--
06/20/89[b]	11	0.28	1.6
09/19/89[b]	4	0.31	1.2
05/29/90[c]	19	0.35	--
09/11/90[c]	12	0.30	--
06/13/91[d]	--	0.25	--
05/11/92[e]	23	0.30	0.4
08/24/92[e]	10	0.30	1.1

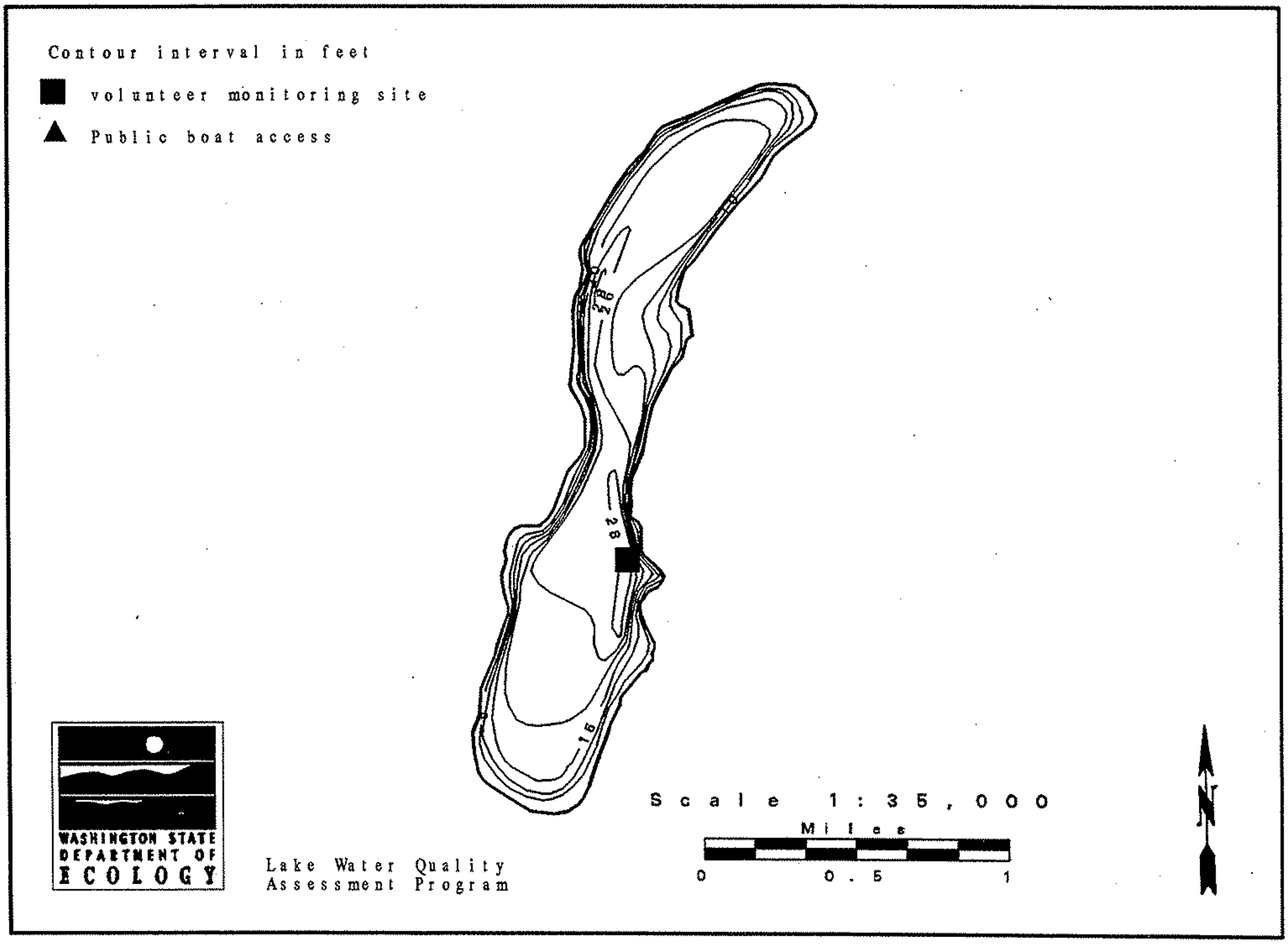
a. Dion *et al.* (1976)
b. Brower and Kendra (1990)
c. Rector (1991)
d. Rector (1992)
e. Rector (1993)

Black Lake -- Thurston County

Black Lake is located four miles southwest of Olympia. It is 2.5 miles long. The lake is fed by two unnamed perennial tributaries, and drains via Percival Creek to Budd Inlet.

Size (acres)	570
Maximum Depth (feet)	29
Mean Depth (feet)	19
Lake Volume (acre-feet)	11,000
Drainage Area (miles^2)	10.1
Altitude (feet)	131
Shoreline Length (miles)	6.0

Data From Bortleson *et al.* (1976)



Overall Assessment

Black Lake was classified as eutrophic in 1993. This assessment is based on poor water clarity, high phosphorus concentrations, and high amounts of algae. Also, the volunteer reported that algae in the lake has increased during the past five years.

A Centennial Clean Water Fund grant was awarded by Ecology to study the extent and sources of water quality problems, and to recommend possible solutions for improving water quality. However, the grant was declined.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in Black Lake was not very good, as indicated by Secchi depths which ranged from 3.5 feet to 8.0 feet. Water clarity was best in June when cool, windy weather may have restricted algae growth, or from nitrogen limitation of algae (see Total Nitrogen, below).

Total Phosphorus

Total phosphorus concentrations were high on both sampling dates (51 µg/L in June, and 55 µg/L in August). High phosphorus concentrations (greater than 24 µg/L) can cause algae blooms during warm and calm weather.

Total Nitrogen

Total nitrogen concentrations were high on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae usually use at least 10 times the amount of nitrogen as phosphorus. In June, the ratio of total nitrogen to total phosphorus was low, so it is possible that algae growth in June was not limited by the amount of phosphorus. When the lake was sampled in August, the nitrogen concentration was higher and there was a higher density of algae. More available nitrogen, as well as warmer weather, probably contributed to the greater amount of algae during late summer.

Fecal Coliform Bacteria

One sample was collected on each sampling date. The June sample was collected near the public access, and the August sample was collected on the west side of the lake, just north of a cove that is heavily overgrown with water lilies. Although results for the samples were moderately high (the June sample had 24 colonies/100 mL, and the August sample had 35 colonies/100 mL), they were within State water quality standards for recreational use of lake water.

Solids
Results from solids samples are used to evaluate whether Secchi depths were affected primarily by algae, or if suspended sediments affected water clarity at the time of sampling. Of four solids samples collected, only the June sample for total suspended solids was above the detection limit for the test. The solids in the sample were probably sediments from recent storms in the area.

Profile Data
The lake was weakly stratified in June, but was not thermally stratified in August. A lake may destratify during summer if it is shallow and if there are frequent or strong winds that mix the lake water. Although dissolved oxygen decreased with depth on both sampling dates, the concentrations decreased considerably in the bottom two meters of the lake. Dissolved oxygen concentrations decrease when bacteria use oxygen as they decompose algae and aquatic plants in the bottom water and sediments. It is typical for eutrophic lakes to have very low dissolved oxygen in bottom waters.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. The high concentrations of chlorophyll *a* indicate that there were high densities of algae growing during both sampling dates. Algal densities were particularly high when the lake was sampled in August. As mentioned above, algae growth in June could have been limited by the lower amount of nitrogen in the water, as well as by the cool and windy weather.

Aquatic plants identified by Ecology staff were observed in the cove on the west side of the lake during the August sampling visit. Plants observed included curly-leaf pondweed (*Potamogeton crispus*), waterweed (*Elodea canadensis*), white-flowering water lily (*Nymphaea odorata*), naiad (*Najas guadalupensis*), iris (*Iris pseudacorus*), and watershield (*Brasenia schreberi*). Watershield (which looks like a small lily pad, but the stems and the undersides of the leaves are covered with a slimy film) was the most abundant plant in the cove. During the June visit, the watershield stems were also covered with filamentous algae.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed during 1993.

> Black Lake is used for fishing, swimming, motor boating, rowing, jet skiing, lakeshore camping, waterfowl hunting, and sea plane operations. Public facilities on the lakeshore include three resorts and one boat ramp. There are no restrictions for motor boat use on the lake. Currently, the watershed is being used for crop agriculture and animal grazing, although grazing animals do not have direct access

to the lakeshore or inlet tributaries. The lakeshore is also being developed further for residences. In the past, the watershed was logged and used for crop agriculture and animal grazing.

There are 159 houses on the lakeshore, and none are connected to a sewer collection system. There are no culverts which drain into the lake. Lake water was withdrawn for irrigation only. No lake management activities occurred in 1993.

Overall, the volunteer found that Black Lake had good water quality. Problems in the lake in 1993 were ranked as (1) algae, and (2) decaying plants. The volunteer identified possible sources of problems as failed septic systems in mobile home parks, and runoff from pastures.

Acknowledgment

I thank Ed May for volunteering his time to monitor Black Lake 1993.

Black Lake -- Thurston County

1993 Trophic Status[1]

Estimated Trophic State:	Eutrophic
Mean Trophic State Index (Secchi):	53
Mean Trophic State Index (Total Phosphorus):	61
Mean Trophic State Index (Chlorophyll *a*):	55

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
01-Jun	1430			8.0		gr-brown			breezy	Onsite visit. Boat rocking.
19-Jun	1500	19.4	67.0	9.0	-1.00	lt-brown	10	none	light	
01-Jul	1330	20.0	68.0	7.0	-1.00	lt-brown	75	light	light	
16-Jul	1430	21.1	70.0	5.0		lt-green	50	light	light	
01-Aug	1200	21.7	71.0	4.0		green	0	none	light	
20-Aug	1400	22.8	73.0	5.0		green	10	trace	light	
25-Aug	1415			5.0		green	0		breezy	Onsite visit. Algae particles visible.
12-Sep	1400	23.3	73.9	4.0	-2.50	green	0	none	light	
21-Sep	1600	20.0	68.0	3.5	-2.50	green	0	none	calm	
16-Oct	1430	16.7	62.0	4.0		green	50	light	light	

1 Trophic State Indices calculated from Carlson (1977).
2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Blake Lake dropped 1.5" from June 19 to September 21.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
06/01	0.0	19.9	7.6	8.5	63
	1.0	19.9	7.5	8.4	63
	1.9	19.9	7.4	8.3	63
	3.0	19.8	7.3	8.3	62
	4.0	19.7	7.2	8.1	63
	5.0	16.9	7.1	5.3	65
	6.0	15.0	7.1	2.7	71
	7.2	14.4	7.0	1.1	77
08/25	0.0	21.0	7.6	9.3	73
	1.0	20.5	7.6	8.8	74
	2.0	20.0	7.5	7.7	74
	3.1	19.8	7.4	7.2	75
	4.0	19.8	7.3	6.8	74
	5.1	19.6	7.2	5.4	76
	6.0	19.4	7.1	1.5	81
	6.9	18.0	7.0	0.2	113

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 1 Epilimnion	51	0.45	4.9	2	bdl	24	--
Hypolimnion	27	0.38	--	--	--	--	--
August 25 Epilimnion	55	0.67	28.1	bdl	bdl	35	--
Hypolimnion	57	0.51	--	--	--	--	--

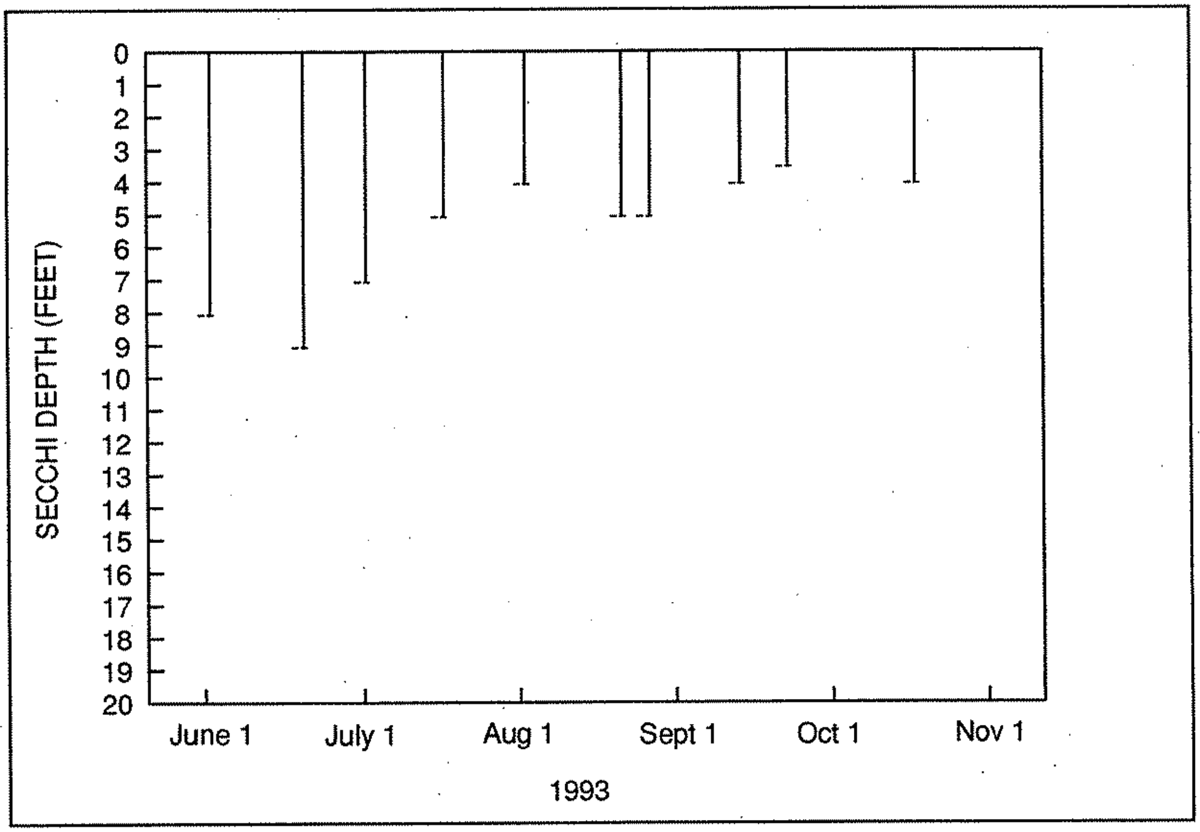
bdl = below analytical detection limit of 1 mg/L

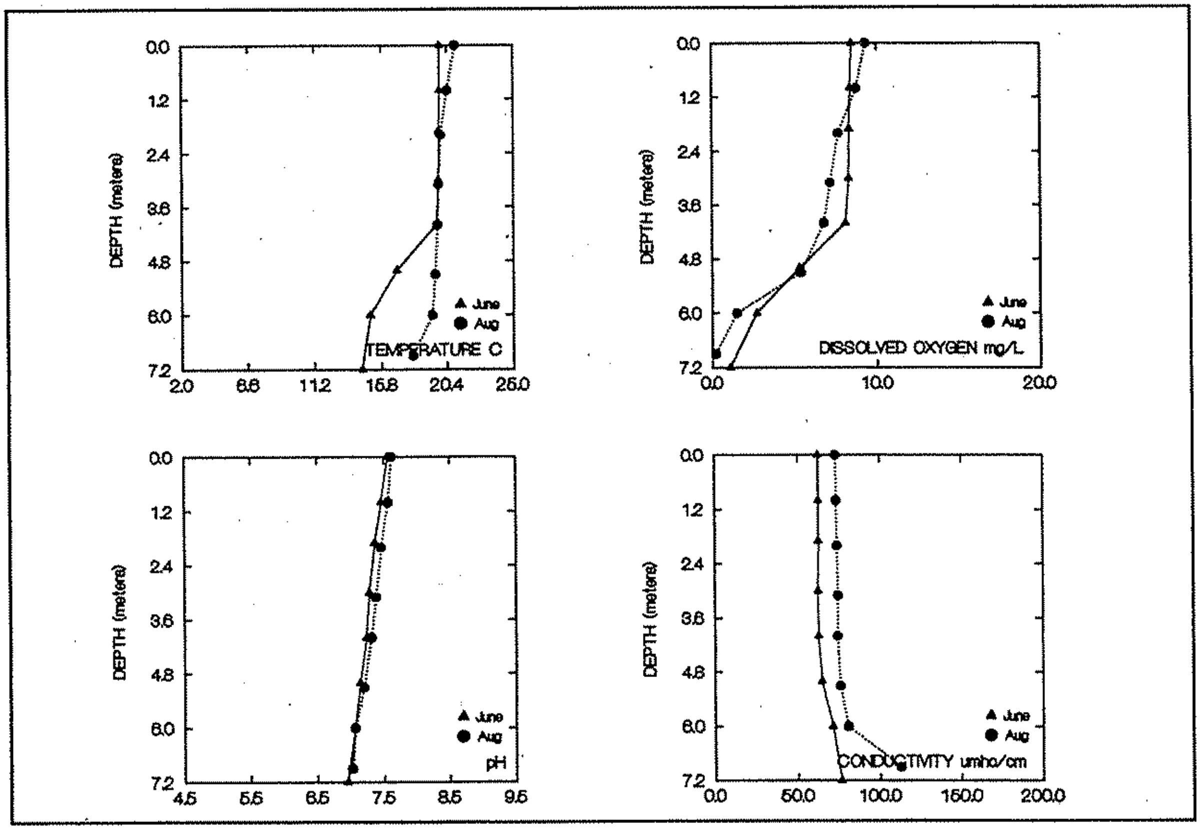
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/07/71[a]	20	--	--
06/07/89[b]	16	0.40	7.6
09/05/89[b]	46	0.75	56.2

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

BLACK LAKE (THURSTON COUNTY)





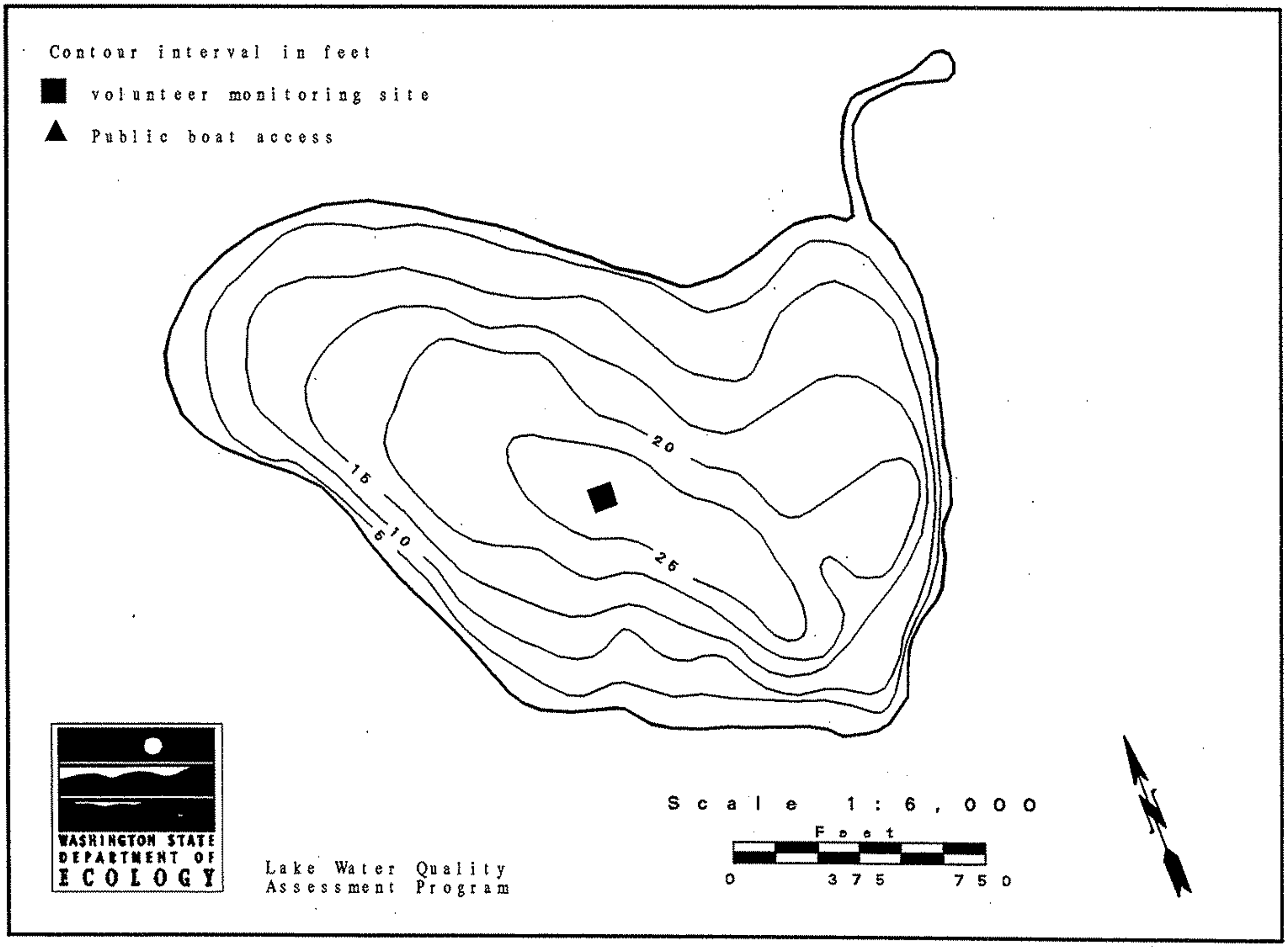
1993 Secchi Depth and Profile Data Graphs

Blackmans Lake -- Snohomish County

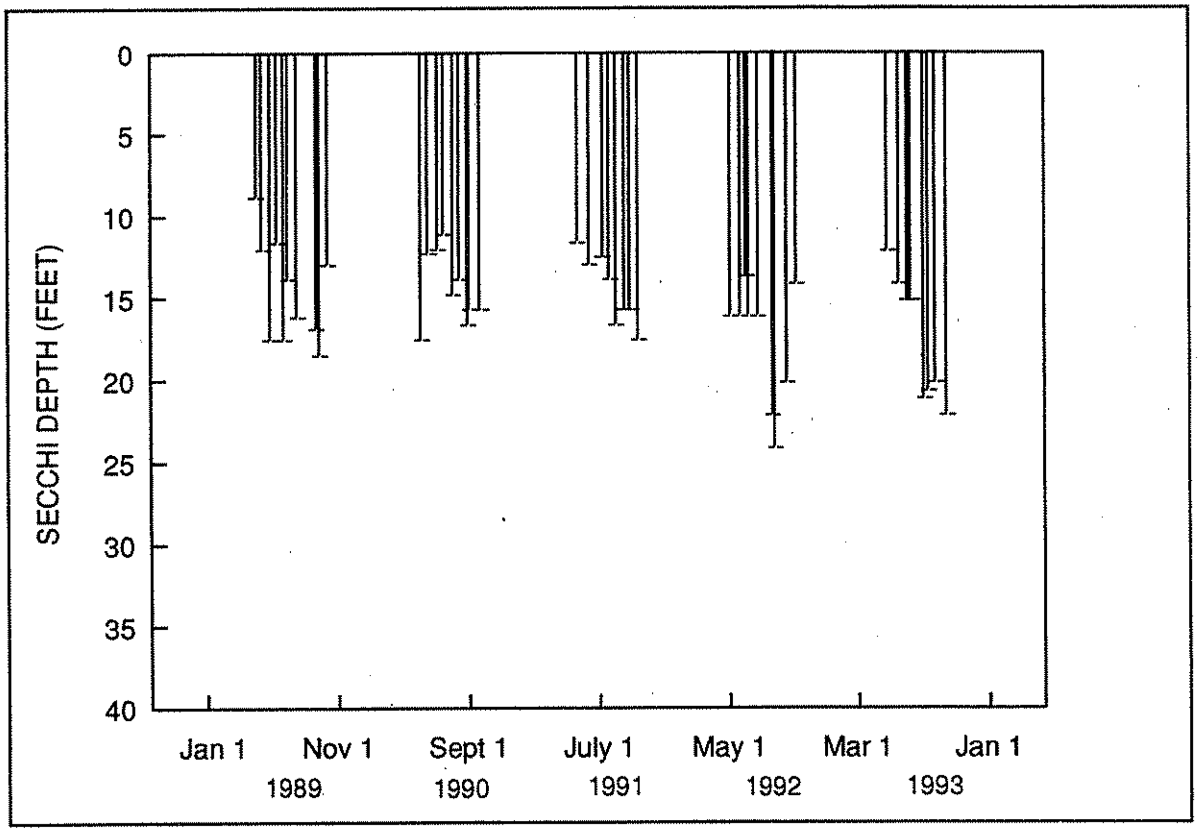
Blackmans Lake is located one mile north of Snohomish. A perennial stream flows into the lake from the north. Blackmans Lake drains via Swifty Creek to the Snohomish River.

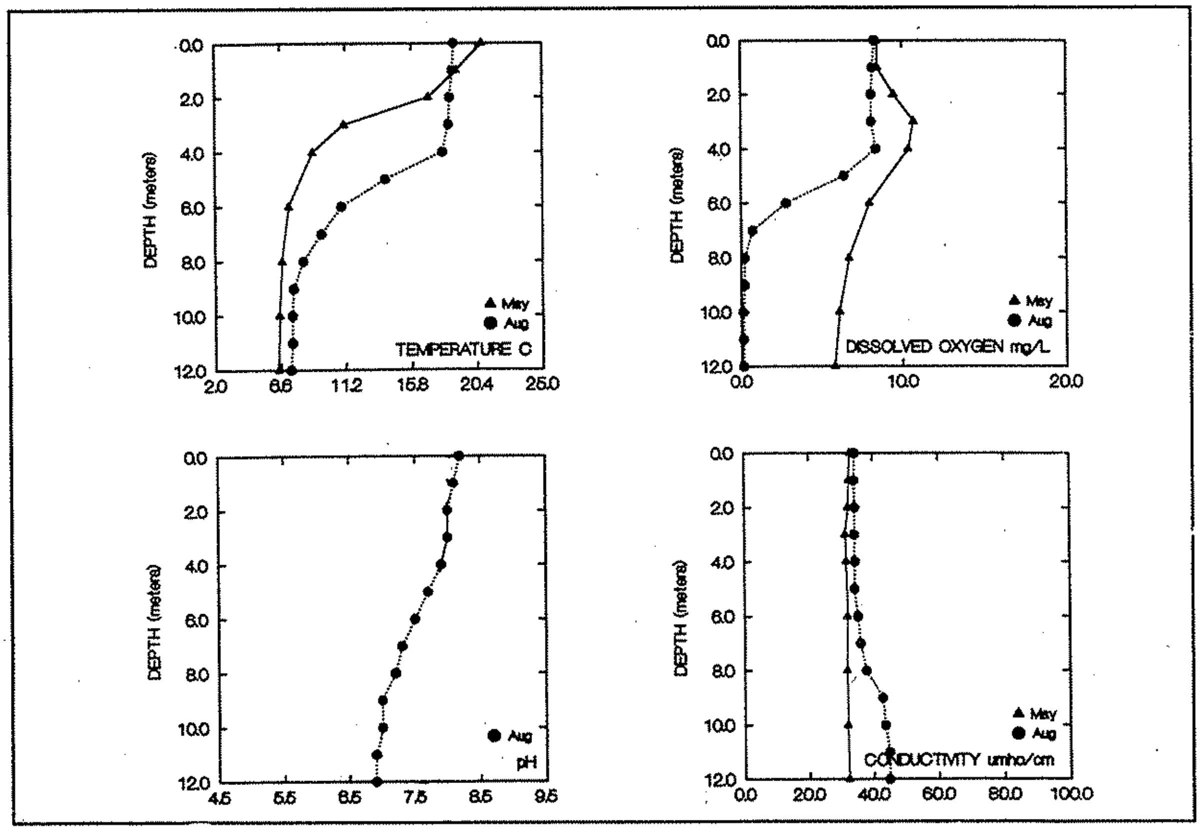
Size (acres)	57
Maximum Depth (feet)	29
Mean Depth (feet)	14
Lake Volume (acre-feet)	798
Drainage Area (miles^2)	0.8
Altitude (feet)	1.5
Shoreline Length (miles)	

Data From Bortleson *et al.* (1976)



BLACK LAKE (STEVENS COUNTY)





1993 Secchi Depth and Profile Data Graphs

Overall Assessment

Blackmans Lake was assessed as mesotrophic in 1993, based on fair water clarity and moderately high amounts of algae and aquatic plants. Nutrient concentrations ranged from moderately low to high. Considering that the lake is located in an urban-suburban area, and in the past has had water quality problems from large numbers of resident geese (waterfowl feeding on the shore has since been banned), the water quality was fairly good. KCM (1994) has recommended measures for controlling nutrient loading from stormwater, agriculture development, forestry, and lake sediments, for improving water quality and reducing nuisance blue-green algal blooms.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Secchi depths in 1993 ranged from 5.8 feet to 17.0 feet, and most values were in the range that is generally associated with mesotrophic lakes (6.5 to 13 feet).

Total Phosphorus

Total phosphorus in the upper layer of water (the epilimnion) was high in May (29 µg/L), and moderate in August (13 µg/L). These concentrations were somewhat higher than those measured in 1989. Concentrations between 12 µg/L and 24 µg/L are typical for mesotrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were high on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. In May, the ratio of total nitrogen to total phosphorus was less than 17:1 (14:1), so algal growth may have been nitrogen-limited in May. In August, the total nitrogen to total phosphorus ratio was high (31:1), so it is likely that algal growth was not limited by nitrogen when the lake was sampled in August.

Profile Data

The lake was thermally stratified during May. In August, temperature gradually decreased from surface to bottom, so the dissolved oxygen profile was used to determine the water sampling depths. On both sampling dates, dissolved oxygen concentrations decreased in the bottom two meters of the lake. Dissolved oxygen usually decreases from bacterial decomposition of algae and aquatic plants in the water and sediments. Low dissolved oxygen concentrations in bottom waters is typical of mesotrophic lakes.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Chlorophyll *a* concentrations both sampling dates indicated moderately high densities of algae at the time of sampling. Chlorophyll *a* values were slightly lower than values from 1989.

Aquatic plants identified by Ecology staff during the August sampling visit included naiad (*Najas* sp.), yellow-flowering water lily (*Nuphar* sp.), waterweed (*Elodea canadensis*), coontail (*Ceratophyllum demersum*), and Berchtold's pondweed (*Potamogeton berchtoldii*). A small bryozoan colony was brought up with the aquatic plant sampler. Bryozoans are colonial invertebrates, and were observed in several lakes in 1993. Bryozoans are eaten by fish, and often indicate a diverse biological community within a lake.

Other Available Information

From KCM (1994): Blackmans Lake is mesotrophic and experiences blue-green algal blooms. The majority (69%) of the lake's annual total phosphorus load is from external sources, and about 17% is from internal loading. Stormwater contributes about 28% of the total volume of water entering the lake. Watershed management and restoration measures are recommended to improve water quality. In-lake restoration recommendations include a whole-lake alum treatment and hypolimentic aeration. Watershed management recommendations include riparian area buffer zones, public education, stormwater best management practices, and improvements in practices associated with agriculture, development, and forestry. Capital improvement projects may include stream modifications, wetland enhancement, ditch improvements, and construction of a stormwater detention pond.

Summary of Questionnaire Results and Information from the Volunteer

The 1993 questionnaire on lake and watershed uses was not returned.

Acknowledgment

I thank Rick Hart for volunteering his time to monitor Blackmans Lake in 1993.

Blackmans Lake -- Snohomish County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	43
Mean Trophic State Index (Total Phosphorus):	47
Mean Trophic State Index (Chlorophyll *a*):	41

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	pH[2]	Lake Ht (in)[3]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
23-May	1130			17.0			green-brown	0		breezy	Onsite visit.
08-Jun	1343	20.0	68.0	14.3	7.1	14.00	lt-green	100	light	light	I've installed a rain gage in my backyard to measure local rainfall. Measured 0.6" in 48 hours preceding.
20-Jun	1208	21.1	70.0	13.0	7.9	15.50	lt-green	0	none	light	Some foam noticed on eastern shore at Hill Park.
08-Jul	1215	22.2	72.0	9.0	7.2	17.75		0	none	light	Water color yellow-green.
25-Jul	1403	20.6	69.0	5.8	7.4	14.00		75	light	light	Water color yellow-green.
08-Aug	1403	22.2	72.0	11.0	7.7	17.00		100	none	light	Water color yellow-green.
21-Aug	1225	21.7	71.0	11.8	7.4	19.00	lt-green	100	trace	light	
12-Sep	1446	21.1	70.0	8.5	7.4	20.00		0	none	light	Water color yellow-green.

1 Trophic State Indices calculated from Carlson (1977).
2 The volunteer measured surface pH using a two-point calibration pH pen.
3 "Lake height" refers to change in lake level. Based on volunteer-collected data, the level of Blackmans Lake dropped 6" from May 23 to September 12.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/23	0.0	19.6	7.9	9.3	82
	1.1	19.6	7.9	9.4	83
	2.2	19.5	7.9	9.5	82
	3.0	15.2	7.9	9.3	81
	4.1	13.3	7.8	7.6	84
	5.1	12.1	7.7	5.7	88
	6.0	11.5	7.6	4.5	92
	6.3	11.3	7.5	3.3	95
08/21	0.0	21.7	7.8	9.0	86
	1.0	21.7	7.8	9.0	86
	2.0	20.6	7.8	8.8	85
	3.0	19.8	7.6	7.2	85
	4.0	18.0	7.3	2.6	91
	5.1	14.9	7.1	0.4	101
	6.1	13.2	7.1	0.2	122
	6.5	12.8	7.0	0.2	129

1993 Onsite Visit Data - Water Chemistry

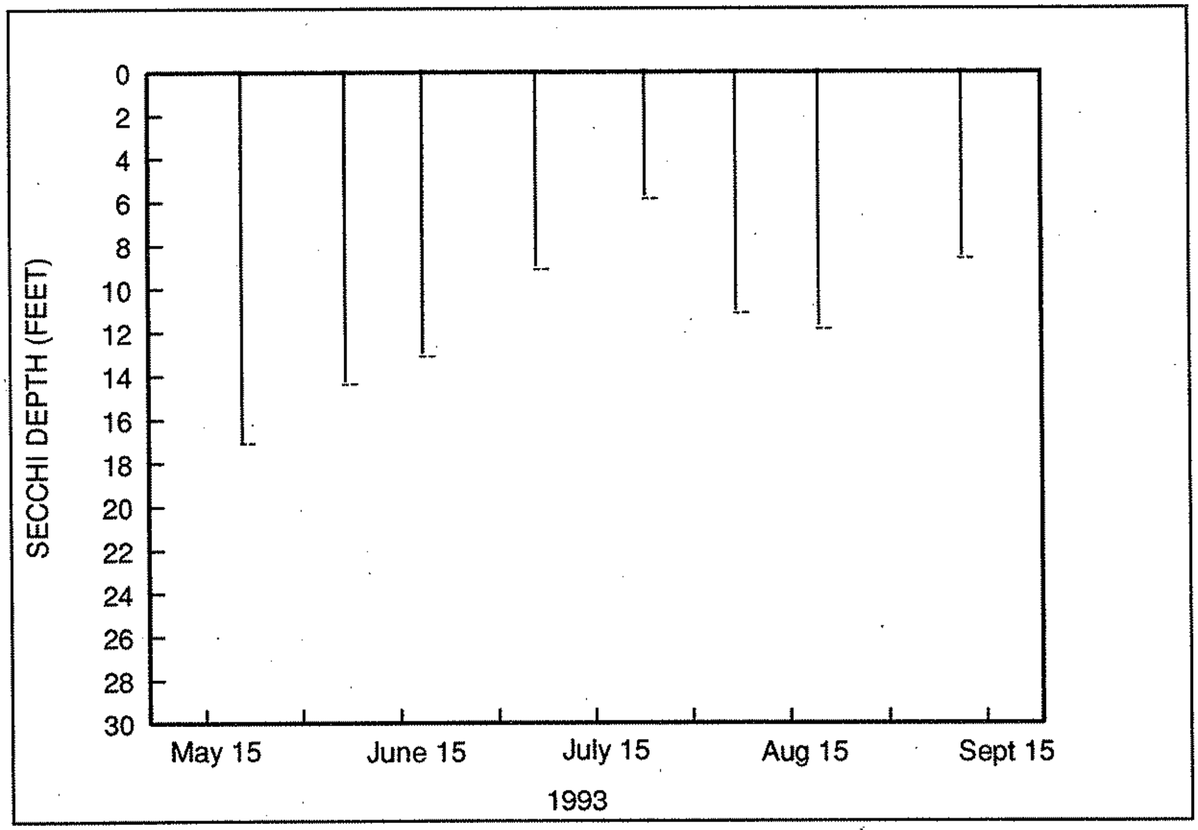
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 23							
Epilimnion	29	0.40	3.0	--	--	--	--
Hypolimnion	42	0.43	--	--	--	--	--
August 21							
Epilimnion	13	0.40	2.8	--	--	--	--
Hypolimnion	28	0.37	--	--	--	--	--

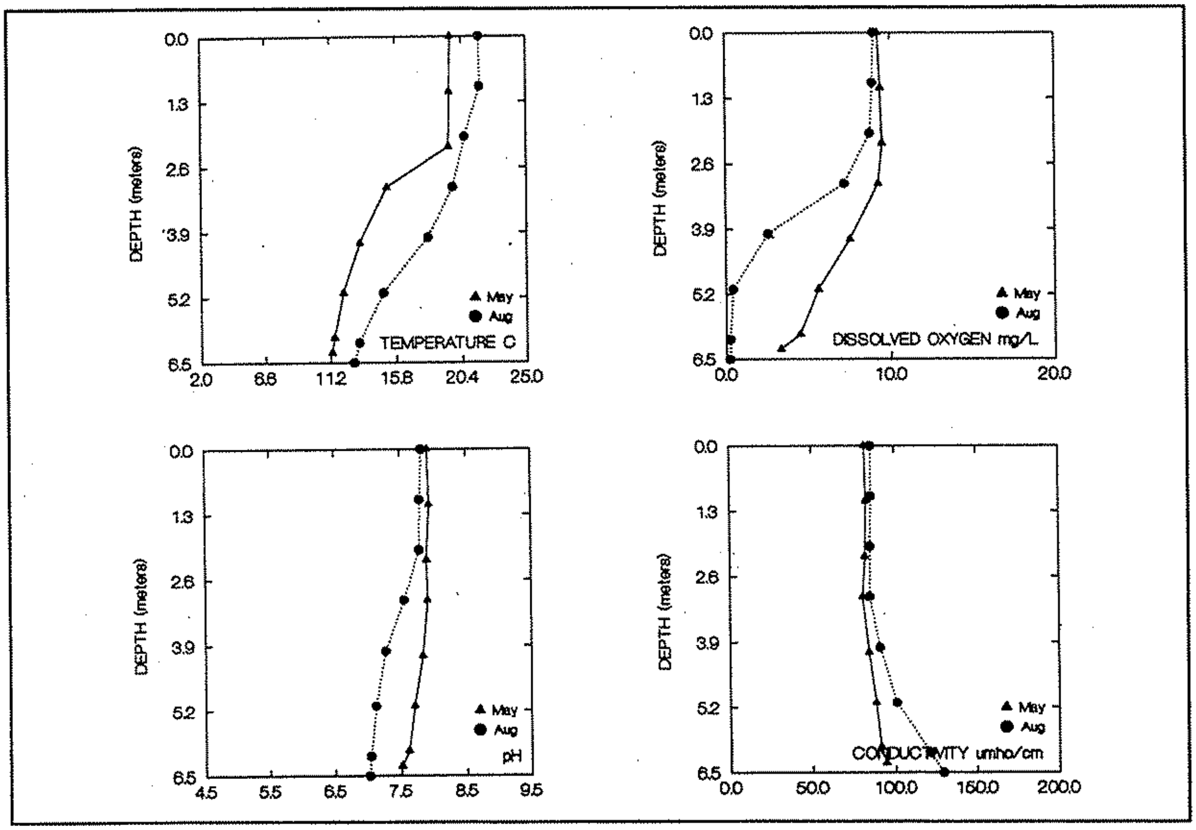
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
08/03/73[a]	8	--	--
06/26/89[b]	16	0.49	3.3
09/25/89[b]	22	0.44	3.9

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

BLACKMANS LAKE (SNOHOMISH COUNTY)





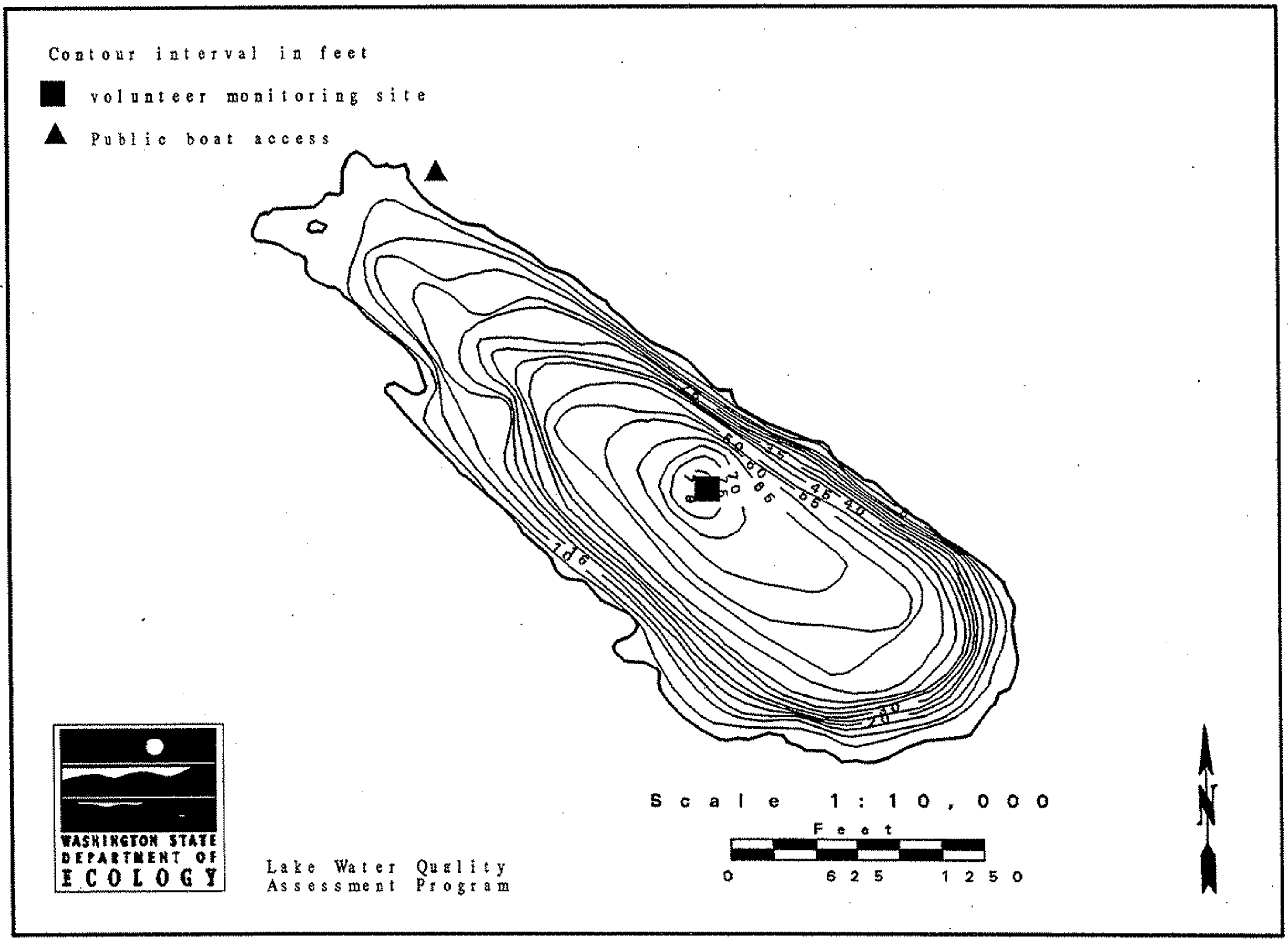
1993 Secchi Depth and Profile Data Graphs

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 Pilchuck 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)



Overall Assessment

In 1993, Lake Bosworth exhibited both oligotrophic and mesotrophic characteristics, so it was classified as oligo-mesotrophic. An oligotrophic characteristic has very good water clarity, which was better in 1993 than in 1992 and 1991. However, concentrations of both total phosphorus and chlorophyll *a* were higher in 1993 than in previous years, and were in the ranges associated with mesotrophic lakes. Because trophic state is used to describe a lake with respect to its water clarity, nutrient concentrations, and amount of plant and algae growth, the trophic state assessment for Lake Bosworth can't be based entirely on its good water clarity.

Other Snohomish County lakes monitored by volunteers in 1993 included Lake Howard, Lake Ketchum, Lake Ki, Lake Martha, Martha Lake, Lake Roesiger, Lake Stevens, and Sunday Lake. Of these, Lake Ki had the best water clarity and the lowest phosphorus concentrations.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in 1993 was very good, as indicated by Secchi depths which ranged from 11.0 feet to 22.0 feet. Measurements from late September through October were the deepest recorded since monitoring in the lake began in 1990.

Total Phosphorus

The total phosphorus concentration from the May sampling visit was moderately high (21 μg/L), but the August value (12 μg/L) was much lower. Both values were in the range associated with mesotrophic lakes (12 to 24 μg/L), and were higher than the phosphorus concentrations measured in 1992 (10 μg/L on both sampling dates).

Total Nitrogen

Concentrations of total nitrogen were high on both sampling dates, although the August concentration (0.35 mg/L) was low in comparison to other lakes sampled for the program. In both 1993 and 1992, total nitrogen concentrations were higher in May than in August. Small changes in total nitrogen concentration are not as critical to water quality as changes in total phosphorus. However, the ratio of total nitrogen to total phosphorus concentrations can indicate which nutrient may first become responsible for limiting algae growth. In Lake Bosworth, the ratios of total nitrogen to total phosphorus were greater than 17:1 (30:1 in May and 29:1 in August), so it is likely that algal growth in the lake was not limited by nitrogen.

Profile Data
On both sampling dates, the lake was thermally stratified. Both pH and dissolved oxygen values increased at three to six meters depth. This probably resulted from a combination of the sharp decrease in water temperature at these depths (because dissolved gases are more soluble in cold water than in warm water), as well as increased algae growth at these depths.

Dissolved oxygen decreased with depth in the lower layer of water (the hypolimnion). 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. Dissolved oxygen in oligotrophic lakes may not change, or may even increase in the lower layer of water due to temperature changes. In mesotrophic lakes, dissolved oxygen decreases with depth in the lower layer of water.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Chlorophyll *a* concentrations on both sampling dates indicated moderate to moderately high densities of algae at the time of sampling. The range of chlorophyll concentrations associated with mesotrophic lakes is 2.6 to 6.4 µg/L.

Aquatic plants were not prevalent in the lake, although iris (*Iris pseudacorus*) grew along parts of the shoreline. Additional aquatic plants observed in 1993 included quillwort (*Isoetes* sp.) and an unidentified narrow-leaf pondweed (*Potamogeton* sp.). These plants were observed in sparse patches nearshore.

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 1993.

> Lake Bosworth is used for fishing, swimming, and non-motorized boating. There is one public boat ramp, making about one percent of the shoreline publicly-owned. Only electric motors are allowed on the lake. Rainbow trout were stocked in the lake in 1993. Currently, the only activity in the watershed is lakeshore development for residences. In the past, the watershed was logged.
>
> There are 111 houses on the lakeshore, and none of the houses are connected to a sewer. About six culverts/stormdrains drain into the lake. There is no homeowners association for the lake. No lake management activities occurred in 1993, although the lake was treated in the past with chemicals to control undesirable fish species. Lake water is withdrawn for drinking and other domestic uses.

Overall, the volunteer found that Lake Bosworth had good water quality. Excessive plant growth was the worst water quality problem in the lake in 1993, and the volunteer also noted that not enough fish were stocked in the lake (this latter comment was also made in 1992). There were no changes in the lake since the 1992 monitoring season.

Acknowledgment

I thank Dick McFadden for volunteering his time to monitor Lake Bosworth during 1991-1993. Robert and Delores Maxwell monitored the lake during 1990-1991.

Lake Bosworth -- Snohomish County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	37
Mean Trophic State Index (Total Phosphorus):	44
Mean Trophic State Index (Chlorophyll *a*):	43

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (ft)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
24-May	0945	18.3	65.0	15.0	10.00	pea-green	0		calm	Onsite visit. Water color light pea-green.
15-Jun	0810	16.7	62.0	15.5	11.04	pea-green	100			
01-Jul	1545	19.4	67.0	14.5	12.06	pea-green	100	none	light	
17-Jul	1615	18.3	65.0	14.5	14.50	pea-green	90	moderate	light	
16-Aug	1215	18.3	65.0	11.5	14.50	pea-green	0	light	light	
18-Aug	0915			11.0	14.50	pea-green	0		calm	Secchi with view tube. Onsite visit.
01-Sep	1130	20.0	68.0	14.0	14.50	pea-green	0	none	light	
17-Sep	1300	20.0	68.0	22.0	16.00	pea-green	0	trace	calm	
02-Oct	0845	17.8	64.0	20.0	16.06	pea-green	0	none	calm	
17-Oct	1130	14.4	58.0	22.0		pea-green	100	light	light	

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Bosworth dropped 6.1" from May 24 to October 17.

Lake Bosworth -- Snohomish County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/24	0.0	19.8	8.3	9.4	32
	1.0	19.2	8.2	9.6	32
	1.9	19.0	8.2	9.8	32
	3.0	17.0	8.3	10.6	32
	4.0	13.0	8.4	11.6	31
	5.0	10.6	8.2	10.7	32
	6.0	9.5	8.0	9.6	32
	7.0	7.9	7.9	9.3	32
	8.1	7.1	7.7	8.9	31
	10.0	6.0	7.7	8.9	32
	12.0	5.5	7.6	8.5	31
	14.1	5.2	7.6	7.9	32
	16.2	5.0	7.5	7.2	32
	18.1	5.0	7.4	6.4	32
	20.2	5.0	7.3	5.0	33
	21.0	5.0	7.2	4.1	35
08/18	0.0	19.6	8.3	9.2	33
	1.0	19.6	8.3	9.4	33
	2.1	19.4	8.3	9.5	32
	3.0	19.1	8.2	9.6	33
	4.0	17.8	8.1	10.0	32
	6.0	10.8	8.0	8.3	35
	8.0	8.3	7.9	7.8	34
	10.0	6.8	7.8	7.3	35
	12.0	5.8	7.7	6.4	33
	14.1	5.4	7.6	5.0	34
	16.1	5.3	7.5	4.0	39
	18.1	5.2	7.4	3.3	54
	20.1	5.2	7.3	2.4	63
	21.0	5.2	7.2	2.2	68

1993 Onsite Visit Data - Water Chemistry

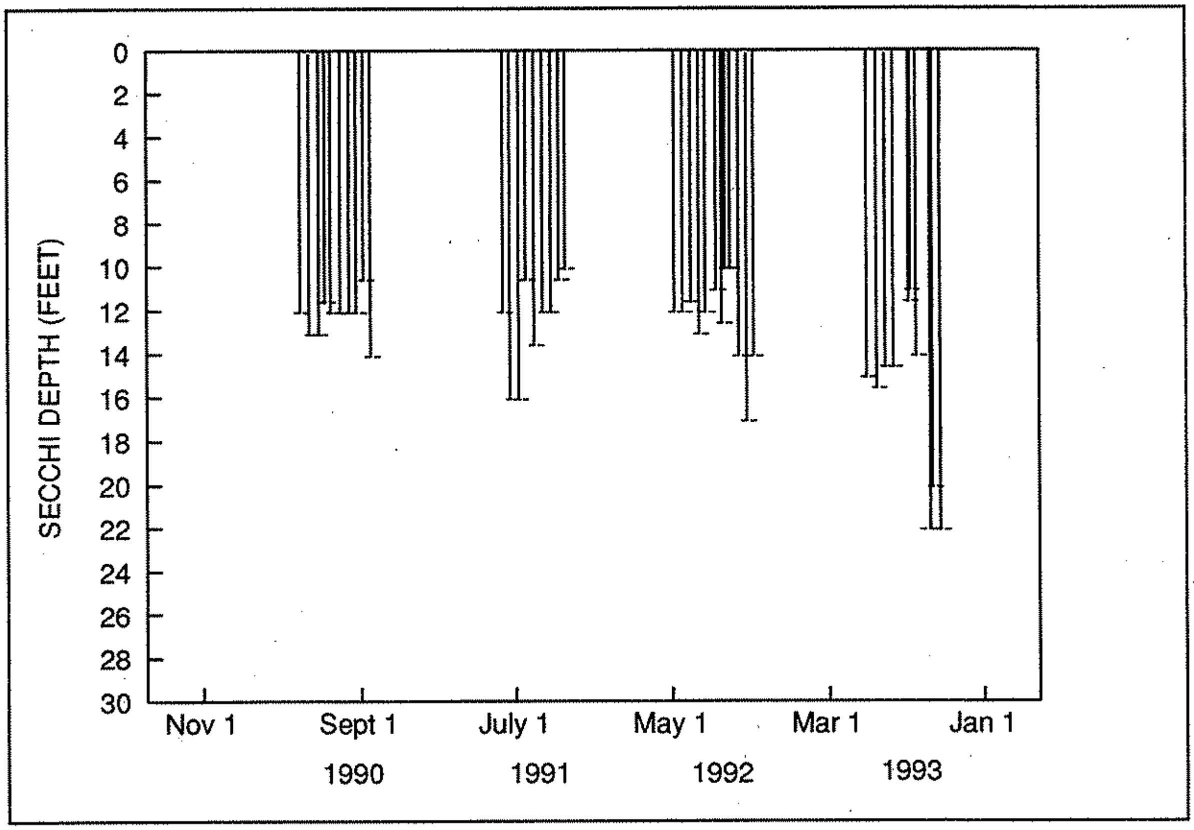
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 24							
Epilimnion	21	0.62	2.4	--	--	--	--
Hypolimnion	20	0.73	--	--	--	--	--
August 18							
Epilimnion	12	0.35	5.7	--	--	--	--
Hypolimnion	24	0.56	--	--	--	--	--

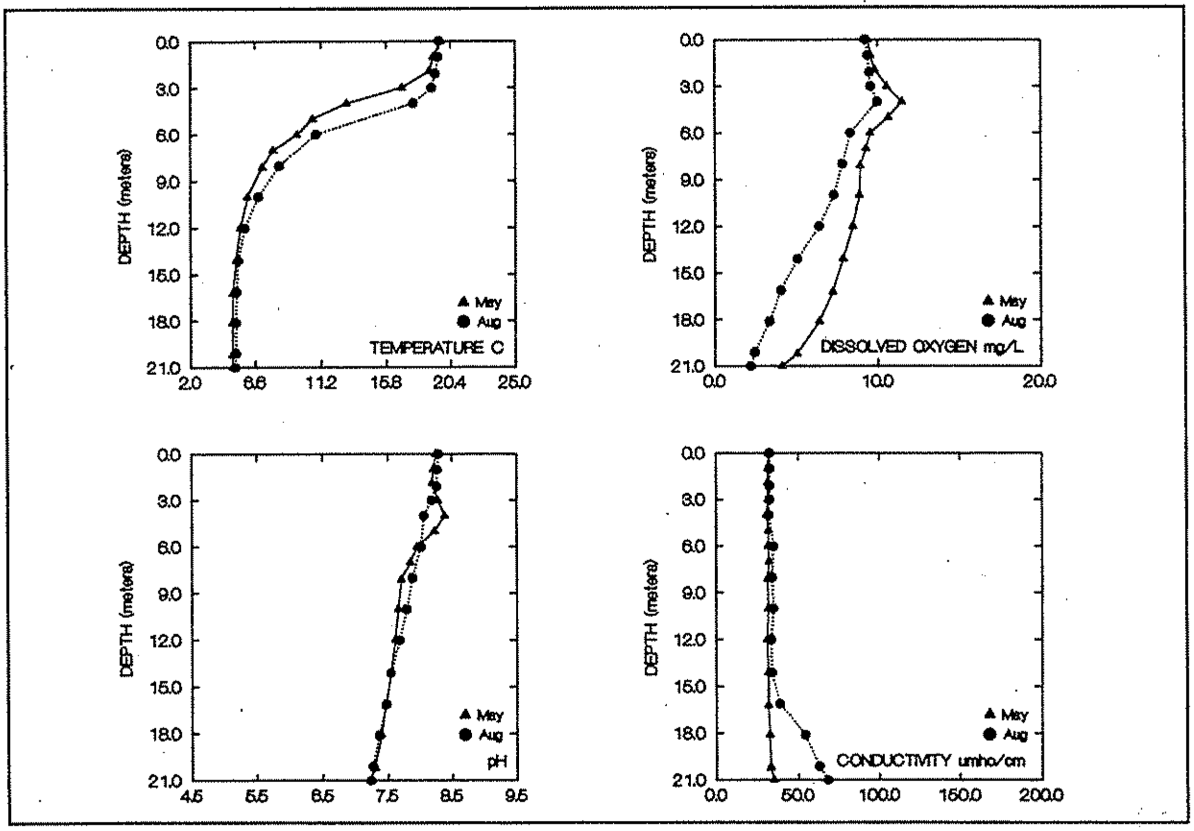
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
08/02/73[a]	4	--	--
06/06/90[b]	7	--	--
05/29/91[c]	--	0.72	--
05/15/92[d]	10	0.67	1.5
08/21/92[d]	10	0.32	2.2

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)

LAKE BOSWORTH (SNOHOMISH COUNTY)





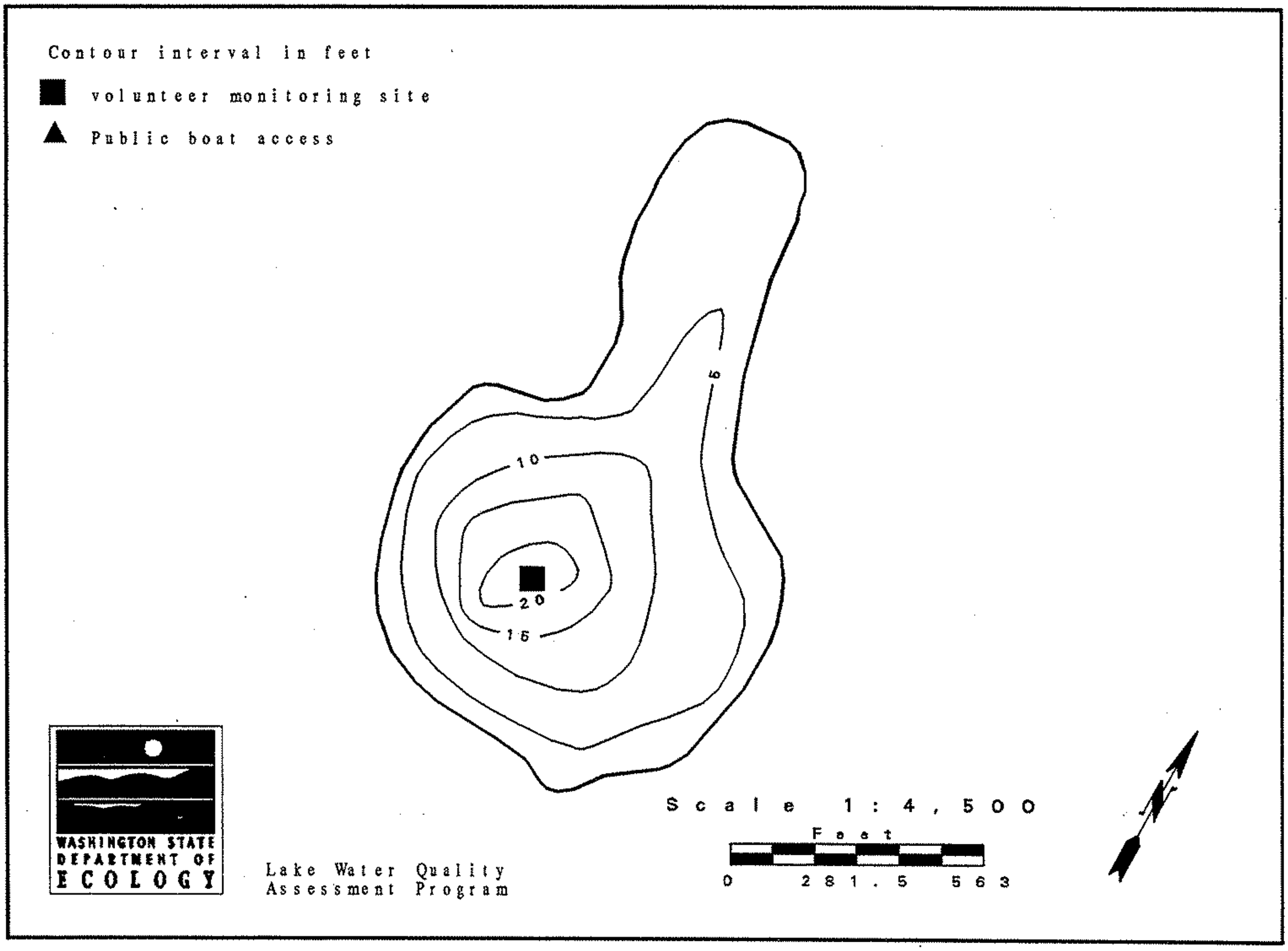
1993 Secchi Depth and Profile Data Graphs

Buck Lake -- Kitsap County

Buck Lake is located 1.5 miles southwest of Hansville. It has no surface inlets, and seeps to Puget Sound.

Size (acres)	22
Maximum Depth (feet)	24
Mean Depth (feet)	7
Lake Volume (acre-feet)	157
Drainage Area (miles^2)	0.3
Altitude (feet)	130
Shoreline Length (miles)	0.9

Data From Sumioka and Dion (1985)



Overall Assessment

In 1993, Buck Lake exhibited both mesotrophic and eutrophic characteristics so it was assessed as meso-eutrophic. This assessment is based on fair water clarity, yet had high nutrient concentrations and moderately high amounts of aquatic plants and algae.

Generally, eutrophication is considered to be a nuisance when it occurs as a result of human activities within a lake's watershed. Because most of Buck Lake's watershed is forested, and the only development near shore is a local park, Buck Lake is a good example of a naturally eutrophying lake. Much of Buck Lake's shore is wetlands, and the volunteers reported that the area is used by a variety of wildlife. Despite the trophic state assigned to the lake, "restoring" the lake to enhance recreational uses may not be warranted.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was fairly good, as indicated by Secchi depths that ranged from 8.8 feet to 12.0 feet. Values from 6.5 feet to 13 feet are in the range associated with mesotrophic lakes.

Total Phosphorus

Total phosphorus concentrations were high on both sampling dates (38 µg/L in June, and 31 µg/L in August). Concentrations greater than 24 µg/L are typical for eutrophic lakes, and can cause heavy algal growth.

Total Nitrogen

Total nitrogen concentrations were high on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios total nitrogen to total phosphorus were greater than 17:1 (19:1 in June, and 24:1 in August), it is likely that algal growth was not limited by nitrogen at the time of sampling.

Fecal Coliform Bacteria

Samples for fecal coliform bacteria were collected during the June sampling visit only. Site #1 was located offshore near the swimming area of the park, and Site #2 was located at the public access. The result for the sample near the swimming area was 5 colonies/100 mL, and the result for the sample near the public access was too low to be detected. Both results are within State water quality standards for lake water.

Solids
Results from solids samples are used to evaluate whether Secchi depths were affected primarily by algae, or if suspended sediments affected water clarity at the time of sampling. Solids samples were collected during the June sampling visit only. Both results were 1 mg/L, which is low and suggests that at the time of sampling water clarity was primarily affected by algae.

Profile Data
On both sampling dates, the lake was thermally stratified. Dissolved oxygen concentrations decreased with depth, particularly in the lower layer of water (the hypolimnion). Dissolved oxygen usually decreases when bacteria use oxygen as they decompose algae and aquatic plants in the bottom water and sediments. Low concentrations of dissolved oxygen in the lower layer of water are typical for mesotrophic and eutrophic lakes.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. The concentration of chlorophyll *a* in June (9.4 µg/L) indicated a high density of algae at the time of sampling. In August, algal density was moderately high, as indicated by the moderately high concentration of chlorophyll (4.4 µg/L).

Aquatic plants observed during the 1993 sampling visits include yellow-flowering water lily (*Nuphar*), cattails (*Typha* sp.), coontail (*Ceratophyllum demersum*), quillwort (*Isoetes* sp.), waterweed (*Elodea canadensis*), and largeleaf pondweed (*Potamogeton amplifolius*). An additional pondweed observed in August was suspected to be *Potamogeton foliosus*. A large bryozoan colony was also observed during the August sampling visit. Bryozoans are colonial invertebrates that are often eaten by fish. The jelly masses noted by the volunteer on the July 19, 1993, monitoring date were probably bryozoans; a clear gelatinous mass remains for a while after the colony dies. Many of the monitored lakes had bryozoan colonies in 1993.

Summary of Questionnaire Results and Information from the Volunteer

The 1993 questionnaire on lake and watershed uses was not received by the volunteer.

Acknowledgments

I thank Sue Koenig for volunteering her time to monitor Buck Lake in 1993. Barbara Forsnier also assisted with the monitoring.

Buck Lake -- Kitsap County

1993 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	43
Mean Trophic State Index (Total Phosphorus):	55
Mean Trophic State Index (Chlorophyll *a*):	49

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
07-Jun	1400	20.0	68.0	8.8			100	moderate	light	Water color yellow-brown.
23-Jun	1830	20.0	68.0	10.0	24.00		25	moderate	light	Water color yellow-brown. Lake height measured from mark on piling to water surface.
08-Jul	1130	22.2	72.0	9.5	23.25		0	none	calm	Water color yellow-brown. Lake level seems to have dropped several inches in a few days.
19-Jul	1800	21.1	70.0	10.5	24.25		100	moderate	calm	Water color yellow-brown. Found a bunch of the underwater "jelly" masses.
07-Aug	1500	23.3	74.0	12.0	24.50		50	none		Water color yellow-brown. There are "clots" of a bluish-green algae floating in the water lakewide. I'll try to get a sample.
30-Aug	1645	21.1	70.0	10.0				none	breezy	Water color yellow-brown. Onsite visit.
12-Sep	1000	20.0	68.0	12.0	28.00		0	trace	calm	Water color yellowish-green.
28-Sep	1715	17.8	64.0	12.0W*	21.00	gr-brown	90	none	breezy	* Secchi disk obscured by weeds
13-Oct	1415	16.1	61.0	12.0	25.00	gr-brown	75	trace	light	

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Buck Lake dropped 1" from June 23 to October 13.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
06/07	0.0	20.0	7.4	8.7.	69
	0.9	19.9	7.3	8.7	69
	2.0	18.7	7.2	6.6	70
	3.0	13.9	7.3	4.2	72
	4.0	10.4	7.2	1.6	79
	4.4	9.5	7.2	0.7	80
	5.1	8.8	7.2	2.7	82
	6.1	8.0	7.1	1.4	94
	6.5	7.8	7.1	0.7	99
08/30	0.0	21.1	7.8	9.2	69
	1.0	20.9	7.7	9.0	69
	2.0	20.7	7.7	8.9	69
	3.1	17.5	7.5	2.9	76
	4.0	13.6	7.5	2.1	81.
	4.3	12.7	7.5	0.7	86

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 7 Epilimnion	38	0.716	9.4	1	1	5	bdl
Hypolimnion	114	0.815	--	--	--	--	--
August 30 Epilimnion	31	0.756	4.4	--	--	--	--
Hypolimnion*							

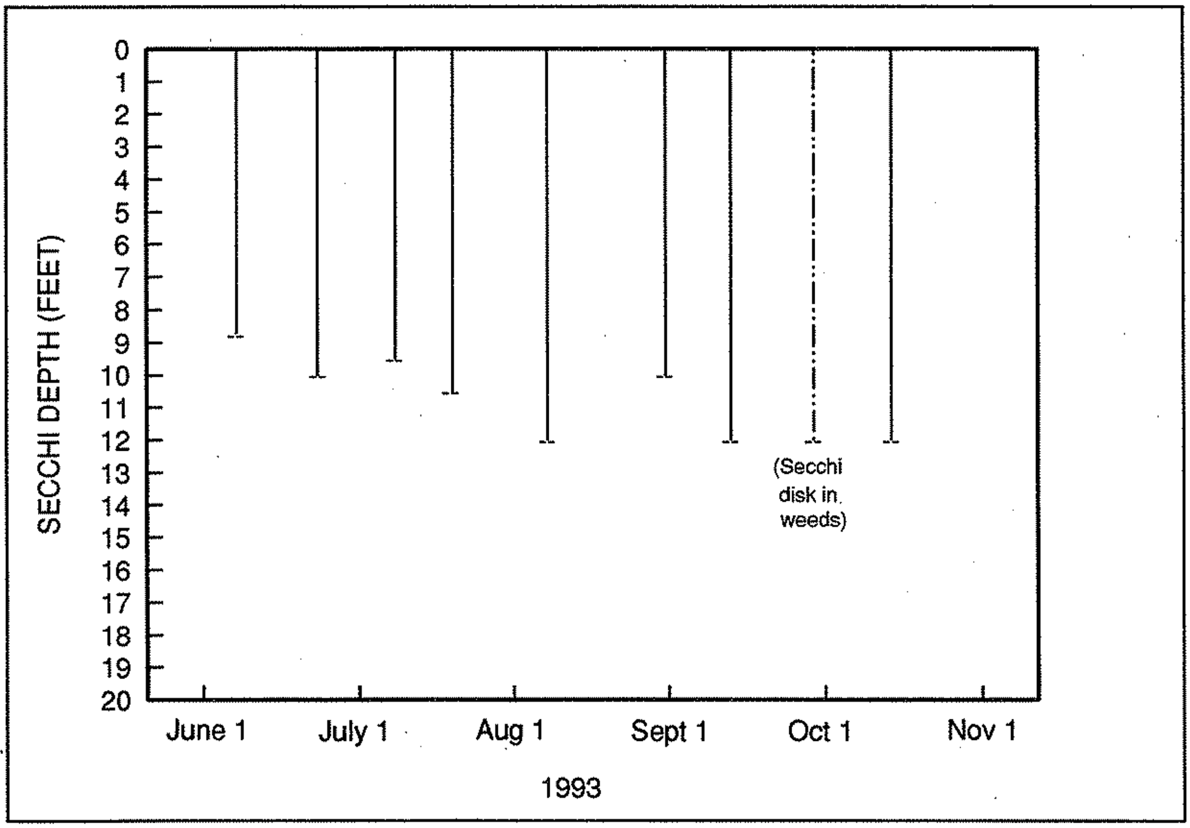
* lake was not stratified at the time of sampling; only one set of water samples was collected

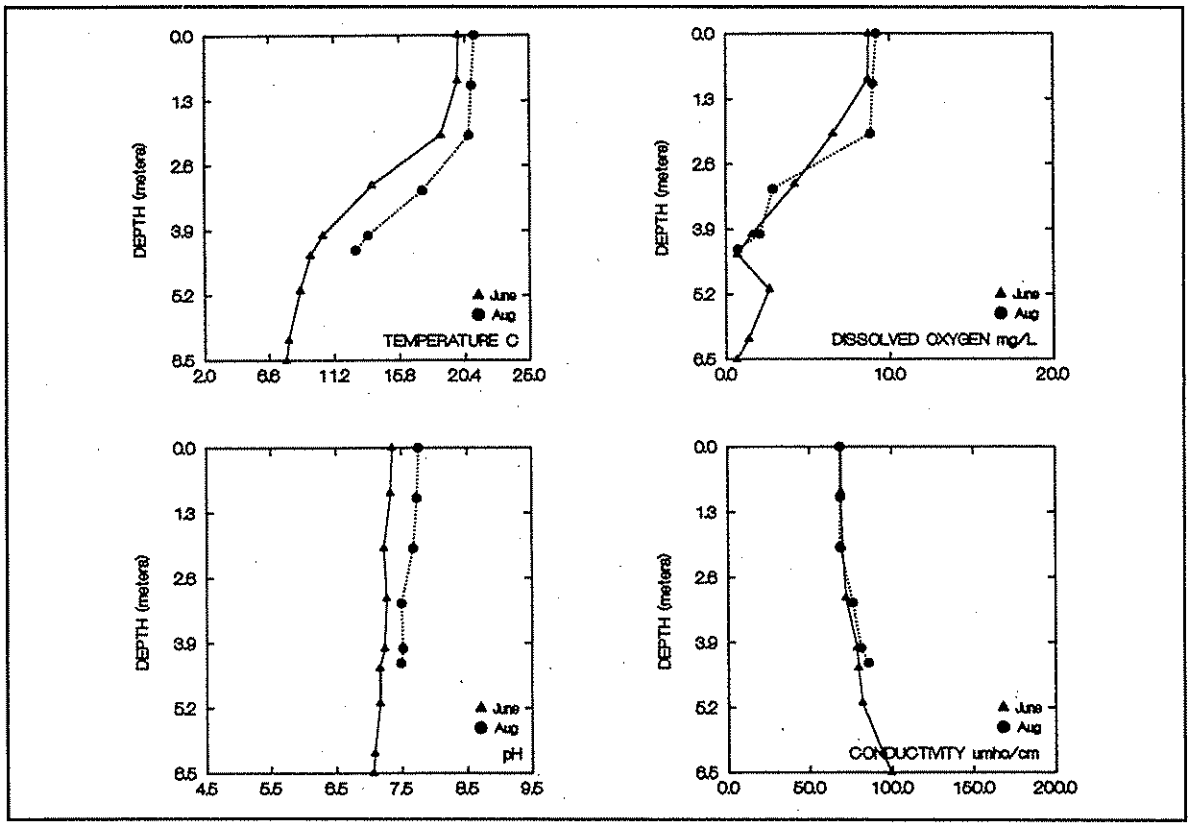
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)
07/02/81[a]	50	1.3	3.4

a. Sumioka and Dion (1985)

BUCK LAKE (KITSAP COUNTY)



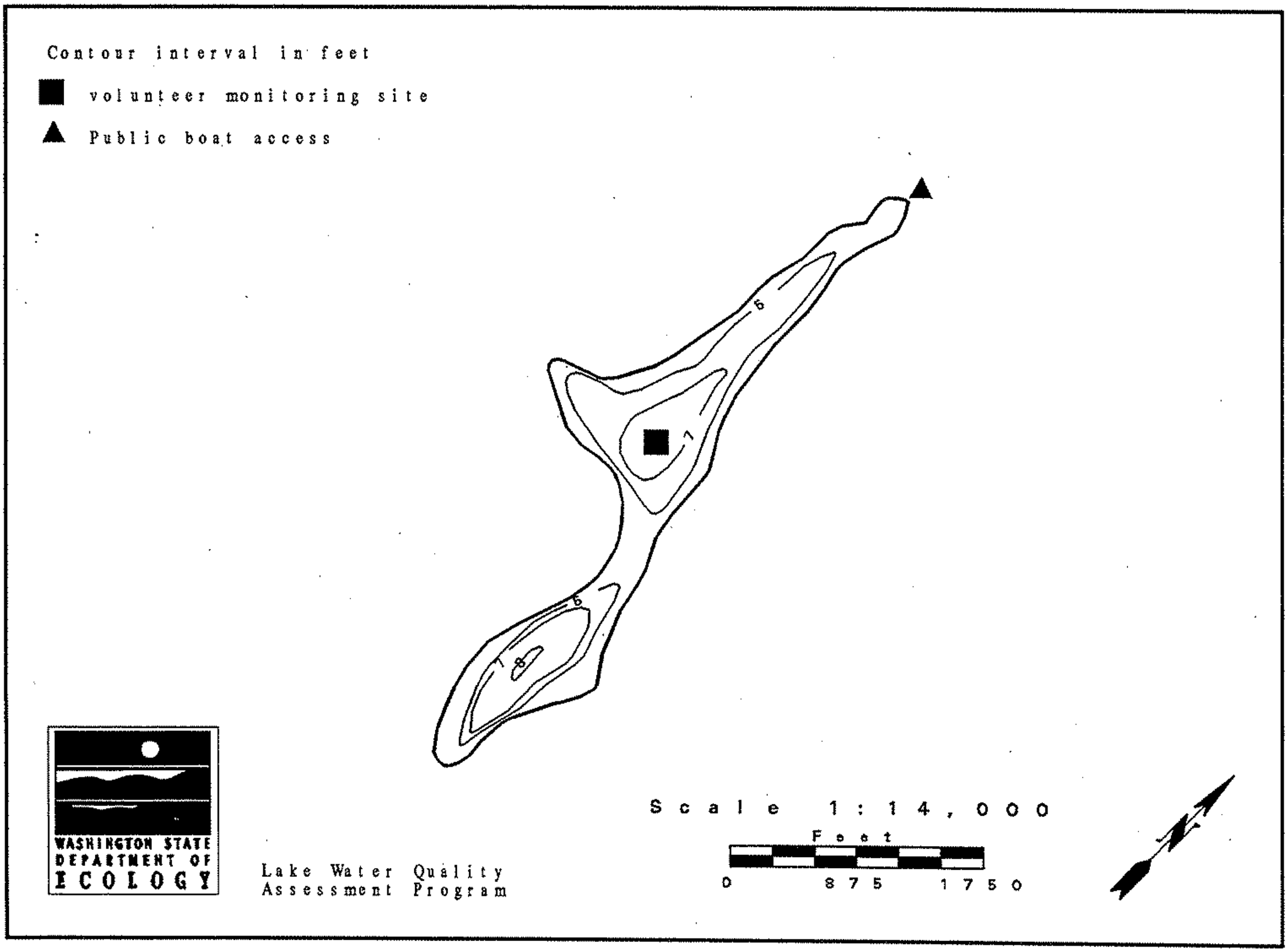


1993 Secchi Depth and Profile Data Graphs

Chambers Lake -- Thurston County

Chambers Lake is located three miles southeast of Olympia. It is also known as Big Chambers Lake, and was originally known as Russell Lake. Chambers Lake has no surface inlets, but is fed by stormwater and surface runoff. As a result, it varies in size. Chambers Lake drains via Little Chambers Lake to the Deschutes River.

Size (acres)	60
Maximum Depth (feet)	8
Mean Depth (feet)	5
Lake Volume (acre-feet)	270
Drainage Area ($miles^2$)	0.8
Altitude (feet)	194
Shoreline Length (miles)	2.2



Overall Assessment

In 1993, Chambers Lake was eutrophic, meaning that water clarity was poor, nutrient concentrations were high, and there was a high amount of aquatic plants and algae in the water. Uses of the lake were limited because the lake is very shallow, and up to 35% of the lake surface was covered with floating-leaved aquatic plants.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was very poor, as indicated by Secchi depths which ranged from 3.0 to 5.0 feet. On two monitoring dates (July 27 and September 21), though, the water was clear enough to be able to see the Secchi disk on the bottom of the lake. Secchi depths less than 6.5 feet indicate poor water clarity, and are typical for eutrophic lakes.

Total Phosphorus
Total phosphorus concentrations were very high on both sampling dates. The June sample in particular was very high (70 µg/L). Concentrations greater than 24 µg/L indicate that a lake is eutrophic.

Total Nitrogen
Total nitrogen concentrations were high on both sampling dates and were high in comparison to other lakes monitored for the program. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. In June, the ratio of total nitrogen to total phosphorus was less than 17:1 (13.1), so algal growth may have been limited by nitrogen when the lake was sampled. In August, the ratio of total nitrogen to total phosphorus was 23:1, so it is likely that algal growth was not limited by nitrogen in August.

Fecal Coliform Bacteria
On both sampling dates, fecal coliform bacteria samples were collected at the volunteer's sampling site (Site #1) and at the public access (Site #2). Both results for samples collected at the volunteer's sampling site were very low. However, results for samples collected near the public boat access were high (290 colonies/100 mL in June, and 35 colonies/100 mL in August). The state water quality standard for fecal coliform in lakes is a geometric mean of 50 colonies/100mL, with not more than 10% of the samples exceeding 100 colonies/100 mL. There were not enough data available to directly compare to the water quality standards, but both values were reported to an inspector at Ecology's Southwest Regional Office.

Solids

Results from solids samples are used to evaluate whether Secchi depths were affected primarily by algae, or if suspended sediments affected water clarity at the time of sampling. Of four solids samples collected, only one total suspended solids sample collected in June was above the detection limit of 1 mg/L. Most of the solids were likely algae, because the total nonvolatile suspended solids result was very low. This suggests that water clarity was primarily affected by algae when the lake was sampled.

Profile Data

Chambers Lake is too shallow to thermally stratify. As a result, there was little change in dissolved oxygen, pH, and conductivity data from surface to bottom. Interesting points about the data are (1) the water temperature was actually warmer in June than it was in August; (2) in June, the data collected from the bottom of the lake were probably affected by the probe entering the interface between sediments and the water column; (3) dissolved oxygen in August was not very high, possibly because bacterial decomposition of algae and aquatic plants in the water may have offset increased oxygen that would be expected from the large amount of aquatic plant growth. Like terrestrial plants, aquatic plants use carbon dioxide and give off oxygen during the day.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Chlorophyll *a* concentrations were high on both sampling dates indicated high densities of algae at the time of sampling.

Predominant plants in the lake were watershield (*Brasenia schreberi*) and a purple water lily (*Nymphaea* sp.). The latter was probably introduced into the lake. During the August sampling visit, watershield covered about 25% of the lake surface, and the water lilies covered about 10% of the lake surface. Epiphytic algae grew on both floating-leaved plants.

Other Available Information

In 1990, a four-year demonstration project on the use of grass carp was initiated by the city of Lacey, the University of Washington School of Fisheries, Ecology, and the Chambers Lake Environment and Neighborhood Association (CLEAN). Grass carp were planted in Big Chambers Lake and Little Chambers Lake to evaluate the effectiveness of grass carp on controlling floating-leaved aquatic plants, and to evaluate different stocking rates used in the two lake basins. About 3,000 fish were stocked in Little Chambers Lake, and about 12,500 were stocked in Big Chambers Lake. Two net pens used as "controls" (meaning, they are used to keep the fish out, to see what plants would grow if there are no fish present to eat them) are still present in the wide central part of the lake. The demonstration project is still in progress.

The city of Lacey monitored several of storm drains that drain into Chambers Lake. Nonpoint source controls will be implemented to reduce nutrient loading to the lake from stormwater.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire on lake and watershed uses.

> Chambers Lake is used mainly for fishing. There are two boat ramps on the lakeshore. There are no restrictions for motor boat use on the lake, although aquatic plants limit boating on the lake. Cutthroat trout were stocked in the lake in 1993, and while bass and bluegill were also observed in the lake, grass carp seemed to dominate the fish population. The lakeshore is currently being developed further for residences. In the past, the watershed was also used for animal grazing.
>
> There are approximately 30-50 houses on the lakeshore, and there are no culverts which drain into the lake.
>
> Overall, the volunteer found that Chambers Lake had fair water quality. Problems in the lake in 1993 included excessive aquatic plant growth and impaired fisheries. However, the lake was excellent for bird and wildlife watching (ducks, herons, coots, pheasant, quail, etc.).

Acknowledgment

I thank Ernie Schmidt for volunteering his time to monitor Chambers Lake during 1993.

Chambers Lake -- Thurston County

1993 Trophic Status[1]

Estimated Trophic State:	Eutrophic
Mean Trophic State Index (Secchi):	57
Mean Trophic State Index (Total Phosphorus):	61
Mean Trophic State Index (Chlorophyll *a*):	58

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
01-Jun	1030			3.5		red-brown	100	light	breezy	Onsite visit. Raining, some gusts.
15-Jun	1200	16.7	62.0	4.3	26.50	red-brown	75	light	light	Water color reddish brown. Considerable fish of different sizes observed.
29-Jun	0900	17.8	64.0	4.0	25.00	red-brown	90	light	breezy	Water color dark reddish brown.
13-Jul	1030	17.8	64.0	4.0		red-brown	75	light	light	Water color dark brownish-red.
27-Jul	1030	17.8	64.0	5.0			10	none	light	Second Secchi hit bottom. Water color light brownish-red.
24-Aug	1020	18.9	66.0	3.0		red-brown	0	light		Water color dark red-brown. Onsite visit.
21-Sep	1040	15.6	60.0	4.0b*	40.00	red-brown	10	none	light	*Hit bottom. Water color yellowish for two feet, turning reddish brown down to the bottom. This is the clearest I've seen Chambers since we started.

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

[2] "Lake height" refers to change in water level. Based on volunteer collected data, the level of Chambers Lake dropped 13.5" from June 15 to September 21.

Chambers Lake -- Thurston County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
06/01	0.0	19.7	7.0	8.0	18
	1.0	19.2	6.7	7.3	19
	1.1	19.0	6.1	6.3	32
08/24	0.0	18.9	6.7	4.2	20
	0.5	18.5	6.5	4.4	20
	0.9	18.4	6.3	4.0	20

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL)	
						Site #1	Site #2
June 1 Epilimnion	70	0.91	39.9	3	bdl	bdl	290
Hypolimnion*							
August 24 Epilimnion	36	0.82	6.3	bdl	bdl	1	35
Hypolimnion*							

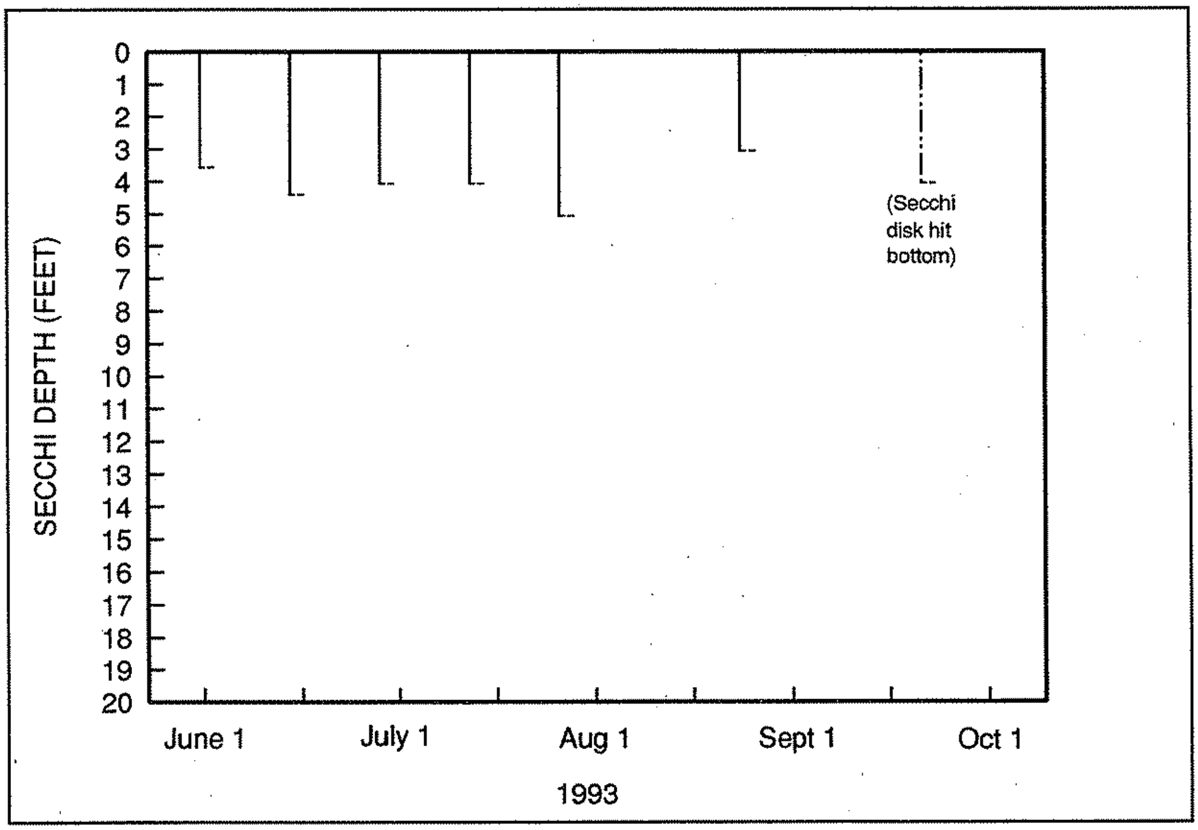
bdl = below analytical detection limit of 1 unit
* = The lake was not stratified at the time of sampling; only one set of samples was collected.

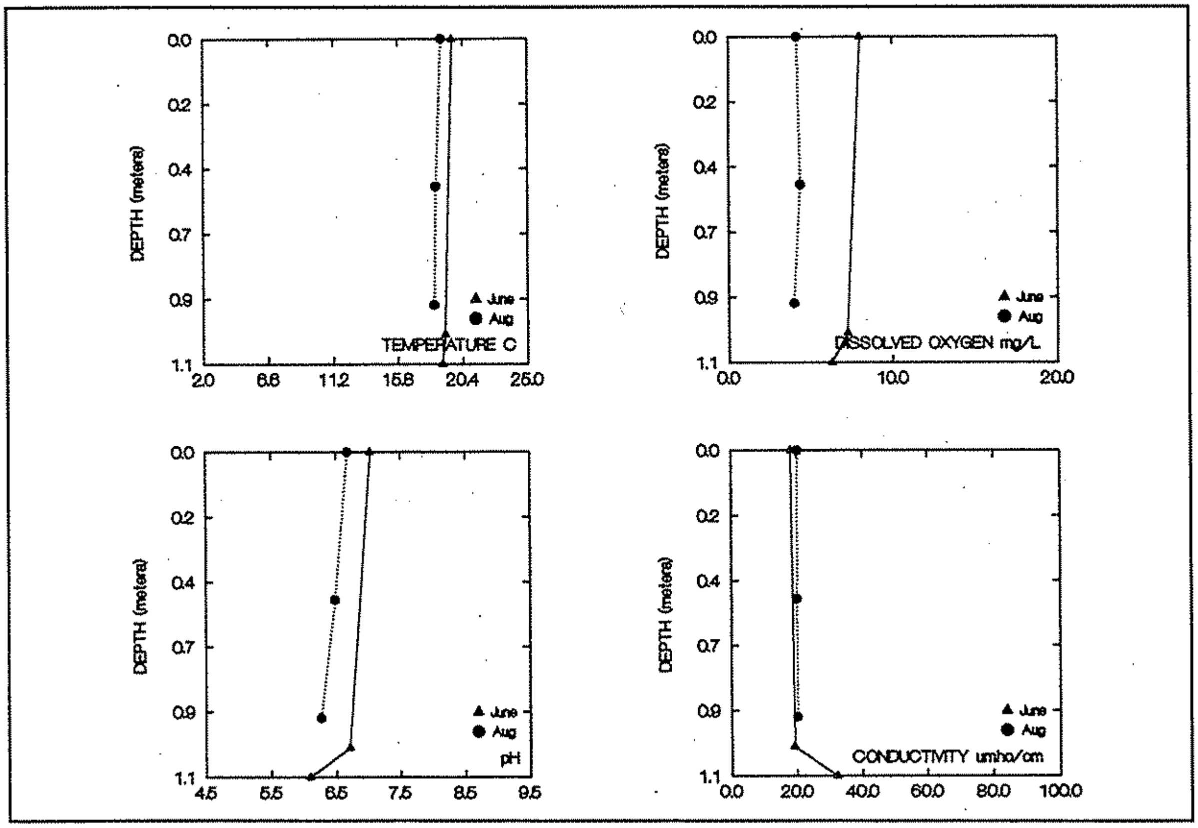
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
08/20/74[a]	27	--	--
08/10/75[b]	33	--	2.9
09/10/75[b]	31	--	6.3

a. Bortleson *et al.* (1976)
b. Dion *et al.* (1980)

CHAMBERS LAKE (THURSTON COUNTY)



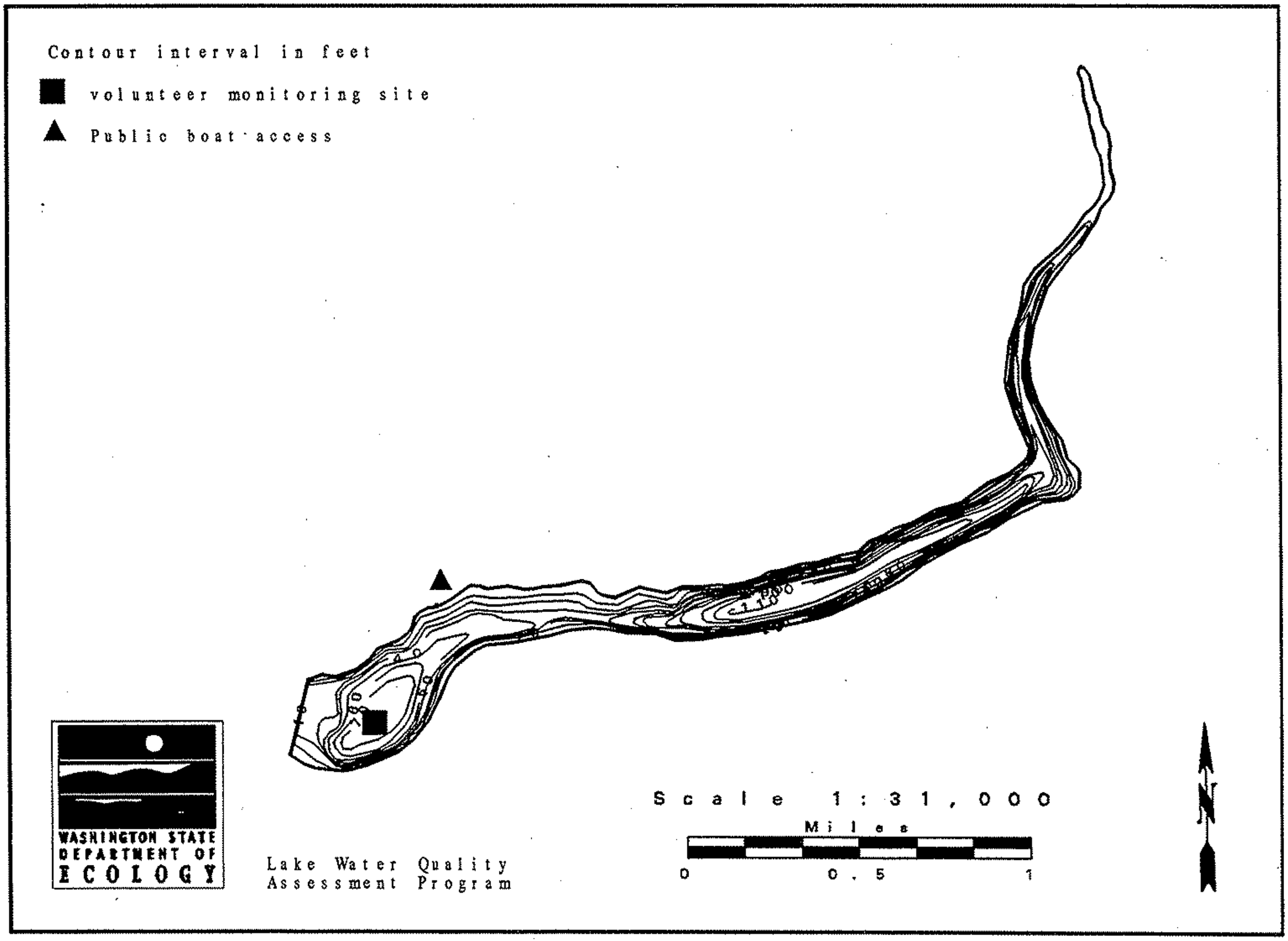


1993 Secchi Depth and Profile Data Graphs

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 enters Conconully Lake just above the dam. The lake drains south via Salmon Creek to Conconully Reservoir. Before Salmon Creek was dammed, 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



Overall Assessment

Conconully Lake had very good water clarity at the open-water monitoring site, and the volunteer did not report any water quality problems in the lake. Despite these, the lake was assessed as mesotrophic, based on the moderately high concentrations of total phosphorus, visible colonies of blue-green algae, and very low concentrations of dissolved oxygen and presence of hydrogen sulfide in the lower layer of water.

The lake was added to the monitoring program in 1992, and was characterized in 1992 as meso-eutrophic because of high phosphorus concentrations, very low oxygen concentrations, and water quality problems reported by the volunteer. Based on 1993 data, the lake was characterized as mesotrophic. There are not enough data available to determine whether this really represents a change in water quality in Conconully Lake. However, the volunteer noted that there was more water in the lake in 1993, which possibly resulted in better water quality. Water quality trends in the lake may be evaluated when at least three more years of data are collected.

A milfoil, possibly Eurasian watermilfoil (*Myriophyllum spicatum*), was growing in Conconully Lake. Eurasian watermilfoil is an aggressive non-native plant that is known to create nuisance problems in lakes and rivers. People using Conconully Lake should be advised to carefully clean their boats (or jet skis), boat trailers, and fishing gear, before using them in other lakes. This precaution will prevent spreading the milfoil to other water bodies. In 1994, Ecology staff will collect plant samples from Conconully Lake, and determine whether the milfoil is Eurasian watermilfoil.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
Secchi depths in 1993 ranged from 15.0 to 32.0 feet. These readings indicate good water clarity.

Total Phosphorus
The total phosphorus concentration was high in May (28 µg/L), but was lower in August (14 µg/L). Concentrations from 12 µg/L to 24 µg/L in the upper layer of water (the epilimnion) are typical of mesotrophic lakes, and can cause moderately high densities of algae.

As in 1992, phosphorus concentrations in the lower layer of water (the hypolimnion) were much higher than they were in the upper layer, suggesting that phosphorus may have been released from the sediments into the water column (see Profile Data, below).

Total Nitrogen
Concentrations of total nitrogen were moderately high on both sampling dates, although the concentrations were low in comparison to other lakes monitored for the program. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because total nitrogen concentrations were less than 17:1 low on both sampling dates, it is likely that algae growth was not limited by phosphorus when the lake was sampled.

Profile Data
Profile data were very similar to data collected in 1992. On both 1993 sampling dates, the lake was thermally stratified. Dissolved oxygen concentrations decreased with depth in the lower layer of water, particularly during August. Because most salmonids prefer at least 4.5 mg/L dissolved oxygen and temperatures less than 20°C, trout habitat in the lake was probably restricted to depths from 6 to 10 meters, where temperatures and dissolved oxygen levels were more favorable.

Oxygen in water usually decreases when bacteria use oxygen to decompose algae and aquatic plants in bottom water and sediments. Very low oxygen concentrations are often associated with other reactions, such as phosphorus being released from sediments into the water column and the formation of hydrogen sulfide. Both of these occurred during August 1993 and August 1992. The water sample collected from the bottom of the lake (20 meters in 1993, and 18 meters in 1992) smelled of hydrogen sulfide, which is produced by bacteria in the absence of oxygen. Hydrogen sulfide production (which results in a "rotten-egg" smell) occurs mainly in eutrophic lakes.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. The concentrations of chlorophyll *a* on both sampling dates indicated moderately high densities of algae. The field notes from May state that "large algae clumps were visible throughout the upper water column." In August, blue-green algal colonies (*Aphanizomenon* and possibly *Anabaena*) were observed by Ecology staff. Blue-green algae are common during late summer, but large colonies usually indicate high nutrient concentrations as well as favorable weather conditions (warm and calm water) for growth. Chlorophyll *a* concentrations from 2.4 µg/L to 6.6 µg/L are typical for mesotrophic lakes.

Aquatic plants identified by Ecology staff during the 1993 sampling visits included Eurasian watermilfoil (*Myriophyllum spicatum;* although the identification needs verification), coontail (*Ceratophyllum demersum*), waterweed (*Elodea canadensis*), Illinois pondweed (*Potamogeton illinoensis*), *Nitella*, and muskgrass (*Chara*). Milfoil growth was not heavy.

In 1992, the blue-green alga *Anabaena* was present in the lake during both the May and August onsite sampling visits. In May, though, the algae was localized nearshore and the chlorophyll concentration from the sampling site was low. *Anabaena circinalis* was observed in an algae sample collected in August 1992.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires completed in 1992 and 1993.

> 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 in 1993. Currently, the watershed is being logged and used for crop agriculture and animal grazing/feeding. The lakeshore is also being developed further for residences. In the past, the watershed was logged and mined, and used for animal grazing/feeding.
>
> There are approximately 50 houses on the lakeshore, and all the houses are connected to a sewer. About four culverts/stormdrains drain into the lake. There is no lake association for the lake, and no lake management activities occurred in 1993.
>
> Overall, the volunteer found that Conconully Lake had excellent water quality. There were no water quality problems in the lake in 1993, but gas powered motor boats may be a potential source of problems. In comparison to the 1992 monitoring season, there was more water in the lake, and the lake was clearer. (In 1992, the volunteer noted that the lake had fair water quality, and problems in the lake included aquatic plants, low water level, impaired fisheries, degraded water quality, and degraded aesthetics.)

Acknowledgment

I thank Lee Moore for volunteering his time to monitor Conconully Lake during 1992-1993.

Conconully Lake -- Okanogan County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	34
Mean Trophic State Index (Total Phosphorus):	47
Mean Trophic State Index (Chlorophyll *a*):	47

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
27-May	1200	19.0	66.2	15.0		lt-green	10			Water color 126, light olive.
20-Jun	1030	20.0	68.0	32.0			0		breezy	Water color 133 chartreuse. Algae clearing.
10-Jul		20.0	68.0	19.0			0			Water color 171. Data given to Dave during onsite visit.
04-Aug	1520	22.0	71.6	17.0			25	none	breezy	Water color apple green.
07-Aug		20.0	68.0	17.0			0			Water color 171. Data given to Dave during onsite visit.
24-Aug	0900	19.0	66.2	15.0			50	trace	calm	Water color apple green.
22-Sep	1300	17.0	62.6	18.0			0	trace	light	Water color apple green.

1 Trophic State Indices calculated from Carlson (1977).

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/27	0.0	19.2	8.5	10.3	172
	1.0	18.4	8.5	10.4	173
	2.0	18.0	8.6	10.5	171
	3.0	18.0	8.6	10.5	171
	4.0	16.8	8.5	10.3	172
	5.0	15.9	8.5	10.3	174
	6.0	12.9	8.4	10.5	186
	7.0	9.2	8.2	9.1	193
	8.0	7.7	8.1	7.1	192
	10.0	6.5	8.0	4.6	193
	12.0	6.0	7.9	3.8	194
	14.0	5.8	7.8	3.1	194
	16.0	5.4	7.8	1.3	195
	18.0	5.1	7.7	0.3	196
	20.0	4.9	7.7	0.2	200
08/24	0.0	19.5	8.8	8.5	168
	2.0	19.6	8.8	8.4	168
	4.0	19.5	8.8	8.4	168
	5.0	19.4	8.7	8.4	168
	6.0	19.4	8.7	8.3	168
	7.0	19.3	8.7	8.1	168
	8.0	17.9	8.3	5.2	174
	9.0	16.2	8.0	3.2	177
	10.0	14.4	7.9	1.9	183
	12.0	8.8	7.8	0.5	202
	14.0	7.6	7.7	0.5	202
	16.0	6.4	7.6	0.2	204
	18.0	6.0	7.5	0.1	208
	20.0	5.6	7.4	0.1	210
	22.0	5.5	7.4	0.1	212
	24.0	5.4	7.3	0.1	214

1993 Onsite Visit Data - Water Chemistry

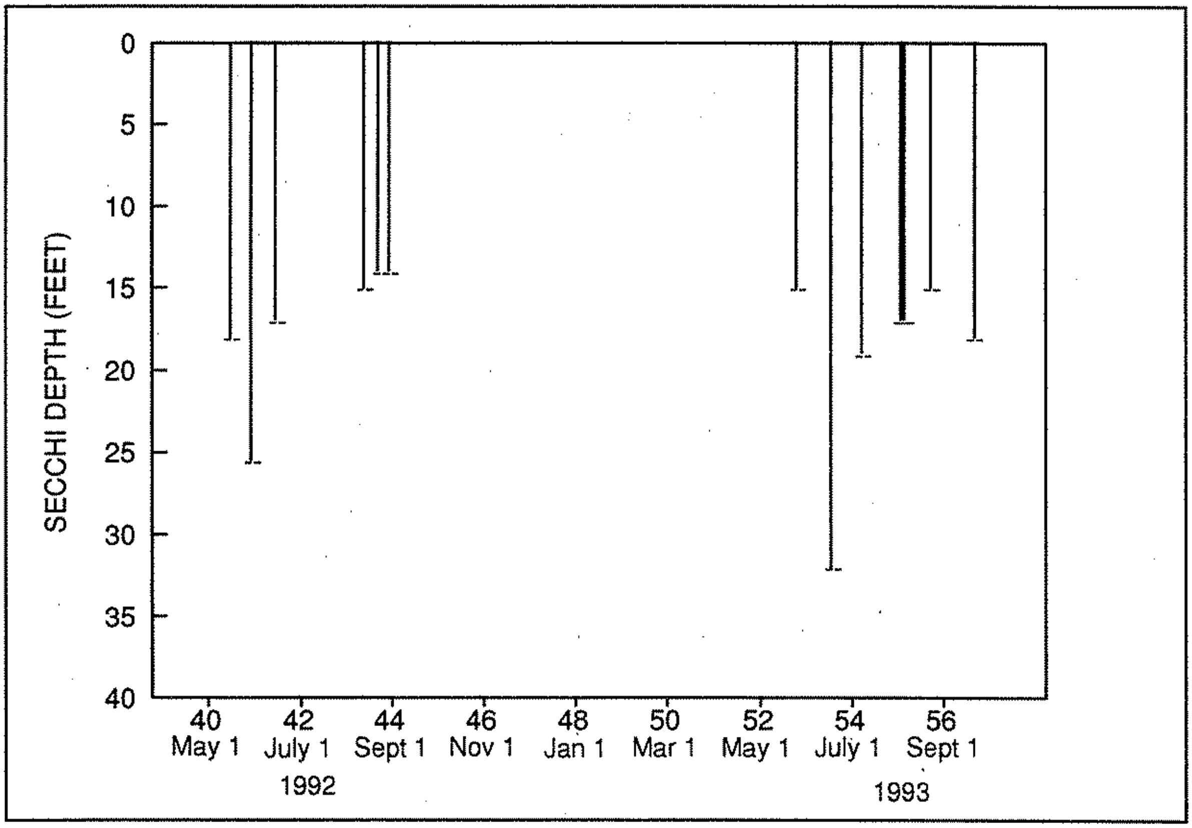
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 27							
Epilimnion	28	0.45	4.0	--	--	--	--
Hypolimnion	93	0.30	--	--	--	--	--
August 24							
Epilimnion	14	0.23	6.6	--	--	--	--
Hypolimnion	96	0.45	--	--	--	--	--

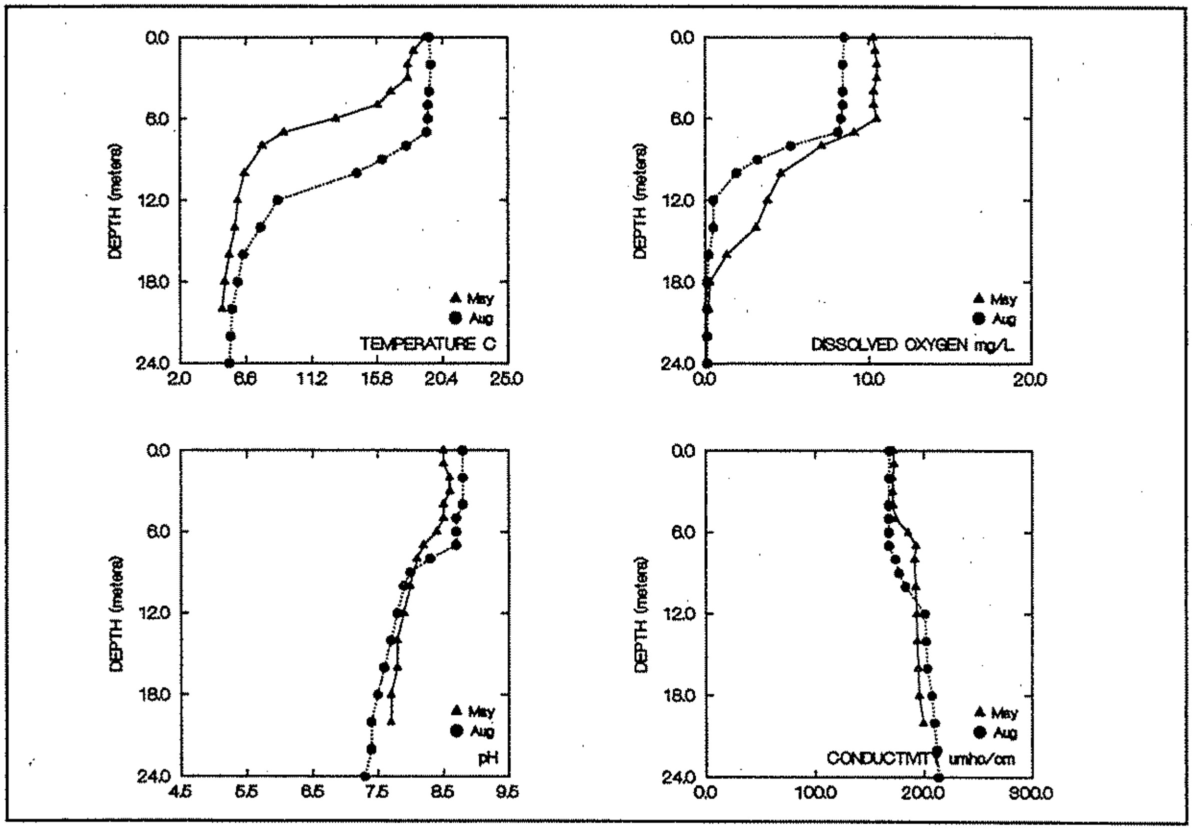
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/16/74[a]	19	--	--
05/18/92[b]	32	0.31	0.8
08/31/92[b]	24	0.33	5.3

a. Dion *et al.* (1976)
b. Rector (1993)

CONCONULLY LAKE (OKANOGAN COUNTY)





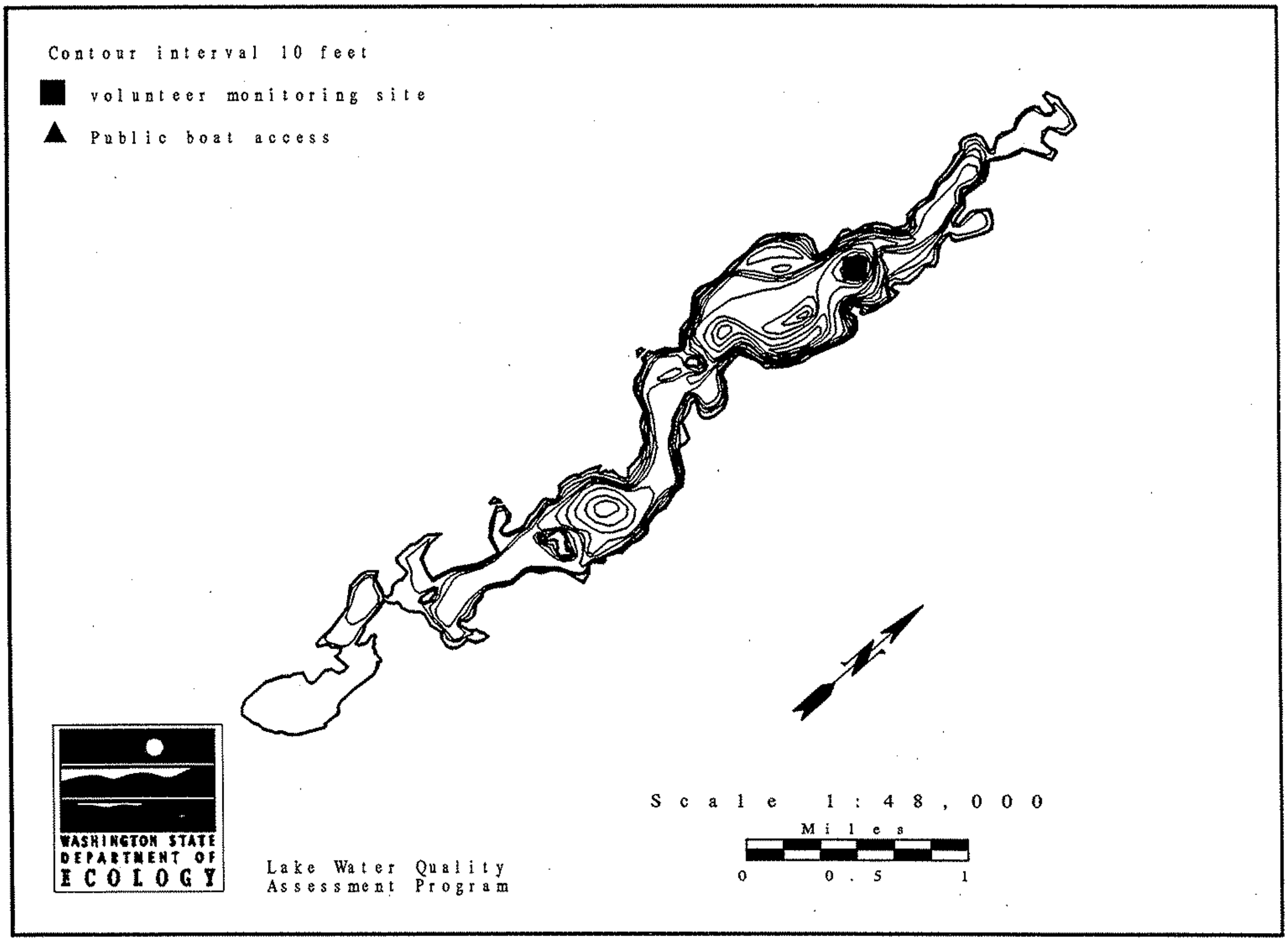
1993 Secchi Depth and Profile Data Graphs

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.

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

Data From Dion *et al.* (1976)



Overall Assessment

In 1993, Curlew Lake exhibited both mesotrophic and eutrophic characteristics, so it was classified as meso-eutrophic. Mesotrophic characteristics were the moderately deep Secchi depths, and moderately high concentrations of total phosphorus and chlorophyll *a*. Eutrophic characteristics were the extremely low concentrations of dissolved oxygen, and the presence of hydrogen sulfide, in the lower layer of water. From 1989-1992, water clarity at the open-water sampling site was very good, and better than would be expected given the moderately high nutrient concentrations.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

In 1993, Secchi depths ranged from 9.0 feet to 22.0 feet. Although Secchi depths in 1993 were not as deep as in the four previous years, there was not a statistically significant trend in water clarity from 1989-1993.

Total Phosphorus

The concentration of total phosphorus in the upper layer of water (the epilimnion) was moderately high during May (24 µg/L), but was much lower during August (11 µg/L). Concentrations from 12 µg/L to 24 µg/L are typical of mesotrophic lakes.

Suspended sediments in the water following lake thaw and spring turnover could have caused the May concentration to be much higher than the August concentration. A similar pattern of higher phosphorus in spring than in late summer was also found in 1992, and solids samples collected in 1992 indicated that the suspended sediment concentration was higher in May 1992 than in September 1992. Solids samples were not collected in 1993.

Concentrations of phosphorus were high in the lower layer of water (the hypolimnion), particularly during August. It is likely that phosphorus was released from the sediments into the water column (known as "internal loading"). Internal loading can occur when dissolved oxygen concentrations are depleted near the lake bottom, allowing phosphorus, iron, and other compounds to be chemically reduced and released from the sediments into the water column. Higher conductivity values near the lake bottom (See Profile Data) also indicate that internal loading may have occurred.

Total Nitrogen

Total nitrogen concentrations were moderately high on both sampling dates, and were similar to concentrations measured in 1991 and 1992. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. In May, the ratio of total nitrogen to total phosphorus was less than 17:1 (16:1), so algal growth may have been nitrogen limited in May. In August, the ratio of total nitrogen to total phosphorus was 39:1, so it is likely that algal growth was not limited by nitrogen when the lake was sampled in August.

Profile Data

The lake was strongly stratified on both sampling dates. Below the thermocline, dissolved oxygen concentrations decreased with depth in May, but were nearly depleted in the lower layer of water during August. Oxygen concentrations decrease when bacteria use oxygen as they decompose algae and aquatic plants in the bottom water and sediments. The very low oxygen in the water also resulted in the production of hydrogen sulfide near the lake bottom. Hydrogen sulfide ("rotten-egg" smell) was smelled in the 20 meter and 30 meter water samples in August 1993, and in the water sample collected at 24 meters in September 1992.

Trout generally prefer at least 4.5 mg/L dissolved oxygen and water temperatures below 20°C. As a result, trout were probably restricted to water from six to eight meters deep, where oxygen levels were higher and water temperatures were not too warm.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Concentrations of chlorophyll *a* on both sampling dates indicated moderately high densities of algae at the time of sampling.

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 observed in the lake during sampling visits in 1990 included muskgrass (*Chara*; this plant created the biggest problem in the lake according to the volunteer), 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.

Other Available Information

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).

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 1993.

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 in 1993. Lake water is withdrawn for irrigation. Currently the watershed is being logged and used for animal grazing. The lakeshore is also being developed further for residences. In the past the watershed was logged and mined, and used for animal grazing and crop agriculture. Also, the lake was dredged and the shoreline was altered.

There are 225 residences, and about 65 rental units, on the lakeshore. None of the residences are connected to a sewer. About six culverts/stormdrains drain into the lake. There is a lake association for the lake. No lake management activities occurred in 1993. 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 found that Curlew Lake had good water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, (2) swimmer's itch, (3) algae, (4) decaying plants, (5) odor from decaying algae, (6) degraded aesthetics, (7) fluctuating water level, (8) water quality gradually degraded over years, and (9) suspended sediments. Excessive weed and algae growth contributed to most of the problems. (In 1992, the worst problems were algae, and excessive and decaying aquatic plants. In 1991, the worst problems were aquatic plants, algae, and undesirable fish species.) New residential development was also noted as a problem, and potential source of problems, to the lake. There were no changes in the lake since the 1992 monitoring season.

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. In 1992, there was an increase in development, that included removal of lakeshore vegetation and wetlands. Also, a gold mine was 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. In the past, the lake was treated with chemicals to control aquatic plants 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.

Acknowledgment

I thank Marion Dammann for volunteering her time to monitor Curlew Lake during 1989-1993.

Curlew Lake -- Ferry County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	40
Mean Trophic State Index (Total Phosphorus):	44
Mean Trophic State Index (Chlorophyll *a*):	40

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
24-May				9.0			5		calm	Onsite visit. Water color pale green.
16-Jun	0830	18.3	65.0	9.0	31.50		100	moderate	light	Water color clear light green.
03-Jul	0800	18.9	66.0	12.5	33.00	green	50	light	light	
01-Aug	0800	20.0	68.0	14.5	37.00	green	0	trace	light	Floating algae.
23-Aug	1130			12.0		lt-green	75		breezy	Onsite visit.
05-Sep	0830	17.8	64.0	15.0	34.20	lt-green	0	trace	breezy	
20-Sep	0900	15.6	60.0	15.0	31.20	clear	90	light	breezy	Rain last night.
04-Oct	1000	15.6	60.0	22.0	30.24	lt-green	0	none	calm	
12-Oct	0930	13.3	56.0	20.5	28.80	lt-green	25	none	light	Profuse clouds of tiny particles swirling at about 20 foot level.

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Curlew Lake dropped 2.7" from June 16 to October 12.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/24	0.0	18.8	8.2	9.7	221
	1.0	18.6	8.3	9.7	221
	2.0	18.1	8.3	9.8	220
	3.0	16.6	8.3	9.4	217
	4.0	14.8	8.2	9.1	217
	5.0	11.2	8.2	9.2	221
	6.0	9.8	8.1	7.8	222
	8.0	7.9	8.0	4.5	228
	10.0	6.9	7.9	3.0	231
	12.0	6.5	7.8	2.1	236
	14.0	6.2	7.7	1.6	236
	16.0	6.0	7.7	1.5	237
	18.0	5.9	7.6	1.2	237
	20.0	5.7	7.6	0.9	237
	25.0	5.5	7.6	0.3	239
	29.8	5.4	7.5	0.1	250
08/23	0.0	20.9	8.9	8.2	221
	2.0	21.0	8.9	8.2	222
	4.0	20.9	8.9	8.2	222
	5.0	20.9	8.9	7.1	222
	6.0	18.6	8.5	6.0	231
	7.0	11.0	8.0	2.0	245
	8.0	9.5	7.8	0.3	245
	10.0	7.7	7.7	0.1	245
	12.0	7.2	7.7	0.1	246
	14.0	6.8	7.6	0.1	246
	16.0	6.7	7.6	0.1	246
	18.0	6.5	7.6	0.1	247
	20.0	6.4	7.5	0.1	247
	25.0	5.9	7.5	0.1	251
	30.0	5.6	7.5	0.1	256

1993 Onsite Visit Data - Water Chemistry

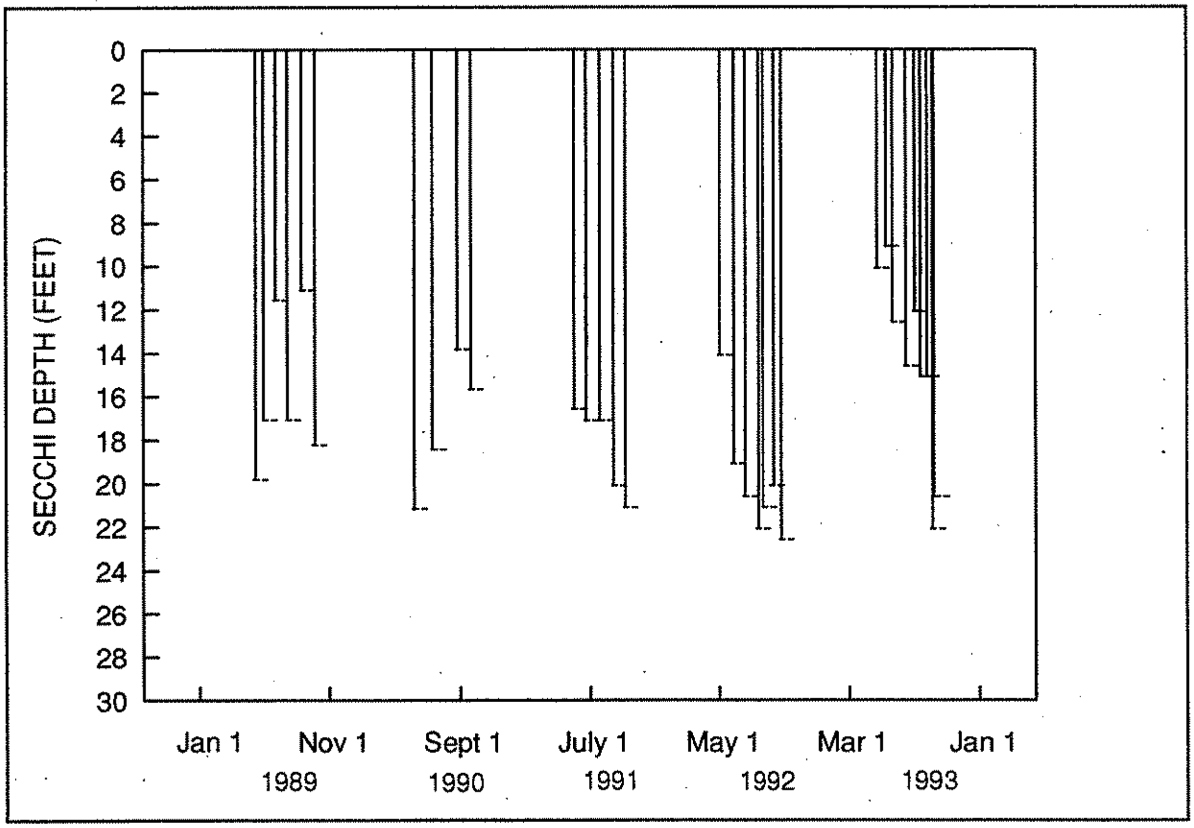
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL)	
						Site #1	Site #2
May 24							
Epilimnion	24	0.38	3.3	--	--	--	--
Hypolimnion	59	0.52	--	--	--	--	--
August 23							
Epilimnion	11	0.43	2.1	--	--	--	--
Hypolimnion	143	0.66	--	--	--	--	--

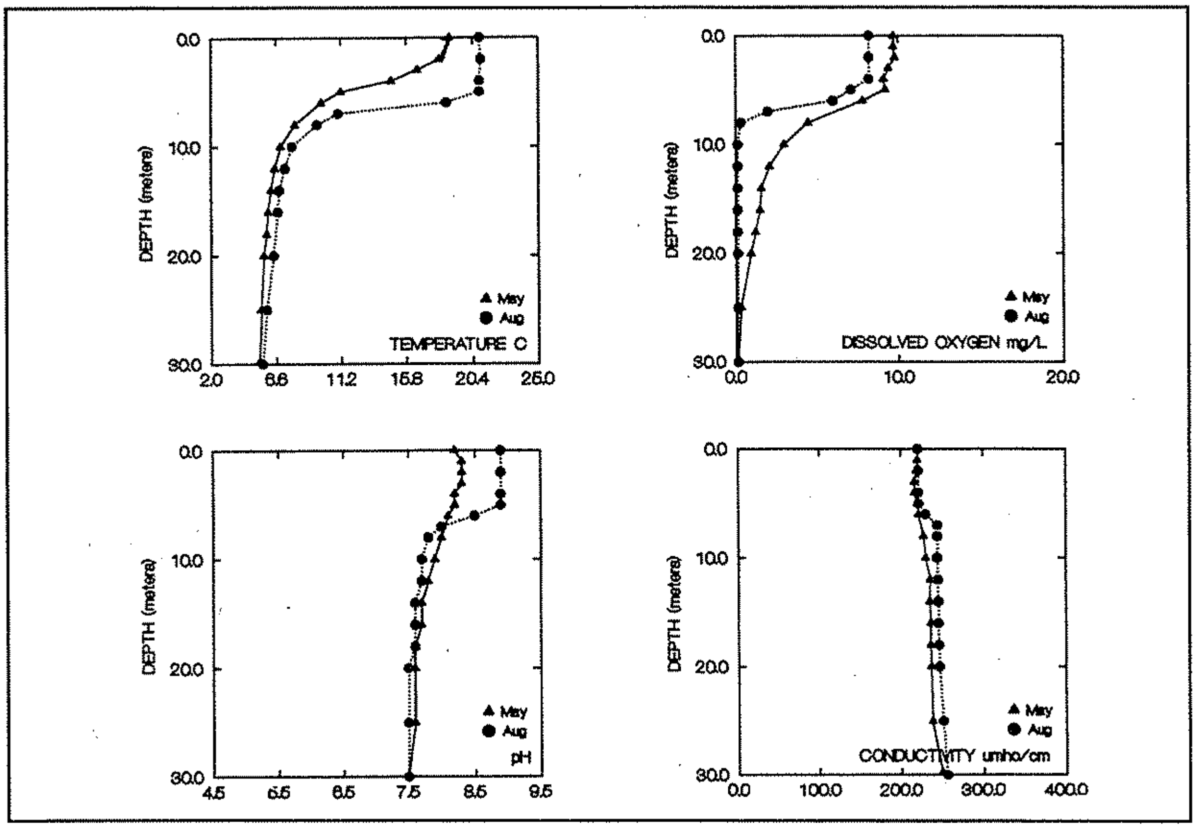
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/13/74[a]	22	--	--
07/15/81[b]	20	--	2.4
09/13/90[c]	15	0.60	--
06/26/91[d]	--	0.40	--
05/20/92[e]	39	0.47	0.4
09/09/92[e]	13	0.44	1.1

a. Dion *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)
e. Rector (1993)

CURLEW LAKE (FERRY COUNTY)



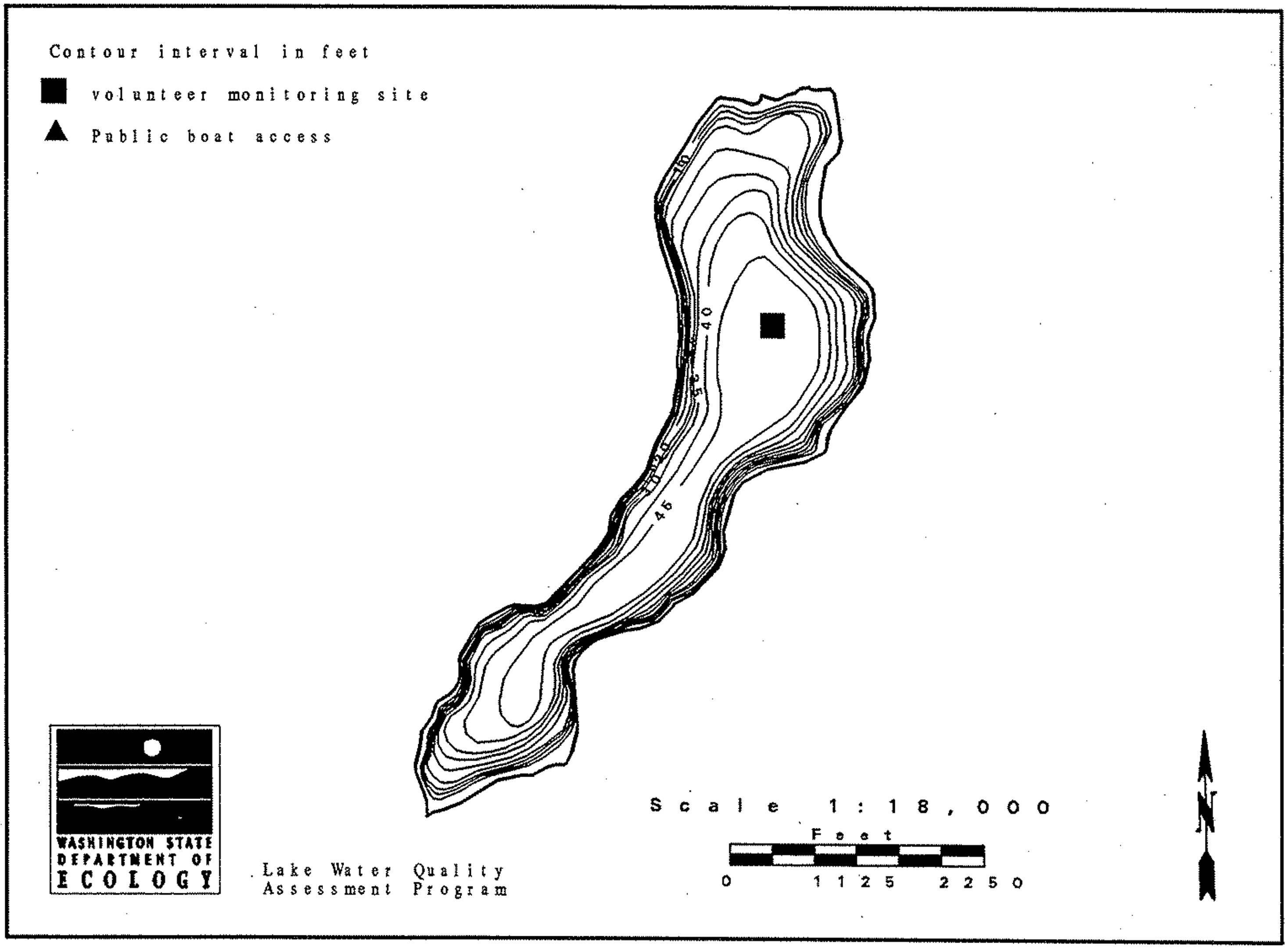


1993 Secchi Depth and Profile Data Graphs

Deep Lake -- Stevens County

Size (acres)	210
Maximum Depth (feet)	49
Mean Depth (feet)	34
Lake Volume (acre-feet)	7,203
Drainage Area (miles^2)	48.1
Altitude (feet)	2,025
Shoreline Length (miles)	3.5

Data from Dion *et al.* (1976)



Overall Assessment

In 1993, Deep Lake was described as oligo-mesotrophic, because it exhibited both oligotrophic and mesotrophic characteristics. Oligotrophic characteristics were good water clarity throughout most of the monitoring season, and had low nutrient concentrations and low algal density in August. Mesotrophic characteristics were the moderately high nutrient concentrations and a moderately high amounts of algae in May, and on both sampling dates there were very low concentrations of dissolved oxygen in the lower layer of water.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was very good, as indicated by Secchi depths that ranged from 22.0 feet to 26.3 feet.. Secchi depths deeper than 13.0 feet are typical for oligotrophic lakes.

Total Phosphorus

The amount of algae that can grow in a lake will depend on the concentration of total phosphorus in the upper layer of water (the epilimnion). The concentration of total phosphorus in Deep Lake was moderately high during May (21 µg/L), yet very low during August (6 µg/L). The higher concentration during May corresponded to a moderately high density of algae at the time of sampling (see Plants, below).

Six other total phosphorus samples have been collected from the lake since 1989. Except for one high value measured in May 1990 (31 µg/L), total phosphorus results ranged from 12-14 µg/L. Usually, concentrations of total phosphorus less than 12 µg/L are typical for oligotrophic lakes.

Total Nitrogen

In 1993, total nitrogen concentrations in Deep Lake were low in comparison to other lakes monitored for the program, although they were slightly higher than most concentrations measured from 1989-1992. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. In May, the ratio of total nitrogen to total phosphorus was greater than 17:1 (13:1), so it is possible that algal growth was nitrogen-limited when the lake was sampled. In August, the ratio of total nitrogen to total phosphorus was 23:1, so it is likely that algal growth was not limited by nitrogen in August.

Profile Data

The lake was stratified on both sampling dates, and both pH and dissolved oxygen concentrations decreased considerably with depth. Low oxygen concentrations in the bottom layer of water result when bacteria decompose aquatic plants and algae in the water and sediments. It is likely that low oxygen in the bottom water also affected conductivity of the water. In the absence of oxygen, iron and other compounds in sediments can be released into the water column, causing an increase in conductivity. There are no pH data from May because there was a problem with the probe at the time of sampling.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. The concentration of chlorophyll *a* in May (3.4 µg/L) indicated a moderately high density of algae at the time of sampling. In August, algal density was low, as indicated by the low concentration of chlorophyll *a* (1.6 µg/L). Chlorophyll *a* concentrations from 0.0 µg/L to 2.4 µg/L are typical for oligotrophic lakes.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire. Information on lake and watershed uses are from a different volunteer's responses to the 1989 questionnaire.

> Deep Lake is used for fishing, swimming, boating, jet skiing, lakeshore camping, and waterfowl hunting. There is one resort and two boat ramps on the lakeshore. No fish were stocked in the lake in 1993.
>
> There are approximately 25 houses on the lakeshore, and none are connected to a sewer collection system. The volunteer did not know if there was an organization for the lake, or whether lake water was withdrawn for any uses. No lake management activities occurred in 1993. Currently, the watershed is being logged, and is used for crop agriculture and animal grazing. The lakeshore is also being developed further for residences. In the past, the watershed was logged and mined.
>
> Overall, the volunteer found that Deep Lake had excellent water quality. There were no water quality problems in the lake in 1993, although old septic systems present a potential for problems.
>
> There is a wetland at the south end of the lake near the outlet. Aquatic plants are especially thick in the shallow areas at the north and south ends of the lake. The 1989 volunteer noted that cattle grazing close to the lake and near the inlet tributary were sources of problems to the lake.

Acknowledgement

I thank Jim Wiese for volunteering his time to monitor Deep Lake during 1993.

Deep Lake -- Stevens County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	32
Mean Trophic State Index (Total Phosphorus):	39
Mean Trophic State Index (Chlorophyll *a*):	39

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
17-May				9.6		Green	0		Calm	
03-Jun	1300	17.8	64.0	26.3		Green	25	Moderate	Calm	
18-Jun	1000	16.7	62.0	24.5		Green	25	Light	Calm	
24-Jul	1015	14.4	58.0	22.0		Green	75	Heavy	Breezy	The weather at the lake has been miserable for some time.
18-Aug	1100	20.0	68.0	23.0		Green	75	Moderate	Calm	Nice day.

1 Trophic State Indices calculated from Carlson (1977).
2 "Lake height" refers to change in water level. The volunteer did not measure lake height in 1993.

Deep Lake -- Stevens County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/17	0.0	17.6	.	9.9	304
	2.0	14.0	.	10.5	304
	4.0	12.5	.	10.3	316
	6.0	8.3	.	6.7	372
	8.0	6.0	.	2.9	380
	10.0	5.6	.	1.5	384
	12.0	5.3	.	0.9	386
08/18	0.0	19.7	8.6	8.6	302
	1.0	19.3	8.5	8.5	302
	2.0	19.3	8.4	8.5	302
	3.0	19.2	8.4	8.5	302
	4.0	17.6	8.3	8.0	316
	5.0	16.8	8.1	6.4	336
	6.0	14.9	7.9	6.7	362
	7.0	11.9	7.7	0.8	388
	8.0	9.4	7.7	0.3	400
	9.0	8.0	7.6	0.2	400
	10.0	7.2	7.6	0.2	400
	12.0	6.3	7.5	0.1	406

Deep Lake -- Stevens County

1993 Onsite Visit Data - Water Chemistry

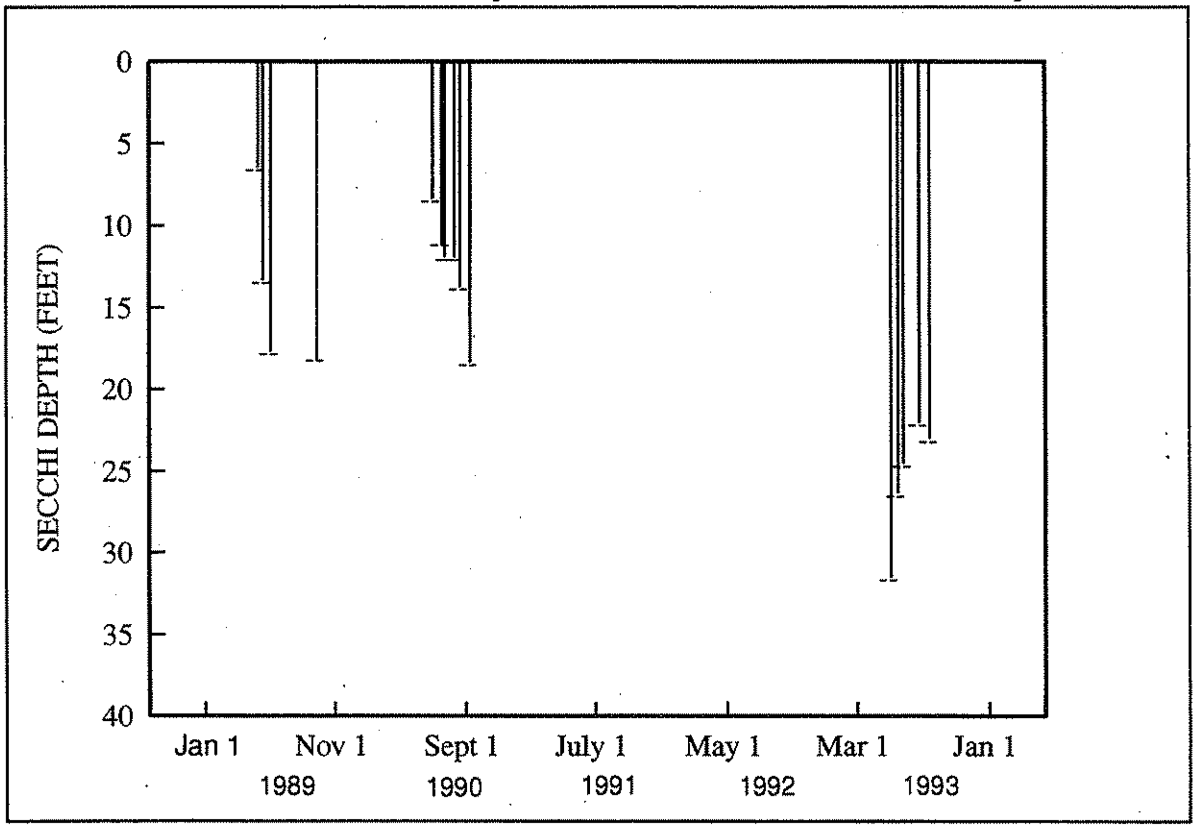
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 17							
Epilimnion	21	0.28	3.4	--	--	--	--
Hypolimnion	26	0.30	--	--	--	--	--
August 18							
Epilimnion	6	0.14	1.6	--	--	--	--
Hypolimnion	18	0.20	--	--	--	--	--

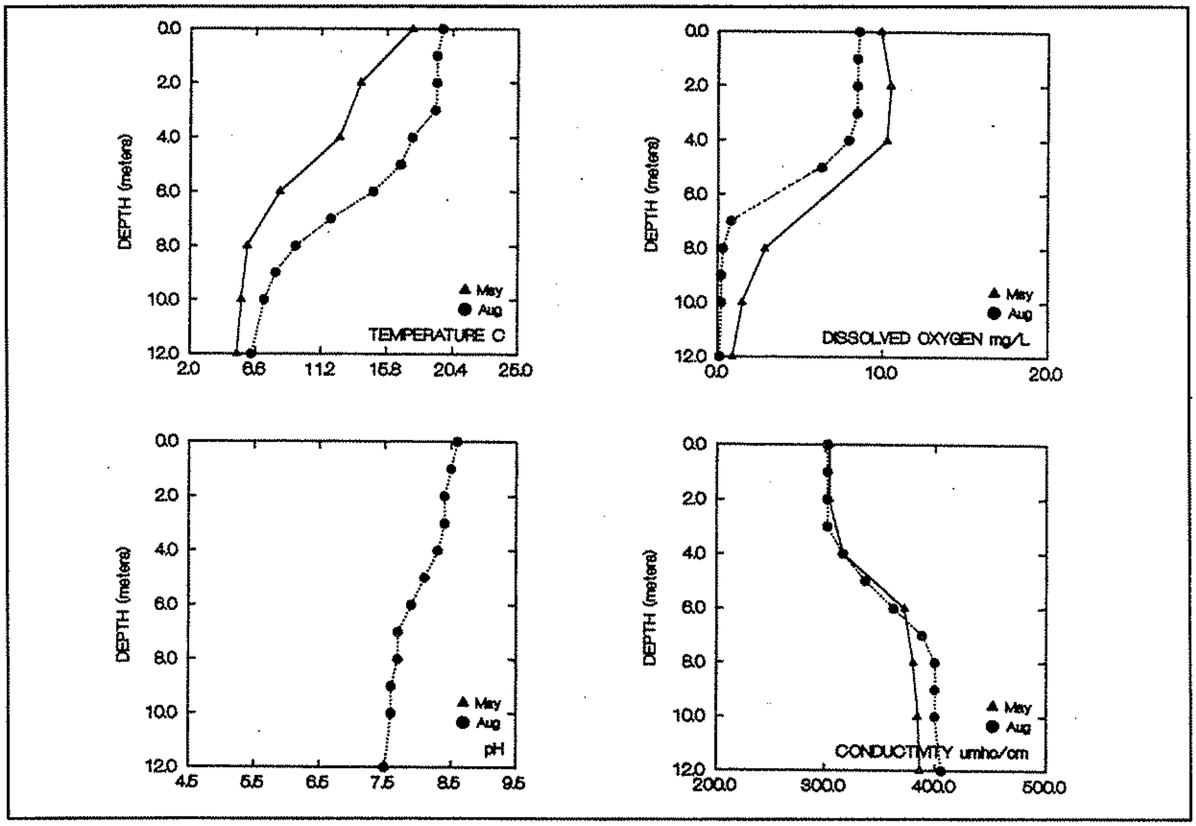
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/12/74[a]	11	--	--
06/20/89[b]	13	0.15	2.6
09/19/89[b]	12	0.28	3.4
05/25/90[c]	31	0.31	--
09/12/90[c]	13	0.23	--
06/14/91[d]	--	0.13	--
05/19/92[d]	14	0.20	0.9
09/01/92[d]	14	0.18	1.5

a. Dion *et al.* (1976)
b. Brower and Kendra (1990)
c. Rector (1991)
d. Washington's Citizen Lake Monitoring Program (unpublished data)

DEEP LAKE (STEVENS COUNTY)





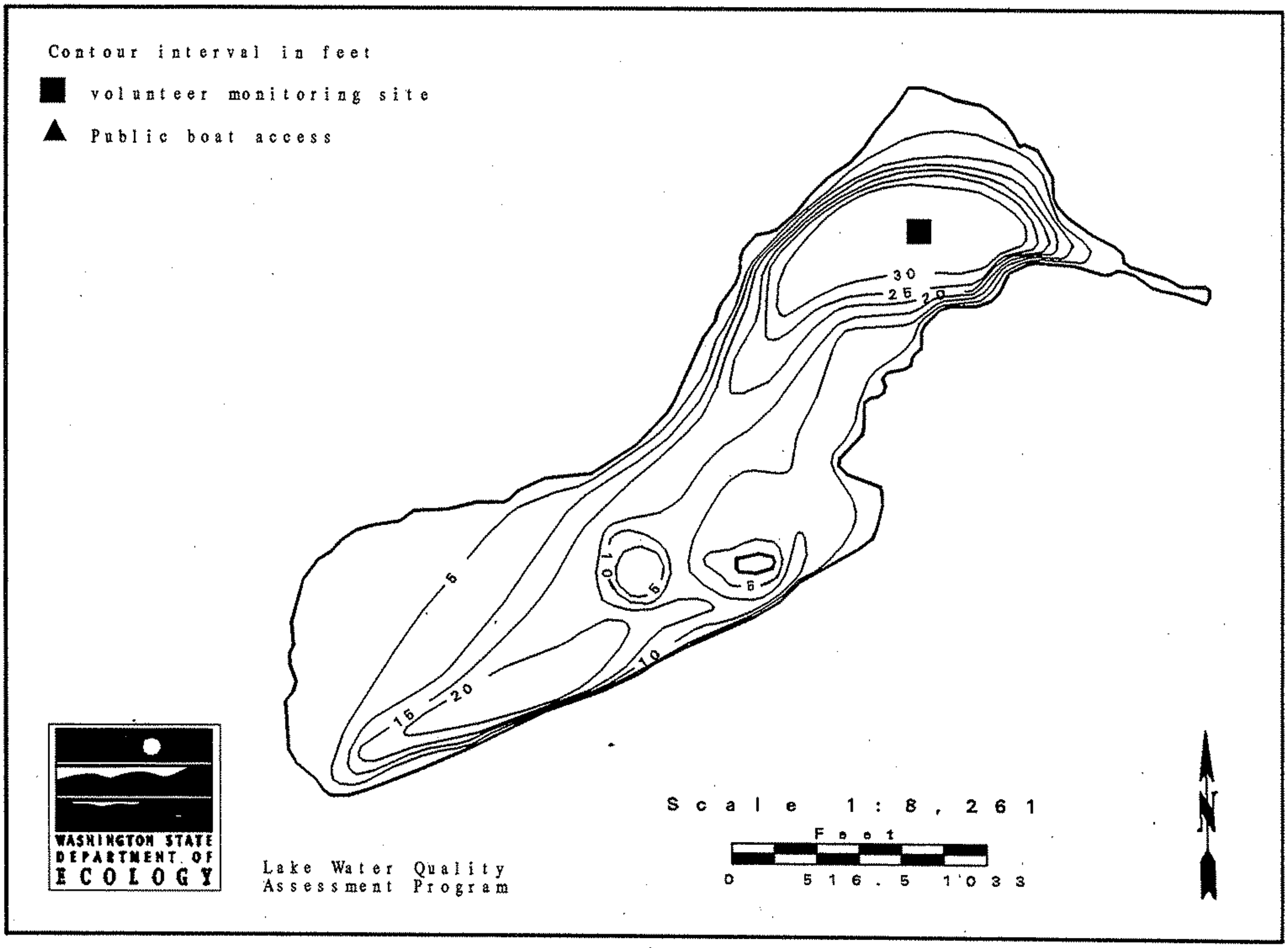
1993 Secchi Depth and Profile Data Graphs

Lake Ellen -- Ferry County

Lake Ellen is located 14 miles north of Inchelium. It is fed primarily by springs.

Size (acres)	77.8
Maximum Depth (feet)	34
Mean Depth (feet)	*
Lake Volume (acre-feet)	*
Drainage Area (miles^2)	*
Altitude (feet)	2,300
Shoreline Length (miles)	*

Data From Wolcott (1973), other data not available



Overall Assessment

Most lakes monitored for the program were sampled previously by Ecology in the 1970s. However, Lake Ellen was sampled by Ecology for the first time in 1993.

In 1993, Lake Ellen exhibited both oligotrophic and mesotrophic characteristics, so it was described as oligo-mesotrophic. Oligotrophic characteristics include very good water clarity, low nutrient concentrations, and low amounts of aquatic plants and algae. Mesotrophic characteristics include low concentrations of dissolved oxygen in the lower layer of water, and it appeared that internal loading of phosphorus from the sediments occurred.

The volunteer reported that grazing animals had direct access to the lakeshore or its inlet tributaries. To protect the lake, grazing animals should be fenced away from surface water. Best Management Practices for controlling agricultural pollution are addressed by Conservation Districts in cooperation with Ecology's regional offices.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was good, as indicated by Secchi depths which ranged from 13.0 feet to 20.0 feet. Secchi depths greater than 13.0 feet indicate good water clarity.

Total Phosphorus
Concentrations of total phosphorus were low on both sampling dates (9 µg/L in May, and 6 µg/L in August).

Although there were low concentrations of phosphorus in the upper layer of water, in August there was a high concentration of phosphorus in the lower layer of water. Phosphorus was probably released from the sediments into the water column during late summer when oxygen concentrations near the lake bottom were very low (see Profile Data, below). Because there are no houses on the lakeshore, the most likely sources of phosphorus into the lake, in addition to natural sources, include agricultural runoff from grazing animals and logging within the watershed.

Total Nitrogen
Total nitrogen concentrations were moderately high on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 (53:1 in May, and 72:1 in August), it is likely that algal growth was not limited by nitrogen.

Profile Data

In May, the lake was weakly stratified with respect to temperature. Dissolved oxygen concentrations increased with depth from one to four meters, most likely because of the decrease in water temperature at these depths. Cooler water holds more oxygen, because dissolved gases are more soluble in cool water than in warm water. There are no pH data for May because the pH sensor on the probe was not working properly.

In August, the lake was strongly stratified. Below the thermocline, both pH and dissolved oxygen decreased with depth. Both parameters will decrease because bacteria use oxygen from the water when decomposing aquatic plants and algae in the bottom water and sediments.

Conductivity, which measures the ability of the water to conduct an electrical current, depends on the ion content of the water. Below the thermocline, oxygen concentrations were low and conductivity of the water increased with depth. This may indicate that iron, phosphorus, and other compounds in the sediments were chemically reduced and released into the water column. As noted above, phosphorus concentrations in August were much higher in the lower layer of water than in the upper layer, suggesting that compounds could have been released from the sediments into the water column.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Concentrations of chlorophyll *a* were low on both sampling dates indicated low densities of algae when the lake was sampled.

There was a "cattail marsh" (*Typha* sp.) in a shallow embayment on the east side of the lake at the campground. Other aquatic plants identified by Ecology staff in the marshy area include white-flowering water lily (*Nymphaea odorata*), largeleaf pondweed (*Potamogeton amplifolius*), berchtold's pondweed (*Potamogeton berchtoldii*), floatingleaf pondweed (*Potamogeton natans*), slender naiad (*Najas flexilis*), smartweed (*Polygonum amphibium*), cinquefoil (*Potentilla* sp.), waterplantain (*Alisma plantago-aquatica*), and muskgrass (*Chara*). Cattails, muskgrass, and naiad were the most abundant plants in the lake during August.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire.

> Lake Ellen is used for fishing, swimming, rowing, lakeshore camping, and waterfowl hunting. There is one boat ramp on the lakeshore, and there are no restrictions for motor boat use on the lake. Trout were stocked in the lake in 1993. Currently, the watershed is being logged and used for animal grazing, and grazing animals have direct access to the lakeshore or inlet tributaries.

There are no houses on the lakeshore, and no culverts which drain into the lake. There are no organizations for the lake, no lake management activities occurred in 1993, and lake water is not withdrawn for any uses.

Overall, the volunteer found that Lake Ellen had good water quality. There were no water quality problems in the lake, although litter and petrochemicals from gas motors present a potential for problems. In comparison to 1992, the water level was higher in 1993.

Acknowledgement

I thank David King for volunteering his time to monitor Lake Ellen during 1993.

Lake Ellen -- Ferry County

1993 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	37
Mean Trophic State Index (Total Phosphorus):	33
Mean Trophic State Index (Chlorophyll *a*):	38

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
16-May				20.0			10			Onsite visit. Water color evergreen.
28-May	1500	21.1	70.0	19.5			100	none	light	Water color dark green.
14-Jun	1530	18.3	65.0	18.5		green	100		breezy	I was surprised to have a warmer temp reading.
07-Jul	1500	21.1	70.0	13.0	0.00	milky-gr	90	heavy	light	First measurement for lake height.
01-Aug	1700	21.1	70.0	14.0	6.00	milky-gr	0	none	calm	Very unusual for this lake to rise in July--we had about 3" rain in July.
17-Aug	1730	21.1	70.0	15.5	-2.00	lt-green	90	heavy	calm	
12-Oct	1300	13.9	57.0	20.0	-3.00	lt-green	10	trace	breezy	About a 3" drop in level.

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

[2] "Lake height" refers to change in lake level. Based on volunteer-collected data, the level of Lake Ellen dropped 3" from July 7 to October 12.

Lake Ellen -- Ferry County

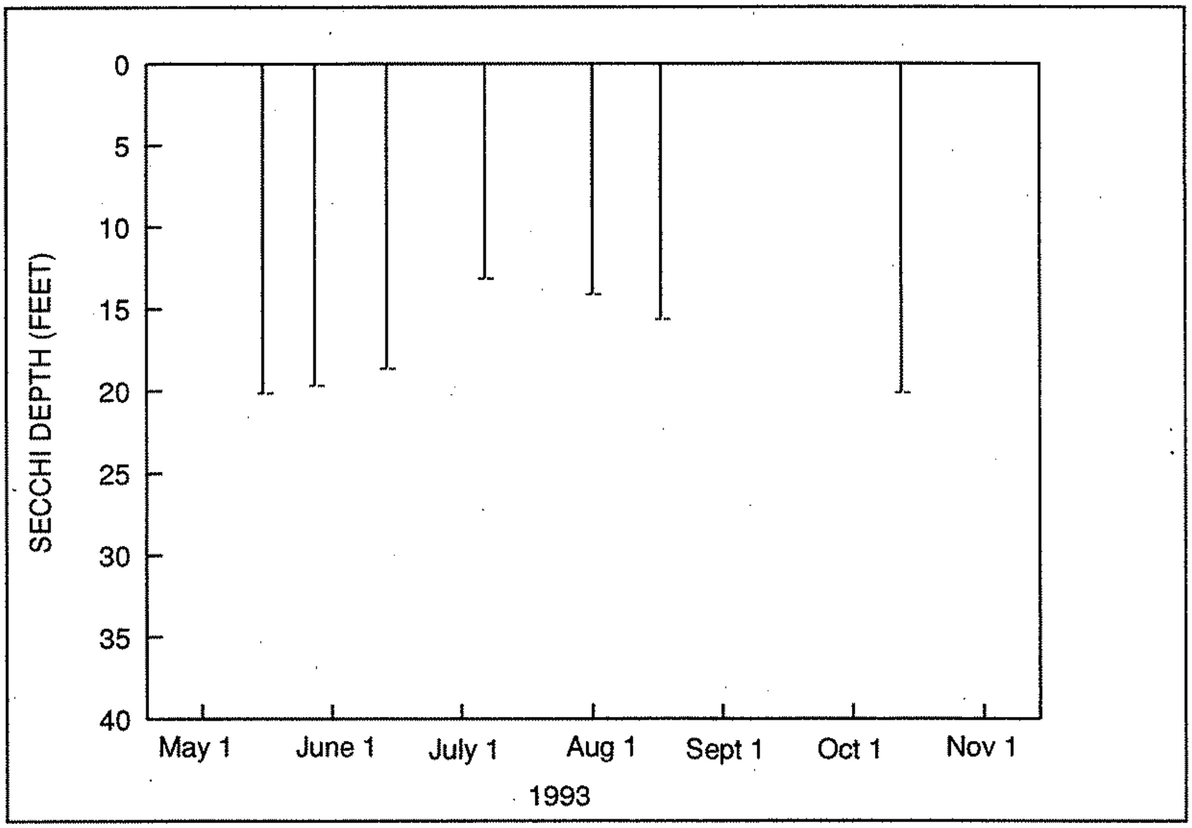
1993 Onsite Visit Data - Profile Data

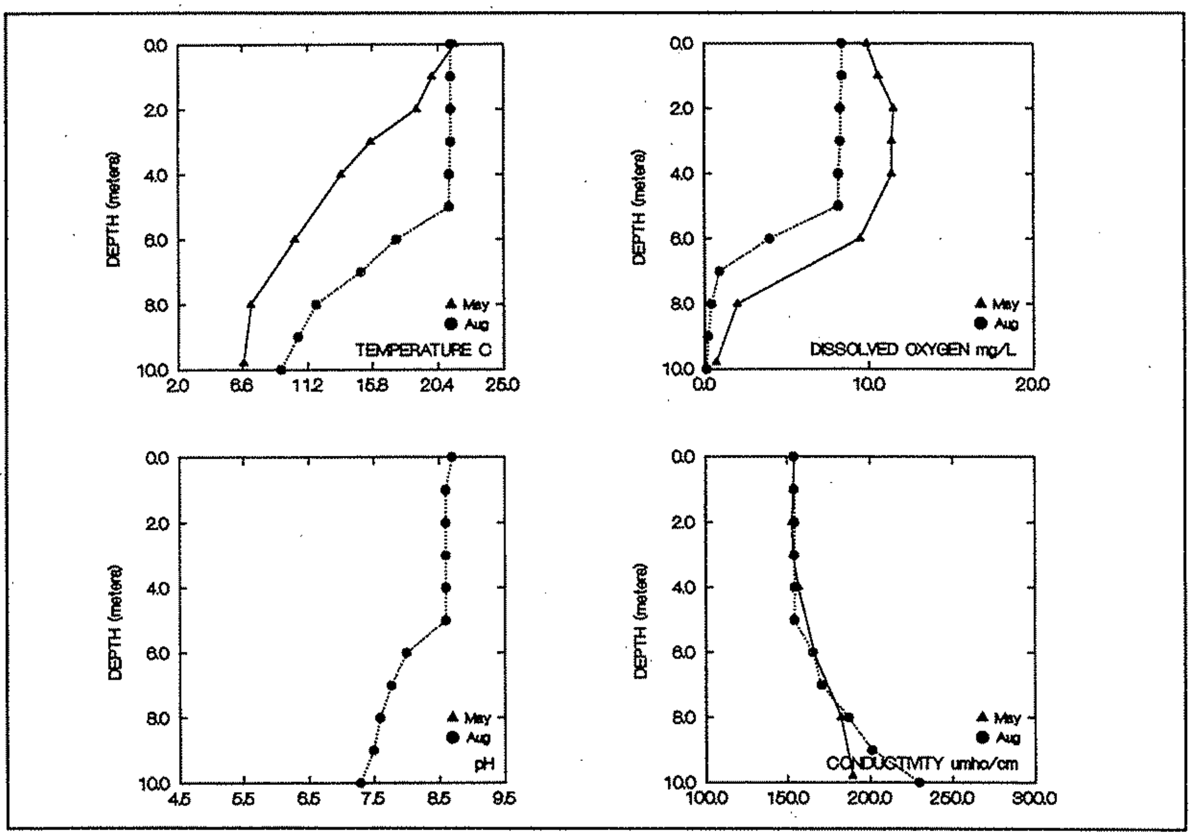
Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/16	0.0	21.6	.	9.9	154
	1.0	20.0	.	10.6	154
	2.0	18.9	.	11.5	153
	3.0	15.7	.	11.4	154
	4.0	13.6	.	11.4	157
	6.0	10.3	.	9.5	166
	8.0	7.2	.	2.0	182
	9.8	6.7	.	0.7	189
08/17	0.0	21.3	8.7	8.4	154
	1.0	21.3	8.6	8.4	154
	2.0	21.3	8.6	8.3	155
	3.0	21.3	8.6	8.3	154
	4.0	21.2	8.6	8.2	155
	5.0	21.2	8.6	8.2	154
	6.0	17.5	8.0	4.0	165
	7.0	15.0	7.8	0.9	171
	8.0	11.8	7.6	0.4	187
	9.0	10.5	7.5	0.2	201
	10.0	9.3	7.3	0.1	230

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 16							
Epilimnion	9	0.47	1.8	--	--	--	--
Hypolimnion	11	0.57	--	--	--	--	--
August 17							
Epilimnion	6	0.44	2.6	--	--	--	--
Hypolimnion	27	0.75	--	--	--	--	--

LAKE ELLEN (FERRY COUNTY)





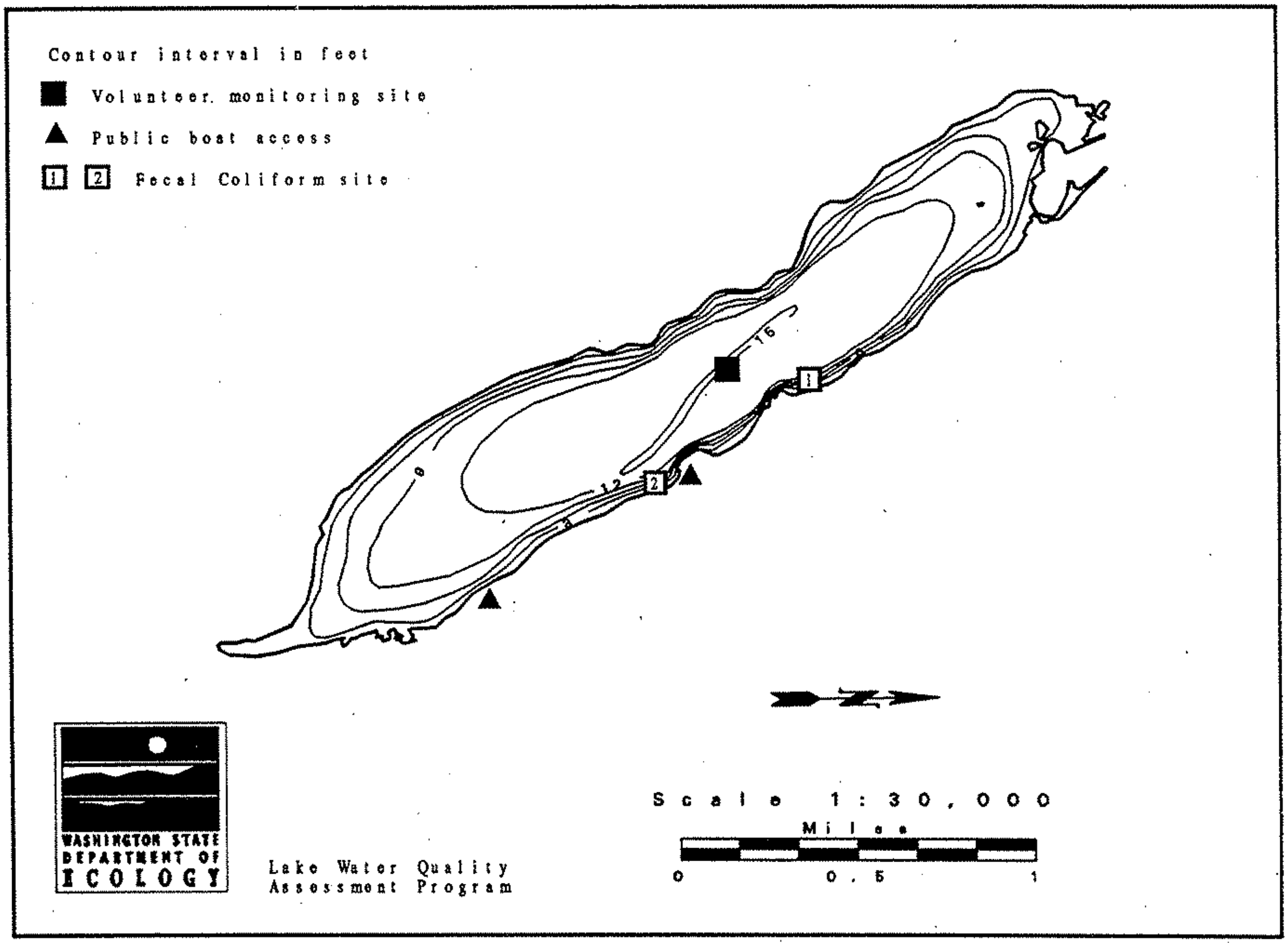
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, Lake Eloika was assessed as meso-eutrophic, because it exhibited both mesotrophic and eutrophic characteristics. Secchi depths, were in the mesotrophic range, but the high phosphorus concentrations, moderate to high amounts of aquatic plants, and the high amount of algae during August were eutrophic characteristics.

Aquatic plant problems in Lake Eloika result because the lake is shallow and has thick, nutrient-rich sediments which are optimal for growing rooted plants (Soltero *et al.*, no date). Construction of a water level control dam has been proposed to maintain the level at the natural spring high level. Continued monitoring of Lake Eloika should eventually indicate whether water quality in the lake improves after all lake restoration and watershed controls have been implemented.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity gradually declined throughout the 1993 monitoring season; Secchi depths decreased from 10.1 feet in May, to 4.3 feet in October. Although water clarity was better in 1992-1993 than in the previous two years, there was not a statistically significant trend in water clarity from 1989-1993.

Total Phosphorus

Concentrations of total phosphorus were high on both sampling dates. The concentration during August was particularly high (55 µg/L). Total phosphorus concentrations greater than 24 µg/L are typical for eutrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were moderately high on both sampling dates (0.33 mg/L and 0.32 mg/L). However, these concentrations were low relative to the high concentrations of total phosphorus particularly during May. Because the ratios of total nitrogen to total phosphorus were less than 17:1 (6:1 in May and 11:1 in August), it is likely that algal growth was nitrogen-limited when the lake was sampled.

Fecal Coliform Bacteria

Samples for fecal coliform were collected during the May onsite sampling visit. Both sampling sites were located near shore; site #1 was located on the east side of the lake about 1,000 feet north of the volunteer's sampling site, and site #2 was located just south of the public access area. Results for both samples were very low, and were within state water quality standards for lake water.

Profile Data

The lake was not stratified during either sampling date, so only one set of water samples was collected during each onsite sampling visit. As evidence of an unstratified lake, profile data did not change much from surface to bottom. There are no pH data from May because the pH sensor on the probe was not working properly.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. The concentration of chlorophyll *a* in May (1.6 µg/L) indicated a low density of algae at the time of sampling. Chlorophyll *a* was also low in May 1992. Lower water temperatures and lower ratios of nitrogen to phosphorus may have restricted algae growth in spring.

During August 1993, the chlorophyll *a* concentration was high (7.6 µg/L), indicating a high density of algae. Visible colonies of the blue-green alga *Gloeotrichia* were observed in water samples collected from the top two meters of the lake.

No new aquatic plants were identified during the 1993 sampling visits. Plants identified by Ecology staff during the May 13, 1992, sampling visit included waterweed (*Elodea* sp.), flatleaf pondweed (*Potamogeton robbinsii*), coontail (*Ceratophyllum demersum*), and watershield (*Brasenia schreberi*). During the 1990 sampling visits, fairly extensive patches of watershield, coontail, bladderwort (*Utricularia vulgaris*), two pondweeds (including flatleaf pondweed), duckweed (*Lemna* sp.), and waterweed were observed.

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. 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. Construction of the water level control dam is a Phase II project to be funded from the EPA Clean Lakes Program and Ecology's Centennial Clean Water Fund. ("Phase II" projects refer to the implementation phase of a two-phase lake restoration effort.) Residents near Lake Eloika are in the process of deciding whether to form a taxing district that will be responsible for operating and maintaining the dam once it is constructed (Soules, 1993).

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 1993.

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 being logged and used for animal grazing. The lakeshore is also being developed further for residences. In the past, the watershed was logged and used for crop agriculture, the lake was dredged, and the shoreline was altered.

There are 67 houses on the lakeshore. There are six stormdrains which drain into the lake. Currently, the minimum setback for lakeshore development is 100 feet. Lake water is withdrawn for irrigation. There is a community association for the lake. No lake management activities occurred in 1993, although progress is being made toward installing a water level control dam on the lake's outlet. The lake has been treated with chemicals in the past to control aquatic plants.

Overall, the volunteer found that Lake Eloika had fair water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, (2) suspended sediments, (3) water quality gradually degraded over years, and (4) decaying plants. These were also problems in 1992. The shallow depth of the lake, and the thick bottom sediment, contribute to the excessive plant growth. There were no major changes in the lake in comparison to the 1992 monitoring season, although there was no major algae bloom in 1993 and there have been fewer algae blooms in the past few years. Cooler weather, upstream nonpoint pollution controls by the Pend Oreille Conservation District, and the recently installed Diamond Lake sewer system may have all helped to reduce algae growth. [These watershed activities were also noted in the 1992 questionnaire as being possible reasons for better water quality in 1992 than in the past four years.]

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.

Acknowledgment

I thank Victor H. Soules for volunteering his time to monitor Eloika Lake during 1989-1993.

Lake Eloika -- Spokane County

1993 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	47
Mean Trophic State Index (Total Phosphorus):	57
Mean Trophic State Index (Chlorophyll *a*):	43

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (ft)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
25-May				10.1			100	light		Onsite visit.
16-Jun	1350	20.0	68.0	10.1	1906.2	gr-brown	50	heavy	light	Bright sun with thunder showers both north and south.
03-Jul	1201	18.9	66.0	8.0	1905.8	gr-brown	90	light	light	
27-Jul	1245	25.0	77.0	10.0		gr-brown	25	moderate	breezy	Water level very high for this time of year. Thunderstorms every day in mid-month with strong winds.
21-Aug	1515			7.5		gr-brown	90		breezy	Onsite visit.
03-Sep	1220	20.5	69.0	6.6		gr-brown	0	none	calm	Slight haze from grass burn. Observed a light tan spider (not a water skipper) walking on top of water at middle.
15-Sep		17.5	63.5	6.9	1905.0	gr-brown	25	trace	light	
28-Sep	1135	16.5	61.7	6.7	1905.0	gr-brown	10	none	light	Light brown "dustlike" patches on surface near center of lake. Many small severed pieces of coontail floating at surface.
19-Oct	1315	11.0	51.8	4.3		green	0			Severe algae near shore. Some wind stirring up yesterday.

1 Trophic State Indices calculated from Carlson (1977).
2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Eloika dropped 1.2" from June 16 through September 28.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/25	0.0	20.6	.	9.0	82
	1.0	20.4	.	9.0	83
	2.0	19.4	.	9.0	82
	3.0	17.1	.	9.2	79
	4.0	15.0	.	7.0	76
08/21	0.0	21.4	8.7	9.0	98
	1.0	21.3	8.7	9.2	98
	2.0	21.1	8.7	9.2	98
	3.0	20.6	8.0	6.4	99

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 25 Epilimnion	55	0.33	1.6	--	--	1	bdl*
Hypolimnion**							
August 21 Epilimnion	29	0.32	7.6	--	--	--	--
Hypolimnion**							

* Result was below the detection limit of 1 colony/100 mL

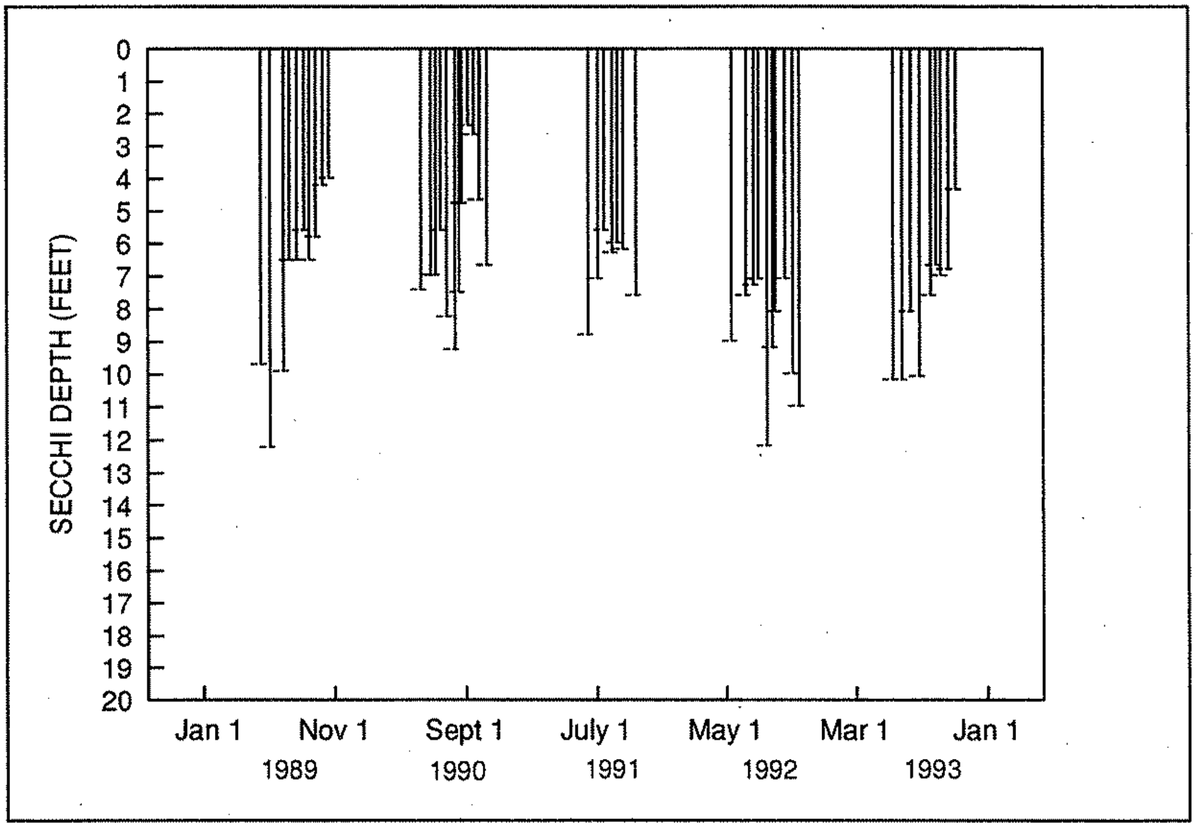
** The lake was not stratified at the time of sampling; only one set of samples was collected

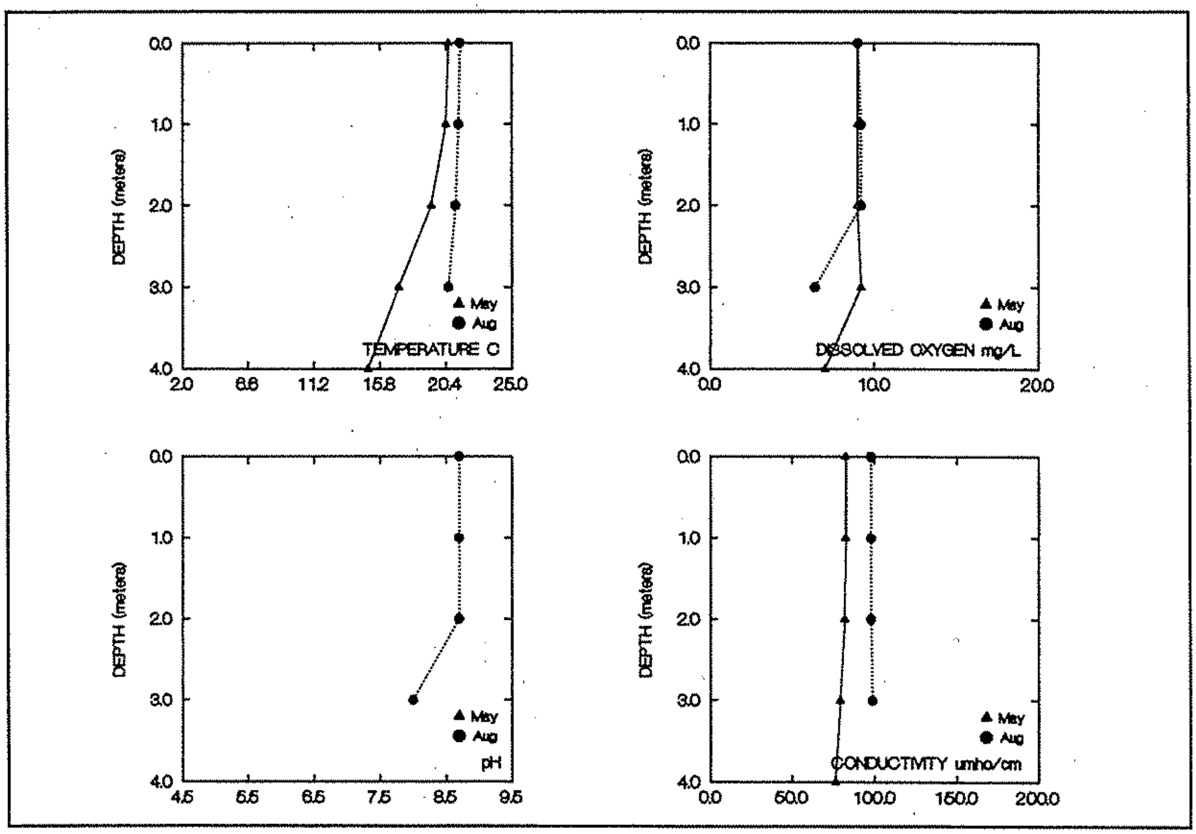
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/01/74[a]	28	--	--
07/13/81[b]	20	0.98	3.7
08/21/90[c]	55	0.68	--
06/10/91[d]	--	0.29	--
05/13/92[e]	25	0.40	2.2
08/26/92[e]	29	0.57	5.5

a. Dion *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)
e. Rector (1993)

ELOIKA LAKE (SPOKANE COUNTY)





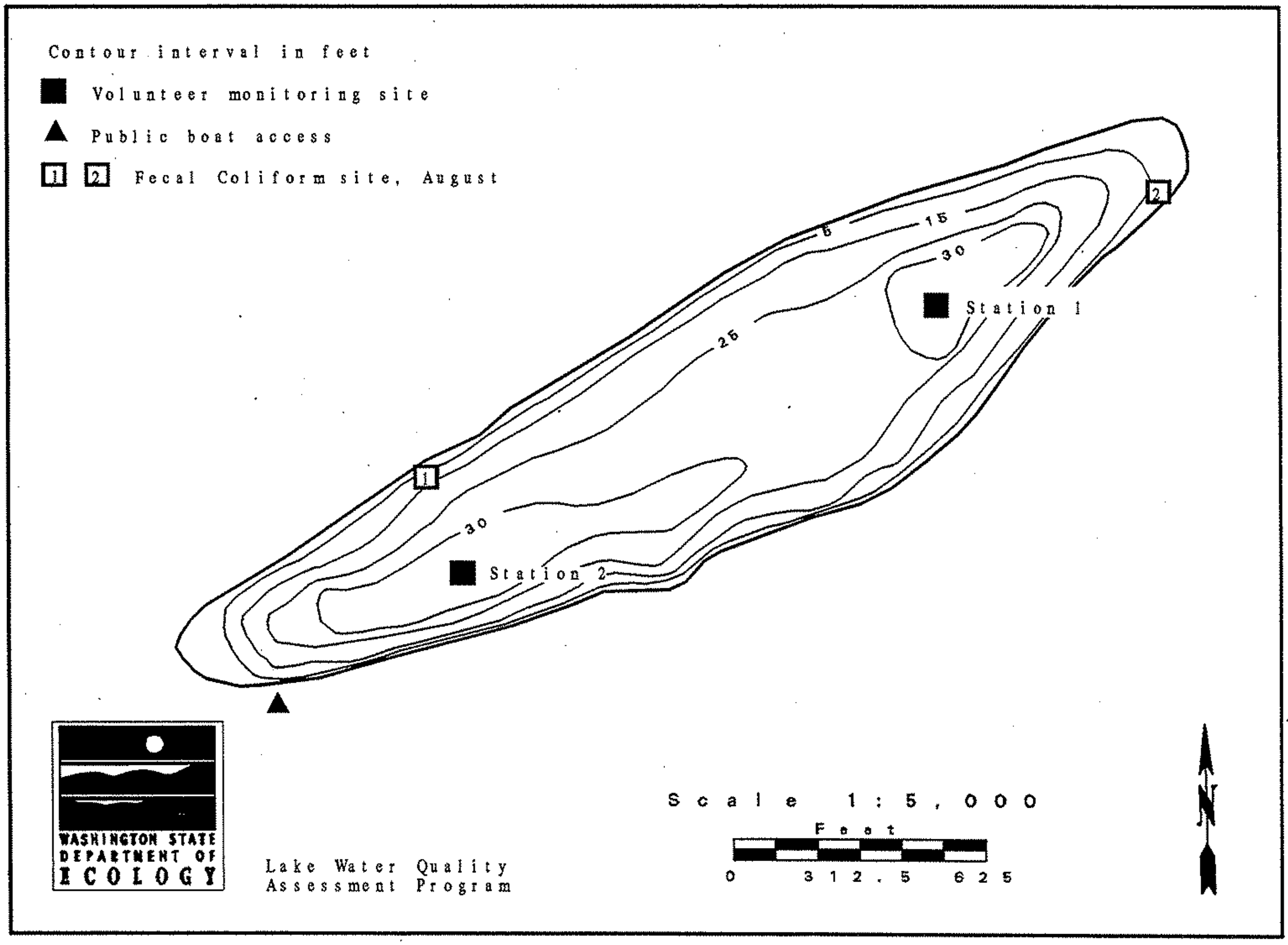
1993 Secchi Depth and Profile Data Graphs

Emerald Lake -- Whatcom County

Emerald Lake is located five miles northeast of Bellingham. It has one surface inlet, and drains via an unnamed creek to Squalicum Creek and Bellingham Bay. Emerald Lake is also referred to as Toad Lake on older maps and references.

Size (acres)	33
Maximum Depth (feet)	31
Mean Depth (feet)	20
Lake Volume (acre-feet)	660
Drainage Area (miles^2)	0.5
Altitude (feet)	714
Shoreline Length (miles)	1.2

Data From Bortleson et al. (1976)



Overall Assessment

In 1993, Emerald Lake was assessed as meso-eutrophic, because it exhibited both mesotrophic and eutrophic characteristics. Secchi depts were in the mesotrophic range, but the moderately high to high concentrations of total phosphorus and amounts of algae were characteristic of eutrophic lakes. The lake also had low oxygen concentrations at the lake bottom, and it appeared that internal loading of phosphorus from the sediments may have occurred.

Emerald Lake was added to the Lake Water Quality Assessment Program in 1993.

1993 Monitoring Results/Summary of Other Available Information

Volunteers measured Secchi depth at two lake stations. Station #1 was located in the deep part at the northeast end of the lake, and Station #2 was located mid-basin at the southwest end of the lake. Water samples and profile data were collected from station #1 during May and August.

Secchi Depths

Water clarity at both stations was fair to good, as indicated by Secchi depths that ranged from 6.0 feet to 17.0 feet at Station #1, and from 6.0 feet to 17.2 feet at Station #2. Secchi depths from 6.5 feet to 13.0 feet are fair, and are typical for mesotrophic lakes.

Total Phosphorus

In May, the concentration of total phosphorus was very high throughout the water column (97 µg/L in the upper layer, and 108 µg/L in the lower layer). It is possible that these high concentrations resulted from internal loading of phosphorus from sediments. Internal loading usually occurs when oxygen concentrations near sediments are depleted, creating an environment that allows phosphorus, iron and other compounds in sediments to be chemically reduced and released into the water column. However, high pH can also result in high rates of sediment phosphorus release; high pH values in Emerald Lake could have caused the high phosphorus concentrations in May. High spring phosphorus concentrations were also measured in 1974, when orthophosphorus concentrations were highest in March and April, and decreased considerably during summer (McBride, 1975). The summer decrease could possibly be due to algae rapidly taking up available phosphorus.

In August, the concentration of total phosphorus was moderately high (17 µg/L), and there was a moderately high density of algae at the time. The high phosphorus concentrations from May either settled with suspended particles (either suspended sediments or algae) to the sediment, or were flushed downstream.

Total Nitrogen

Concentrations of total nitrogen were high in May and moderately high in August. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae generally use at least ten times the amount of nitrogen as phosphorus. In May, the ratio of total nitrogen to total phosphorus was less than 17:1 (it was 5:1). This suggests that algal growth was not limited by phosphorus in May, and some other growth requirement (such as nitrogen or silica) limited algal growth. McBride (1975) suggested that algae in Emerald Lake were nitrogen-limited throughout the year, based on ratios of nitrate-nitrogen and orthophosphorus concentrations.

In August, the ratio of total nitrogen to total phosphorus was 21:1, suggesting that algae growth was not limited by nitrogen in August.

Profile Data

The lake was thermally stratified on both sampling dates. In the bottom two meters of the lake, concentrations of dissolved oxygen were low and probably resulted from bacteria which use oxygen as they decompose aquatic plants and algae in the water and sediment. Very low oxygen concentrations near sediments result in phosphorus and other compounds being released from sediment into the water column. This process probably caused the higher conductivity values near the bottom of the lake.

In May, pH values were high from the surface down to four meters. The increase in pH values at one and two meters probably resulted from increased algae growth at these depths, which was also indicated by the high chlorophyll concentration in the epilimnion sample (see Plants, below). As noted in "Total Phosphorus" above, high pH values in May could have caused phosphorus release from the sediments.

Fecal Coliform Bacteria

Two nearshore samples for fecal coliforms were collected in August. Site #1 was located about 50 feet offshore, on the northwest side of the lake. Site #2 was located at the private beach access on the northeast end of the lake. Results for both samples were low. The state water quality standard for fecal coliforms in Lake Class waters is a geometric mean of 50 colonies/ 100 mL.

Solids

Solids samples were collected during August only. Results from solids samples are used to evaluate whether Secchi depths were affected primarily by algae, or if suspended sediments affected water clarity at the time of sampling. Results were low, indicating that Secchi depths in August were probably affected primarily by algae, and not by suspended sediments.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. In May, the chlorophyll concentration indicated that there was a high density of algae at the time of sampling. The high density of algae is related to the high nutrient concentrations, although algae in May were probably limited by the amount of nitrogen in the water. This may explain why there was not as much algae as we would expect given the high phosphorus concentration.

In August, the chlorophyll concentration was moderately high, and was in the range that would be expected given the moderately high concentration of total phosphorus.

Other Available Information

From Dion et al. (1976): In 1974, most homes on the lake were recently constructed and were occupied seasonally. There was a moderate amount of algae and aquatic plants. Concentrations of dissolved oxygen were very low in the hypolimnion during stratification, particularly in July and September 1974.

From McBride (1975): Bimonthly samples for chemical oxygen demand (COD), orthophosphorus, nitrate-nitrogen and turbidity were collected from February 1974 through February 1975. COD results ranged from 1.8 mg/L to 13.9 mg/L, with highest values occurring in March 1974 and lowest values occurring in June and July 1974. Orthophosphorus ranged from 0.025 mg/L to 0.122 mg/L, with the highest values occurring in March and April 1974. Lowest values occurred from June through September 1974. Nitrate-nitrogen values ranged from 0.00 mg/L to 0.320 mg/L; highest values occurred from February through April 1974, and lowest values occurred from July through October 1974. Turbidity results also indicated highest values in March and April 1974, and lowest values in July and August 1974. Heavy growths of the blue-green alga *Anabaena* occurred in October 1974, resulting in surface mats and "interfer[ing] with the recreational and aesthetic enjoyment of the lake." Additional algae observed were *Mougoetia*, *Spirogyra* and *Piaropus*. Aquatic macrophytes observed in the lake included *Elodea*, *Potamogeton* sp., and *Typha*.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire on lake and watershed uses.

> Emerald Lake is used for fishing, swimming, and non-motorized boating. There is one boat ramp on the lakeshore, and motor boating is not allowed on the lake. Rainbow trout were stocked in the lake in 1993. Currently the watershed is being logged and the lakeshore is being developed further for residences.

There are approximately 26 houses on the lakeshore, and none are connected to a sewer collection system. There is a community association for the lake. No lake management activities occurred on the lake in 1993, and lake water is not withdrawn for any uses.

Overall, the volunteer found that Emerald Lake had excellent water quality. Problems in the lake in 1993 were ranked as (1) algae, and (2) excessive aquatic plant growth. The volunteer noted that these problems are minimal and the lake presently has a good fishery and healthy wildlife population. Possible sources of problems include sewage disposal (especially is additional nearshore homes are built), and the naturally slow flushing rate of the lake.

Acknowledgement

I thank Kent and Jina Barber, Michael Barclay, Bev and Murray Halliday, Carol and James Maher, and Marg Burns for volunteering their time to monitor Emerald Lake in 1993.

Emerald Lake -- Whatcom County

1993 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	41
Mean Trophic State Index (Total Phosphorus):	58
Mean Trophic State Index (Chlorophyll *a*):	49

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (m)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
Station 1										
05-Jun	1245	18.0	64.5	7.0	1.32	green	50	light	light	Depth in meters.
19-Jun	1130	22.0	71.5	7.0	1.29	milky-gr	10	light	breezy	
04-Jul	1300	19.0	66.2	6.0	1.19		0	none	gusty	East side lake station.
18-Jul	1200	21.0	69.8	17.0	1.06	gr-brown	90	none	light	East side lake station.
07-Aug	1200	23.0	73.4	17.0	1.10	green	90	none	light	
21-Aug	1130	21.0	69.8	13.3	1.00	green	50	light	breezy	lot of white specks in water. Reading two weeks ago done at noon.
04-Sep	1145	21.0	69.8	14.2	0.90	green	10	none	breezy	A lot of tiny worms floating. Not as many white specks.
18-Sep	1325	19.0	66.2	12.8	0.90	lt-green	90	none	light	
06-Oct	1530			11.0		lt-green	90	moderate	light	Thermometer broken
16-Oct	1330	15.6	60.0	10.2	0.90	green	50	trace	light	There is evidence of a green slimy looking algae bloom starting.
Station 2										
22-May	1150	18.0	64.5	10.0	1.39	green	75	heavy	light	
05-Jun	1300	18.0	64.5	6.5	1.32	green	50	light	breezy	
19-Jun	1130	22.0	71.5	6.3	1.29	green	0	light	breezy	
04-Jul	1300	19.0	66.2	6.0	1.19	lt-brown	0	none	gusty	Readings for
18-Jul	1200	21.0	69.8	17.2	1.06	gr-brown	90	none	light	West side lake station.
17-Aug	0920			17.0			0			Onsite visit.

[1] Trophic State Indices calculated from Carlson (1977).
[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Emerald Lake dropped 0.26 meters from June 5 to October 16.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/22	0.0	18.0	9.2	7.2	98
	0.9	18.0	9.3	7.8	98
	2.0	17.9	9.4	7.9	98
	2.9	13.9	9.1	9.2	94
	4.1	11.0	8.7	9.5	93
	5.1	9.0	8.2	2.2	95
	6.0	8.1	7.7	0.7	112
08/17	0.0	19.4	7.4	8.7	99
	1.0	19.3	7.4	8.7	99
	2.1	19.2	7.4	8.7	99
	3.0	19.2	7.5	8.7	99
	4.0	19.2	7.5	8.6	100
	5.0	15.4	7.3	5.4	104
	6.0	11.0	7.1	3.3	137
	6.3	10.5	7.2	5.7	178

1993 Onsite Visit Data - Water Chemistry

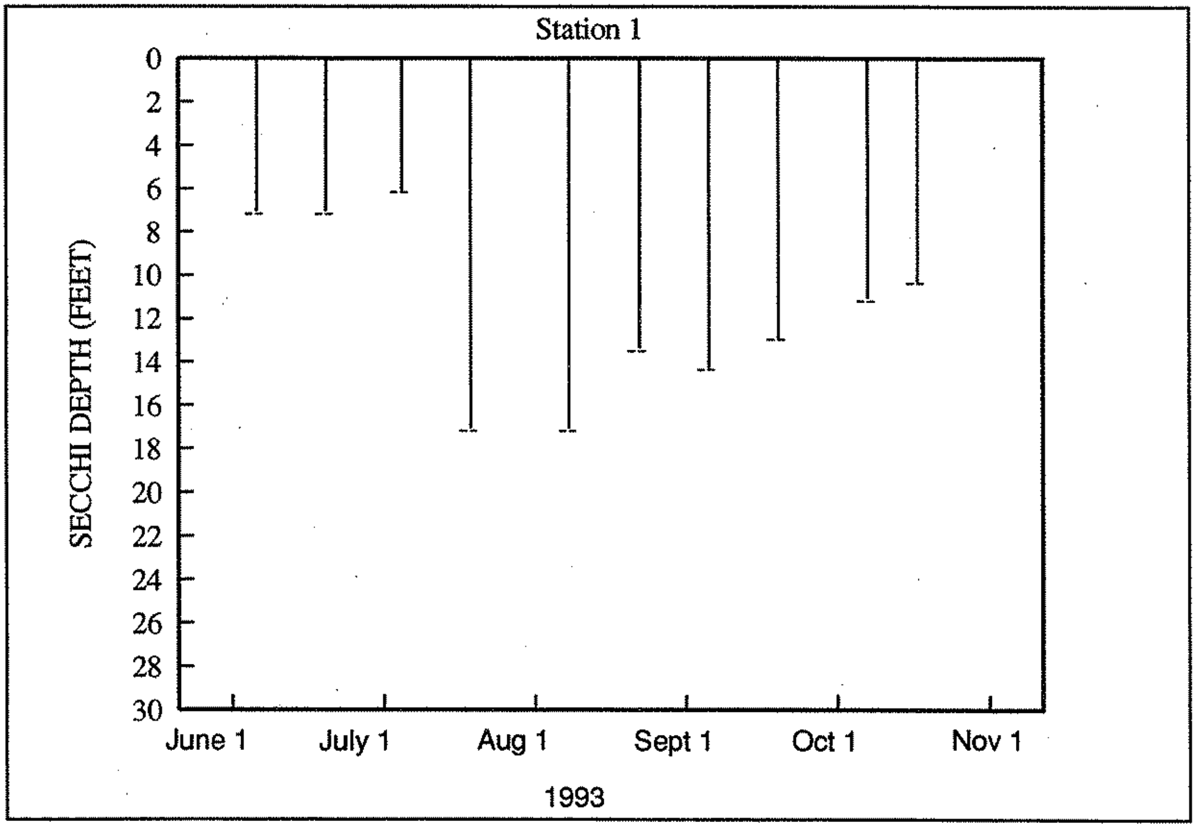
	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 22							
Epilimnion	98	0.51	10.8	--	--	--	--
Hypolimnion	108	0.82	--	--	--	--	--
August 17							
Epilimnion	17	0.36	4.1	1	<1	3	1
Hypolimnion	46	0.47	--	--	--	--	--

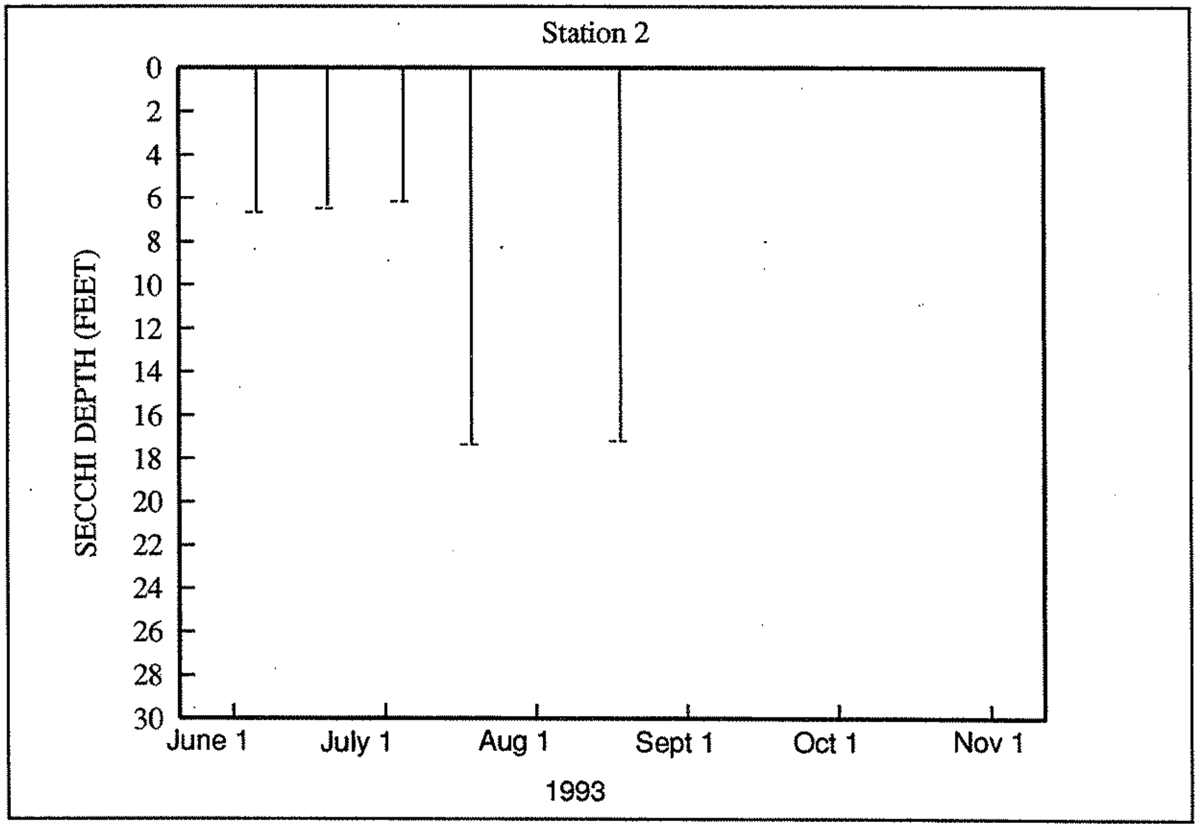
Historical Data From Ecology -- Epilimnion Data Only

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)
05/07/74[a]	23	--	2.8
09/17/74[a]	13	--	3.9

a. Dion et al. (1976)

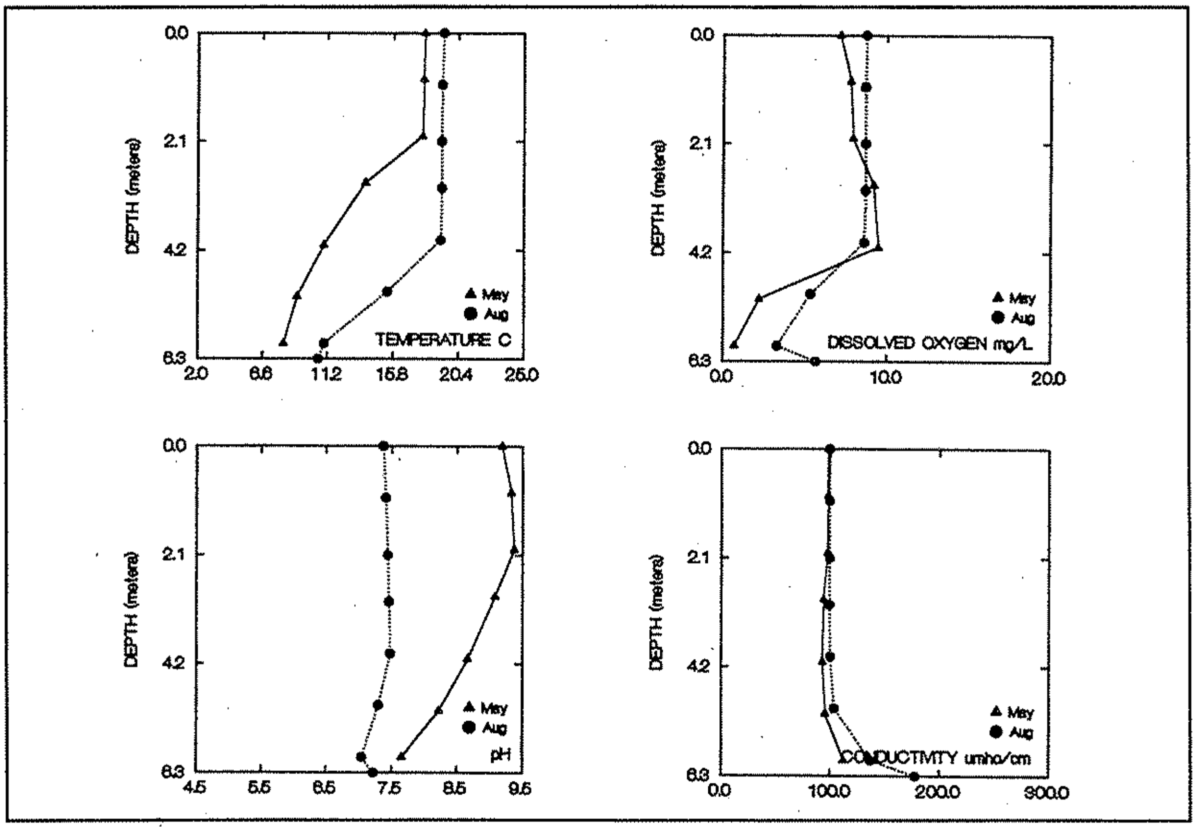
EMERALD LAKE (WHATCOM COUNTY)





1993 Secchi Depth and Profile Data Graphs

PROFILE DATA FOR STATION #1



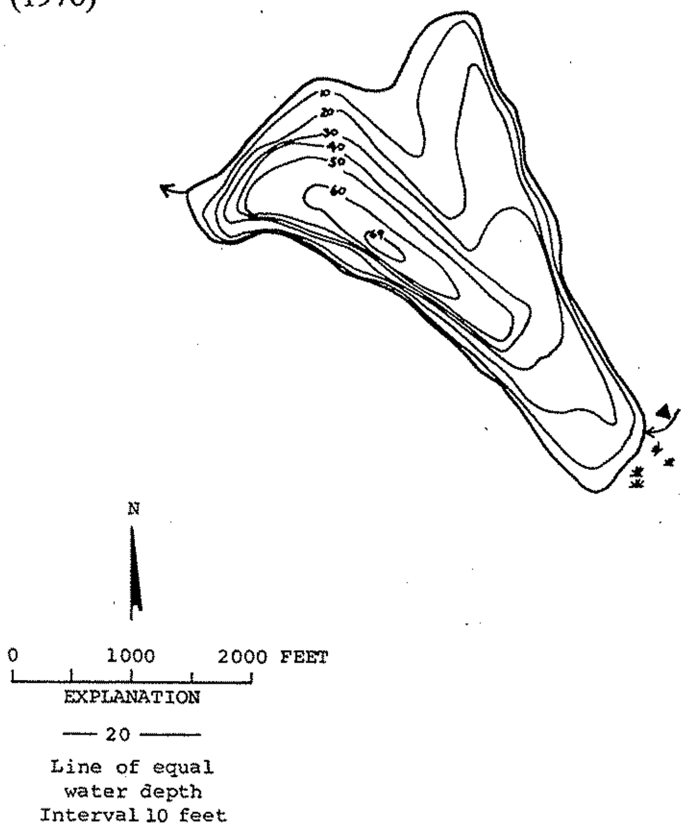
1993 Secchi Depth and Profile Data Graphs

Flowing Lake -- Snohomish County

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

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

Data From Bortleson *et al.* (1976)



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

Overall Assessment

In 1993, Flowing Lake had good water clarity, yet moderate (neither high nor low) concentrations of total phosphorus and chlorophyll *a* Based on these, the lake was described as oligo-mesotrophic. The lake was characterized as mesotrophic in 1990 and 1991, based primarily on shallower Secchi depths (collected by a previous volunteer), and slightly higher concentrations of total phosphorus.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good, as indicated by Secchi depths that ranged from 12.0 feet to 17.5 feet. These Secchi depths were deeper than those measured by a different volunteer from 1989-1991, when Secchi depths ranged from 6.0 to 12.5 feet. Secchi depths greater than 13.0 feet indicate good water clarity, and are typical for oligotrophic lakes.

Total Phosphorus

The concentrations of total phosphorus were 14 µg/L in May, and 10 µg/L in August. These concentrations were similar to those measured in 1990. Concentrations less than 12 µg/L are low and are typical of oligotrophic lakes, and concentrations between 12 µg/L and 24 µg/L are typical for mesotrophic lakes.

Total Nitrogen

Total nitrogen concentrations were moderately high on both sampling dates although concentrations were very low in comparison to other lakes monitored for the program. There are no indications that algae growth may have been limited by the amount of nitrogen in the water. Although nitrogen was especially low during May, the density of algae (indicated by the concentration of chlorophyll *a*) was not surprising, given the moderately high concentration of total phosphorus.

Profile Data

The lake was thermally stratified on both sampling dates. Oxygen decreased with depth below the thermocline, particularly during August. Oxygen concentrations decrease when bacteria decompose algae and aquatic plants in the water and sediments. During May, the slight increase in dissolved oxygen at three to four meters was probably from the decrease in water temperature at these depths, because dissolved gases are more soluble in cooler water than in warmer water.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. In May, the concentration of chlorophyll *a* indicated a low density of algae at the time of sampling. In August, algal density was moderately high.

Aquatic plants identified by Ecology staff near the Department of Wildlife access area included waterweed (*Elodea canadensis*), which was particularly abundant, Nuttall's waterweed (*Elodea nuttalli*), and clubmoss (*Lycopodium* spp.). (There was also a considerable amount of garbage and cans at this site.) At the north end of the lake near the county park, clubmoss, Nuttall's waterweed and the alga *Nitella* were observed. White-flowering water lily (*Nymphaea odorata*), yellow-flowering water lily (*Nuphar polysepalum*), and cattails (*Typha* spp.) were observed along undeveloped shoreline on the north end of the lake.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire.

> Flowing Lake is used for fishing, swimming, motor boating, rowing, jet skiing, and lakeshore camping. Public facilities on the lakeshore include a day use park, city/county park, State park, and two boat ramps. Restrictions for boat use on the lake include a speed limit of 8 mph before 10 a.m., and no wakes within 100 feet of the shoreline. Trout were stocked in the lake in 1993. Currently, the watershed is being logged and used for crop agriculture and animal grazing, although grazing animals do not have direct access to the lakeshore or inlet tributaries. The lakeshore is also being developed further for residences. In the past, the watershed was logged and used for crop agriculture. The shoreline has been altered with bulkheads.
>
> There are approximately 104 houses on the lakeshore, and there are no culverts which drain into the lake. The volunteer did not know if there was an organization for the lake, or whether lake water was withdrawn for any uses. No lake management activities occurred in 1993.
>
> Overall, the volunteer found that Flowing Lake had excellent water quality. The worst problem in the lake in 1993 was shoreline erosion, although some minor algae blooms occurred. Minor shoreline erosion may have been affected by boat activity.

Acknowledgement

I thank Joel Evans for volunteering his time to monitor Flowing Lake during 1993.

Flowing Lake -- Snohomish County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	39
Mean Trophic State Index (Total Phosphorus):	40
Mean Trophic State Index (Chlorophyll *a*):	42

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
26-May	1050			14.5		gr-brown	100		calm	Onsite visit.
13-Jun	1725	18.3	65.0	12.0		lt-green	90	light	light	
04-Jul	1500	18.3	65.0	13.0			100	moderate	calm	Water color tea green.
18-Jul	1830	20.0	68.0	14.5			0	moderate	light	Water color weak tea green.
02-Aug	1805	22.2	72.0	12.0		green	0	none		
19-Aug	1120	21.1	70.0	14.0		gr-brown	0	trace	calm	Onsite visit.
03-Sep	1150	21.1	70.0	17.5		lt-green	0	none	calm	
09-Oct	1437	15.6	60.0	17.5		lt-green	0	trace	light	

1 Trophic State Indices calculated from Carlson (1977).
2 "Lake height" refers to change in water level. The volunteer did not measure lake height in 1993.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/26	0.0	20.2	7.5	9.3	37
	1.0	20.1	7.5	9.4	37
	2.0	20.0	7.4	9.4	37
	3.0	16.4	7.5	10.3	36
	4.0	13.0	7.5	10.2	36
	5.0	11.1	7.4	9.2	36
	6.1	10.0	7.4	8.9	36
	7.1	9.0	7.3	8.6	36
	7.9	8.5	7.2	8.0	35
	10.1	7.5	7.1	8.0	35
	12.0	6.8	7.0	8.1	37
	14.1	6.3	6.9	7.2	36
	15.6	6.2	6.8	6.2	37
08/19	0.0	21.8	7.5	8.7	39
	1.0	21.1	7.5	8.4	39
	2.0	20.5	7.5	8.4	38
	3.0	19.9	7.5	8.2	38
	4.0	18.3	7.4	6.8	39
	5.0	15.0	7.3	4.1	39
	6.0	12.1	7.1	2.2	39
	8.0	9.4	7.1	1.6	38
	10.0	8.1	7.0	1.9	38
	12.0	7.3	7.0	2.3	38
	12.7	7.1	7.0	2.1	38

1993 Onsite Visit Data - Water Chemistry

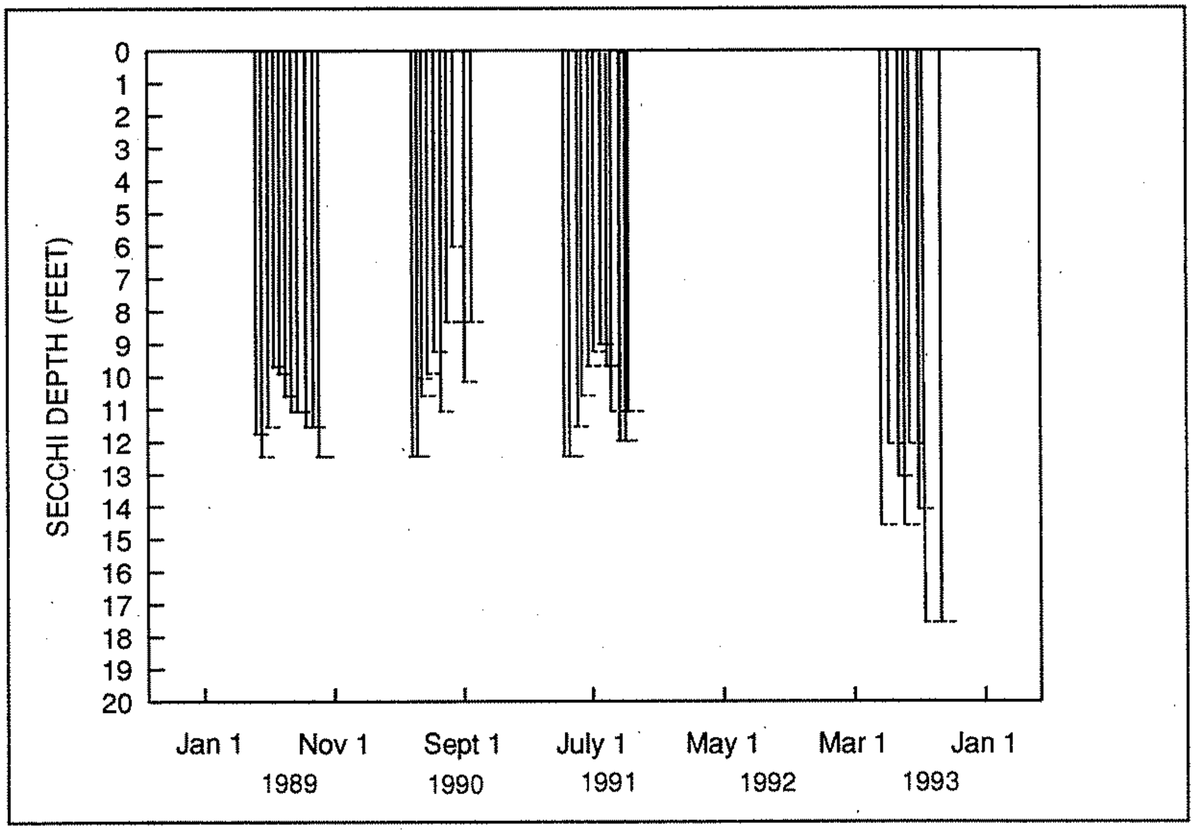
	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 26 Epilimnion	14	0.15	2.3	--	--	--	--
Hypolimnion	25	0.47	--	--	--	--	--
August 19 Epilimnion	10	0.27	4.3	--	--	--	--
Hypolimnion	13	0.40	--	--	--	--	--

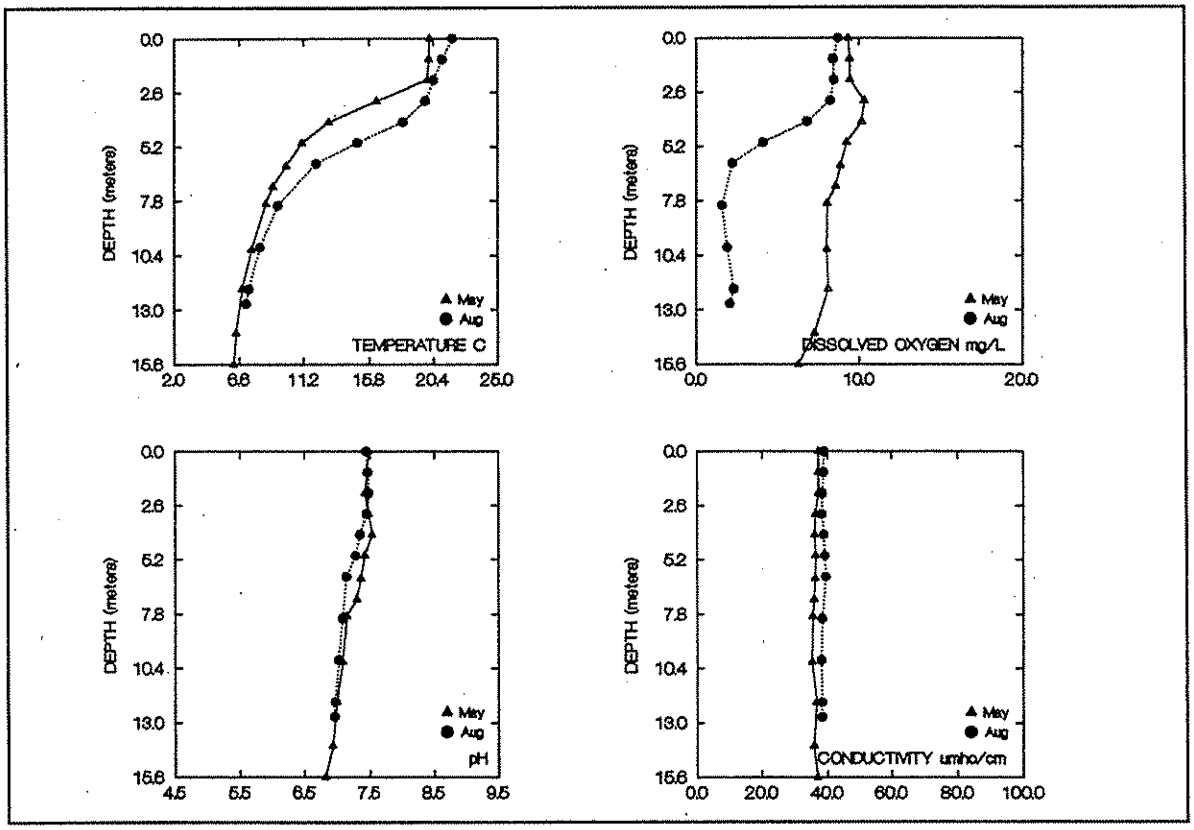
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)
07/23/73[a]	7	--	--
06/06/90[b]	15	0.54	3.7
08/30/90[b]	12	0.42	--
06/18/90[c]	--	0.47	1.3
09/17/90[c]	9	0.39	2.3
05/29/91[d]	--	0.56	--

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

FLOWING LAKE (SNOHOMISH COUNTY)





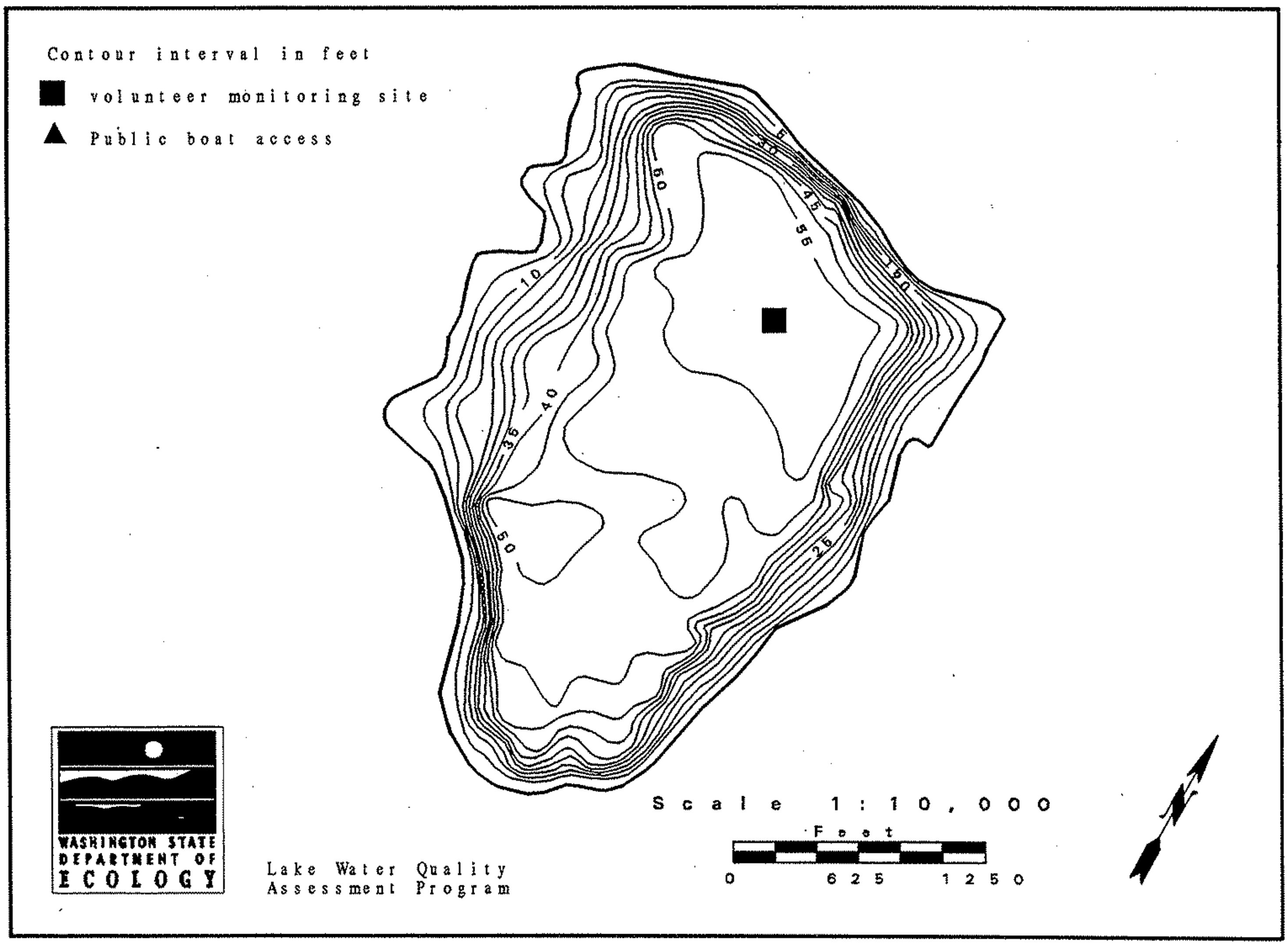
1993 Secchi Depth and Profile Data Graphs

Gravelly Lake -- Pierce County

Gravelly Lake is located 0.5 mile northwest of Ponders, between American and Steilacoom Lakes. It has no surface inlets, and seeps to Puget Sound.

Size (acres)	160
Maximum Depth (feet)	55
Mean Depth (feet)	38
Lake Volume (acre-feet)	6,000
Drainage Area (miles^2)	0.7
Altitude (feet)	220
Shoreline Length (miles)	2.1

Data From Bortleson *et al.* (1976)



Overall Assessment

In 1993 Gravelly Lake had very good water clarity, low densities of algae in open water, and low concentrations of phosphorus in the upper layer of water. These indicate that the lake was exhibiting characteristics of an oligotrophic lake. However, Secchi depth and algal densities were probably affected by the annual application of algicides to the lake. Although controlling algae with chemical treatments is generally considered to be a short-term solution for water quality problems, Gravelly Lake has a long history (over 20 years) of algicide applications. In addition, it appeared that phosphorus was recycled from sediments into the water column, and dissolved oxygen was very low throughout the lower layer of water in late summer. Sediment release of phosphorus and low oxygen concentrations are mesotrophic characteristics. Because Gravelly Lake exhibited both oligotrophic and mesotrophic characteristics, it was described as oligo-mesotrophic in 1993.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was very good in Gravelly Lake, indicated by Secchi depths which ranged from 26.0 feet to 33.5 feet. Gravelly Lake was one of only two lakes monitored for the program that had a clear turquoise water color.

Total Phosphorus

The concentrations of total phosphorus in the upper layer of water (the epilimnion) were very low on both sampling dates (5 µg/L in June, and 7 µg/L in August). Concentrations less than 12 µg/L are typical for oligotrophic lakes.

In the lower layer of water (the hypolimnion), though, total phosphorus concentrations were very high (182 µg/L and 133 µg/L) and probably resulted from internal loading of phosphorus from the sediments. Internal loading occurs when oxygen concentrations near the lake bottom are very low (see Profile Data, below), and phosphorus and other compounds in the sediments are chemically reduced, allowing them to be released from the sediments into the water column. Because the lower layer of water does not mix with the upper layer while the lake is stratified, these higher concentrations are trapped until the lake mixes (most Western Washington lakes mix in October or November, depending on the weather). These high phosphorus concentrations cause algae to grow in the lake when the lake is not treated with algicides.

Total Nitrogen

Total nitrogen concentrations were high in the upper layer of water. In the lower layer of water, concentrations were very high. Nutrient concentrations can be high in the lower layer of water and low in the upper layer during stratification, because stratification prevents the water layers from mixing. Lakes in western Washington usually destratify during fall; when destratification occurs (also known as "mixing" or "turnover"), high nutrient concentrations from the lower layer can be mixed throughout the water column, resulting in a fall algae bloom. Because of the high nutrient concentrations in the lower layer, Gravelly Lake has a high potential for algae blooms. These blooms have been prevented or controlled with algicides.

Profile Data

The lake was thermally stratified on both sampling dates. At the thermocline (the depths where temperatures change considerably with small changes in depth), both dissolved oxygen and pH increased sharply. These increases could result from the change in temperature, which would allow more dissolved oxygen to be held in the water (because dissolved gases are more soluble in cooler water than in warmer water), as well as increased algae growth at these depths.

Near the lake bottom, dissolved oxygen concentrations were very low. Oxygen can decrease in the lower layer of water when bacteria use oxygen to decompose algae and aquatic plants in the bottom water and sediments. However, ground water may also affect the oxygen content of the lower layer of water; it is likely that the lake is fed by springs, and ground water is very low in oxygen.

Plants

Concentrations of chlorophyll *a* are used to indicate the density of algae growth at the time of sampling. Chlorophyll *a* concentrations on both sampling dates indicated low densities of algae in open water. However, a filamentous green alga was observed during both sampling dates, and the volunteer noted that the algae was getting to be a nuisance in areas, particularly because it was very green and slimy and was located in nearshore areas. The alga appeared to be *Mougeotia*, but this identification needs to be confirmed.

Other Available Information

From Collings (1973): "The lake's urban environment probably has an enriching effect. The lake is being treated with algicides and herbicides which help to lessen the rate of eutrophication." On October 8, 1970, the predominant aquatic plants in the lake were pondweed (*Potamogeton* sp.) and muskgrass (*Chara*). Both were located in the west-central area of the lake .

Summary of Questionnaire Results and Information from the Volunteer

The 1993 questionnaire on lake and watershed uses was not returned.

Acknowledgement

I thank Amy Perkins for volunteering her time to monitor Gravelly Lake during 1993.

Gravelly Lake -- Pierce County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	28
Mean Trophic State Index (Total Phosphorus):	30
Mean Trophic State Index (Chlorophyll *a*):	28

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
04-Jun	1300	20.0	68.0	31.5			100	light	calm	Water color clear turquoise-blue.
18-Jun	1515	21.1	70.0	33.5			0	trace	calm	Water color clear turquoise-blue.
03-Jul	1530	20.0	68.0	31.0			50	light	calm	Water color clear blue-green.
17-Jul	1435	20.0	68.0	27.0			50	moderate	breezy	Water color blue-green.
30-Jul	1500			38.0			75	heavy	calm	Water color clear blue.
18-Aug	1345	21.1	70.0	26.0			0	light	gusty	Water color clear blue-green.
30-Aug	1030	20.0	68.0	28.0			0		breezy	Water color clear light green. Onsite visit.
14-Sep	1600	18.9	66.0	26.5		lt-green	75	trace	breezy	
27-Sep	1430	16.7	62.0	30.0			25	none	calm	
13-Oct	1530	15.6	60.0	32.0		lt-green	0	moderate	calm	

[1] Trophic State Indices calculated from Carlson (1977).
[2] "Lake height" refers to change in water level. The water level was not monitored in 1993.

Gravelly Lake -- Pierce County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
06/04	0.0	19.4	8.0	9.7	140
	1.1	19.2	7.9	9.8	140
	2.0	19.1	7.8	10.0	140
	3.1	19.1	7.8	10.0	140
	4.0	19.0	7.7	10.1	140
	5.0	18.1	7.7	12.4	142
	6.1	14.4	8.1	14.6	143
	7.0	11.6	8.3	14.9	141
	8.0	10.0	8.2	13.9	142
	10.0	8.1	7.8	9.0	143
	12.0	7.2	7.6	6.0	145
	14.0	6.6	7.5	3.9	148
	16.1	6.5	7.3	2.2	150
08/30	0.0	20.4	8.0	10.4	141
	1.0	20.4	8.0	10.3	141
	2.0	20.3	8.0	10.2	141
	3.0	20.3	8.0	10.1	141
	4.0	20.3	8.0	10.0	141
	5.0	20.3	8.0	9.9	141
	5.9	19.7	8.5	15.5	141
	8.0	14.8	7.9	11.4	144
	10.1	10.8	7.5	1.1	145
	11.9	9.0	7.4	0.5	144
	14.2	7.7	7.1	0.3	153
	15.2	7.4	7.0	0.3	173

1993 Onsite Visit Data - Water Chemistry

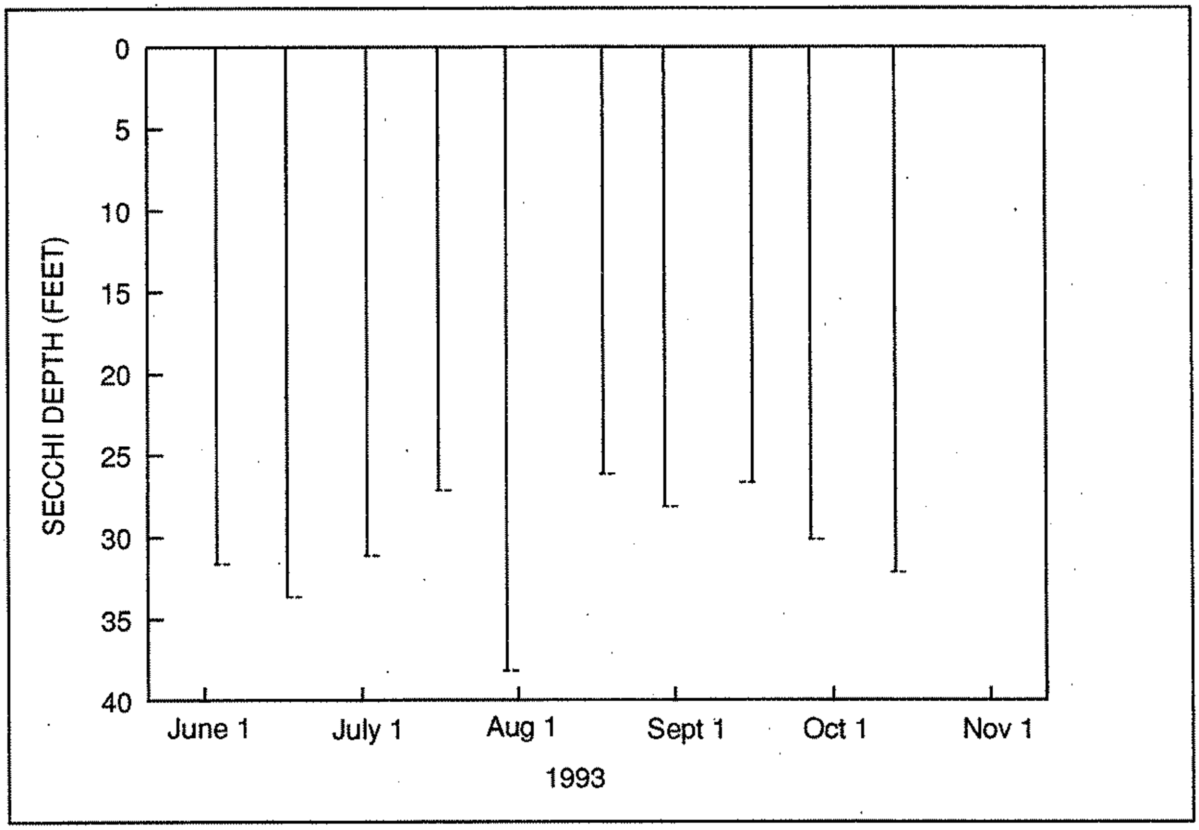
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 4 Epilimnion	5	0.64	1.2	--	--	--	--
Hypolimnion	182	1.5	--	--	--	--	--
August 30 Epilimnion	7	0.61	0.5	--	--	--	--
Hypolimnion	133	0.92	--	--	--	--	--

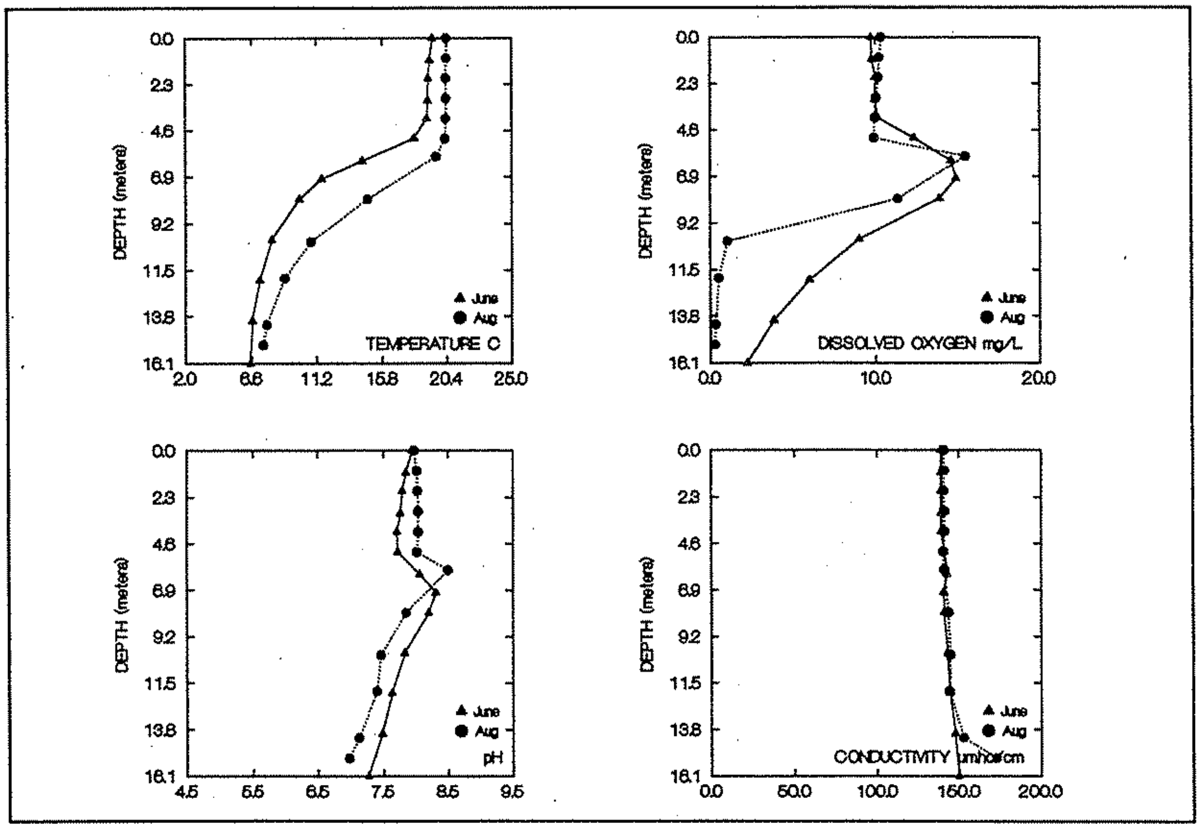
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
09/25/69[a]	6	0.50	--
10/08/70[a]	26	0.57	--

a. Collings (1973)

GRAVELLY LAKE (PIERCE COUNTY)





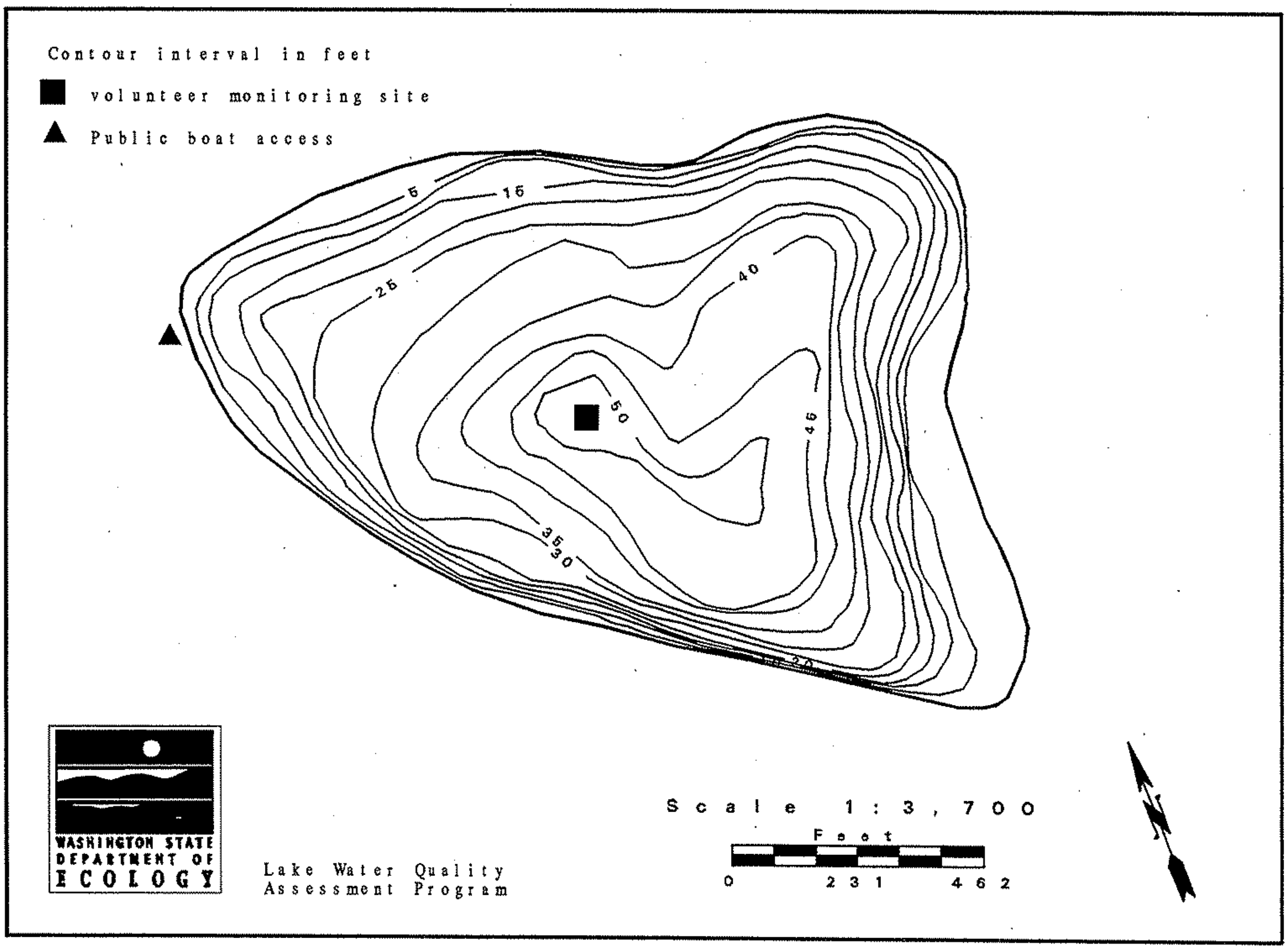
1993 Secchi Depth and Profile Data Graphs

Lake Howard -- Snohomish County

Lake Howard is located 1.25 miles west of the north end of Lake Goodwin. It has no surface inlets, and drains to Lake Martha and ultimately to Port Susan.

Size (acres)	28
Maximum Depth (feet)	50
Mean Depth (feet)	29
Lake Volume (acre-feet)	790
Drainage Area (miles^2)	0.5
Altitude (feet)	238
Shoreline Length (miles)	0.9

Data From Bortleson *et al.* (1976)



Overall Assessment

In 1993, Lake Howard exhibited both oligotrophic and mesotrophic characteristics, so it was assessed as oligo-mesotrophic. Oligotrophic characteristics were the very good Secchi depths throughout the monitoring season, and the low amounts of algae. However, concentrations of total phosphorus were moderate to high on both sampling dates, and were in the range associated with mesotrophic lakes.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in Lake Howard was very good, as indicated by Secchi depths that ranged from 16.5 feet to 23.8 feet. Secchi depths greater than 13 feet are typical for oligotrophic lakes.

Total Phosphorus

The concentration of total phosphorus was higher in August (28 μg/L) than it was in May (16 μg/L). Concentrations in the upper layer of water between 12 μg/L and 24 μg/L are typical of mesotrophic lakes. In most lakes, the concentration of total phosphorus determines how much algae may grow in the water. Although phosphorus concentrations were moderate to high, algae densities were not high. This suggests that some other requirement(s) for algae growth (such as nitrogen or silica) were limiting the amount of algae that could grow.

Total Nitrogen

Concentrations of total nitrogen were higher in May (0.47 mg/L), than in August (0.32 mg/L). The August concentration was moderately low, and may have resulted from algae taking up nitrogen and then sinking into the lower layer of water. This process traps nutrients in the lower layer of water until the lake mixes during fall. in August, the ratio of total nitrogen to total phosphorus was less than 17:1 (it was 11:1), so it is possible that algal growth was nitrogen-limited when the lake was sampled. In May, the ratio of total nitrogen to total phosphorus was 11:1, so it is likely that algal growth was not limited by nitrogen in May.

Profile Data

On both sampling dates the lake was thermally stratified. Below the thermocline, both dissolved oxygen and pH decreased with depth. Oxygen concentrations can decrease in the lower layer of water when bacteria use oxygen to decompose algae and aquatic plants in the water and sediments.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae growing in a volume of water. On both sampling dates the concentrations of chlorophyll *a* indicated low densities of algae at the time of sampling. As mentioned above under the discussion of total nitrogen, algae growth during August was probably nitrogen-limited.

Aquatic plants identified by Ecology staff near the public access included waterweed (*Elodea canadensis*), largeleaf pondweed (*Potamogeton amplifolius*), and another pondweed that was possibly *Potamogeton foliosus*. Waterweed was the most abundant plant observed near the public access.

Other Available Information

The volunteer measured temperature and dissolved oxygen at the surface and at ten feet using a YSI meter borrowed from another agency. Data results (see Comments section of volunteer-collected data) indicate that dissolved oxygen concentrations remained high in the upper layer of water (the epilimnion) through mid-October.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire.

> Lake Howard is used for fishing, swimming, rowing, catching crayfish, and bird watching. Public facilities on the lakeshore include a day use park and one boat ramp. No motor boats are allowed on the lake. Currently the watershed is being logged, and the lakeshore is being developed further for residences. In the past, the watershed was also logged and the shoreline was altered.
>
> There are 19 houses on the lakeshore, and none are connected to a sewer collection system. There are no culverts which drain into the lake. There is an inactive sewer district for the lake, and no lake management activities occurred in 1993. Lake water was withdrawn for drinking and other domestic uses, and for irrigation.
>
> Overall, the volunteer found that Lake Howard had excellent water quality. The volunteer felt there were no water quality problems in the lake in 1993, although one resident complained about excessive plant growth. A potential source of problems is runoff from yard chemical use.

Acknowledgement

I thank Curt Howard for volunteering his time to monitor Lake Howard during 1993.

Lake Howard -- Snohomish County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	35
Mean Trophic State Index (Total Phosphorus):	48
Mean Trophic State Index (Chlorophyll *a*):	36

Volunteer-Collected Data

Date 1993	Time	Temp (°C) surf	Temp (°C) 10'	Secchi (ft)	Lake Ht (in)[2]	DO (mg/L) surf	DO (mg/L) 10'	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
25-May	1210	17.2		18.0	13.38			lt-green	90	none	breezy	
08-Jun	1405	18.9		18.5				lt-green	90	light	calm	"Bloom" seen through the viewing tube. Depth of water at site 47'.
23-Jun	1305	18.9	19.0	21.0	13.25		8.8		25	light		Water color very clear light green.
05-Jul	1300	20.0	20.0	19.0	14.94		8.3	lt-green	100	light	calm	
23-Jul	1100	19.7	20.0	16.5	14.50	9.0	8.9	lt-green	100	heavy	light	pH 7.5. Rain in last 2 days 1.75"
03-Aug	1100	22.2		18.3	14.63	8.3	8.6	lt-green	0	none	light	
17-Aug	1330	21.1	20.3	23.8	16.19	7.4	7.8	lt-green	25	light	light	Water very clear. Huge amount of litter at access area.
18-Aug	1100			23.5					0			Onsite visit.
03-Sep	1330	21.1	21.0	18.5	17.50	8.1	8.0	lt-green	0	none	light	
16-Sep	1400	17.2	19.3	18.3	18.81	8.3	8.3	lt-green	0	light	light	
28-Sep	1300	16.7	17.0	18.0	19.25	9.2	9.3	lt-green	0	none	light	
13-Oct	1300	15.6	16.0	21.3	19.88	8.8	8.9	lt-green	99	none	light	Much light green "pollen" (granular) on windward side.

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Howard dropped 6.5" from May 25 through October 13.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/25	0.0	20.6	8.2	9.6	100
	1.1	20.5	8.2	9.5	100
	2.0	20.4	8.1	9.5	100
	3.0	17.4	8.3	10.7	98
	4.0	13.2	8.3	11.6	99
	5.0	9.4	8.1	9.8	99
	6.0	7.6	7.9	7.8	99
	7.0	6.6	7.7	6.0	101
	8.0	6.0	7.5	2.9	102
08/18	0.0	21.1	8.0	9.1	104
	1.0	20.7	7.9	9.3	103
	2.1	20.6	7.9	9.3	103
	3.0	20.5	7.9	9.3	104
	4.1	20.1	7.8	9.4	103
	5.0	15.6	7.8	10.5	103
	6.1	11.5	7.8	8.5	103
	8.1	7.7	7.7	6.4	103
	9.9	6.3	7.6	4.9	109
	12.1	5.8	7.4	4.3	116
	14.4	5.6	7.2	3.5	145
	14.4	5.6	7.1	3.3	147

1993 Onsite Visit Data - Water Chemistry

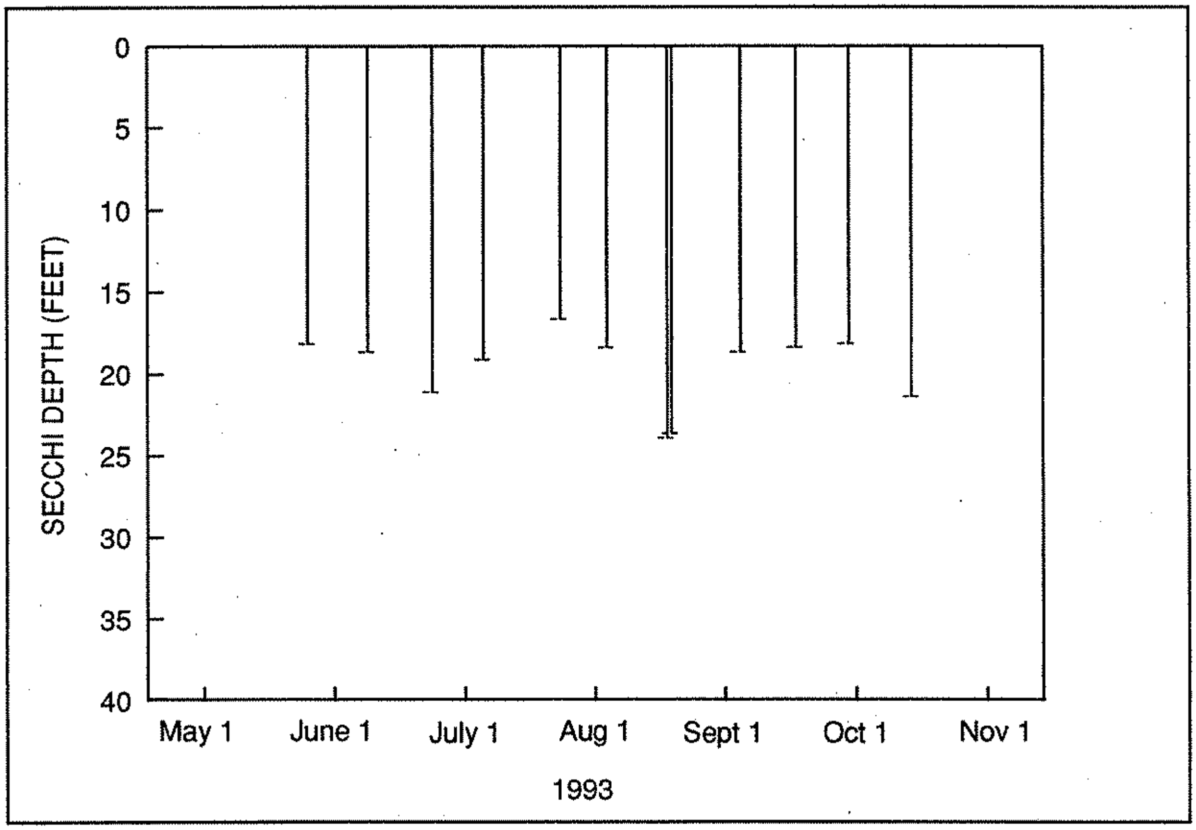
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 25							
Epilimnion	16	0.47	1.8	--	--	--	--
Hypolimnion	33	0.69	--	--	--	--	--
August 18							
Epilimnion	28	0.32	1.6	--	--	--	--
Hypolimnion	37	0.71	--	--	--	--	--

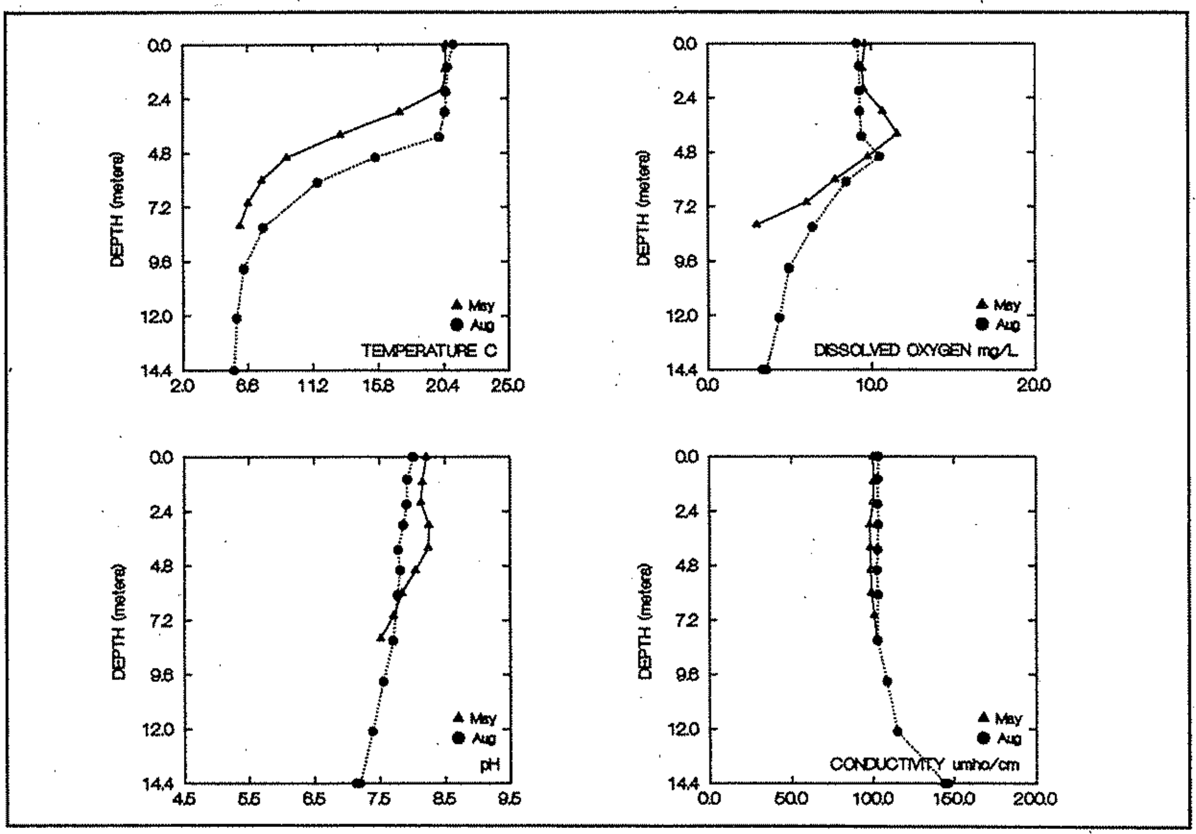
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/18/73[a]	60	--	1.8
09/24/73[a]	14	--	2.0
06/30/81[b]	20	1.3	2.3

a. Bortleson *et al.* (1976), McConnell *et al* (1976)
b. Sumioka and Dion (1985)

LAKE HOWARD (SNOHOMISH COUNTY)





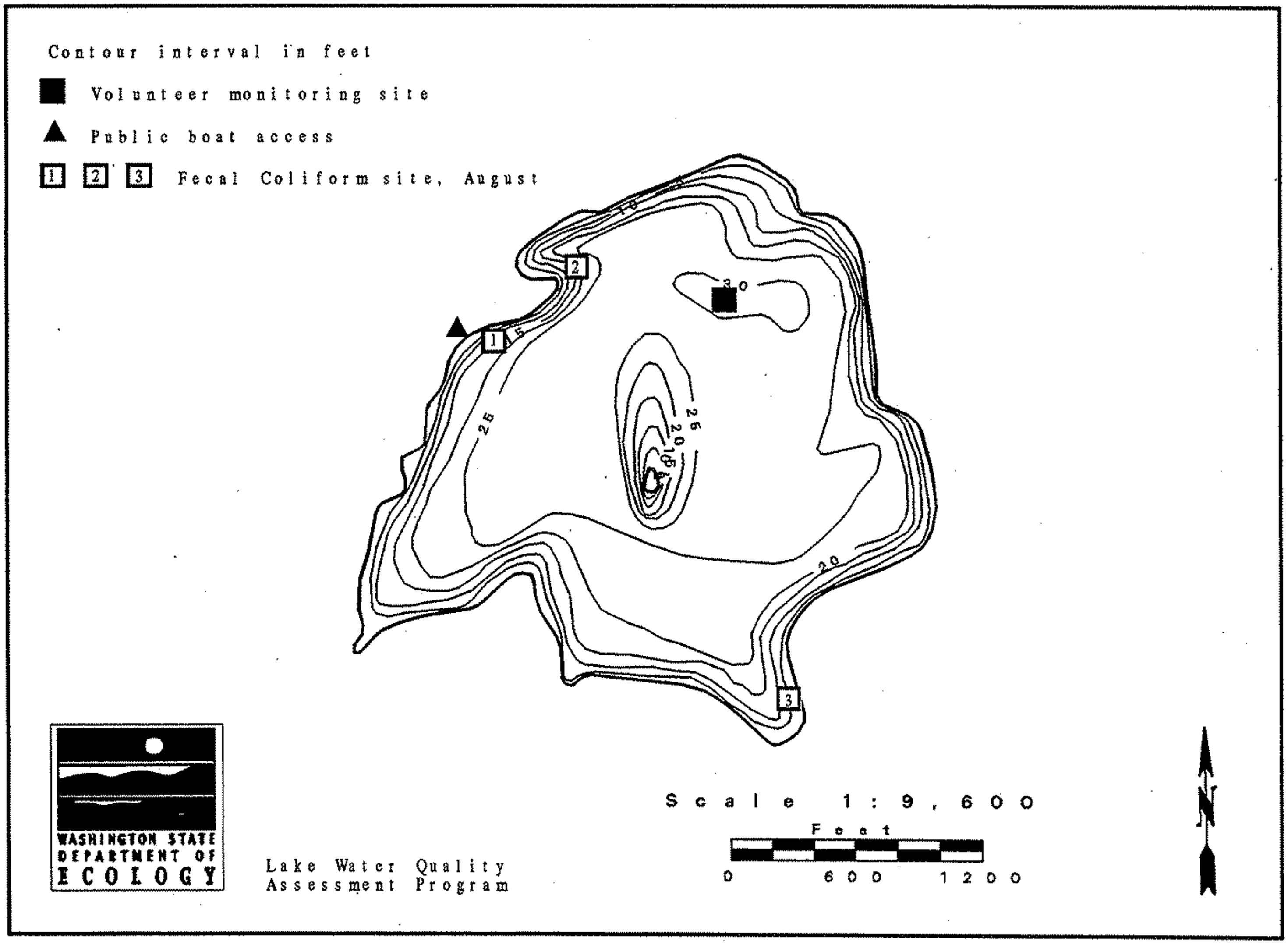
1993 Secchi Depth and Profile Data Graphs

Island Lake -- Mason County

Island Lake is located 2.5 miles north of Shelton. It drains via a swamp to Goldsborough Creek and Oakland Bay.

Size (acres)	108
Maximum Depth (feet)	31
Mean Depth (feet)	21
Lake Volume (acre-feet)	2,246
Drainage Area (miles^2)	0.3
Altitude (feet)	230
Shoreline Length (miles)	1.7

Data From Bortleson *et al.* (1976)



Overall Assessment

In 1993, Island Lake was assessed as oligotrophic, based on very good water clarity, low nutrient concentrations, and low amounts of algae (measured by chlorophyll *a*).

Lake water was also very low in ion content, as indicated by the very low conductivity of the water. Results from three fecal coliform samples were also very low, and were within State water quality standards for lake water.

Other Mason County lakes monitored for the program in 1993 were Limerick, Lost, Mason, Nahwatzel, Phillips, Spencer, and Wooten. Of these, Lost, Mason, Nahwatzel, and Wooten had lower phosphorus concentrations and better water clarity than Island Lake.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was very good, as indicated by Secchi depths which ranged from 15.9 feet to 21.8 feet. Secchi depths deeper than 13 feet are typical for oligotrophic lakes.

Total Phosphorus

On both sampling dates, the concentrations of total phosphorus were very low. These concentrations were very similar to those measured when the lake was last sampled for the program in 1990 (10 µg/L and 11 µg/L). Concentrations less than 12 µg/L are typical for oligotrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were low to moderate on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because ratios of total nitrogen to total phosphorus were greater than 17:1 (it was 31:1 in May and 21:1 in September), it is not likely that algae growth in Island Lake was limited by the amount of nitrogen at the time of sampling.

Fecal Coliform Bacteria

Samples for fecal coliform bacteria were collected at three nearshore sites during August. Site #1 was located near the public access, Site #2 was located off the point just north of the public access, and Site #3 was located in a cove at the south end of the lake. Results for all three samples were low, and were within state water quality standards for lakes.

Profile Data
The lake was not thermally stratified on either sampling date. As would be expected from an unstratified lake, there was very little change in profile data. Because the lake was not stratified, only one set of water samples was collected from the lake on each sampling date.

Conductivity, which measures the ability of water to conduct an electrical current, will depend on the ion content of water. Conductivity in Island Lake was very low (around 40 µmhos/cm), indicating that the ion content was very low.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae growing in a volume of water. Chlorophyll *a* concentrations on both sampling dates indicated low densities of algae at the time of sampling.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire.

Island Lake is used for fishing, swimming, motor boating, rowing, and jet skiing. There is one boat ramp on the lakeshore, and there are no restrictions for motor boat use on the lake. Fish (species unknown) were stocked in the lake. Currently, the lakeshore is being developed further for residences. In the past, the watershed was logged and the shoreline was altered many years ago when a small marshy area was filled.

There are 87 houses on the lakeshore, and none are connected to a sewer collection system. There is no organization for the lake, and no lake management activities occurred in 1993. Lake water was withdrawn for irrigation only.

Overall, the volunteer found that Island Lake had good water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, (2) water quality gradually degraded over years, (3) suspended sediments, and (4) low water level. Possible sources of problems include septic tanks and lawn fertilizers.

Acknowledgement

I thank Steve Whitehouse for volunteering his time to monitor Island Lake during 1993.

Island Lake -- Mason County

1993 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	36
Mean Trophic State Index (Total Phosphorus):	35
Mean Trophic State Index (Chlorophyll *a*):	36

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
29-May	1430	18.9	66.0	21.8	-24.00	green	25	light	light	
12-Jun	1430	18.9	66.0	19.2	-25.00	green	50	trace	light	
04-Jul	1230	20.0	68.0	17.5	-31.00	milky-gr	75	light	light	
18-Jul	1430	21.1	70.0	15.9	-34.00	milky-gr	10	trace	light	
01-Sep	1830	21.1	70.0	18.4	-42.00	milky-gr	0	none	breezy	
26-Sep	1430	17.8	64.0	17.4	-44.00	milky-gr	0	none	light	
10-Oct	1415			17.8		pea-green	90	trace	calm	

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

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Island Lake dropped 20" from May 29 to October 10.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/28	0.0	20.5	7.7	8.9	41
	1.0	19.6	7.7	9.0	41
	2.2	19.5	7.7	9.0	41
	3.2	19.4	7.7	9.0	41
	4.2	18.7	7.7	9.3	40
	5.4	16.4	7.9	9.8	39
09/01	0.0	21.7	7.6	9.4	41
	1.0	21.7	7.6	9.0	41
	2.0	21.2	7.6	9.0	41
	3.0	20.6	7.7	9.0	41
	4.0	20.5	7.6	8.8	41
	5.0	20.4	7.6	8.6	40
	6.0	20.3	7.4	6.8	41

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL)		
						Site #1	Site #2	Site #3
May 28								
Epilimnion	7	0.22	1.5	--	--	--	--	--
Hypolimnion*	--	--	--	--	--	--	--	--
September 1								
Epilimnion	11	0.23	2.1	--	--	6	bdl	2
Hypolimnion*	--	--	--	--	--	--	--	--

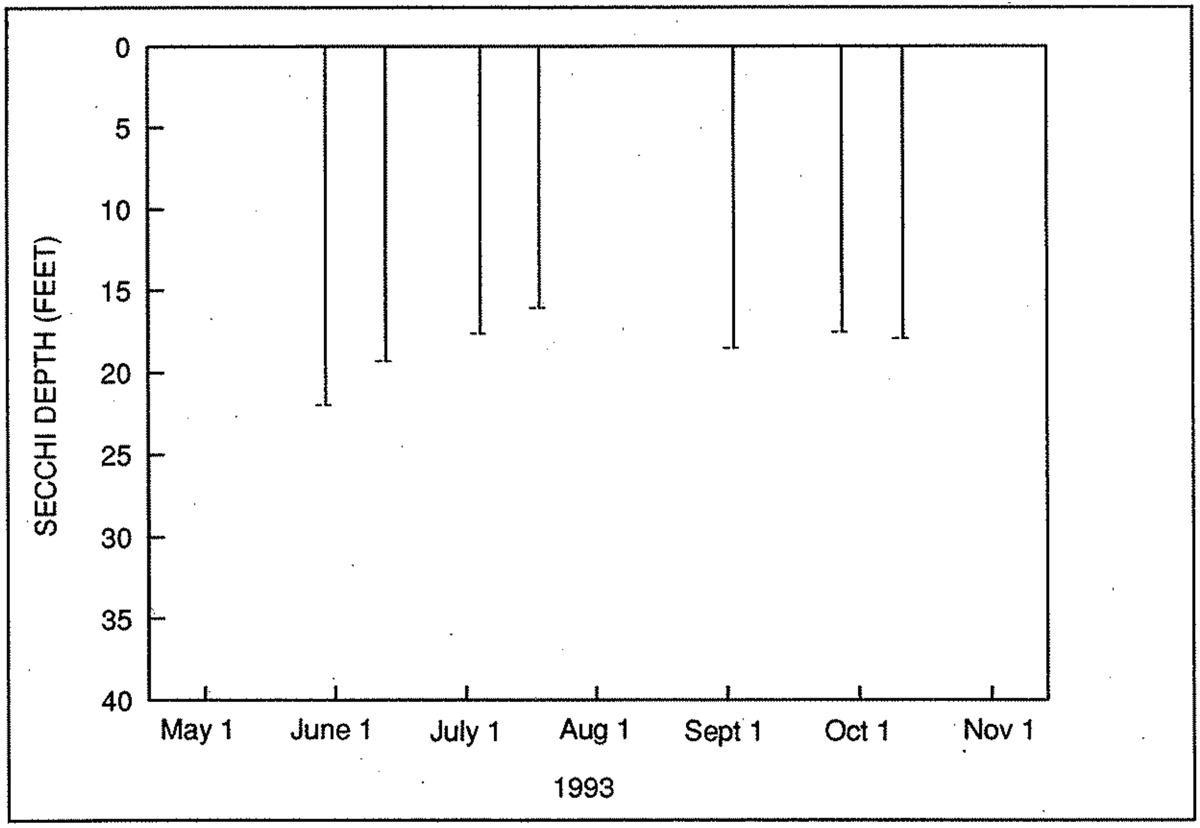
* The lake was not stratified at the time of sampling, so only one set of water samples was collected
bdl = below analytical detection limit of 1 colony/100 mL.

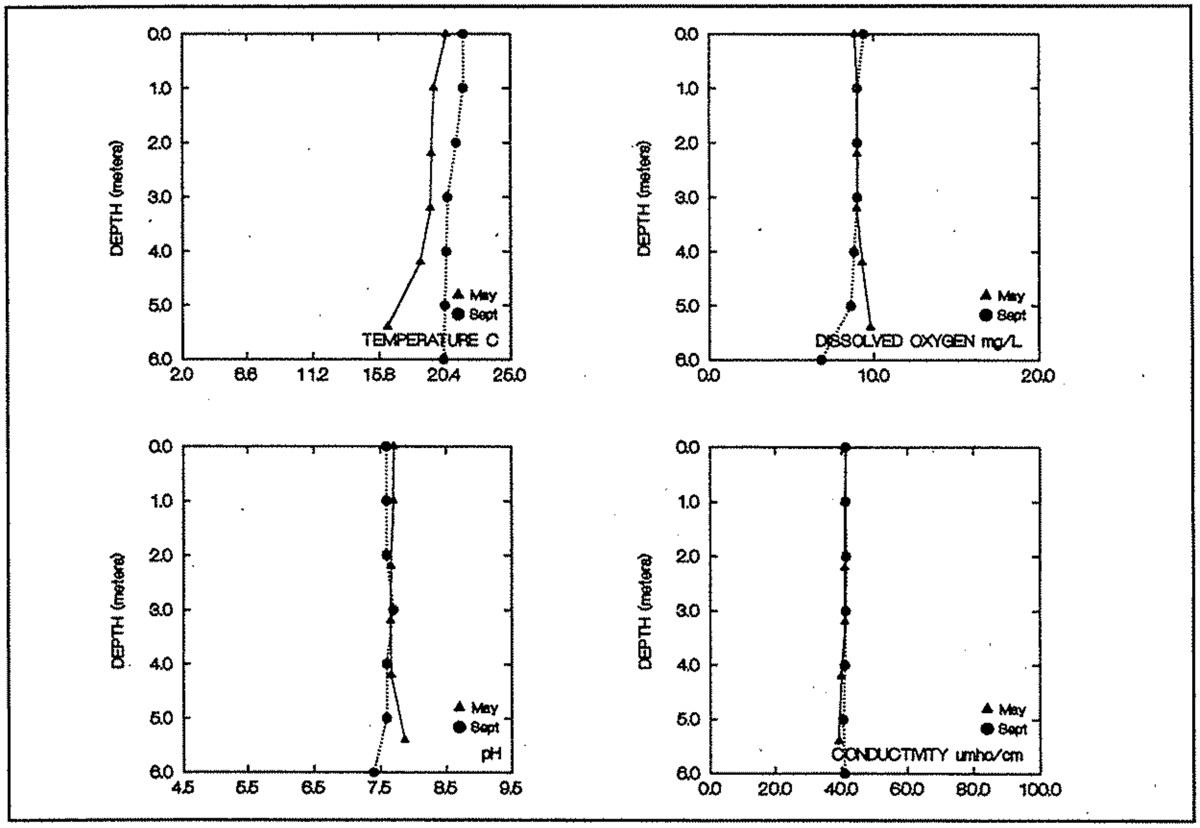
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)
08/16/74[a]	11	--	--
06/10/81[b]	30	0.45	2.0
05/31/90[c]	10	0.23	--
08/16/90[c]	11	0.27	--

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

ISLAND LAKE (MASON COUNTY)





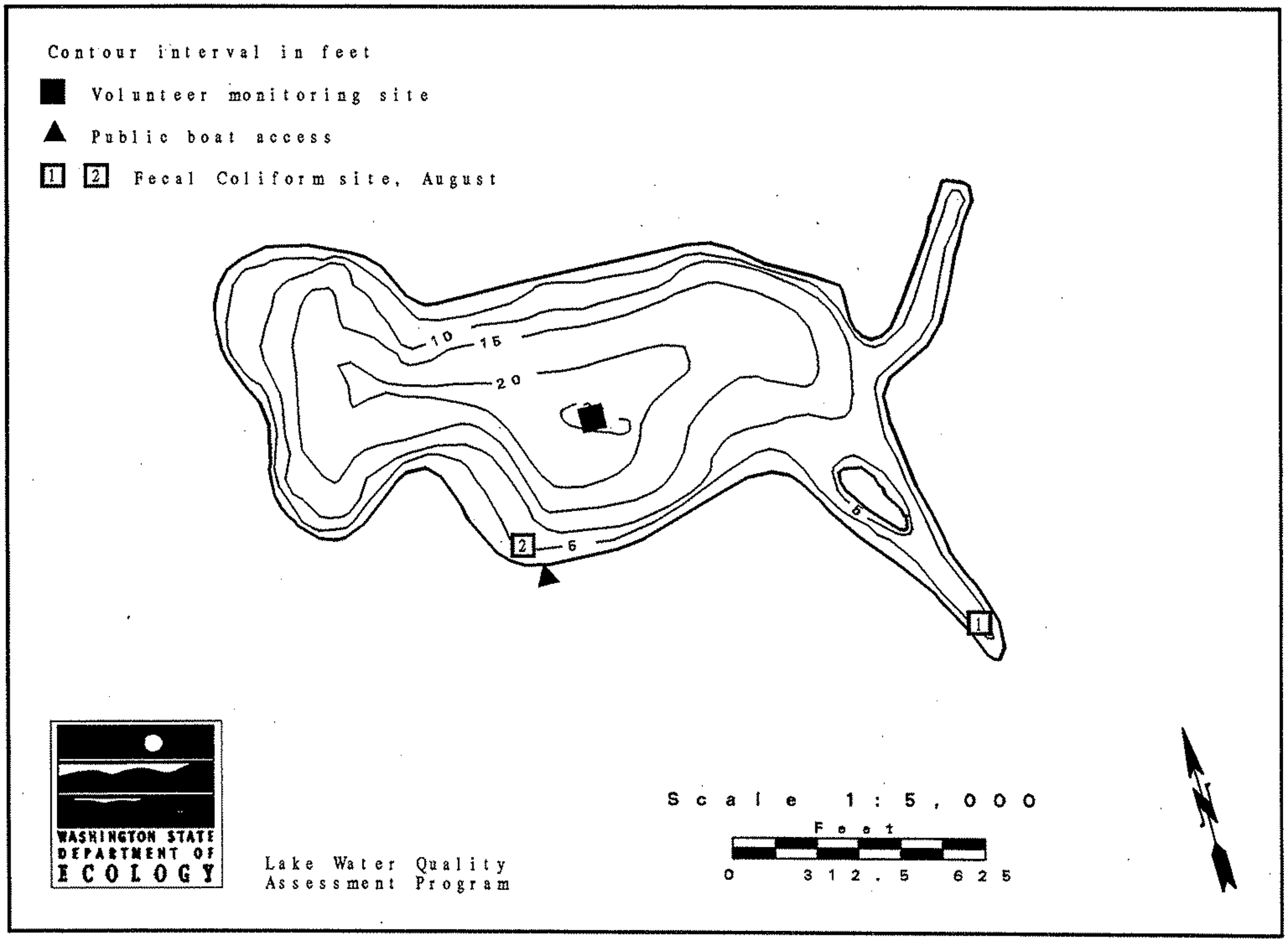
1993 Secchi Depth and Profile Data Graphs

Lake Ketchum -- Snohomish County

Lake Ketchum is located three miles north of 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)



Overall Assessment

In 1993, Lake Ketchum was eutrophic, based on very low Secchi depths. Although water samples were not collected from the lake in 1993, results from 1992 suggest that heavy plant and algae growth resulted from the extremely high phosphorus concentrations in the water. Currently, herbicides are used to control plants and algae in Lake Ketchum. Because of problems from algae and aquatic plants, a grant through Ecology's Centennial Clean Water Fund was awarded for investigating the extent and sources of water quality problems in Lake Ketchum.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was moderately poor in 1993, as indicated by Secchi depths which ranged from 5.0 feet to 9.0 feet. Water clarity was better in 1993 than in 1992. The volunteer noted that the 9.0 foot Secchi depth measured on October 10, 1993, was the deepest he had measured in two years.

Plants

Aquatic plants collected and identified by Ecology staff during the 1992 sampling visits included water net (*Hydrodictyon* sp.), duckweed (*Lemna* sp.), cattails (*Typha* sp.), and yellow-flowering water lily (*Nuphar polysepalum*). Water net is an alga that reproduces very rapidly. Duckweed was the dominant plant in the lake in 1992 and 1993.

Other Available Information

In 1993, Snohomish County was awarded a Centennial Clean Lakes Grant to study the extent of eutrophication in Lake Ketchum, and to recommend possible solutions for restoring the lake. Lake monitoring is expected to begin in 1994.

The duckweed bloom in 1992 began in August. The lake was treated with copper sulfate in May to control the water net, and endothall was applied in June to control aquatic plants. The volunteer noted that an herbicide applicator had told them that while herbicides could be used to control the problems in Lake Ketchum the cost may exceed the benefit.

From Serdar *et al.* (1994): Sediment samples were collected from five sites in Lake Ketchum on February 2, 1993, and were analyzed for copper. All sites had high concentrations of copper. Samples results ranged from 260 to 600 mg/Kg dry weight, and averaged 480 mg/Kg. Concentrations above 110 mg/Kg produce severe disturbances to benthic organisms. Because of high sediment copper concentrations in several areas of this small lake, copper sulfate treatments to control algae should be discontinued.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire.

> There are 51 houses on the lakeshore, and none are connected to a sewer collection system. There is a lake association for the lake, and in 1993 the lake was chemically treated to control algae and aquatic plants. There is one public boat ramp on the lakeshore. Rainbow trout were stocked in the lake in 1993.
>
> Overall, the volunteer found that Lake Ketchum had fair water quality. Problems in the lake in 1993 included algae, excessive aquatic plant growth, decaying plants, degraded aesthetics, both recent and long-term degradation of water quality, and odor from decaying algae. Possible sources of problems include runoff from an upstream dairy farm. The duckweed bloom was less severe in 1993 than in 1992.

Acknowledgment

I thank Anton Ehinger for volunteering his time to monitor Lake Ketchum during 1992-1993.

Lake Ketchum -- Snohomish County

1993 Trophic Status[1]

Estimated Trophic State:	Eutrophic
Mean Trophic State Index (Secchi):	50
Mean Trophic State Index (Total Phosphorus):	*
Mean Trophic State Index (Chlorophyll *a*):	*

* The lake was not sampled for the program in 1993.

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
24-Jul	1500	20.0	68.0	6.5	14.00	lt-brown	50	moderate	breezy	Allied Aquatics treated the lake for algae during June. No significant duckweed or other blooms to this date.
08-Aug	1500	22.8	73.0	7.0	15.50	lt-brown	50	none	breezy	Significant duckweed bloom occurring. Water temperature up.
27-Aug	1430	21.1	70.0	6.0	18.25	lt-brown	10	none	light	Duckweed bloom continues, not to last year's extremes.
12-Sep	1400	20.0	68.0	5.0	21.00	lt-brown	0	trace	breezy	Water is cloudy, lake level getting low. Moderate duckweed bloom continues.
10-Oct	1615	15.6	60.0	9.0	24.50	lt-brown	50	none	calm	This is the deepest Secchi reading that I have ever made on this lake. Lake level very low.

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

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Ketchum dropped 10.5" from July 24 to October 10.

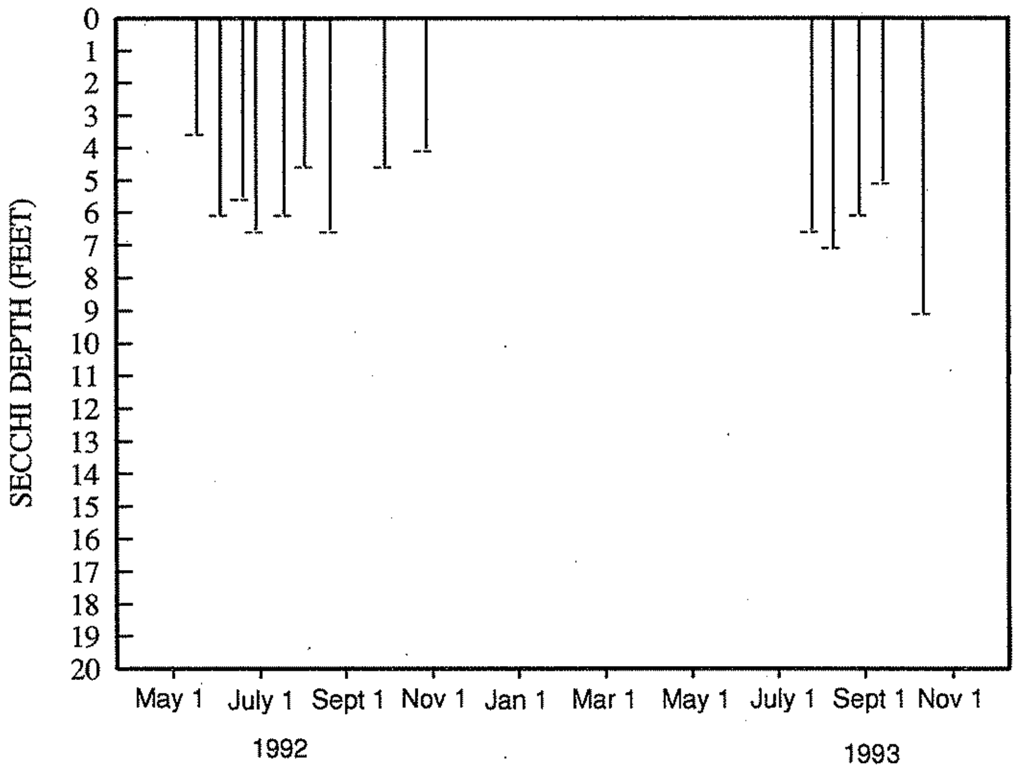
Lake Ketchum -- Snohomish County

Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/09/81[a]	190	1.6	2.0
05/18/92[b]	592	1.1	9.2
08/31/92[b]	460	1.1	13.4

a. Sumioka and Dion (1985)
b. Rector (1993)

LAKE KETCHUM (SNOHOMISH COUNTY)



NO PROFILE DATA COLLECTED IN 1993

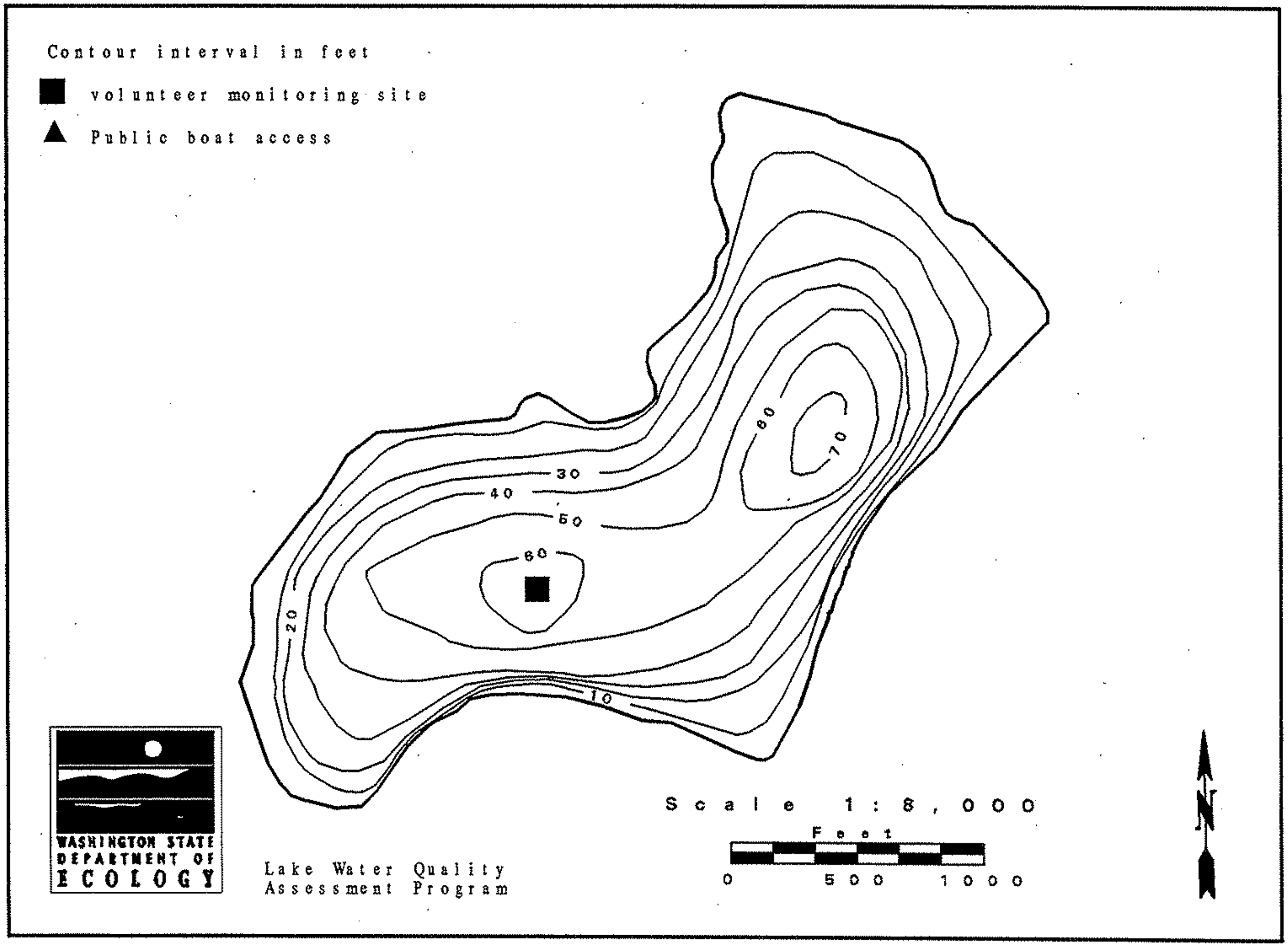
1993 Secchi Depth and Profile Data Graphs

Lake Ki -- Snohomish County

Lake Ki is located 7.75 miles northwest of Marysville. It has an intermittent surface inlet at the south end, and drains via an unnamed outlet to Portage Creek and South Slough.

Size (acres)	98
Maximum Depth (feet)	70
Mean Depth (feet)	33
Lake Volume (acre-feet)	3,300
Drainage Area (miles^2)	0.7
Altitude (feet)	414
Shoreline Length (miles)	1.9

Data From Bortleson *et al.* (1976)



Overall Assessment

In 1993, Lake Ki was assessed as oligotrophic, based on very good water clarity, low nutrient concentrations, and very little aquatic plant and algae growth. The challenge for managing Lake Ki will be to maintain the current high water quality of the lake.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was very good, as indicated by Secchi depths that ranged from 20.0 feet to 30.5 feet. Secchi depths greater than 13.0 feet indicate good water clarity.

Total Phosphorus
The concentrations of total phosphorus in the water usually determine how much algae may grow. Concentrations of total phosphorus in Lake Ki were very low on both sampling dates (9 µg/L in May, and 6 µg/L in August). Concentrations less than 12 µg/L are low, and are typical for oligotrophic lakes.

Total Nitrogen
Concentrations of total nitrogen were moderately low on both sampling dates. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 (28:1 in May, and 37:1 in August), algal growth in Lake Ki was not limited by nitrogen when the lake was sampled.

Profile Data
The lake was thermally stratified on both sampling dates. At the thermocline (the depths where water temperature decreases rapidly with depth), dissolved oxygen concentrations and pH values increased. The increase in oxygen probably resulted from the sharp decrease in water temperature (because dissolved gases are more soluble in cooler water than in warmer water) as well as increased algae growth at these depths. Increased algae growth may have also caused pH values to increase in the thermocline.

In August, dissolved oxygen and pH decreased with depth below the thermocline. Oxygen usually decreases in the lower layer because bacteria use oxygen when decomposing algae and aquatic plants in the bottom water and sediments. However, if springs feed the lake, ground water may be affecting oxygen concentrations in the lower layer of water. Ground water, which is low in oxygen, would be trapped in the lower layer while the lake is stratified.

Low oxygen may have caused hydrogen sulfide ("rotten-egg" smell) to be formed near the lake bottom. Hydrogen sulfide is only found in water that has no oxygen, and was smelled in water samples collected at 18 meters.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae growing in a volume of water. Chlorophyll *a* concentrations in Lake Ki on both sampling dates indicated low densities of algae at the time of sampling. Algal densities were higher in May than in August.

There were few aquatic plants observed when the lake was sampled. Most aquatic plants were located in shallow water near the beach access on 176th Street.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire.

> Lake Ki is used for fishing, swimming, and rowing. Public facilities on the lakeshore include a day use park and a city/county park. There is one boat ramp on the lakeshore, and restrictions for boat use on the lake include a speed limit of 8 mph and no wake within 50 feet of shore. Rainbow trout were stocked in the lake in 1993. Currently, the lakeshore is being developed further for residences. In the past, the watershed was logged.
>
> There are approximately 130 houses on the lakeshore, and none are connected to a sewer collection system. There is one culvert which drains into the lake. There is one organization for the lake, the Lake Ki Yacht Club. No lake management activities occurred in 1993. Lake water was withdrawn for irrigation only.
>
> Overall, the volunteer found that Lake Ki had excellent water quality. There were no water quality problems in the lake, although the volunteer is concerned about the potential for algae problems, or the possibility of an introduction of noxious aquatic plants such as Eurasian watermilfoil.

Acknowledgment

I thank Bob Freestad for volunteering his time to monitor Lake Ki in 1993.

Lake Ki -- Snohomish County

1993 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*):	39

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
25-May	1415			20.0			100		light	Onsite visit. Water color turquoise. Light rain.
07-Jun	0900	18.9	66.0	20.3		clear	90	heavy	calm	
20-Jun	1200	19.4	66.9	21.1		clear	0	none	calm	
06-Jul	1300	20.0	68.0	20.3		clear	0	trace	light	
17-Jul	1846	17.2	63.0	20.2		clear	0	moderate	light	Reider stood in for Bob.
01-Aug	1145	20.6	69.0	24.8		clear	0	trace	light	
15-Aug	1345	19.4	67.0	25.2		clear	100	light	calm	
19-Aug	1345			22.0		clear	0		calm	Onsite visit.
01-Sep	1530	21.1	70.0	25.0		clear	0	none	calm	
18-Sep	1200	21.1	70.0	25.0		clear	0	none	light	
02-Oct	1200	20.6	69.0	24.8		clear	0	calm		
16-Oct	1030	15.6	60.0	30.5		clear	0	moderate	calm	

1 Trophic State Indices calculated from Carlson (1977).
2 "Lake height" refers to change in water level. Lake height was not monitored in 1993.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/25	0.0	20.0	8.2	9.6	36
	1.0	19.9	8.2	9.7	36
	2.2	19.7	8.2	9.8	36
	3.1	19.2	8.3	9.9	37
	4.0	17.0	8.9	11.2	37
	5.1	15.2	9.0	11.4	37
	6.1	12.3	9.0	12.3	36
	7.0	10.6	8.9	12.4	36
	8.0	8.9	8.8	12.6	35
	10.1	7.3	8.7	11.4	35
	12.1	7.0	8.4	9.7	35
	14.1	6.8	8.2	8.9	36
	16.2	6.7	8.1	8.5	36
	18.1	6.8	7.9	8.0	35
08/29	0.0	21.8	7.4	8.7	38
	1.0	21.3	7.4	8.4	38
	2.0	20.8	7.3	8.3	38
	3.1	20.8	7.3	8.2	38
	3.9	20.7	7.3	8.2	37
	5.1	20.5	7.2	8.1	38
	6.1	20.0	7.2	8.4	37
	8.2	13.9	8.4	11.0	38
	10.1	10.1	8.1	9.7	37
	12.0	8.7	7.7	5.9	38
	14.1	8.2	7.5	2.8	40
	16.1	8.1	7.4	0.8	40
	18.0	8.0	7.3	0.4	43
	19.4	8.0	7.2	0.3	44

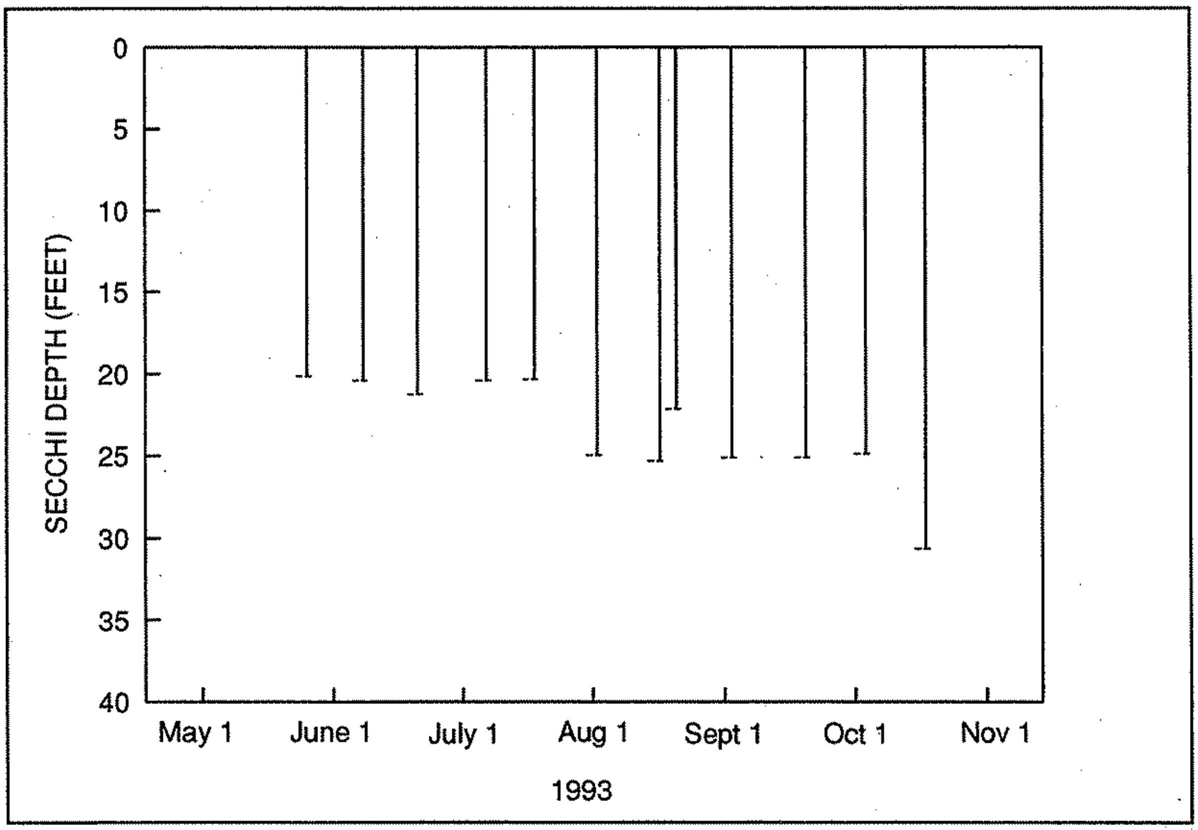
1993 Onsite Visit Data - Water Chemistry

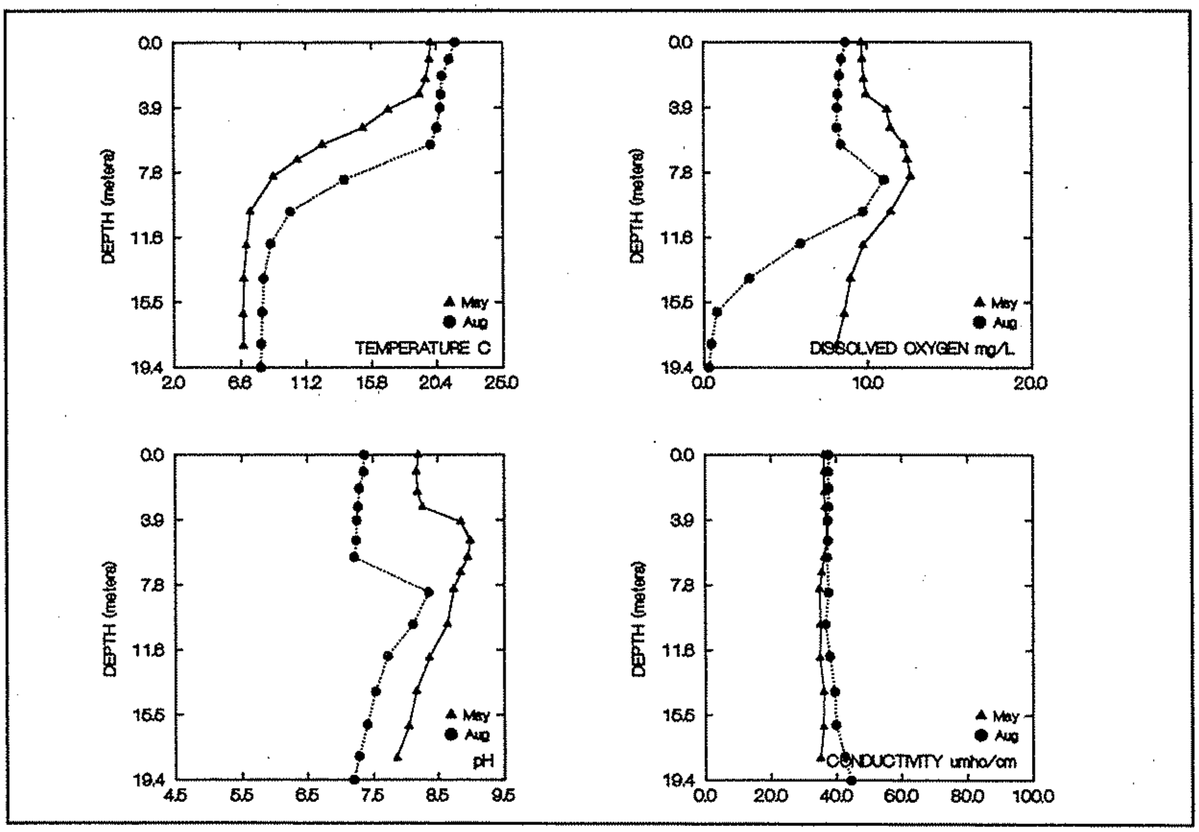
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 25 Epilimnion	9	0.25	3.0	--	--	--	--
Hypolimnion	28	0.29	--	--	--	--	--
August 19 Epilimnion	6	0.22	1.7	--	--	--	--
Hypolimnion	19	0.23	--	--	--	--	--

Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
06/20/74[a]	7	--	2.3
08/27/74[a]	6	--	0.8
07/06/81[b]	10	0.6	2.2

LAKE KI (SNOHOMISH COUNTY)





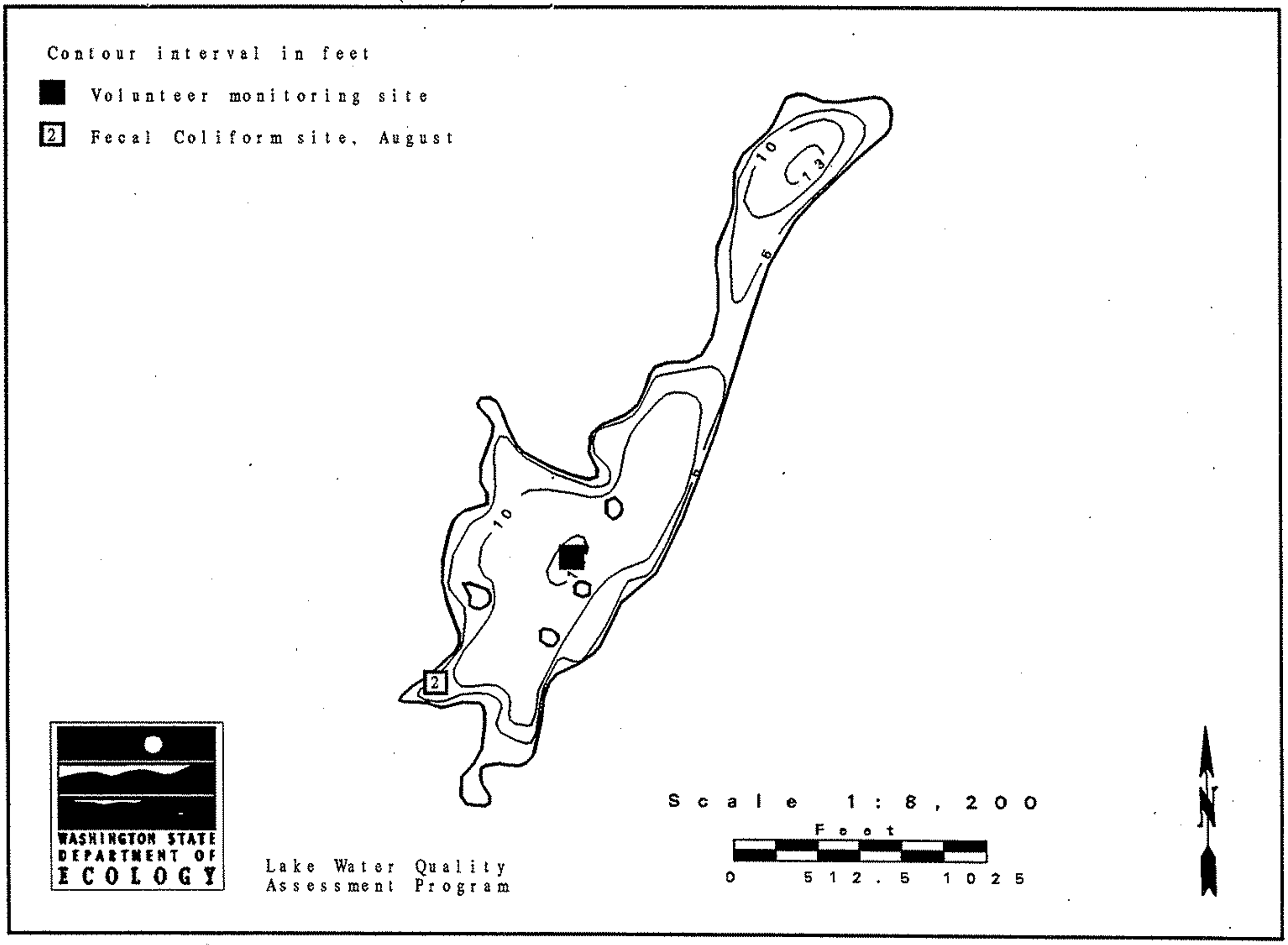
1993 Secchi Depth and Profile Data Graphs

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)	34
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)



Overall Assessment

In 1993, Lake Killarney was assessed as eutrophic, based on high concentrations of total phosphorus and moderately high amounts of aquatic plants. Because algae growth in Lake Killarney is controlled with algaecides, chlorophyll concentrations (which indicate the amount of algae in the water) and Secchi depth are not the best indicators of the trophic status for the lake. The lake has been monitored for the program since 1989, and has been described as eutrophic each year since 1990.

Although Lake Killarney was one of the more eutrophic lakes monitored for the program during 1990-1992, several eutrophic lakes were added to the program in 1993. As a result, 15 lakes had higher concentrations of total phosphorus than Lake Killarney in 1993.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Secchi depths in 1993 ranged from 5.0 feet to 9.0 feet. These depths were very similar to depths measured since 1989. Secchi depth data collected from 1989 to 1993 were analyzed for statistical trend in water clarity. There was no statistical trend, quite possibly because of algicide treatments in the lake.

Total Phosphorus

Concentrations of total phosphorus were high on both sampling dates (28 and 33 µg/L). Although concentrations were high, they were lower than concentrations measured in 1992 (38 and 39 µg/L) and 1990 (43 µg/L). Total phosphorus concentrations greater than 24 µg/L are considered high, and typical for eutrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were moderately high to high on both sampling dates. With the exception of one higher value measured in May 1992 (0.72 mg/L), concentrations measured in 1993 were very similar to those measured during the months of May and August 1990 and 1991, and in August 1992.

Fecal Coliform Bacteria

Samples for fecal coliform bacteria were collected from two sites during August. Site #1 was located at the public access on the north basin of the lake, and Site #2 was located at the south end of the south basin, near the outlet. The result for the sample collected at the public access was high (240 colonies/100 mL), and was reported to Ecology's Northwest Regional Office. The result for the south basin sample was low (9 colonies/100 mL).

Often, there is high variability in fecal coliform results; high results must be confirmed by multiple sampling before a violation of water quality standards can be determined. This program collects samples as a screening tool.

Solids
Results from solids samples are used to evaluate whether Secchi depths were affected primarily by algae, or if suspended sediments affected water clarity at the time of sampling. Samples for total suspended solids and nonvolatile suspended solids were collected from Lake Killarney during August. Results for both samples were below the detection limits for the tests. In 1992, samples collected during August had both total and total nonvolatile suspended solids above detection limits. This indicated that suspended particles in the water in 1992 (but not 1993) consisted of suspended sediments as well as algae, which could affect Secchi depths.

Profile Data
On both sampling dates, there was little change in profile parameters in the top two meters of water. At the bottom of the lake (about three meters deep), dissolved oxygen was very low and there were slight changes in both pH and conductivity.

Oxygen concentrations usually decrease when bacteria use oxygen to decompose organic material (such as algae and aquatic plants) in the water and sediments. Aquatic plants and algae killed by algicide and herbicide applications probably contribute part of the oxygen demand in the water.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. The concentration of chlorophyll *a* was moderately high in May (4.8 μg/L), and high in August (7.4 μg/L). Chlorophyll *a* concentrations greater than 6.4 μg/L indicate high densities of algae growth, and are typical of eutrophic lakes.

Aquatic plants observed during the 1993 sampling visit included watershield (*Brasenia schreberi*), bladderwort (*Utricularia vulgaris*), largeleaf pondweed (*Potamogeton amplifolius*), the alga *Nitella*, and an unidentified "grassy" plant that resembled *Isoetes*. Purple loosestrife (*Lythrum salicaria*), an aggressive non-native wetland plant, was in bloom along parts of the shore in August. All plants listed above were also observed in 1992.

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."

Other Available Information
Herbicide treatment in Lake Killarney requires a permit from King County in addition to the short-term water quality variance permit required by Ecology.

Lake Killarney -- King County

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 1993.

> Lake Killarney is used for fishing, swimming, and rowing. There is one boat ramp on the lakeshore, and combustion engines are not allowed on the lake. The ban on combustion engines began in spring 1992. No fish were stocked in the lake in 1993. The lakeshore is being developed further for residences. In the past, the watershed was logged and the shoreline was altered.
>
> There are 64 houses on the lakeshore, and none 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 algae, pondweeds, and bladderwort in the lake. The lake was treated with chemicals in 1993, but because of the high cost of the herbicide used on the lake (Sonar), some residents were hand pulling pondweeds from the lake so that less area would need treating. Currently, the minimum setback for lakeshore development is 100 feet, minimum lot size is 15,000 square feet, and there is no restriction on residential density.
>
> Overall, the volunteer found that Lake Killarney had good water quality. Problems in the lake in 1993 were ranked as (1) algae, (2) suspended sediments, and (3) goose feces. (In 1992 the worst problems were (1) algae (which was very persistent in 1992), (2) suspended sediments, (3) aquatic plants, (4) water level, and (5) degraded aesthetics.) Pondweeds covered a larger area in 1993 than in 1992, and in 1993 there was more purple loosestrife along the shoreline. In 1993, some property was sold to the City of Federal Way for a future park site.
>
> In 1991, bladderwort was most dense in the north end of the lake, and was spreading south. Most pondweeds grew in the north and center areas of the lake. Algae grew throughout the lake. The amount of submerged weed and pond lily growth increased 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.

Acknowledgment

I thank Paul DesJardin for volunteering his time to monitor Lake Killarney during 1989-1993.

Lake Killarney -- King County

1993 Trophic Status[1]

Estimated Trophic State:	Eutrophic
Mean Trophic State Index (Secchi):	50
Mean Trophic State Index (Total Phosphorus):	53
Mean Trophic State Index (Chlorophyll *a*):	48

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
16-May	1300	22.0	71.5	5.0	-0.75	dk-brown	0	trace	light	We had a brown algae bloom this week. Is very heavy right now. Couldn't see shore bottom this evening.
27-May	1045			8.3			100		light	Onsite visit.
02-Jun	1200	21.0	69.8	9.0	-1.00	gr-brown	90	heavy	calm	Put water sample in freezer.
16-Jun	1400	22.0	71.6	8.5	0.00	lt-green	50	heavy	calm	none.
30-Jun	1430	23.0	73.4	6.8	-3.50	lt-brown	75	moderate	light	Had lake treated 6/25/93 with Sonar and copper sulfate.
15-Jul	1500	21.0	69.8	5.5	-6.25	lt-brown	100	moderate	light	Cloudy/overcast, cooler than average.
31-Jul	1330	22.0	71.6	8.0	-7.00	lt-brown	0	none	light	Colder than average temperature, and more rain this month.
15-Aug	1100	21.0	69.8	7.0	-10.25	lt-brown	50	trace	calm	Cooler than normal this time of year.
23-Aug	1015			7.5			60			Onsite visit. Water color brown-green.
02-Sep	1430	23.0	73.4	8.3	-13.50	lt-brown	0	none	light	
16-Sep	1000	19.0	66.2	8.0	-16.25	lt-brown	0	none	calm	
02-Oct	1400	19.0	66.2	7.3	-18.75	lt-brown	0	none	calm	
16-Oct	1400	16.0	60.8	7.5	-19.50	lt-brown	75	heavy	light	

[1] Trophic State Indices calculated from Carlson (1977).
[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Killarney dropped 18.75" from May 16 to October 16.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/27	0.0	20.9	7.1	8.5	45
	1.0	20.9	7.0	8.5	45
	2.1	18.4	6.9	7.8	45
	3.1	14.8	6.6	2.3	50
08/23	0.0	20.8	7.5	7.8	46
	1.0	20.8	7.4	7.5	46
	2.1	20.8	7.3	7.3	46
	3.0	19.2	6.9	0.3	58

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 27 Epilimnion	28	0.50	4.8	--	--	--	--
Hypolimnion*							
August 23 Epilimnion	33	0.47	7.4	<1	<1	240	9
Hypolimnion	31	0.47	--	--	--	--	--

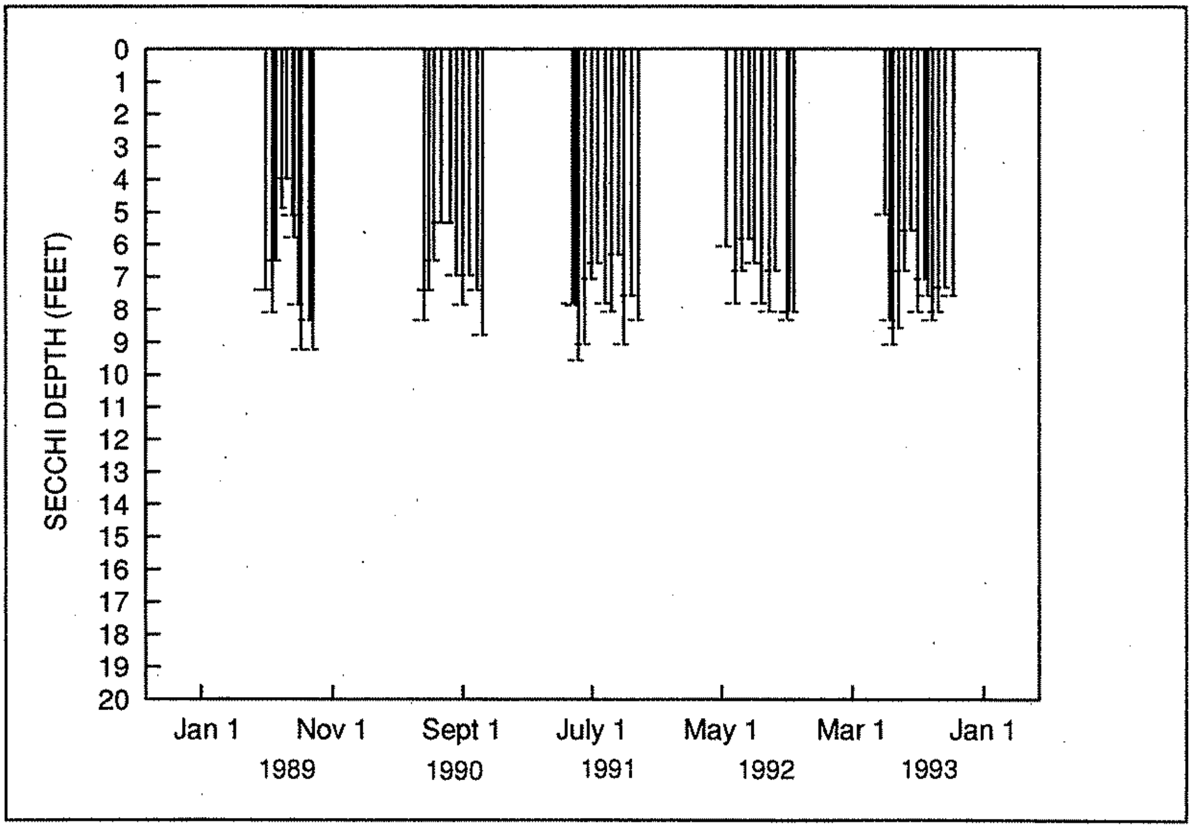
* The lake was not stratified at the time of sampling; only one set of samples was collected

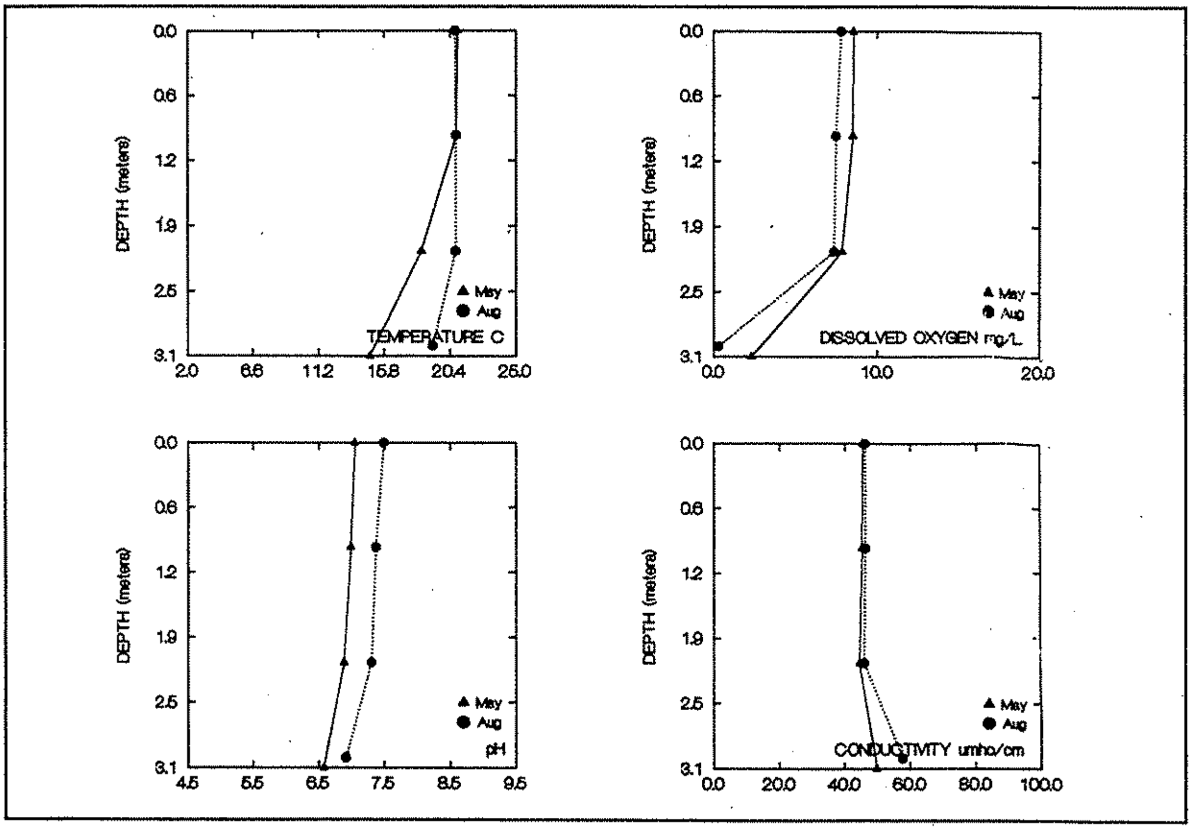
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)
07/05/73[a]	22	--	1.4
06/14/90[b]	43	0.45	--
05/22/91[c]	--	0.43	--
05/11/92[d]	38	0.72	4.9
08/18/92[d]	39	0.52	2.5

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)

LAKE KILLARNEY (KING COUNTY)





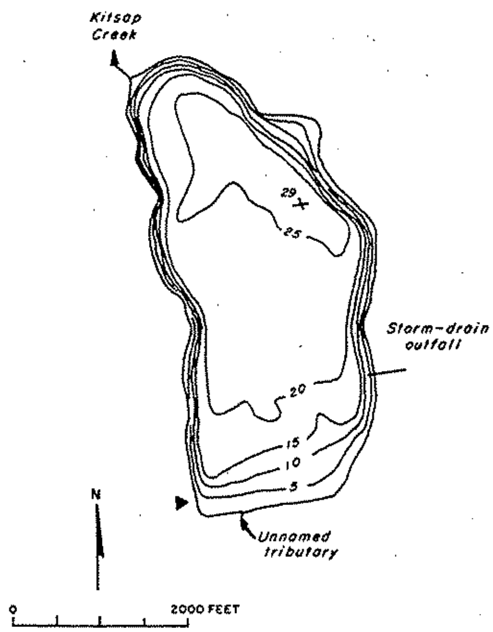
1993 Secchi Depth and Profile Data Graphs

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)



EXPLANATION

——10——

Line of equal water depth
Interval 5 feet

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

Overall Assessment

In 1993, Kitsap Lake was assessed as mesotrophic, based on moderately high concentrations of total phosphorus and chlorophyll *a*, and areas with heavy growths of aquatic plants. Despite the moderately high amounts of algae, Kitsap Lake had good water clarity.

Other Kitsap County lakes monitored for the program in 1993 were Mission Lake, Buck Lake, and Wye Lake. Tiger Lake, which is in both Kitsap and Mason Counties, was also monitored in 1993. Only Tiger Lake had lower concentrations of total phosphorus, and lower densities of algae, than Kitsap Lake.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was good in 1993, as shown by Secchi depths which ranged from 10.7 feet to 19.0 feet. Secchi depths greater than 13.0 feet are typical for oligotrophic lakes.

Total Phosphorus
The concentration of total phosphorus in August was moderately high (16 µg/L). This concentration was lower than concentrations measured in 1992 and 1990. Total phosphorus concentrations between 12 µg/L and 24 µg/L are typical for mesotrophic lakes.

Total Nitrogen
The concentration of total nitrogen was moderately low in August. Concentrations of total nitrogen were also moderately low in 1992.

Profile Data
The lake was not thermally stratified when the lake was sampled in August. In 1990, profiles were measured four times during summer (May, June, August, and September) and the lake was not stratified. In 1992, the lake was weakly stratified on both sampling dates. Kitsap Lake appears to destratify at times during summer, most likely because it is rather shallow, and winds and motorboats may promote mixing.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants that is used to determine the amount of algae in a volume of water. In August, the concentration of chlorophyll *a* indicated a moderately high density of algae at the time of sampling.

Plants observed during the May 27, 1992, sampling visit with the volunteer included largeleaf pondweed (*Potamogeton amplifolius*), coontail (*Ceratophyllum demersum*), waterweed (*Elodea canadensis*), leafy pondweed (*Potamogeton foliosus*; which was heavily encrusted with epiphytic algae), flatstem pondweed (*Potamogeton zosteriformis*), another pondweed (possibly *Potamogeton pectinatus*), yellow-flowering water lily (*Nuphar*), and iris (*Iris pseudacorus*).

Algae samples collected by the volunteer in July and October 1992, primarily contained the blue-green alga *Anabaena*. Algae in the July sample was possibly dominated by *A. circinalis*.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteers' responses and remarks to the 1993, 1990, and 1989 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. Currently, the watershed is used for industry and for animal grazing. The lakeshore is also being developed further for residences. In the past, the watershed was logged, mined, and used for crop agriculture.
>
> There are about 115 houses on the lakeshore, and about 50% of the lakeshore is sewered. There are 15 storm drains which drain into the lake. There is a community association for the lake. No lake management activities occurred in 1993.
>
> Overall, the volunteer found that Kitsap Lake had good water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, (2) swimmer's itch, (3) water quality gradually degraded over years, (4) algae, (5) shoreline erosion, (6) degraded aesthetics, (7) decaying plants, and (8) suspended sediments. Possible sources of problems include excessive nutrient loading from lawn fertilizers and lake sediment; motor boats contribute by stirring up
>
> lake sediments in shallow areas. Heavy boat traffic was listed as a problem in the 1990 questionnaire. In comparison to the 1992 monitoring season, water temperatures were cooler, which may have reduced plant growth somewhat.

Acknowledgment

I thank Randena Schaap for volunteering her time to monitor Kitsap Lake in 1993, 1992, and 1990.

Kitsap Lake -- Kitsap County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	38
Mean Trophic State Index (Total Phosphorus):	44
Mean Trophic State Index (Chlorophyll *a*):	45

Volunteer-Collected Data

Date 1993	Time	Temperature[2] (°C)	(°F)	Secchi (ft)	Lake Ht (in)[3]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
15-Jul	1145	19.2	66.6	18.5	30.00	pea-green	100	light	breezy	
05-Aug	1145	24.2	75.6	19.0	30.50	pea-green	0	none	calm	Heavy algae bloom with green-brown color.
25-Aug	1300	20.9	69.6	12.0	31.00	pea-green	50	trace	breezy	
31-Aug	1500	22.0	71.6	17.0	31.00	green	25		light	Onsite visit.
15-Sep	1045	22.0	71.6	10.7	31.50	pea-green	50	trace	light	Heavy algae.
09-Oct	1345	17.5	58.0	16.0		gr-brown	0	trace	breezy	

[1] Trophic State Indices calculated from Carlson (1977).
[2] Based on a quality assurance check on the volunteer's thermometer, all temperatures reported here were corrected by adding 3.1°C.
[3] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Kitsap Lake dropped 1.5" from July 15 to October 9.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
08/31	0.0	22.0	7.5	9.4	95
	0.9	21.3	7.6	9.1	95
	2.0	21.1	7.7	9.0	95
	3.0	21.0	7.7	8.9	95
	4.0	21.0	7.7	8.8	95
	5.0	20.6	7.5	6.9	95
	6.0	20.3	7.3	3.2	98

1993 Onsite Visit Data - Water Chemistry

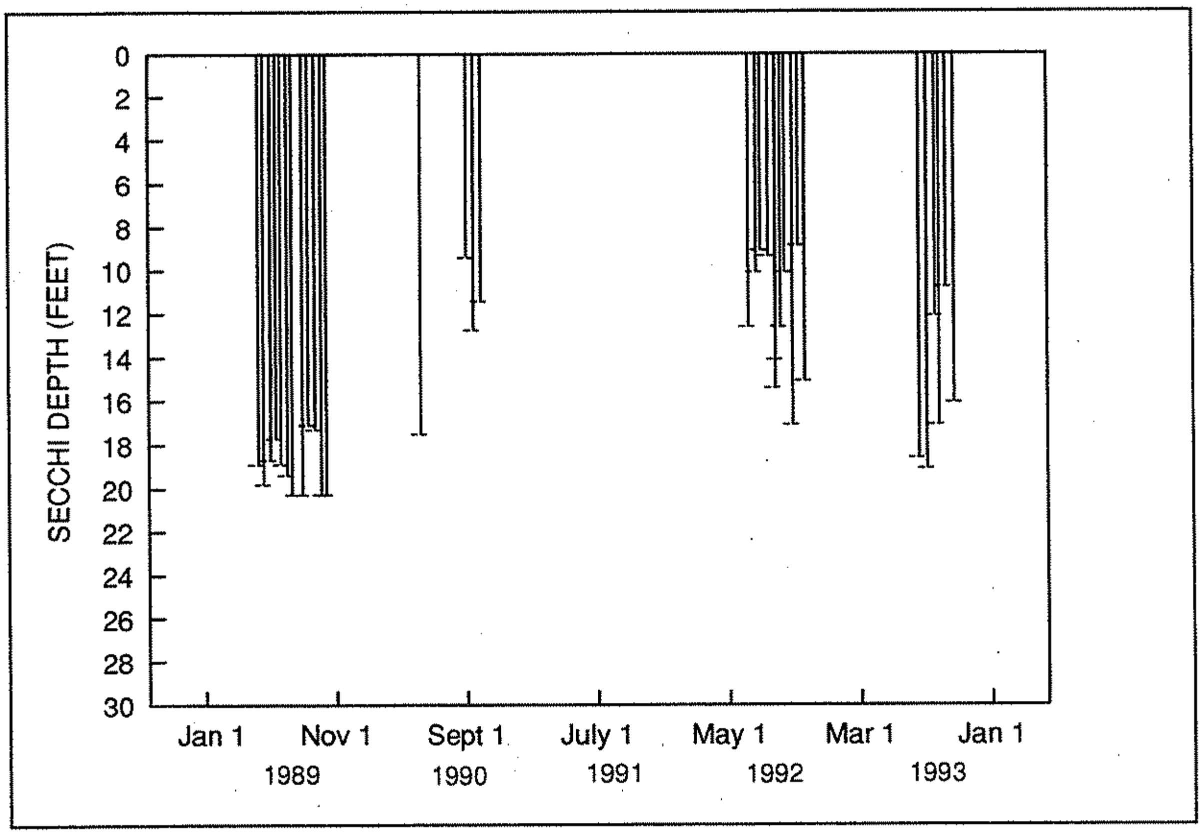
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
August 31 Epilimnion	16	0.24	4.3	--	--	--	--
Hypolimnion	16	0.25	--	--	--	--	--

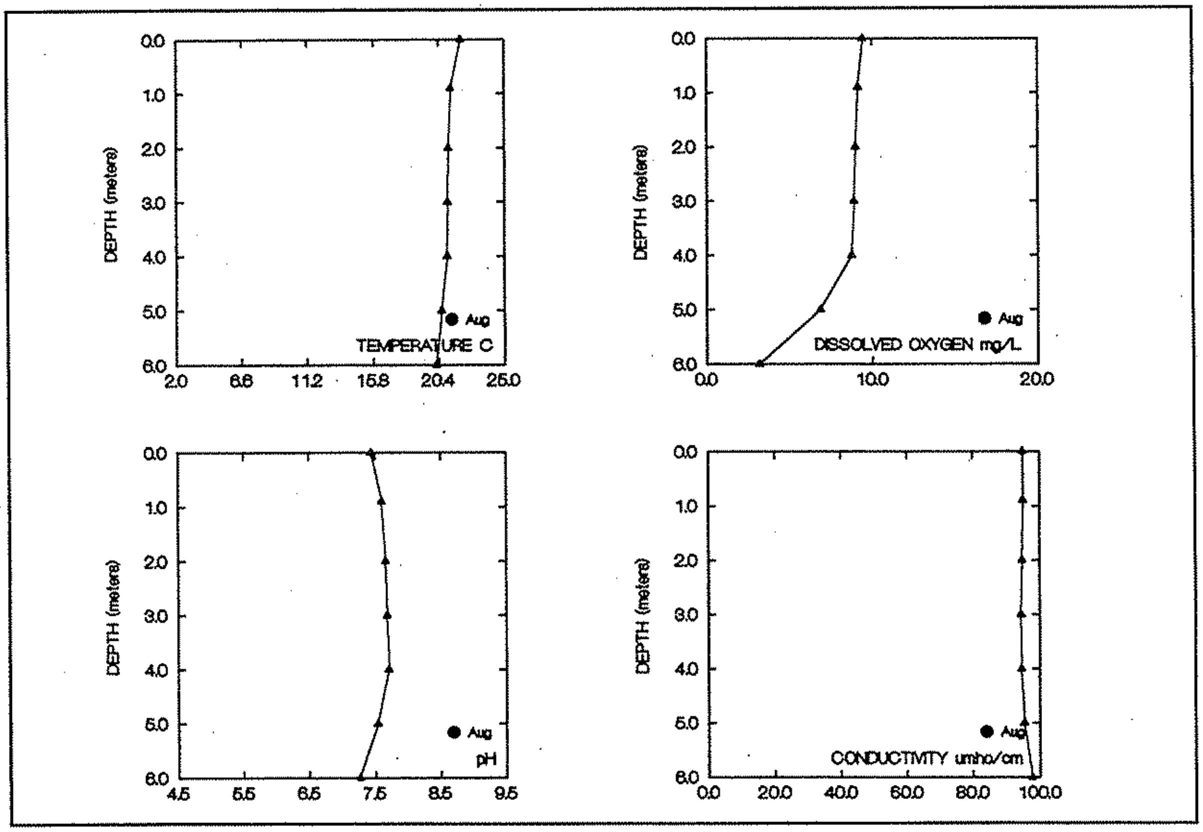
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
06/03/71a	20	--	1.4
07/21/81b	30	0.68	2.5
05/23/90c	18	0.23	--
06/13/90d	--	0.19	3.5
09/04/90c	35	0.44	--
09/12/90d	32	0.35	7.9
05/27/92e	18	0.23	1.2
08/19/92e	19	--	2.5

a. Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Coots (1991)
e. Rector (1993)

KITSAP LAKE (KITSAP COUNTY)





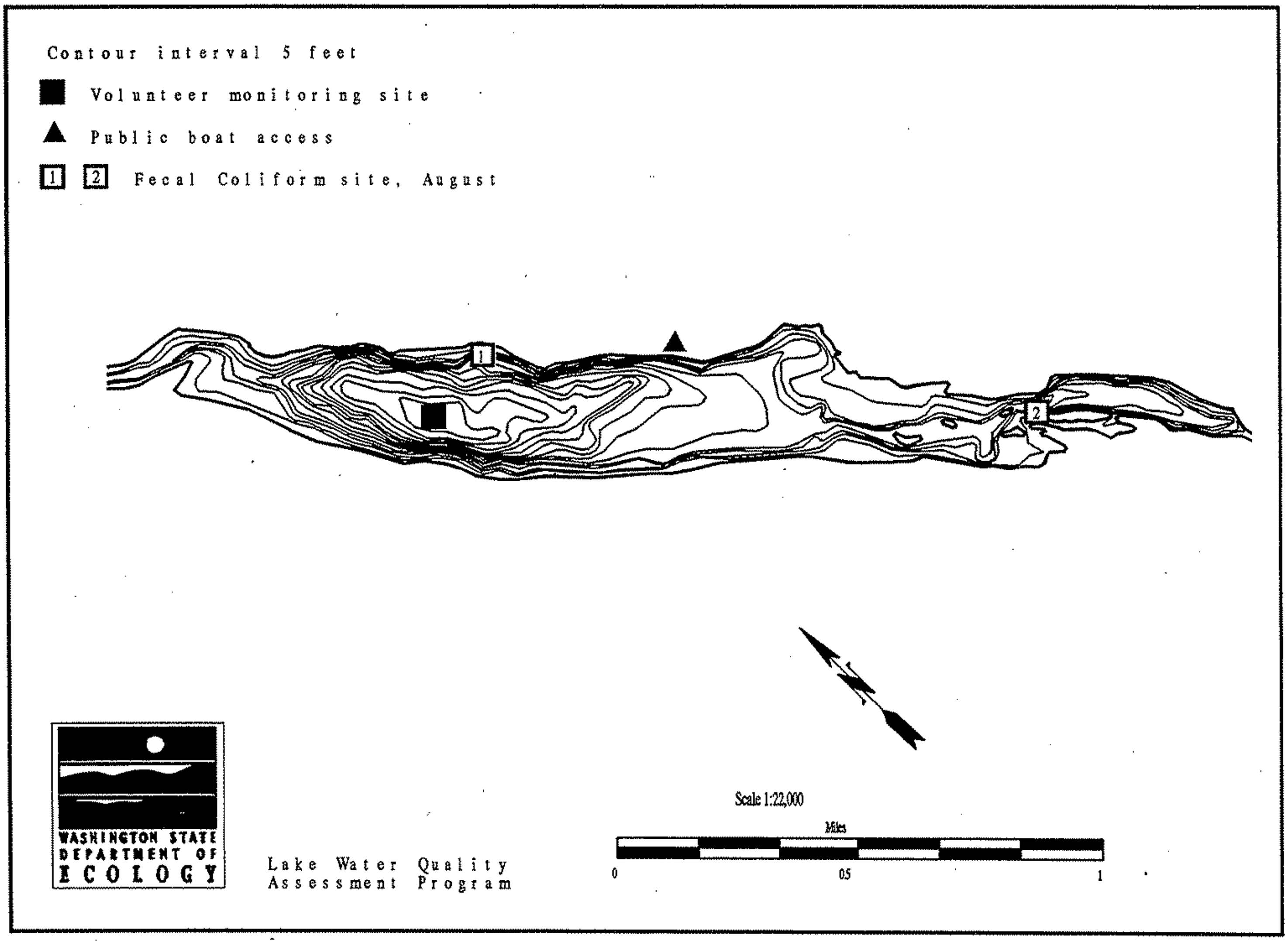
1993 Secchi Depth and Profile Data Graphs

Lacamas Lake -- Clark County

Lacamas Lake is located one mile north of Camas. 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)



Overall Assessment

In 1993, Lacamas Lake was assessed as eutrophic, based on poor water clarity, high nutrient concentrations, high algal densities, and dense growths of aquatic plants.

The historical enrichment from agricultural runoff has resulted in nuisance levels of aquatic plants and algae. Although water clarity was expected to improve following implementation of best management practices to control dairy waste runoff in the watershed, there was no statistically significant trend in water clarity (Secchi depths) from 1989 to 1993.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
In 1993, water clarity was poor, as indicated by Secchi depths that ranged from 1.4 feet to 7.5 feet. Secchi depths less than 6.5 feet are typical for eutrophic lakes.

Total Phosphorus
The concentrations of total phosphorus in the upper layer of water (the epilimnion) were high on both sampling dates (61 µg/L in June, and 31 µg/L in August). The higher value in June was probably from suspended sediments in the water (see Solids, below), because phosphorus often adsorbs onto particles of suspended sediment. Total phosphorus concentrations greater than 24 µg/L are typical for eutrophic lakes.

Total Nitrogen
Concentrations of total nitrogen were also very high on both sampling dates (0.96 mg/L in June, and 0.97 mg/L in August). The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were high (16:1 in June, and 29:1 in August), algae growth in Lacamas Lake was not limited by nitrogen at the time of sampling.

Fecal Coliform Bacteria
Samples for fecal coliform bacteria were collected from two sites in August. Site #1 was located on the northeast side of the lake, and Site #2 was located at the center of the bridge at the south end of the lake (see map on Page (1). The results for both sites were very low. The state water quality standard for Lake Class waters is a geometric mean of 50 colonies/100 mL.

Solids
Total suspended solids is a measure of the concentration of all suspended material in water (including algae), whereas total nonvolatile suspended solids is a measure of solids that are left after the volatile sediments (which are carbon-based, such as algae) are removed. Samples

collected in June indicated that most of the total solids were non-volatile, indicating that there were some suspended sediments in the water at the time of sampling. This may explain the very low Secchi depth measured during the onsite sampling visit. Solids samples collected in August indicated that water clarity (and hence, Secchi depths) was probably affected by algal growth, as opposed to suspended sediments, at the time of sampling.

Profile Data

The lake was thermally stratified on both sampling dates. Below the thermocline, dissolved oxygen concentrations decreased, particularly when the lake was sampled in August. Dissolved oxygen usually decreases from bacteria which use oxygen when decomposing algae and aquatic plants in the water and sediments. Although there was no oxygen in the bottom layer of the lake in August, no hydrogen sulfide ("rotten-egg" smell) was detected in hypolimnion water samples. Hydrogen sulfide was detected in all water samples collected from the hypolimnion in September 1992. Profile data collected in 1993 were very similar to data collected in 1992, 1991, and 1990. However, pH data for June 1993 are not reported because the probe was not functioning properly at the time.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Concentrations of chlorophyll *a* on both 1993 sampling dates indicated high densities of algae at the time of sampling. Chlorophyll concentrations greater than 6.4 μg/L are typical for eutrophic lakes.

Aquatic plants identified by Ecology staff during 1992 onsite visits included waterweed (*Elodea canadensis*), largeleaf pondweed (*Potamogeton amplifolius*), yellow-flowering lily (*Nuphar polysepalum*), and Brazilian elodea (*Egeria densa*). Brazilian elodea is an aggressive non-native aquatic plant, but it has not dominated the aquatic plant population in Lacamas Lake.

An algae sample collected during the June 1992 onsite sampling visit contained numerous diatoms (primarily *Synedra* and *Asterionella*). Some filaments, possibly *Oscillatoria*, were also present in the sample. An alga attached to the waterweed sample was *Spirogyra*.

Other Available Information

During the August 1993 onsite sampling visit, a large bryozoan was observed on a log near the volunteer's house. Bryozoans are colonial invertebrates that are eaten by fish. Bryozoans were observed in several lakes during the August 1993 onsite sampling visits. Despite references which suggest that bryozoans are found only in relatively clean and quiet waters, several of the bryozoan colonies observed in 1993 were in urban or eutrophying lakes.

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 areas with failing or malfunctional 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. 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.

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 1993.

> 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. German brown trout were stocked in the lake in 1993. Currently the watershed is being logged, and is used for animal grazing and crop agriculture. Also, the lakeshore is being developed further for residences. In the past the watershed was logged and used for animal grazing and crop agriculture, and the shoreline was altered.
>
> There are 82 houses on the lakeshore (there were 43 in 1992), 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. No lake management activities occurred in 1993. Currently, the minimum setback for lakeshore development is 100 feet. Lake water is withdrawn for industrial use.
>
> Overall, the volunteer found that Lacamas Lake had poor water quality. Problems in the lake in 1993 were ranked as (1) algae, (2) odor from decaying algae, (3) decaying plants, (4) water quality gradually degraded over years, (5) shoreline erosion, (6) excessive aquatic plant growth, and (7) degraded aesthetics. (Algae

and odor from decaying algae were also listed as the worst problems in 1992, and were particularly bad that year. Aquatic plants, algae, and odor have been among the worst problems listed in the questionnaires every year since 1989.) Possible sources of problems include farm animal waste from the watershed, and development on the lakeshore and within the watershed. There were no changes in lake quality in comparison to the 1992 monitoring season. In the past 4-5 years, the James River Corporation has kept the water level high during summer. This has added to erosion of the shoreline.

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 10 feet. There are wetland areas on each end of the lake; lily pads cover much of the area near the southern wetland.

Acknowledgments

I thank Judy and Jan Baldwin for volunteering their time to monitor Lacamas Lake during 1989-1993.

Lacamas Lake -- Clark County

1993 Trophic Status[1]

Estimated Trophic State:	Eutrophic
Mean Trophic State Index (Secchi):	52
Mean Trophic State Index (Total Phosphorus):	59
Mean Trophic State Index (Chlorophyll *a*):	56

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
04-Jun				1.4		brown	10		light	Onsite visit.
12-Jun	1315	17.8	64.0	5.0		green	75	moderate	light	
29-Jun	1130	18.9	66.0	5.5		green	50	trace	breezy	Small balls of algae flowing in water; not on top but mixed in with it 1/4" to 1/16".
08-Jul	1300	18.3	65.0	6.8		pea-green	0	none	breezy	Have some algae blankets forming.
24-Jul	1215	18.9	66.0	4.3		pea-green	100	moderate	calm	Big blankets of algae, bubbly in appearance.
04-Aug	1115	24.4	76.0	6.8		green	0	none	light	Weeds growing great. Still having large blankets of algae floating on the lake.
22-Aug	1115	22.2	72.0	5.3		pea-green	10	trace	light	Algae film on top.
31-Aug	0900			6.3		pea-green	35		calm	Onsite visit. Both Secchi with view tube.
10-Sep	1230	22.2	72.0	7.5		green	0	none	calm	Algae minimal, weed growth great.
30-Sep	1300	20.0	68.0	6.5		pea-green	0	none	calm	

[1] Trophic State Indices calculated from Carlson (1977).
[2] "Lake height" refers to change in water level. Lake level was not monitored in 1993.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
06/09	0.0	20.3	.	12.8	67
	1.0	18.6	.	12.8	66
	2.0	16.6	.	8.6	66
	3.0	15.7	.	8.1	65
	4.0	15.6	.	8.0	65
	5.0	14.7	.	5.7	64
	6.0	13.6	.	5.8	61
	7.0	12.4	.	4.1	57
	8.0	11.4	.	4.9	56
	10.0	10.8	.	4.4	57
	12.0	10.3	.	3.7	58
08/31	0.0	19.6	8.1	7.9	96
	1.0	19.6	8.1	7.8	97
	2.0	19.6	8.1	7.8	96
	3.0	19.6	8.0	7.8	96
	4.0	17.7	7.7	2.2	103
	5.0	17.1	7.5	2.8	104
	6.0	14.9	7.3	0.2	85
	7.0	13.6	7.2	0.1	78
	8.0	13.2	7.0	0.1	76
	10.0	11.4	6.9	0.1	70
	12.0	10.8	6.7	0.1	71
	14.0	10.4	6.7	0.1	71

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 4							
Epilimnion	61	0.96	16.7	8	6	--	--
Hypolimnion	39	0.84	--	--	--	--	--
August 31							
Epilimnion	33	0.97	11.1	4	2	3	bdl
Hypolimnion	56	0.81	--	--	--	--	--

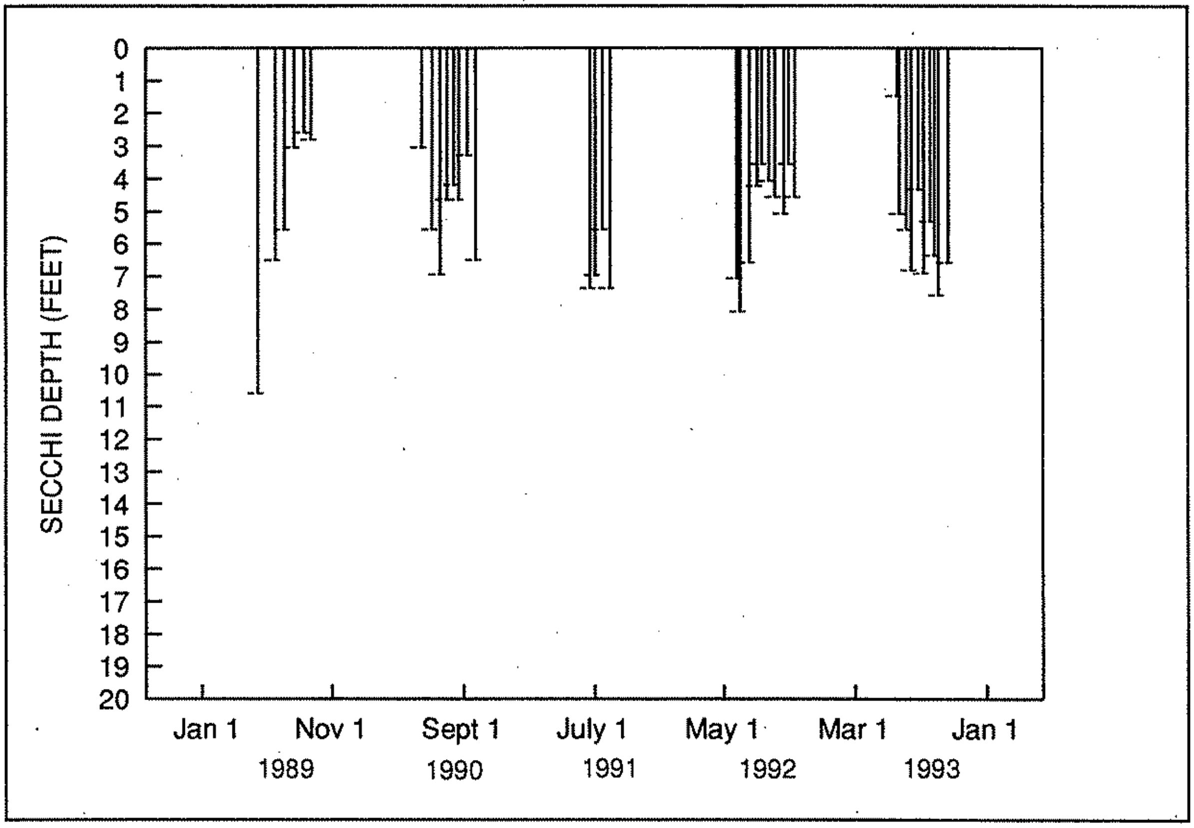
bdl = below analytical detection limit of 1 colony/100 mL

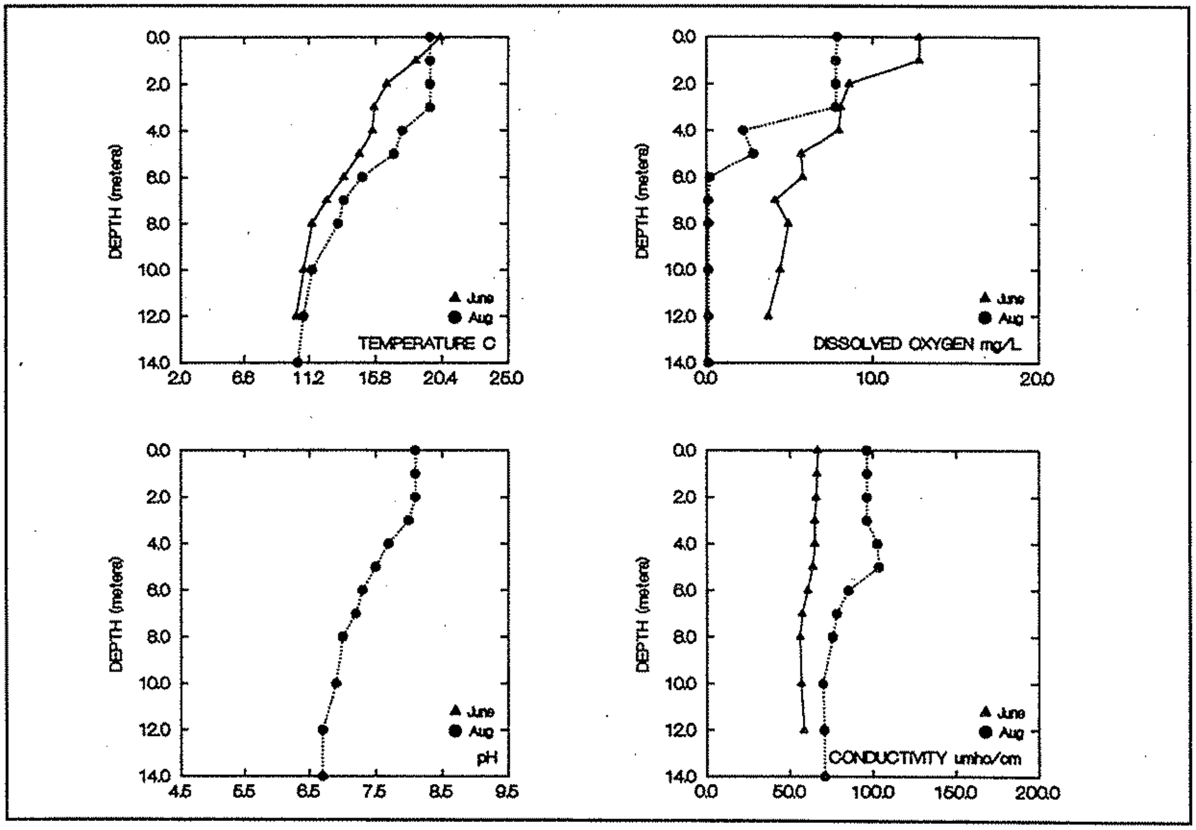
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
06/26/74[a]	47	--	--
06/16/81[b]	100	1.2	5.0
05/26/90[c]	37	3.3	--
08/20/90[c]	32	0.78	--
06/21/91[d]	--	0.64	--
06/08/92[e]	22	0.85	3.5
09/09/92[e]	39	0.73	12.1

a. Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)
e. Rector (1993)

LACAMAS LAKE (CLARK COUNTY)





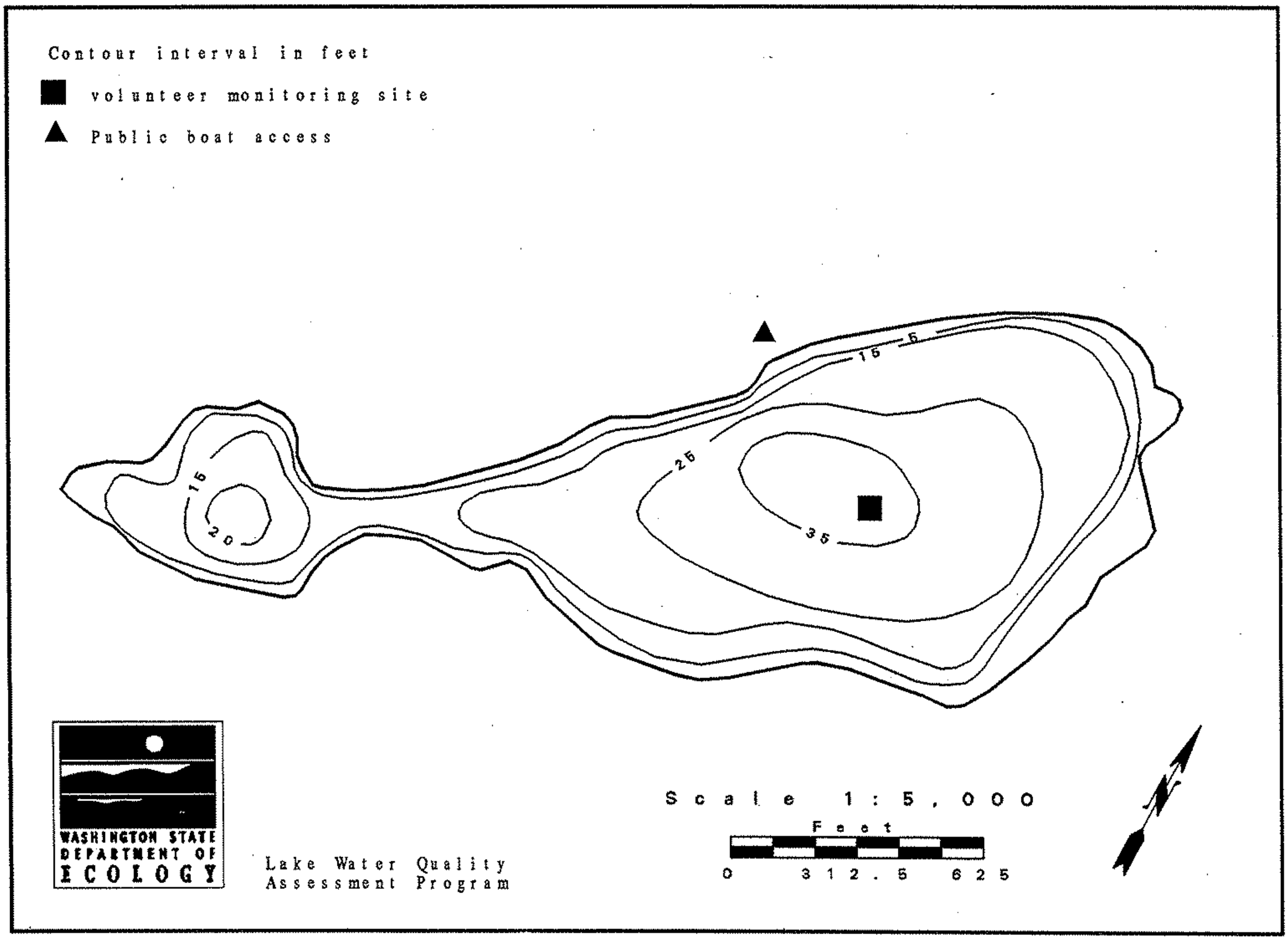
1993 Secchi Depth and Profile Data Graphs

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 (acres)	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)



Overall Assessment

In 1993, Lake Leo exhibited both oligotrophic and mesotrophic characteristics, so it was assessed as oligo-mesotrophic. Oligotrophic characteristics were the good water clarity throughout the monitoring season, and low amounts of algae during August. Mesotrophic characteristics include the moderately high amounts of total phosphorus and algae during May, the low concentrations of dissolved oxygen near the lake bottom, and areas of the lake had moderately dense growths of aquatic plants.

Lake Leo and Lake Thomas are both in the Little Pend Oreille chain of lakes, and both have been monitored for the program for several years. Eurasian watermilfoil, an aggressive non-native aquatic plant, was discovered in Lake Thomas in 1990. It has not yet been reported in Lake Leo, but Lake Leo will be screened each year it is in the program for early signs of infestation.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good in 1993, as indicated by Secchi depths that ranged from 13.5 feet to 23.0 feet. The lowest reading was measured following two weeks of heavy rains. Secchi depths greater than 13 feet indicate good water clarity, and are typical for oligotrophic lakes.

Total Phosphorus

The concentration of total phosphorus was moderately high in May (18 µg/L), and probably allowed the moderately high density of algae at the time of sampling. In August the total phosphorus concentration was low (6 µg/L). Total phosphorus concentrations less than 12 µg/L are low, and are typical for oligotrophic lakes.

The higher concentration of total phosphorus in the lower layer of water (the hypolimnion) during August indicates that phosphorus was probably being released from the sediments into the water column (referred to as internal loading). Internal loading can occur when dissolved oxygen is depleted near the lake bottom, creating an environment that allows phosphorus, iron and other compounds in sediment to be chemically reduced and released into the water column. Increased conductivity in the lower layer of water (see Profile Data, below) was another indicator that internal loading may have occurred. Internal loading is a characteristic of mesotrophic and eutrophic lakes.

Total Nitrogen

Total nitrogen concentrations were moderately high on both sampling dates (0.31 mg/L in May, and 0.24 mg/L in August), although these concentrations were low in comparison to concentrations measured in other lakes in the program. Concentrations from 1993 were similar to those measured for the program in 1992, 1991, and 1990. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 (17:1 in May, and 40:1 in August), algae growth in Lake Leo was not limited by nitrogen when the lake was sampled.

Profile Data

The lake was stratified on both sampling dates. Below the thermocline, dissolved oxygen concentrations decreased with depth, and were particularly low when the lake was sampled in August.

Oxygen concentrations decrease in the lower layer of water from bacteria which use oxygen as they decompose algae and aquatic plants in the water and sediments. The decrease in pH with depth, and the increase in conductivity with depth, are probably related to the lower concentrations of oxygen in the lower layer of water. There are no pH data from May because the probe was not functioning properly at the time.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants that is used to determine the amount of algae in a volume of water. In May, the concentration of chlorophyll *a* indicated a moderately high density of algae. At the time of sampling, there was also a moderately high concentration of total phosphorus, which probably encouraged the algae growth.

In August, the total phosphorus concentration was low, and the concentration of chlorophyll *a* indicated a low density of algae. In 1992, higher algal densities were measured in August than in May, most likely because the weather in August 1992 was much warmer than in August 1993.

Aquatic plants observed during the 1993 onsite sampling visits include largeleaf pondweed (*Potamogeton amplifolius*), flatleaf pondweed (*Potamogeton robbinsii*), ribbonleaf pondweed (*Potamogeton epihydrus*), waterweed (*Elodea canadensis*), tapegrass (*Vallisneria americana*), yellow-flowering water lily (*Nuphar polysepalum)*, muskgrass (*Chara*), and another pondweed that may have been *Potamogeton pusilus*. Ribbonleaf pondweed was the most abundant plant when the lake was sampled in 1990. Water buttercup (*Ranunculus* sp.) was also observed in 1990.

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 1993.

Lake Leo is used for fishing, swimming, motor boating, and lakeshore camping. Public recreational facilities on the lakeshore include eight campsites. One hundred percent of the shoreline is publicly-owned National Forest. There are no houses on the lakeshore, and no lake association for the lake. There is one public boat ramp, and there are no restrictions for motorboating. No fish were stocked in the lake in 1993. Currently, the watershed is being logged and used for animal grazing. No plant or algae management occurred in 1993, although the volunteer reported that the lake has been chemically treated in the past to control undesirable fish species.

Overall, the volunteer found that Lake Leo had good water quality. Problems in the lake in 1993 were ranked as (1) impaired fisheries, (2) suspended sediments, and (3) excessive aquatic plant growth. The problems were not severe, but the lake was not stocked this year, so fishing was poorer than in 1992. (In 1992, the lake was stocked with cutthroat fingerlings, instead of cacheable-sized fish, and fishing was poorer in 1992 than in previous years.) In comparison to the 1992 monitoring season, the boat ramp was improved, resulting in a few larger boats using the lake, although the unusually cool summer resulted in less overall use of the lake. Otherwise, Lake Leo has not changed much the past three years.

There are wetland areas near the public access, along the east shore of the lake, and near the island. Yellow-flowering lilypads grow all along the wetland areas. 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.

Acknowledgment

I thank Earl W. Robinson for volunteering his time to monitor Lake Leo during 1990-1993.

Lake Leo -- Pend Oreille County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic[2]
Trophic State Index (Secchi):	35
Trophic State Index (Total Phosphorus):	38
Trophic State Index (Chlorophyll *a*):	37

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	pH	Lake Ht (in)[3]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
18-May	1015	19.4	67.0	20.0	7.3	0.00	gr-brown	10	none	light	Water color light.
01-Jun	1330	18.3	65.0	20.0	7.3	4.00	lt-green	90		breezy	Second Secchi with view tube.
16-Jun	1145	17.8	64.0	22.0	7.2	2.00		75	moderate	light	Water color very light green.
30-Jun	1216	17.2	63.0	16.5	7.2	-3.00	lt-green	75	moderate	breezy	Low Secchi readings perhaps due to gusty winds and rain previous two days.
15-Jul	1106	16.7	62.0	13.5	7.2	-4.00	lt-green	100	moderate	light	Ambient temp 56 degrees. Record low temps, winds and rainfall over past two weeks.
28-Jul	1223	19.4	67.0	15.0	7.2	-4.00	lt-green	50	light	breezy	
15-Aug		20.0	68.0	21.0	7.3	-4.00	lt-green	10	none	light	(sampling date not on card; subtracted one day from postdate.)
19-Aug	1415			19.6			lt-green	10		calm	Onsite visit. Secchi with view tube.
27-Aug	1315	17.8	64.0	20.3	7.2	-8.00	lt-green	25	none	breezy	
08-Sep	1420	20.0	68.0	20.2	7.2	-8.00	lt-green	0	none	breezy	
23-Sep	1350	14.4	58.0	20.3	7.2	-8.00	lt-green	0	none	calm	Water color very light green.
10-Oct	1240	13.3	56.0	22.5	7.0	-8.00	lt-green	10	none	calm	
19-Oct	1305	10.6	51.0	23.0	7.2	-10.00	lt-green	0	trace	breezy	Very little algae.

[1] Trophic State Indices calculated from Carlson (1977).
[2] See Overall Assessment.
[3] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Leo dropped 10" from May 18 to October 19.

Lake Leo -- Pend Oreille County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/18	0.0	19.7	.	8.8	56
	1.0	19.1	.	8.8	56
	2.0	16.3	.	10.3	56
	3.0	11.7	.	9.8	58
	4.0	9.8	.	8.3	62
	5.0	8.2	.	4.7	68
	6.0	7.4	.	0.9	70
	8.0	6.6	.	0.3	84
08/19	0.0	21.6	7.9	8.0	58
	1.0	19.6	7.9	8.1	58
	2.0	19.3	7.8	8.0	58
	3.0	18.2	7.6	7.5	66
	4.0	15.6	7.4	2.6	74
	5.0	12.4	7.2	0.6	83
	6.0	9.7	7.1	0.4	84
	7.0	8.9	7.0	0.4	88
	8.0	8.5	7.0	0.1	105
	9.0	8.1	7.0	0.1	121

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 18 Epilimnion	18	0.31	2.9	--	--	--	--
Hypolimnion	16	*					
August 19 Epilimnion	6	0.24	1.2	--	--	--	--
Hypolimnion	32	0.29	--	--	--	--	--

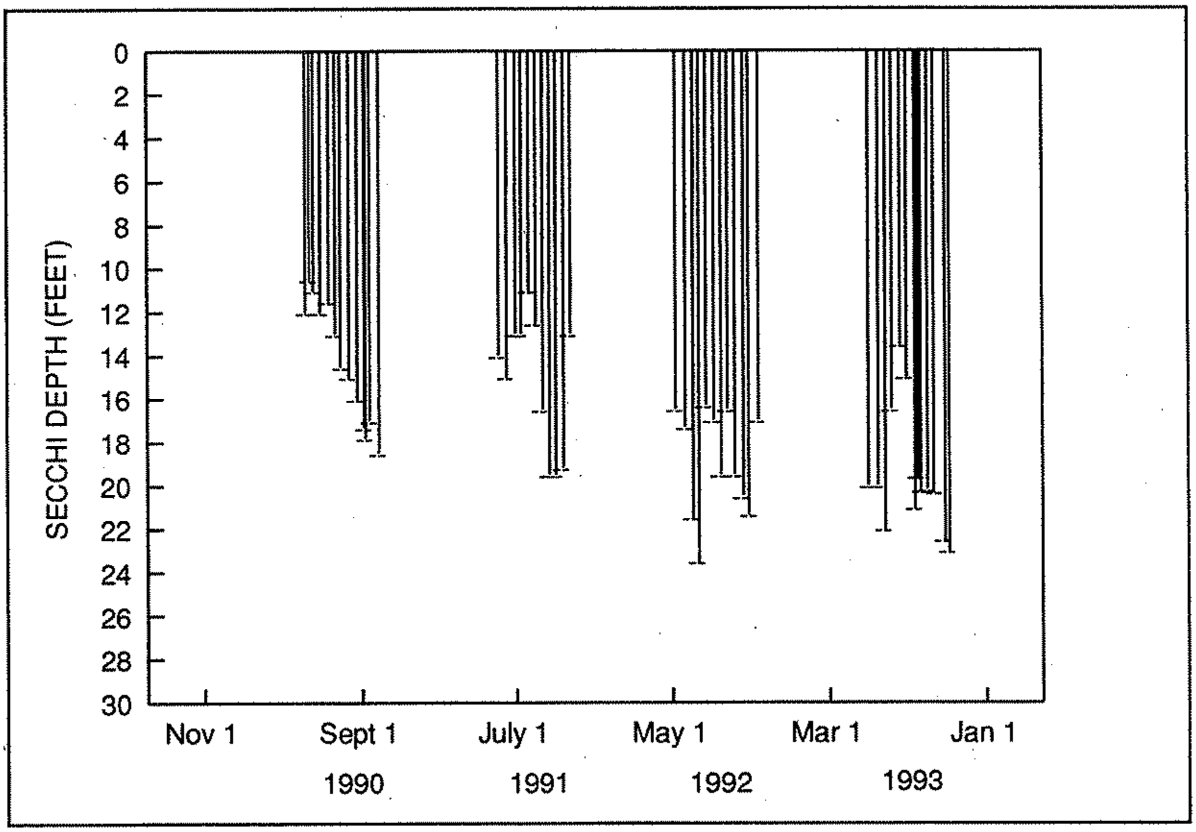
* Sample was not analyzed

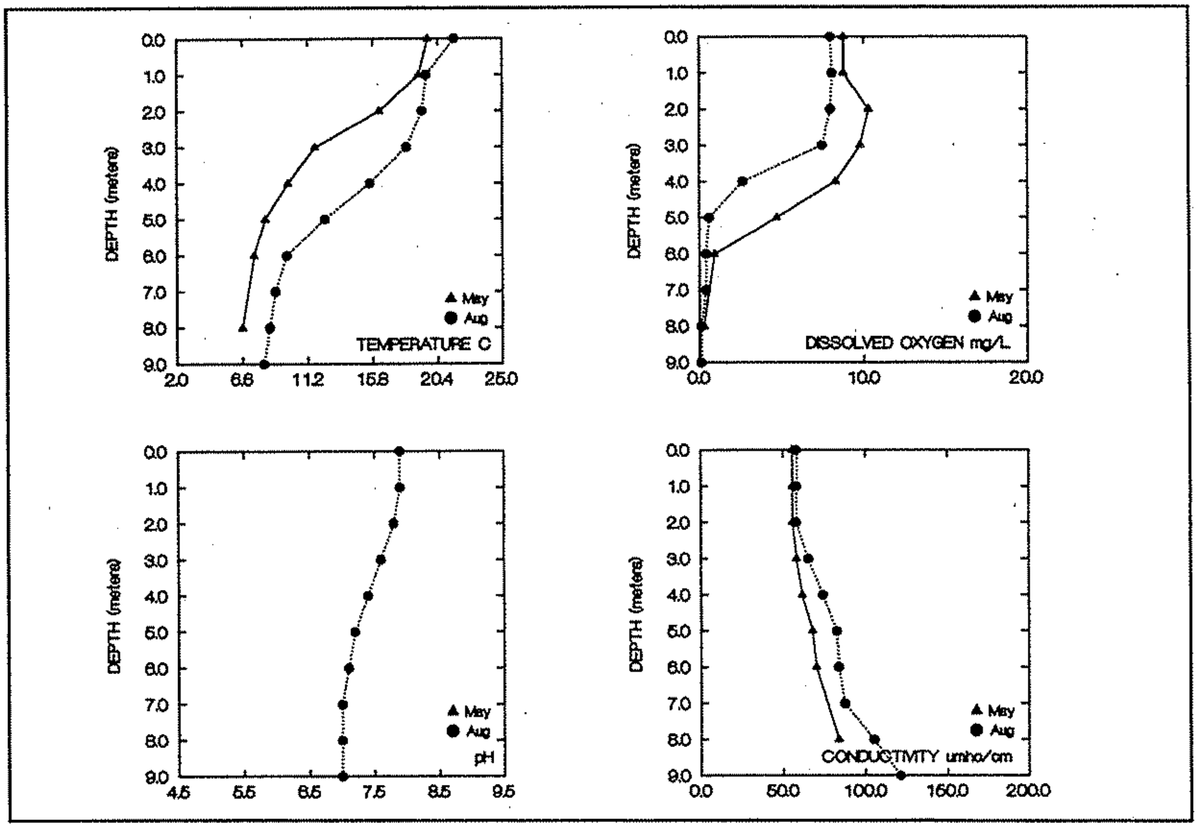
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
08/16/72[a]	25	--	2.6
05/25/90[b]	12	0.27	--
09/11/90[b]	13	0.29	--
06/13/91[c]	--	0.21	--
05/11/92[d]	11	0.30	0.7
08/27/92[d]	13	0.26	2.8

a. Bortleson *et al.* (1976), Dion *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)

LAKE LEO (PEND OREILLE COUNTY)





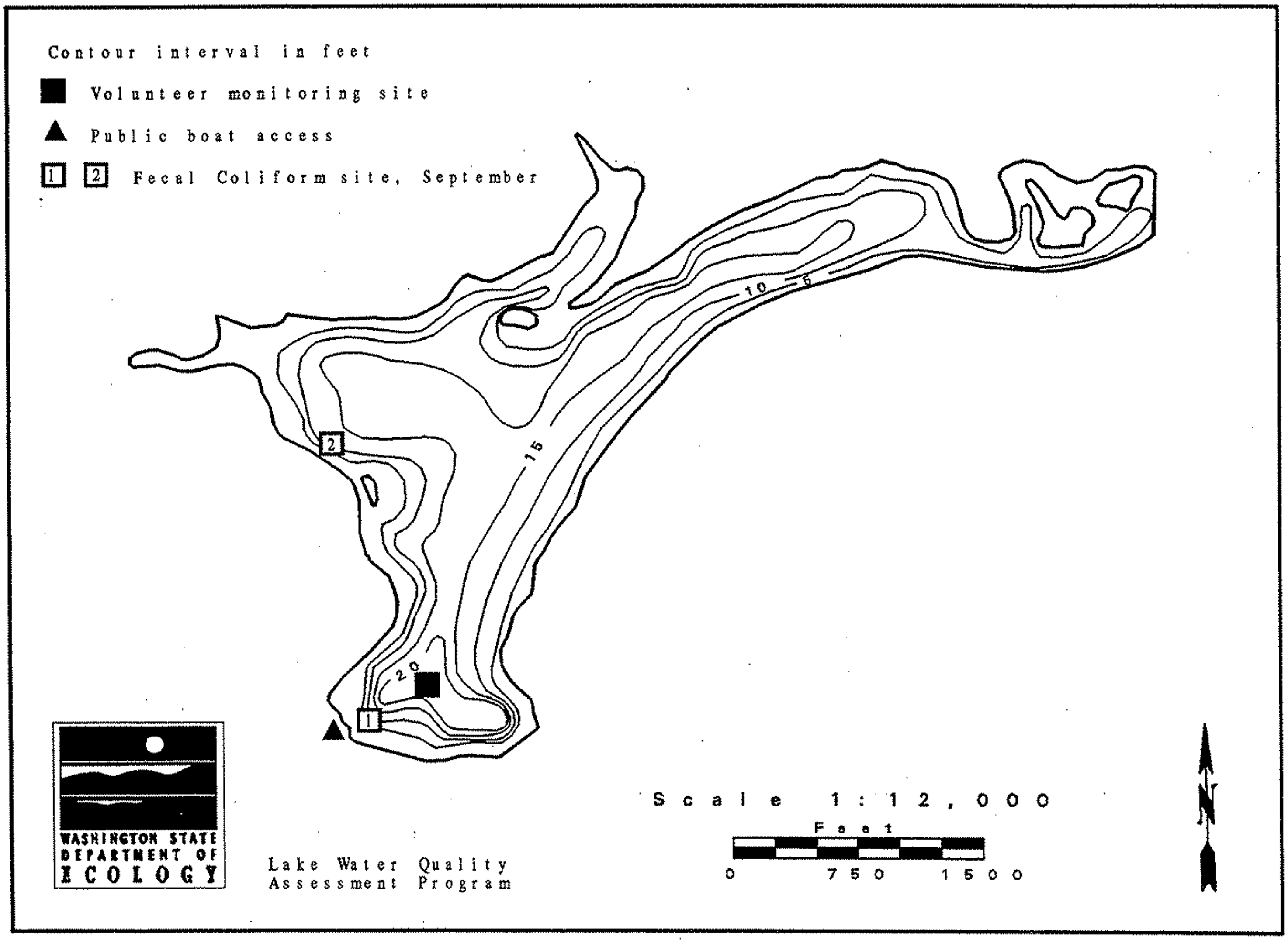
1993 Secchi Depth and Profile Data Graphs

Lake Limerick -- Mason County

Lake Limerick is located about five miles northeast of Shelton. It was formed in 1966 by impoundment of Cranberry Creek. In addition to Cranberry Creek, Lake Limerick is fed by three other minor inlets. The lake drains through a control weir to Cranberry Creek.

Size (acres)	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)



Overall Assessment

In 1993, Lake Limerick was assessed as mesotrophic, based on fair water clarity throughout the monitoring season, and moderately high amounts of total phosphorus, algae, and aquatic plants. Brazilian elodea, an aggressive non-native aquatic plant that is not found in many lakes in Washington State, is very abundant in Lake Limerick. Boaters using Lake Limerick should clean their boats, trailers, and motors very thoroughly after boating in the lake, in order to prevent the spread of this noxious plant into other lakes. The lake was treated with herbicides in 1993 to control both plants and algae.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

In 1993, water clarity was fair, as indicated by Secchi depths that ranged from 9.1 feet to 12.0 feet. Secchi depths from 6.5 feet to 13.0 feet are typical for mesotrophic lakes. As in 1992, there was very little variability among Secchi depth measurements.

Total Phosphorus

In September, the concentration of total phosphorus was moderately high (21 µg/L). This was higher than concentrations measured for the program in 1992 and 1990. Concentrations between 12 µg/L and 24 µg/L are typical for mesotrophic lakes.

Total Nitrogen

The total nitrogen concentration in September was moderately high, and was similar to concentrations measured for the program in 1992 and 1990. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratio of total nitrogen to total phosphorus was less than 17:1 (it was 12:1), it is possible that algae growth in Lake Limerick was nitrogen-limited when the lake was sampled.

Profile Data

Both temperature and dissolved oxygen decreased with depth. Lower dissolved oxygen concentrations result as bacteria use oxygen when they decompose algae and aquatic plants in the water and sediments. Similar profile data were collected in 1992, 1991, and 1990.

Fecal Coliform Bacteria

Two nearshore samples were collected; Site #1 was located at the public boat launch, and Site #2 was located offshore of the Lake Limerick community center. Results for both samples were very low (1 colony/100 mL) and were well within state water quality standards for lakes.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. In September, the concentration of chlorophyll *a* indicated a moderately high density of algae in the water at the time of sampling.

In 1992 and 1993, the lake was treated with herbicides to control algae as well as other aquatic plants. When the lake was sampled in 1992, chlorophyll concentrations at the sampling site were low, although algae was clearly visible in localized areas of the lake and much was attached to aquatic plants. In September 1993 the chlorophyll *a* concentration at the deep site was still low, despite algae problems in other areas of the lake. Because of these, chlorophyll *a* results from the deep site are not good indicators of trophic status for Lake Limerick.

Aquatic plants observed by Ecology staff during the September 1993 sampling visit include Brazilian elodea (*Egeria densa*), largeleaf pondweed (*Potamogeton amplifolius*), waterweed (*Elodea candensis*), and watershield (*Brasenia schreberi*). Brazilian elodea was the most abundant plant observed.

Largeleaf pondweed, Brazilian elodea, and waterweed were also observed in 1992. The volunteer noted that largeleaf pondweed was the main nuisance species in the lake in 1992, since the Brazilian elodea was treated with herbicides in 1991. The volunteer noted that the lake also had watershield, duckweed, and tapegrass in 1992, but in 1993 the tapegrass was not found.

Other Available Information

WATER Environmental Sciences conducted a survey of Lake Limerick during 1991 and proposed 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 1993.

> 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 established for the lake. Trout were stocked in the lake in 1993. Currently, the watershed is used for crop agriculture, and the lakeshore is being developed further for residences. In the past, the watershed was logged.
>
> There are about 170 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 lake association and community association for the lake. In 1993, the lake was treated with herbicides to control algae and aquatic plants. In addition, the lake was drawn down during winter. Currently, the minimum setback for lakeshore development is 50 feet, minimum lot lengths are 200 feet, and residential density is restricted to one house per lot.

Overall, the volunteer found that Lake Limerick had fair water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, (2) algae, and (3) beach closure [presumably, due to water use restrictions following application of aquatic herbicide]. There were no changes in the lake since the 1992 monitoring season.

Acknowledgment

I thank Bob King and Bill Weston for volunteering their time to monitor Lake Limerick in 1993. David Best, Bob King, and Bill Weston monitored the lake during 1992, and David Best and Bob King monitored the lake during 1990-1991.

Lake Limerick -- Mason County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	43
Mean Trophic State Index (Total Phosphorus):	48
Mean Trophic State Index (Chlorophyll *a*):	40

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
07-Jul	0900	18.9	66.0	9.8	6.00	lt-yellow	10	none	calm	
22-Jul	1010	20.0	68.0	10.0	6.50	lt-green	100	moderate	breezy	
04-Aug	0900	25.6	78.0	12.0	6.25	lt-green	0	none	calm	
18-Aug	0900	20.6	69.0	11.2	6.00	lt-yellow	10	trace	calm	
01-Sep	0900	19.4	67.0	11.2	5.50	lt-yellow	75	none		Second Secchi taken at 1315 during onsite visit when weather was sunny and calm.
15-Sep	1215	21.1	70.0	9.1	5.00	lt-yellow	10	trace	calm	
29-Sep	1015	19.4	67.0	11.0	5.00	lt-yellow	0	none	calm	
13-Oct	0930	15.6	60.0	10.4	1.75	lt-yellow	100	light	calm	

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
09/01	0.0	20.8	6.8	9.2	45
	0.9	20.1	6.9	9.0	45
	1.9	20.0	6.9	9.0	45
	3.0	19.5	6.8	6.6	47
	4.0	18.6	6.7	2.2	52
	5.0	15.6	6.8	0.3	79
	5.4	14.3	6.9	0.2	131

1 Trophic State Indices calculated from Carlson (1977)

2 "Lake height" refers to change in water levels. Based on volunteer-collected data, the level of Lake Limerick dropped 4.25" from July 7 to October 13.

1993 Onsite Visit Data - Water Chemistry

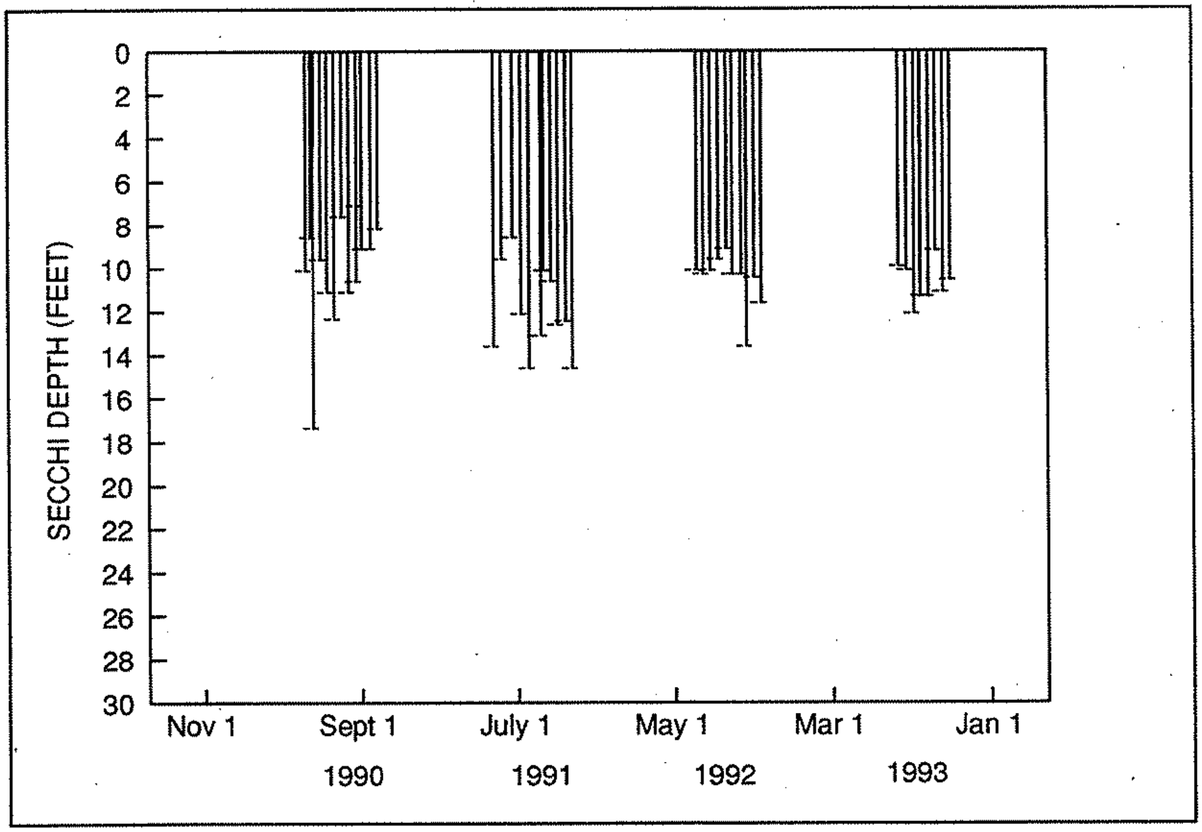
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
September 1 Epilimnion	21	0.25	2.6	--	--	1	1
Hypolimnion	19	0.32	--	--	--	--	--

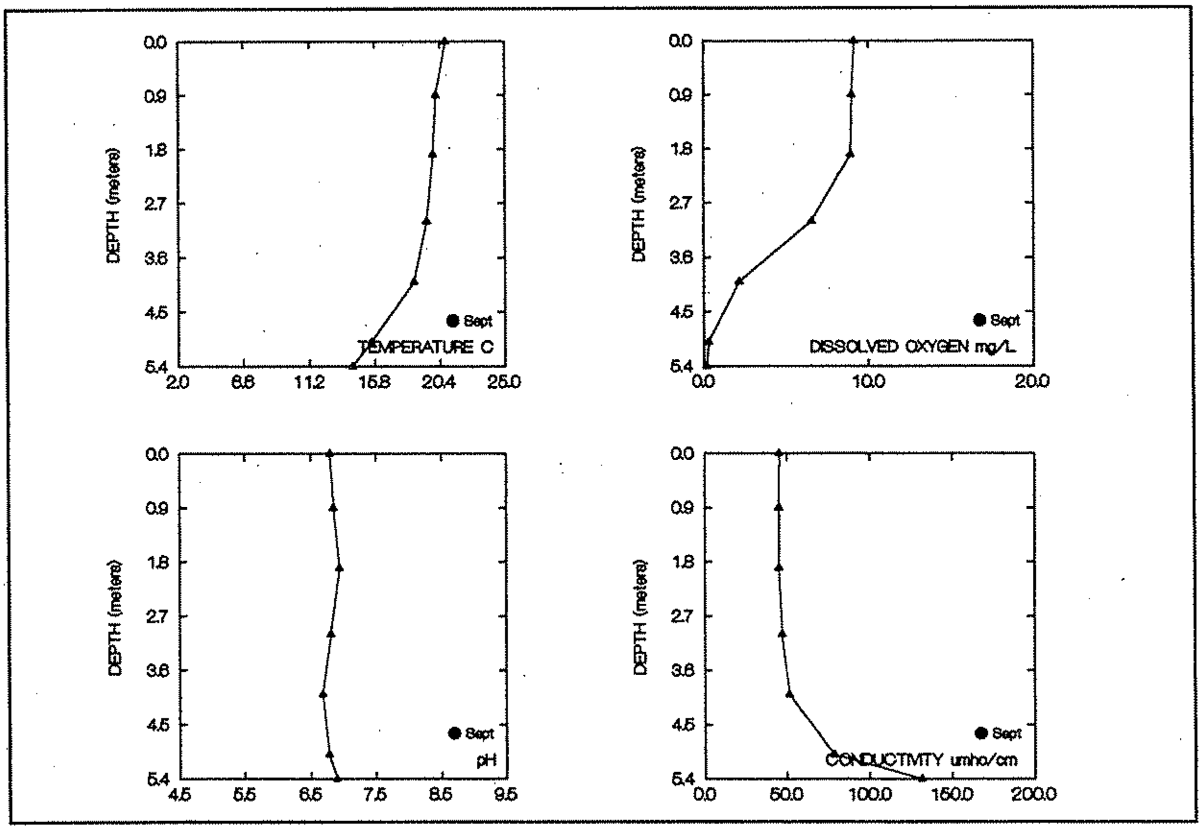
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
08/16/74[a]	8	--	--
05/24/90[b]	17	0.24	--
08/15/90[b]	15	0.49	--
05/15/91[c]	--	0.15	--
05/29/92[d]	12	0.27	1.2
08/26/92[d]	12	0.29	0.5

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)

LAKE LIMERICK (MASON COUNTY)





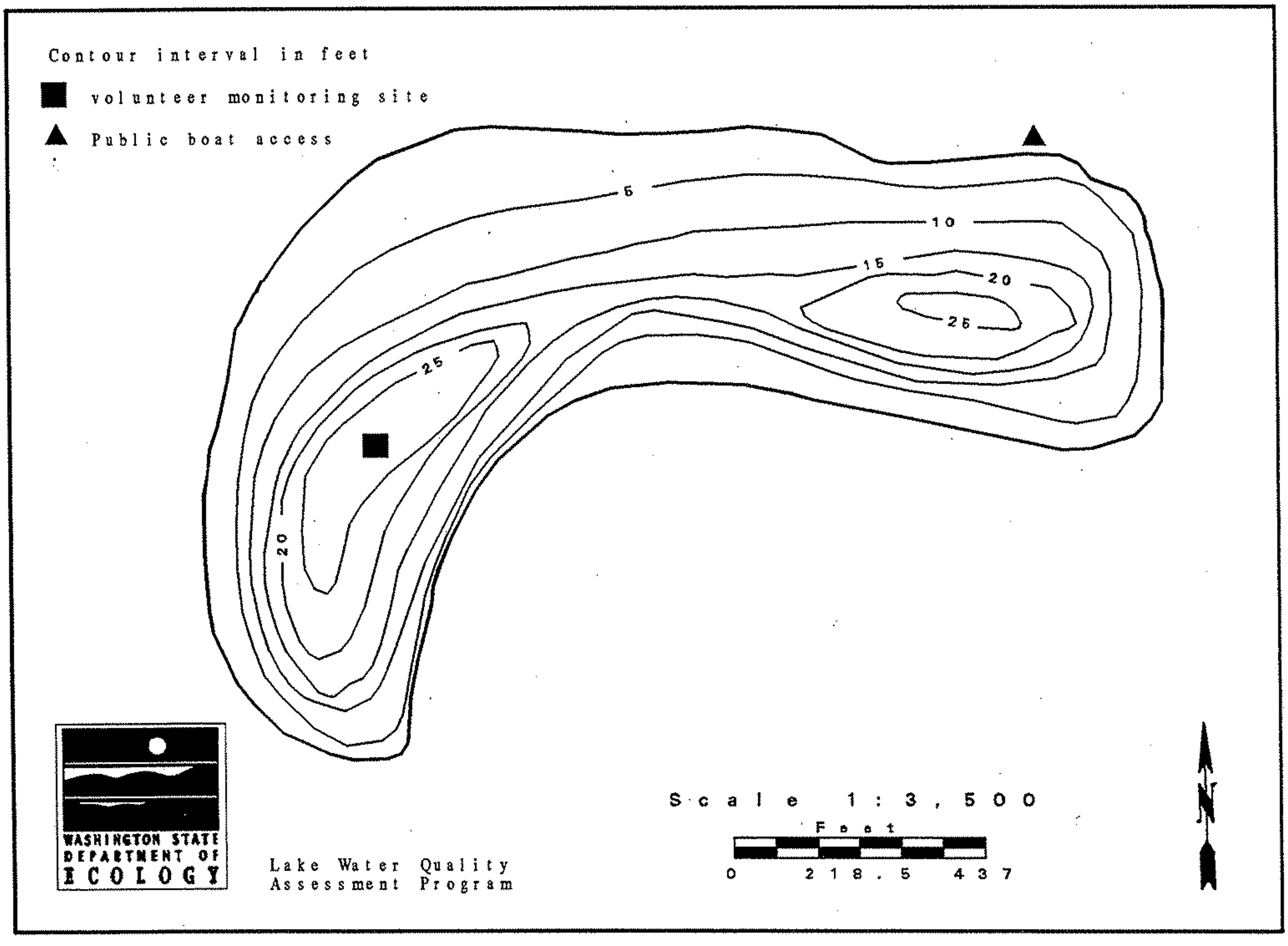
1993 Secchi Depth and Profile Data Graphs

Lake Loma -- Snohomish County

Lake Loma is located 6.5 miles northwest of Marysville. It has no surface inlets, and drains via an intermittent outlet to Crabapple Lake and Tulalip Bay. Lake Loma was formerly called Cranberry Lake.

Size (acres)	21
Maximum Depth (feet)	28
Mean Depth (feet)	11
Lake Volume (acre-feet)	230
Drainage Area (miles^2)	0.2
Altitude (feet)	565
Shoreline Length (miles)	0.9

Data From Bortleson *et al.* (1976)



Overall Assessment

In 1993, Lake Loma was assessed as eutrophic, based on fair water clarity, high nutrient concentrations, and high densities of algae and aquatic plants. Lake Loma's chlorophyll concentration in August was the highest of all the lakes sampled for the program in 1993.

Other Snohomish County lakes monitored for the program in 1993 were Blackmans Lake, Lake Bosworth, Flowing Lake, Lake Howard, Lake Ki, Lake Martha, Martha Lake, Lake Roesiger, Lake Stevens, and Sunday Lake. Of these, only Sunday Lake had higher concentrations of total phosphorus.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was fair, as indicated by Secchi depths which ranged from 6.0 feet to 8.5 feet. Normally, Secchi depths from 6.5 feet to 13.0 feet indicate fair water clarity that is typical for mesotrophic lakes. However, water clarity was actually better than would be expected, considering that lake water is naturally colored and algae densities were high. The reddish brown color of Lake Loma is most likely from humic acids and tannins in the water, orginating from bog substrate in the watershed.

Total Phosphorus

The concentration of total phosphorus was moderately high in May (22 µg/L), and was high in August (37 µg/L). Algae growth is usually determined by the amount of phosphorus in lake water, so high total phosphorus concentrations (greater than 24 µg/L) indicate a high potential for dense growths of algae and aquatic plants.

Total Nitrogen

Concentrations of total nitrogen were high on both sampling dates. Because nitrogen is generally found in much greater concentrations than phosphorus, it is not as critical as phosphorus in determining the potential for plant and algae growth. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were high (33:1 in May, and 16:1 in August), it is likely that algae in Lake Loma were not limited by nitrogen.

Profile Data

The lake was thermally stratified on both sampling dates. Below the thermocline, dissolved oxygen concentrations decreased considerably with depth. Oxygen concentrations can decrease in the lower layer of water (the hypolimnion) when bacteria use oxygen as they decompose algae and aquatic plants in the water and sediments. Also, the lake is fed primarily by springs; ground water is very low in oxygen, and is probably trapped in the lower layer while the lake is stratified. There are no sources of oxygen to the lower layer of water while the lake is stratified (the top layer does not mix with the lower layer during stratification). When oxygen concentrations are depleted, hydrogen sulfide ("rotten-egg" smell) may be formed near the lake bottom. Hydrogen sulfide is formed by bacteria, and is found only in water that is completely depleted of dissolved oxygen. In August, water samples collected from six meters and seven meters depth smelled very strongly of hydrogen sulfide.

Plants

Chlorophyll *a* is a pigment that is found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Concentrations of chlorophyll *a* on both sampling dates indicated high densities of algae at the time of sampling. The density of algae in August was particularly high, as indicated by the very high concentration of chlorophyll *a* (69.6 µg/L). Chlorophyll concentrations over 6.4 µg/L are typical for eutrophic lakes.

Aquatic plants identified by Ecology staff during the 1993 sampling visits include cattails (*Typha* sp.), iris (*Iris pseudacorus*), milfoil (*Myriophyllum* sp.; possibly *hippiroides*), and yellow-flowering water lily (*Nuphar*). Milfoil was the most abundant plant in the lake. The species present was not the aggressive Eurasian variety, but nonetheless has created a nuisance in the lake. Cattails grew along 50% of the shoreline in natural, vegetated areas.

Other Available Information

From McConnell *et al.* (1976): In 1973, the lake was highly colored ("tea" color) and dissolved oxygen was depleted in the hypolimnion (the lower layer of water). The number of nearshore homes increased from about 17 in 1956 to about 53 in 1973. Blue-green algae (*Anabaena* sp.) were observed on May 30, 1973.

From Manasveta (1961): From 1955 to 1957, approximately 4,400 pounds of oyster shell and 13,850 pounds of hydrated lime were added to Lake Loma to raise the pH of the water and improve the lake for trout habitat. About 4,900 pounds of crab meal, 10,700 pounds of crab waste, and 400 pounds of potash were also added from 1955 to 1958 to fertilize the water and enhance the fishery.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire.

> There are 63 houses on the lakeshore. There is no lake association for the lake. No lake management activities occurred in 1993. Rainbow trout were stocked in the lake in 1993. Overall, the volunteer found that Lake Loma had fair water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, (2) recently

degraded water quality, (3) impaired fisheries, (4) degraded aesthetics, (5) swimmer's itch, and (6) algae. Possible sources of problems include milfoil and the development of large homes on the lakeshore in recent years. In addition, milfoil has spread to shoreline areas and covers about 90% of the shoreline.

Acknowledgment

I thank Jim Brodie for volunteering his time to monitor Lake Loma during 1993.

Lake Loma -- Snohomish County

1993 Trophic Status[1]

Estimated Trophic State:	Eutrophic
Mean Trophic State Index (Secchi):	50
Mean Trophic State Index (Total Phosphorus):	52
Mean Trophic State Index (Chlorophyll *a*):	61

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
29-May	1045	20.5	60.0	6.8		red-brown	90	light	light	Onsite visit. (All temperature data have been corrected, by adding 4°C.)
13-Jun	1155	18.0	64.4	7.5	-12.00	red-brown	75	light	light	Clouds high and bright. Marked lake level this test. Will monitor from now on.
29-Jun	1640	20.0	68.0	7.0	-13.88	red-brown	25	moderate	calm	
14-Jul	1145	19.0	66.2	7.0	-15.50	red-brown	100	moderate	light	Slight drizzle during test.
24-Jul	1205	18.0	64.4	6.0	-15.25	red-brown	80	moderate	light	
09-Aug	1645	21.0	69.8	6.8		red-brown	75	none	calm	
21-Aug	0945	21.0	69.8	6.5		red-brown	100		breezy	Onsite visit.
06-Sep	1310	20.0	68.0	8.5	-19.50	red-brown	0	none	light	
22-Sep	1330	15.0	59.0	8.0	-20.50	red-brown	0	trace	light	
02-Oct	1405	18.0	64.4	8.5	-21.50	red-brown	0	none	calm	
19-Oct	1640	14.0	57.2	7.8	-21.00	red-brown	0	moderate	light	

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Loma dropped 9" from June 13 to October 19.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/29	0.0	20.5	7.7	8.0	39
	1.0	20.0	7.5	8.0	38
	2.0	13.3	7.1	5.8	38
	3.0	9.9	6.8	2.9	39
	4.0	8.6	6.6	1.9	40
	5.1	8.3	6.6	1.3	39
	6.1	8.1	6.5	1.0	40
	7.0	7.8	6.5	0.4	43
08/21	0.0	21.0	7.4	8.0	39
	0.0	21.0	7.3	8.0	39
	1.0	20.9	7.2	7.9	39
	1.0	20.8	7.2	7.9	39
	2.0	17.8	7.2	6.0	38
	2.9	13.6	7.1	3.9	44
	4.0	10.8	7.0	1.2	45
	5.1	9.5	6.9	0.6	44
	6.0	8.7	6.8	0.4	45
	7.0	8.4	6.7	0.3	47

1993 Onsite Visit Data - Water Chemistry

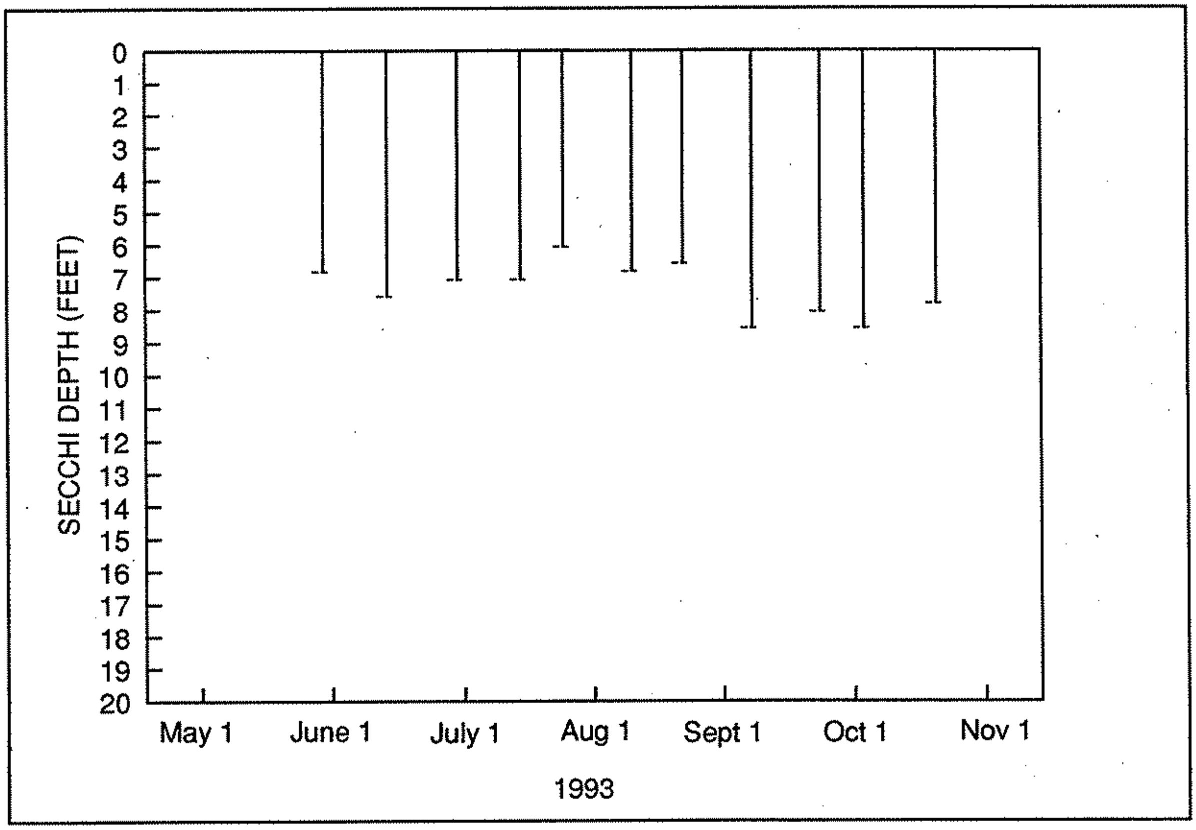
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 29 Epilimnion	22	0.73	7.2	--	--	--	--
Hypolimnion	33	0.70	--	--	--	--	--
August 21 Epilimnion	37	0.58	69.6	--	--	--	--
Hypolimnion	43	0.50	--	--	--	--	--

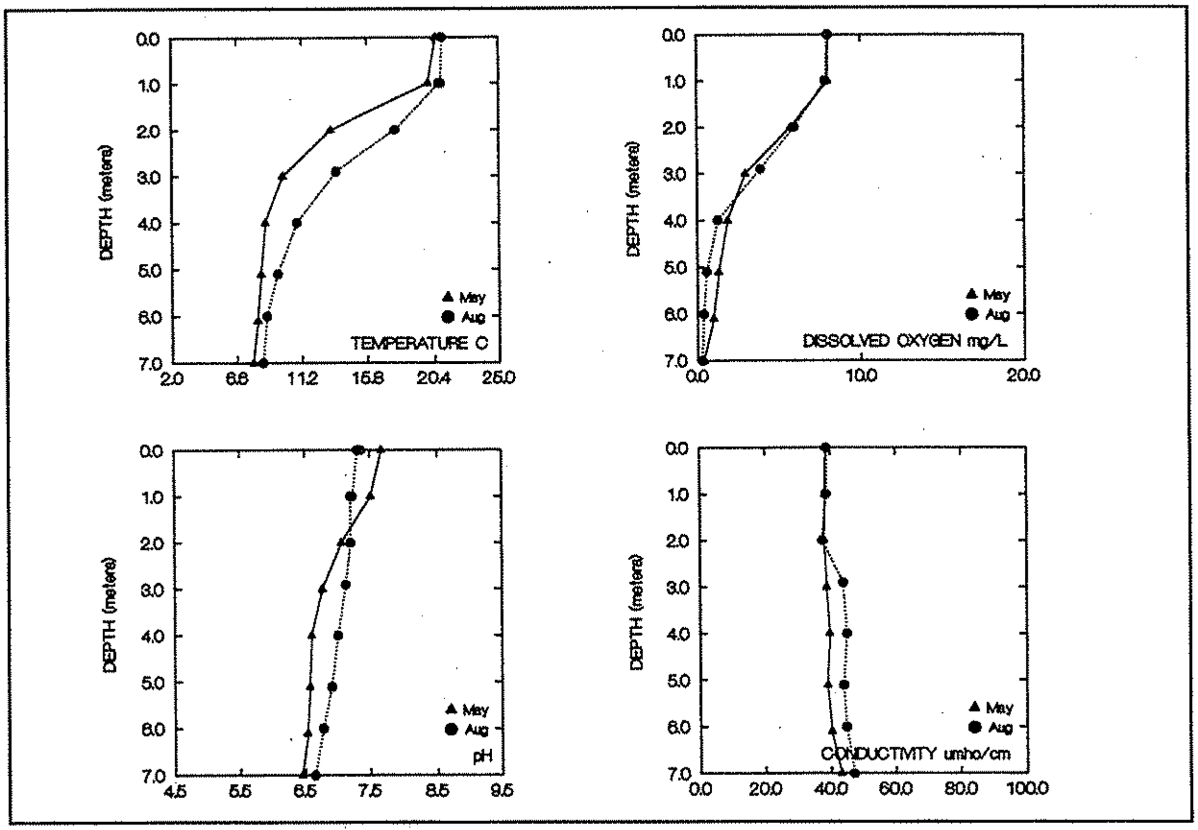
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* µg/L)
06/27/73[a]	30	--	8.5
09/25/73[a]	30	--	6.3
06/30/81[b]	40	1.5	8.0

a. McConnell *et al.* (1976)
b. Sumioka and Dion (1985)

LAKE LOMA (SNOHOMISH COUNTY)





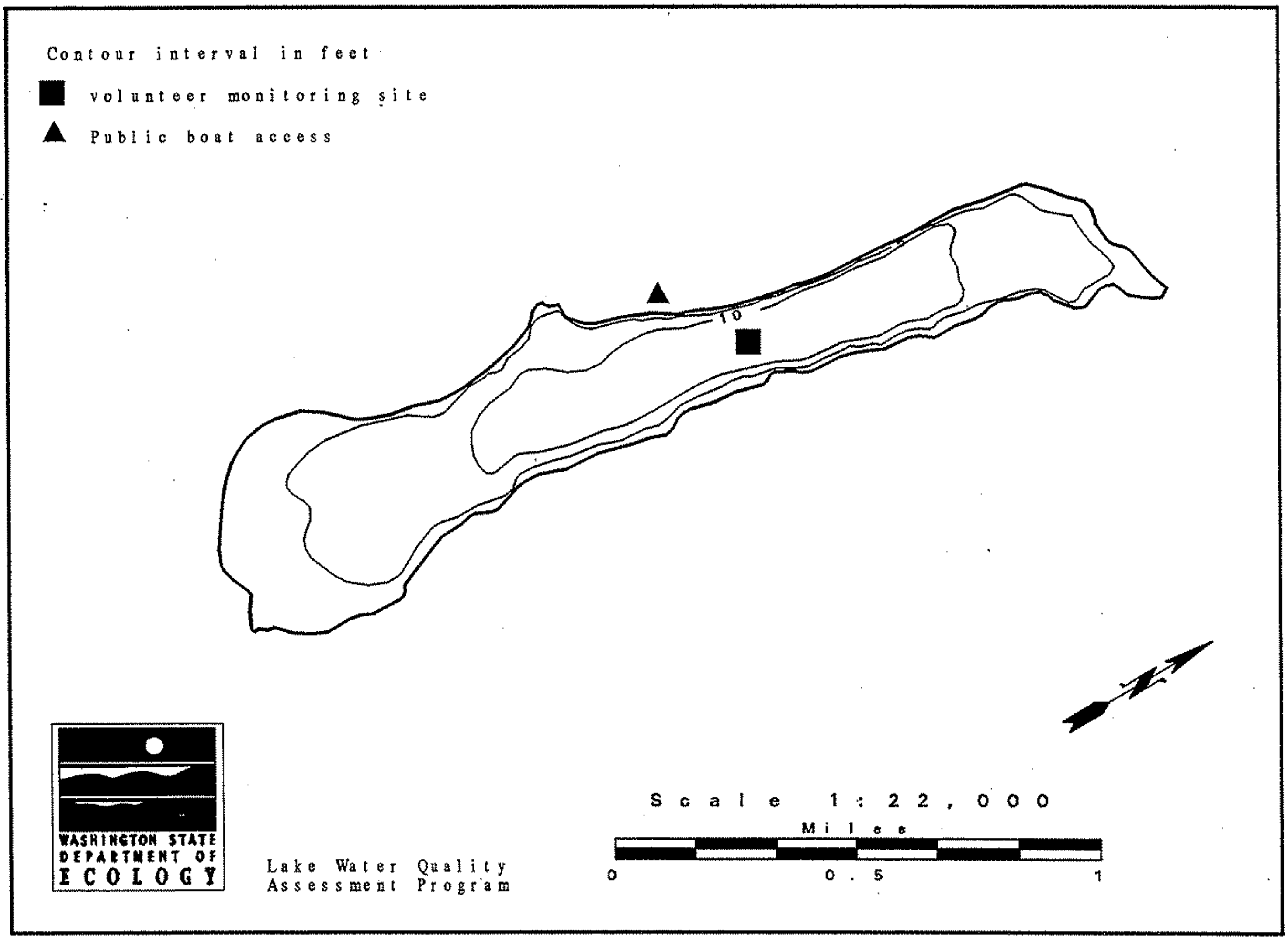
1993 Secchi Depth and Profile Data Graphs

Long Lake -- Kitsap County

Long Lake is located 3.5 miles southeast of Port Orchard. It is two miles long. The lake 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

Data From Bortleson *et al.* (1976)



Overall Assessment

In 1993, Long Lake was assessed as eutrophic, based on poor water clarity, high nutrient concentrations, and high densities of algae and aquatic plants. Brazilian elodea, an aggressive non-native plant, was very abundant in the lake. This plant can easily be spread to other lakes; skiers and boaters using Long Lake should carefully clean all boat and trailer parts before entering other waterbodies, in order to prevent the spread of this noxious plant into other lakes or streams. Lake Limerick in Mason County is the only other lake in the program that is also known to have Brazilian elodea.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was poor, as indicated by Secchi depths that ranged from 3.0 feet to 8.0 feet. Secchi depths less than 6.5 feet indicate poor water clarity. Long Lake was monitored (by another volunteer) from 1989-1991. During this time, the deepest Secchi depths were measured in October of 1989, 1991, and 1993.

Total Phosphorus
Both total phosphorus concentrations were very high (62 µg/L in June, and 60 µg/L in August). Concentrations greater than 24 µg/L are high, can support dense growths of algae, and are typical of eutrophic lakes. In June, there was a low density of algae at the time of sampling, despite the high concentration of phosphorus. At the time, the concentration of total phosphorus was high relative to the concentration of total nitrogen, which suggests that algae were not limited by the amount of available phosphorus during the June sampling visit.

Total phosphorus concentrations measured in 1993 were very similar to the concentration measured in 1990.

Total Nitrogen
The concentrations of total nitrogen were also high. The ratio of total nitrogen to total phosphorus can indicate which nutrient is first responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were less than 17:1 (11:1) in June, and 12:1 in August), it is possible that algae growth was nitrogen-limited when the lake was sampled.

Profile Data
The lake was not stratified on either sampling date, so only one set of water samples was collected during each sampling visit. As would be expected from an unstratified lake, profile parameters (temperature, pH, dissolved oxygen and conductivity) did not change much from the

surface to bottom. Seasonal stratification probably does not occur because the lake is very shallow, and mixing is promoted by winds and heavy recreational use by ski boats.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants and is used to determine the amount of algae in a volume of water. The concentrations of chlorophyll on both sampling dates indicated high densities of algae at the time of sampling. In August, the density of algae was particularly high, possibly because of the higher nitrogen concentration as well as the warmer weather.

Aquatic plants identified by Ecology staff during the 1993 sampling visits include Brazilian elodea *(Egeria densa)*, whitestem pondweed (*Potamogeton praelongus*), largeleaf pondweed (*Potamogeton amplifolius*), another pondweed (possibly *Potamogeton illinoensis*), and coontail (*Ceratophyllum demersum*). Brazilian elodea, an aggressive non-native plant, was the most abundant plant in the lake. This plant was probably introduced into the lake from an aquarium, and can be easily spread to other lakes.

Other Available Information

In 1993, residents at Long Lake were awarded a grant from Ecology's Freshwater Aquatic Weeds Account grants program, to prepare an aquatic plant management plan for the lake. Work on the plan will begin in 1994.

From Welch *et al.* (1988): The lake was drawn down two meters during summer 1979 to reduce aquatic plant populations, and was treated with alum in 1980 to inactivate phosphorus in the sediments. The alum treatment resulted in a 50% reduction in mean concentrations of chlorophyll *a* and total phosphorus, and a 50% increase in water clarity. The treatment lasted for 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 Brazilian elodea, *Egeria 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 to 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 alum treatments in Long Lake.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire. Additional information on lake and watershed uses are from a previous volunteer's responses to the 1990 and 1991 questionnaires.

Long Lake is used for fishing, boating, swimming, rowing, jet skiing, and camping. Public recreational facilities on the lakeshore include a park, camping area, and a beach. There is one boat ramp on the lakeshore, and there is a speed restriction of 8 mph for motorboats within 300 feet of the shore, docks, and the swimming area. No fish were stocked in the lake in 1993. Currently the watershed is being logged and used for animal grazing, and grazing animals have direct access to the lakeshore or inlet tributaries. The lakeshore is also being developed further for residences. Lake water is withdrawn for drinking and other domestic uses.

There are approximately 150 houses on the lakeshore, and none are connected to a sewer. There is a lake association for the lake, and residents are attempting to form a lake management district (a petition was circulated starting September 30, 1993). No algae or aquatic plant management activities occurred in 1993, although in the past the lake has been treated with herbicides [and alum] to control aquatic plants and algae, and aquatic plants have been mechanically harvested.

Overall, the volunteer found that Long Lake had good water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, and (2) algae and shoreline erosion. (In 1991, the worst problems in the lake were aquatic plants, algae, lake level, and suspended sediments.)

Submerged plants grow in the south end of the lake in areas where the water is about six feet deep. The University of Washington has conducted several research projects related to the Brazilian elodea in the lake. The lake has seven inlets (some are very small), including Salmonberry Creek and Olalla Creek, and the lake is also fed by springs.

Acknowledgment

I thank Kathy Smith for volunteering her time to monitor Long Lake in 1993. Wells Soden monitored the lake from 1989-1991.

Long Lake -- Kitsap County

1993 Trophic Status[1]

Estimated Trophic State:	Eutrophic
Mean Trophic State Index (Secchi):	57
Mean Trophic State Index (Total Phosphorus):	63
Mean Trophic State Index (Chlorophyll *a*):	59

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
07-Jun	1000	20.0	68.0	4.5		brown-gr	100		calm	Onsite visit.
21-Jun	1048	20.6	69.0	3.0		lt-brown	90	none	strong	Current moving fast - water has waves. Hard to take Secchi reading with current pulling disk horizontal.
05-Jul	1400	21.0	70.0	3.0	18.00		50	trace	strong	Water color light brown/greenish brown. Made a pole for water depth measurement so it will decrease in measurement.
15-Jul	1200	20.0	68.0	3.5	12.00	lt-brown	100	moderate	breezy	
02-Aug	1209	22.2	72.0	4.0	16.50	lt-brown	0	none		
16-Aug	1430	20.6	69.0	4.0	16.25		100	trace	light	Water color light green-brown.
30-Aug	1405	21.1	70.0	3.8	14.25	lt-brown	0	none	strong	Onsite visit.
12-Sep	1345	21.1	70.0	3.5	15.00	lt-brown	0	trace	light	
26-Sep	1315	18.9	66.0	4.0	14.50	lt-brown	0	none	breezy	
10-Oct	1530	16.7	62.0	6.0	16.00	lt-brown	75	none	light	
24-Oct	1135	13.9	62.0	8.0	19.00	clear	25	none	calm	Water was clear, maybe a tint of brown.

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Long Lake drooped 7" from July 15 to October 24.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
06/07	0.0	19.3	6.9	8.3	92
	1.0	19.3	6.9	8.1	92
	2.0	19.3	6.9	8.0	91
	3.0	18.6	6.8	5.5	109
08/30	0.0	20.9	7.7	9.8	101
	0.9	20.8	7.7	9.3	101
	2.1	20.7	7.7	9.1	101
	2.7	19.9	7.6	7.3	102

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 7 Epilimnion	62	0.69	10.8	–	–	–	–
Hypolimnion*							
August 30 Epilimnion	60	0.73	28.4	–	–	–	–
Hypolimnion*							

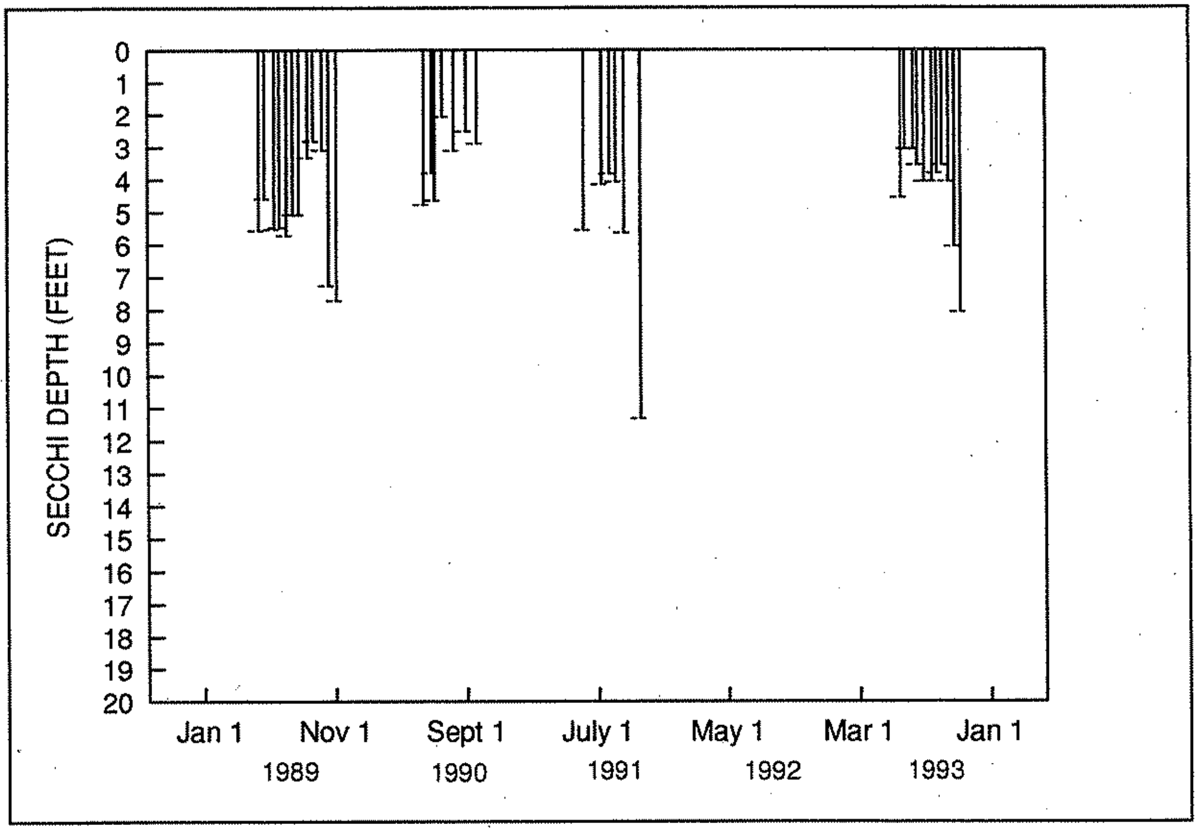
* The lake was not stratified at the time of sampling; only one set of samples was collected

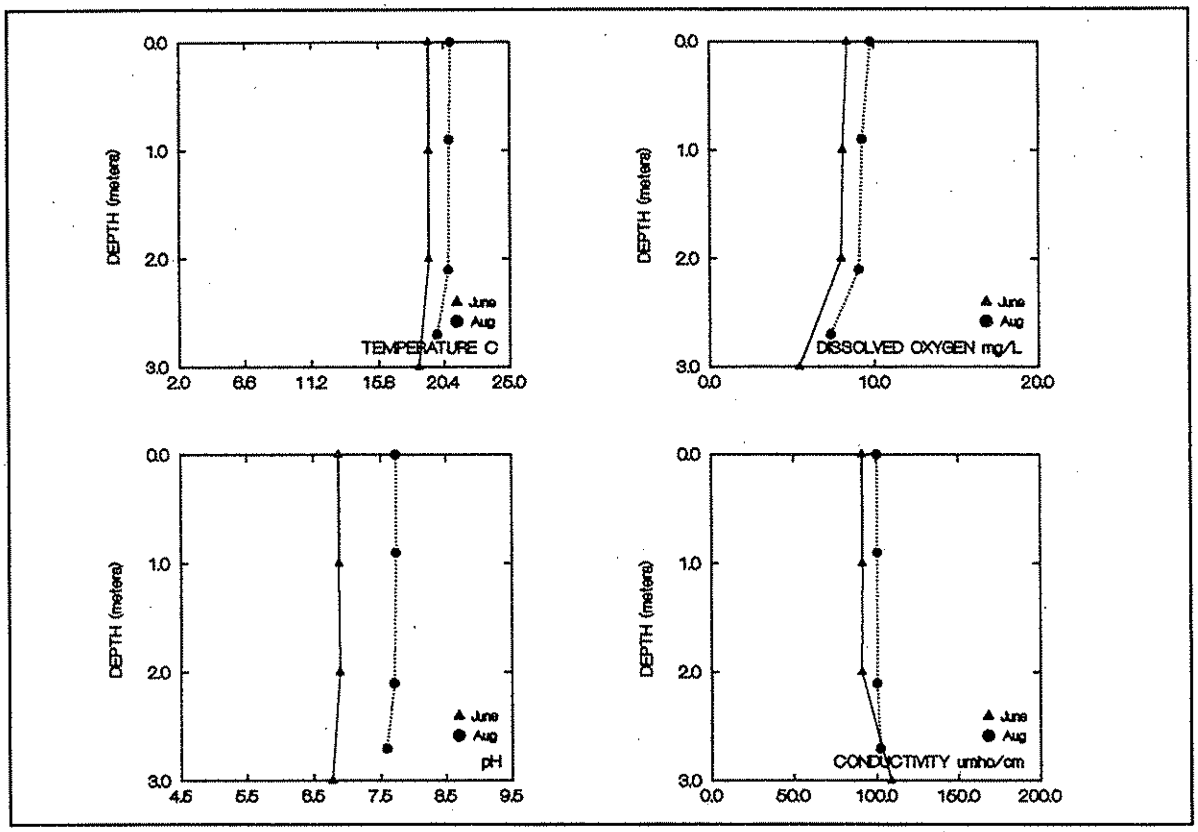
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)
08/16/74[a]	8	–	–
08/30/90[b]	60	0.73	28.4
05/31/91[c]	–	0.36	–
08/27/92[d]	22	0.41	–

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Washington's Citizen Lake Monitoring Program (unpublished data)

LONG LAKE (KITSAP COUNTY)





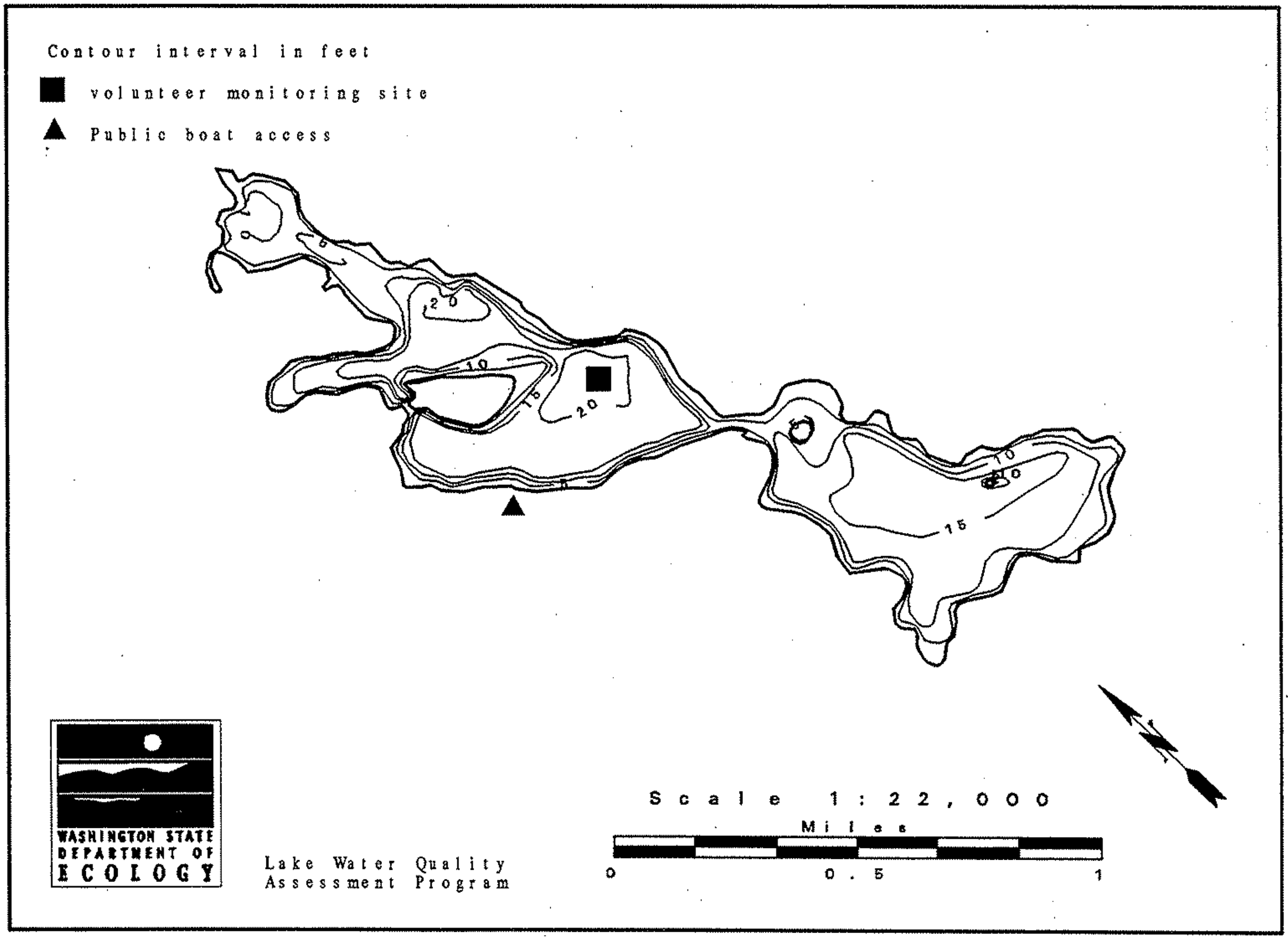
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, Long Lake exhibited both mesotrophic and eutrophic characteristics, so it was assessed as meso-eutrophic. Eutrophic characteristics include the high concentrations of total phosphorus and high densities of algae. Secchi depths were in the range expected for mesotrophic lakes. Long Lake was described as mesotrophic from 1989 to 1992.

In 1993, the lake level was very low, possibly because the inlet from Pattison Lake was blocked by a beaver dam. The blocked inlet, and low rainfall in 1992, may have caused the statistically significant decreasing trend in lake level from 1990 to 1993 ($P<0.10$).

In 1993, aquatic plants in the lake were dominated by the macro-alga: *Nitella*. Largeleaf pondweed was stunted and dying, and Eurasian watermilfoil appeared to be controlled in most areas of the lake.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

In 1993, water clarity was fair, indicated by Secchi depths which ranged from 5.0 feet to 13.0 feet. Secchi depths from 6.5 feet to 13.0 feet are typical for mesotrophic lakes.

Secchi depth data collected since 1989 were analyzed for trend in water clarity. Although Secchi depths decreased from 1989 to 1993, the decrease was not statistically significant.

Lake Level

Using lake height data collected by the volunteer, there was a declining trend in lake level from 1990-1993 ($P<0.10$). The decline in lake level was particularly noticeable in 1993, when the level dropped 23" from May through October, and by October the level was the lowest measured by the volunteer since 1990. The low level in Long Lake in 1993 was coincident with the rise in level at Pattison Lake; Thurston County staff found a beaver dam that blocked the waterway between the two lakes. Although the dam was broken up, the beavers rebuilt it (Lakes Improvement Association, 1993a, 1993b, 1994).

Total Phosphorus

Concentrations of total phosphorus were high on both sampling dates (32 µg/L in May, and 45 µg/L in August). Concentrations greater than 24 µg/L are typical for eutrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were high, and were similar to concentrations measured earlier for the program.

Profile Data

The lake was barely stratified during May, and was not stratified when the lake was sampled in August. Late-summer destratification was also noted in 1992. Despite destratification, dissolved oxygen was very low in the bottom two meters of the lake. Low oxygen concentrations result from bacterial decomposition of aquatic plants and algae in the water and sediments. 1993 profile data were very similar to profile data collected from 1990-1992.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. The concentration of chlorophyll *a* in May indicated a moderately high density of algae at the time of sampling. Algal density was lower than would be expected, given the high concentration of total phosphorus, but recent storms probably restricted algae growth. In August, the chlorophyll concentration indicated a high density of algae.

The lake was treated with Sonar® (fluridone) during summer 1991 to control Eurasian watermilfoil (*Myriophyllum spicatum*; see Summary of Questionnaire Results, below). In 1992, aquatic plant growth in the lake was reduced, and emergent plants (such as cattails) and floating-leaved plants (such as lily pads) were brownish, most likely from taking up residual Sonar from sediment.

Aquatic plants observed in the lake during the August 1993 sampling visit were bulrush (*Scirpus*), largeleaf pondweed (*Potamogeton amplifolius*), cattails (*Typha*), iris (*Iris pseudacorus*), white-flowering water lily (*Nymphaea odorata*), and the macro-alga *Nitella*. Sparse patches of curly-leaf pondweed (*Potamogeton crispus*) and naiad (*Najas flexilis*) were also observed. Much of the largeleaf pondweed in the south basin was stunted, with few leaves on the stems. When leaves were present, they were brown and rotting. Also, the bulrush was yellowish at the base of the stems (and may have been affected by low water level). While it is possible that the plants were affected by residual Sonar in the sediment, Sonar was expected to degrade long before 1993. So far, dieback of the largeleaf pondweed is unexplained. Nitella, which is not affected by Sonar and is known to increase in abundance after a Sonar treatment, was the most abundant plant in the lake in 1993. Although milfoil was not observed in the lake when the lake was surveyed in 1993, the sampler used for collecting plants would only pick up milfoil if it were growing in large quantities.

Except for the naiad, all plants listed above were also observed during the May 11, 1992, onsite sampling visit. Sago pondweed (*Potamogeton pectinatus*) was also observed in 1992.

Other Available Information

Water quality data have been collected by the Thurston County Health Department since 1989. Water clarity in these five years ranged from 1.0-4.28 meters (3.3-14.0 feet), and chlorophyll concentrations ranged from 2.3-98.1 µg/L. In general, chlorophyll values indicated heaviest algae growth in June and July, and in September and October (Thurston County Health Department).

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 North Pattison Lakes were treated with alum. Mechanical harvesting of plants in Long Lake 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 resulted in 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.

Summary of Questionnaire Results and Information from the Volunteer

The 1993 questionnaire on lake and watershed uses was not returned. 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 one 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. The lakeshore is also being developed further for residences. In the past, the watershed was logged and used for animal grazing, the lake was dredged, and the shoreline was altered.
>
> 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 found that Long Lake had good water quality in 1992. 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.

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 previous 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. In 1992, milfoil was still growing in the inlet channel and a few scattered areas around the lake.

Acknowledgment

I thank Kathey Adams for volunteering her time to monitor Long Lake during 1989-1993. Sue Mauermann was the primary monitor at Long Lake during 1992.

Long Lake -- Thurston County

1993 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	48
Mean Trophic State Index (Total Phosphorus):	57
Mean Trophic State Index (Chlorophyll *a*):	52

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
21-May	1620	17.8	64.0	13.0	15.50	gr-brown	90	heavy	strong	Lots of Nitella and Spirogyra.
07-Jun	1430	16.7	62.0	10.0	16.00	gr-brown	75	heavy	strong	
03-Jul	1330	17.8	64.0	10.0	18.50	lt-green	100	light	light	
19-Jul	1430			7.0	21.50	gr-brown	100	moderate	light	
02-Aug	1330	20.0	68.0	5.0		gr-brown	0	none	light	
18-Aug	1830	21.1	70.0	6.0	27.50	gr-brown	25	light	breezy	
26-Aug	0930	17.8	64.0	6.0	28.50	gr-brown	25	trace	calm	Lake bottom depth maybe due to construction on Pacific Avenue. Algae bloom. Investigated plant growth with Julie R. (onsite visit).
11-Oct	1500	14.4	58.0	5.0	37.50	pea-green	75		calm	Heavy algae. Water level the lowest I have ever seen.

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

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Long Lake dropped 2.2" from May 21 to October 11.

Long Lake -- Thurston County

1993 Onsite Visit - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/21	0.0	20.8	7.5	9.0	110
	1.0	20.8	7.7	8.5	110
	2.0	20.1	7.7	8.0	109
	2.9	16.9	7.6	7.7	108
	4.0	15.4	7.4	2.8	115
	4.8	14.8	7.3	1.2	120
08/26	0.0	19.8	7.8	8.9	118
	1.0	19.9	7.8	8.6	118
	2.0	19.9	7.8	8.4	118
	3.0	19.9	7.8	8.2	118
	3.9	19.4	7.1	0.3	124
	4.6	18.4	7.0	0.1	157

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 21 Epilimnion	32	0.33	4.6	--	--	--	--
Hypolimnion*							
August 26 Epilimnion	45	0.56	17.8	--	--	--	--
Hypolimnion*							

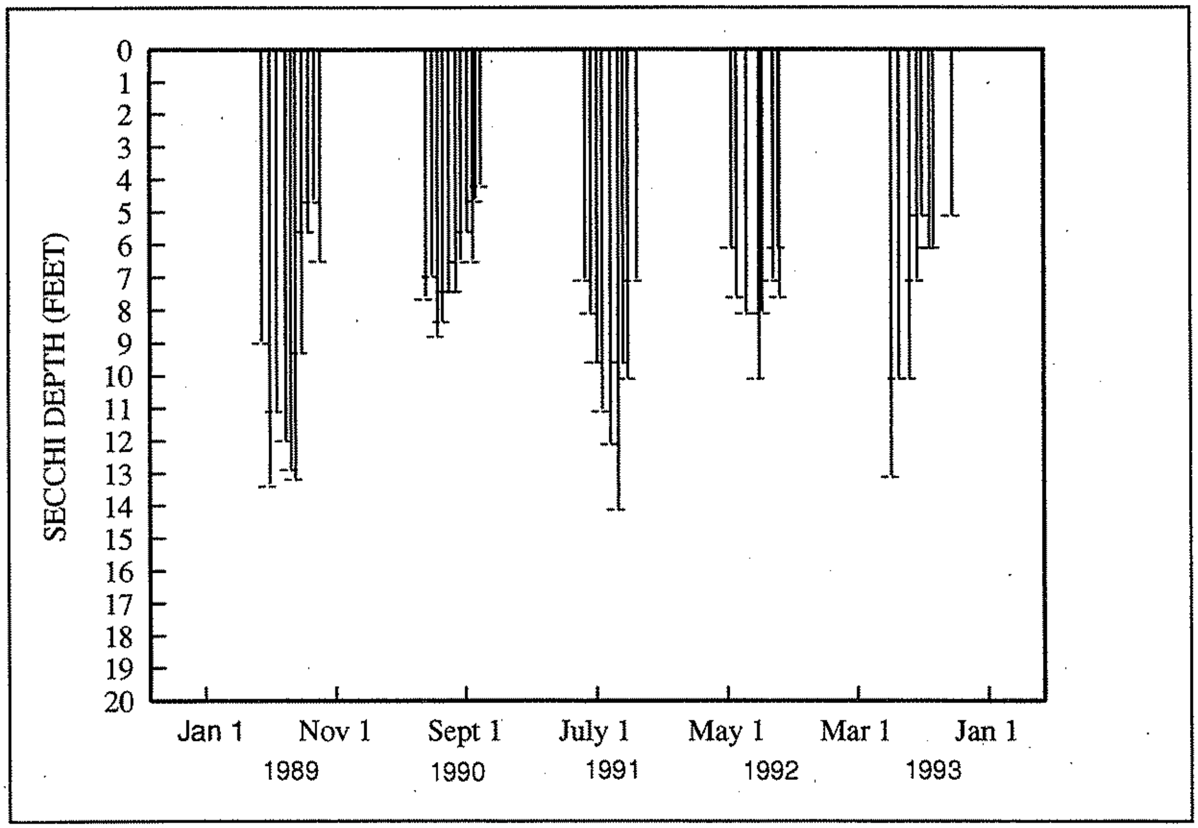
* The lake was not stratified at time of sampling; only one set of samples was collected.

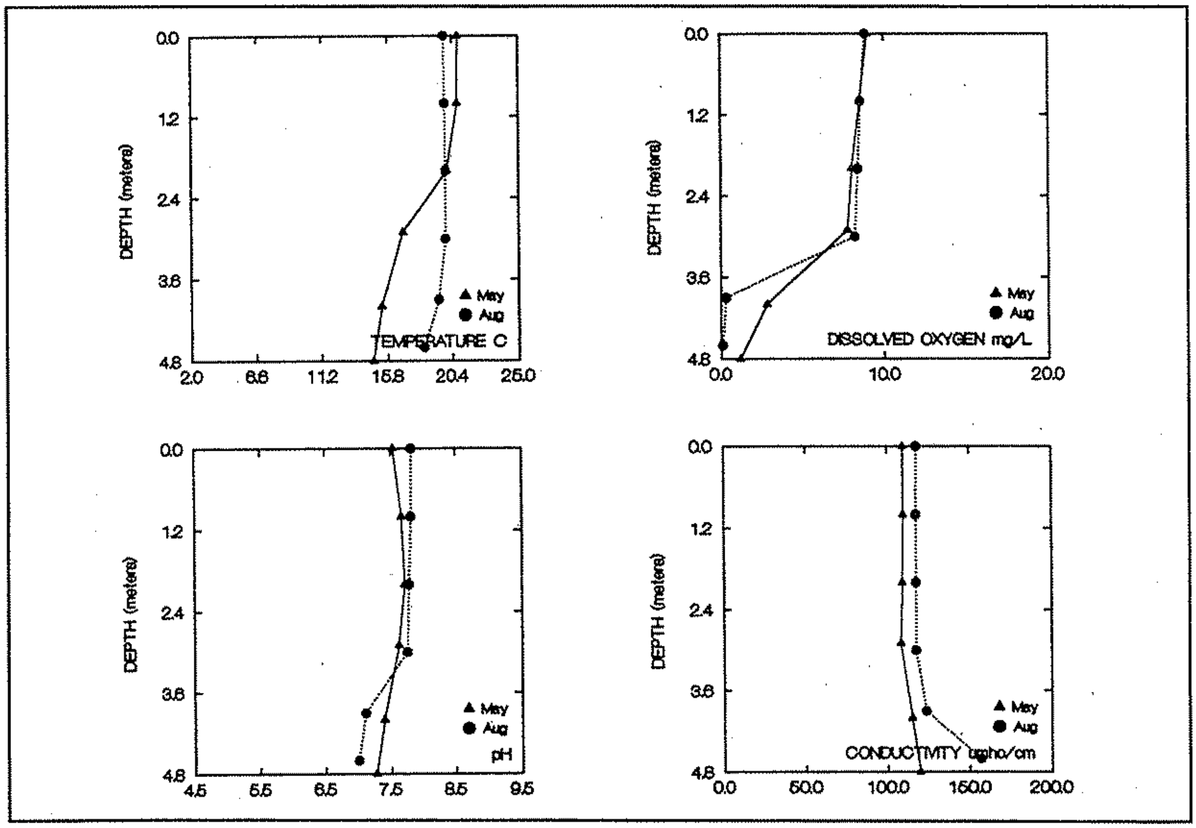
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
08/20/74[a]	10	--	--
05/29/90[b]	20	0.41	--
08/21/90[b]	28	0.54	--
06/04/91[c]	--	0.40	--
05/11/92[d]	31	0.44	3.2
09/02/92[d]	36	0.43	6.3

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)

LONG LAKE (THURSTON COUNTY)





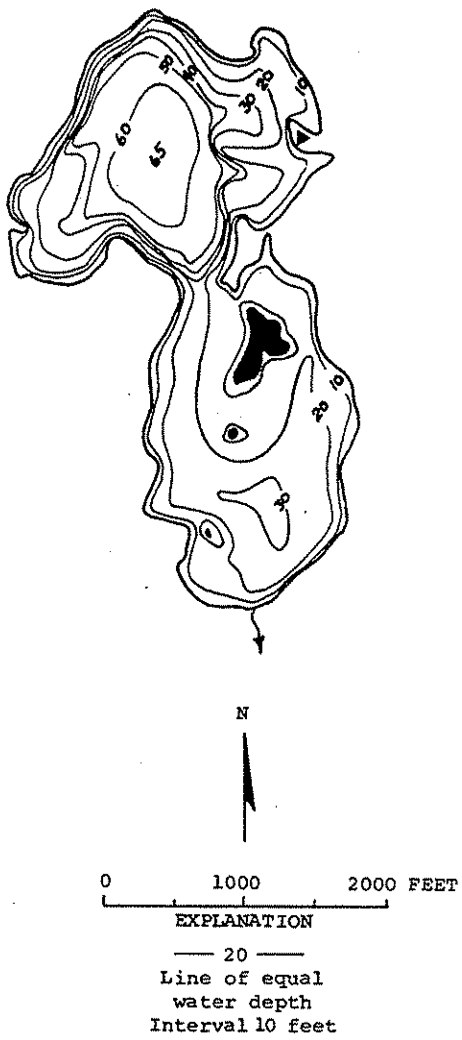
1993 Secchi Depth and Profile Data Graphs

Lost Lake -- Mason County

Lost Lake is located 7.75 miles southwest of Shelton. It has no surface inlets, and drains via the south fork of Goldsborough Creek to Oakland Bay. It has a three-acre island.

Size (acres)	120
Maximum Depth (feet)	65
Mean Depth (feet)	28
Lake Volume (acre-feet)	3,400
Drainage Area (miles^2)	1.08
Altitude (feet)	480
Shoreline Length (miles)	3.2

Data From Bortleson *et al.* (1976)



Lost Lake, Mason County. From Washington
Department of Game, February 12, 1952.

Overall Assessment

In 1993, Lost Lake was assessed as oligotrophic, based on good water clarity, low nutrient concentrations, and low densities of algae in open-water areas. Although there were some localized areas of algae growth in the lake, localized algae growth may occur from a combination of nearshore sources of nutrients (such as yard runoff or septic system leachate) and favorable weather conditions for algae growth (warm and calm water).

Other Mason County lakes monitored for the program in 1993 were Island Lake, Lake Limerick, Mason Lake, Lake Nahwatzel, Phillips Lake, Spencer Lake, and Lake Wooten. In comparison with these lakes, only Lake Wooten had lower concentrations of total phosphorus and less algae (open-water) than Lost Lake. Mason Lake had the best water clarity of the Mason County lakes.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity during the monitoring season (May through October) was very good, indicated by Secchi depths that ranged from 18.5 feet to 21.5 feet. Secchi depths greater than 13.0 feet indicate good water clarity and are typical for oligotrophic lakes.

Total Phosphorus

The concentrations of total phosphorus were low on both sampling dates. Concentrations were higher in May than they were in September, possibly because of stormy weather during May that could have caused a higher amount of runoff to enter the lake. Runoff generally includes suspended sediments, which can have phosphorus adsorbed onto the particles.

Total Nitrogen

Total nitrogen concentrations were moderately high on both sampling dates, although concentrations in Lost Lake were very low relative to concentrations measured in other lakes in the program. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. In September, the ratio of total nitrogen to total phosphorus was greater than 17:1 (it was 50:1). In May, the ratio of total nitrogen to total phosphorus was 14:1, so it is possible that algae growth was nitrogen-limited in the spring.

Profile Data

The lake was thermally stratified on both sampling dates. Dissolved oxygen concentrations increased in the thermocline, most likely because of the lower water temperatures at these depths (because dissolved gases are more soluble in cooler water than in warmer water). Below the thermocline, dissolved oxygen concentrations decreased considerably with depth which probably resulted largely from spring water entering the lake. Spring water is very low in oxygen. Oxygen concentrations can be low in the lower layer of water, but high in the upper layer, because these layers do not mix while the lake is stratified. Oxygen in the lower layer is replenished when the lake turns over (mixes) in fall or early winter.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants that is used to determine the amount of algae in a volume of water. Concentrations of chlorophyll *a* on both sampling dates indicated low densities of algae in the lake at the time of sampling.

During the May sampling visit, there was a thick mass of algae in a cove near the public access. A sample of the mass contained several algae species, including *Melosira*, *Mougeotia*, *Spirogyra*, several large pinnate diatoms and at least two unidentified filamentous algae. The dominant algae was *Tabellaria*, which was intertwined with a filamentous green alga that could have been *Cylindrocapsa*. Both *Spirogyra* and *Mougeotia* are known for being nuisance algal species. During the September onsite visit, another algae sample was collected. This sample contained one species of a filamentous green algae that was either *Zygnema* sp. or *Zygnemopsis* sp. (confirmation requires conjugation).

Aquatic plants identified by Ecology staff during the onsite sampling visits were water starwort (*Callitriche* sp.), Nuttall's waterweed (*Elodea nuttallii*), quillwort (*Isoetes* sp.), waterthread pondweed (*Potamogeton diversifolius*) and muskgrass (*Chara*). Muskgrass was brought up on the profiling instrument in May when the deep site of the lake was profiled.

Other Available Information

From McConnell *et al.*, (1976): In 1973 the lake had few aquatic plants. Dissolved oxygen in the hypolimnion was nearly depleted by mid-June.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire on lake and watershed uses.

> Lost Lake is used for swimming, fishing, motoring, rowing, and jet skiing. There is one boat ramp on the lakeshore, and there are no restrictions for boating on the lake. Trout were stocked in the lake in 1993. Currently, the watershed is being logged, and the lakeshore is being developed further for residences. In the past, the watershed was logged.

There are several houses on the lakeshore, and none of them are connected to a sewer. There are no culverts that drain into the lake. There is no lake association for the lake, although residents are presently trying to form one. No lake management activities occurred in 1993.

Overall, the volunteer found that Lost Lake had excellent water quality. The worst problems in the lake in 1993 were ranked as (1) shoreline erosion, and (2) excessive aquatic plant growth. The eroding shoreline is from a five-acre lot that was clearcut almost to the water's edge in 1991.

Acknowledgment

I thank Bruce Spong for volunteering his time to monitor Lost Lake during 1993.

Lost Lake -- Mason County

1993 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	34
Mean Trophic State Index (Total Phosphorus):	32
Mean Trophic State Index (Chlorophyll *a*):	25

Volunteer-Collected Data

Date 1993	Time	Temperature (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	%Cloud Cover	Recent Rain	Wind	Abbreviated Comments
24-Apr	1430	12.8	55.0		18.5			90	heavy	breezy No anchor.
23-May	1430	17.2	63.0	19.0		green	0	trace	breezy	
27-May	1400			21.5			100	light	breezy	Onsite visit. Raining.
13-Jun	1600			20.0		green	0			
05-Jul	1100	17.2	63.0	20.0			0			
18-Jul	1100			19.6			0			
05-Aug	1330			20.0			0			
28-Aug	0930	20.0	68.0	19.0			0			
02-Sep	1330			20.0		lt-green	0		light	Onsite visit.

[1] Trophic State Indices calculated from Carlson (1977).
[2] "Lake height" refers to change in water level. Lake height was not monitored in 1993.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/27	0.0	19.4	7.2	9.5	19
	0.9	19.4	7.1	9.4	19
	2.1	19.4	7.1	9.5	19
	3.1	18.8	7.1	9.6	19
	4.0	18.3	7.0	9.7	19
	5.0	16.1	7.1	10.4	18
	5.1	15.8	7.0	10.5	18
	5.9	14.0	7.1	11.0	18
	7.0	12.0	7.2	11.6	18
	8.0	9.8	7.2	12.2	18
	9.0	8.1	7.2	12.4	18
	10.0	7.0	7.2	12.2	18
	11.4	6.1	7.1	11.3	18
09/02	0.0	21.4	7.1	9.3	19
	1.0	21.1	7.1	9.0	19
	2.0	21.0	7.1	8.9	19
	3.0	21.0	7.1	8.8	18
	4.0	20.8	7.0	8.8	18
	5.0	20.8	7.0	8.8	19
	6.0	20.7	7.0	8.8	19
	7.0	19.4	7.0	9.8	19
	8.0	15.4	7.5	12.6	18
	9.0	12.9	7.6	12.7	18
	10.1	10.3	7.7	12.4	18
	12.1	8.4	7.5	8.4	18
	14.0	6.9	7.2	3.3	19
	16.0	6.5	7.0	0.4	21
	16.5	6.5	7.0	0.2	21

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 27 Epilimnion	12	0.17	0.6	–	–	–	–
Hypolimnion	15	0.19	–	–	–	–	–
September 2 Epilimnion	4	0.20	0.5	–	–	–	–
Hypolimnion	9	0.20	–	–	–	–	–

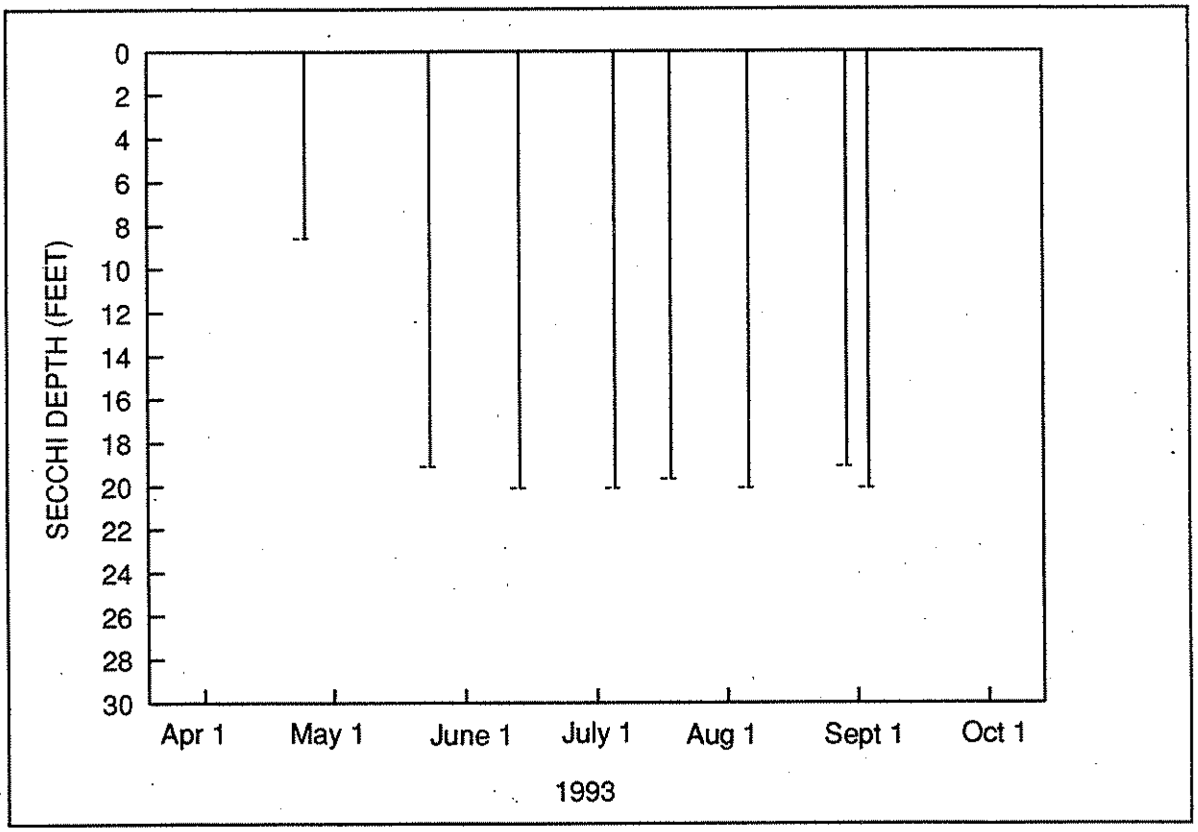
Lost Lake -- Mason County

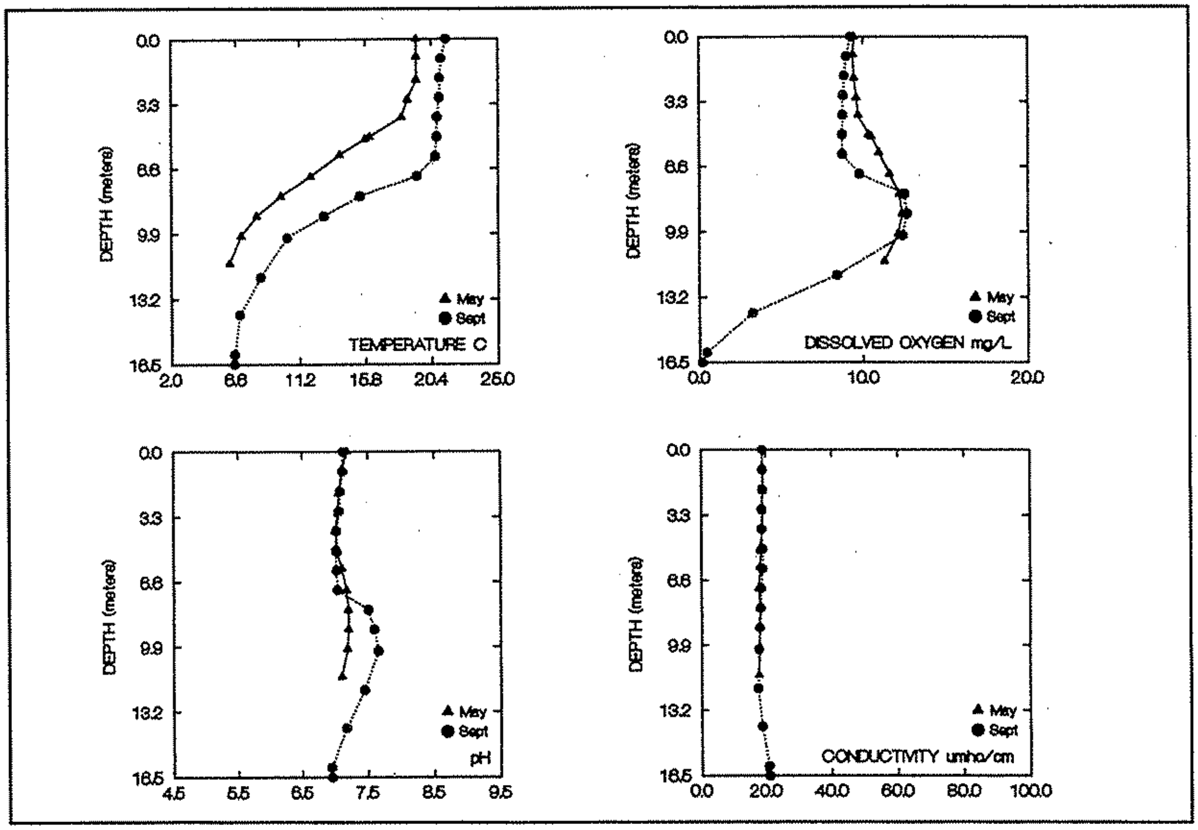
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
06/21/73a	7	--	1.9
09/06/73a	4	--	0.8
06/24/81b	10	0.55	0.9

a. Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)

LOST LAKE (MASON COUNTY)





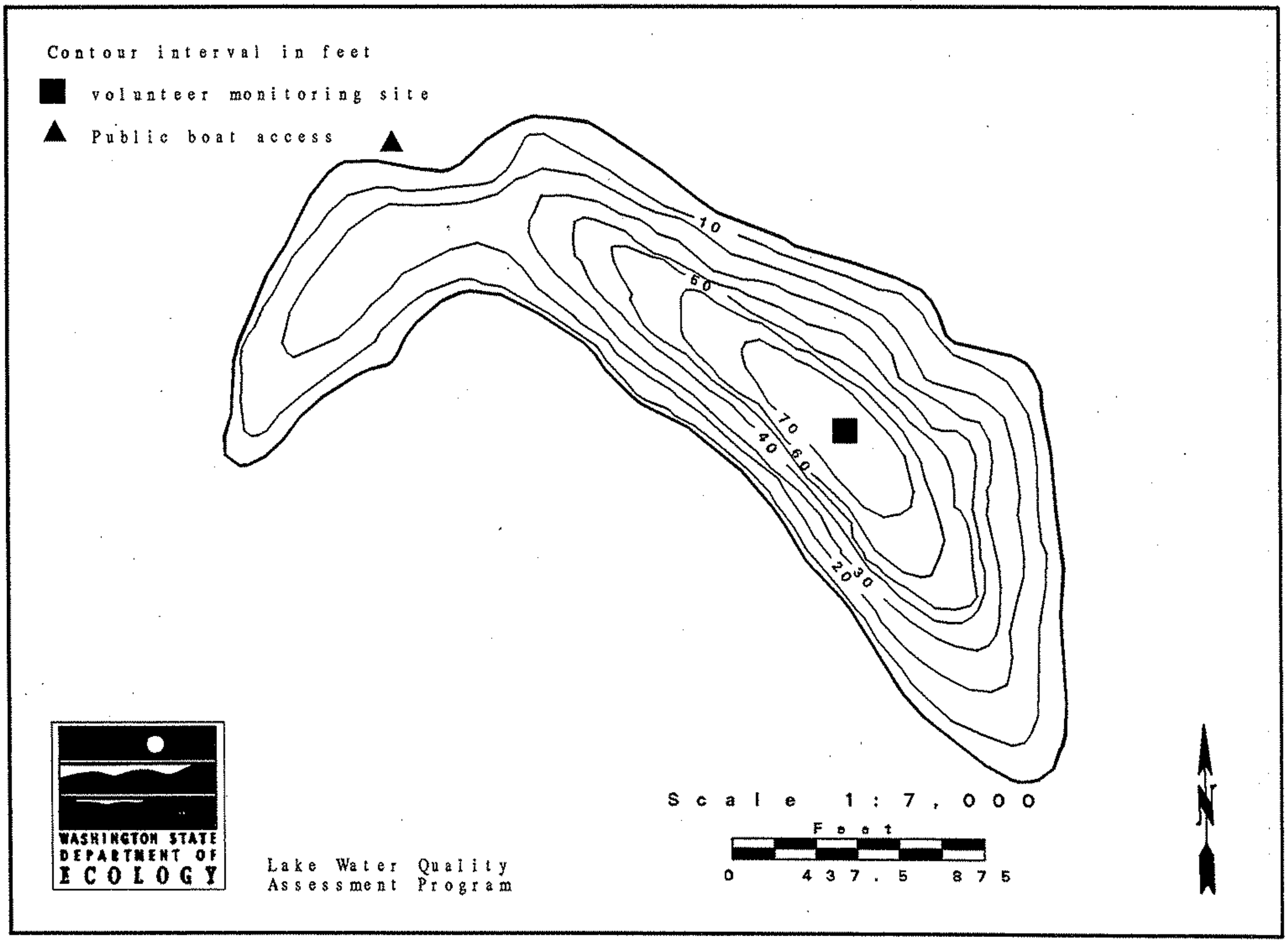
1993 Secchi Depth and Profile Data Graphs

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 Lake Howard and drains to Port Susan. (Lake Martha is not the same as 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)



Overall Assessment

In 1993, Lake Martha was assessed as mesotrophic, based on moderately high concentrations of chlorophyll *a*, a fall algal bloom, and the high total phosphorus concentration in May. Despite the heavier than usual algal growth in Lake Martha, water clarity was very good at the open water monitoring site. Most algae growth in the lake was localized in calm nearshore areas; most likely, weather conditions in 1993 were optimal for algae growth in Lake Martha.

In 1990, 1991, and 1992, Lake Martha was classified as oligotrophic based on data collected for this program. There were not enough data available to determine whether the water quality of Lake Martha has declined since 1990; however, phosphorus and chlorophyll concentrations from 1974 were moderately high, indicating that moderately high phosphorus and algal densities were not a recent phenomena for the lake.

Other Snohomish County lakes monitored for the program in 1993 are Blackmans, Bosworth, Howard, Ketchum, Ki, Loma, Martha Lake, Roesiger, Stevens and Sunday. Lake Howard, which feeds into Lake Martha via an intermittent inlet, had good water clarity and low algal densities despite moderately high concentrations of total phosphorus.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good in 1993, as indicated by Secchi depths which ranged from 12.5 feet to 20.0 feet. Secchi depths greater than 13.0 feet indicate good water clarity. The lowest Secchi depth was measured during the May onsite sampling visit; a moderately high density of algae at the time probably affected the water clarity (see Plants, below).

Secchi depths during June and July were deeper in 1993 than in 1990-1992, most likely because of cool and wet weather during these months in 1993. Although water clarity increased throughout the monitoring season from 1990-1992, in 1993 there was an algae bloom in late September and October that noticeably reduced water clarity. Warm and calm weather during fall was favorable for algae growth; fall algae blooms occurred in several western Washington lakes monitored for the program in 1993.

Total Phosphorus

In May, the concentration of total phosphorus in the upper layer of water (41 µg/L) was much higher than concentrations measured previously for the program. The higher concentration of total phosphorus coincided with a moderately high density of algae and a lower Secchi depth.

In August, the total phosphorus concentration was the same as that measured on both sampling dates in 1992 (12 µg/L). Concentrations from 12 to 24 µg/L are typical for mesotrophic lakes.

Total Nitrogen

The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Although total nitrogen concentrations were moderately high on both sampling dates, the ratio of total nitrogen to total phosphorus was low (10:1) when the lake was sampled in May. This resulted from the higher total phosphorus concentration in May, and suggests that algae may have been nitrogen-limited. However, cool and windy weather may have also limited algae growth in May. When the lake was sampled in August, the ratio of total nitrogen to total phosphorus was much higher (27:1), and indicated that algae were not limited by nitrogen.

Profile Data

On both sampling dates, the lake was stratified with respect to temperature. Both pH and dissolved oxygen decreased from surface to bottom, most likely due to bacterial decomposition of aquatic plants and algae in the water and sediments. Profile data from 1993 were very similar to data collected in 1992, 1991, and 1990. However, in August 1993 there were higher concentrations of dissolved oxygen in the lower layer of water (below the thermocline) than in August 1992.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Concentrations of chlorophyll *a* on both sampling dates indicated moderately high densities of algae at the time of sampling.

The volunteer reported increased algae growth in fall and winter 1993. An algae sample collected by the volunteer in October 1993 contained primarily the blue-green alga *Anabaena circinalis*. This algae was reported to concentrate in calm, protected areas of the lake. Another algae sampled collected in February 1994 contained the blue-green filamentous alga *Oscillatoria*. Several lakes monitored for the program had increased algae growth during fall. Warm and calm weather in October and November appeared to encourage blue-green algae growth in these lakes.

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, contained *Oscillatoria*. Detritus clumps were also examined, and contained *Gomphonema*, *Scenedesmus*, *Stephanodiscus*, a lot of *Aphanocapsa*, and "little green balls" that may have been *Sphaerocystis*.

Aquatic plants identified by Ecology staff in 1992 were located mostly near the south end of the lake. Plants observed included American waterweed (*Elodea canadensis*), Nuttall's waterweed (*Elodea nutalli*), coontail (*Ceratophyllum demersum*), muskgrass (*Chara*), largeleaf pondweed (*Potamogeton amplifolius*), flatleaf pondweed (*Potamogeton robbinsii*), iris (*Iris pseudacorus*), cattails (*Typha*), and yellow-flowering water lily (*Nuphar* sp.). 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.

In 1993, a freshwater sponge was growing on the volunteer's dock.

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 1993.

> Lake Martha is used for fishing, swimming, motor boating, non-motorized boating, lakeshore camping, and bird watching. There is one public boat ramp on the lakeshore, and the only restriction for motorboating is a speed limit of 8 mph. About one percent of the shoreline is publicly-owned. Trout were stocked in the lake in 1993. Currently, the watershed is being logged and used for animal grazing/feeding. The lakeshore is also being developed further for residences. In the past, the watershed was logged and used for 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 77 houses on the lakeshore, and none of the houses are connected to a sewer. There is a residents' group for education about the lake. No lake management activities occurred on the lake in 1993. Currently, the minimum setback for development is 26 feet.
>
> Overall, the volunteer found that Lake Martha had good water quality. Problems in the lake in 1993 were ranked as (1) algae, and (2) water quality gradually degraded over years. Possible sources of problems include increased surface runoff resulting from removal of shoreline vegetation and construction close to the shoreline. In comparison to the 1992 monitoring season, total phosphorus and total nitrogen concentrations were higher during May, and in 1993 there was more algae during fall.

Acknowledgment

I thank Nancy Dean for volunteering her time to monitor Lake Martha during 1993. Joan Lucas monitored the lake from 1990-1992.

Lake Martha (near Warm Beach) -- Snohomish County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	35
Mean Trophic State Index (Total Phosphorus):	49
Mean Trophic State Index (Chlorophyll *a*):	44

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
25-May	1030			12.5			80	none	light	Onsite visit. Water color yellow split pea.
10-Jun	1030	18.9	66.0	20.5			100	heavy	calm	Water color green-yellow. Lake very clear. Up 4" from 6/2 when I installed yardstick. Still lots of pollen.
24-Jun	1030	19.4	67.0	19.7	32.50		90	moderate		Water color greenish yellow. Water contains a lot of irregular particular matter, probably pollen.
10-Jul	0930	20.8	69.5	18.0	34.63		100	none	calm	Water color yellow-green-brown. Moderate particulate matter of varying size-probably pollen.
25-Jul	1100	18.9	66.0	17.5	34.50		50	light	breezy	Water color definitely a deep yellow color.
07-Aug	1100	22.8	73.0	18.0	35.50		90	none	breezy	Water definitely a deep yellow color. Very little particulate matter. Hot last week - 80 to 90 degrees.
18-Aug	1100	21.1	70.0	19.0	36.50		0	none	light	Water definitely a deep yellow color. Moderate particulate matter.
01-Sep	1000	20.0	68.0	20.0	38.50		90	none	breezy	Water color yellow--almost gold. Lots of particulate matter. Found another freshwater sponge on south side of lake, western end, very large.
15-Sep	0930	19.4	67.0	18.0	40.00		100	light	calm	Water color green-tinted gold. Lots of very tiny particulate matter. Looks like grass chaff. 3 osprey, 3 otter, 2 coots, 2 terns, 1 blue heron, 1 deer.
28-Sep	1000	16.9	62.5	16.5	41.50		0	none	calm	Water color greenish gold. Lots of particulate matter. Water looks cloudy. Record highs past week. Neighbor reports blue-green color south side - will check.
10-Oct	1030	15.6	60.0	16.0	42.50		0			Water color greenish gold. Algae scum covering entire lake, dusting to 1/4." Elodea comparatively sparse this year. Sponge doing very well, E, W, and S edges of lake.

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

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Martha dropped 10" from June 24 to October 10.

Lake Martha (near Warm Beach) -- Snohomish County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/25	0.0	20.6	8.3	9.3	86
	1.0	20.5	8.2	9.3	86
	2.0	20.4	8.2	9.3	86
	3.0	16.7	8.1	8.8	83
	4.0	14.4	8.1	8.5	84
	5.0	12.7	8.0	8.1	83
	6.0	10.9	7.9	8.0	83
	7.1	8.3	7.8	8.0	83
	8.0	7.4	7.8	8.1	83
	10.0	6.2	7.8	8.1	82
	12.0	5.9	7.7	7.9	82
	14.0	5.8	7.7	7.6	82
	15.5	5.8	7.6	7.3	83
08/18	0.0	21.0	7.7	10.1	89
	1.0	20.8	7.7	9.2	89
	2.1	20.6	7.7	9.1	89
	3.0	20.5	7.7	9.1	88
	4.0	19.9	7.5	7.5	88
	5.0	16.4	7.4	6.1	88
	6.0	12.7	7.4	5.4	87
	8.0	8.4	7.5	5.7	86
	10.0	6.6	7.4	6.0	84
	12.0	6.0	7.3	6.0	84
	14.2	5.9	7.3	5.4	85
	16.0	5.9	7.2	4.7	86
	18.3	5.7	7.2	2.9	89
	19.2	5.8	7.1	2.2	101

Lake Martha (near Warm Beach) -- Snohomish County

1993 Onsite Visit Data - Water Chemistry

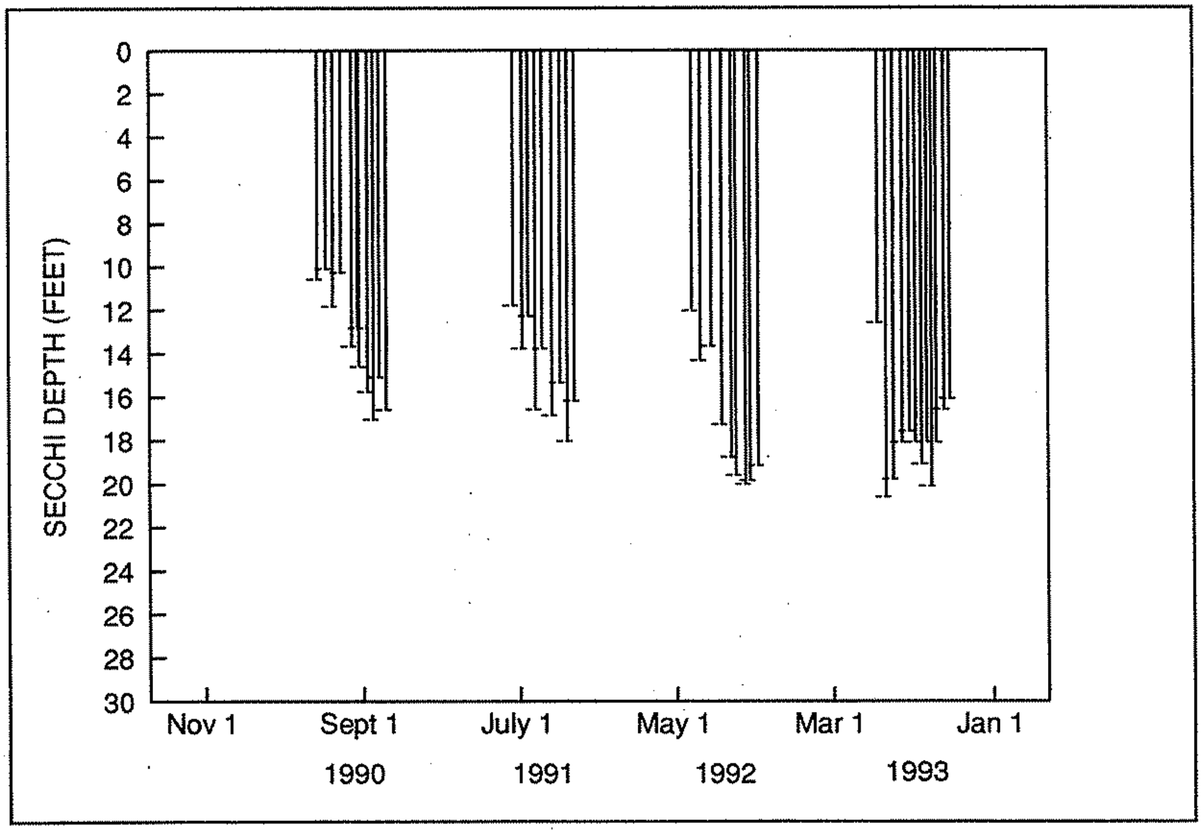
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL)	
						Site #1	Site #2
May 25							
Epilimnion	41	0.41	5.0	--	--	--	--
Hypolimnion	22	0.47	--	--	--	--	--
August 18							
Epilimnion	12	0.32	3.1	--	--	--	--
Hypolimnion	29	0.44	--	--	--	--	--

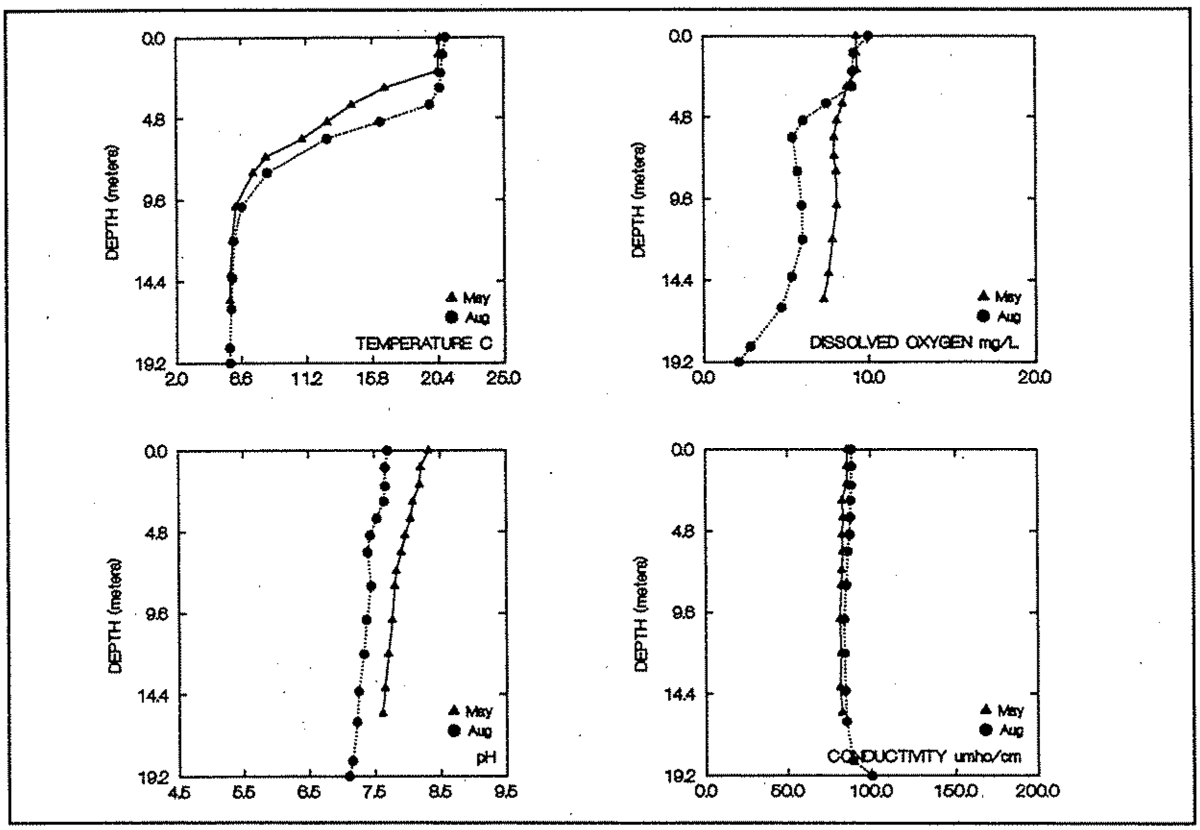
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
6/20/74[a]	17	--	3.5
06/30/81[b]	10	1.0	6.0
06/05/90[c]	8	0.62	--
08/28/90[c]	12	0.46	--
06/18/91[d]	--	0.61	--
06/01/92[e]	12	0.46	1.9
08/25/92[e]	12	0.38	0.59

a. Bortleson *et al.* (1976); Dion *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)
e. Rector (1993)

LAKE MARTHA (SNOHOMISH COUNTY)





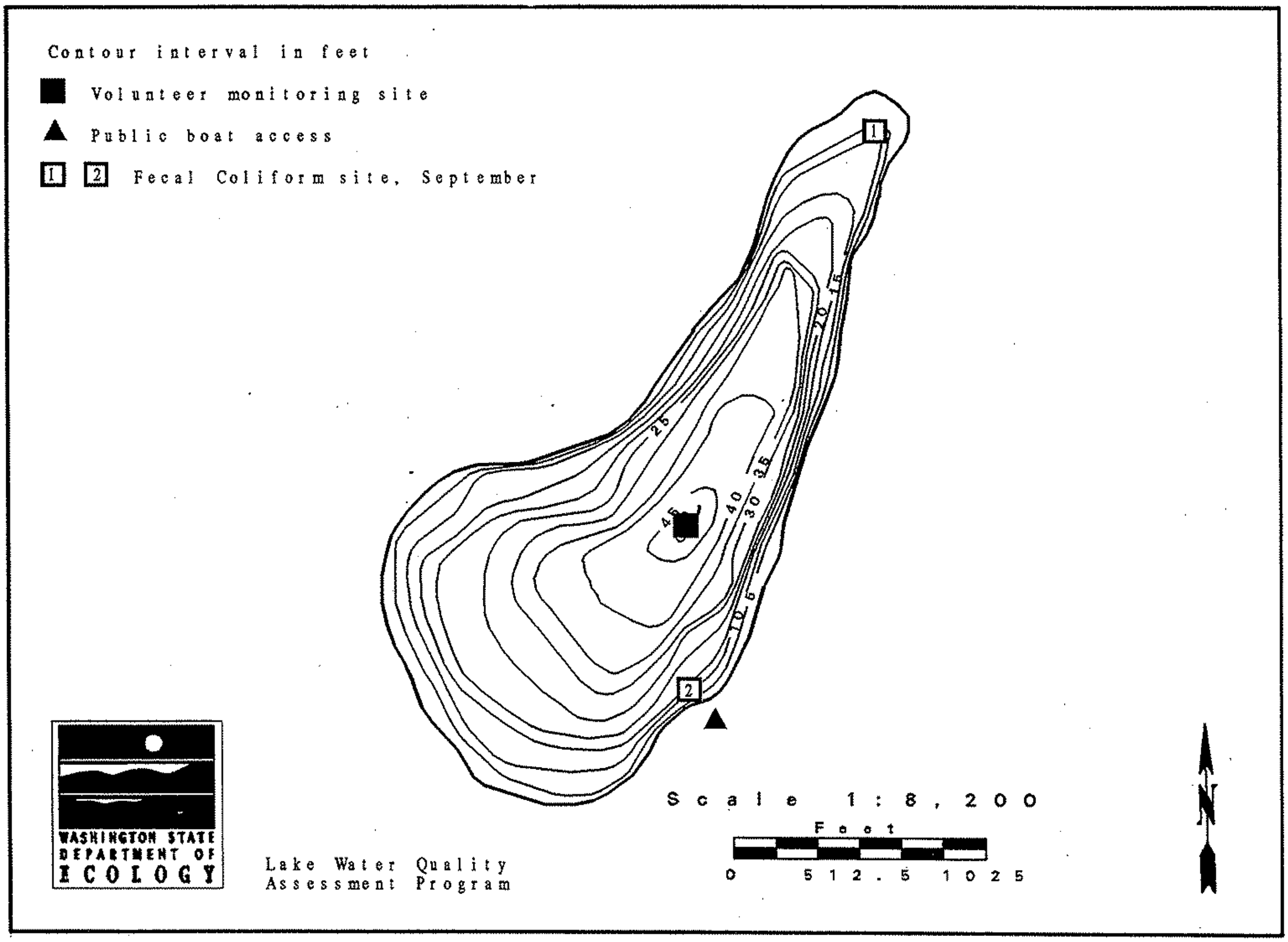
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, Martha Lake was assessed as oligo-mesotrophic, because it exhibited both oligotrophic and mesotrophic characteristics. Oligotrophic characteristics were the very good water clarity, moderate to low phosphorus concentrations, and low concentrations of chlorophyll *a* (which indicate low densities of algae). Mesotrophic characteristics include the moderate amounts of aquatic plants at the north and south areas of the lake, very low concentrations of dissolved oxygen near the lake bottom (both sampling dates), and a history of high bacteria levels near the inlet.

Other Snohomish County lakes monitored for the program in 1993 were Blackmans, Bosworth, Howard, Ketchum, Ki, Loma, Lake Martha (near Warm Beach), Roesiger, Stevens, and Sunday. Of these, Lake Ki had the best water clarity and lowest nutrient concentrations. Compared to other urban lakes in the program (Blackmans Lake and Kitsap Lake), Martha Lake is deeper, which may contribute to it having fairly good water quality in comparison to Blackmans Lake and Kitsap Lake.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in 1993 was good, as indicated by Secchi depths which ranged from 11.2 feet to 24.0 feet.

Total Phosphorus

The concentration of total phosphorus in the epilimnion was moderately high when the lake was sampled in May (16 µg/L), but was very low in August (5 µg/L). Concentrations less than 12 µg/L are typical for oligotrophic lakes. In 1992, phosphorus concentrations were also higher in May than they were in August. Phosphorus concentrations can be higher in spring from increased runoff, and can decrease later in summer as algae take up phosphorus and then sink into lower water where they decompose.

Total Nitrogen

Concentrations of total nitrogen were moderately high (0.45 mg/L, and 0.32 mg/L) in 1993, and but lower than concentrations measured in 1992. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 (28:1 in May, and 64:1 in August), algae in Martha Lake were not limited by nitrogen when the lake was sampled.

Fecal Coliform Bacteria

Samples for fecal coliform bacteria were collected during August. Site #1 was located near the intermittent inlet, and Site #2 was located near the public access. The result for Site #1 (52 colonies/100 mL) was high, but was lower than 1992 results for this site (430 and 160 colonies/100 mL). The result for Site #2 was low (28 colonies/100 mL). 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).

Profile Data

On both sampling dates the lake was thermally stratified, and dissolved oxygen concentrations decreased considerably below the thermocline. Profile data from 1993 were very similar to data collected in 1992, 1991, and 1990.

Very low dissolved oxygen in the lower layer of water (the hypolimnion) results from bacteria using oxygen as they decompose algae and aquatic plants in the water and sediment. In August, dissolved oxygen was virtually depleted in the bottom 4.5 meters of the lake. Trout, which prefer at least 4.5 mg/L dissolved oxygen, may have been restricted to the top five meters of the lake where there were higher oxygen concentrations.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. On both sampling dates, the concentrations of chlorophyll *a* in the upper layer of water (the epilimnion) were low, indicating low densities of algae at the time of sampling. It is possible that algae growth in May occurred below the epilimnion, as indicated by the higher dissolved oxygen concentration and pH at the thermocline. This also appeared to have happened in 1992.

Aquatic plants identified by Ecology staff in 1993 included white-flowering water lily (*Nymphaea odorata*), yellow-flowering water lily (*Nuphar polysepalum*), iris (*Iris pseudacorus*), and the alga *Nitella*. The lilies and iris were also observed during onsite visits in 1992 and 1991. Water lilies were abundant along the southwest shoreline and along the north tip of the lake.

Other Available Information

Martha Lake was also monitored by the same volunteers for Snohomish County's Citizen Lake Monitoring Program during 1992 and 1993. For this program, volunteers measured Secchi depth two times per month. (These data were also reported to Ecology, and are listed in this report.) Once each month, temperature, dissolved oxygen (LaMotte kit), and pH (Hannah pH pen) were measured at discrete depths (surface, 1 meter, 3 meters, 6 meters, and 1 meter from the bottom).

These data indicated that the lake was stratified during the monitoring season (May through October), and on each sampling date dissolved oxygen at the lake bottom was very low (0.2 to 1.8 mg/L).

From Entranco (1991): A Phase I Restoration study was conducted from December 1989 to 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/100 mL); 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.

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 1993.

> Martha Lake is used for fishing, swimming, non-motorized boating, and lakeshore camping. There is a park on the lakeshore, and about eight 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 in 1993. Currently, the lakeshore is being developed for residences. In the past, the watershed was logged.
>
> There are 97 houses on the lakeshore, and homes along about 40% of the lakeshore are connected to a sewer. About three 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 four houses per acre. No lake management activities occurred in 1993, although the lake was treated with chemicals in the past to control undesirable fish species.

Martha Lake (near Alderwood Manor) -- Snohomish County

Overall, the volunteer found that Martha Lake had good water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, and (2) one failed septic system. Possible sources of problems include runoff from I-5 to the west end of the lake, and the potential for more septic system failures. There were no changes in the lake since the 1992 monitoring season.

Acknowledgment

I thank both Keith Johnson and John W. Moore for volunteering their time to monitor Martha Lake during 1993. John Moore monitored the lake during 1990-1992.

Martha Lake (near Alderwood Manor) -- Snohomish County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	36
Mean Trophic State Index (Total Phosphorus):	36
Mean Trophic State Index (Chlorophyll *a*):	31

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
24-May	1440	20.0	68.0	19.4	15.00	lt-green	0	none	light	Beautiful day.
05-Jun	1100	17.0	62.6	20.3		lt-green	100	light	calm	
19-Jun	1030	19.0	66.2	16.7			90	none	breezy	A lot of suspended particulate matter in the water.
03-Jul	1336	19.0	66.2	12.8		lt-green	100	heavy	calm	
17-Jul	1445	19.0	66.2	11.2	16.88	lt-green	90		calm	Water lilies on perimeter.
01-Aug	1500	21.0	69.8	13.5	16.00	lt-green	0	none	breezy	Very sunny.
15-Aug	1400	20.0	68.0	16.1	18.38	lt-green	100	light		
28-Aug	1140	18.5	65.3	17.4		lt-green	100	trace		
12-Sep	1245	22.0	71.6	24.0		lt-green	25	trace	light	Significant water lilies at north end.
25-Sep	1700	17.5	63.5	19.0	20.00	lt-green	0	none	light	
08-Oct	1330	16.5	61.7	18.7	20.50	lt-green	50	trace	light	
24-Oct	1145	16.5	61.7	12.8	21.00	lt-green	50	moderate	calm	Storm caused debris on top of water.

[1] Trophic State Indices calculated from Carlson (1977).
[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Martha Lake dropped 6" from May 24 to October 24.

Martha Lake (near Alderwood Manor) -- Snohomish County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/24	0.0	20.4	7.9	9.4	95
	1.0	20.1	7.8	9.5	95
	2.0	19.5	7.8	9.5	94
	3.0	19.0	7.8	9.4	94
	4.0	15.4	8.1	10.6	92
	5.1	13.4	8.1	10.5	92
	6.1	12.0	7.9	8.6	91
	7.0	9.8	7.7	5.2	94
	8.0	9.1	7.5	2.7	95
	9.0	8.6	7.4	1.7	95
	10.0	8.4	7.4	1.1	94
	11.0	8.3	7.3	0.9	97
08/29	0.0	19.9	7.7	8.8	91
	1.0	19.7	7.7	8.5	91
	2.1	19.7	7.6	8.5	91
	3.0	19.6	7.6	8.3	91
	4.0	19.5	7.6	8.0	91
	5.0	17.5	7.3	2.5	93
	6.0	14.1	7.3	0.6	96
	7.1	11.6	7.3	0.5	95
	8.0	10.4	7.2	0.2	96
	9.0	9.2	7.1	0.2	105
	10.0	8.8	7.1	0.1	113
	10.7	8.7	7.0	0.1	114

Martha Lake (near Alderwood Manor) -- Snohomish County

1993 Onsite Visit Data - Water Chemistry

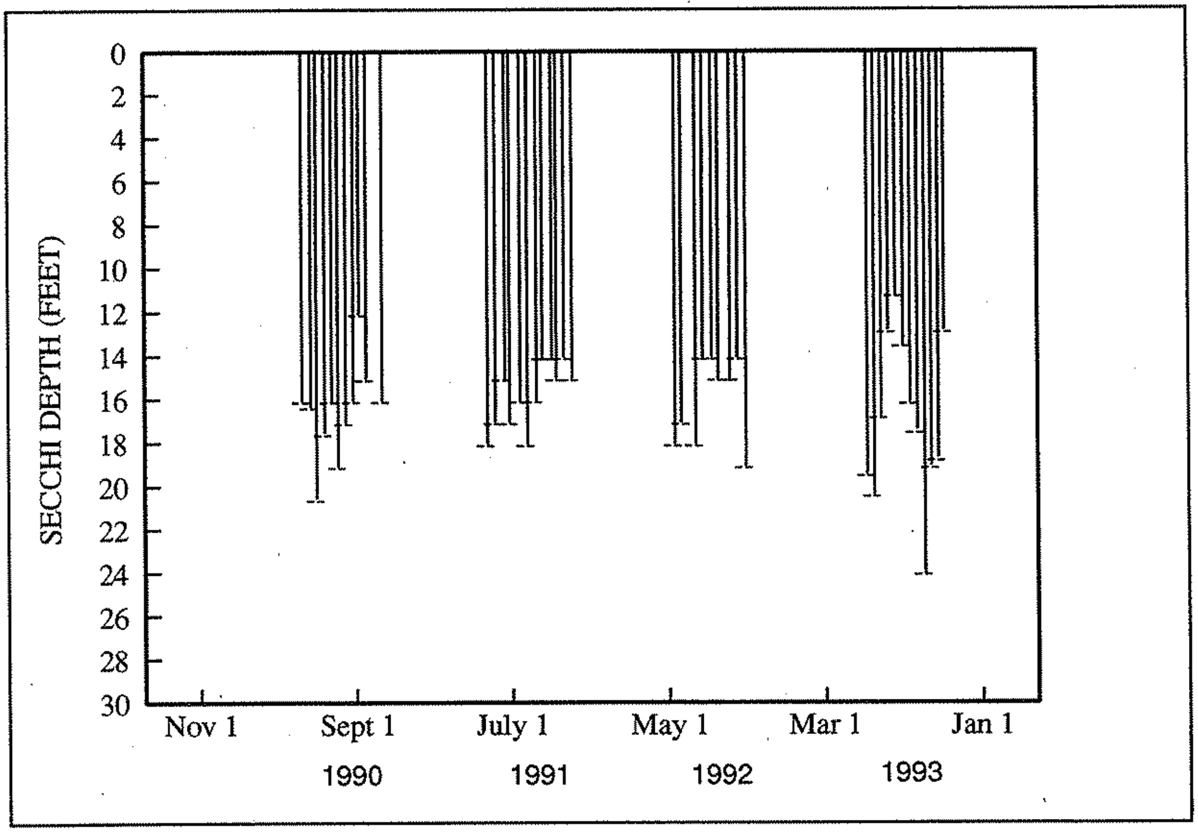
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 24							
Epilimnion	16	0.45	1.1	--	--	--	--
Hypolimnion	33	0.56	--	--	--	--	--
August 29							
Epilimnion	5	0.32	1.1	--	--	52	28
Hypolimnion	21	0.37	--	--	--	--	--

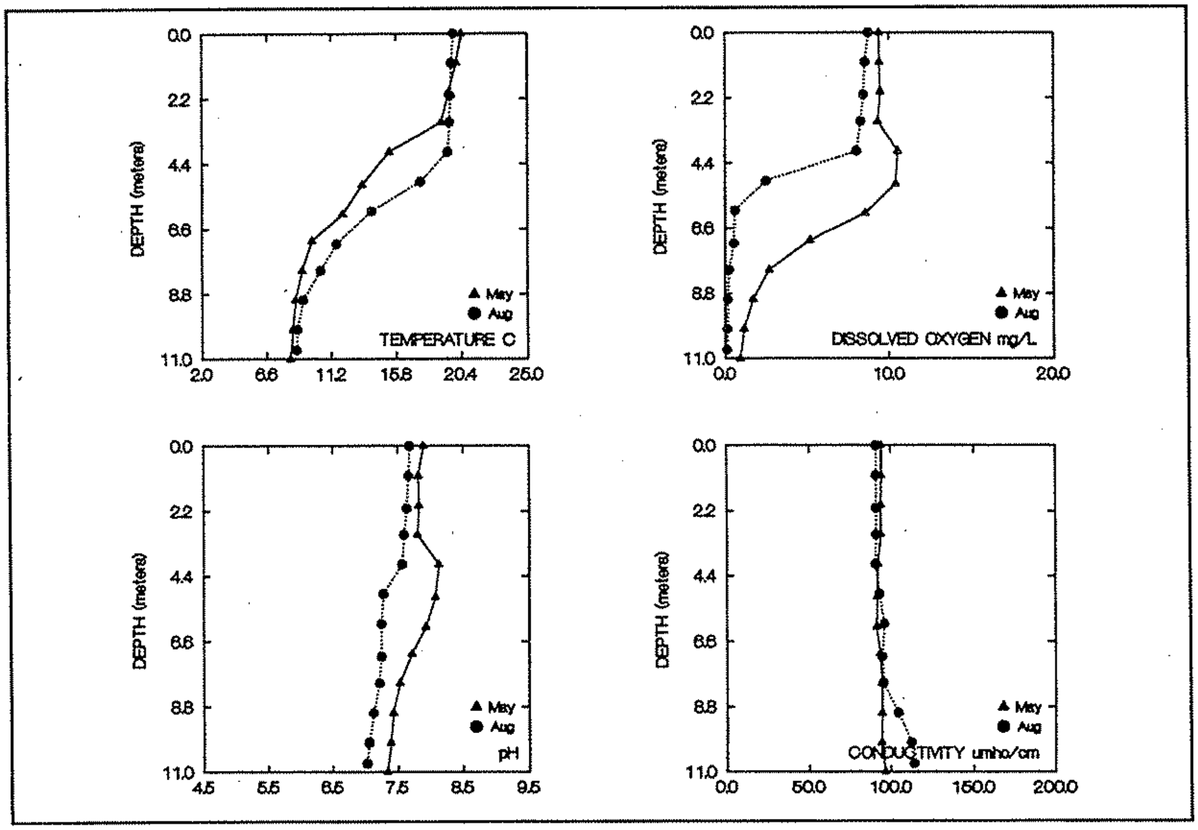
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/25/73[a]	3	--	--
08/28/90[b]	15	0.53	--
05/30/91[c]	--	0.81	--
05/18/92[d]	16	0.66	0.4
08/31/92[d]	11	0.41	1.1

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)

MARTHA LAKE (SNOHOMISH COUNTY)





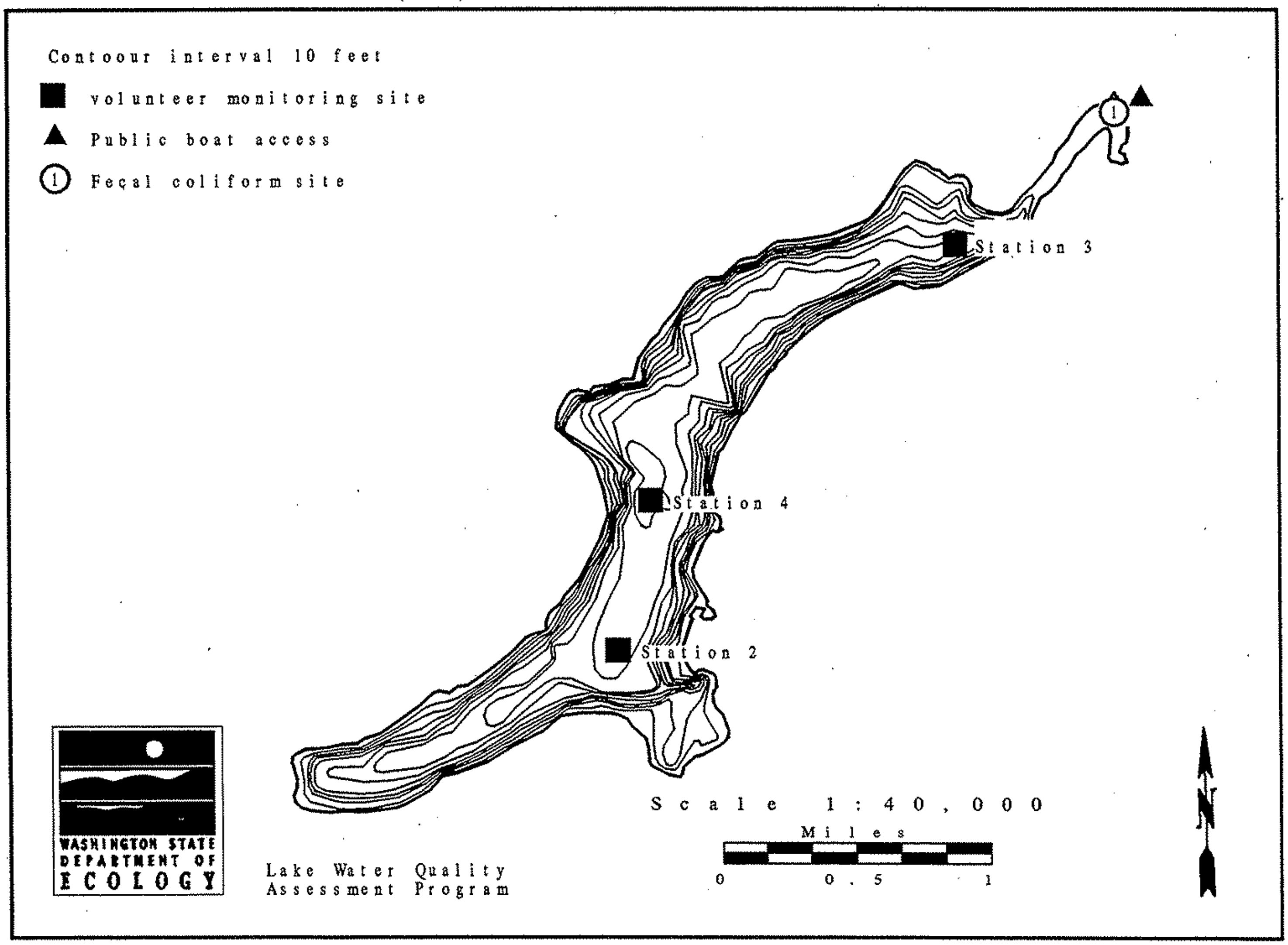
1993 Secchi Depth and Profile Data Graphs

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.

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)



Overall Assessment

In 1993, Mason Lake was assessed as oligotrophic, based on very good water clarity, low nutrient concentrations, and low algal densities when water samples were collected from the lake. However, a heavy bloom of the blue-green alga *Gloeotrichia echinulata* occurred in September, and bioassays conducted by Pacific Lutheran University researchers indicated that the bloom produced natural toxins. As a result, the Mason County Office of Water Quality issued a health advisory for Mason Lake from September 10 to September 27, 1993. The bloom most likely resulted from very warm and calm weather in September and October; several other lakes in the program, including normally unproductive lakes, had heavy algae blooms in September and October.

1993 Monitoring Results/Summary of Other Available Information

Although volunteers monitored three lake stations in 1993, profile data and water samples were collected from Station 4 only. Station 4 is located at the deepest site of the lake.

Secchi Depths

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 1993. In 1990, five lake stations were monitored by volunteers.

Water clarity was very good in 1993, as indicated by Secchi depths which ranged from 19.0 feet to 31.0 feet. Secchi depths greater than 13.0 feet are deep and indicate good water clarity. Mean Secchi depth (and the mean trophic state index for Secchi depth) was the same for all three monitoring stations.

All Secchi depths collected from Mason Lake since 1989 have been deep and in the range associated with oligotrophic lakes. There was no statistically significant trend in water clarity from 1989 to 1993.

Total Phosphorus

Concentrations of total phosphorus in the upper layer of water (the epilimnion) were low on both sampling dates (11 µg/L in May, and 6 µg/L in September). Although the May concentration was low, it was the highest concentration measured for the program since 1989. Stormy weather the week before sampling probably contributed sediment-laden runoff into the lake, which could have increased the phosphorus concentration somewhat.

Total Nitrogen
The concentrations of total nitrogen were low on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. In May, the ratio of total nitrogen to total phosphorus was less than 17:1 (9:1), indicating that algae may have been nitrogen-limited when the lake was sampled in May. In September, the ratio of total nitrogen to total phosphorus was 33:1, indicating that algae growth was not limited by nitrogen when the lake was sampled in September.

Profile Data
The lake was thermally stratified on both sampling dates. Below the thermocline, dissolved oxygen concentrations decreased gradually with depth. Dissolved oxygen usually decreases when bacteria use oxygen as they decompose algae and aquatic plants in the water and sediments. The pH values from September, which increased in water from one to nine meters deep, suggests that algae were actively growing in the epilimnion (see Plants, below).

Fecal Coliform Bacteria
Two samples for fecal coliform bacteria were collected from the public access during the September onsite sampling visit. Both results were very low and within state water quality standards for lake water.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Concentrations of chlorophyll *a* on both sampling dates indicated low densities of algae at the time of sampling.

Despite low chlorophyll values in the epilimnion during September, pH values increased from the surface to nine meters, indicating that algae at these depths were actively photosynthesizing. During the sampling visit, Ecology staff observed particles of two to three algal species, including *Gloeotrichia*, that were visible in the water. On September 10, 1993, Mason County issued a health advisory for Mason Lake because of a toxic bloom of *Gloeotrichia echinulata*. Under some conditions (that have not yet been entirely determined through research) this alga can produce a toxin that causes skin rashes or gastrointestinal disturbances in swimmers, and may cause illnesses in animals that ingest the toxin (*The Olympian*, September 15, 1993; Mason County, no date). Presence of toxin in Mason Lake samples was confirmed by mouse bioassay, conducted by Dr. Michele Crayton at Pacific Lutheran University. The Mason County Office of Water Quality received some complaints of swimmer's itch that were probably from contact with algal toxins, but no serious illnesses in swimmers or animals were reported (W. Clifford, Mason County Office of Water Quality, pers. comm.). Although newspaper reports and Mason County staff indicated that the bloom was throughout the lake, two volunteers from the program mentioned that the algae bloom was not noticeable. The algae could have been localized in areas of the lake.

A plant sample collected by one of the volunteers on October 5, 1993, was muskgrass (the alga *Chara*). Residents were concerned about this plant because it had a bad smell, and it had tiny worms among the roots. Muskgrass has a distinctive "garlic" odor, and the sample sent in by the volunteer was particularly pungent. Muskgrass was among the plants observed when the lake was sampled in 1972 (Bortleson *et al.*, 1976).

Plants collected at the south end of the lake (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*.

In September 1983, Allied Aquatics identified and mapped the following aquatic plants in Mason Lake: largeleaf pondweed, white-flowering waterlily (*Nymphaea 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. Watershield and waterweed were noted to be the dominant species (Bortleson *et al.*, 1976).

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteers' remarks and responses to questionnaires from 1993, 1991, 1990, and 1989.

> 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. No fish were stocked in the lake in 1993. Currently the watershed is being logged and used for animal grazing and crop agriculture. The lakeshore is also being developed further for residences. In the past the watershed was logged and used for animal grazing and crop agriculture.
>
> There are 685 houses on the lakeshore; of these, about 350 are occupied year-round. About 90 percent of the shoreline has been developed for residences. The lakeshore is not sewered, and there are 47 culverts along the shore that drain 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. No lake management activities occurred in 1993.

Overall, the volunteer found that Mason Lake had excellent water quality. Problems in the lake in 1993 were ranked as (1) algae, (2) beach closure, (3) degraded aesthetics, (4) odor from decaying algae, and (5) swimmer's itch. Most of the problems resulted from a toxic bloom of *Gloeotrichia echinulata* in September 1993 that resulted in closing the lake to recreation. The algae bloom was due to weather conditions; many people continued to swim and ski, and had no problems during the algae bloom.

Acknowledgments

I thank the following volunteers who have collected data for the program: Tom Black (1989-1990; 1992), Jerry Nelson (1989-1993), Al Bernhard (1991-1992), Dick Bowers (1989-1993), Bob Groves (1989-1991), Harold Holm (1991-1993), Ray Hussey (1989-1990), Clay Johnson (1989-1993), Don Lamberto (1989-1990), Roy Magnussen (1989-1993), Jack Richmond (1991-1993), and John Smith (1989-1992).

Mason Lake -- Mason County

1993 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi, Station (4):	31
Mean Trophic State Index (Total Phosphorus, Station (4):	34
Mean Trophic State Index (Chlorophyll *a*, Station (4):	31

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	pH	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
Station 2											
23-Jun	1000	16.7	62.0	23.0	6.5		clear	25	trace	calm	
09-Jul	1000	17.2	63.0	27.0	6.0	30.00		100	none	breezy	Water color dark green.
19-Jul	1030	18.3	65.0	19.0	6.5		lt-green	75	light	breezy	Water choppy.
02-Aug	1015	20.0	68.0	21.0	6.5		clear	0	none		Young eagle and osprey.
19-Aug	1000	20.0	68.0	24.0	7.5		clear	0	none	calm	Full sun, no wind.
27-Aug	1130	20.0	68.0	24.0	7.5		clear	0	none	light	Full sun.
03-Sep	1130	20.0	68.0	27.0	6.5			0	none	calm	Lots of speckled algae.
15-Sep	1000	19.0	66.2	24.0	6.5		lt-green	50	trace	calm	Algae very heavy on top.
29-Sep	1020	18.3	65.0	31.0	6.5	34.50	lt-green	0	none	calm	
08-Oct	1330	13.3	56.0	23.0	6.5	34.50	green	75	trace	breezy	
Station 3											
05-Jun	1010	17.8	64.0	22.0			lt-green	90	light	calm	
11-Jul	1030	20.0	68.0	25.0	6.5	30.00	green	25	none	light	
30-Jul	1600	20.0	68.0	28.0	6.5	24.00	lt-green	75	light	light	
14-Aug	1400	20.0	68.0	25.0	6.0	27.00	green	10			
22-Aug	1020	20.0	68.0	22.0	6.0		green	75	none	calm	
01-Sep	1430	20.0	68.0	28.0	7.0	34.00	lt-green	0	none	calm	
17-Sep	1030	19.0	66.2	22.0	6.0		lt-green	0	none	calm	Heavy algae bloom.
29-Sep	1100	18.3	65.0	25.0	6.5	34.50	lt-green	0	none	calm	
08-Oct	1345	13.3	56.0	22.0	6.5	34.50	green	75	trace	breezy	
Station 4											
28-May	1245			21.0							Onsite visit.
08-Jun	1004	16.7	62.0	22.0	6.0	30.00		100	trace	light	Water color dark green. Using viewing tube, could see 5' deeper.
25-Jun	1500	21.1	70.0	30.6	6.5	31.50		10	none	breezy	
05-Jul	1015	17.8	64.0	22.0	6.5		lt-green	90	light	calm	
21-Jul	1020	17.8	64.0	24.0	6.0	27.50		100		breezy	Water color dark green.
04-Aug	1000	24.0	75.2	25.0	6.5	24.50	clear	0	none	calm	Water color dark green.
22-Aug	1000	20.0	68.0	24.0	6.0	33.25	green	75	none	calm	
01-Sep	1030	20.0	68.0	24.0	7.2	34.00	lt-green	0	none	calm	Onsite visit.
17-Sep	1000	19.0	66.2	24.0	6.5		lt-green	0	none	calm	Heavy algae bloom.
29-Sep	1100	18.3	65.0	25.0	6.5	34.50	lt-green	0	none	calm	
08-Oct	1315	13.3	56.0	22.0	6.5	34.50	green	75	trace	breezy	

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Mason Lake dropped 4.5" from June 8 to October 8.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/28	0.0	18.1	7.9	9.3	40
	1.1	17.5	7.8	9.4	40
	2.0	17.3	7.8	9.4	40
	3.1	17.2	7.8	9.5	40
	4.0	17.2	7.8	9.5	40
	5.1	17.1	7.8	9.5	40
	6.0	17.1	7.8	9.4	40
	7.1	16.8	7.8	9.5	39
	8.0	14.8	7.8	9.7	39
	9.0	13.5	7.8	9.8	38
	9.9	12.2	7.8	9.9	39
	12.0	10.6	7.7	9.7	38
	14.1	9.9	7.7	9.4	39
	16.1	9.5	7.7	9.2	39
	18.2	9.1	7.6	9.0	39
	20.1	9.0	7.6	8.9	39
	22.0	8.9	7.5	8.7	39
	25.1	8.8	7.5	8.5	39
09/01	0.0	20.1	7.2	10.0	41
	1.0	20.1	7.3	9.7	41
	2.0	20.0	7.3	9.7	41
	3.0	19.9	7.4	9.6	41
	4.0	19.9	7.5	9.5	41
	5.0	19.8	7.5	9.4	41
	5.9	19.8	7.6	9.3	41
	7.1	19.8	7.6	9.2	41
	8.0	19.7	7.6	9.2	40
	9.0	19.3	7.6	9.1	41
	10.1	16.2	7.5	9.1	39
	12.1	12.5	7.4	7.6	39
	14.9	10.3	7.3	5.2	37
	20.1	9.5	7.0	2.7	39
	23.5	9.2	6.9	0.7	39

1993 Onsite Visit Data - Water Chemistry

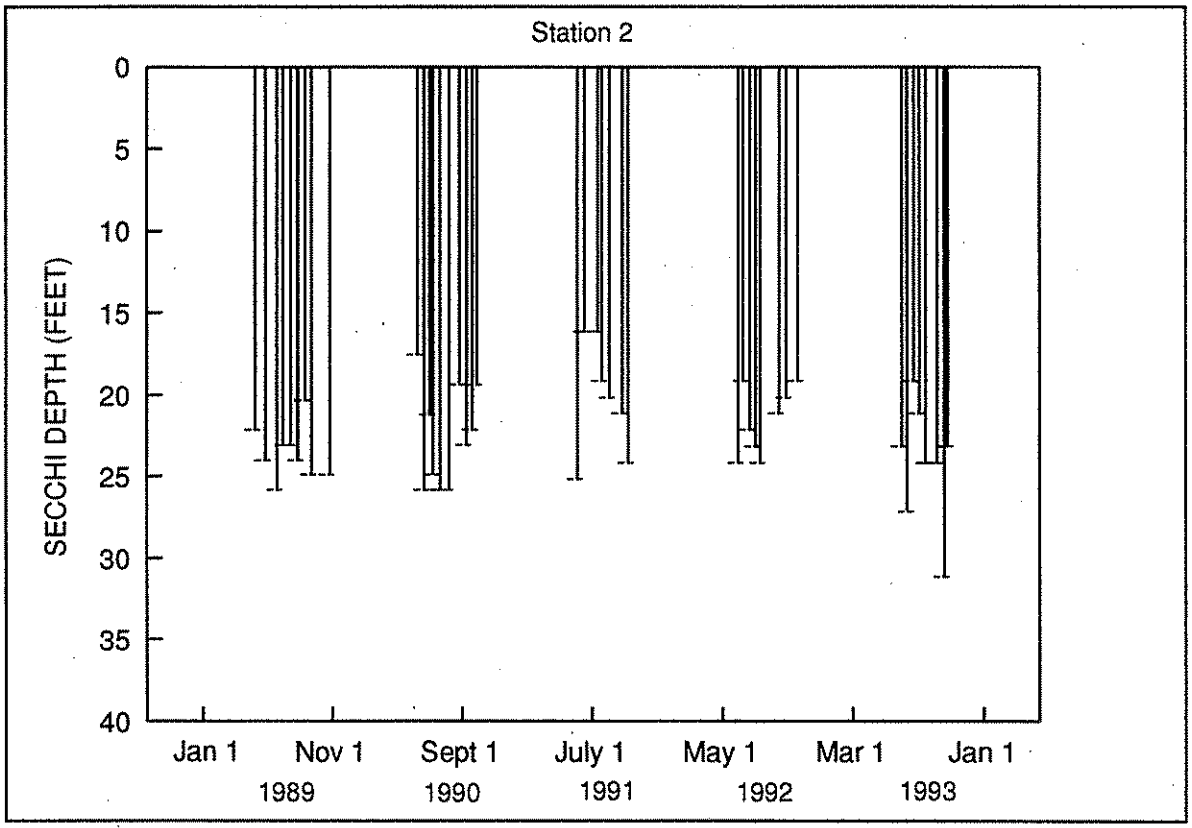
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 28							
Epilimnion	11	0.10	1.1	--	--	--	--
Hypolimnion	18	0.11	--	--	--	--	--
September 1							
Epilimnion	6	0.20	1.0	--	--	1	7
Hypolimnion	9	0.13	--	--	--	--	--

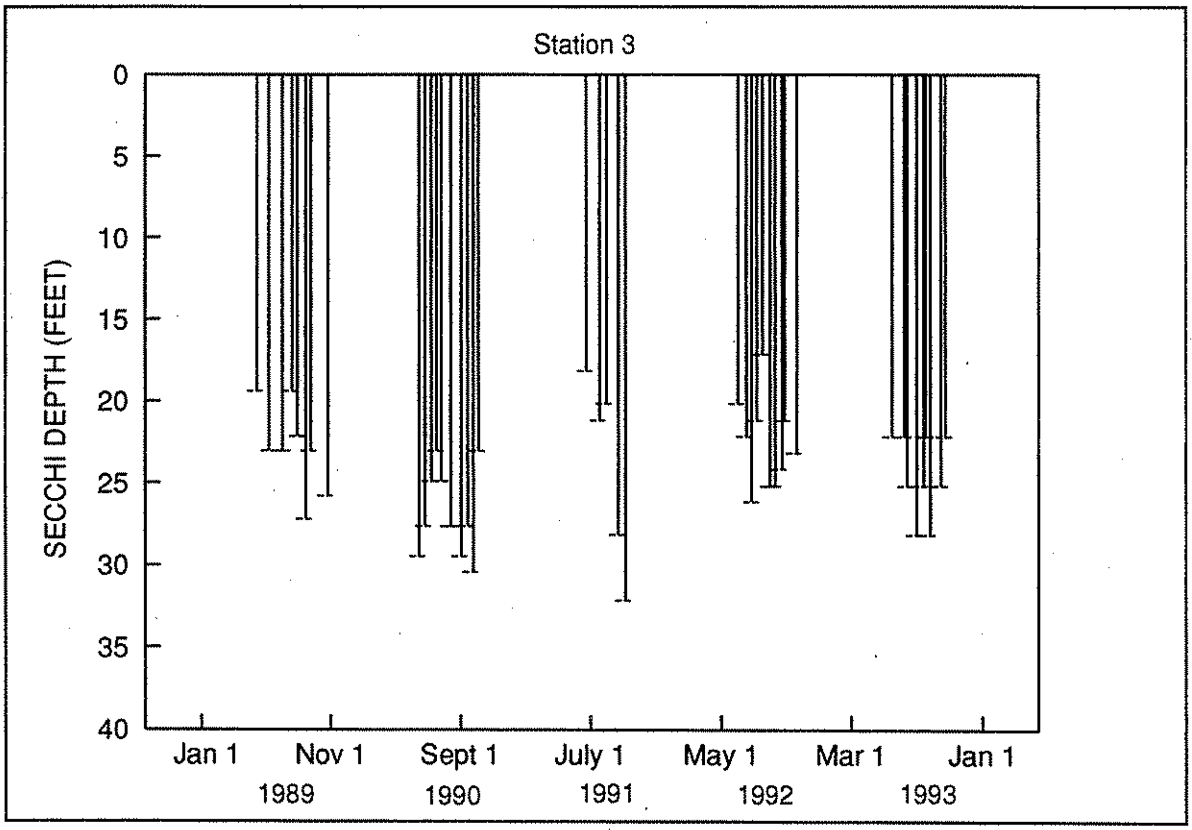
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
06/29/72[a]	12	--	3.0
06/12/81[b]	20	--	1.5
06/28/89[c]	8	0.14	0.7
09/27/89[c]	9	0.19	1.0
05/25/90[d]	7	0.23	--
08/16/90[d]	7	0.23	--
05/21/91[e]	--	0.10	--
05/19/92[f]	5	0.16	1.2
08/27/92[f]	4	0.14	1.1

a. Bortleson *et al.* (1976a, 1976b)
b. Sumioka and Dion (1985)
c. Brower and Kendra (1990)
d. Rector (1991)
e. Rector (1992)
f. Rector (1993)

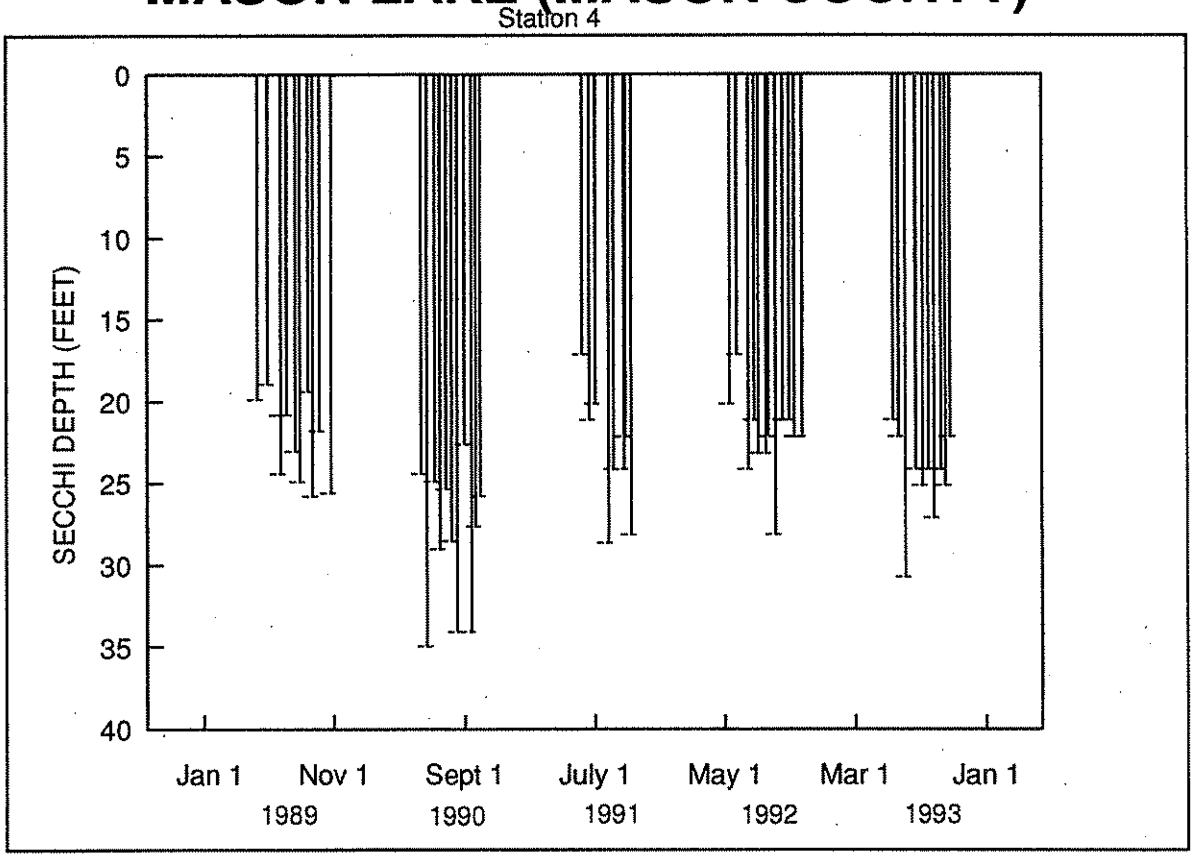
MASON LAKE (MASON COUNTY)

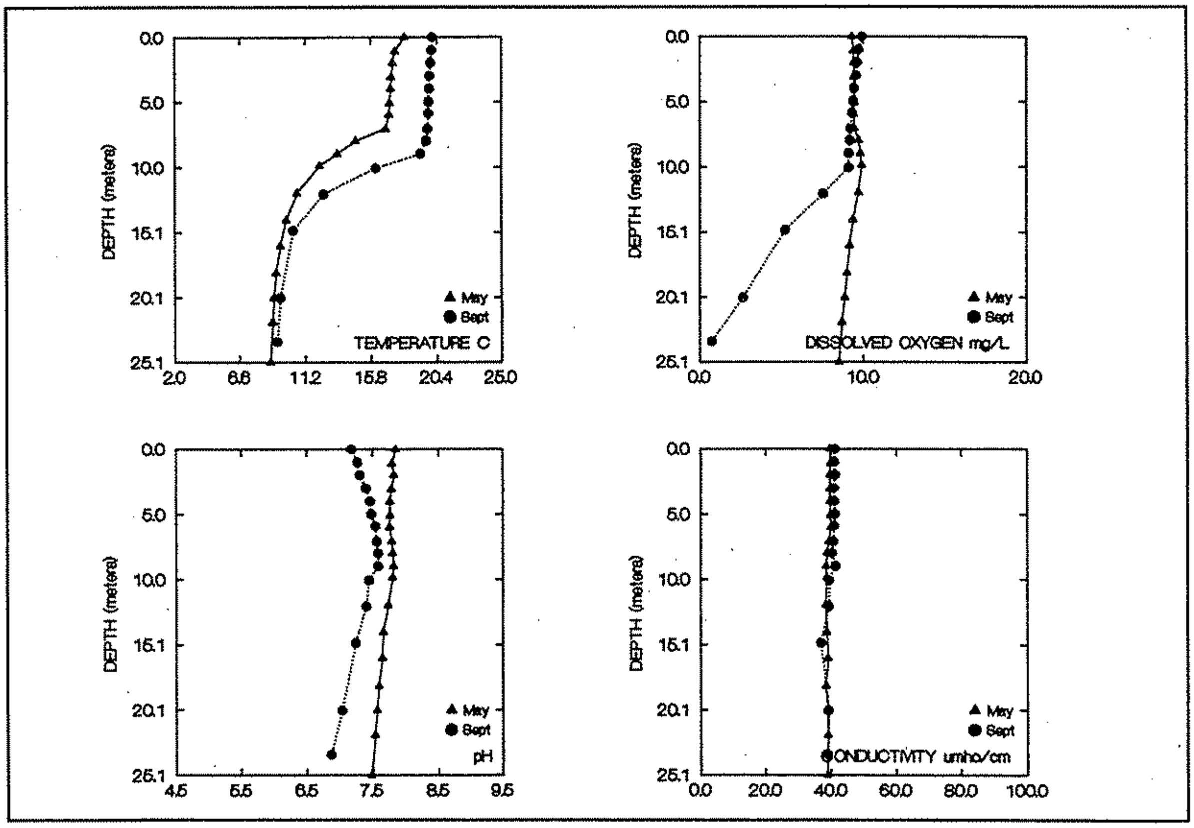




1993 Secchi Depth and Profile Data Graphs

MASON LAKE (MASON COUNTY)





1993 Secchi Depth and Profile Data Graphs

Lake Merwin -- Clark/Cowlitz Counties

Lake Merwin is located 9.75 miles northeast of Woodland. It is an artificial reservoir in the north fork of the Lewis River below Yale Reservoir. It is fed by the north fork of the Lewis River, Speelyai, Brooks, Rock, Canyon, Buncombe Hollow, Indian George, Jim, Cape Horn, and Marble Creeks. About 2,400 acres are in Clark County, and about 1,600 acres are in Cowlitz County.

Size (acres)	4,000
Maximum Depth (feet)	190
Mean Depth (feet)	100
Lake Volume (acre-feet)	42,000
Drainage Area (miles^2)	730
Altitude (feet)	239
Shoreline Length (miles)	32

Data From Bortleson *et al.* (1976)

No Map Available.

Overall Assessment

In 1993, Lake Merwin was assessed as oligotrophic, based on very good water clarity, low nutrient concentrations, and low amounts of aquatic plants and algae.

Lake Cle Elum (Kittitas County) and Sullivan Lake (Pend Oreille County) are other reservoirs monitored for the program that have good water quality.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was very good, as indicated by Secchi depths that ranged from 17.5 feet to 24.5 feet. Secchi depths greater than 13.0 feet are deep, and are typical of oligotrophic lakes.

Total Phosphorus

The concentrations of total phosphorus were very low on both sampling dates (10 µg/L in May, and 3 µg/L in August). Concentrations less than 12 µg/L are low and typical of oligotrophic lakes. Generally, total phosphorus concentrations greater than 20 µg/L will result in high densities of algae growth.

Total Nitrogen

The concentrations of total nitrogen were very low on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. In August, the ratio of total nitrogen to total phosphorus was greater than 17:1 (it was 27:1), so it is likely that algal growth was not limited by nitrogen in August.

Profile Data

The lake was stratified with respect to temperature on both sampling dates. Dissolved oxygen concentrations were high throughout the water column, which is definitely an indication that the lake was oligotrophic and in very good condition. The pH values in August decreased below the thermocline. There are no pH data from May because the probe was not functioning properly at the time.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Concentrations of chlorophyll *a* on both sampling dates indicated low densities of algae at the time of sampling. When water clarity is affected primarily by algae, low algal densities will result in deep Secchi depths.

Aquatic plants identified by Ecology staff during the sampling visits include two pondweeds (possibly *Potamogeton foliosus* and *Potamogeton berchtoldii*), and a large algae that was either muskgrass (*Chara*) or *Nitella*.

Other Available Information

Water from the lake is used for hydroelectric power by Pacific Power and Light. When the lake was sampled in 1974, no emerged or submerged macrophytes were observed, and dissolved oxygen concentrations were near saturation throughout the water column (Bortleson *et al.*, 1976).

Summary of Questionnaire Results and Information from the Volunteer

The 1993 questionnaire on lake and watershed uses was not returned.

Acknowledgment

I thank Jim and Mary Casey for volunteering their time to monitor Lake Merwin in 1993.

Lake Merwin -- Clark/Cowlitz Counties

1993 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Trophic State Index (Mean Secchi):	32
Trophic State Index (Mean Total Phosphorus):	29
Trophic State Index (Mean Chlorophyll *a*):	37

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	Temp (°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
04-Jun				17.5			95		breezy	Onsite visit.
23-Jun	2000	16.0	60.8	20.8	0.00	lt-green	0		light	Lake height (0) is reference point.
07-Jul	1905	18.0	64.4	24.5	24.00	lt-green	0	none	light	Osprey nest near dam has little baby birds--at least 3.
26-Jul	1900	19.0	66.2	24.0	36.00	lt-green	0	trace	light	Water level approx. 3' below high water mark. Osprey nest has two birds; one adult, one young.
16-Aug	1935	19.5	67.1	24.5	42.00	lt-green	75	light	light	
30-Aug	1555			24.5		lt-green	0	light		Onsite visit.

[1] Trophic State Indices calculated from Carlson (1977).
[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Merwin dropped 42" from June 23 to August 16.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
06/04	0.0	18.4	.	10.1	38
	1.0	17.3	.	10.8	38
	2.0	16.4	.	11.4	38
	3.0	15.5	.	11.6	38
	4.0	14.8	.	11.8	38
	5.0	14.5	.	11.8	38
	6.0	14.0	.	11.8	38
	8.0	13.4	.	11.8	38
	10.0	12.7	.	11.6	38
	15.0	11.5	.	11.5	38
	20.0	10.6	.	11.5	37
	25.0	9.9	.	11.4	37
	30.0	9.6	.	11.4	37
	35.0	9.2	.	11.6	38
	40.0	8.8	.	11.6	38
	45.0	8.5	.	11.4	38
	50.0	8.2	.	10.8	38
08/30	0.0	21.1	8.1	9.4	41
	1.0	20.6	8.1	9.4	41
	2.0	20.3	8.1	9.4	41
	4.0	20.1	8.1	9.5	41
	6.0	19.8	8.1	9.5	41
	8.0	19.5	8.1	9.6	41
	10.0	17.6	7.9	9.7	40
	12.0	16.5	7.8	8.7	40
	14.0	15.7	7.7	8.4	40
	16.0	15.4	7.6	8.4	40
	18.0	15.1	7.5	8.1	40
	20.0	14.8	7.4	8.1	40
	25.0	14.3	7.4	8.3	40
	30.0	14.0	7.3	8.6	40
	35.0	13.7	7.3	8.8	40
	40.0	13.3	7.2	9.0	40
	45.0	12.8	7.2	8.2	40

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 4							
Epilimnion	10	0.11	2.0	--	--	--	--
Hypolimnion	8	0.08	--	--	--	--	--
August 30							
Epilimnion	3	0.08	2.0	--	--	--	--
Hypolimnion	bdl	0.07	--	--	--	--	--

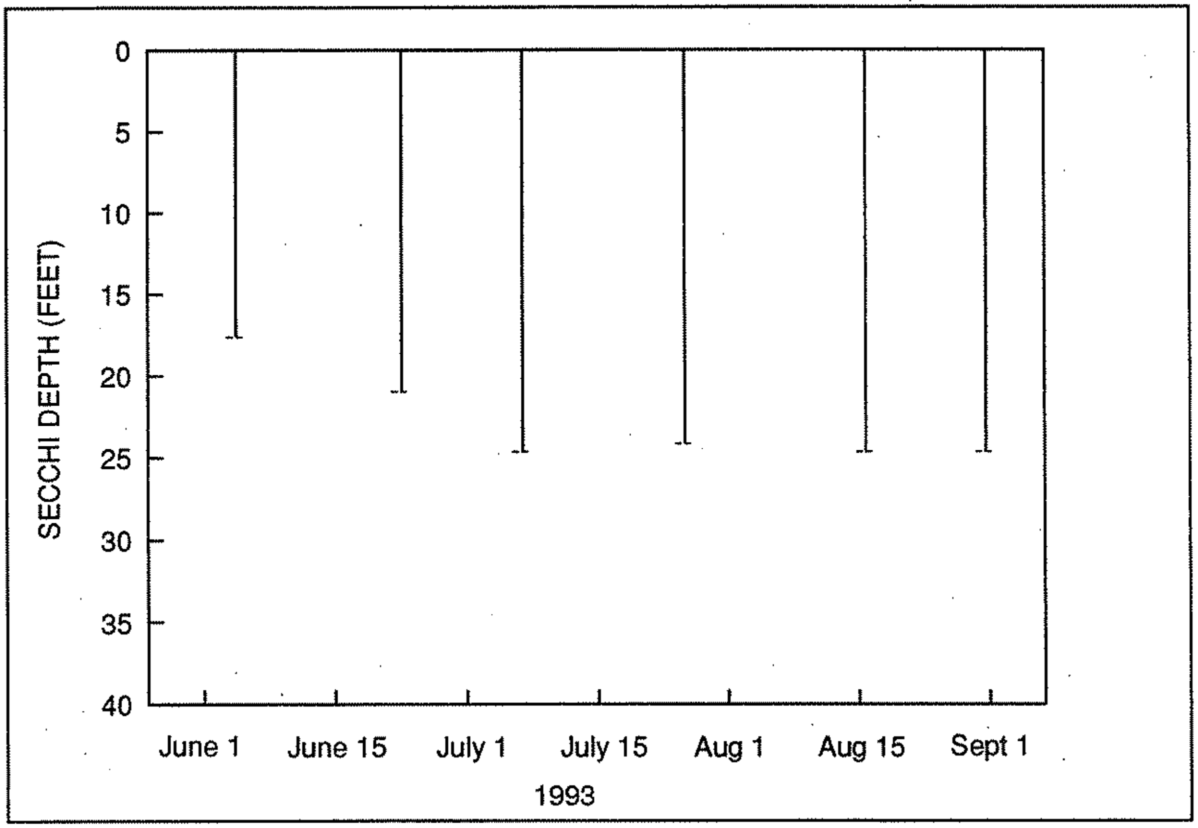
bdl = below analytical detection limit of 3 µg/L

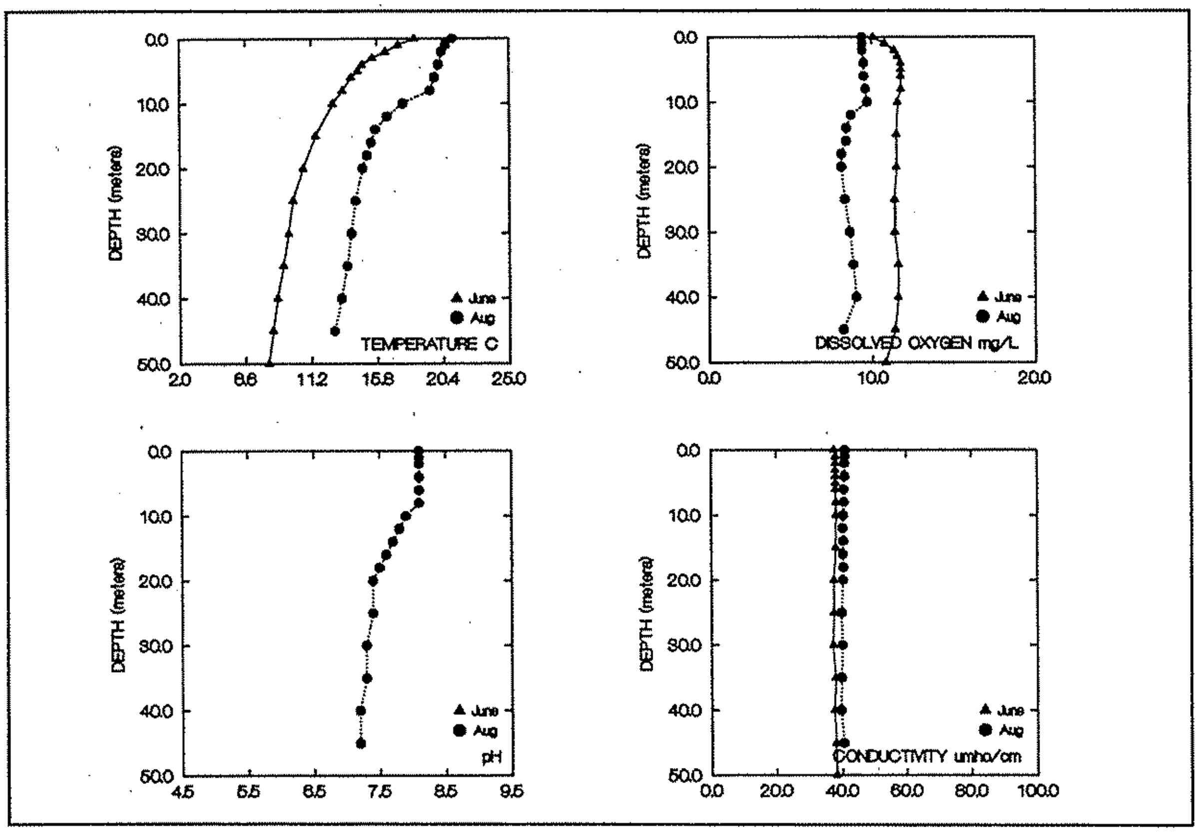
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
09/13/74[a]	3	--	--

a. Bortleson *et al.* (1976)

LAKE MERWIN (CLARK/COWLITZ COUNTIES)





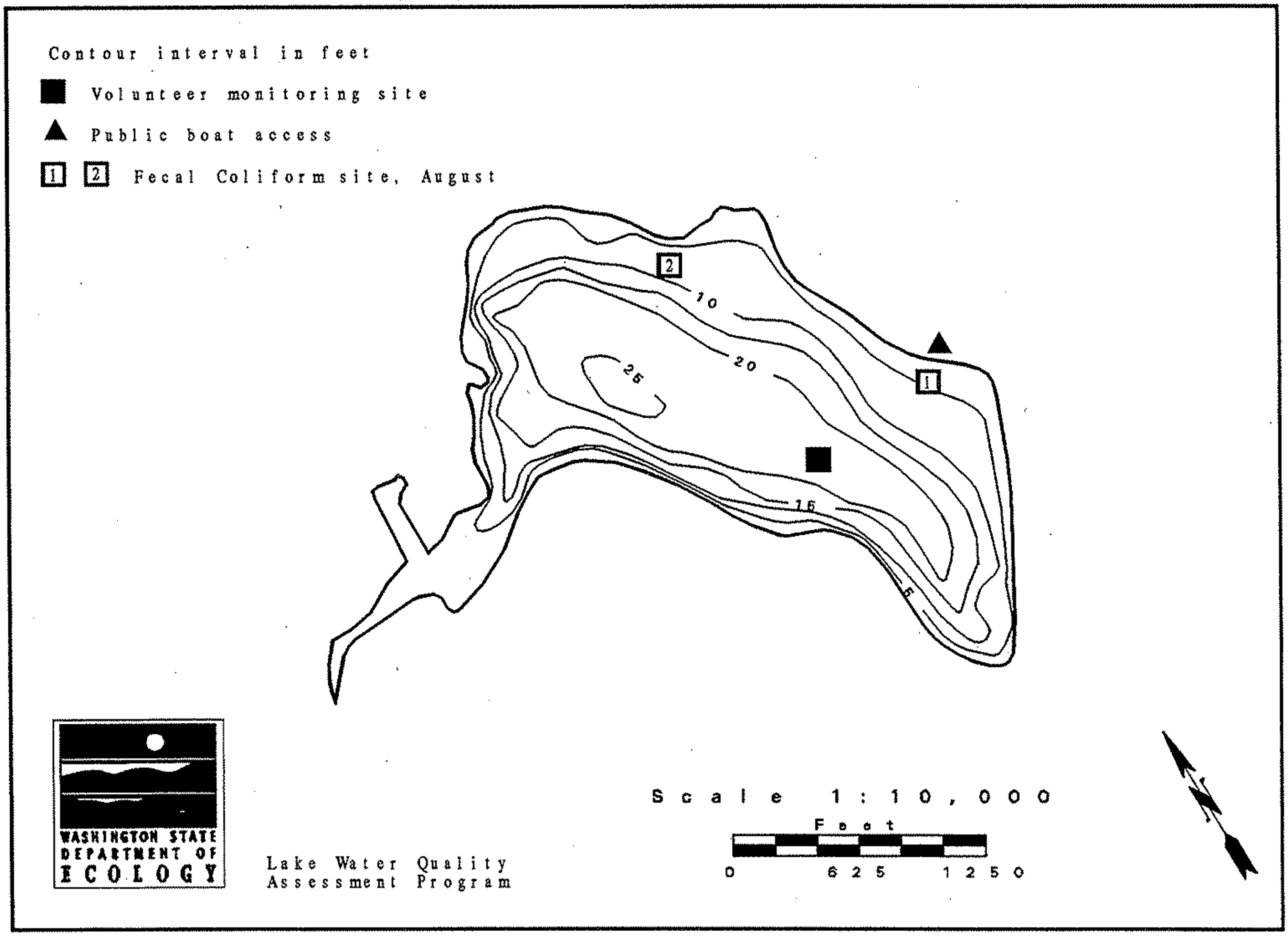
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, Mission Lake was assessed as mesotrophic, based on fair water clarity, moderate to high concentrations of total phosphorus, and moderately high densities of algae and aquatic plants. Based on data collected for this program, Mission Lake has been described as mesotrophic each year since 1990.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in 1993 was fair, as indicated by Secchi depths that ranged from 7.8 feet to 15.0 feet. Secchi depths from 6.5 feet to 13.0 feet are typical for mesotrophic lakes. In 1993, water clarity did not vary much after May, and overall was better in 1993 than in 1992. In 1992, Secchi depths were very variable, and at the end of the monitoring season (September and October) suspended sediments turned the water brown and considerably reduced water clarity.

Total Phosphorus

In June the concentration of total phosphorus in the upper layer of water (the epilimnion) was high (34 µg/L), and was still moderately high in August (21 µg/L). These concentrations were much higher than concentrations measured for the program in 1992 and 1990, and may have caused the higher algal densities measured in 1993 than in 1992. Total phosphorus concentrations from 12 to 24 µg/L are typical for mesotrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were moderately low on both sampling dates, and were similar to concentrations measured in 1990 and 1992. Because the ratios of total nitrogen to total phosphorus were less than 17:1 (6:1 in June, and 13:1 in August), it is possible that algal growth was nitrogen-limited.

Fecal Coliform Bacteria

Samples for fecal coliform bacteria were collected during the August onsite sampling visit. Site #1 was located near the public access, and Site #2 was located at the northeast end of the lake, near a large patch of lily pads. Results for both samples were low. In 1992, the result for Site #2 was high (92 colonies/100 mL in August, and 31 colonies/100 mL in May). The state water quality standard for Lake Class waters is a geometric mean of 50 colonies/100 mL, with not more than 10% of samples exceeding 100 colonies/100 mL.

Profile Data
The lake was not stratified on either sampling date. As would be expected from an unstratified lake, temperature, pH, dissolved oxygen and conductivity values did not change much from surface to bottom.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. The concentration of chlorophyll in June (3.3 µg/L) indicated a moderately high density of algae at the time of sampling. However, when the lake was sampled in June there was a high phosphorus concentration that could have resulted in a much higher chlorophyll concentration (over 10 µg/L), but algae growth was probably nitrogen-limited in June (see Total Nitrogen, above). In August, the chlorophyll concentration (7.2 µg/L) indicated a high algal density. The chlorophyll concentration was at the level that would be expected, given the high concentration of total phosphorus at the time.

An algae sample collected by the volunteer on November 1, 1993, contained three species of blue-green algae: *Anabaena macrospora*, *Anabaena flos-aquae*, and *Coelosphaerium* sp. *A. macrospora* was the most abundant algae in the sample. Several other lakes monitored for the program also had blue-green algae blooms in fall 1993, most likely because of dry and relatively warm and calm weather that encourage algae blooms.

Aquatic plants identified by Ecology staff during the August 1993 sampling visit were largeleaf pondweed (*Potamogeton amplifolius*), yellow-flowering water lily (*Nuphar polysepalum*), waterweed (*Elodea canadensis*), white-flowering water lily (*Nymphaea odorata*), cattails (*Typha* sp.), iris (*Iris pseudacorus*), bladderwort (*Utricularia vulgaris*), an unidentified pondweed (possibly *Potamogeton foliosus*), and muskgrass (*Chara*). All but the bladderwort and muskgrass were also observed in 1992. A "lettuce"-like plant observed during both 1992 and 1993 still has not been identified; the plant is very fragile and difficult to collect using the plant sampler. Individual plants were found in deeper water near the water lilies on the northeast side of 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 1993.

> Mission Lake is used for fishing and swimming. 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 in 1993. Currently, the watershed is being logged and used for crop agriculture and animal grazing/feeding. The lakeshore is also being developed further for residences. In

the past, the watershed was logged and used for crop agriculture, and 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 community association for the lake. Lake water is not withdrawn for any uses. No lake management activities occurred in the lake in 1993.

Overall, the volunteer found that Mission Lake had poor water quality and exhibited characteristics of eutrophication. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, (2) algae, (3) suspended sediments, (4) water quality gradually degraded over years, (5) decaying plants, (6) high water level, (6) swimmer's itch, (7) degraded aesthetics, (8) eye/skin problems after swimming, (9) impaired fisheries, and (10) bacteria. Possible sources of problems include aquatic plants which were planted in the lake by residents, high water level from beaver dams, fish parasites which were brought in by seagulls, and development within wetland areas. In comparison to the 1992 monitoring season, the water level was higher in 1993, and there were more algae and plants. Swimmer's itch and excessive aquatic plant growth were the worst problems in the lake in 1992.

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.

Acknowledgment

I thank Eleanora Fedenk for volunteering her time to monitor Mission Lake during 1990-1993.

Mission Lake -- Kitsap County

1993 Trophic Status[1]

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

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
03-Jun	1120	20.0	68.0	15.0		lt-green	80		calm	Onsite visit. Secchi with view tube.
17-Jun	1100	20.0	68.0	10.0	16.50	lt-green	10	trace	light	Clouds and green algae(?) along beach area. No container to take sample.
29-Jun	1300	21.1	70.0	10.0	17.50	gr-brown	75	moderate	light	Water color greenish brown. Lake continues to rise. Found lily plants growing in our front. Lake very cloudy all over; do you want a sample? pH 6.5.
15-Jul	1100	17.8	64.0	10.0	11.50	lt-brown	100	heavy	strong	Beaver dam removed, lake depth decrease. pH 6.0.
02-Aug	1030	22.2	72.0	9.5	14.00	lt-brown	0	none	light	
19-Aug	1115	22.2	72.0	9.0	14.00	dk-brown	0	none	light	pH 6.5.
31-Aug	1130			7.8	15.50	br-green	10		calm	Water color brown-green. Onsite visit.
21-Sep	1400	18.9	66.0	8.5	12.00	pea-green	0	none	strong	Tried to get a sample of huge balls of green matter near lakeside.

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Mission Lake dropped 4.5" from June 17 to September 21.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
06/03	0.0	19.4	8.0	9.1	70
	1.9	19.3	7.9	8.9	69
	3.0	19.3	7.8	8.7	69
	4.0	18.7	7.7	7.7	71
	5.0	16.9	7.4	4.2	79
08/31	0.0	19.8	7.6	8.9	71
	1.0	19.5	7.6	8.6	71
	1.9	19.4	7.6	8.3	71
	3.1	19.3	7.6	7.9	71
	4.1	19.3	7.6	7.8	71
	5.1	19.3	7.6	7.4	73

1993 Onsite Visit Data - Water Chemistry

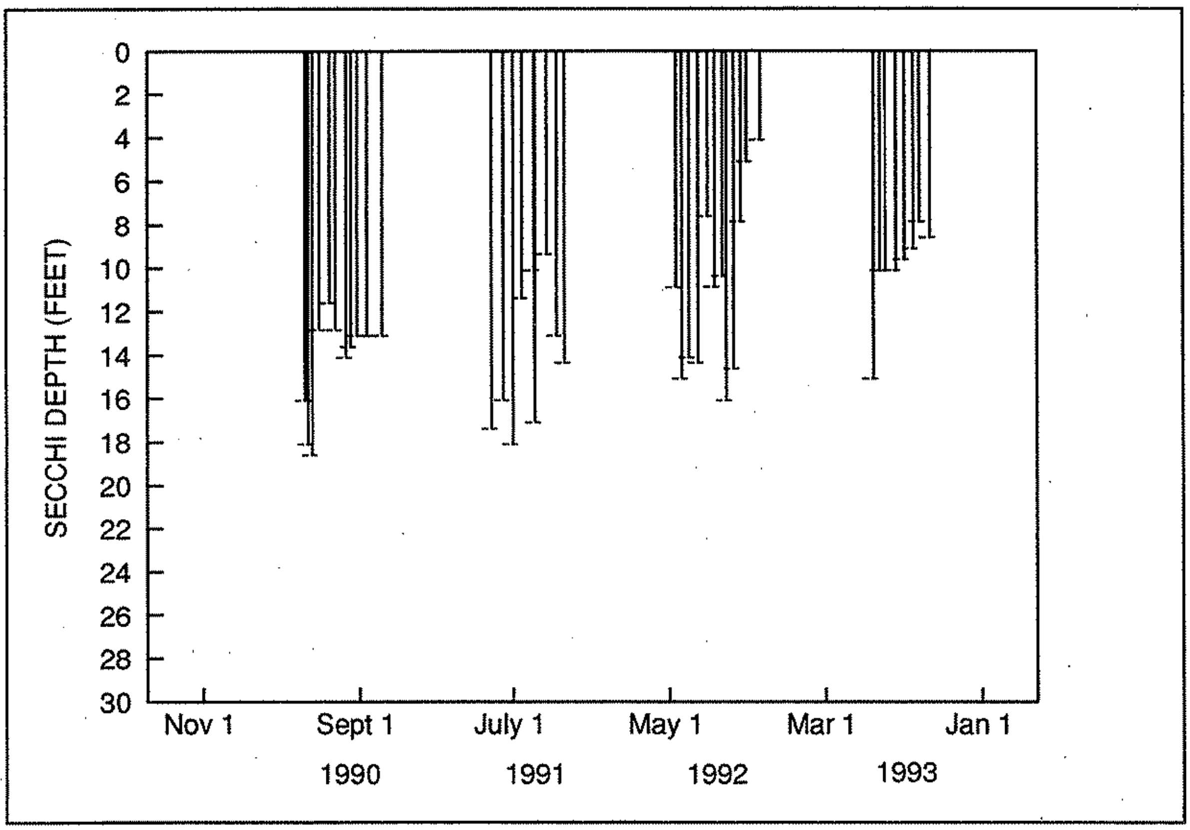
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 3							
Epilimnion	34	0.21	3.3	--	--	--	--
Hypolimnion	29	0.62	--	--	--	--	--
August 31							
Epilimnion	21	0.27	7.2	--	--	2	13
Hypolimnion	29	0.62	--	--	--	--	--

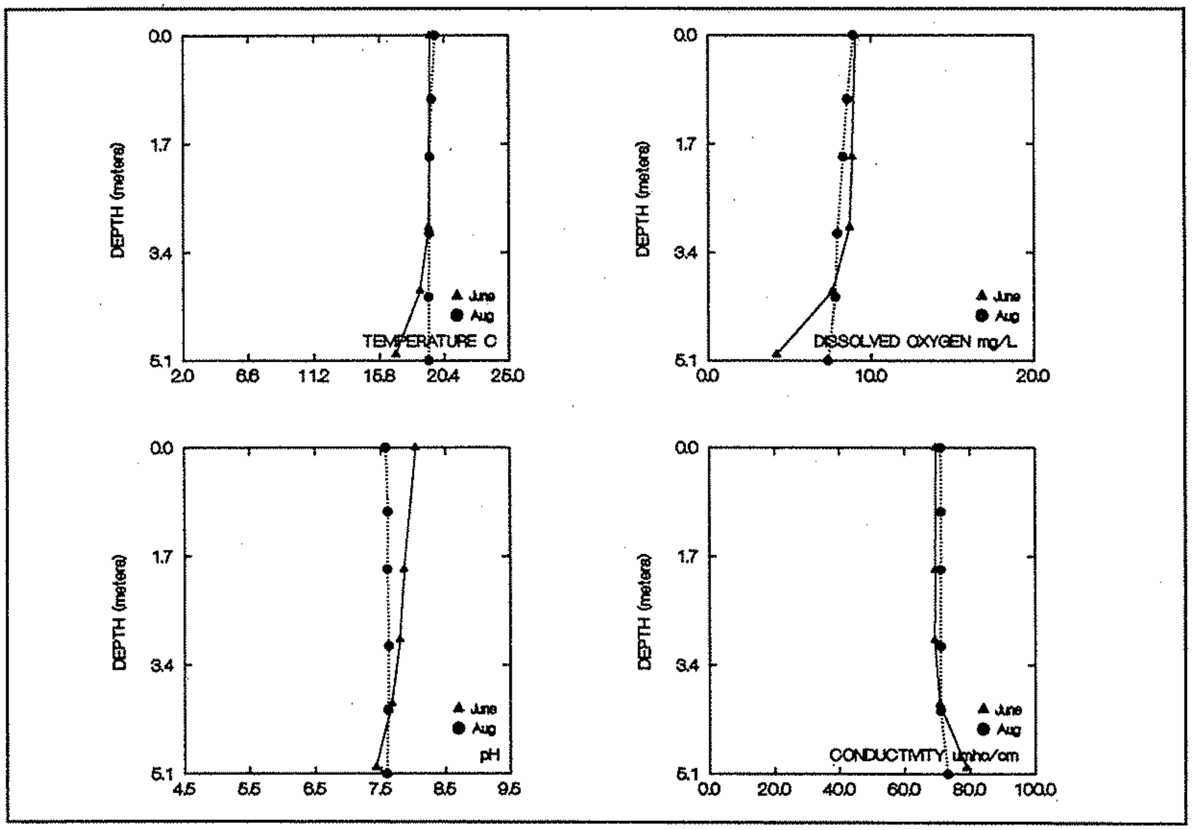
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
09/05/74[a]	6	--	--
05/23/90[b]	14	0.22	--
08/14/90[b]	14	0.23	--
05/20/91[c]	--	0.16	--
05/13/92[d]	9	0.20	1.2
08/20/92[d]	13	0.25	1.1

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)

MISSION LAKE (KITSAP COUNTY)





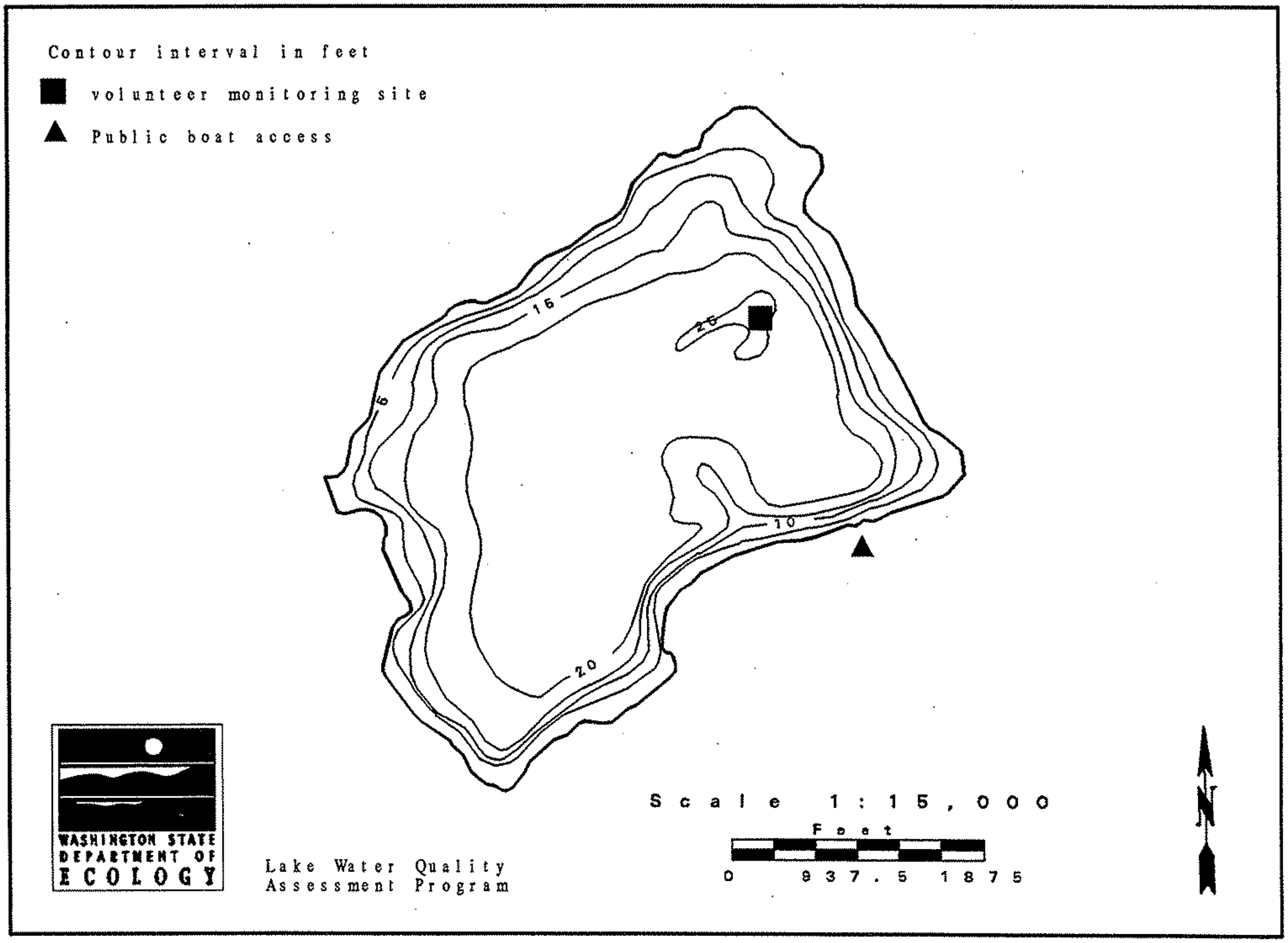
1993 Secchi Depth and Profile Data Graphs

Lake Nahwatzel -- Mason County

Lake Nahwatzel is located 11 miles west of Shelton. It has two unconfirmed 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)



Overall Assessment

In 1993, Lake Nahwatzel was assessed as oligotrophic, based on good water clarity, low nutrient concentrations, and relatively low densities of algae (as indicated by low concentrations of chlorophyll *a*). Lake Nahwatzel has been described as oligotrophic each year since 1990.

Six other Mason County lakes were monitored for the program in 1993. These lakes were Island, Limerick, Mason, Phillips, Spencer, and Wooten Lakes.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was very good in 1993, as indicated by Secchi depths which ranged from 16.0 feet to 22.0 feet. Secchi depths deeper than 13.0 feet indicate good water clarity. Secchi depths were deeper in 1993 than in 1992.

Total Phosphorus

Concentrations of total phosphorus were low (7 µg/L on both sampling dates). Results from 1993 were lower than results from 1992 and 1990. Total phosphorus concentrations less than 12 µg/L are low and are typical for oligotrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were moderately low on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were greater than 17:1, algae growth in Lake Nahwatzel was not limited by nitrogen.

Profile Data

The lake was not stratified on either sampling date. As a result, only one set of water samples was collected on each sampling date. Very little change in temperature, pH, dissolved oxygen and conductivity from surface to bottom is typical for an unstratified lake. 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

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount algae in a volume of water. Chlorophyll concentrations in May, indicated low densities of algae. In September, the chlorophyll concentration was 3.0 µg/L, which indicates a moderately low amount of algae. The water color was grass-green at the time of sampling. Chlorophyll concentrations less than 2.6 µg/L indicate low densities of algae.

Lake Nahwatzel -- Mason County

On the June 12, 1991, 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 1993.

> Lake Nahwatzel is used for fishing, swimming, motor boating, non-motorized boating, jet skiing, and lakeshore camping. There is one resort on the lakeshore. 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 is publicly-owned. Trout were stocked in the lake in 1993. Currently, the watershed is being logged, and the lakeshore is being developed further for residences. In the 1930s, the watershed was logged and there was a sawmill on the lakeshore. Numerous old pilings in the lake, which in 1992 the volunteer noted were safety hazards for boating, were removed from the lake in 1993.
>
> There are about 114 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, and no lake management activities occurred on the lake in 1993. 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 found that Lake Nahwatzel had excellent water quality. The worst problem in the lake in 1993 was excessive aquatic plant growth. Possible sources of problems include failing septic systems.
>
> 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. The volunteer noted that the lake is primarily fed by springs, and that despite maps which show there are inlets, none are apparent.

Acknowledgment

I thank Dave Fowble for volunteering his time to monitor Lake Nahwatzel during 1990-1993.

Lake Nahwatzel -- Mason County

1993 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*):	39

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
27-May	1545			20.0		lt-green	100		light	Onsite visit. Some foam.
03-Jul	1050	20.0	68.0	16.0		lt-green	100	trace	light	Just got boat back from repairs.
17-Jul	1035	18.9	66.0	16.5		lt-green	90	light	light	
01-Aug	1009	21.1	70.0	16.5	-2.00	lt-green	0	none	calm	
14-Aug	0915	18.9	66.0	18.0		lt-green	100	light	calm	Light rain.
28-Aug	1010	20.6	69.0	21.5	-6.00	lt-green	90	none	calm	
01-Sep	1515			22.0		lt-green	0		light	Onsite visit.
16-Sep	1330	21.1	70.0	22.0	-10.00	lt-green	0	none		

1 Trophic State Indices calculated from Carlson (1977).
2 "Lake height" refers to changes in water level. Based on volunteer-collected data, the level of Lake Nahwatzel dropped 8" from August 1 to September 16.

Lake Nahwatzel -- Mason County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/27	0.0	19.1	7.1	9.7	16
	1.2	19.3	7.1	9.6	16
	3.0	19.1	7.1	9.7	16
	4.0	18.9	7.1	9.8	16
	4.9	18.4	7.1	9.7	16
	6.0	15.8	7.1	9.8	17
	6.4	15.5	6.9	9.0	17
09/01	0.0	21.9	6.6	8.8	17
	1.0	21.5	6.7	8.6	16
	2.0	20.6	6.7	8.7	16
	3.0	20.4	6.7	8.6	17
	4.0	20.2	6.7	8.6	16
	5.0	20.2	6.7	8.6	16
	6.0	20.1	6.7	8.7	16

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 27							
Epilimnion	7	0.17	1.9	--	--	--	--
Hypolimnion*							
September 1							
Epilimnion	7	0.21	3.0	--	--	--	--
Hypolimnion*							

* The lake was not stratified at the time of sampling; only one set of samples was collected

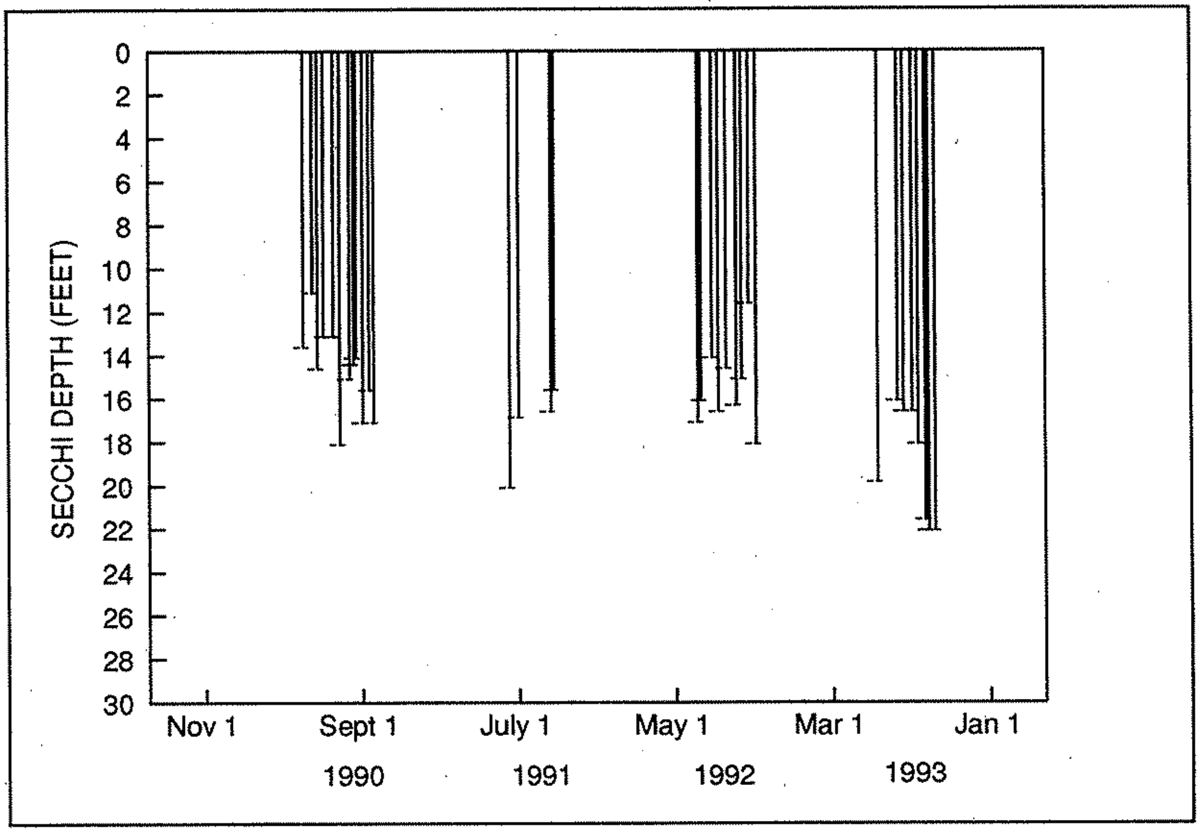
Lake Nahwatzel -- Mason County

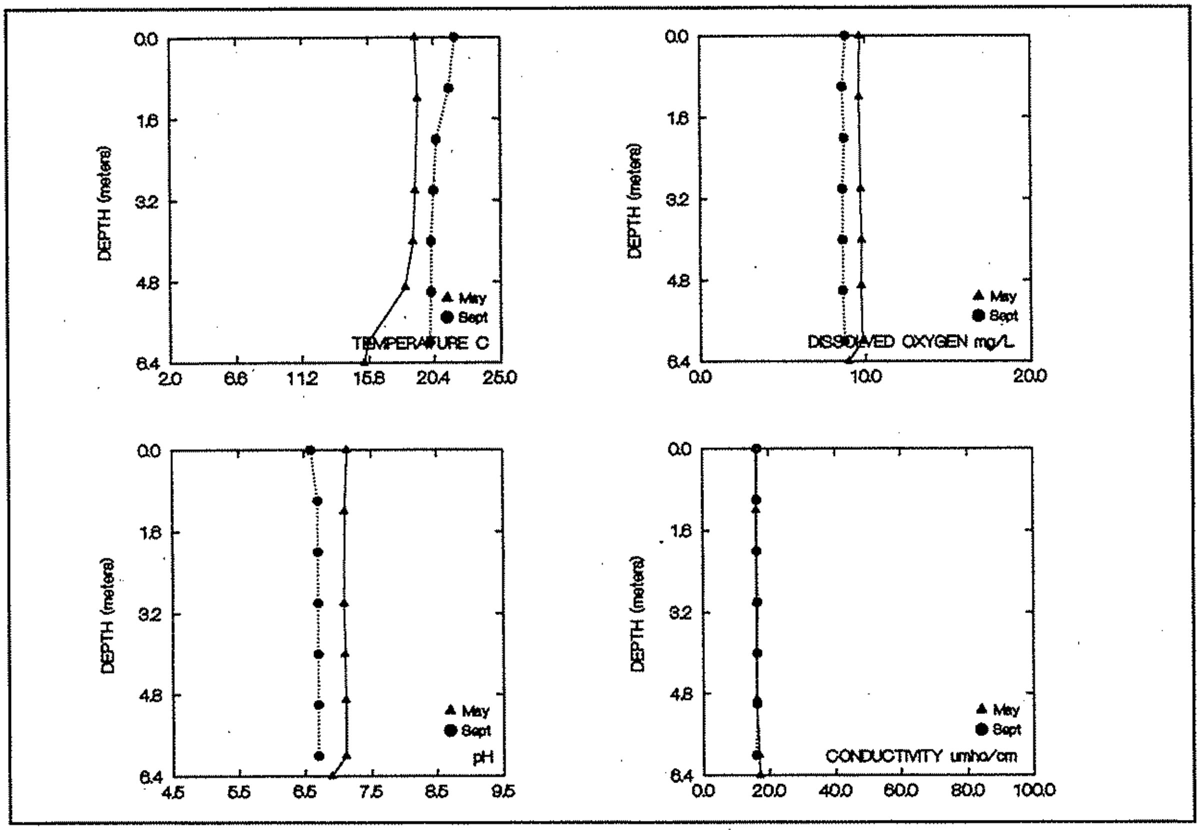
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
08/15/74[a]	7	--	--
06/10/81[b]	40	--	1.5
06/13/90[c]	--	0.15	2.2
09/12/90[c]	--	0.21	2.2
05/24/90[d]	12	0.27	--
08/15/90[d]	12	0.24	--
06/12/91[e]	--	0.16	--
05/19/92[f]	9	0.23	1.2
08/26/92[f]	8	0.32	0.3

a. Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Coots (1991)
d. Rector (1991)
e. Rector (1992)
f. Rector (1993)

LAKE NAHWATZEL (MASON COUNTY)





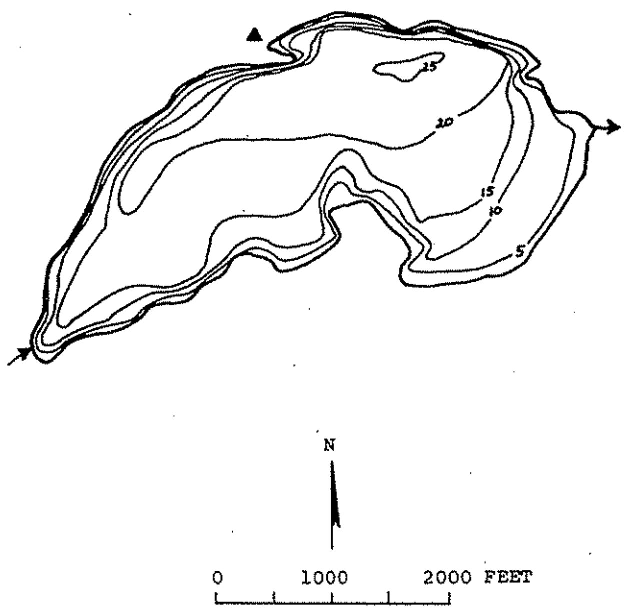
1993 Secchi Depth and Profile Data Graphs

Offutt Lake -- Thurston County

Offutt Lake is located nine miles south of Olympia. It is fed by an unnamed surface inlet, and drains to the Deschutes River.

Size (acres)	200
Maximum Depth (feet)	25
Mean Depth (feet)	15
Lake Volume (acre-feet)	2,900
Drainage Area (miles^2)	2.7
Altitude (feet)	230
Shoreline Length (miles)	2.9

Data From Bortleson *et al.* (1976)



EXPLANATION

—— 10 ——

Line of equal water depth Interval 5 feet

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

Overall Assessment

In 1993, Offutt Lake was assessed as eutrophic, based on high phosphorus concentrations and very high densities of algae were very high in September and October.

Other Thurston County lakes monitored for the program in 1993 were Black, Chambers, Long, South Pattison, St. Clair, Summit, and Ward. Black Lake, South Pattison, and Chambers Lake were also classified eutrophic due to high nutrient concentrations and large amounts of aquatic plants and algae; these lakes (and Offutt Lake) are shallow.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was fair as indicated by Secchi depths that ranged from 2.0 feet to 13.0 feet. Secchi depths less than 6.5 feet indicate poor water clarity. The lowest Secchi depths were measured in September and October, when algae growth was heavy.

Total Phosphorus

Concentrations of total phosphorus were high on both sampling dates. Concentrations measured in the upper layer of water (the epilimnion) in 1993 (25 µg/L in May, and 26 µg/L in September) were very similar to concentrations measured in 1972. Total phosphorus concentrations greater than 24 µg/L are high and are typical of eutrophic lakes.

In September, the concentration of total phosphorus in the lower layer of water (the hypolimnion) was very high (342 µg/L), and probably resulted from sediment release. Sediment release occurs when oxygen concentrations near the lake bottom are depleted, creating conditions that allow phosphorus, iron, and other compounds in sediments to be chemically reduced and released into the water column. The heavy algae bloom reported by the volunteer in October may have occurred after the lake turned over. At turnover, the high phosphorus concentrations from the lower layer would have been mixed throughout the water column and stimulated algal growth in the presence of suitable temperature and light conditions (see Plants, below).

Total Nitrogen

The concentrations of total nitrogen were moderately high on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Algae usually use at least 10 times the amount of nitrogen as phosphorus. Because the ratio of total nitrogen to total phosphorus were greater than 17:1, algae growth in Offutt Lake was not limited by nitrogen.

Profile Data
The lake was weakly stratified on both sampling dates. In August, pH and dissolved oxygen decreased considerably in the bottom two meters of the lake. Oxygen and pH usually decrease from bacteria that use oxygen as they decompose aquatic plants and algae in the water and sediments. Oxygen at the bottom of the lake was depleted in August, probably resulting in phosphorus release from the sediment (see Total Phosphorus, above). The increase in conductivity near the lake bottom also indicates that sediment release occurred. Conductivity in water increases when ion content increases.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. In general, chlorophyll concentrations greater than 6.4 µg/L indicate high densities of algae. In May, the chlorophyll concentration in Offutt Lake indicated a low density of algae. Because the phosphorus concentration was high and algae were not nitrogen-limited, some factor other than nutrient availability was affecting algae growth in the lake during May. When the lake was sampled in September, the chlorophyll concentration was very high (16.0 µg/L), although the concentration of total phosphorus in the epilimnion was not high enough to expect that much algae. High phosphorus in the hypolimnion (see Total Phosphorus, above) may have contributed to the high algal density in September.

Other Available Information
From Bortleson *et al.* (1976): Offutt Lake was eutrophic in 1972, based on moderately high phosphorus concentrations, a shallow Secchi depth, and very low concentrations of dissolved oxygen in the hypolimnion during summer. Aquatic plants observed in 1972 were white-flowering water lily (*Nymphaea*), sedge (*Cyperaceae*), coontail (*Ceratophyllum demersum*), waterweed (*Elodea* sp.), and muskgrass (the alga *Chara*). The outlet is dry during summer.

Summary of Questionnaire Responses and Information From the Volunteer

The 1993 questionnaire on lake and watershed uses was not returned.

Acknowledgment

I thank J. A. Daniels and Sue Bailey for volunteering their time to monitoring Offutt Lake in 1993.

Offutt Lake -- Thurston County

1993 Trophic Status[1]

Estimated Trophic State:	Eutrophic[2]
Mean Trophic State Index (Secchi):	47
Mean Trophic State Index (Total Phosphorus):	51
Mean Trophic State Index (Chlorophyll *a*):	<41[3]

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (ft)[4]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
18-May	1830	20.0	68.0	13.0			100		calm	Onsite visit.
05-Jun	1400	20.0	68.0	12.0	21.00	lt-brown	75	trace	breezy	
10-Jul	1230	20.0	68.0	8.0		lt-brown	75	trace	breezy	
22-Aug	1230	22.0	71.5	7.0		gr-brown	90	none	breezy	
17-Sep	1620			6.6		gr-brown	100		calm	Lots of algae visible.
03-Oct	1230	18.0	64.4	2.0	21.00	pea-green	0	none	calm	Heavy algae bloom.

1 Trophic State Indices calculated from Carlson (1977).
2 See Overall Assessment for basis of trophic state.
3 One chlorophyll value was below the detection limit, so a mean TSI for chlorophyll could not be calculated.
4 Lake height refers to change in water level. Based on volunteer-collected data, there was no change in water level from June 5 to October 3.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/23	0.0	18.9	8.4	10.9	275
	1.0	18.8	8.5	10.8	275
	2.0	18.3	8.5	10.9	271
	3.0	17.9	8.5	10.9	270
	4.0	17.4	8.5	10.9	273
	5.0	17.2	8.5	10.9	272
	6.0	16.9	8.5	10.9	273
	7.0	15.4	8.4	10.7	286
	8.0	13.3	8.3	9.7	295
	9.0	11.8	8.2	8.9	300
	10.0	11.0	8.1	8.2	300
	12.0	10.3	8.0	7.7	302
	14.0	9.9	8.0	7.0	302
	16.0	9.7	7.9	6.9	304
	18.0	9.3	7.9	6.3	306
	20.0	9.0	7.8	5.8	304
	22.0	8.8	7.8	5.1	310
08/24	0.0	20.7	8.6	8.1	258
	2.0	20.8	8.5	8.1	259
	4.0	20.7	8.5	8.1	259
	5.0	20.8	8.5	8.1	259
	6.0	20.8	8.5	8.0	259
	7.0	20.8	8.5	8.1	259
	8.0	20.7	8.4	7.6	261
	9.0	19.3	8.1	4.7	273
	10.0	19.0	8.0	4.6	274
	11.0	18.2	7.9	3.2	282
	12.0	16.0	7.7	1.0	298
	14.0	14.2	7.7	0.2	308
	16.0	13.5	7.6	0.1	316
	18.0	13.1	7.6	0.1	320
	20.0	12.8	7.6	0.1	318
	22.0	11.8	7.6	0.1	324

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 18							
Epilimnion	25	0.40	bdl	--	--	--	--
Hypolimnion	23	0.45	--	--	--	--	--
September 7							
Epilimnion	26	0.53	16.0	--	--	--	--
Hypolimnion	342	0.68	--	--	--	--	--

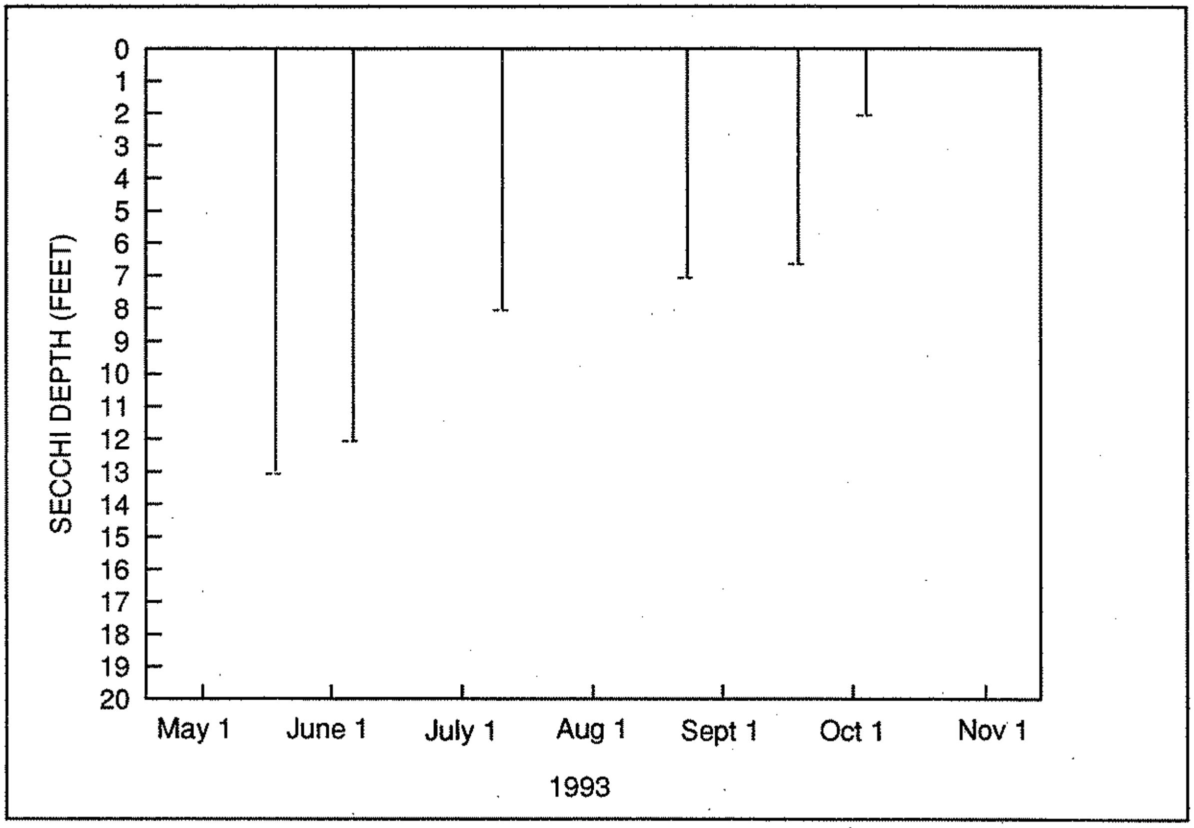
bdl = below analytical detection limit of 0.50 µg/L

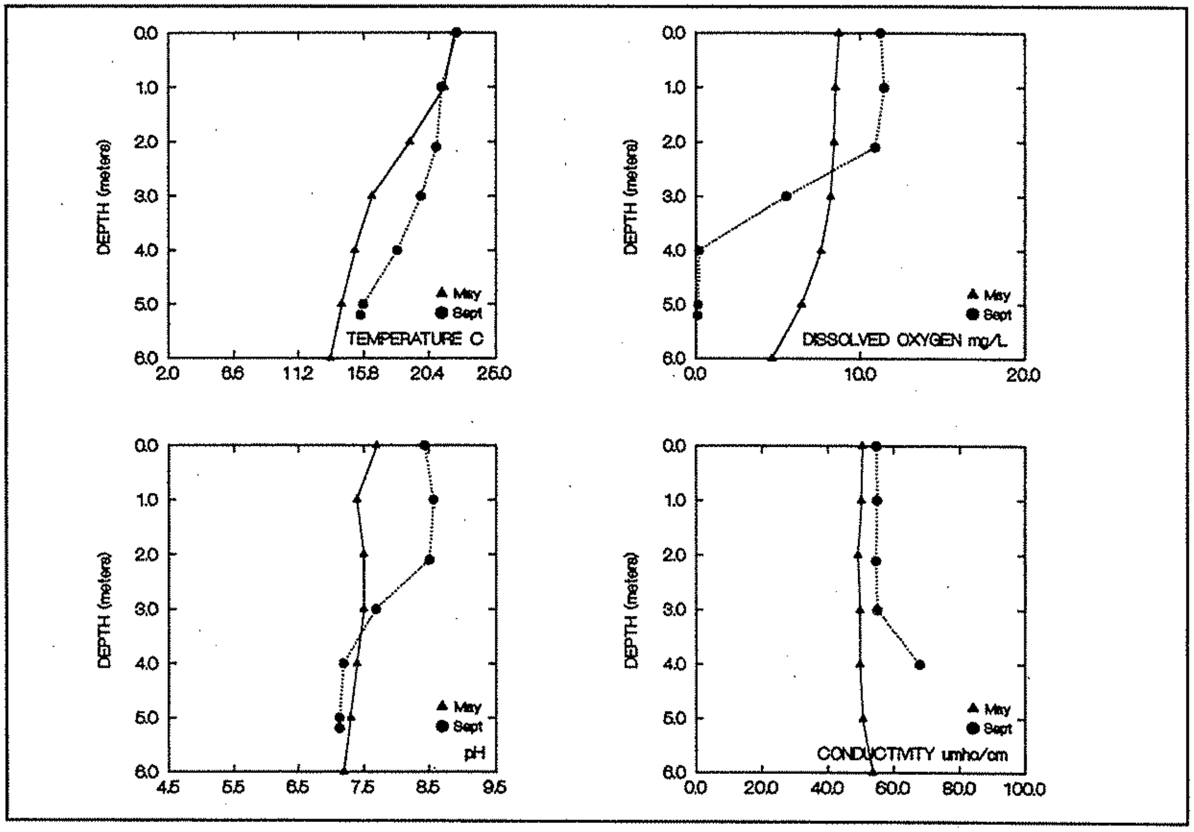
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
06/28/72[a]	20	--	3.8
10/04/72[a]	29	--	6.9
07/21/81[b]	0	0.59	8.6

a. Bortleson *et al.* (1976)

OFFUTT LAKE (THURSTON COUNTY)





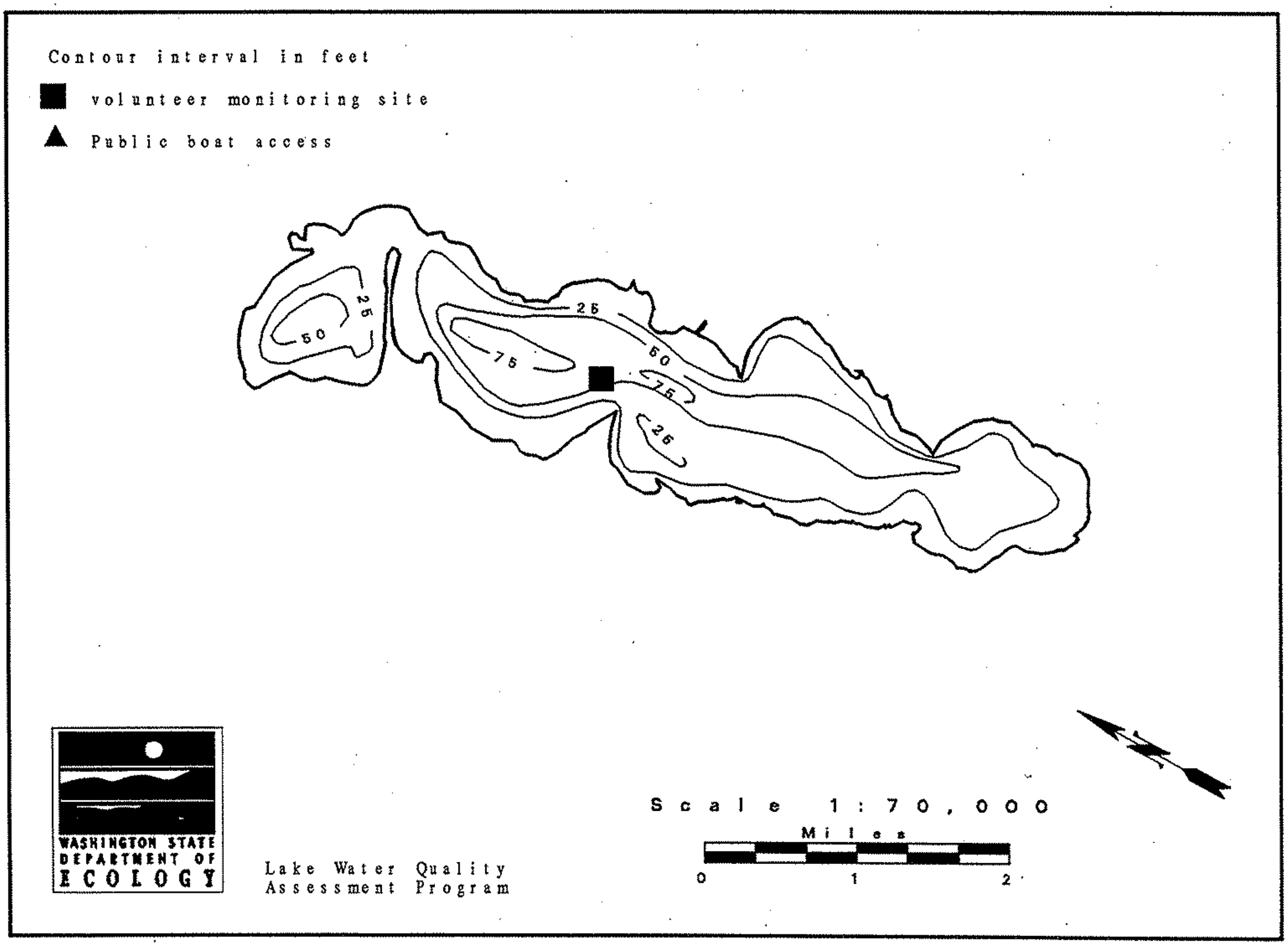
1993 Secchi Depth and Profile Data Graphs

Lake Osoyoos -- Okanogan County

Lake Osoyoos is located one mile north of Oroville. It is 10 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)



Overall Assessment

In 1993, Lake Osoyoos was assessed as mesotrophic, based on water clarity, moderately low to moderately high phosphorus concentrations, and moderately high concentrations of chlorophyll *a*. Lake Osoyoos has been described as mesotrophic each year since 1989.

In 1992, I reported that the water quality of Lake Osoyoos appeared to be improving because in 1992 there was fair water clarity, less milfoil in the water than in previous years, and lower concentrations of total phosphorus and chlorophyll *a* in comparison with concentrations from 1989. The improvement appears to have been temporary, and may have been related to the varying storage of water in the lake in 1992 compared with earlier years. Dilution due to higher water levels could have improved water quality in 1992, although there are not enough data available to confirm this.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good to fair, as indicated by Secchi depths which ranged from 7.8 feet to 10.5 feet. Secchi depths in 1993 were not as deep, and were not as variable, as data collected from 1990-1992. Despite the apparent differences in water clarity each year, there was not a statistically significant trend in water clarity from 1989 to 1993.

Total Phosphorus

The concentration of total phosphorus was moderate in May (15 µg/L), and moderately low in August (10 µg/L). Concentrations between 12 µg/L and 24 µg/L are typical for mesotrophic lakes. The May concentration was very similar to concentrations measured for the program in 1992 and 1989, but the August value was lower than values measured in previous years.

In August, the concentration of total phosphorus was higher in the lower layer of water (the hypolimnion) than in the upper layer of water (the epilimnion). It is likely that the very low dissolved oxygen concentration at the lake bottom created a condition that allowed phosphorus, iron and other compounds in sediments to be chemically reduced and released into the water column (see Profile Data, below). When the lake destratified, water from the lower layer with high total phosphorus concentrations could mix throughout the water column, creating a potential for more aquatic plant and algae growth.

Total Nitrogen

Concentrations of total nitrogen were moderately low on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient is not responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 on both sampling dates, it is likely that algae growth in Lake Osoyoos was not limited by nitrogen.

Profile Data
The lake was stratified with respect to temperature on both sampling dates. Below the thermocline, pH and dissolved oxygen decreased with depth. Dissolved oxygen concentrations and pH can decrease from bacteria which use oxygen as they decompose aquatic plants and algae in the water and sediments.

In August, dissolved oxygen was depleted in the bottom 10 meters of the lake. Very low oxygen concentrations can result in internal loading of phosphorus from the sediments (see Total Phosphorus, above) as well as increased conductivity of the water from iron and other ions that are released into the water column from sediment.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and it is used to determine the amount of algae in a volume of water. Chlorophyll concentrations in Lake Osoyoos on both sampling dates indicated moderately high densities of algae.

Aquatic plants identified by Ecology staff were Eurasian watermilfoil (*Myriophyllum spicatum*), curlyleaf pondweed (*Potamogeton crispus*), and waterweed (*Elodea canadensis*). According to the volunteer, there was more milfoil in 1993 than in 1992.

Other Available Information
From Rensel (1993): To enhance the native population of sockeye salmon in Lake Osoyoos, the Douglas County Public Utility District has proposed rearing juvenile salmon in small net pens in the lake. The juveniles would be released from the pens after 6-8 weeks. Initial use of the net pens, and water quality monitoring at the site, will begin in summer 1994 (J. Rensel, pers. comm.).

Ambient monitoring data from the Okanogan River at Oroville from 1977 through 1993 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 Monitoring Program, and trend analysis was conducted using WQHYDRO (Aroner, 1990). No significant trend was detected for time or season. There was a decreasing trend in total phosphorus pounds/day, but the trend was not significant (α=0.05).

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): In 1989, Ecology staff collected sediment and largemouth bass samples from Lake Osoyoos. 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 Okanagan River, and secondary sewage effluent from the town of Oliver is pumped into the Okanagan River about three 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, 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 1993. Questionnaire responses apply to lake and watershed uses on the U.S. portion of the lake, unless otherwise indicated.

Lake Osoyoos -- Okanogan County

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 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 183 houses on the U.S. side of the lakeshore. The lakeshore is not sewered on the U.S. side, although most homes on the Canadian side are sewered. There is a lake association and a sewer district for the lake. No lake management activities occurred on the U.S. side of the lake in 1993. In 1990, growths of milfoil and algae were very heavy. Aquatic plants were harvested on the Canadian side of the lake in 1990, but not on the U.S. side.

Overall, the volunteer found that Lake Osoyoos had excellent water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, (2) impaired fisheries, and (3) suspended sediments. Possible sources of problems include new development along the shoreline, growth of business along Highway 97, and lack of a sewer collection service on the U.S. side of the lake.

In 1993, the lake level was kept at 912.5 MSL [fluctuating water level was the worst problem in the lake in 1992, and was listed as one of the problems in 1991]. Milfoil growth in the lake increased since the 1992 monitoring season, which made boating and swimming difficult in areas. In addition, milfoil harvested on the Canadian side washed up on U.S. shores. Reduced patrol by U.S. Customs increased enjoyment of lake in 1993. Fishing in upper Okanogan County was terrible.

Acknowledgments

I thank Walter Ullrich for volunteering his time to monitor Lake Osoyoos during 1990-1993, and Kathy Jones for monitoring the lake during 1989.

Lake Osoyoos -- Okanogan County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Trophic State Index (Mean Secchi):	45
Trophic State Index /(Mean Total Phosphorus):	40
Trophic State Index (Mean Chlorophyll *a*):	45

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (ft)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
23-May				7.8				heavy	light	Onsite visit. 8.5' with view tube.
04-Jun	1345	21.1	70.0	11.0	912.30	lt-green	25	light	light	Osoyoos, B.C. Committee for Quality does lake monitoring. Would desire to exchange data.
18-Jun	1315	25.0	77.0	8.0	912.20	lt-green	10	light	light	Received draft in mail - will give to Osoyoos Water Quality Committee.
01-Jul	1415	22.8	73.0	8.0	912.30	green	75	none	light	Milfoil growth heavy this year after slow growth in 1992.
19-Jul	1445	21.7	71.0	7.0	912.10	green	90		breezy	North end of Dairy Point heavy with milfoil this year. Much wind and rain each day.
04-Aug	1345	25.0	77.0	7.0	912.00	lt-brown	10	none	light	Tourist season-many boats for Osoyoos. Weed growth heavy.
17-Aug	1115	23.3	74.0	9.5	911.60	pea-green	25	heavy	light	Both Secchi readings with view tube.
24-Aug	0705			9.0		green	5		breezy	Onsite visit.
03-Sep	1530	24.4	76.0	9.0	911.70	green	0	none	calm	Summer in September this year.
16-Sep	1315	18.9	66.0	9.0	911.75	green	0	none	calm	
02-Oct	1430	18.9	66.0	10.5	911.50	green	0	none	calm	Summer in October. Lake going down. Much weed growth.
10-Oct	1230	16.7	62.0	10.0	911.50	lt-green	0	none	calm	

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

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Osoyoos dropped 0.8" from June 4 to October 10.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/23	0.0	18.9	8.4	10.9	275
	1.0	18.8	8.5	10.8	275
	2.0	18.3	8.5	10.9	271
	3.0	17.9	8.5	10.9	270
	4.0	17.4	8.5	10.9	273
	5.0	17.2	8.5	10.9	272
	6.0	16.9	8.5	10.9	273
	7.0	15.4	8.4	10.7	286
	8.0	13.3	8.3	9.7	295
	9.0	11.8	8.2	8.9	300
	10.0	11.0	8.1	8.2	300
	12.0	10.3	8.0	7.7	302
	14.0	9.9	8.0	7.0	302
	16.0	9.7	7.9	6.9	304
	18.0	9.3	7.9	6.3	306
	20.0	9.0	7.8	5.8	304
	22.0	8.8	7.8	5.1	310
08/24	0.0	20.7	8.6	8.1	258
	2.0	20.8	8.5	8.1	259
	4.0	20.7	8.5	8.1	259
	5.0	20.8	8.5	8.1	259
	6.0	20.8	8.5	8.0	259
	7.0	20.8	8.5	8.1	259
	8.0	20.7	8.4	7.6	261
	9.0	19.3	8.1	4.7	273
	10.0	19.0	8.0	4.6	274
	11.0	18.2	7.9	3.2	282
	12.0	16.0	7.7	1.0	298
	14.0	14.2	7.7	0.2	308
	16.0	13.5	7.6	0.1	316
	18.0	13.1	7.6	0.1	320
	20.0	12.8	7.6	0.1	318
	22.0	11.8	7.6	0.1	324

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 23							
Epilimnion	15	0.29	4.7	--	--	--	--
Hypolimnion	13	0.36	--	--	--	--	--
August 24							
Epilimnion	10	0.25	4.3	--	--	--	--
Hypolimnion	31	0.30	--	--	--	--	--

Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/22/74[a]	12	--	--
07/15/81[b]	20	0.71	3.3
06/06/89[c]	16	0.36	2.3
09/06/89[c]	21	0.31	6.0
06/27/91[d]	--	0.21	--
05/18/92[e]	12	0.34	0.8
08/31/92[e]	12	0.24	1.3

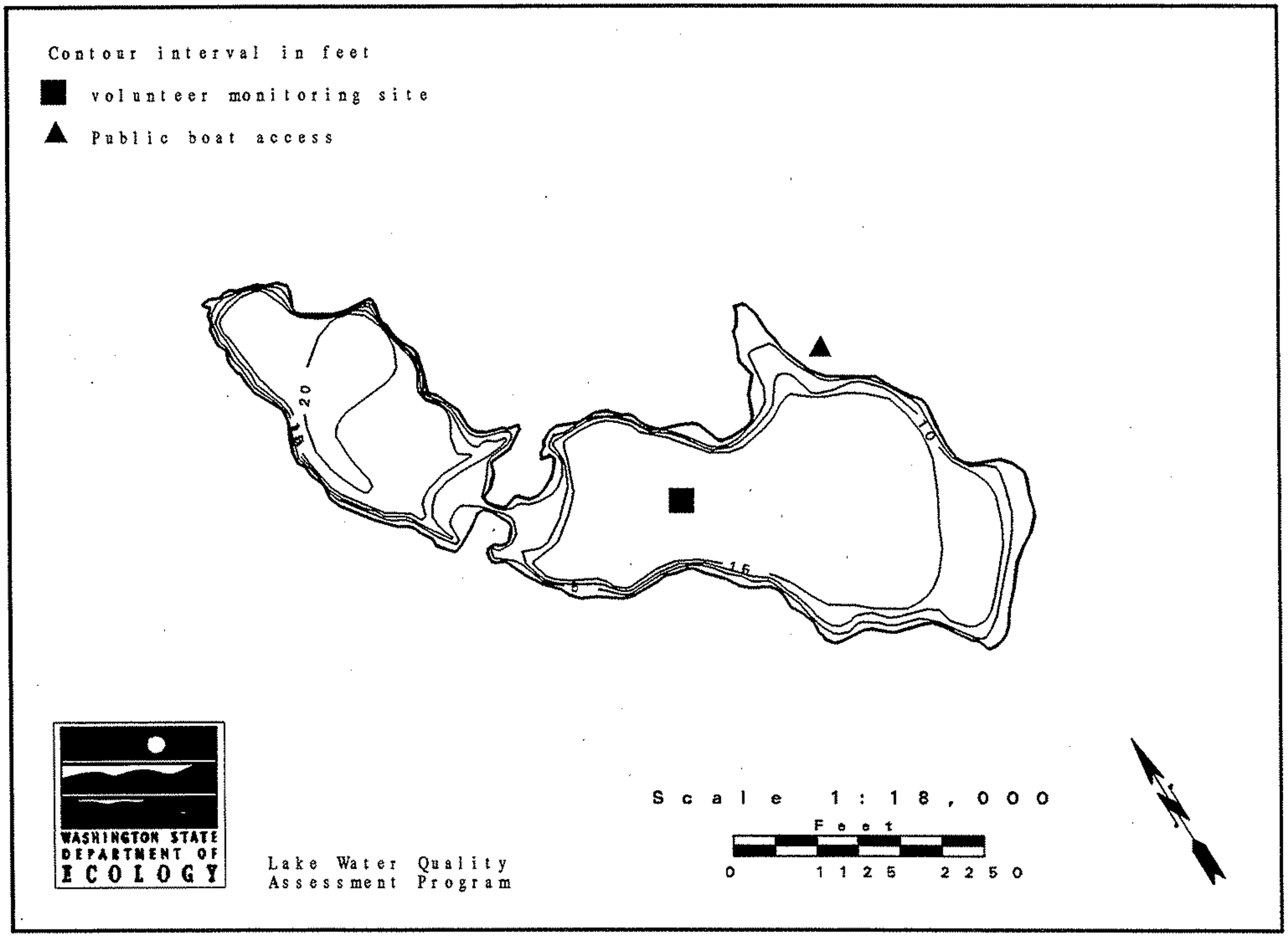
a. Dion *et al.* (1976)
b. Sumioka and Dion (1985)
c. Brower and Kendra (1990)
d. Rector (1992)
e. Rector (1993)

South 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 190 acres. The lake is fed by Hicks Lake through North Pattison 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)	190
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)



Overall Assessment

In 1993, South Pattison Lake was assessed as meso-eutrophic, because it exhibited both mesotrophic and eutrophic characteristics. Secchi depths were in the mesotrophic range, but the moderately high to high concentrations of total phosphorus, the algae bloom in August, and the moderately high amounts of aquatic plants were more characteristic of a eutrophic lake. The lake was in better condition in 1993 than when it was monitored under the program in 1989.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in 1993 was fair, as indicated by Secchi depths that ranged from 6.0 feet to 12.0 feet. Secchi depths between 6.5 feet and 13.0 feet are typical for mesotrophic lakes. Deepest Secchi depths were measured when the volunteer noted that algae clumps were visible in the water; although increased algae growth usually decreases water clarity, some algae colonies form large clumps that still allow the Secchi disk to be seen, instead of clouding the water with smaller particles. Algae growing during the August onsite visit were primarily of a variety that form large round colonies that can be easily seen, yet do not reduce water clarity as much as other algae (see Plants, below).

Total Phosphorus

In May, the concentration of total phosphorus was very high (79 μg/L). Because the concentration of total phosphorus was high relative to the concentration of total nitrogen, it is likely that algae growth was not limited by phosphorus in May.

In August, the phosphorus concentration was moderately high (22 μg/L). Concentrations greater than 24 μg/L are high and are typical for eutrophic lakes. High total phosphorus concentrations are generally associated with high amounts of aquatic plants and algae.

Total Nitrogen

Despite high concentrations of both nitrogen and phosphorus in May, there was a very low concentration of chlorophyll *a* (which indicates the volume of algae in water; see Plants, below). This suggests that some factor other than nutrient limitation may have been restricting algae growth in May.

In August, the ratio of total nitrogen to total phosphorus was greater than 17:1, so algae growth was not limited by nitrogen in August.

Profile Data
The lake was not stratified at the time of sampling on either sampling date, so water samples were composted from surface to bottom. In August, dissolved oxygen and pH decreased in the bottom meter of the lake. Oxygen and pH can decrease from bacteria which use oxygen as they decompose algae and aquatic plants in the water and sediments.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Although there were high concentrations of nutrients in May, the chlorophyll concentration indicated a very low density of algae. It is possible that the high nutrient concentrations resulted from suspended sediments in water. Suspended sediments can result in high total nitrogen and total phosphorus concentrations, yet the nutrients are not in a form that can be readily taken up by growing algae.

During August, the chlorophyll concentration indicated a high density of algae. The density of algae was at the level expected, given the moderately high nutrient concentrations at the time. At the time of sampling in August, floating scums from a recent blue-green algae bloom were observed in protected nearshore areas. Most of the scums were bluish green, although some bright blue scums were seen. This is typical of decomposed blue-green algae. An algae sample collected during the onsite visit contained primarily *Gloeotrichia* sp. This is a blue-green algae that can form round colonies, and is capable of growing to bloom proportions.

Aquatic plants identified by Ecology staff during the August 1993 sampling visit were coontail (*Ceratophyllum demersum*), whitestem pondweed (*Potamogeton praelongus*), waterweed (*Elodea canadensis*), tapegrass (*Vallisneria americana*), white-flowering water lily (*Nymphaea odorata*), and cattails (*Typha*). Coontail was the most abundant plant in the lake when it was monitored in 1989.

Other Available Information
Water quality data were collected by the Thurston County Health Department from 1989-1992. Data collected in 1991 and 1992 indicated fair to poor water clarity ranging from 1.35 meters to 4.36 meters (4.4 feet to 14.3 feet), and high concentrations of total phosphorus ranging from 12 µg/L to 53 µg/L). All total phosphorus concentrations from 1992 were high (above 23 µg/L). Chlorophyll concentrations indicated heaviest algal densities occurred from September 1991 through February 1992, and in December 1992 (Thurston County Health Department).

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 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. In comparison with the north basin, the south basin had more of its bottom surface covered with submerged species of plants, and more of the shoreline supported emergent plants (except for an area surrounding the public access area, the entire shoreline of the south basin was ringed with aquatic plants).

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).

North Pattison Lake was monitored for the program from 1990-1992.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire on lake and watershed uses.

> South Pattison Lake is used for fishing and swimming. There is one public boat ramp, and boat speed is restricted to 5 mph. Trout and bass were stocked in the lake in 1993. Currently, the watershed is being logged and used for crop agriculture. The lakeshore is also being developed further for residences. In the past, the watershed was used for crop agriculture, and the shoreline was altered when a railroad bridge was built between the north and south basins of the lake.
>
> There are over 100 houses on the lakeshore, but there are no culverts which drain into the lake. There is a lake association for the lake. No lake management activities occurred on the lake in 1993. Lake water was withdrawn for drinking and other domestic uses, and irrigation.
>
> Overall, the volunteer finds that South Pattison Lake had fair water quality. Problems in the lake in 1993 were ranked as (1) algae, (2) excessive aquatic plant growth, and (3) decaying plants and odor from decaying algae. There was more algae and fewer coontail mats in 1993 than in 1992.

Acknowledgments

I thank Hugh Walkup for volunteering his time to monitor south Pattison Lake during 1993. Dave Hallock monitored the lake during 1989-1990.

South Pattison Lake -- Thurston County

1993 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	42
Mean Trophic State Index (Total Phosphorus):	56
Mean Trophic State Index (Chlorophyll *a*):	49

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
23-May		22.0	71.6	10.3		green	0			Pulled coontail up with disk.
10-Jun		23.0	73.4	8.3	-0.50		0			Water color olive green. Cloudy.
25-Jun		25.0	77.0	6.0	-1.00		0			Water color olive green. Cloudy.
11-Jul		25.0	77.0	11.5	-2.00		0			Water color olive green. Pulled up coontail with disk. Many algae clumps.
30-Jul		23.0	73.4	12.0	-1.50	green	0			More blue-green clumps floating. Sunny.
14-Aug		24.0	75.2	11.0	-1.00	green	0			Sunny. Many floaters.
26-Aug		23.0	73.4	7.5	-1.00		0		calm	Water color gray-green. Pulled up coontail on disk.
06-Sep	1525	21.0	69.8	8.8	-15.00	pea-green	0	none	light	
20-Sep	1710	20.0	68.0	8.8		green	0	none	calm	
10-Oct	1600	20.0	68.0	8.8	-1.00		25	trace	calm	Water color gray-green.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/21	0.0	20.7	8.0	6.6	122
	0.5	20.7	8.1	5.9	122
	0.9	20.7	8.1	5.5	122
	2.1	17.9	8.4	6.1	121
	3.0	15.6	8.1	6.0	123
08/26	0.0	21.9	8.4	10.2	127
	1.0	20.7	8.5	10.2	126
	2.0	20.4	8.5	9.8	126
	3.1	20.3	8.3	8.9	127
	3.7	19.8	7.6	1.7	132
	4.3	19.3	7.2	1.0	167

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

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of South Pattison Lake dropped from June 10 through October 10.

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 21							
Epilimnion	79	0.816	bdl	--	--	--	--
Hypolimnion*							
August 26							
Epilimnion	22	0.534	8.8	--	--	--	--
Hypolimnion*							

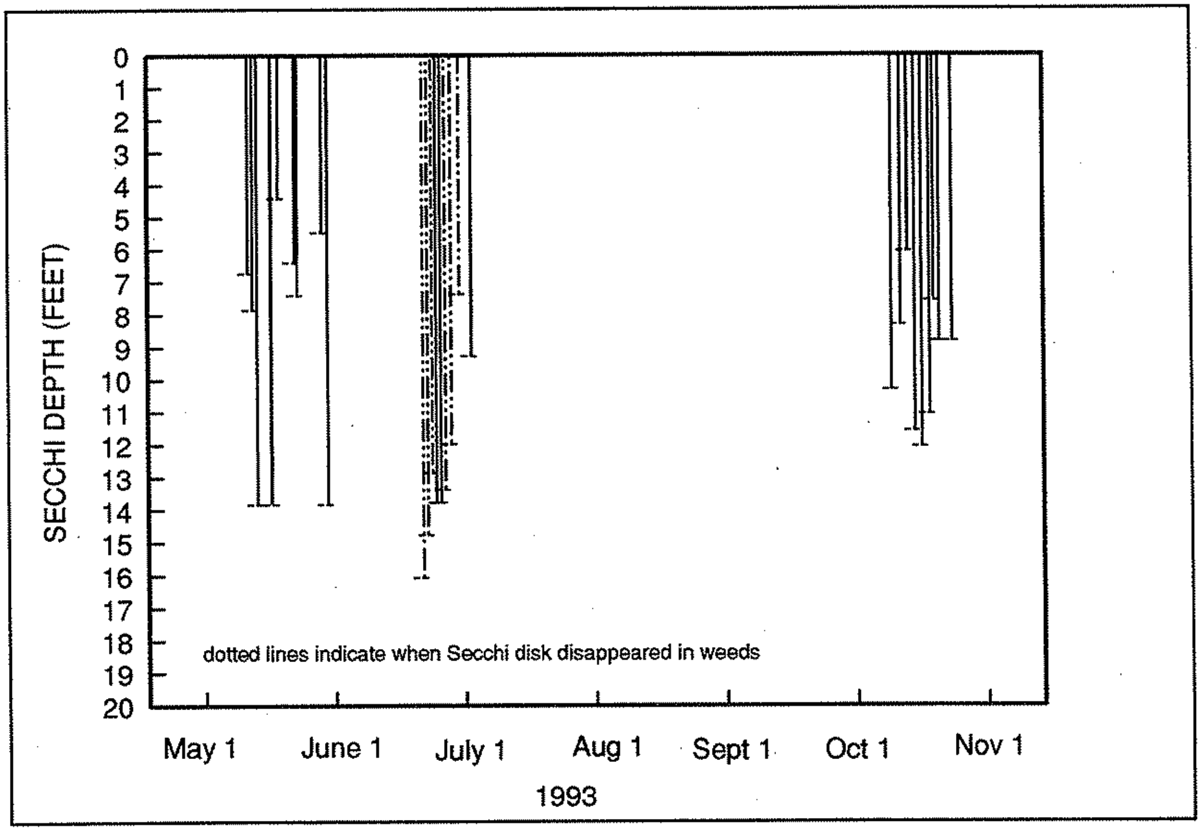
* The lake was not stratified at the time of sampling; only one set of samples was collected.

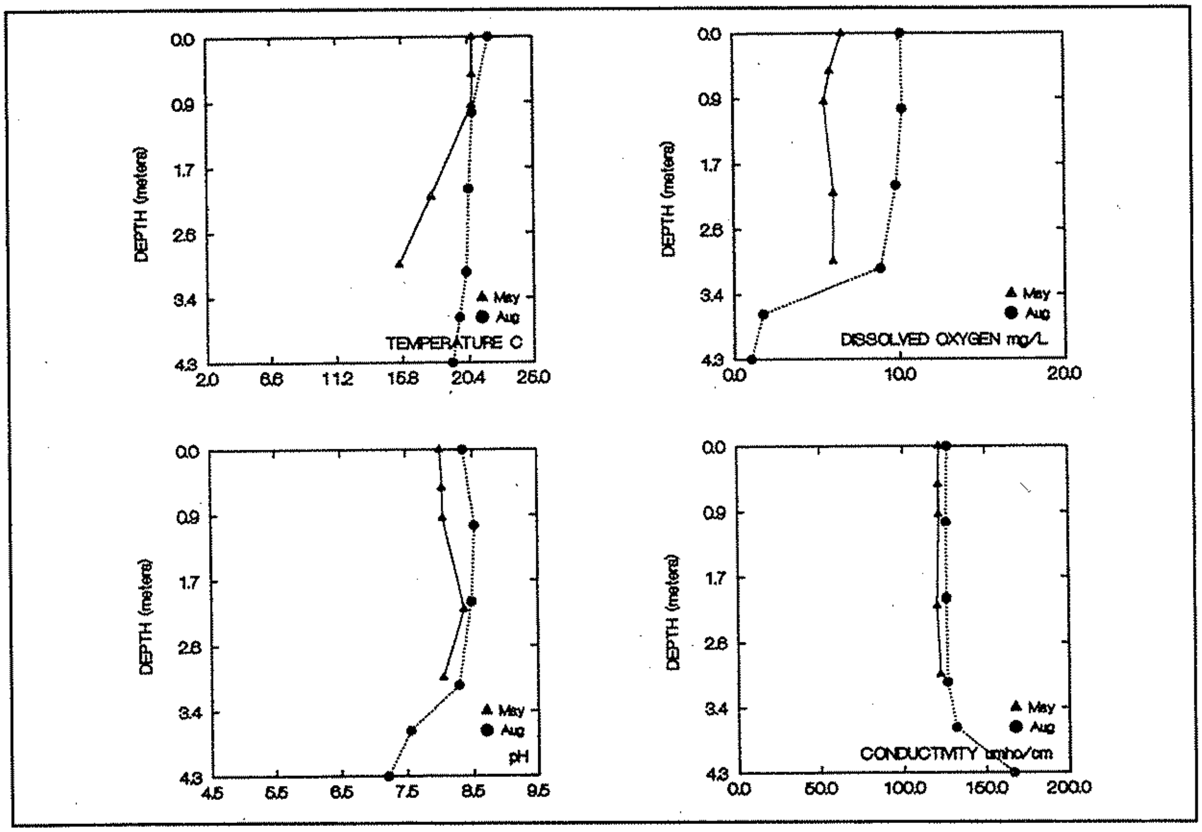
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
06/19/74[a]	19	--	14.0
08/29/74[a]	23	--	6.6
07/21/81[b]	30	1.4	3.4

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

SOUTH PATTISON LAKE (THURSTON COUNTY)





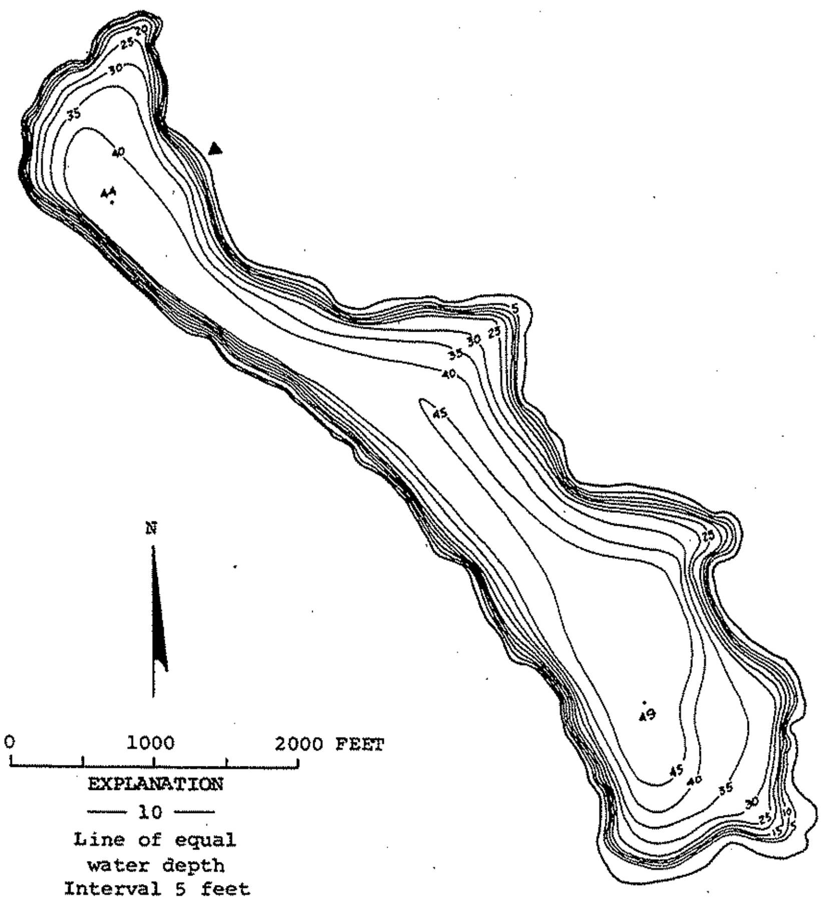
1993 Secchi Depth and Profile Data Graphs

Pearrygin Lake -- Okanogan County

Pearrygin Lake is located 1.4 miles northeast from Winthrop. It is fed by a diversion from Chewack River and several small inlets. It drains via Lake Creek to the Chewack River.

Size (acres)	210
Maximum Depth (feet)	48
Mean Depth (feet)	30
Lake Volume (acre-feet)	6,300
Drainage Area (miles^2)	11.8
Altitude (feet)	1,924
Shoreline Length (miles)	3.6

Data From Dion *et al.* (1976)



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

Overall Assessment

In 1993, Lake Pearrygin was assessed as mesotrophic, based on fair water clarity, and moderately high to high concentrations of nutrients and chlorophyll.

Other Okanogan County lakes monitored for the program in 1993 were Conconully Lake, Lake Osoyoos and Big Twin Lake. Of the monitored Okanogan County lakes, Pearrygin Lake had the highest concentrations of phosphorus and chlorophyll.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was fair, as indicated by Secchi depths that ranged from 6.6 feet to 11.0 feet. Secchi depths between 6.5 feet and 13.0 feet are typical for mesotrophic lakes.

Total Phosphorus
Total phosphorus concentrations were high in May (28 µg/L), and moderate in August (16 µg/L). Concentrations between 12 and 24 µg/L are typical for mesotrophic lakes.

Total Nitrogen
The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were both greater than 20:1, algae growth in Pearrygin Lake was not limited by nitrogen when the lake was sampled.

Profile Data
The lake was thermally stratified on both sampling dates. Below the thermocline, dissolved oxygen concentrations and pH decreased considerably with depth. These decreases probably resulted from respiration and bacterial decomposition of organic material (such as algae and aquatic plants) in the water and sediments. Conductivity, on the other hand, increased with depth below the thermocline. Conductivity indicate the ion content of the water. High conductivity probably resulted from the very low dissolved oxygen concentrations in the bottom five meters of the lake which would create conditions that cause phosphorus, iron, and other compounds in sediments to be chemically reduced and released into the water column.

Lack of oxygen also resulted in the production of hydrogen sulfide by anaerobic bacteria at the bottom of the lake. In August, hydrogen sulfide ("rotten-egg" smell) is smelled in water samples collected from 9 meters and 11 meters. Hydrogen sulfide is only produced in water that has no dissolved oxygen.

Solids
Results from solids samples are used to determine if water clarity is primarily affected by algae, or if there were suspended sediments in the water at the time of sampling. Results from solids samples indicated that most of the solids in the water were volatile (meaning carbon-based, which would include algae). Therefore, water clarity in Lake Pearrygin was probably primarily affected by algae growth and not fine sediment particles.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. The chlorophyll concentrations on both sampling dates indicated high densities of algae. The August value was particularly high (13.8 µg/L). An algae sample collected during the August onsite sampling visit contained many short filaments of *Lyngbia* sp.

Aquatic plants identified by Ecology staff during the 1993 sampling visits included waterweed (*Elodea candensis*), muskgrass (the alga *Chara*), and purple loosestrife (*Lythrum salicaria*). Muskgrass was the most abundant plant observed. Purple loosestrife is an invasive non-native wetland species that can out compete other wetland plants along the shoreline. This plant should be destroyed or contained in order to preserve other shoreline plants and habitat areas around the lake. The presence of purple loosestrife was reported to Okanogan County.

Other Available Information
From Dion (1976): water from Pearrygin Lake was used for irrigation. When the lake was sampled in 1974, there was a moderate amount of biological productivity. In July and September 1974, dissolved oxygen concentrations throughout the hypolimnion were near 0.0 mg/L.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire on lake and watershed uses.

> Pearrygin Lake is used for fishing, swimming, motor boating, rowing, jet skiing, and lakeshore camping. Public facilities on the lakeshore include a day use park, State park, two resorts, and three boat ramps. Currently, the watershed is being logged and used for crop agriculture, animal grazing, and heavy recreational use. Grazing animals have direct access to the lakeshore or inlet tributaries. In the past, the watershed was logged and used for crop agriculture and animal grazing.
>
> There are no houses on the lakeshore, and no culverts drain into the lake. There is no organization for the lake, and no lake management activities occurred in 1993. Overall, the volunteer found that Pearrygin Lake had good water quality. Problems in the lake in 1993 were ranked as (1) algae, (2) swimmer's itch, and

(3) suspended sediments. Possible sources of problems include motorboats, the high density of campers on the lakeshore (50 to 100 camp units per night during summer), and the low flushing rate of the lake.

Acknowledgment

I thank Dana Visalli for volunteering his time to monitor Pearrygin Lake during 1993.

Pearrygin Lake -- Okanogan County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	46
Mean Trophic State Index (Total Phosphorus):	48
Mean Trophic State Index (Chlorophyll *a*):	50

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
27-May				11.0		lt-green			light	Onsite visit. Lots of pollen.
13-Jun	1000	16.7	62.0	9.5		lt-green	0	trace	calm	
28-Jun	1100	19.4	67.0	9.0		lt-green	10	trace	strong	
12-Jul	1500	20.0	68.0	6.6		lt-green	75	moderate	light	
30-Jul	1300	20.6	69.0	8.0		lt-green	10	light	light	
15-Aug	1200	21.1	70.0	9.0		lt-green	90	moderate	calm	
03-Sep	1200	21.1	70.0	10.0		lt-green	0	none	calm	

1 Trophic State Indices calculated from Carlson (1977).
2 "Lake height" refers to change in water level. Lake height was not monitored in 1993.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/27	0.0	20.3	8.6	10.8	243
	1.0	20.1	8.6	11.0	243
	2.0	19.9	8.6	11.1	242
	3.0	18.9	8.7	13.5	234
	4.0	16.2	8.7	13.3	229
	5.0	13.1	8.5	6.9	255
	6.0	10.7	8.3	2.3	264
	7.0	10.0	7.9	0.1	261
	8.0	8.7	7.8	0.1	265
	10.0	8.0	7.8	0.1	268
	12.0	7.8	7.7	0.1	271
08/24	0.0	20.6	9.0	8.9	207
	2.0	20.5	9.0	8.9	207
	4.0	20.3	9.0	8.5	208
	6.0	19.2	8.4	3.4	225
	7.0	16.0	8.0	2.0	257
	8.0	13.1	7.8	0.1	281
	9.0	11.3	7.6	0.1	298
	10.0	10.6	7.5	0.1	306
	12.0	9.7	7.3	0.1	330

1993 Onsite Visit Data - Water Chemistry

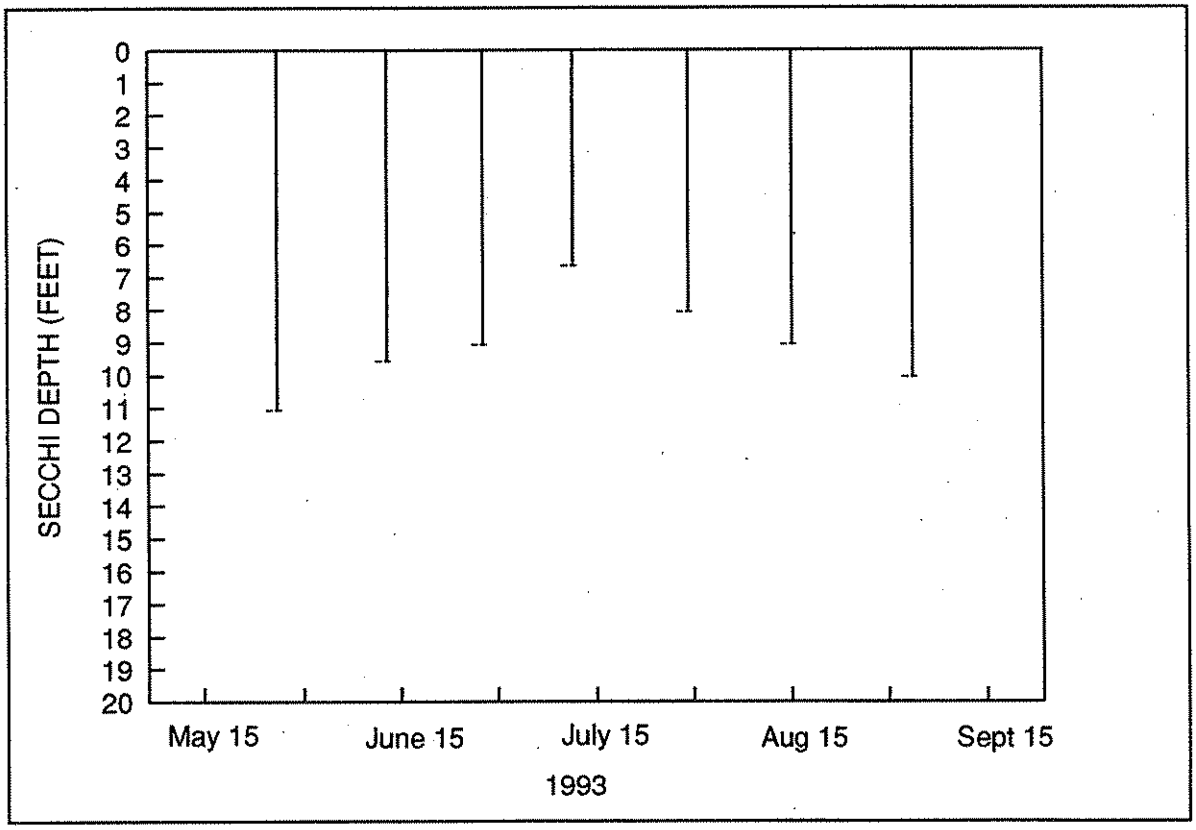
	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 27 Epilimnion	28	0.64	3.9	3	1	--	--
Hypolimnion	52	1.07	--	--	--	--	--
August 24 Epilimnion	16	0.45	13.8	3	1	--	--
Hypolimnion	36	1.52	--	--	--	--	--

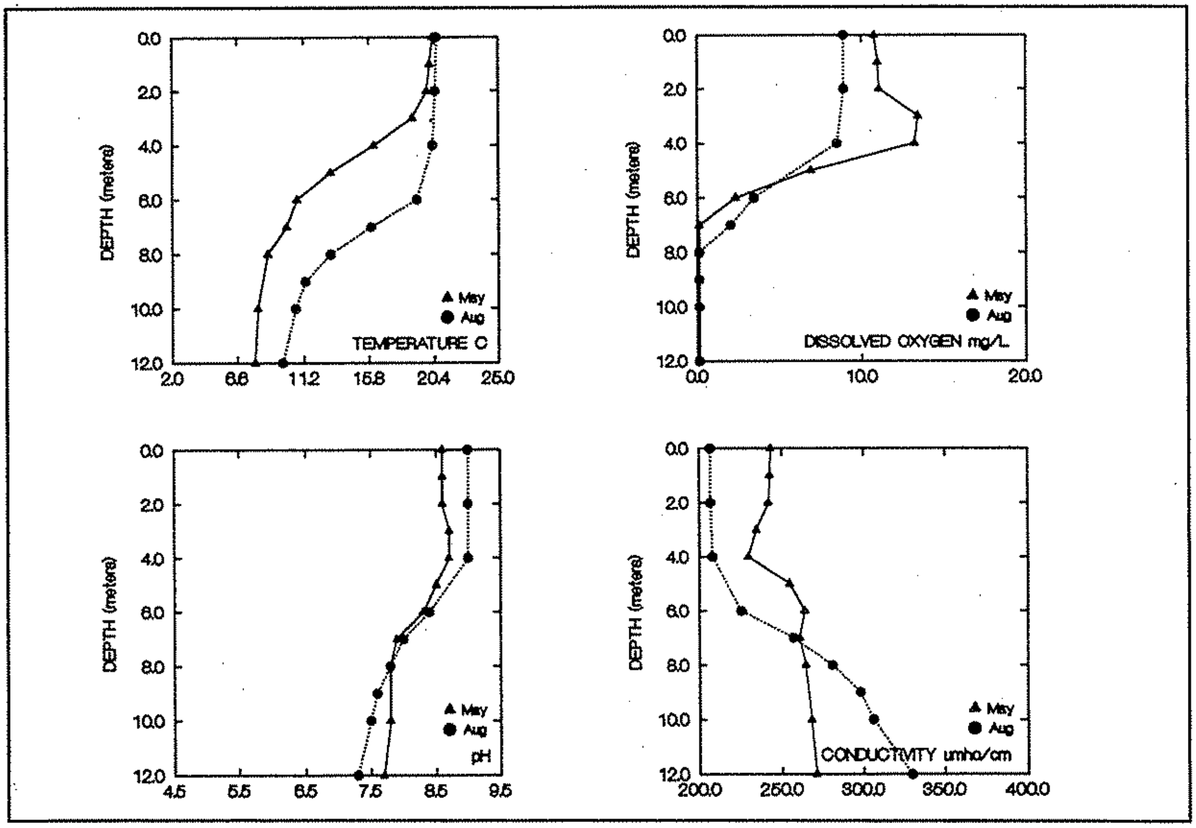
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (μg/L)
07/15/74[a]	12	--	1.6
09/23/74[a]	7	--	1.6

a. Dion *et al.* (1976)

PEARRYGIN LAKE (OKANOGAN COUNTY)





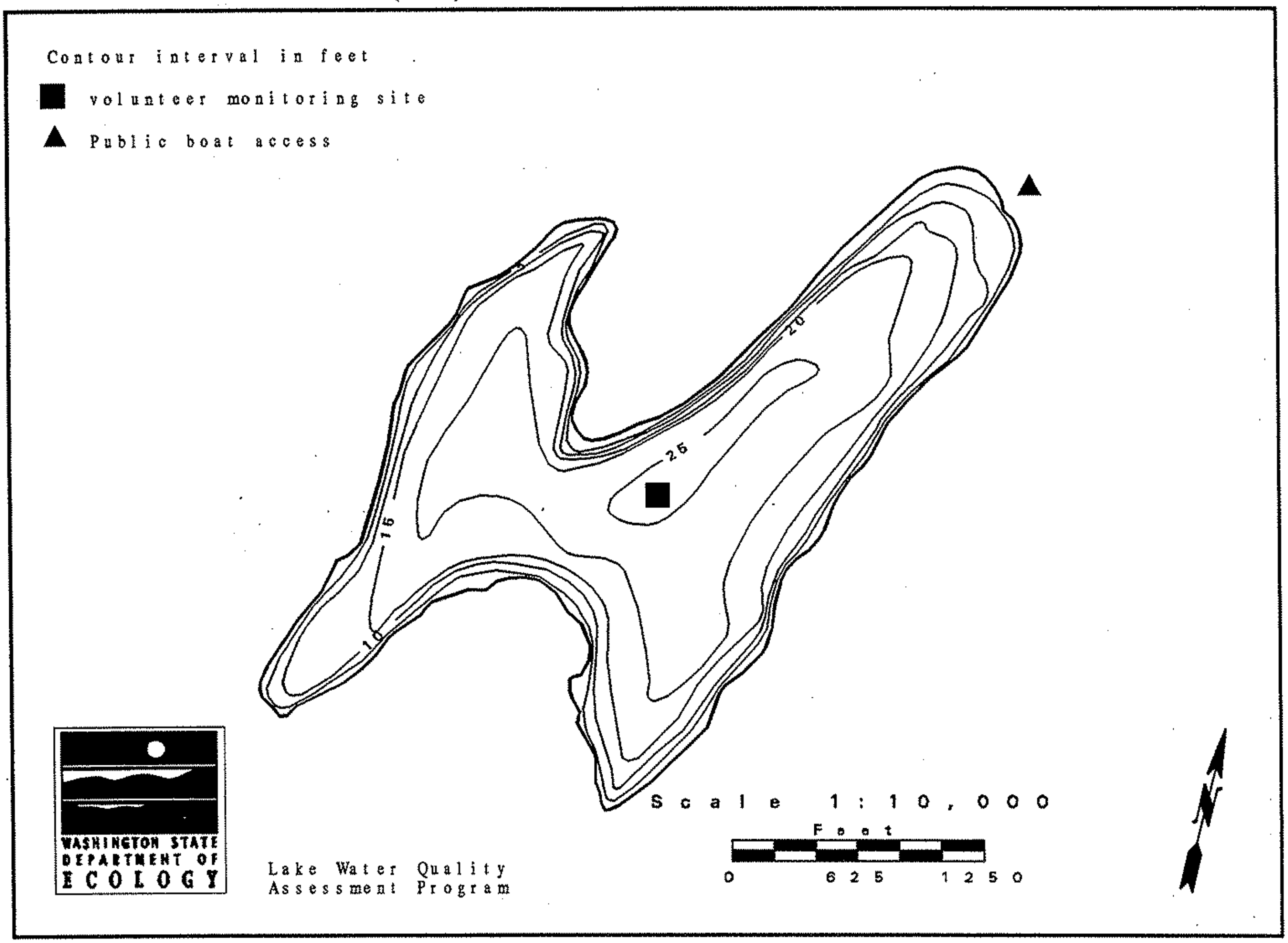
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, Phillips Lake was assessed as mesotrophic, based on moderately high concentrations of total phosphorus, and a full algal bloom. Assessments of Phillips Lake since 1989 have alternated between mesotrophic and oligo-mesotrophic, mainly because data results for all parameters were in the range that borders between oligotrophy and mesotrophy.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in 1993 was good as indicated by Secchi depths which ranged from 11.5 feet to 17.5 feet. Secchi depths between 6.5 feet and 13.0 feet are typical of mesotrophic lakes. In general, Secchi depths in 1993 were deeper than in 1992 and 1991. Despite this improvement in water clarity during 1993, there was no statistically significant trend in water clarity from 1989 to 1993.

Total Phosphorus

The concentration of total phosphorus was moderately high in May (21 µg/L), and was moderately low in August (12 µg/L). Concentrations between 12 and 24 µg/L are typical for mesotrophic lakes. The August concentration was similar to concentrations measured for the program in 1990 and 1992, but the May concentration was higher than previously measured.

Total Nitrogen

The concentrations of total nitrogen were moderately low on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the total nitrogen to total phosphorus ratio was 14.5:1 and 25:1, algae growth in Phillips Lake was probably phosphorus-limited.

Profile Data

The lake was not thermally stratified on either sampling date. As a result, there was very little change in DO, pH, and conductivity profile data from surface to bottom. The lake was not stratified when it was monitored for the program in 1992, 1991, and 1990.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. On both sampling dates, chlorophyll concentrations in Phillips Lake indicated low densities of algae.

A lakeshore resident called and reported that there was a blue-green algae bloom during September 1993. Algae problems occurring after the August onsite sampling visit. This also happened in 1992, which suggests that chlorophyll samples collected in May and August do not reflect the productivity of the lake. 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*. In both June and November 1991, algal blooms consisted of *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.).

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 1993, 1992, 1990, and 1989.

> 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 one percent of the shoreline is publicly-owned. There are five culverts that drain into the lake. Rainbow trout were stocked in the lake in 1993. Currently the watershed is being logged, and the lakeshore is being developed further for residences. In the past, the watershed was logged 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 154 houses on the lakeshore, and none of the houses are connected to a sewer. Lake water is withdrawn for drinking and other domestic uses. There is a lake association for the lake. Currently, the minimum setback for lakeshore development is 15 feet, and minimum lot size is 12,500 square feet (zoning for lot sizes depends on soil type). No lake management activities occurred in 1993.
>
> Overall, the volunteer found that Phillips Lake had good water quality. Problems in the lake in 1993 were ranked as (1) algae and (2) shoreline erosion. The algae bloom was localized near the boat launch. In comparison to the 1992 monitoring season, there were four new lakeshore homes and a few more lots were logged and cleared. Algae has been the worst problem in the lake since 1989.

Acknowledgment

I thank James Keeley and Gaylord Kidney for volunteering their time to monitor Phillips Lake in 1993.

Phillips Lake -- Mason County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	40
Mean Trophic State Index (Total Phosphorus):	44
Mean Trophic State Index (Chlorophyll *a*):	28

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
01-May	1300	13.3	56.0	15.5	6.00	lt-green	25		moderate	
15-May	1200	18.9	66.0	13.5	8.00	lt-green	10	none	light	
28-May	1120	20.6	69.0	17.5	9.50	lt-green	25	trace	light	
15-Jun	1300	20.0	68.0	15.0	9.50	lt-green	50	light	light	Light rain.
01-Jul	1200	19.4	67.0	12.0	11.00	green	75	light	light	
16-Jul	1400	18.9	66.0	13.0	12.50	lt-green	90	moderate	light	
02-Aug	1200	20.6	69.0	13.0	14.00	lt-green	10	trace	light	
16-Aug	1215	19.4	67.0	12.5	16.00	lt-green	100	light	light	Light rain now.
02-Sep	1100	20.0	68.0	13.0	19.00	lt-green	25		light	
15-Sep	1300	20.0	68.0	12.0	20.50		50	trace	light	Water color light milky green. Blue-green algae bloom early this week.
01-Oct	1215	18.3	65.0	11.5	23.00	lt-green	10	none	light	Sunny.
15-Oct	1230	15.6	60.0	14.0	24.00	lt-green	90	moderate	calm	
30-Oct	1400	12.2	60.0	12.0	23.00	lt-green	50	trace	light	

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Phillips Lake dropped 17" from May 1 to October 30.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/28	0.0	20.4	8.0	8.4	21
	1.0	19.9	7.9	8.5	21
	2.0	19.8	7.8	8.6	21
	3.1	19.7	7.7	8.6	21
	4.1	19.5	7.6	8.5	21
	5.0	17.5	7.6	8.9	21
	5.5	17.0	7.4	8.4	21
09/0	0.0	21.4	7.2	9.5	23
	0.9	21.2	7.1	8.7	23
	2.0	21.2	7.1	8.7	22
	3.0	21.1	7.0	8.6	22
	4.0	21.1	7.0	8.6	23
	5.0	20.9	7.0	8.2	23

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 28 Epilimnion	21	0.31	0.6	--	--	--	--
Hypolimnion*							
September 2 Epilimnion	12	0.31	1.0	--	--	--	--
Hypolimnion*							

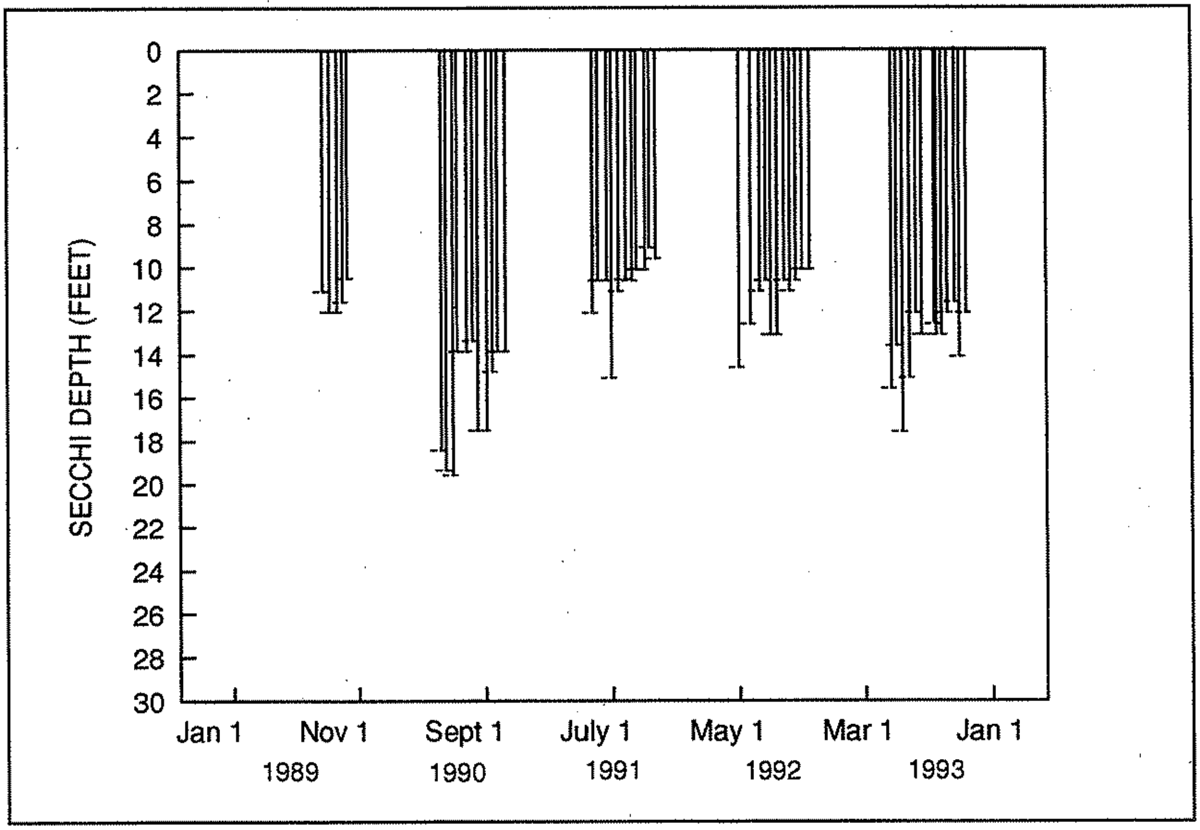
* The lake was not stratified at the time of sampling; only one set of samples was collected

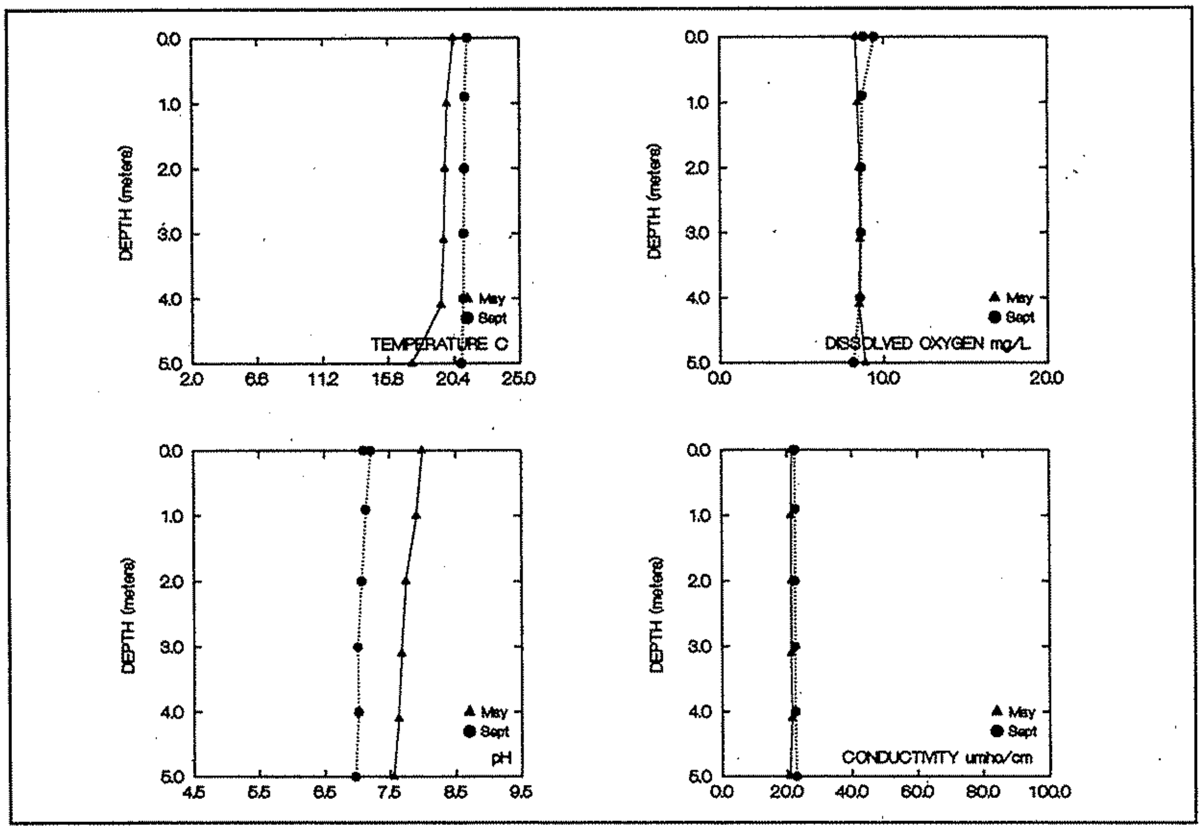
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
06/29/72[a]	15	--	2.2
05/24/90[b]	13	0.30	--
08/15/90[b]	13	0.49	--
05/21/91[c]	--	0.27	--
06/02/92[d]	8	0.30	0.8
08/26/92[d]	11	0.38	1.2

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)

PHILLIPS LAKE (MASON COUNTY)





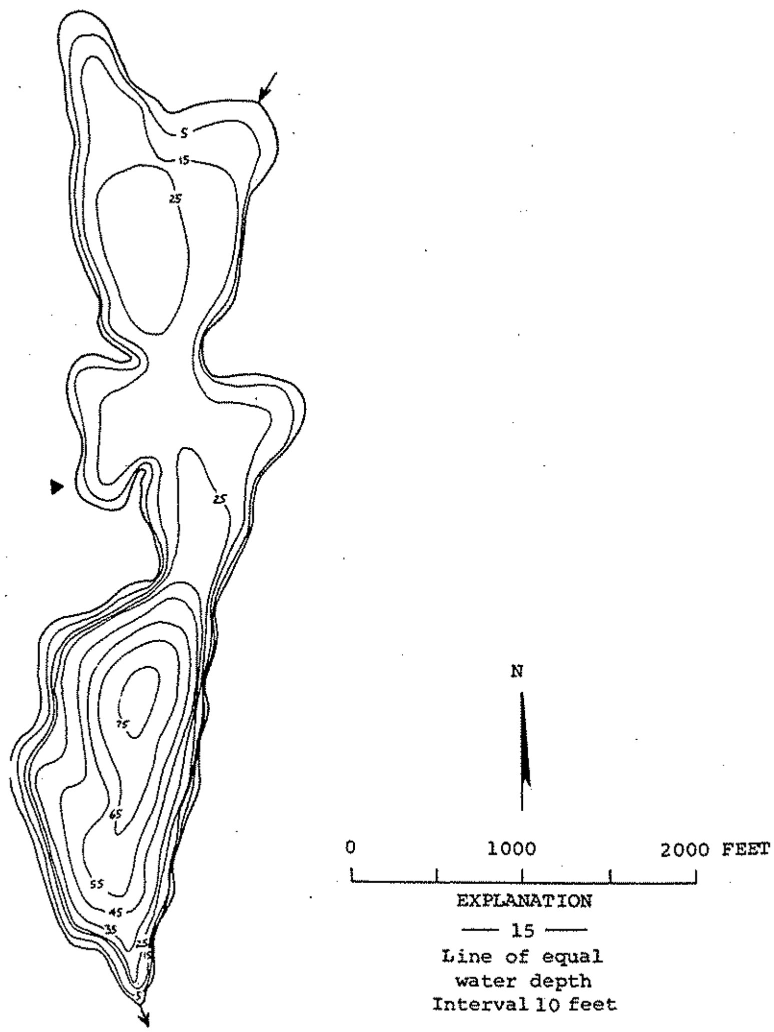
1993 Secchi Depth and Profile Data Graphs

Lake Pierre -- Stevens County

Lake Pierre is located four miles northeast of Orient, in the headwaters of Toulou Creek. It is about one mile long. It is fed by Pierre Creek, and drains via Toulou Creek to Little Pierre Lake and the Kettle River.

Size (acres)	110
Maximum Depth (feet)	75
Mean Depth (feet)	28
Lake Volume (acre-feet)	3,000
Drainage Area (miles^2)	26.8
Altitude (feet)	2,005
Shoreline Length (miles)	2.9

Data From Dion *et al.* (1976)



Pierre Lake, Stevens County. From Washington Department of Game, January 13, 1947.

Overall Assessment

In 1993, Lake Pierre was assessed as oligo-trophic, because it exhibited oligotrophic and mesotrophic characteristics. Oligotrophic characteristics were the good water clarity and low concentrations of total phosphorus and chlorophyll during August. Mesotrophic characteristics include the moderately high concentrations of total phosphorus and chlorophyll in May, the low concentrations of dissolved oxygen in the entire lower layer of water, and the presence of hydrogen sulfide in water samples collected from the lake bottom.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good, as indicated by Secchi depths that ranged from 11.6 feet to 20.0 feet. Secchi depths greater than 13.0 feet indicate good water clarity, and are typical of oligotrophic lakes.

Total Phosphorus

The concentration of total phosphorus in the upper layer of water (the epilimnion) was moderately high in May (15 µg/L), and was very low in August (5 µg/L). Concentrations less than 12 µg/L are low, and are typical for oligotrophic lakes.

In the lower layer of water (the hypolimnion), total phosphorus concentrations were considerably higher than in the epilimnion. It is likely that the very low dissolved oxygen concentrations in the lower layer of water created conditions that allowed phosphorus, iron, and other compounds in the sediments to be chemically reduced and released into the water column (see Profile Data, below).

Total Nitrogen

The concentrations of total nitrogen (in the epilimnion) were moderately low on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae usually need at least 10 times the amount of nitrogen as phosphorus. Because the total nitrogen to total phosphorus ratios were 16.6 and 45 in the epilimnion, algae growth in Lake Pierre was not limited by nitrogen.

Profile Data

The lake was thermally stratified on both sampling dates. Below the thermocline, the concentrations of dissolved oxygen decreased considerably and oxygen was depleted in the entire bottom layer of water. This condition is not a characteristic of oligotrophic lakes. Oxygen is usually depleted by bacteria that use oxygen as they decompose algae and organic material in the water and sediment. Low oxygen in the hypolimnion of Lake Pierre is not a new phenomena. Bortleson *et al.* (1976) reported very low oxygen concentrations throughout the hypolimnion from April through September 1972.

In 1993, the lack of oxygen in the lower layer of water created an environment that would cause phosphorus to be released from the sediments into the water column, as well as creating conditions that allow hydrogen sulfide ("rotten-egg" smell) to be produced in the water. Hydrogen sulfide was smelled in water samples collected from 12 meters and 16 meters in May, and at 10 meters in August. Hydrogen sulfide is stable only in the absence of oxygen.

The very low oxygen concentrations probably restrict fish habitat in the lake, because trout species generally prefer at least 4.5 mg/L dissolved oxygen. As a result, fish are probably limited to the top five meters of water during stratification.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. The concentration of chlorophyll in May indicated a moderately high density of algae at the time of sampling. In August, the chlorophyll concentration (and the phosphorus concentration) indicated a low density of algae.

Aquatic plants identified by Ecology staff during the August sampling visit were iris (*Iris pseudacorus*), milfoil (*Myriophyllum*, but not the aggressive Eurasian variety), pondweed (*Potamogeton pectinatus*), cattails (*Typha*), duckweed (*Lemna minor*), and muskgrass (the alga *Chara*).

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire on lake and watershed uses.

> Lake Pierre is used for fishing, swimming, motor boating, rowing, jet skiing, lakeshore camping, and waterfowl hunting. Public facilities on the lakeshore include a day use park and one boat ramp. There are no restrictions for motor boat use on the lake. Currently, the watershed is being logged and used for agriculture and animal grazing. The lakeshore is also being developed further for residences. In the past, the watershed was logged and used for agriculture and animal grazing.
>
> There are four houses on the lakeshore, and none are connected to a sewer collection system. No culverts drain into the lake. There is no organization for the lake, and no lake management activities occurred in 1993.

Overall, the volunteer found that Lake Pierre had good water quality. Problems in the lake in 1993 were ranked as (1) shoreline erosion, (2) degraded aesthetics, (3) excessive aquatic plant growth, and (4) algae. Possible sources of problems include cattle grazing, and litter in lake from lake users. The volunteer also noted that Lake Pierre is very beautiful, and not overused or overbuilt with residences.

Acknowledgment

I thank Kathy Chapman for volunteering her time to monitor Lake Pierre in 1993.

Pierre Lake -- Stevens County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	36
Mean Trophic State Index (Total Phosphorus):	35
Mean Trophic State Index (Chlorophyll *a*):	38

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
24-May				11.6		lt-green		heavy	light	Onsite visit.
15-Jun	1140	17.8	64.0	19.0		lt-green	50	light	light	Very beautiful yellow flowers all around shore; like lilies.
28-Jun	1320	17.8	64.0	20.0		lt-green	75	trace	calm	
13-Jul	1530	19.4	67.0	18.0		lt-green	75	moderate	calm	Fourth of July bottle rockets on lake bottom by shore. Yellow flowers gone. Lots of fish!
28-Jul	1430	20.0	68.0	17.0		pea-green	25	trace	breezy	Very nice day - 85 degrees.
10-Aug	1125	20.0	68.0	18.0	-4.00	pea-green	75	none	calm	
14-Sep	1230	16.7	62.0	20.0	-5.00	lt-green	90	moderate	light	

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

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Pierre Lake dropped 1" from August 10 to September 14.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/24	0.0	19.4	8.1	10.0	332
	1.0	17.5	8.1	10.2	330
	2.0	16.9	8.1	10.2	332
	3.0	16.0	8.1	10.4	334
	4.0	12.9	8.1	10.2	340
	5.0	11.0	8.0	8.2	346
	6.0	9.1	7.9	1.9	358
	7.0	7.9	7.7	0.3	362
	8.0	7.1	7.7	1.2	364
	10.0	6.5	7.6	0.2	370
	15.0	5.5	7.5	0.2	380
	20.0	5.3	7.3	0.1	392
08/23	0.0	20.2	8.5	8.5	352
	1.0	20.2	8.5	8.5	352
	2.0	20.2	8.5	8.6	352
	3.0	20.2	8.5	8.5	357
	4.0	18.8	8.4	8.3	366
	5.0	16.8	8.2	5.8	388
	6.0	13.0	7.9	0.4	402
	7.0	11.5	7.8	0.2	396
	8.0	9.4	7.7	0.1	390
	9.0	7.9	7.6	0.1	390
	10.0	6.6	7.6	0.1	394
	12.0	6.0	7.5	0.1	398
	14.0	5.8	7.5	0.1	400

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 24 Epilimnion	15	0.25	3.3	--	--	--	--
Hypolimnion	75	0.79	--	--	--	--	--
August 23 Epilimnion	5	0.23	1.4	--	--	--	--
Hypolimnion	63	0.74	--	--	--	--	--

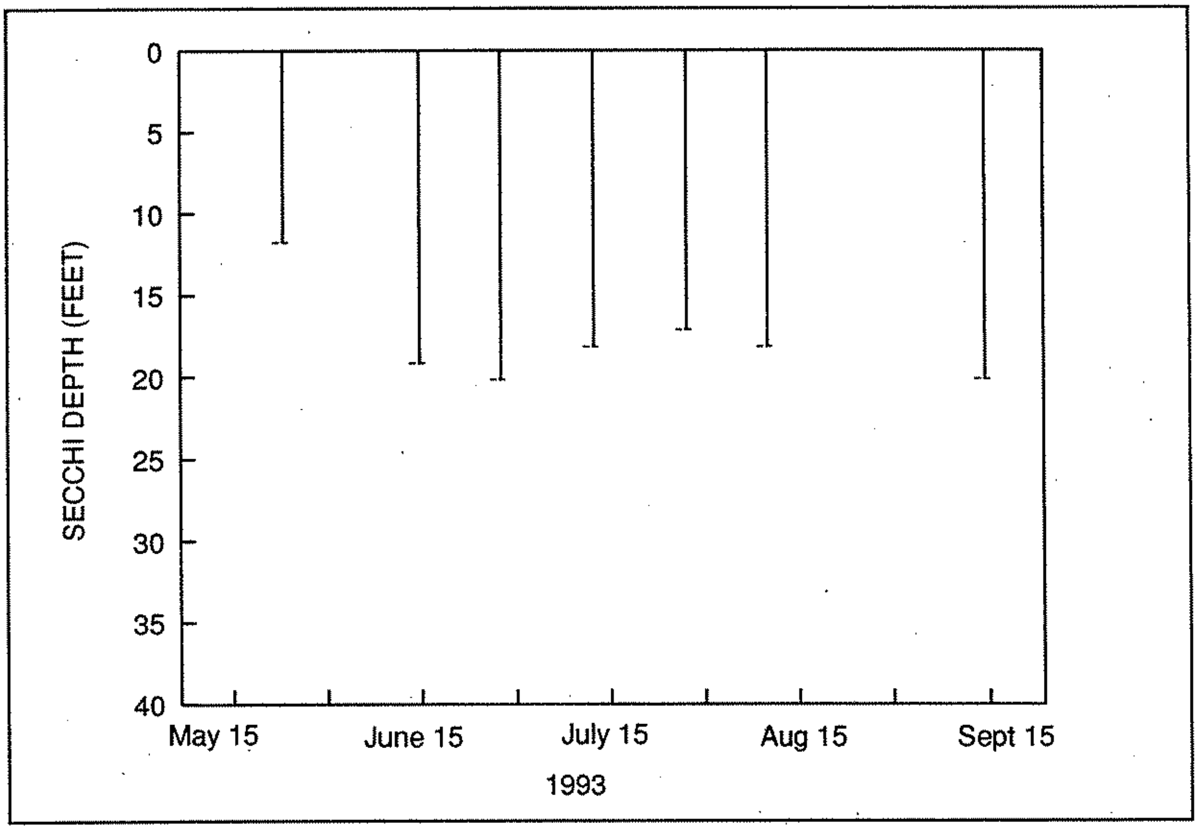
Pierre Lake -- Stevens County

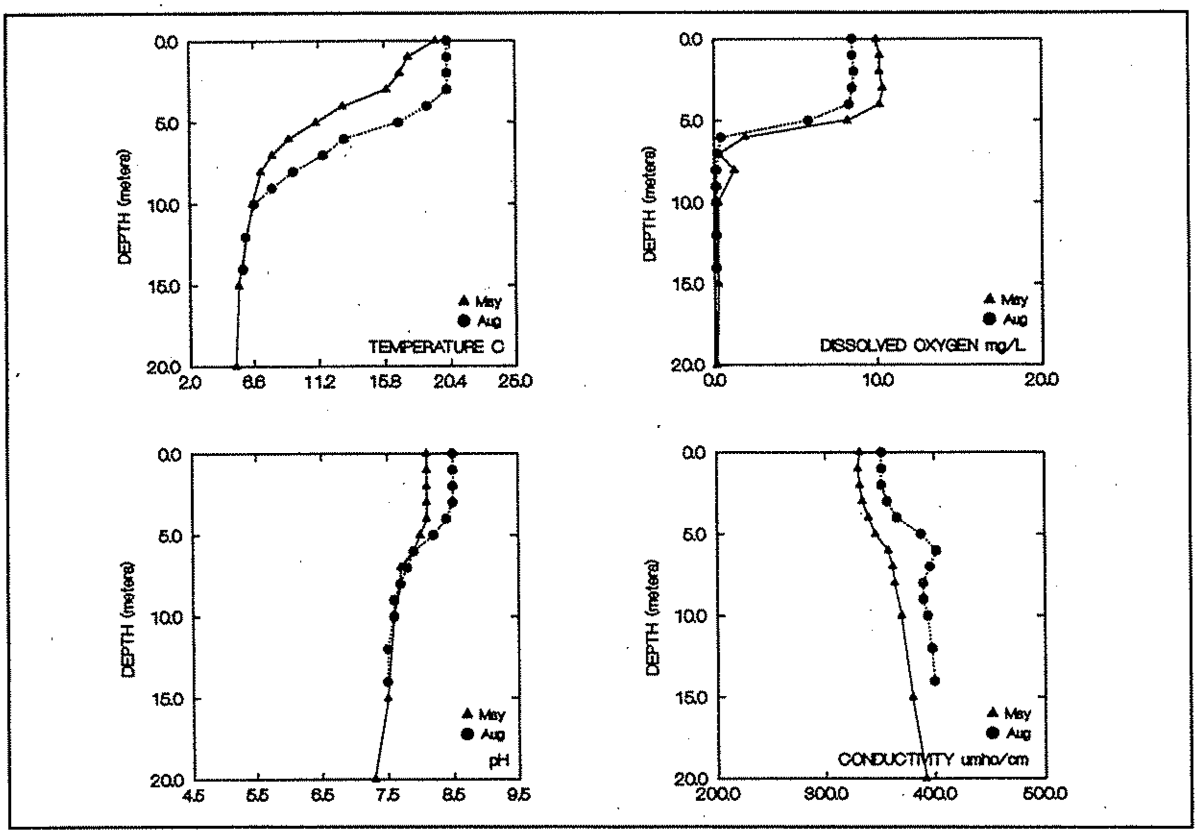
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
08/17/72[a]	11	--	3.7
09/28/72[a]	37	--	23.2

a. Bortleson *et al.* (1976)

LAKE PIERRE (STEVENS COUNTY)





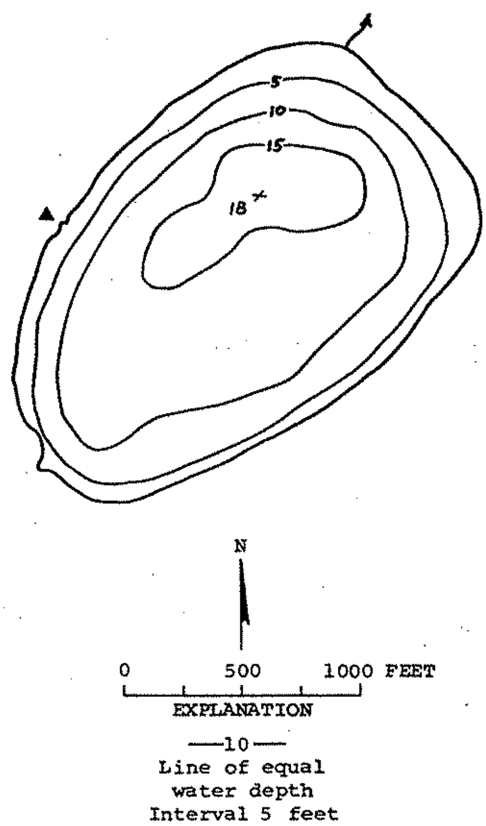
1993 Secchi Depth and Profile Data Graphs

Rapjohn Lake -- Pierce County

Rapjohn Lake is located 4.5 miles northwest of Eatonville. It has no surface inlets, and drains to Tanwax Creek and the Nisqually River.

Size (acres)	56
Maximum Depth (feet)	18
Mean Depth (feet)	10
Lake Volume (acre-feet)	550
Drainage Area (miles^2)	1.3
Altitude (feet)	632
Shoreline Length (miles)	1.1

Data From Bortleson *et al.* (1976)



Rapjohn Lake, Pierce County. From Washington Department of Game, date unknown.

Overall Assessment

In 1993, Rapjohn Lake was assessed as meso-eutrophic, because it exhibited both mesotrophic and eutrophic characteristics. Mesotrophic characteristics were the fair water clarity and the moderately high amounts of algae and aquatic plants. Eutrophic characteristics include the high nutrient concentrations, low concentrations of dissolved oxygen near the lake bottom, and the likelihood that phosphorus was released from the sediment into the water column.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was fair as indicated by Secchi depths that ranged from 6.0 feet to 9.0 feet. Water clarity in Rapjohn Lake was better than would be expected, given the high densities of algae and the reddish brown water color. Secchi depths between 6.5 feet and 13.0 feet are typical for mesotrophic lakes.

Total Phosphorus
The concentrations of total phosphorus were high on both sampling dates (43 µg/L in June, and 31 µg/L in August). Concentrations greater than 24 µg/L are high and are typical for eutrophic lakes. In June, the water sample collected from the lake bottom had a very high concentration of total phosphorus. The phosphorus probably came from the sediment; when oxygen near the lake bottom is very low, phosphorus can be released into the water column (see Profile Data, below).

Total Nitrogen
Concentrations of total nitrogen were high on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the total nitrogen to total phosphorus ratios were 24:1 and 30:1 in the epilimnion, algal growth in Rapjohn lake was not limited by nitrogen.

Profile Data
On both sampling dates, the lake was weakly stratified with respect to temperature. Dissolved oxygen and pH decreased with depth, most likely from bacteria that use oxygen as they decompose algae and aquatic plants in bottom water and sediments. Conductivity increased with depth, most likely from the release of ions from sediment; as with total phosphorus (see Total Phosphorus, above), iron and other compounds can be released from sediment when oxygen concentrations over the sediment are very low.

Solids
Results from solids samples are used to evaluate whether Secchi depths were affected primarily by algae, or if suspended sediments affected water clarity at the time of sampling. Results from solids samples were low, indicating that Secchi depths were probably affected primarily by algae when the lake was sampled in June.

Fecal Coliform Bacteria
Samples for fecal coliform were collected at two nearshore sites in June. Site #1 was located at the volunteer's sampling site, and Site #2 was located at the public access. The result from Site #1 was low. The result from Site #2 was high (210 colonies/100 mL) and was reported to Ecology's regional office. The state water quality standard for fecal coliform in Lake Class water is a geometric mean of 50 colonies/100/mL, with not more than 10% of the samples exceeding 100 colonies/100 mL.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Chlorophyll concentrations from Rapjohn Lake indicated high densities of algae at the time of sampling. Large plankton and zooplankton were observed in the water on both sampling dates.

Aquatic plants identified by Ecology staff included yellow-flowering water lilies (*Nuphar*), cattails (*Typha*), sedge (*Dulichium arundinaceum*), largeleaf pondweed (*Potamogeton amplifolius*), ribbonleaf pondweed (*Potamogeton epihydrus*), waterweed (*Elodea canadensis*), and the alga *Nitella*. Cattails and water lilies were observed along the entire shore. A freshwater sponge was also retrieved on the plant sampler.

Other Available Information
The volunteer reported that on October 3, there was a makeshift mooring buoy about 50 feet from the boat launch that appeared to have been made with an old railroad tie. A surface film on the lake covered about 20% of the lake surface, and according to the volunteer, could have been creosote from the railroad tie. The volunteer removed the buoy from the lake. On the October 30 sampling date, the volunteer noted that there was less surface film on the water.

From Bortleson *et al.* (1976): When the lake was sampled in 1973, water color was tea-brown, and dissolved oxygen was 0.2 mg/L at the lake bottom. Emergent plants (such as cattails) covered the shoreline in a thin band around the lake.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire on lake and watershed uses.

Rapjohn Lake -- Pierce County

Rapjohn Lake used for fishing and motor boating. There is one boat ramp on the lakeshore. Rainbow trout were stocked in the lake in 1993. Currently, the watershed is used mainly for animal grazing, although grazing animals do not have direct access to the lakeshore or inlet tributaries.

There is one house on the lakeshore, which is not connected to a sewer collection system. There are no culverts which drain into the lake. The volunteer did not know if there is a lake organization for the lake, whether lake management activities occurred in 1993, or if water was withdrawn from the lake for any uses.

Overall, the volunteer found that Rapjohn Lake had good water quality. Problems in the lake in 1993 were ranked as (1) hazardous substances (oil and creosote films from logs which were dumped into the lake), and (2) bacteria. Motorboats present additional potential problem sources to the lake.

Acknowledgment

I thank Ron Zarges for volunteering his time to monitor Rapjohn Lake in 1993.

Rapjohn Lake -- Pierce County

1993 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	48
Mean Trophic State Index (Total Phosphorus):	56
Mean Trophic State Index (Chlorophyll *a*):	49

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
06-Jun	1020			6.0		rust	100			
19-Jun	1200	22.0	71.6	6.5	15.00		75	none	light	Water color reddish brown.
04-Jul	1130	19.0	66.2	7.0	16.50		100	trace	light	Water color orange brown.
17-Jul	1330	21.0	69.8	6.3	20.00		75	trace	light	Water color orange-brown.
31-Jul	1600	25.0	77.0	6.5	21.00		0		light	Water color amber (reddish brown).
14-Aug	1500	22.0	71.6	8.0	24.00		100	trace	light	Water color amber (reddish-brown).
28-Aug	1220	20.0	68.0	9.0			90		light	Water color red-brown. Onsite visit.
03-Oct	1100	18.0	64.4	7.5	29.75		0	none	calm	Water color orange-brown.
30-Oct	1200	16.0	60.8	7.0	29.00		10	trace	calm	Much less creosote on water surface.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
06/06	0.0	19.7	7.3	8.2	77
	1.1	19.5	7.1	7.3	77
	2.0	16.1	7.1	5.2	77
	3.0	13.5	6.9	1.4	82
	4.0	12.1	6.9	0.9	104
	4.4	12.0	6.9	0.7	107
08/28	0.0	20.2	6.8	8.6	78
	1.0	19.6	6.8	8.0	78
	3.0	15.2	6.5	0.4	99
	4.0	13.8	6.6	0.3	133

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Rapjohn Lake dropped 14" from June 19 to October 30.

Rapjohn Lake -- Pierce County

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 6							
Epilimnion	43	1.03	6.5	2	1	2	210
Hypolimnion	183	1.11	--	--	--	--	--
August 28							
Epilimnion	31	0.94	7.0	--	--	--	--
Hypolimnion*							

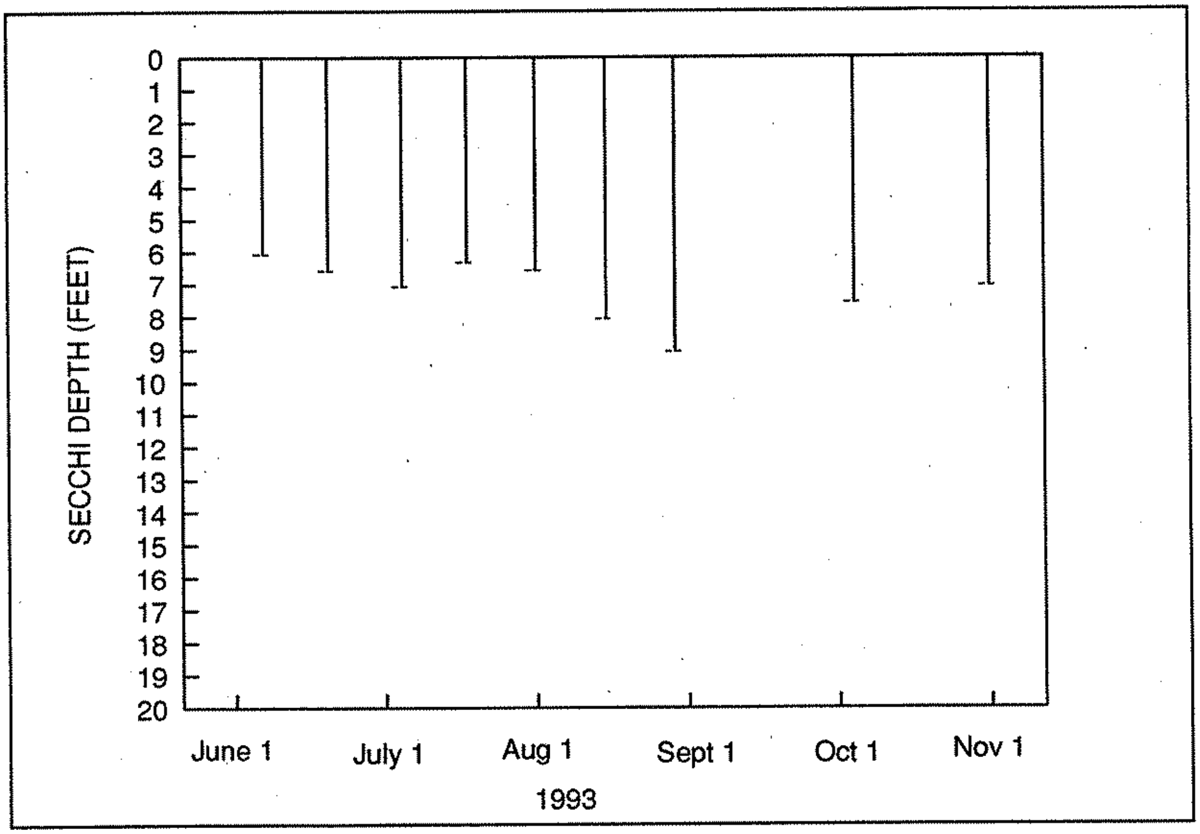
* Only one set of water samples was collected.

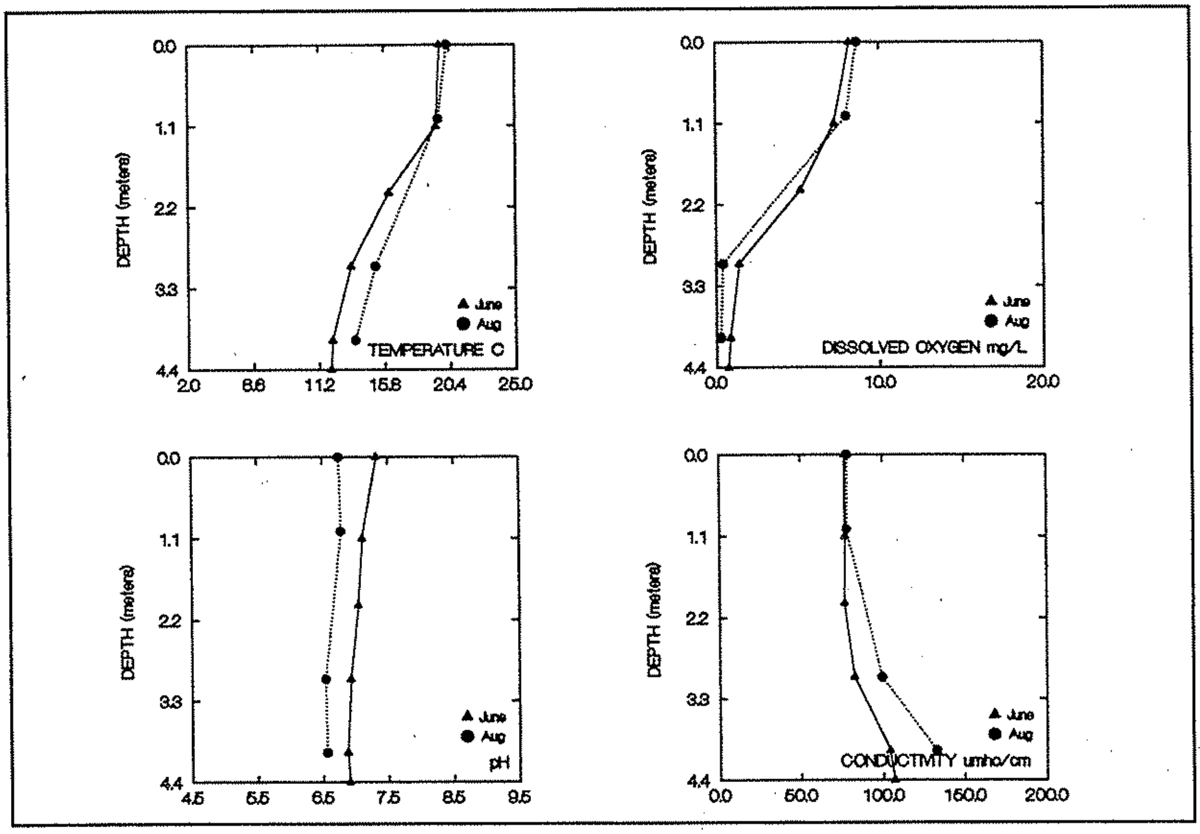
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
08/11/73[a]	24	--	--

a. Bortleson *et al.* (1976)

RAPJOHN LAKE (THURSTON COUNTY)





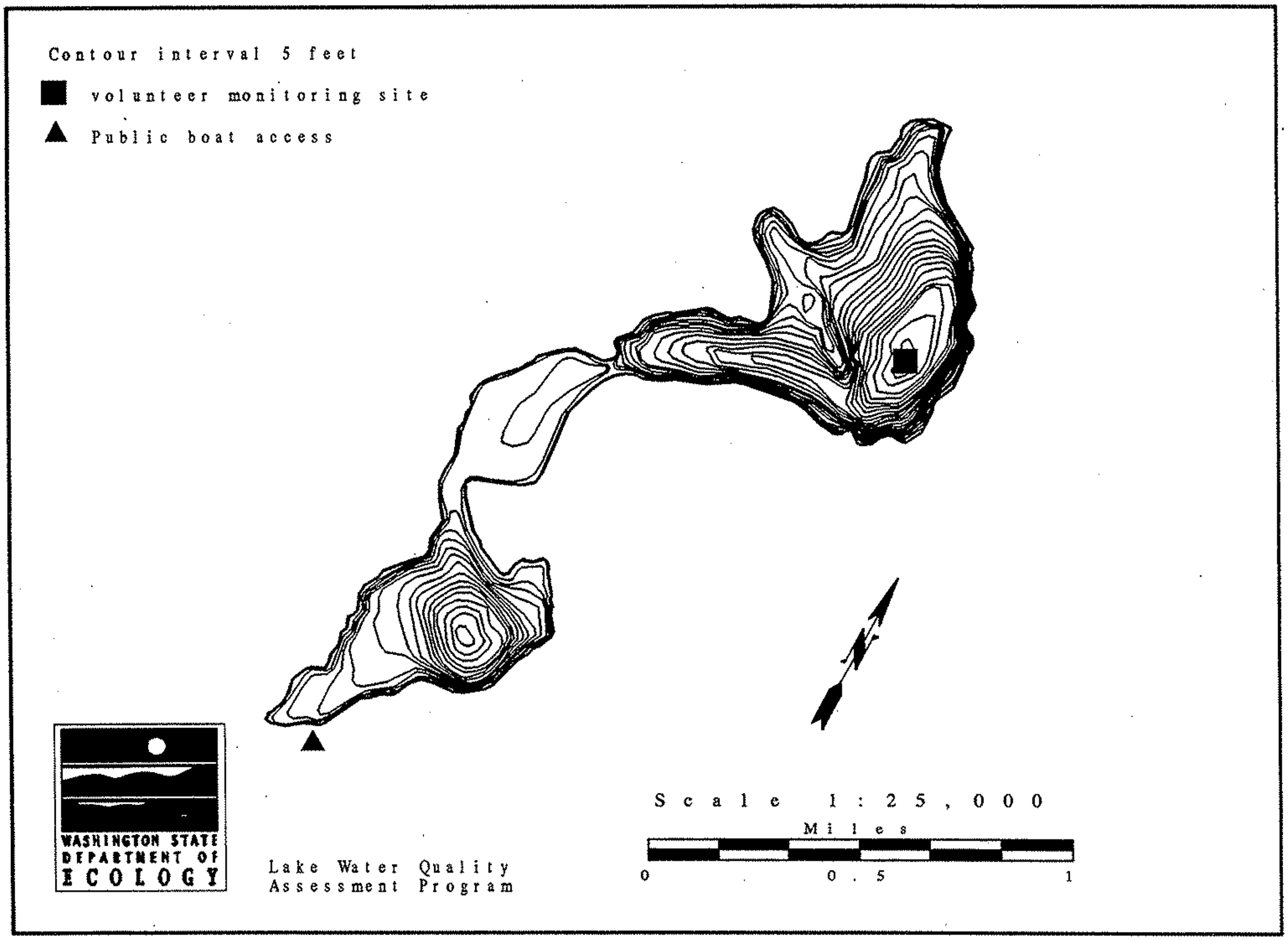
1993 Secchi Depth and Profile Data Graphs

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 basins. 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.

	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

Data From Bortleson *et al.* (1976)



Overall Assessment

In 1993, Lake Roesiger was assessed as oligo-mesotrophic. Both basins of Lake Roesiger had very good water clarity. Water samples and profile data were collected from the north basin in May and August. Except for one high phosphorus sample collected from the epilimnion in May (see Total Phosphorus, below), nutrient concentrations and algal densities were low and were in the ranges associated with oligotrophic lakes. However, Lake Roesiger had very low concentrations of dissolved oxygen in the hypolimnion, which is not an oligotrophic characteristic. Data collected by the Association of Lake Roesiger Property Owners during 1993 also indicated that water clarity in both basins was good, nutrient concentrations were low, and algal densities were in the range that is borderline between oligotrophy and mesotrophy. They also assessed both basins as oligo-mesotrophic.

1993 Monitoring Results/Summary of Other Available Information

Water samples were collected from the north basin only in 1993. Volunteers measured Secchi depth and surface temperature in both basins.

Secchi Depths
Water clarity was very good in 1993. Secchi depths in the north basin ranged from 14.0 to 27.0 feet, and from 16.0 to 23.0 feet in the south basin. Secchi depths greater than 13.0 feet indicate good water clarity, and are typical for oligotrophic lakes.

Total Phosphorus
In May, the result for the epilimnetic total phosphorus (TP) sample was very high (112 µg/L). The result from a second sample (field split) was sent to a different laboratory and the result was 150 µg/L. The result from a third sample collected by the volunteers on the same date at the same sampling depths (they expanded their monitoring program to include water sampling, but they use a different lab), was 2 µg/L. The high TP results for Ecology's two epilimnion samples could have been caused by a contaminated sampling bottle (although this seems unlikely; the hypolimnion sample result was not unusual). Ecology's results for May are unexplained, and will be considered as errors.

In August, epilimnetic TP was very low (4 µg/L), which was very similar to the result for the volunteer's sample collected at the same depths (6 µg/L). Results from 1993 were very similar to results from epilimnion samples collected at the north basin site in 1992 (5 µg/L and 6 µg/L). Epilimnetic TP concentrations less than 12 µg/L are typical for oligotrophic lakes.

Total Nitrogen

Epilimnetic total nitrogen in the north basin was moderately high on both sampling dates (0.36 mg/L in May, and 0.20 mg/L in August). Results were similar to values measured in 1992 and 1990.

Profile Data

The north basin was stratified on both sampling dates. Below the thermocline, both pH and dissolved oxygen concentrations decreased considerably with depth. Similar profile data were also measured in 1992. Although dissolved oxygen concentrations probably decreased from bacterial decomposition and respiration in the water and sediments, it is possible that in addition, the lake does not fully mix during turnover. As a result, the hypolimnion would not get completely mixed with oxygenated water from the epilimnion. Data collected by the Association of Lake Roesiger Property Owners indicated that the highest dissolved oxygen concentration in the hypolimnion was 6.0 mg/L during March 1993, which is much lower than would be expected if the lake had fully turned over.

The metalimnion of each basin was at about 4 to 10 meters. At depths of 4 to 6 meters, dissolved oxygen increased considerably compared to epilimnion concentrations. This increase most likely occurred from the corresponding decrease in water temperature at these depths because dissolved gases are more soluble in cold water than in warm water. Increased algal growth could also increase dissolved oxygen concentrations, but this is not likely, due to low nutrient concentrations measured in both the epilimnion and hypolimnion. The pH increase through the metalimnion is from the increased oxygen concentrations; pH will change in response to small changes in dissolved oxygen when water has low conductivity and low alkalinity (see Other Available Information, below). When oxygen concentrations are depleted in the hypolimnion, microbial breakdown of organic sulfur compounds can produce hydrogen sulfide. Hydrogen sulfide was smelled in samples collected by a volunteer while collecting water samples for the Association of Lake Roesiger Property Owners in 1992, as well as by Ecology staff. Hydrogen sulfide was not smelled in water samples collected by Ecology in 1993.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Concentrations of chlorophyll *a* (1.3 µg/L in May, and 2.3 µg/L in August) indicated low densities of algae. Chlorophyll concentrations measured for the program in 1992 were very low in both basins. Chlorophyll concentrations less than 2.6 µg/L are typical for oligotrophic lakes.

Chlorophyll *a* and pheophytin results from the Association of Lake Roesiger Property Owners from January through December 1993 ranged from 0.3 to 5.9 µg/L in the north basin, and from 0.6 to 5.7 µg/L in the south basin. Mean concentrations for May through October were 2.5 µg/L in the north basin, and 2.9 µg/L in the south basin. These values are in the range that is borderline between oligotrophy and mesotrophy. The highest concentrations were measured in

October 1993, which is not unusual because several lakes in the program had blue-green algae blooms during fall. Lake Martha (near Stanwood) in Snohomish County had unusually heavy algae growth from October 1993 through February 1994. Mason Lake, an oligotrophic lake in Mason County, had a toxic bloom of *Gloeotrichia echinulata* that resulted in a health advisory being issued for the lake on September 10, 1993. Unusually warm and calm weather from September through November probably encouraged blue-green algae blooms in these lakes.

Other Available Information

The Association of Lake Roesiger Property Owners began monitoring both basins in 1992. Data and samples were collected monthly from November through April, and bimonthly from May through October. Temperature and dissolved oxygen profiles were measured using a YSI meter. Secchi depth was also measured. Epilimnion samples were composited from water collected at 1, 2, and 3 meter depths. These samples were analyzed for total phosphorus and chlorophyll a. Hypolimnion samples were composited from water collected at 16, 22, and 28 meter depths. These samples were analyzed for total phosphorus. Additional samples were collected at discrete depths from both basins in April and November. Metalimnion samples were collected for chlorophyll analysis and algae identification and enumeration. Bottom samples were collected for TP, iron, alkalinity, and conductivity. All water samples were analyzed using an Ecology-accredited laboratory.

From KCM (1989): A Phase I lake restoration study of Lake Roesiger was conducted from May 1988 to 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 has been withheld by Ecology. This decision was based on the likelihood that the large expense of the project will not have appreciable benefits to lake water quality and fish habitat. Despite this, the Snohomish County Board of Commissioners has committed to installing aerators in both lake basins, in order to mitigate potential water quality effects from increased development and water withdrawal from 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 from 1990-1993.

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 in 1993. Less than five percent of the shoreline is publicly-owned. The watershed is being logged and is used for horse grazing. The lakeshore is also 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 350 houses on the lakeshore. Except for the county park area, there are residences all along the shore of the south basin. The lakeshore is not sewered. Currently, the minimum setback for lakeshore development is 25 feet, and residential density is restricted to two 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 lake association and a community association (Gemmer Association) for the lake. No aquatic plant or algae control occurred in 1993. 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.

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, 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 found that Lake Roesiger had excellent water quality. Problems in the lake in 1993 were ranked as (1) shoreline erosion, and (2) suspended sediments. These were also the worst problems in the lake in 1992. Possible sources of problems include runoff from driveways and highly fertilized lawns, shoreline erosion from ski boat wakes from May 25 to September 25, and siltation from lot clearing. In comparison to the 1992 monitoring season, water clarity for both lakes was high (up to 25 feet), and algae growth was low.

Acknowledgments

Volunteer monitors at Lake Roesiger in 1993 were Elsie Sorgenfrei and Frank Stegmeier (north basin), and Robert and Jo Miller (south basin). Andy Loch monitored both basins during 1992, and Elsie Sorgenfrei and Frank Stegmeier monitored the south basin during 1991.

Lake Roesiger -- Snohomish County

1993 Trophic Status[1]	North Basin	South Basin
Estimated Trophic State:	Oligo-mesotrophic[2]	Oligo-mesotrophic[2]
Mean Trophic State Index (Secchi):	33	35
Mean Trophic State Index (Total Phosphorus):	[3]	--
Mean Trophic State Index (Chlorophyll *a*):	36	--

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[4]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
North Basin, Deep Site										
24-May	1130			14.0			0		light	Onsite visit.
20-Aug	1130	22.0	71.6	23.0		lt-green	0		calm	
10-Sep	1400	23.0	73.4	25.0		lt-green	0	none	calm	
08-Oct	1050	16.0	60.8	27.0	11.00	lt-green	0	light	calm	Lake height in feet; lake surface at 0" on yard stick. pH at surface 7.0.
25-Oct	1230	15.0	59.0		17.00	lt-green		trace	calm	
South Basin, Deep Site										
23-Jul	1115	18.3	64.9	16.0	14.00	lt-green	90	heavy	light	
13-Aug	1000	20.0	68.0	18.0	21.00	lt-green	100	none	calm	
11-Sep	1000	22.0	71.6	19.0	21.00	lt-green	100	none	light	
17-Sep	1028	18.9	66.0	23.0	21.00	lt-green	0	none	calm	
01-Oct	1000	18.0	64.4	22.0	21.00	lt-green	0	none	calm	
24-Oct	1330	13.3	55.9	16.0	20.00	lt-green	50	heavy	breezy	

[1] Trophic State Indices calculated from Carlson (1977).
[2] See Overall Assessment.
[3+] The May total phosphorus concentration was unusually high and may be an error (see Total Phosphorus Section). TSI_{TP} for August was only 24.
[4] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of South Lake Roesiger dropped 6" from July 23 to October 24.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
North Basin					
05/24	0.0	20.1	8.0	9.7	25
	1.0	19.2	7.9	9.9	25
	2.0	18.9	7.9	10.1	25
	2.9	16.0	8.1	11.2	25
	4.0	12.9	8.3	11.9	24
	5.0	10.7	8.2	12.1	24
	6.1	8.7	8.0	11.7	24
	7.0	7.5	7.9	11.0	24
	8.1	6.7	7.8	10.5	24
	10.0	5.9	7.6	9.5	24
	12.1	5.4	7.5	8.9	25
	14.1	5.3	7.4	8.2	24
	16.0	5.1	7.3	7.9	25
	18.0	5.0	7.2	7.6	23
	20.0	5.0	7.1	7.0	24
	22.0	4.9	7.0	6.3	24
	24.2	4.8	7.0	5.9	26
	26.3	4.8	6.9	4.4	27
	28.2	4.9	6.8	3.2	27
	30.3	4.9	6.7	1.8	28
	31.3	5.0	6.6	1.2	120
08/20	0.0	22.3	7.6	8.9	26
	1.0	21.7	7.6	9.0	26
	2.0	21.0	7.7	9.1	26
	2.0	21.0	7.7	9.1	26
	3.0	20.3	7.9	9.4	26
	4.0	19.2	7.8	10.1	25
	5.0	16.0	8.1	11.2	25
	6.0	12.7	8.1	11.7	26
	7.0	10.0	8.1	11.8	24
	7.9	8.7	8.0	11.2	25
	10.1	6.7	7.8	8.6	25
	12.1	5.8	7.6	5.9	26
	14.1	5.5	7.5	5.0	25
	16.1	5.2	7.4	4.1	25
	18.0	5.2	7.3	3.3	24
	20.0	5.1	7.2	2.0	25
	25.0	5.0	7.0	0.5	29
	28.5	5.1	7.0	0.3	48

1993 Onsite Visit Data - Water Chemistry of North Basin

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 24							
Epilimnion	112*	0.36	1.3	--	--	--	--
Hypolimnion	20	0.53	--	--	--	--	--
August 20							
Epilimnion	4	0.20	2.3	--	--	--	--
Hypolimnion	8	0.36	--	--	--	--	--

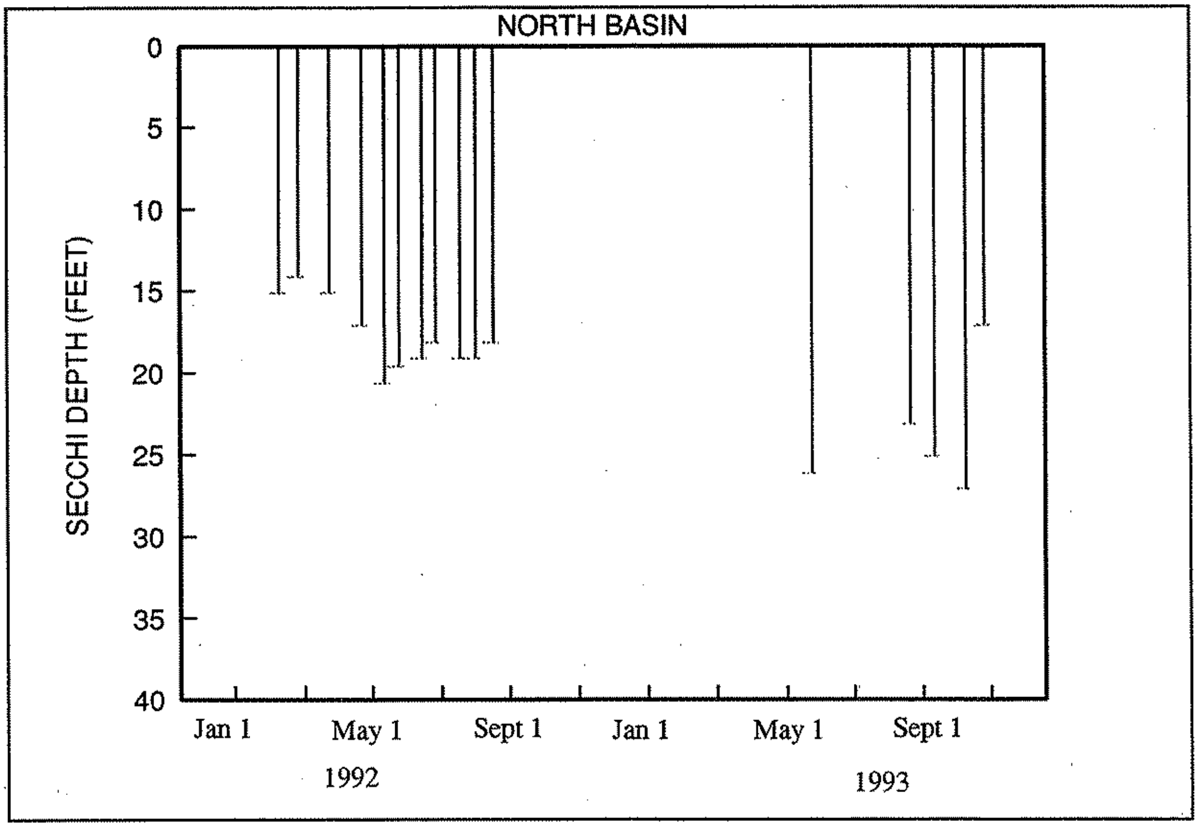
* probably an outlier

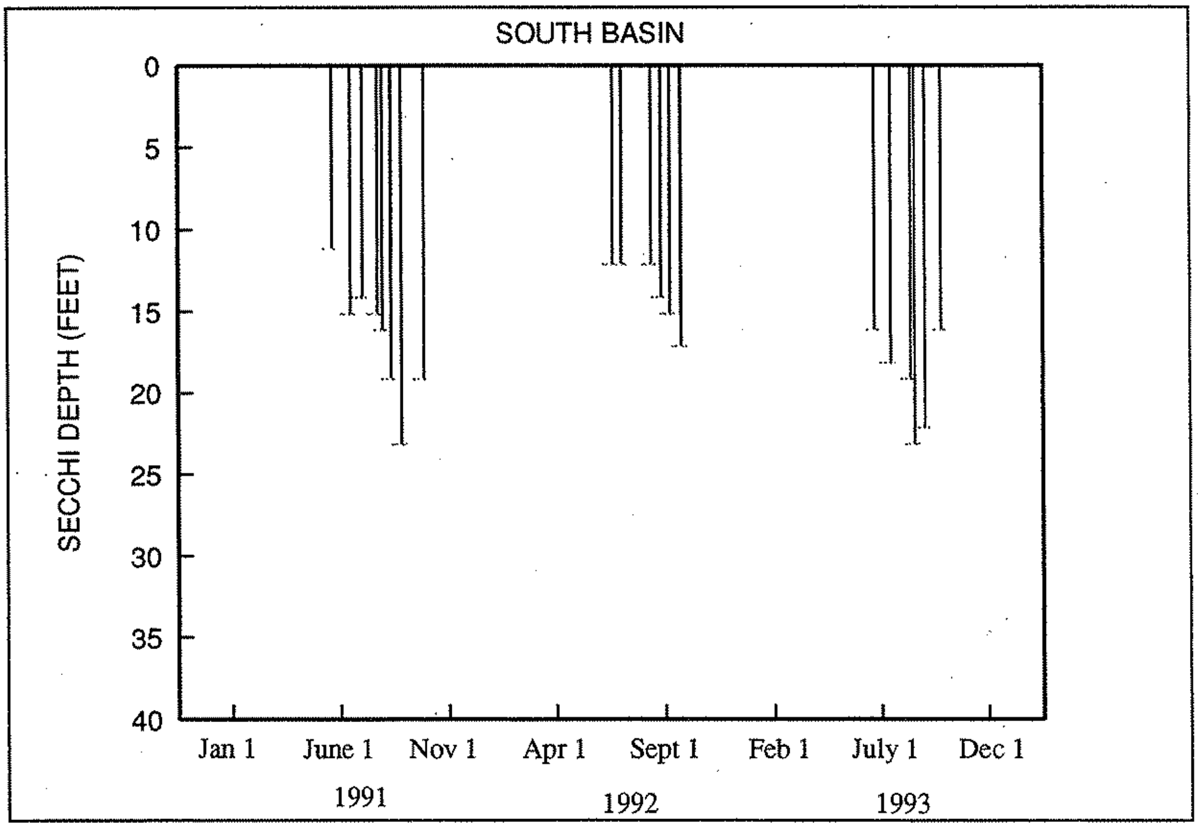
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
North Basin			
07/25/72[a]	29	--	2.3
07/06/81[b]	10	1.0	2.3
05/15/92[c]	5	0.48	0.46
08/21/92[c]	6	0.19	--
South Basin			
07/25/72[a]	5	--	3.1
06/06/90[d]	7	0.40	--

a. Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1993)
d. Washington's Citizen Lake Monitoring Program (unpublished data)

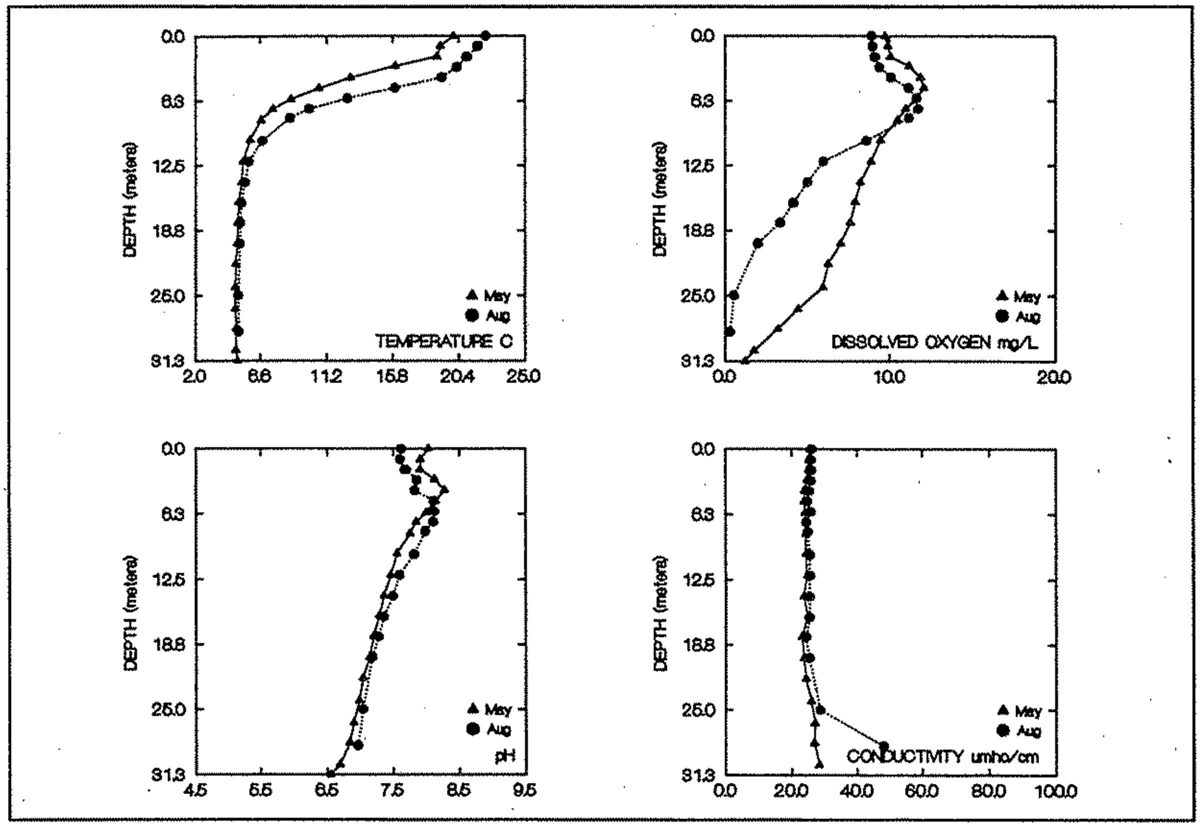
LAKE ROESIGER (SNOHOMISH COUNTY)





1993 Secchi Depth and Profile Data Graphs

PROFILE DATA FROM NORTH BASIN



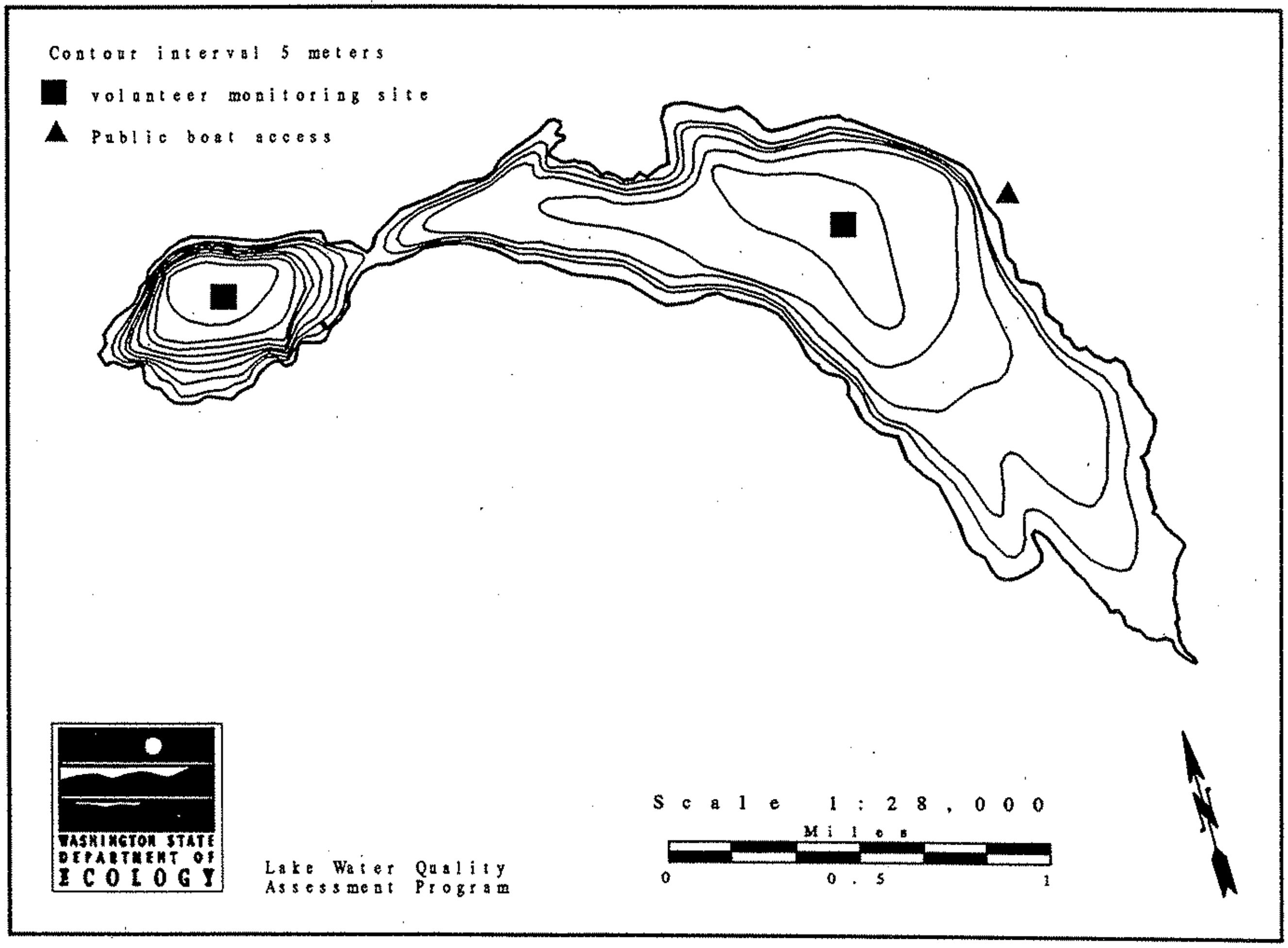
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, both basins of Lake Samish were assessed as oligo-mesotrophic, based primarily on fairly good water clarity. Water samples were collected from the larger east basin in May and August. In May the east basin had a moderately high concentration of total phosphorus, and a low density of algae. In August, it had a low concentration of total phosphorus, and a moderately high density of algae.

In comparison with data collected from 1989-1992, in 1993 water temperatures were lower throughout the water column, dissolved oxygen concentrations were higher in the lower layer of water, and pH values were less variable and closer to neutral. Most likely, cooler summer weather in 1993 resulted in the lower water temperature, which would also tend to reduce algal productivity. Reduced algal productivity was also indicated by surface pH measured by the volunteers from 1992-1993.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good in both basins. Secchi depths ranged from 11.0 feet to 17.0 feet in the east basin, and from 10.3 feet to 21.8 feet in the west basin. Secchi depths greater than 13.0 feet indicate good water clarity, and are typical for oligotrophic lakes.

Secchi depth data collected since 1989 were analyzed for trend in water clarity. There was no statistically significant trend in water clarity from 1989 to 1993.

Total Phosphorus

The concentration of total phosphorus in the upper layer of water (the epilimnion) was moderately high in May (22 µg/L), but was low in August (8 µg/L). The May result was the highest epilimnetic concentration measured in Lake Samish since 1989. However, algal density (as indicated by the chlorophyll *a* concentration) at the time was low, suggesting that phosphorus may not have been in a form that could be readily used by to algae (which can happen if phosphorus is bound to suspended sediments), or there were other factors at the time that limited algae growth (such as wind or low water temperature).

Total Nitrogen

Total nitrogen concentrations were moderately high to high, and the concentration was higher during May (0.57 mg/L) than in August (0.32 mg/L). Data from 1989-1992 also indicated higher total nitrogen concentrations in spring than in late summer.

Profile Data

Profile data collected in August 1993 were quite different from profile data collected in September 1989, August 1990, and August 1992. In comparison to previous years, 1993 water column had lower temperature, higher dissolved oxygen concentrations, and neutral, less variable pH values. Most likely cool air temperatures and cloudy summer weather in 1993 contributed to these changes in profile data.

In previous years, dissolved oxygen in the lower layer of water (the hypolimnion) has been depleted in the bottom four to five meters of the lake. Low concentrations of dissolved oxygen result when bacteria use oxygen as they decompose aquatic plants and algae in the water. However, oxygen concentrations will also be affected by water temperature, because cooler water can hold more dissolved oxygen than warmer water. Cooler water in the epilimnion during 1993 (see above) can also restrict algae growth, which would reduce the oxygen demand in the lower layers of water by reducing the amount of organic material that is decomposing near the lake bottom. Therefore, water temperature throughout the water column, and possibly reduced algae growth, allowed the water to hold more dissolved oxygen.

Seasonal changes in pH are often related to changes in algal growth. Although Secchi depths and chlorophyll data do not indicate that algae growth was unusually low in 1993 compared to earlier years, pH data from 1992 and 1993 suggest there may have been more algae productivity in 1992 than in 1993 (higher pH indicates more productivity). In addition to the less variable pH profiles measured during the 1993 sampling visits, surface pH (measured by the volunteers) was much lower in 1993 than in 1992. The volunteers measured pH in both basins using a temperature-compensated Cole-Parmer pH pen (provided by Ecology) during 1992 and 1993. In the east basin, surface pH ranged from 7.6-10.3 in 1992 and from 7.0-8.0 in 1993. In the west basin, pH ranged from 8.1-10.3 in 1992, and from 7.7-9.1 in 1993. Values from the pH pen used by the volunteers were very similar to values obtained from the profiling instrument during the sampling visits. Observations from the volunteers also indicated that algal productivity was higher in 1992 than in 1993.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. In May, the chlorophyll concentration (1.2 µg/L) indicated a low density of algae. In August, the chlorophyll concentration (3.0 µg/L) was higher than we would expect given the low phosphorus concentration.

Aquatic plants identified by Ecology staff during the August 24, 1992, sampling 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*). Additional aquatic plants observed in 1993 include pondweed (possibly *Potamogeton berchtoldii*) and water buttercup (*Ranunculus* sp.).

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).

Summary of Questionnaire Results and Information from the Volunteers

The 1993 questionnaire on lake and watershed uses was not received by 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 five percent of the shoreline is publicly-owned. Currently the watershed is being logged, and the lakeshore is being developed

further for residences. In the past, the watershed was logged and used for 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. Water District #12, which is responsible for sewage collection, 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.

In 1992, the volunteers found 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.

Acknowledgments

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 1989-1993.

Lake Samish -- Whatcom County

1993 Trophic Status[1]	East Arm	West Arm
Estimated Trophic State:	Oligo-mesotrophic	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	40	38
Mean Trophic State Index (Total Phosphorus):	41	--
Mean Trophic State Index (Chlorophyll *a*):	37	--

Volunteer-Collected Data

Date 1993	Time (°C)	Temp (°F)		Secchi (ft)	pH	Lake Ht (ft)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
East Basin											
03-Jun	1305	19.0	66.2	16.0		268.81	lt-green	75	light	calm	
19-Jun	1330	20.0	68.0	13.5		268.54	lt-green	0	none	breezy	
01-Jul	1330	20.0	68.0	11.0		268.46	lt-green	95	trace	light	
16-Jul	1330	20.0	68.0	14.5	7.0		lt-green	90	moderate	light	
27-Jul	1345	21.0	69.8	17.0	7.1	268.74	lt-green	100	none	calm	
13-Aug	1330	22.0	71.6	14.0	7.2	268.89	lt-green	100	none	breezy	
16-Aug	1015			14.5				100		light	Onsite visit.
26-Aug	1330	22.0	71.6	12.0	7.4	268.90	lt-green	90	trace	light	
15-Sep	1400	21.0	69.8	11.0	8.0	268.36	lt-green	10	trace	calm	
30-Sep	1345	20.0	68.0	12.0		268.14	lt-green	0	none	breezy	
West Basin											
03-Jun	1400	20.0	68.0	21.8		268.81	lt-green	75	light	calm	
19-Jun	1400	20.0	68.0	14.5		268.54	lt-green	0	none	breezy	
01-Jul	1330	21.0	69.8	17.0	7.7	268.46	lt-green	95	trace	light	
16-Jul	1405	20.0	68.0	16.0	8.4	268.50	lt-green	90	moderate	light	Secchi with view tube 19.25'.
27-Jul	1445	21.0	69.8	19.0		268.74	lt-green	100	none	light	Secchi with view tube. No rain last two days, but raining while we were gathering info. on card.
13-Aug	1400	22.0	71.6	17.0	8.2	268.89	lt-green	100	none	breezy	Drift at trolling speed during Secchi reading.
26-Aug	1400	21.0	69.8	13.5		268.90	lt-green	90	trace	light	
15-Sep	1400	21.0	69.8	12.5	8.6	268.36	lt-green	10		light	Lake height changed since last report--beaver dams removed from Friday Creek.
30-Sep	1435	20.0	68.0	10.3	9.1	268.14	lt-green	0	none	breezy	

[1] Trophic State Indices calculated from Carlson's model (1977).

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Samish dropped 0.67" from June 3 to September 30.

1993 Onsite Visit Data - East Basin Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/22	0.0	17.4	7.7	5.9	61
	1.0	17.1	7.7	5.6	61
	1.9	16.8	7.7	5.4	61
	2.0	16.8	7.7	5.5	61
	3.1	16.5	7.7	5.2	60
	4.0	16.1	7.7	5.2	60
	5.0	15.4	7.7	5.2	60
	6.0	13.5	7.7	5.3	60
	7.0	11.8	7.7	5.5	60
	8.1	11.2	7.6	5.4	59
	10.0	10.2	7.6	5.1	59
	12.0	9.7	7.5	4.9	60
	14.1	9.3	7.4	4.7	59
	16.0	8.9	7.4	4.5	60
	16.5	8.7	7.3	4.4	59
08/16	0.0	19.6	7.7	9.4	65
	1.0	19.6	7.8	9.4	64
	2.0	19.7	7.9	9.5	64
	3.0	19.7	8.0	9.5	65
	4.1	19.7	8.0	9.5	65
	5.1	19.7	8.0	9.6	64
	6.0	19.7	8.1	9.6	64
	7.0	18.2	7.8	9.5	63
	8.1	16.0	7.8	9.6	63
	9.0	14.4	7.8	9.3	63
	10.1	12.2	7.8	8.4	62
	12.1	10.3	7.8	7.2	63
	14.0	9.5	7.6	5.4	63
	16.0	8.9	7.5	4.3	64
	18.1	8.6	7.4	3.7	66
	19.2	8.6	7.4	3.3	67

1993 Onsite Visit Data - East Basin Water Chemistry

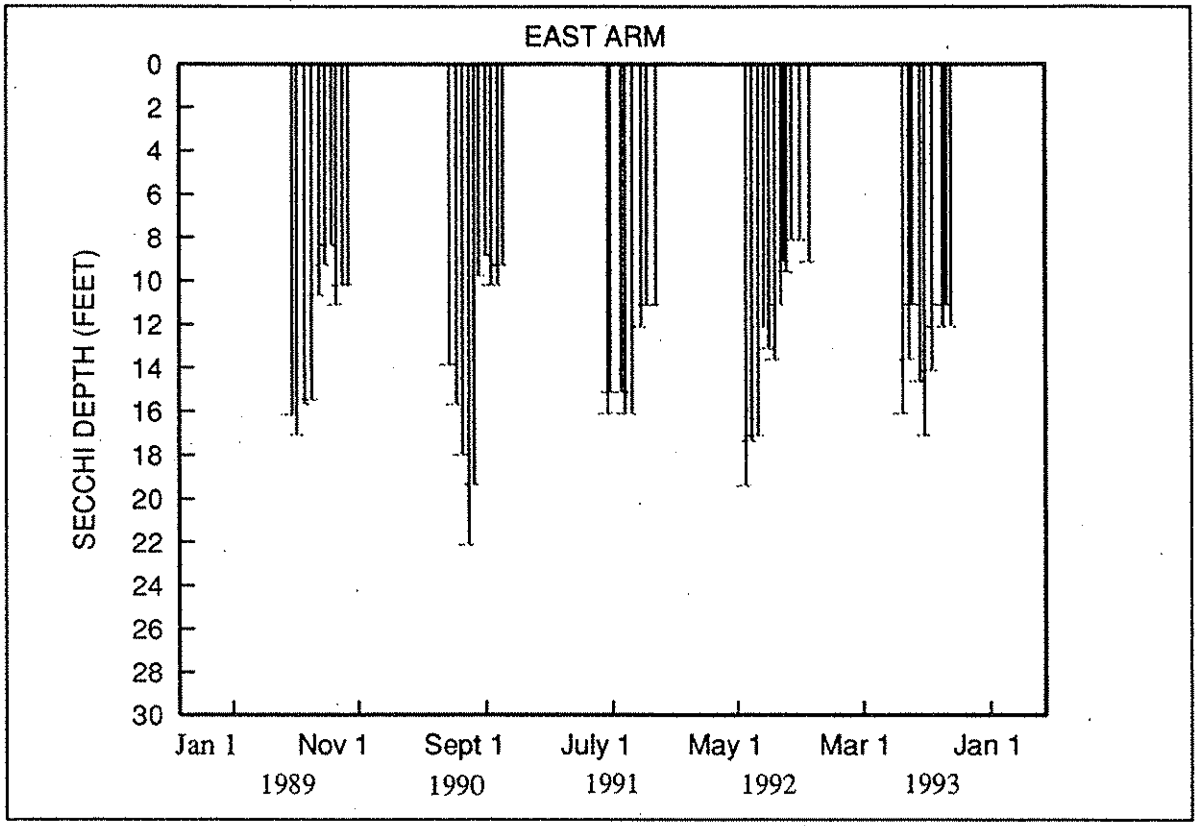
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 22							
Epilimnion	22	0.57	1.2	--	--	--	--
Hypolimnion	18	0.59	--	--	--	--	--
August 18							
Epilimnion	8	0.32	3.0	--	--	--	--
Hypolimnion	12	0.54	--	--	--	--	--

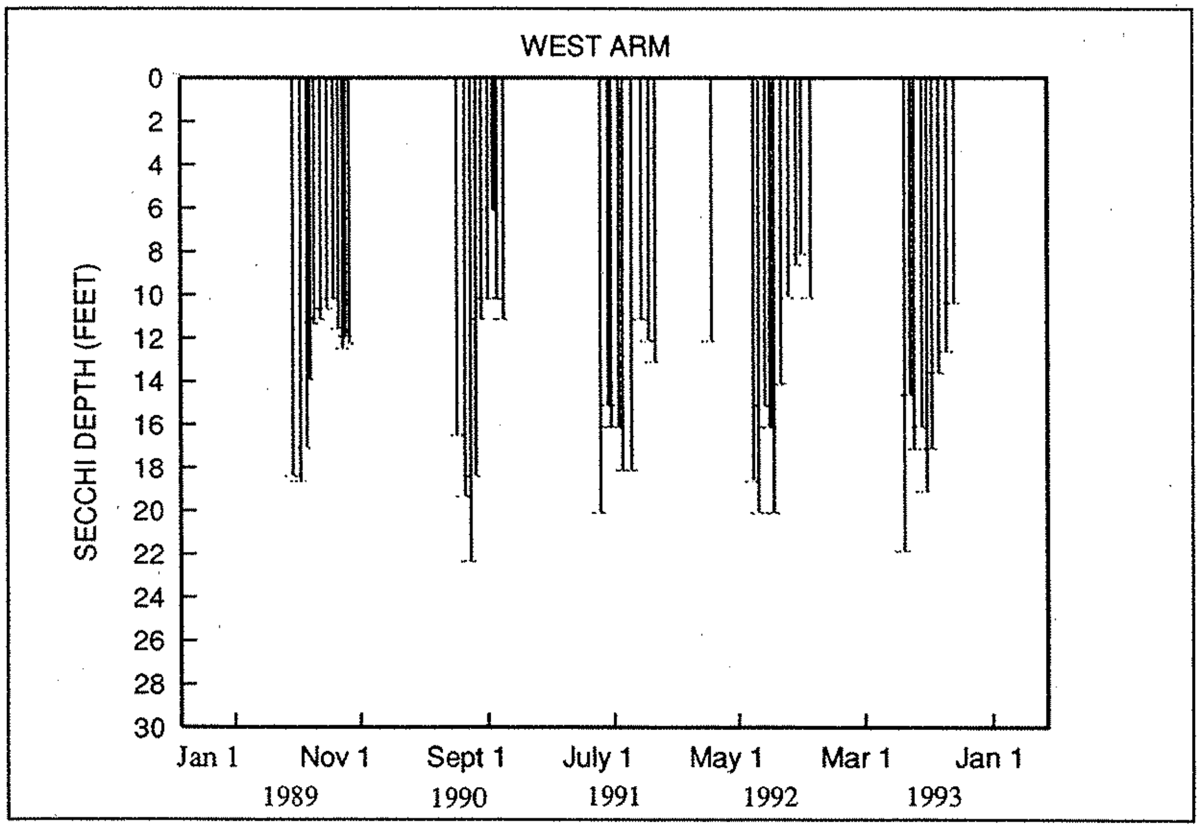
Historical Data From Ecology - Epilimnion Data Only, East Basin

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
08/24/74[a]	0	--	--
06/27/89[b]	6	0.62	2.7
09/26/89[b]	12	0.40	6.3
06/04/90[c]	13	--	--
08/15/90[c]	10	0.36	--
05/29/91[d]	--	0.58	--
05/21/92[e]	4	0.66	1.2
08/24/92[e]	10	0.25	1.3

a. Bortleson *et al.* (1976)
b. Brower and Kendra (1990)
c. Rector (1991)
d. Rector (1992)
e. Rector (1993)

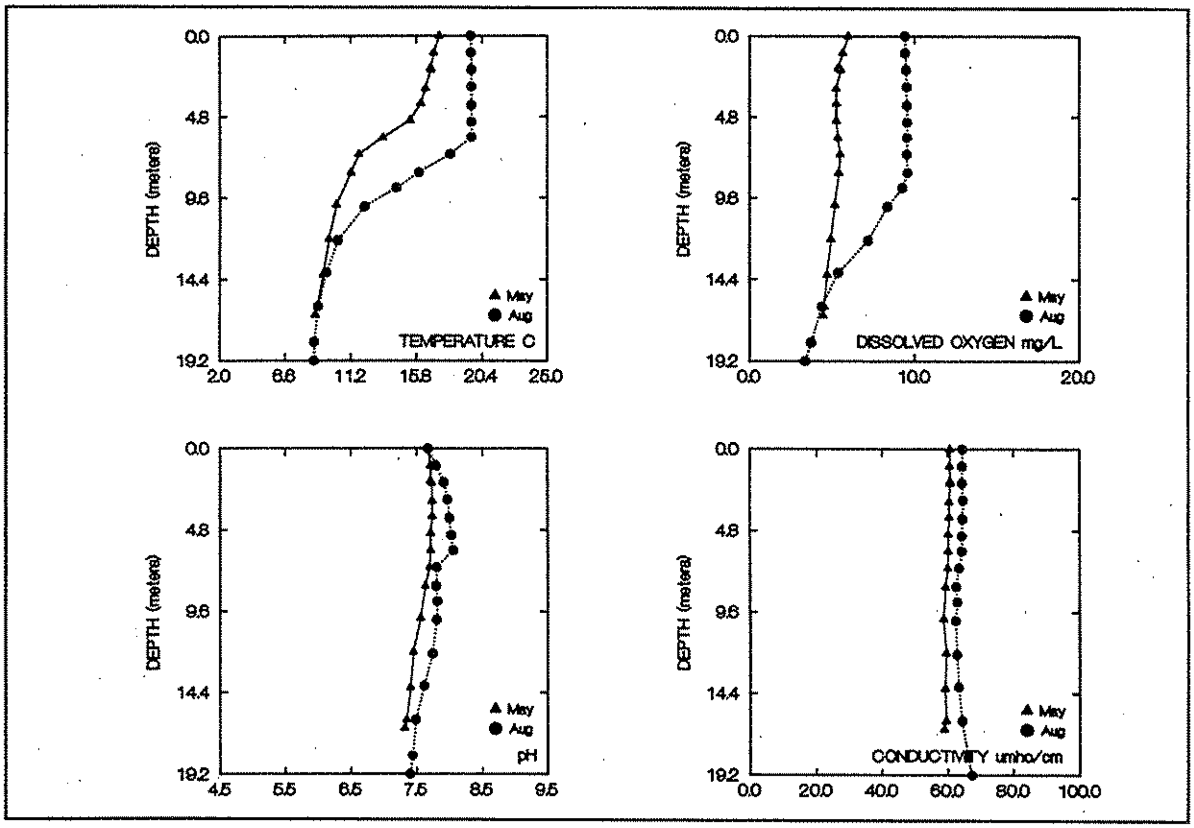
LAKE SAMISH (WHATCOM COUNTY)





1993 Secchi Depth and Profile Data Graphs

PROFILE DATA FOR EAST BASIN STATION



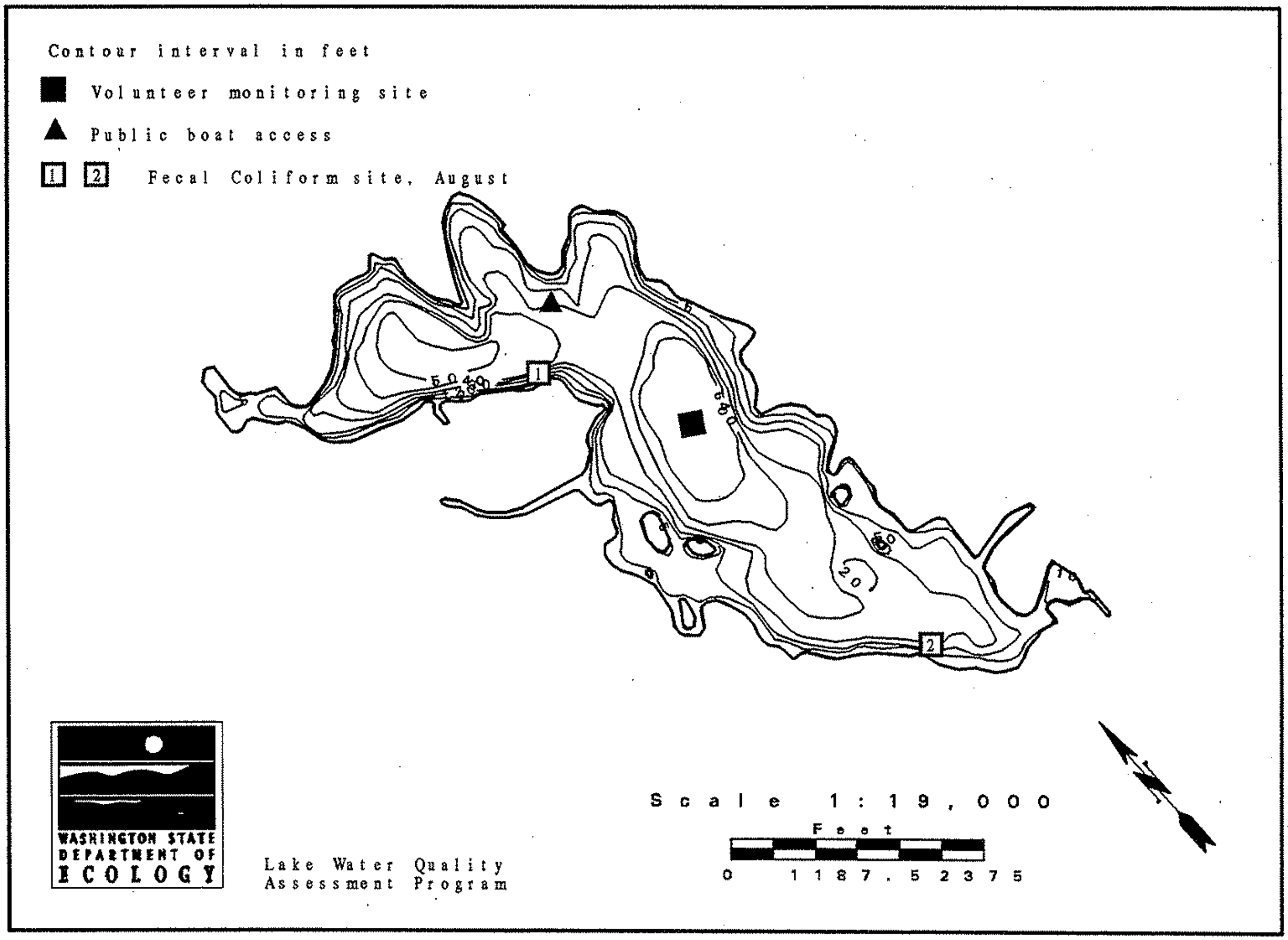
1993 Secchi Depth and Profile Data Graphs

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.

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)



Overall Assessment

In 1993, Lake Sawyer was assessed as mesotrophic, based on fair water clarity throughout the monitoring season, moderately high to high concentrations of chlorophyll on both sampling dates, a high total phosphorus concentration during May, and very low concentrations of dissolved oxygen below the thermocline.

In early 1993, effluent from the Black Diamond wastewater treatment plant was diverted from Lake Sawyer. Because the lake has a high flushing rate, lake water quality is expected to improve providing that nonpoint sources of nutrients to the lake do not increase. Continued education efforts for homeowners and lake users, as well as limiting runoff from further development, may help to control nonpoint sources within the watershed. Continued monitoring of Lake Sawyer is important to record the lake response following the diversion.

Lake Sawyer has Eurasian watermilfoil, which is an aggressive non-native aquatic plant that is known to dominate aquatic plant populations and create nuisance problems to lake users. People using the lake should carefully clean their boats, motors, trailers, and jet skis of all plant fragments before using other water bodies, in order to prevent spreading this noxious plant.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in 1993 was good to fair, as indicated by Secchi depths that ranged from 9.0 feet to 14.8 feet. In general, Secchi depths measured in 1993 were not as deep as those measured in 1992. Secchi depths from 6.5 feet to 13.0 feet are typical for mesotrophic lakes.

Total Phosphorus

In May, there was a high concentration of total phosphorus (34 µg/L) in the upper layer of water (the epilimnion) that corresponded to a high density of algae at the time of sampling. The total phosphorus concentration in the lower layer of water (the hypolimnion) was very similar to the concentration in the epilimnion.

In August, the total phosphorus concentration in the epilimnion was low (11 µg/L), and there was a moderately high density of algae at the time of sampling (see Plants, below). In the hypolimnion, the total phosphorus concentration was very high (138 µg/L), and could have resulted from sediment release. When dissolved oxygen near the sediment is depleted, phosphorus, iron, and other compounds in sediment are chemically reduced and released into the water column (see Profile Data, below). Sediment nutrient release also appeared to occur in 1992, when the August hypolimnion sample had 272 µg/L total phosphorus. This is characteristic of eutrophic lakes.

Total Nitrogen
Concentrations of total nitrogen were moderately high on both sampling dates (0.32 mg/L in May, and 0.23 mg/L in August). These concentrations were very similar to concentrations measured in 1992. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae generally use at least ten times the amount of nitrogen as phosphorus. In May, the ratio of total nitrogen to total phosphorus was 9.5:1 (which could indicate that algae growth was limited by nitrogen). But, nitrogen limitation was not apparent because the chlorophyll concentration was high and in the range expected given the high concentration of total phosphorus. In August, the total nitrogen to total phosphorus ratio was 20:1, and algae growth was not limited by nitrogen.

Fecal Coliform Bacteria
Samples for fecal coliforms were collected from two nearshore sites in August. Site #1 was located at the public access, and Site #2 was located in a shallow area just west of the deep northern basin of the lake. Results for both samples were low. The state water quality standard for fecal coliforms in Lake Class waters is a geometric mean of 50 colonies/ 100 mL.

Solids
Results from solids samples are used to evaluate whether Secchi depths were affected primarily by algae, or if suspended sediments affected water clarity at the time of sampling. Solids samples collected during August were below the detection limits, indicating that there were low concentrations of solids in the water. Secchi depths were probably affected by algae when the samples were collected.

Profile Data
The lake was thermally stratified on both sampling dates. Below the thermocline, dissolved oxygen concentrations decreased considerably with depth. Oxygen concentrations usually decrease as bacteria use oxygen to decompose aquatic plants and algae in the water and sediment. In August, dissolved oxygen in the lower layer of water was completely depleted; this was also noted in August 1992 profile data. In addition to promoting internal phosphorus loading, low dissolved oxygen concentrations probably restrict fish habitat, because most trout prefer at least 4.5 mg/L oxygen and water temperature below 20°C. As a result, trout are probably found within the metalimnion of the lake during summer stratification, at depths from three to five meters.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. In May the chlorophyll concentration (8.7 µg/L) indicated high density of algae. Field notes from May also indicate that there was a lot visible algae during sampling. The high phosphorus concentration at the time probably encouraged algal growth.

In August, the chlorophyll concentration (4.2 µg/L) indicated a moderately high algal density that was higher than would be expected, given the low phosphorus concentration. Chlorophyll concentrations from 1993 were higher than those measured in 1992.

Aquatic plants identified by Ecology staff during the May 12, 1992, sampling visit were yellow-flowering water lily (*Nuphar polysepalum*), duckweed (*Lemna* sp.), cattails (*Typha* sp.), 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 water lily (*Nymphaea odorata*) were also observed.

Other Available Information

Septic tanks from the Black Diamond community leaked into Rock Creek before 1983. From 1983 to 1993, wastewater effluent from the Black Diamond Wastewater Treatment Plant (WTP) discharged to a wetland that drains to Lake Sawyer. Because of insufficient phosphorus removal by the Black Diamond WTP, effluent was diverted from Lake Sawyer to a municipality of Metropolitan Seattle (METRO) sewer in early 1993. METRO has monitored Lake Sawyer for many years.

From Pelletier and Joy (1989): An evaluation of wasteload 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 cause the lake to revert 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 cubic feet per second, entering mainly along the eastern shore of the lake, with greatest inflow during winter. Estimated outflow was about 3 cubic feet per second, 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.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to questionnaires from 1992 and 1993.

> 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. Trout were stocked in the lake in 1993. Currently, the watershed is being logged, and used for animal grazing/feeding and industry (mining for coal and silica sand; there was concern in 1993 that the settling pond at the mining operation had failed). The lakeshore is also being developed further for residences. In 1992, 32 acres of the watershed were cleared for development. In the past, the watershed was logged and mined (coal), and used for animal grazing/feeding. The lake was dredged in the past.
>
> There are 315 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 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. No algae or aquatic plant management activities occurred in 1993.
>
> Overall, the volunteer found that Lake Sawyer had fair water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, (2) suspended sediments, (3) degraded aesthestics, (4) water quality gradually degraded over years, (5) algae, (6) fish kill, (7) low water level, (8) high water level, (9) decaying plants, (10) impaired fisheries, and (11) odor from decaying algae. Possible sources of problems include surface runoff, uncontrolled plant growth, unauthorized development at or near the waterline, and uninformed citizens dumping debris (clippings, oil, chemicals) into the lake. In 1993, there was more

plant growth, and lower clarity, than in 1992. In addition, residents are working with King County Surface Water Management concerning lake level control and water quality monitoring. In 1992, the worst problems were aquatic plants, algae, suspended sediments, and fluctuating water level. The Black Diamond sewage treatment plant, internal loading of nutrients from the sediments, and silting from upstream mining operations were cited as possible sources of the 1992 problems. Aquatic plants were mechanically harvested in 1992.

Acknowledgment

I thank Doug Geiger for volunteering his time to monitor Lake Sawyer during 1992-1993.

Lake Sawyer -- King County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	42
Mean Trophic State Index (Total Phosphorus):	47
Mean Trophic State Index (Chlorophyll *a*):	48

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
20-May	1800			9.0			100			Onsite visit.
08-Jun	1830	20.0	68.0	10.8	-2.75	gr-brown	10	heavy	calm	none
29-Jun	1830	21.7	71.0	10.0	-3.50	gr-brown	50	moderate	light	Sight tube glares around edges. Hard to use on wavy days.
12-Jul	1845	21.1	70.0	11.0	-3.75	gr-brown	90	none	calm	
04-Aug	2050	23.9	75.0	11.5	-4.50	gr-brown	0	none	calm	96 degree day.
23-Aug	1700	21.1	70.0	14.5	-5.00	green	100	moderate	breezy	August DOE visit.
12-Sep	1330	23.9	75.0	14.8	-8.50	lt-green	50	trace	strong	Eight hot days (85°F) in a row.
26-Sep	1830	20.0	68.0	11.0	-13.00	lt-green	0	none	calm	Dry weather past few weeks.

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

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Sawyer dropped 10.25" from June 8 to September 26.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/20	0.0	21.5	8.5	10.4	141
	1.0	21.4	8.5	10.2	141
	2.1	18.7	8.5	10.6	139
	3.0	14.4	8.5	10.5	139
	4.0	12.3	8.2	8.6	140
	5.0	10.7	8.1	7.0	141
	6.1	9.8	8.0	6.1	142
	6.9	8.5	7.8	4.7	143
	8.0	7.8	7.8	4.8	144
	9.0	7.5	7.7	4.8	143
	10.1	7.2	7.7	4.7	142
	12.1	7.0	7.7	4.5	143
	14.2	6.9	7.6	4.2	144
	16.0	6.8	7.5	3.5	145
	16.6	6.7	7.5	3.1	144
08/23	0.0	21.0	7.0	9.3	142
	1.0	21.0	7.2	9.1	142
	2.0	21.1	7.3	9.0	142
	2.9	20.8	7.3	8.8	143
	3.9	16.7	7.1	5.6	147
	5.1	13.6	7.1	0.7	144
	5.9	10.7	7.1	0.3	145
	7.1	9.4	7.0	0.2	144
	8.0	8.5	7.0	0.1	143
	10.0	7.7	7.0	0.1	144
	12.0	7.4	7.0	0.1	145
	14.1	7.3	6.9	0.1	145
	16.1	7.1	6.9	0.1	148
	16.5	7.1	6.9	0.1	152

1993 Onsite Visit Data - Water Chemistry

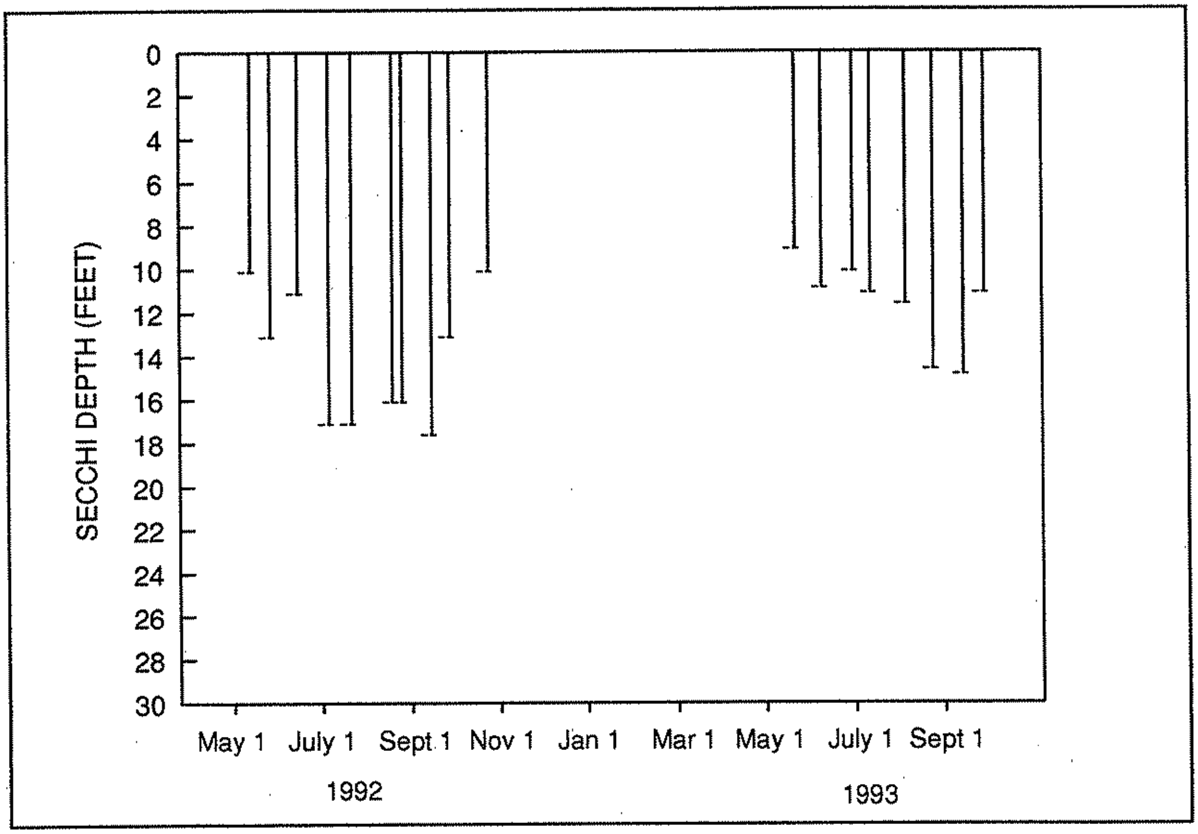
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 20							
Epilimnion	34	0.32	8.7	--	--	--	--
Hypolimnion	28	0.45	--	--	--	--	--
August 23							
Epilimnion	11	0.23	4.2	<1	<1	11	8
Hypolimnion	138	0.48	--	--	--	--	--

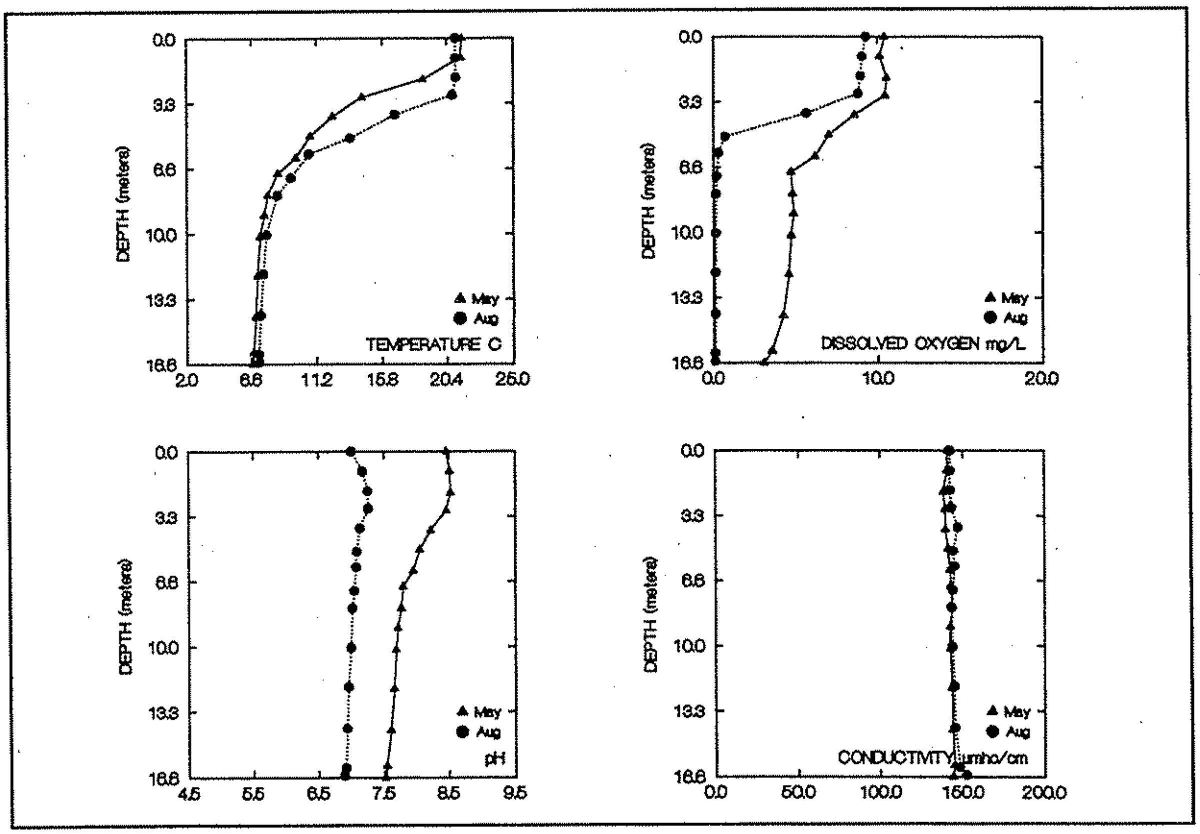
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
06/18/73[a]	28	--	7.3
06/11/81b	--	--	1.6
05/12/92c	19	0.32	3.2
08/24/92c	14	0.27	1.5

a. Bortleson *et al.* (1976), McConnell *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1993)

LAKE SAWYER (KING COUNTY)





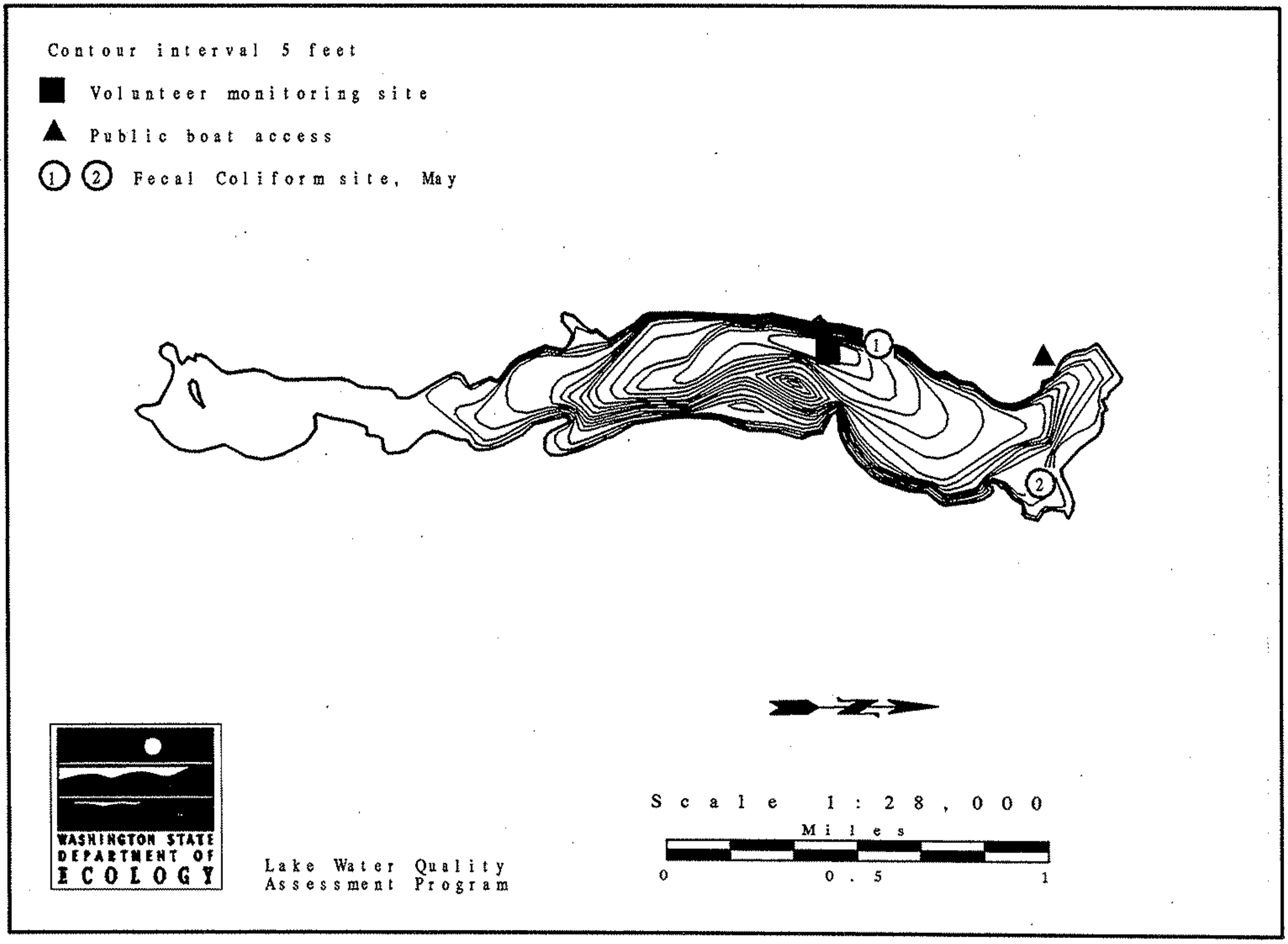
1993 Secchi Depth and Profile Data Graphs

Silver Lake -- Spokane County

Silver Lake is located 1.1 miles due east of the Town of Medical Lake. It is within the Crab Creek watershed.

Size (acres)	490
Maximum Depth (feet)	80
Mean Depth (feet)	30
Lake Volume (acre-feet)	14,000
Drainage Area (miles^2)	19
Altitude (feet)	2,341
Shoreline Length (miles)	8.7

Data From Dion *et al.* (1976)



Overall Assessment

Silver Lake was added to the Lake Water Quality Assessment Program in 1993. In 1993, Silver Lake was assessed as meso-eutrophic, based on fair water clarity, moderately high to high nutrient concentrations, and moderately high densities of algae.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in Silver Lake was fair, as indicated by Secchi depths that ranged from 5.6 feet to 12.5 feet. Secchi depths from 6.5 feet to 13.0 feet are typical of mesotrophic lakes.

Total Phosphorus

In May, the concentration of total phosphorus in the upper layer of water was very high (64 µg/L). Although concentrations of total phosphorus greater than 24 µg/L can encourage large growths of algae, at the time there was only a moderately high density of algae (see Plants, below).

In August, the concentration of total phosphorus in the upper layer of water was moderately high (20 µg/L), which corresponded to a moderately high density of algae.

The concentrations measured in 1975 (32 µg/L and 29 µg/L) were moderately high, and were in the range that is associated with mesotrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were very high on both sampling dates, particularly in May. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 (19:1 in May, and 39:1 in August), algae growth was not limited by nitrogen when the lake was sampled.

Fecal Coliform Bacteria

Samples for fecal coliform bacteria were collected at two nearshore sites in May. Site #1 was located on the west side of the lake, about 500 feet north of the volunteer's sampling site. Site #2 was located in a shallow area of the northeast side of the lake. Results for both samples were very low. The state water quality standard for fecal coliforms in Lake Class waters is a geometric mean of 50 colonies/100 mL .

Solids

Results from solids samples are used to evaluate whether Secchi depths were affected primarily by algae, or if suspended sediments affected water clarity at the time of sampling. Solids samples collected in May indicated that Secchi depth was affected primarily by algae.

Profile Data

The lake was stratified with respect to temperature on both sampling dates. Below the thermocline, concentrations of dissolved oxygen decreased with depth. By August, there was no oxygen in the bottom 11 meters of the lake, indicating that the entire lower layer of water was depleted of oxygen. Low oxygen concentrations probably restricted fish habitat, because trout generally prefer oxygen concentrations higher than 4.5 mg/L. As a result, during summer stratification trout were probably restricted to depths of five to nine meters, where oxygen concentrations were higher and water temperatures were not too high.

Oxygen concentrations usually decrease when bacteria use oxygen as they decompose aquatic plants and algae in the water and sediment. When a lake is stratified, the upper layer of water does not mix with the lower layer of water. As a result, oxygen concentrations can be very low at the bottom of a lake, and very high at the surface.

Conductivity, which is a measure of the ability of water to conduct an electrical current, will increase with increasing ion concentration in water. Conductivity values from Silver Lake were high in comparison to most lakes monitored for the program, and most likely resulted from mineralization of rock within the lake's watershed.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. The concentration of chlorophyll on both sampling dates (4.8 µg/L in May, and 6.5 µg/L in August) indicated moderately high densities of algae when the lake was sampled. Chlorophyll concentrations greater than 6.6 µg/L are typical for eutrophic lakes; the August value for Silver Lake approached the values that are associated with eutrophic lakes.

Aquatic plants identified by Ecology staff during the sampling visits included aquatic moss, smartweed (*Polygonum* sp.), (*Potamogeton filiformis*), milfoil (*Myriophyllum* sp.; but not the aggressive Eurasian variety), water plantain (*Alisma* sp.), water buttercup (*Ranunculus* sp.) two types of muskgrass (*Chara*), sago pondweed (*Potamogeton pectinatus*), rush (*Juncus* sp.), and another plant that was possibly horned pondweed (*Zannichellia palustris*). Milfoil was the most abundant plant observed.

An algae sample collected during the August onsite sampling visit contained primarily *Zygnema*, although *Mougeotia* and *Lyngbia* were also observed.

Summary of Questionnaire Results and Information from the Volunteer

The 1993 questionnaire on lake and watershed uses was not returned.

Acknowledgment

I thank Kristen Stewart for volunteering her time to monitor Silver Lake in 1993.

Silver Lake -- Spokane County

1993 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	47
Mean Trophic State Index (Total Phosphorus):	56
Mean Trophic State Index (Chlorophyll *a*):	47

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
26-May	0910			12.5			85		breezy	Onsite visit.
16-Jun	1220	18.9	66.0	9.0		lt-green	50	trace	light	Haven't marked something to measure lake height, but lake has receded over a foot on shore.
30-Jun	1310	17.8	64.0	8.5	-2.00	lt-green	25	none	breezy	
27-Jul	1305	20.0	68.0	7.2	-1.00	pea-green	25	trace	breezy	Over a week of stormy, raining weather complete with lightning.
11-Aug	1345	22.8	73.0	5.8		pea-green	25	none	calm	
22-Aug	0900			5.6		pea-green	20		calm	Water color light pea-green. Onsite visit.
03-Oct	1330	16.7	62.0	10.8	-12.00	milky-gr	0	none	calm	Very few boats in last 2-3 weeks. Gorgeous day!

[1] Trophic State Indices calculated from Carlson (1977).
[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Silver Lake dropped 10" from June 30 to October 3.

Silver Lake -- Spokane County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/26	0.0	18.4	8.9	9.9	710
	1.0	18.4	8.6	9.9	710
	2.0	18.4	8.7	9.9	712
	3.0	18.3	8.7	9.9	712
	4.0	18.2	8.7	9.9	710
	5.0	17.5	8.5	10.0	710
	6.0	13.7	8.7	9.4	710
	8.0	11.4	8.7	7.8	704
	10.0	9.3	8.6	5.6	706
	12.0	7.8	8.6	3.9	714
	14.0	6.1	8.5	0.8	718
	16.0	5.8	8.0	0.3	720
	18.0	5.6	8.2	0.2	720
	20.0	5.5	8.2	0.2	720
08/22	0.0	20.6	9.3	9.0	730
	1.0	20.6	9.3	9.0	732
	2.0	20.6	9.3	9.1	730
	3.0	20.5	9.3	9.1	732
	4.0	20.5	9.3	9.1	732
	5.0	20.5	9.3	7.8	730
	6.0	19.9	9.2	5.3	736
	7.0	16.9	9.1	2.4	742
	8.0	15.2	9.0	0.3	746
	9.0	12.4	8.9	0.1	742
	10.0	10.1	8.7	0.1	748
	12.0	7.4	8.6	0.2	750
	14.0	6.7	8.6	0.1	754
	16.0	6.3	8.5	0.1	756
	18.0	6.1	8.5	0.1	760
	20.0	6.0	8.5	0.1	764

Silver Lake -- Spokane County

1993 Onsite Visit Data - Water Chemistry

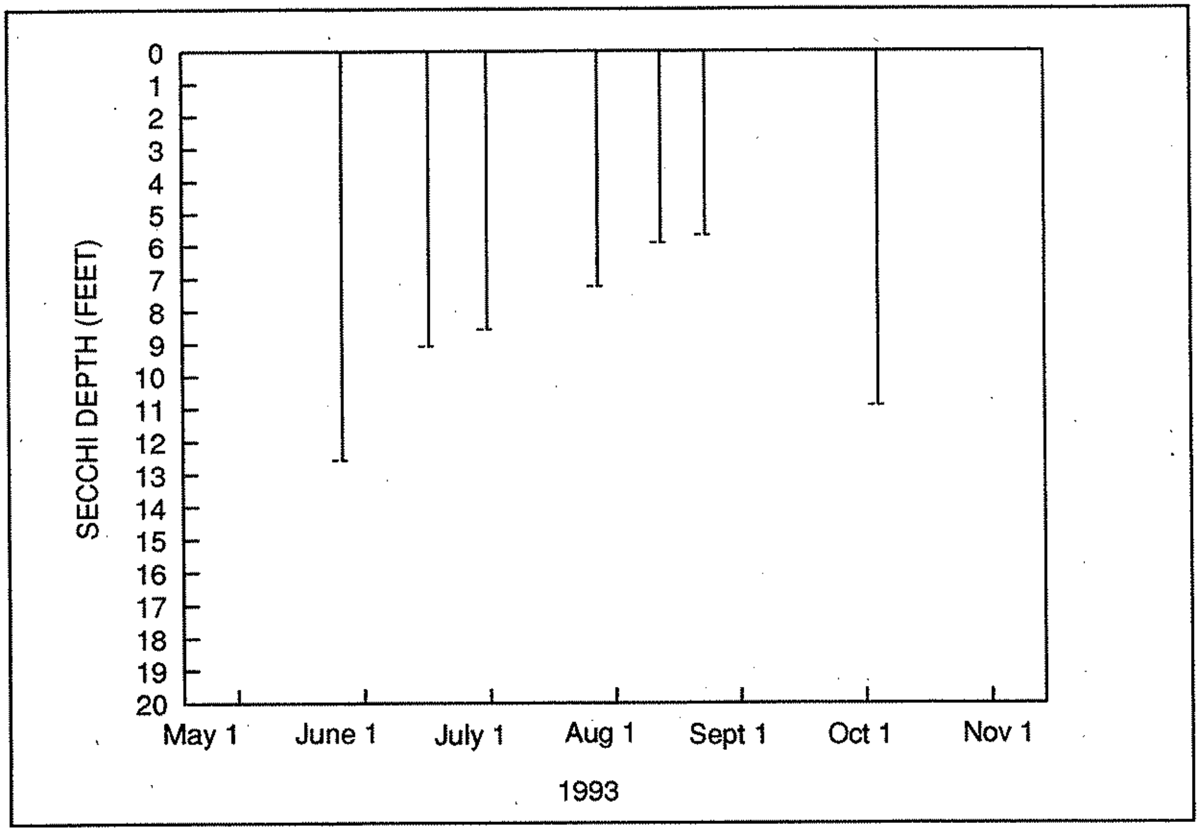
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 26 Epilimnion	64	1.19	4.8	3	1	bdl	3
Hypolimnion	41	1.41	--	--	--	--	
August 22 Epilimnion	20	0.778	6.5	--	--	--	--
Hypolimnion	70	1.52	--	--	--	--	

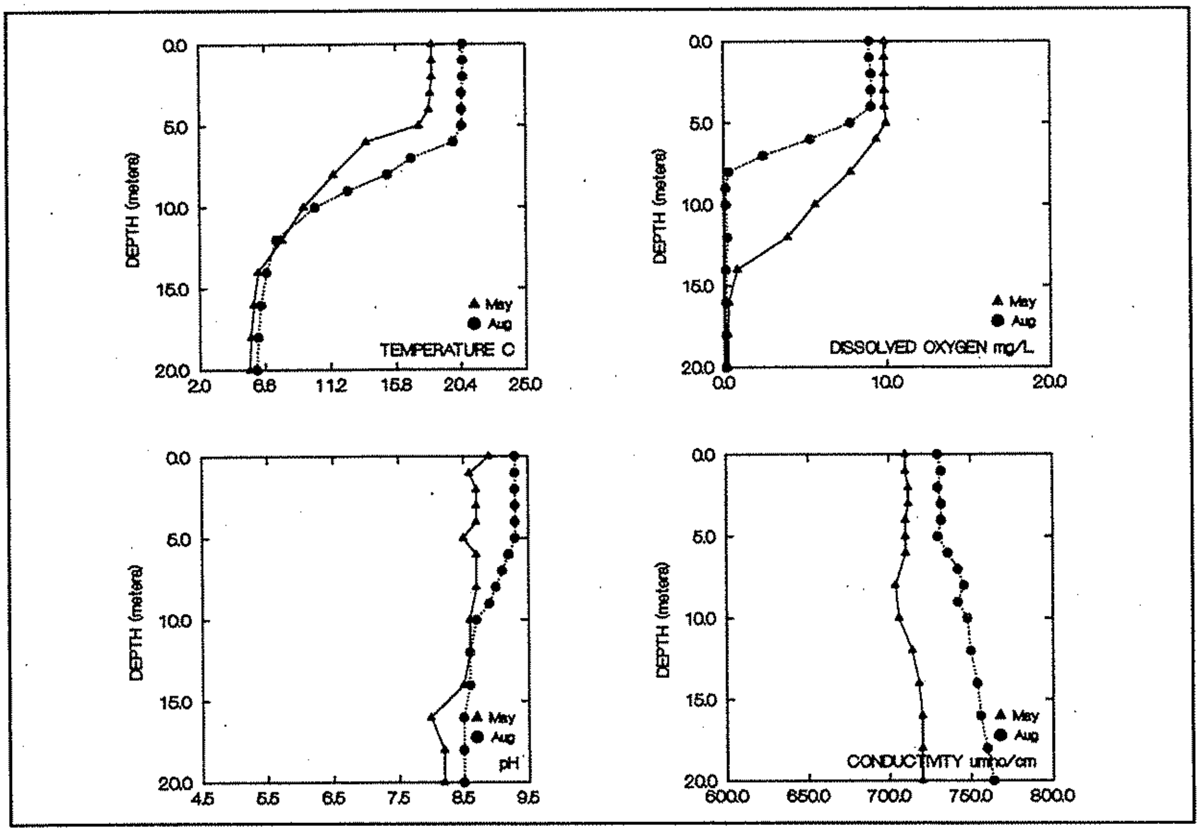
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
05/20/75[a]	32	--	4.3
08/14/75[a]	29	--	1.9

a. Dion *et al.* (1980)

SILVER LAKE (SPOKANE COUNTY)





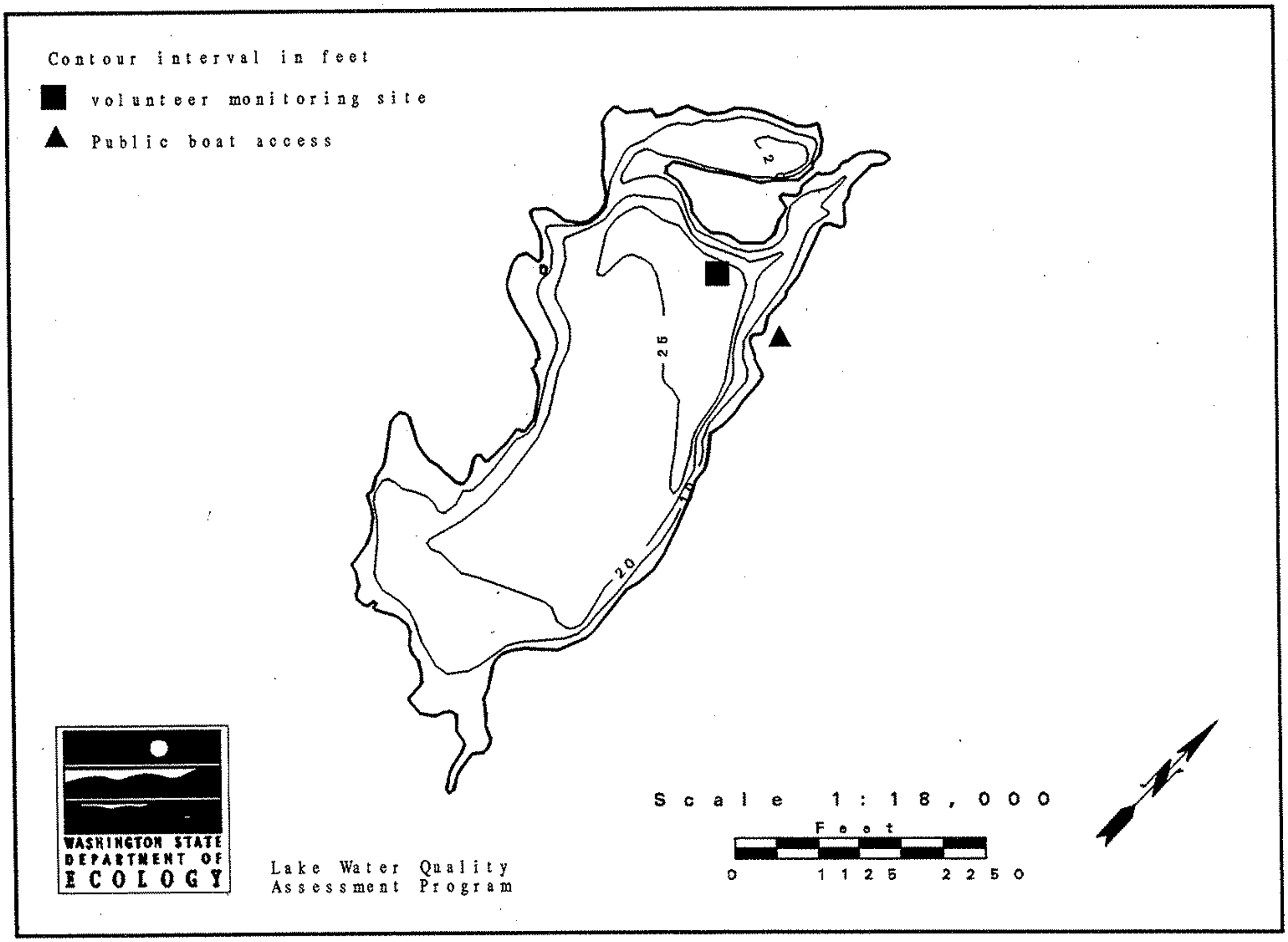
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, Lake Spanaway was assessed as meso-eutrophic, because the lake exhibited both mesotrophic and eutrophic characteristics. Mesotrophic characteristics were the fair water clarity and the moderately high concentrations of total phosphorus. Eutrophic characteristics include high densities of algae and aquatic plants, and very low concentrations of dissolved oxygen in the lower layer of water, which can lead to sediment release of phosphorus and the presence of hydrogen sulfide in water near the lake bottom.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in 1993 was fair, as indicated by Secchi depths that ranged from 7.0 feet to 14.0 feet. Although the pattern in Secchi depths was very similar from 1990-1993, Secchi depths measured in 1993 were not as deep as those measured in 1992. Secchi depths from 6.5 feet to 13.0 feet are typical for mesotrophic lakes.

Total Phosphorus

On both sampling dates, total phosphorus concentrations in the epilimnion were moderately high (13 µg/L in June, and 14 µg/L in August). Concentrations between 12 and 24 are typical for mesotrophic lakes.

In the lower layer of water (the hypolimnion), the concentration of total phosphorus was much higher than the concentrations in the upper layer. In August, phosphorus was very high (103 µg/L) and probably resulted from internal loading from the sediments. Internal loading can occur when oxygen concentrations are depleted near the sediment, creating an environment that allows phosphorus, iron and other compounds in sediment to be chemically reduced and released into the water column (see Profile Data, below). Sediment release of phosphorus can lead to algae blooms during fall after the lake turns over and high phosphorus concentrations in the lower layer of water are mixed throughout the water column.

Total Nitrogen

Concentrations of total nitrogen were very high on both sampling dates, but the June concentration was particularly high (1.1 mg/L). Samples collected for the program in May 1992, May 1991 and May 1990 were also high and over 1.0 mg/L, and were higher than the concentrations measured in late summer. Concentrations in the epilimnion probably decreased by late summer from algae, which take up nitrogen in the epilimnion and then sink into the hypolimnion where they decompose.

The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the total nitrogen to total phosphorus ratios were both much greater than 17:1 (84:1 in June, and 44:1 in August), algae in Lake Spanaway were not limited by nitrogen when the lake was sampled.

Profile Data

The lake was thermally stratified on both sampling dates. Below the thermocline, dissolved oxygen concentrations and pH values decreased considerably with depth. Dissolved oxygen concentrations usually decrease when bacteria use oxygen to decompose aquatic plants and algae in the bottom water and sediments.

The very low dissolved oxygen concentrations near the lake bottom probably caused sediment release of phosphorus (see Total Phosphorus, above). Sediment release is also indicated by the higher conductivity values near the lake bottom. Because iron and other elements can also be released from sediment during low oxygen conditions, conductivity values can increase when this occurs.

The absence of oxygen can also allow hydrogen sulfide to be present in the water. Hydrogen sulfide ("rotten-egg" smell) was smelled in the water sample collected at 7 meters during August. Hydrogen sulfide is produced by bacteria, and is only found in water that has no oxygen.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Concentrations of chlorophyll indicated high densities of algae at the time of sampling. Chlorophyll concentrations greater than 6.6 µg/L are characteristic of eutrophic lakes.

In 1993, aquatic plants were collected and identified from three shallow areas in the southern part of the lake. Plants observed in these areas included whitestem pondweed (*Potamogeton praelongus*), largeleaf pondweed (*Potamogeton amplifolius*), *Nitella* (a macro-algae), coontail (*Ceratophyllum demersum*), and clubmoss. The pondweeds and Nitella were the most abundant plants. In September 1992, coontail and Nitella were observed, as well as Richardson pondweed (*Potamogeton richardsonii*; dominant plant present), Berchtold's pondweed (*Potamogeton berchtoldii*), and waterweed (*Elodea sp.*).

Other Available Information

From Serdar *et al.*(1994): Sediment samples were collected from five lake sites on January 26, 1993, and were analyzed for copper. The shallow bay at the south end of the lake, and the center of the lake, had low copper concentrations in sediments (89.1 and 106 mg/Kg). Three sites in developed areas, the small bay on the west side of the lake, at the outlet, and off the public bathing beach, had high copper concentrations that ranged from 173 to 308 mg/Kg. Higher copper levels were attributed to copper sulfate treatments used to control algal growth.

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 1993.

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 in 1993. Currently, the main activity in the watershed is lakeshore development for residences. In the past, the watershed was logged and used for 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. No lake management activities occurred on the lake in 1993. 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.

Overall, the volunteer found that Lake Spanaway had poor water quality. Problems in the lake in 1993 were ranked as(1) swimmer's itch, (2) excessive aquatic plant growth, (3) algae, (4) excessive amount of resident waterfowl and their feces, (5) eye/skin problems after swimming, (6) bacteria, (7) decaying plants, (8) suspended sediments, (9) degraded aesthestics, (10) odor from decaying algae, (11) recently degraded water quality, (12) water quality gradually degraded over years, (13) shoreline erosion, (14) low water level, (15) fluctuating water level, and (16) high water level. Possible sources of problems include runoff (from roads and septic systems) and waterfowl. In 1993, there was more algae, more plant growth, more suspended sediments, and more swimmers itch than in 1992. Problems reported in 1993 were very similar to those from 1992. Aquatic plants and algae were the worst problems in the lake in 1990 and 1991. Swimmer's itch was not reported to be a problem in 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.

Acknowledgment

I thank Sue Thompson for volunteering her time to monitor Lake Spanaway during 1990-1993.

Lake Spanaway -- Pierce County

1993 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	45
Mean Trophic State Index (Total Phosphorus):	42
Mean Trophic State Index (Chlorophyll *a*):	52

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	Temp (°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
16-May	1345	18.9	66.0	10.5	-0.50	gr-brown	0	none	calm	Very busy with lake activity. Nice weather.
29-May	1230	20.0	68.0	11.5	-0.75		100	moderate	calm	Water color light green/moderate green. Rain and sun off and on.
04-Jun	1020			12.0			100		calm	Onsite visit.
13-Jun	1305	20.0	68.0	9.5	-1.00	lt-green	25	trace	calm	Quiet on the lake - weather cool.
27-Jun	1355	21.1	70.0	8.5	-1.50	gr-brown	75	none	breezy	Moderate lake activity. A lot of algae in water.
11-Jul	1050	18.9	66.0	7.0	-1.75	gr-brown	100	none	breezy	Water still very murky; not clear.
25-Jul	1350	19.4	67.0	8.0	-1.88	gr-brown	75	trace	calm	Poor weather. Not much lake activity.
07-Aug	1145	21.1	70.0	11.5	-3.00	gr-brown	75	trace	calm	
21-Aug	1105	20.6	69.0	14.0	-3.75	gr-brown	100	trace	light	A lot of dead floating algae.
27-Aug	1215			13.5		lt-green	20			Onsite visit.
05-Sep	1145	20.6	69.0	9.5	-4.00	gr-brown	100	none	calm	
20-Sep	1100	17.8	64.0	6.5			100	none	calm	Water color dark greenish-brown. Water very cloudy with a lot of algae.
03-Oct	1100	17.8	64.0	9.0	-5.00	gr-brown	0	none	calm	Floating algae. More weeds growing from bottom. Water cloudy with algae.
17-Oct	1130	15.6	60.1	7.0	-5.50	green	75	trace		Water still very cloudy.

[1] Trophic State Indices calculated from Carlson (1977).
[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Spanaway dropped 5" from May 15 to October 17.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
06/04	1.1	19.2	8.1	10.7	114
	2.0	19.2	8.1	10.8	114
	3.0	17.1	7.9	12.9	116
	4.0	15.1	7.8	12.6	122
	5.0	12.9	7.7	7.6	128
	6.0	11.9	7.5	4.8	131
	7.1	10.8	7.3	2.8	157
	7.7	10.6	7.3	2.0	165
08/27	0.0	20.3	8.1	11.1	115
	1.0	20.1	8.2	10.9	115
	2.0	19.9	8.3	10.7	115
	3.0	19.7	8.3	10.7	115
	4.1	17.6	7.5	5.8	134
	5.0	15.5	7.1	0.3	139
	6.1	12.9	7.0	0.2	188
	7.0	12.1	7.0	0.2	237
	7.8	11.6	6.9	0.2	302

1993 Onsite Visit Data - Water Chemistry

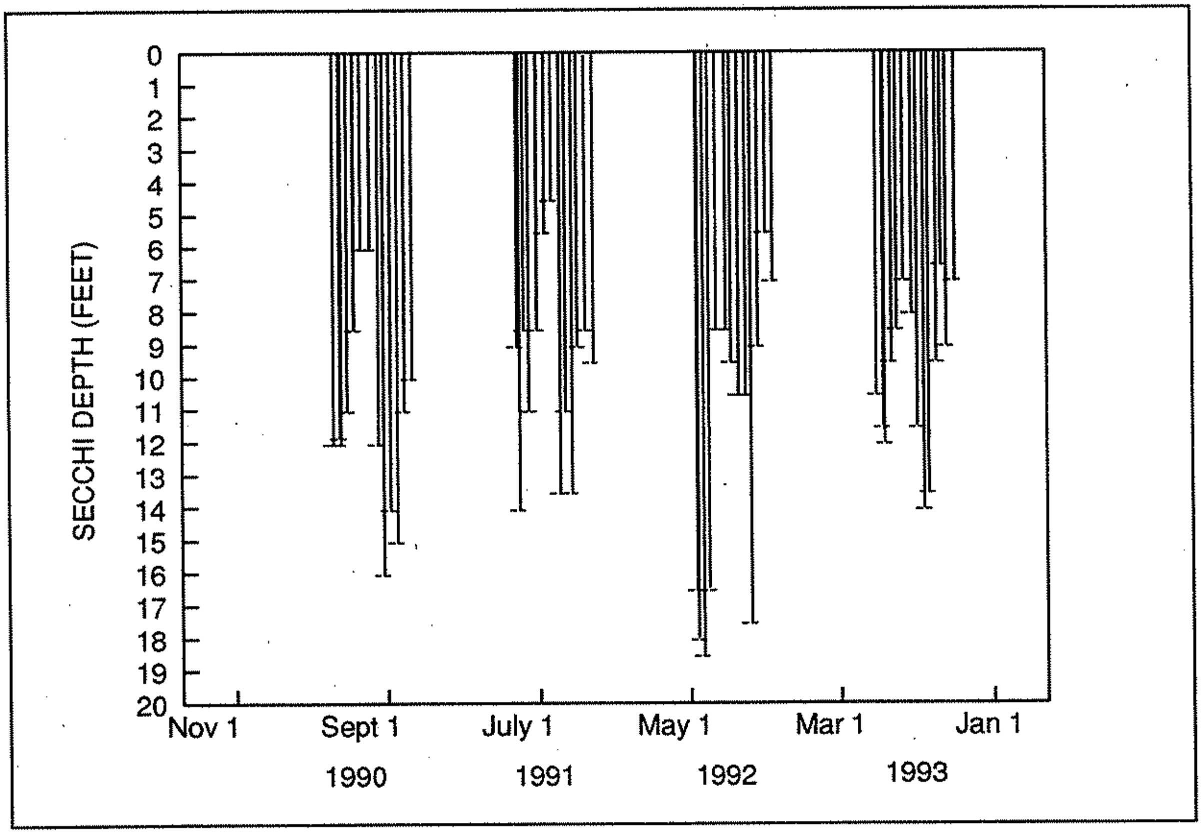
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 4 Epilimnion	13	1.09	7.9	--	--	--	--
Hypolimnion	47	1.19	--	--	--	--	--
August 27 Epilimnion	14	0.62	9.3	--	--	--	--
Hypolimnion	103	1.58	--	--	--	--	--

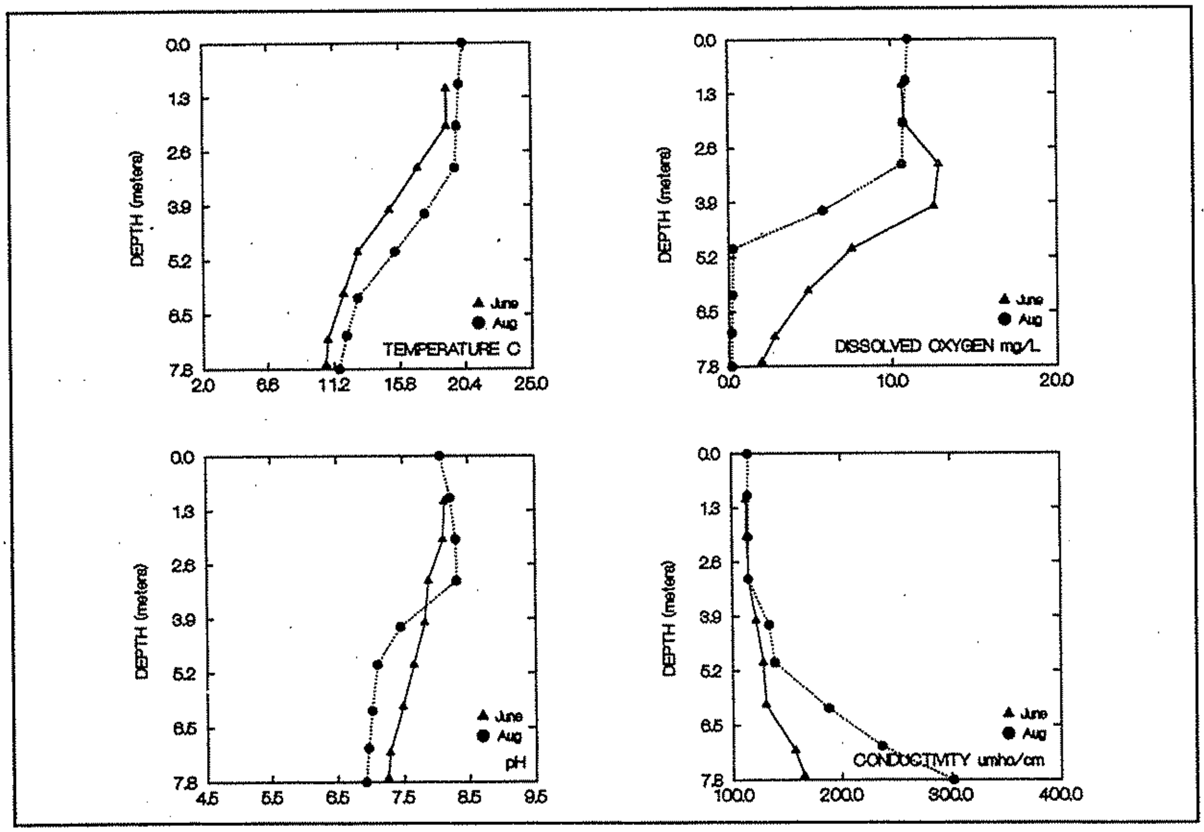
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
06/18/73[a]	28	--	7.3
06/11/81[b]	--	--	1.6
06/01/90[c]	22	1.0	12.4
05/24/91[d]	--	1.2	11.1
05/22/92[e]	8	1.2	1.2
09/04/92[e]	17	0.30	3.3

a. Bortleson *et al.* (1976), McConnell *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)
e. Rector (1993)

LAKE SPANAWAY (PIERCE COUNTY)





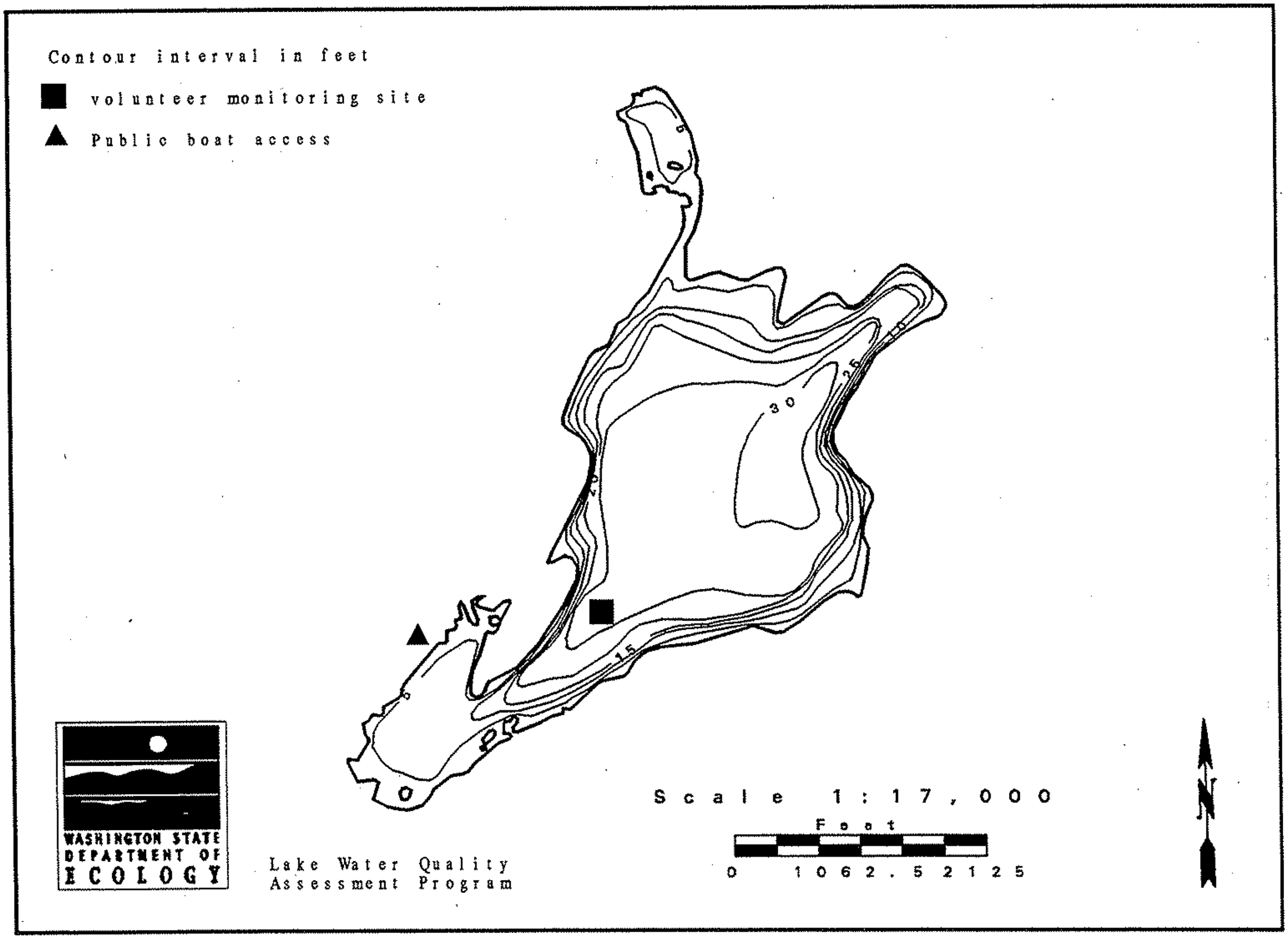
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, Spencer Lake was assessed as oligo-mesotrophic, because it exhibited both oligotrophic and mesotrophic characteristics. The deep Secchi depths were in the oligotrophic range and indicated very good water clarity. However, in May there was a high concentration of total phosphorus and a moderately high density of algae that was more characteristic of a mesotrophic lake. The lake was described as oligotrophic from 1990-1992.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good in 1993, as indicated by Secchi depths that ranged from 11.5 feet to 18.0 feet. Secchi depths greater than 13.0 feet are typical for oligotrophic lakes.

In general, water clarity in Spencer Lake was better in 1993 than in 1992; in 1992 there was a blue-green algae bloom during late summer, whereas there was no algae bloom observed in 1993.

Total Phosphorus

In May, the concentration of total phosphorus in the upper layer of water was high (51 µg/L). Reasons for this high concentration are unknown, because concentrations were not high in the hypolimnion sample, and there were no recent rains that could have washed phosphorus-laden runoff into the lake. The phosphorus concentration in May was high enough to have produced an algal bloom, but some growth requirement other than phosphorus (such as light, temperature, nitrogen or silica) limited algae growth.

In September, the total phosphorus concentration in the upper layer of water was low (8 µg/L). Concentrations less than 12 µg/L in the epilimnion are typical for oligotrophic lakes.

Total Nitrogen

On both sampling dates, the concentrations of total nitrogen were moderately low and were similar to concentrations measured from 1990-1992. Total nitrogen concentrations in Spencer Lake were low relative to concentrations in other lakes in the program.

The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae generally use at least ten times the amount of nitrogen as phosphorus. In September, the ratio of total nitrogen to total phosphorus was greater than 17:1 (32.5:1). As a result, algae were not limited by nitrogen in September.

Profile Data

As in 1992, the lake was weakly stratified in May 1993, but had destratified by September. The shallow depth of the sampling site may make the area prone to mixing from winds and motorboats. Decreases in dissolved oxygen concentrations near the lake bottom probably result from bacteria, which use oxygen as they decompose aquatic plants and algae in bottom water and sediments.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. In May, the concentration of chlorophyll *a* indicated a moderately high density of algae at the time of sampling. In August, the chlorophyll concentration indicated a low density of algae.

In August 1992, there were complaints to the Mason County Office of Water Quality about a severe algae bloom in the north end of Spencer Lake. An algae sample collected for this program from the south end of the lake contained the blue-green filamentous alga *Oscillatoria*; remains of an algae bloom were noted at the south end of the lake when the sample was collected.

Aquatic plants identified by Ecology staff during the May 19, 1992, sampling visit with the volunteer were yellow-flowering water lily (*Nuphar polysepalum*), iris (*Iris pseudacorus*), and an unidentified rush. During the August 1990 onsite visit with the volunteer, large-leaved pondweed (*Potamogeton amplifolius*) was also observed.

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 1993.

> 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 in 1993. Currently, the watershed is used for crop agriculture, animal grazing/feeding, and lakeshore development for residences. In the past, the watershed was logged and used for 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 about 96 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. No lake management activities occurred on the lake in 1993.

Overall, the volunteer found that Spencer Lake had good water quality and there were no water quality problems in the lake in 1993. However, leachate from septic tanks could eventually cause problems if development in the area increases. In comparison to the 1992 monitoring season, there was no significant algae bloom in 1993. Algae was the worst problem in the lake in 1992.

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.

Acknowledgment

I thank Virginia Charrier for volunteering her time to monitor Spencer Lake during 1991-1993, and both Virginia and Larry Charrier for monitoring the lake during 1990.

Spencer Lake -- Mason County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	39
Mean Trophic State Index (Total Phosphorus):	48
Mean Trophic State Index (Chlorophyll *a*):	41

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
15-May	1300	16.1	61.0	12.5	8.00	lt-green	10	trace	light	Lake height starts at 8" below winter high level.
28-May	0930	20.0	68.0	14.0	10.00		25	none	light	Water color light green/yellowish. Onsite visit.
15-Jun	1000	16.7	62.0	12.0	7.00		75	moderate	breezy	Water color light yellow-green.
29-Jun	0930	20.0	68.0	11.5	10.00	lt-green	25	trace	light	
14-Jul	1100	19.4	67.0	14.5	11.00	lt-green	90	light	breezy	
30-Jul	1030	19.4	67.0	15.0		lt-green	75	heavy	light	
02-Aug	0930	21.1	70.0	18.0	14.00		0	none	light	Water color light yellow-green.
16-Aug	1030	20.0	68.0	15.0	12.50		100	light	light	Water color light yellow-green.
02-Sep	0930			18.0			0			Onsite visit. Water color light yellow-green.
14-Sep	1400	20.0	68.0	15.0	16.00		10	trace	calm	Water color light yellow-green.
29-Sep	1030	18.9	66.0	16.0	19.50		0	none	calm	Water color light yellow green.
15-Oct	1300	16.7	62.0	13.0	19.00	lt-green	90	moderate	breezy	

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Spencer Lake dropped 11" from May 15 to October 15.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/28	0.0	19.5	7.2	9.6	30
	1.1	19.5	7.2	9.6	30
	2.0	19.3	7.3	9.6	30
	3.0	19.2	7.3	9.6	30
	4.0	17.7	7.3	9.9	30
	4.9	15.4	7.2	9.8	30
	6.0	14.1	7.1	8.5	30
	7.0	13.0	6.7	4.1	33
	7.4	12.8	6.6	2.8	35
09/02	0.0	20.9	7.3	8.5	31
	1.0	20.8	7.3	8.5	31
	3.0	20.6	7.2	8.5	30
	4.0	20.6	7.2	8.6	30
	5.0	20.4	7.2	8.4	31
	6.0	19.9	7.1	7.2	31
	7.0	18.4	6.9	2.3	33
	7.5	17.3	6.8	0.4	43
	7.5	17.3	6.9	0.6	41

1993 Onsite Visit Data - Water Chemistry

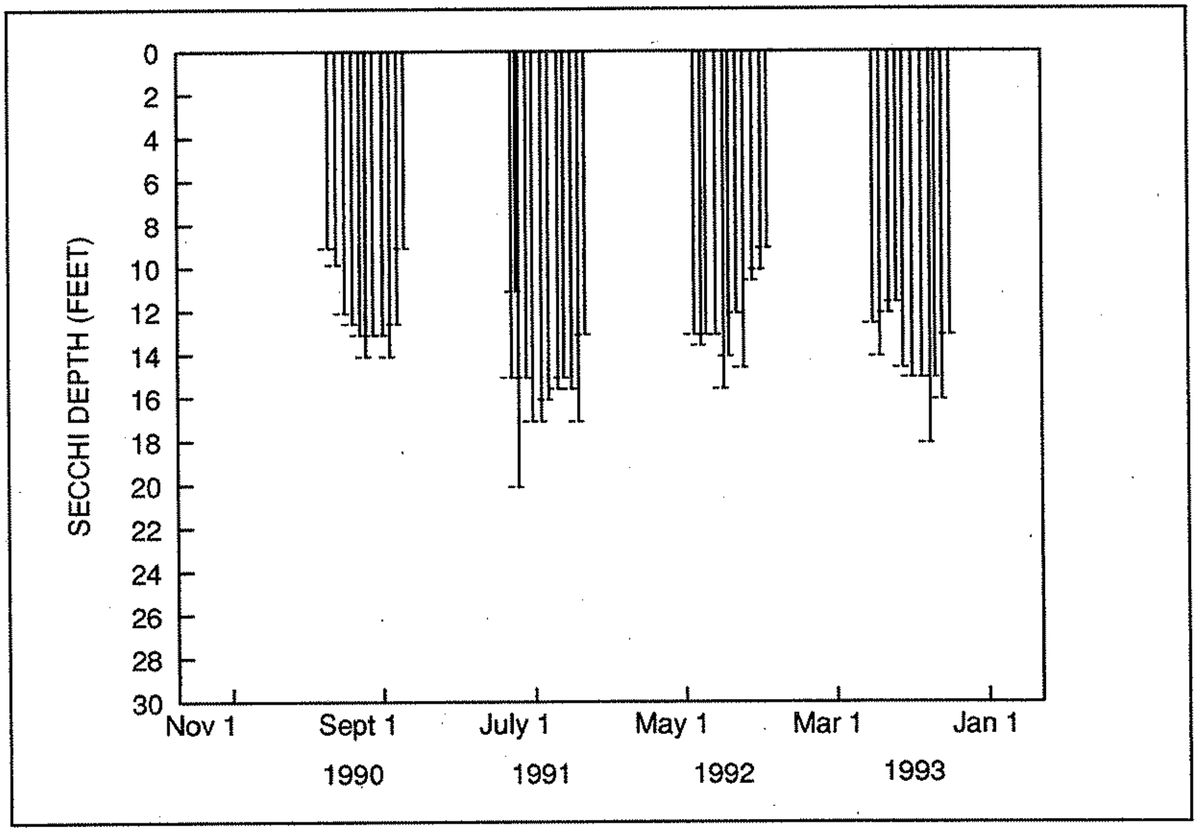
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 28 Epilimnion	51	0.26	4.0	--	--	--	--
Hypolimnion	15	0.28	--	--	--	--	--
September 2 Epilimnion	8	0.26	2.3	--	--	--	--
Hypolimnion	15	0.28	--	--	--	--	--

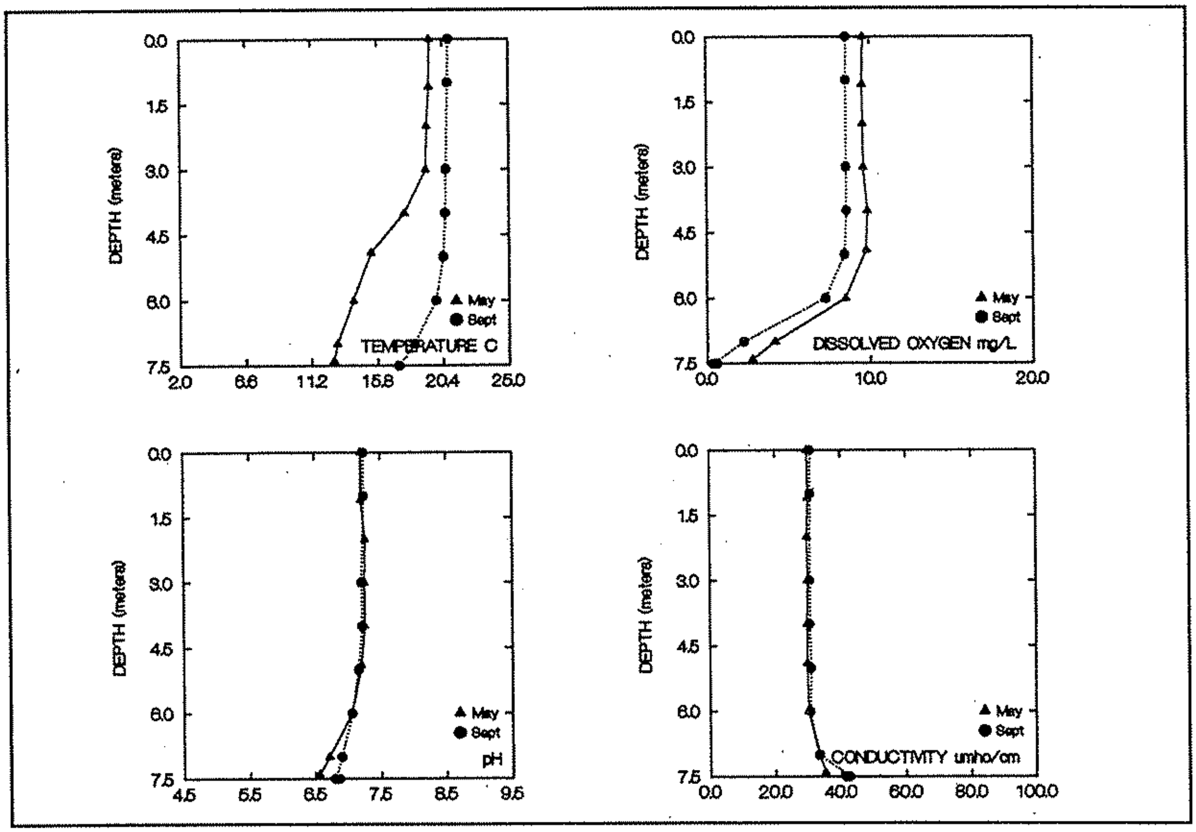
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
08/20/74[a]	9	--	--
05/24/90[b]	9	0.27	--
08/15/90[b]	13	0.35	--
05/21/91[c]	--	0.22	--
05/19/92[d]	10	0.29	1.3
08/26/92[d]	7	0.33	1.1

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)

SPENCER LAKE (MASON COUNTY)





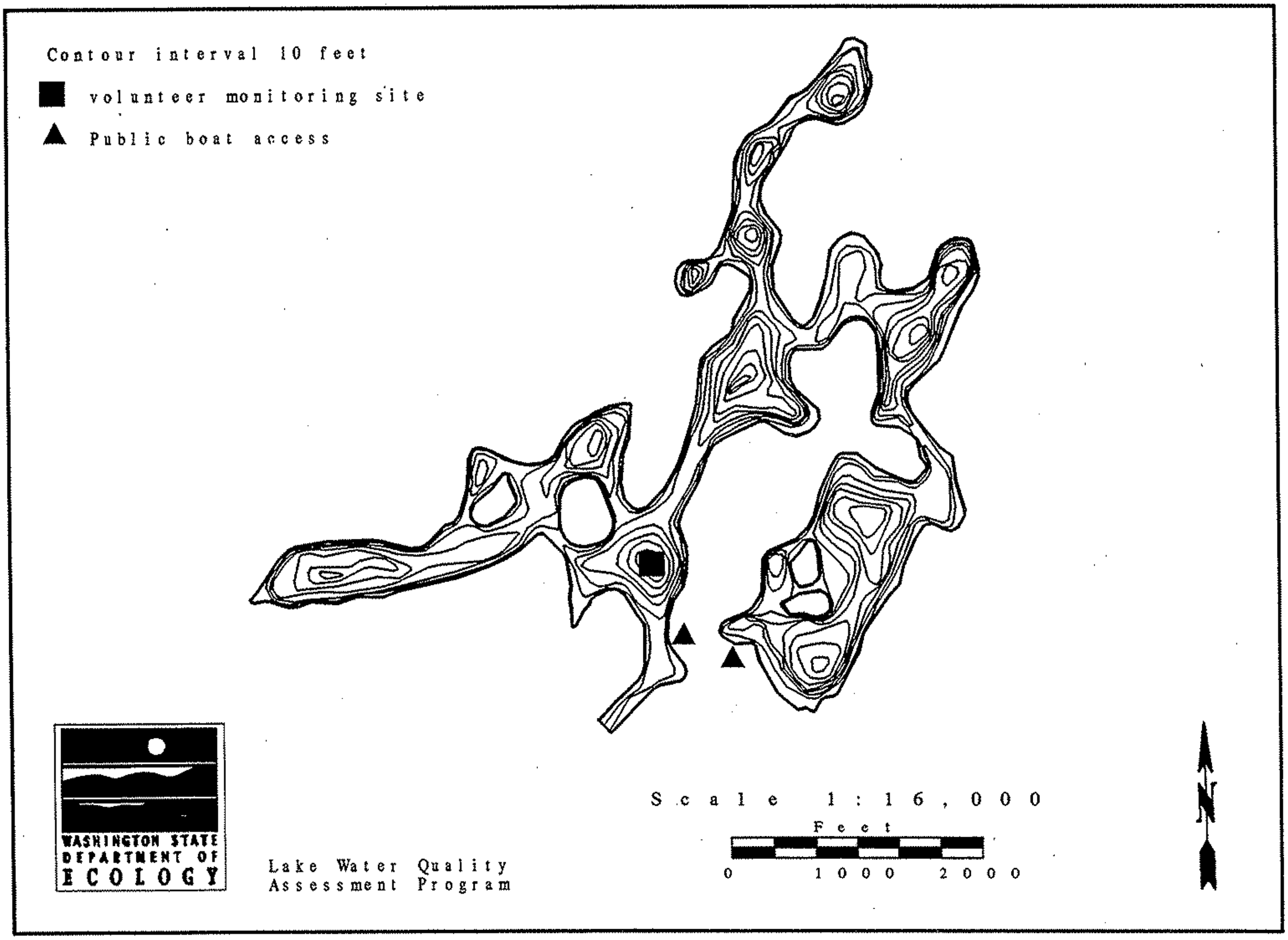
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, Lake St. Clair was assessed as meso-eutrophic, because it exhibited both mesotrophic and eutrophic characteristics. Mesotrophic characteristics were the fair water clarity, a moderately high concentration of total phosphorus in August, and low to moderately high densities of algae on both sampling dates. Eutrophic characteristics include the very low concentrations of dissolved oxygen in the lower layer of water and the high concentrations of total phosphorus in May. The lake was described as eutrophic from 1989 to 1992 because of low water clarity, high concentrations of total phosphorus, and blue-green algae blooms. In 1993, water clarity and total phosphorus were improved compared to earlier data collected for this program, and there was no apparent bloom of algae. Despite these, there was not a statistically significant trend in Secchi depths in Lake St. Clair from 1989 to 1993, and there were not enough data to test for a trend in total phosphorus concentrations.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was fair, as indicated by Secchi depths that ranged from 6.5 feet to 11.5 feet. Secchi depths from 6.5 feet to 13.0 feet are typical for mesotrophic lakes.

In general, Secchi depths were deeper in 1993 than in the previous five years. However, the increase in Secchi depths from 1989 to 1993 was not statistically significant.

Total Phosphorus
The concentration of total phosphorus in the epilimnion was high in May (29 µg/L), and moderately high in September (19 µg/L). These concentrations were lower than concentrations measured for the program in 1992 and 1990. Concentrations in the epilimnion from 12 to 24 µg/L are typical for mesotrophic lakes.

Total Nitrogen
Concentrations of total nitrogen were moderately high on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae generally use at least ten times the amount of nitrogen as phosphorus. Because the ratio of total nitrogen to total phosphorus was greater than 17:1 in September (it was 27:1), algae growth in the lake was not limited by nitrogen when the lake was sampled in September. In May, the ratio of total nitrogen to total phosphorus was much lower (14:1), so algae growth may not have been limited by phosphorus at the time.

Profile Data

There are no profile data for May, due to problems with the profiling equipment. In September, the lake was thermally stratified. Below the thermocline, the concentrations of dissolved oxygen decreased considerably with depth 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 bottom of the epilimnion. Dissolved oxygen usually decreases in water when bacteria use oxygen as they decompose aquatic plants and algae in the water and sediments.

In 1992, hydrogen sulfide was smelled in water samples collected from the bottom of the lake in August. Hydrogen sulfide is produced by bacteria in water that has no oxygen. In 1993, none of the water samples collected smelled of hydrogen sulfide.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. In May, the concentration of chlorophyll indicated a low density of algae at the time of sampling. In August, the chlorophyll concentration (4.5 µg/L) indicated a moderately high density of algae. Chlorophyll concentrations from 2.6-6.6 µg/L are typical for mesotrophic lakes.

Aquatic plants observed in the lake in 1992 included naiad (*Najas* sp.), 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 *Nitella* (Coots, 1991).

Other Available Information

The lake's level decreases considerably during 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. And in 1993, the level dropped 19 inches from May 19 to September 25. Low water level is a concern of lakeshore homeowners. Low water level has been listed as a problem in the lake in questionnaires completed by the volunteer (see Summary of Questionnaire Results, below).

From Davis (1994): Twice monthly from April through October 1993, volunteers collected water samples and measured temperature, dissolved oxygen, pH, and Secchi depth at five lake stations.

Water samples were analyzed for total phosphorus, nitrate, nitrite, turbidity, chloride, hardness, and iron. Overall, surface temperature was slightly lower in 1993 than in 1992. Four of five lake stations had no oxygen in the bottom waters. Surface pH ranged from 6.0 to 7.5, and median values were very similar to values measured in 1992. Secchi depth ranged from 3.5 feet to 12.5 feet and the average Secchi depth for all stations was 7.75 feet. In general, water clarity was lowest in spring, improved throughout summer, and highest in fall. Most surface TP concentrations were in the range 15 to 25 µg/L, and the average surface total phosphorus concentration was 21 µg/L. Concentrations of total phosphorus were considerably higher near the bottom of the lake at three of five stations, suggesting that internal loading of phosphorus may have occurred at these sites. Recommendations included continuing the Lake St. Clair Organization's monitoring program, adding chlorophyll as a parameter, sampling at least once during winter to evaluate mixing and stratification in the lake, and continuing involvement in Ecology's lake monitoring program.

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.

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 1993.

> 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 two percent of the shoreline is publicly-owned. Rainbow trout were stocked in the lake in 1993. Currently the watershed is being logged and used for animal grazing and crop agriculture. The lakeshore is also being developed further for residences. In the past the watershed was logged and used for 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 about 325 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

for the lake, the Lake St. Clair Organization, and a volunteer lake monitoring group for the lake. Currently, the minimum setback for lakeshore development is 30 feet. No lake management activities occurred on the lake in 1993.

Overall, the volunteer found that Lake St. Clair had good water quality. Problems in the lake in 1993 were ranked as (1) low water level, (2) algae, (3) excessive aquatic plant growth, (4) decaying plants, (5) shoreline alteration from new development, (6) suspended sediments, (7) fluctuating water level, and (8) shoreline erosion. Possible sources of problems include continued development, the creek, and possibly lawn fertilizers or treatments. 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. In comparison to the 1992 monitoring season, weed growth was more noticeable in 1993.

Acknowledgment

I thank M.E. Christopherson for volunteering his time to monitor Lake St. Clair during 1989-1993.

Lake St. Clair -- Thurston County

1993 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	46
Mean Trophic State Index (Total Phosphorus):	49
Mean Trophic State Index (Chlorophyll *a*):	41

Volunteer-Collected Data

Date 1993	Time	Temp (°C) (°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
19-May	1030	21.0 69.8	8.0	-8.00	red-brown	50	trace	calm	Lake approx. 8" below last year level at this time - water at base of bulk head (starting point).
02-Jun	1500	21.0 69.8	6.5	-7.00	red-brown	75	moderate	breezy	Water clear except for color. Lake level rose 1".
13-Jun	1400	21.0 69.8	7.0	-8.00	red-brown	50	trace	light	Lake level dropped 1".
27-Jun	1500	22.0 71.6	7.0	-10.50	red-brown	50	trace	gusty	A little algae showing up, none on surface just a little in the water.
12-Jul	1500	21.0 69.8	7.5	-14.50	red-brown	10	light		Water quite clear.
02-Aug	1500	24.0 75.2	7.5	-17.50	red-brown	0	none	breezy	Lake height dropped 2.5" since last reading. Heavier weed growth on local frontage.
23-Aug	1700	23.0 73.4	11.0		red-brown	50	light	breezy	
04-Sep	1300	22.0 71.6	10.0	-24.50	red-brown	25		light	
15-Sep	1030	20.0 68.0	9.0	-26.50	red-brown	25	trace	calm	Seems like more assorted weed types, more than normal on our frontage and other areas.
25-Sep	1330	19.0 66.2	9.5	-28.00	red-brown	0	trace	breezy	
04-Oct	1430	17.0 62.6	10.0	-27.00	red-brown	100	none	breezy	Very dark day, water clear.
20-Oct	1300	15.0 59.0	11.5	-27.00	red-brown	25	trace	light	Lowest point measured 9/25 at 28" down. Came back up 1".

1 Trophic State Indices calculated from Carlson (1977).
2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake St. Clair dropped 19" from May through October 20.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/19	0.0	21.4	7.7	8.9	91
09/07	0.0	22.7	7.4	8.7	95
	1.0	21.2	7.4	8.3	94
	2.0	20.6	7.3	6.8	94
	3.1	17.1	7.3	0.3	91
	4.1	12.9	7.3	0.2	91
	5.0	9.9	7.3	0.1	90
	6.1	7.8	7.2	1.3	89
	7.0	6.9	7.2	1.8	88
	8.1	6.5	7.2	1.4	89
	9.0	6.2	7.1	0.4	90
	10.1	5.8	7.0	0.1	91
	12.1	5.6	7.1	0.1	93

1993 Onsite Visit Data - Water Chemistry

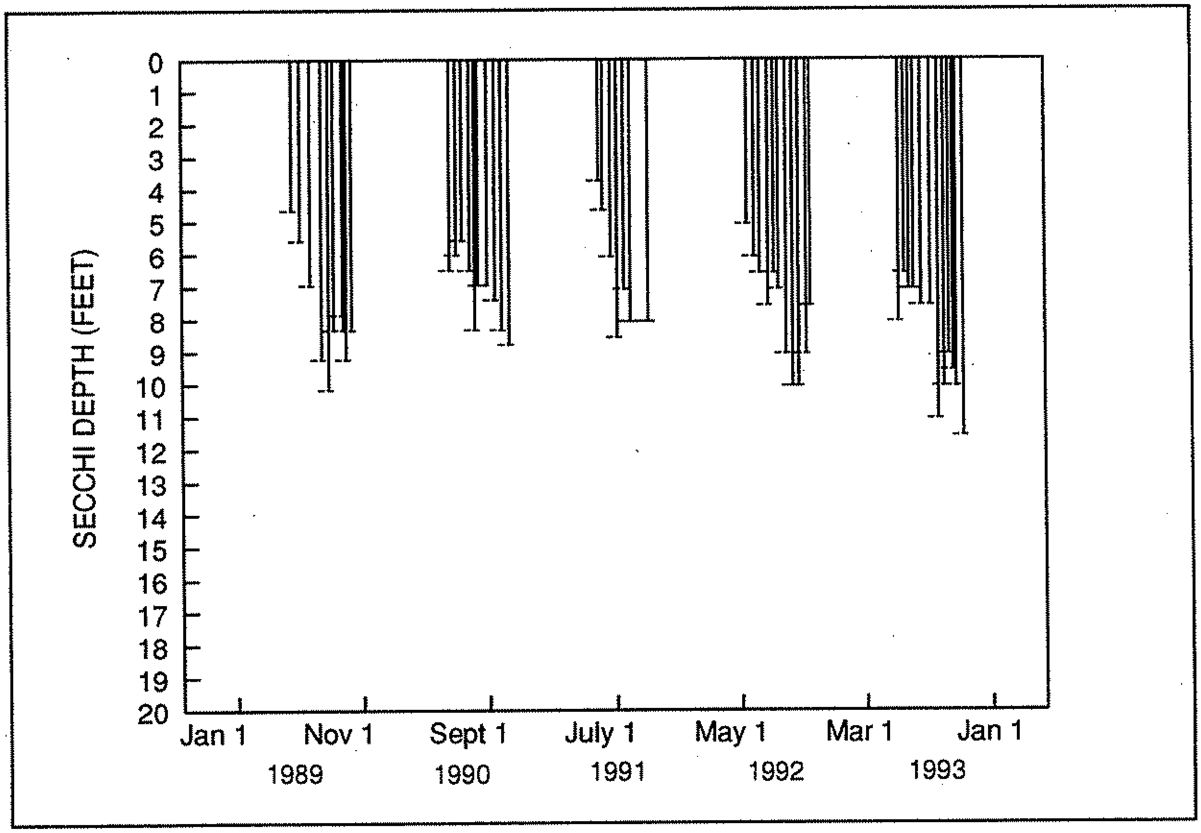
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 19 Epilimnion	29	0.41	2.0	--	--	--	--
Hypolimnion	52	0.57	--	--	--	--	--
September 7 Epilimnion	18	0.48	4.5	--	--	--	--
Hypolimnion	63	0.60	--	--	--	--	--

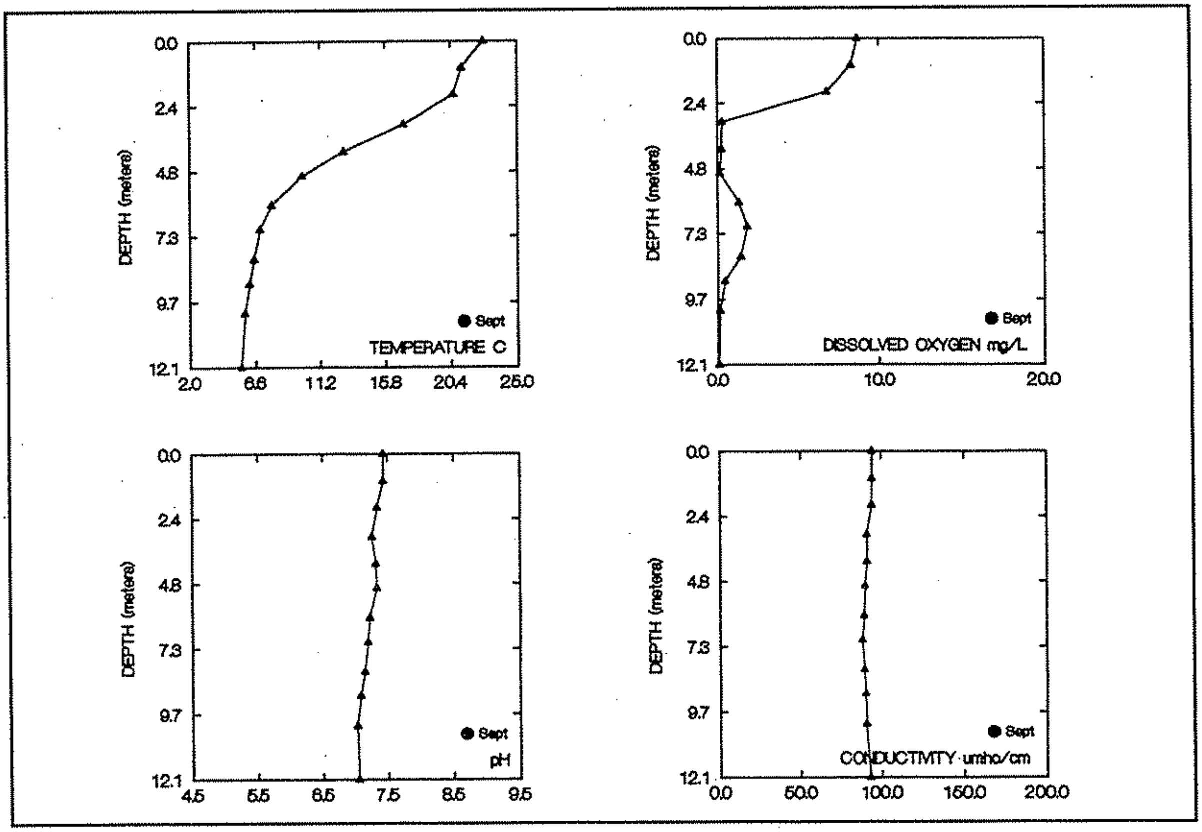
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
North Arm			
06/28/72[a]	20	--	4.6
05/30/90[b]	35	0.53	--
08/22/90[b]	24	0.53	--
05/31/91[c]	--	0.63	--
05/11/92[d]	32	0.61	5.9
09/02/92[d]	25	0.38	1.0
South Arm			
06/28/72[a]	30	--	11.0
06/09/81[e]	80	2.0	54.2
06/11/90[f]	--	0.63	11.6
09/19/90[f]	25	0.66	10.1

a. Bortleson *et al.* (1976b)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)
e. Sumoika and Dion (1985)
f. Coots (1991)

LAKE ST. CLAIR (THURSTON COUNTY)





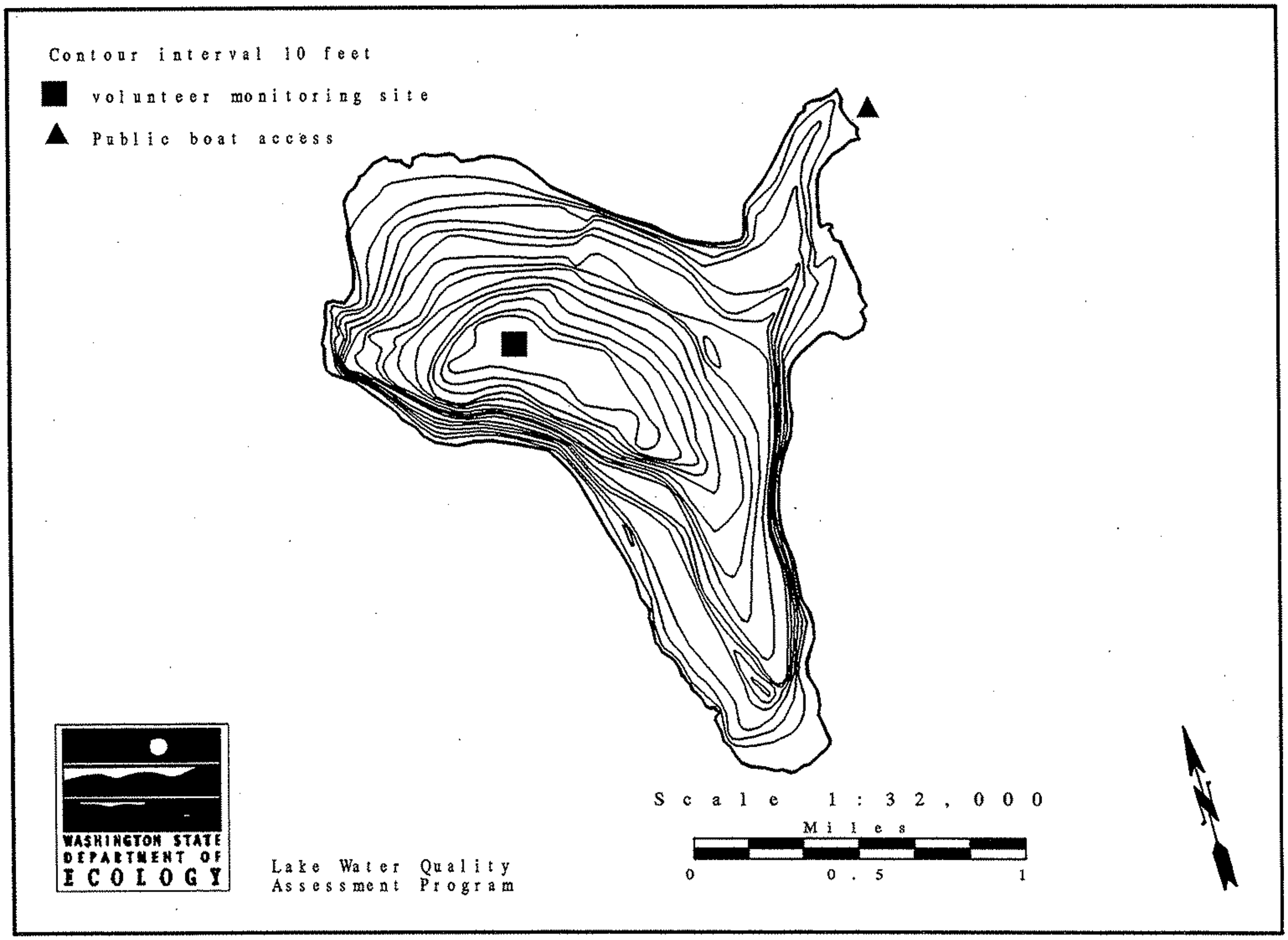
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, Lake Stevens was assessed as oligo-mesotrophic, because it exhibited both oligotrophic and mesotrophic characteristics. Oligotrophic characteristics were the good water clarity and low concentrations of total phosphorus in the upper layer of water. Mesotrophic characteristics include the moderate densities of algae at the time of sampling. Based on data collected for the program, the lake was assessed as oligotrophic from 1990-1992.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good in 1993, as indicated by Secchi depths that ranged from 15.0 feet to 26.0 feet. Water clarity was better in 1993 than in 1992. Secchi depths greater than 13.0 feet are typical for oligotrophic lakes.

Total Phosphorus

Concentrations of total phosphorus in the upper layer of water were low on both sampling dates (7 µg/L in May, and 10 µg/L in August). These concentrations are lower than those measured for the program in 1992 and 1990. Concentrations less than 12 µg/L in the upper layer of water are typical for oligotrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were moderately low on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 (51:1 in May, and 24:1 in August), algae growth in Lake Stevens was not limited by nitrogen when the lake was sampled.

Profile Data

On both sampling dates, the lake was strongly stratified with respect to temperature. Below the thermocline, both pH and dissolved oxygen decreased gradually with depth. Low dissolved oxygen probably resulted from bacteria which use oxygen to decompose aquatic plants and algae in the bottom water and sediments.

In August 1993, temperature was lower throughout the water column, and dissolved oxygen concentrations were higher, in comparison to data collected in August 1992. Poor summer weather in 1993 could have caused lower water temperatures. This in turn probably led to higher oxygen concentrations, because oxygen solubility increases as water temperature decreases.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Chlorophyll concentrations measured on both sampling dates (3.0 μg/L in May, and 4.0 μg/L in August) indicated moderate densities of algae at the time of sampling. Chlorophyll concentrations from 2.6 to 6.6 μg/L are typical for mesotrophic lakes.

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).

Four partial lift hypolimnetic aerators were installed in Lake Stevens, and were operating beginning in May 1994 (Gene Williams, Snohomish County Public Works, pers. comm.).

From KCM, Inc. (1994): In 1993, volunteers and KCM staff independently collected water samples, profile data, and Secchi depth measurements from the deep site of Lake Stevens. Volunteers sampled every two months from December 1989 through December 1993, and composited samples from the first ten meters of the lake, and from 20, 30 and, 40 meters. KCM staff sampled monthly starting in April 1993 (and will continue through 1996), and collected discrete water samples at 0.5, 5, and 10 meters, and composited samples from 20, 30, and 40 meters. Both groups also monitored the inlets and outlet of the lake. In 1993, volunteer-collected Secchi depths ranged from 5.0 to 7.6 meters (16.4 to 24.9 feet). Total phosphorus in samples composited from 0 through 10 meters ranged from 5 to 43 μg/L [the only values greater than 12 μg/L were measured in February and October 1993].

Unpublished data collected by KCM staff from April through October 1993 indicate that the lake was stratified the entire time, and dissolved oxygen concentrations at 40 and 44 meters were very low during September and October. Total phosphorus concentrations averaged from the 0.5, 5, and 10 meter depths ranged from 7 to 12 μg/L, and chlorophyll *a* concentrations averaged from the same depths ranged from 1.3 to 3.9 μg/L.

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 1993.

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 being logged and is used for crop agriculture, animal grazing/feeding, and industry. The lakeshore is also being developed further for residences. In the past, the watershed was logged and used for crop agriculture and animal grazing/feeding, the lake was dredged, and the shoreline was altered (filled wetlands).

There are 284 houses on the lakeshore, and all houses are connected to a sewer. About 6 culverts/stormdrains drain into the lake. There is a lake management district for the lake. No aquatic plant management activities occurred on the lake in 1993.

Overall, the volunteer found that Lake Stevens had excellent water quality. Problems in the lake in 1993 were ranked as (1) algae, (2) excessive aquatic plant growth, (3) fluctuating water level, (4) high water level, (5) low water level, (6) odor from decaying algae, and (7) degraded aesthestics. Runoff was cited as a possible source of the algae problem. The main boat launch is scheduled to be torn up and replaced with new docks, launch, and swimming area during winter 1993. Lake level was maintained at a higher level in 1993 than in 1992; in 1992, the lake level was extremely low.

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.

Acknowledgment

I thank Mark McCullough for volunteering his time to monitor Lake Stevens during 1990-1993.

Lake Stevens -- Snohomish County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	34
Mean Trophic State Index (Total Phosphorus):	35
Mean Trophic State Index (Chlorophyll *a*):	43

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
25-May	1500	21.1	70.0	26.0		green	10	none	breezy	First observation of season.
09-Jun	1745	21.1	70.0	20.0	6.00	green	0	none	light	Lake looks good.
25-Jun	1722	19.4	67.0	15.0	2.00	pea-green	10	none	light	Lots of rain since last reading. Lake higher and much worse. Small amount of algae floating - no weeds yet.
09-Jul	1800	19.7	67.5	18.0	5.00	green	75	trace	light	Weed growth is low. Water visibility is improving.
25-Jul	0910	20.3	68.5	22.0	6.00	green	75	light	calm	Small algae floating, water coming up. Lake looks good.
01-Aug	0930	20.6	69.0	23.5	6.00	green	10	none	calm	Lake looks good.
12-Aug	1930	21.7	71.0	19.0		green	10	none	light	Water temp last week was 76 degrees.
18-Aug	1600	21.1	70.0	19.5	6.00	green	10	none	breezy	Onsite visit.
02-Sep	1730	22.2	72.0	22.0	5.00	green	10	none	calm	
16-Sep	1800	21.7	71.0	23.0		green	0	none	breezy	Lake looks good!
20-Oct	1430	18.3	64.9	17.0	10.00	green		none	breezy	Lake is cooling off fast. Water level dropping fast.

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

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Stevens dropped 4" from June 9 to October 20.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/25	0.0	19.6	8.1	9.9	83
	0.9	19.5	8.2	9.9	83
	1.9	19.3	8.1	10.0	83
	3.0	19.0	8.2	10.0	83
	4.0	17.7	8.2	10.3	82
	4.9	14.8	8.2	10.8	80
	6.0	13.3	8.2	11.0	80
	6.9	12.5	8.1	10.9	80
	8.1	10.9	8.0	10.5	80
	10.0	9.5	7.9	10.2	80
	11.9	8.2	7.8	9.9	79
	13.8	7.4	7.8	9.9	79
	16.2	6.8	7.8	9.9	78
	17.9	6.4	7.7	9.7	79
	20.1	6.2	7.7	9.7	78
	22.0	6.1	7.7	9.5	79
	24.1	5.9	7.6	9.5	78
	26.2	5.7	7.6	9.5	78
	28.1	5.6	7.6	9.4	78
	30.3	5.6	7.6	9.3	79
	32.4	5.5	7.5	9.1	80
	36.0	5.4	7.5	9.0	78
	40.2	5.3	7.5	8.8	77
	43.3	5.3	7.4	7.2	81
08/18	0.0	21.1	7.8	9.6	86
	1.1	21.1	7.8	9.7	86
	2.2	21.0	7.8	9.7	86
	3.0	20.7	7.8	9.7	86
	4.0	20.5	7.8	9.8	86
	5.0	20.4	7.8	9.7	86
	6.1	19.3	7.7	9.5	85
	6.9	17.1	7.8	9.6	83
	8.1	13.0	7.9	9.4	82
	10.1	10.0	7.8	8.5	82
	13.0	8.2	7.7	8.2	81
	15.1	7.5	7.7	8.1	81
	20.0	6.5	7.6	8.2	80
	25.1	6.1	7.6	7.9	80
	30.0	5.9	7.5	7.7	81
	35.2	5.8	7.4	6.8	81
	40.1	5.7	7.4	5.3	81
	43.9	5.7	7.3	3.0	87

1993 Onsite Visit Data - Water Chemistry

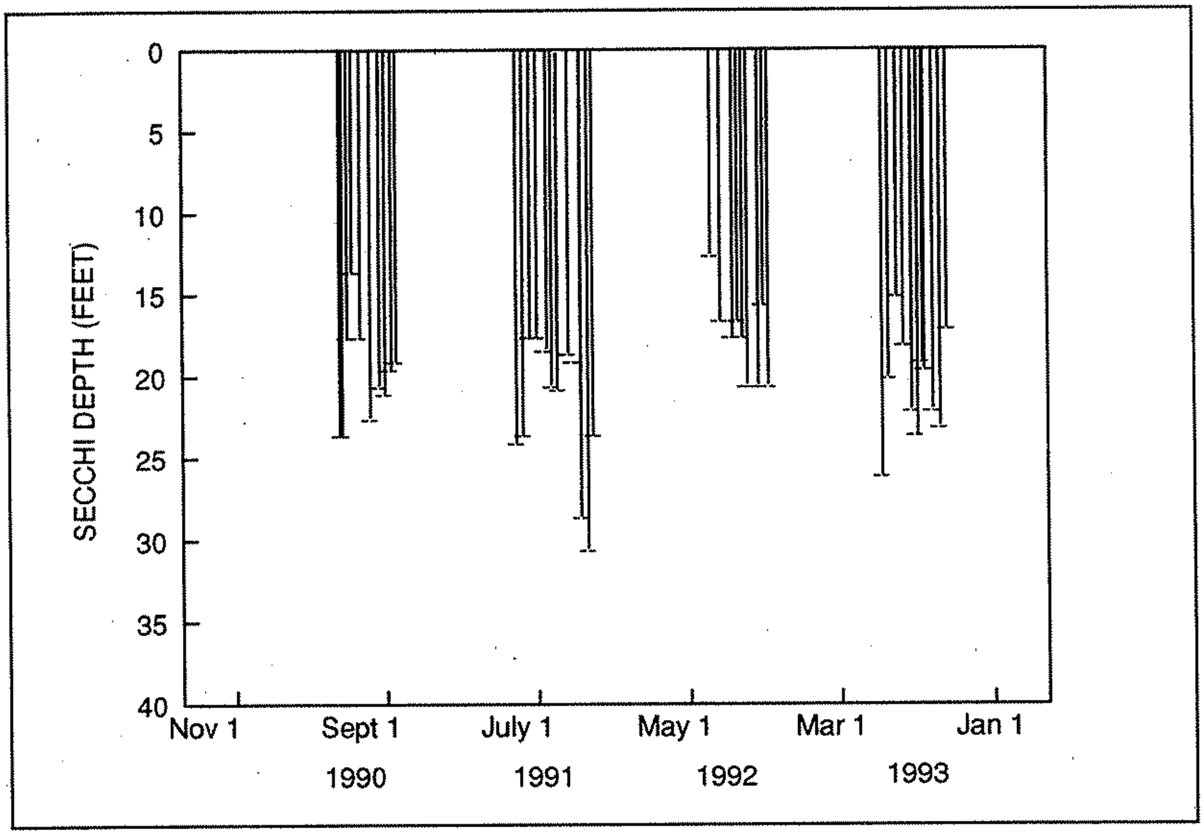
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 25							
Epilimnion	7	0.36	4.0	–	–	–	–
Hypolimnion	32	0.50	–	–	–	–	–
August 18							
Epilimnion	10	0.24	3.0	–	–	–	–
Hypolimnion	11	0.44	–	–	–	–	–

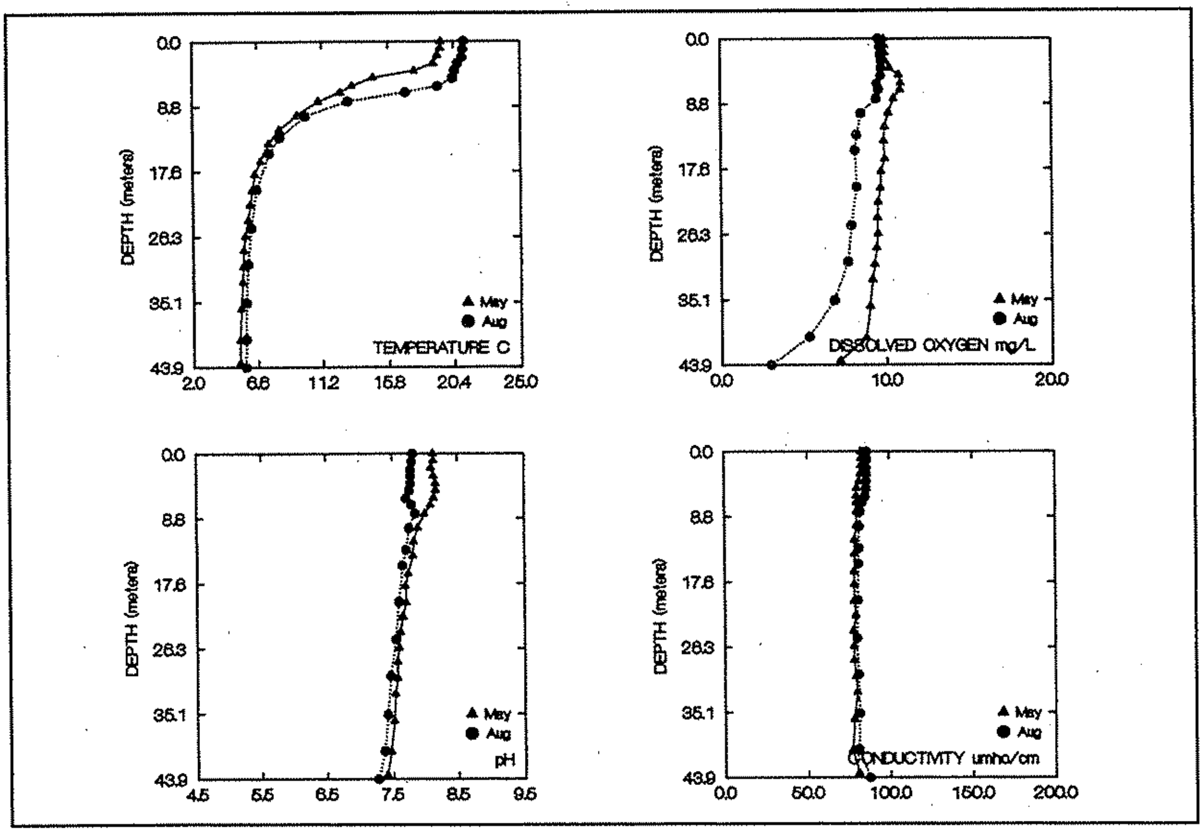
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/27/72[a]	5	–	–
06/06/90[b]	9	0.36	–
08/30/90[b]	12	0.35	–
06/91/91[c]	–	0.37	–
08/31/92[d]	12	0.33	2.2

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)

LAKE STEVENS (SNOHOMISH COUNTY)





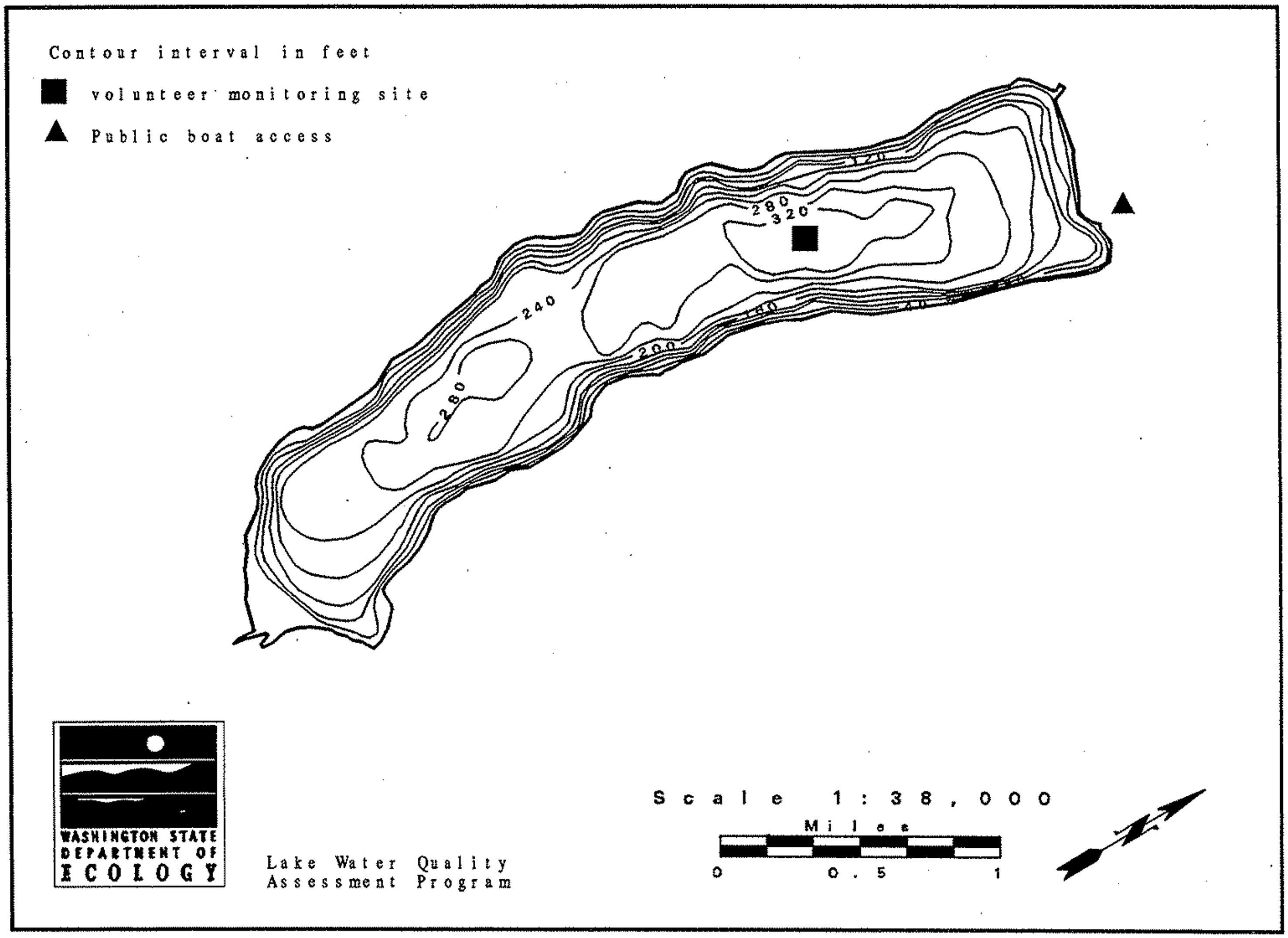
1993 Secchi Depth and Profile Data Graphs

Sullivan Lake -- Pend Oreille County

Sullivan Lake is located 4.3 miles southeast of Metaline Falls. It is a natural lake that was enlarged by a dam built in Harvey Creek in 1931. The lake is 3.6 miles long and averages 0.6 miles in width. Sullivan Lake drains to Sullivan Creek and the Pend Oreille River. There are campgrounds at both the north and south ends of the lake.

Size (acres)	1,380
Maximum Depth (feet)	332
Mean Depth (feet)	193
Lake Volume (acre-feet)	267,000
Drainage Area (miles^2)	51.2
Altitude (feet)	2,583
Shoreline Length (miles)	8.9

Data From Dion *et al.* (1976)



Overall Assessment

In 1993, Sullivan Lake was assessed as oligotrophic, based on good water clarity, low nutrient concentrations, and low densities of algae and aquatic plants. Because of very low nitrogen concentrations in the water, algae in Sullivan Lake were probably nitrogen-limited.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was very good, as indicated by Secchi depths that ranged from 22.0 feet to 31.0 feet. Secchi depths greater than 13.0 feet are typical for oligotrophic lakes.

Total Phosphorus

In May, the concentration of total phosphorus in the upper layer of water (the epilimnion) was moderately high (17 µg/L) and may have resulted from suspended sediments in the water following spring thaw. In August, total phosphorus in the epilimnion was low (7 µg/L). Epilimnetic concentrations less than 12 µg/L are typical for oligotrophic lakes.

Total Nitrogen

The concentrations of total nitrogen were very low on both sampling dates. Concentrations in Sullivan Lake were the lowest of all lakes sampled in 1993.

The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae generally use at least ten times the amount of nitrogen as phosphorus. Because the ratios of total nitrogen to total phosphorus were less than 17:1 (4:1 in May, and 8.6:1 in August), algae in Sullivan Lake were not limited by phosphorus. In May, there was a moderately high concentration of total phosphorus but there was a very low density of algae. This suggests that some growth requirement other than phosphorus (such as nitrogen or silica) limited algae growth in May.

Profile Data

The lake was strongly stratified with respect to temperature on both sampling dates. Below the thermocline, the concentrations of dissolved oxygen decreased somewhat with depth, but because the profiling instrument only had 55 meters of cable, it was not possible to measure oxygen concentrations to the bottom of the lake. Profile data appeared to be characteristic of an oligotrophic lake.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Chlorophyll concentrations on both sampling dates indicated that there were low densities of algae at the time of sampling.

Aquatic plants identified by Ecology staff during the August water quality sampling visit were waterweed (*Elodea canadensis*) and Richard's pondweed (*Potamogeton richardsonii*). No aquatic plants were observed during the May sampling visit.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire. Some of the additional information on lake and watershed uses are from a different volunteer's responses to the 1990 questionnaire.

> Sullivan Lake is used for fishing, boating, swimming, rowing, jet skiing, camping, scuba diving, and bird watching. Public recreational facilities on the lakeshore include a picnic area, a camping area, a beach, and two boat ramps. There are campgrounds located at the north and south ends of the lake. There is a speed restriction of 35 mph for motorboats. No fish were stocked in the lake in 1993.
>
> There are two houses on the lakeshore. Currently the watershed is being logged and used for animal grazing. Grazing animals have direct access to the lakeshore or inlet tributaries. The lakeshore is also being developed further for residences. In the past, the watershed was logged and mined, and the shoreline was altered when the lake was dammed in 1931. There is a PUD for the lake, but no lake user's organization. Every year the lake level is drawn down for hydroelectric use from October 1 through April 15.
>
> Overall, the volunteer found that Sullivan Lake had excellent water quality. Problems in the lake in 1993 included impaired fisheries, fluctuating water level, and low water level. Problems were mainly due to drawdown of the lake during winter, which affected fishing, although ling [burbot] were caught out of Sullivan Lake for the first time in 1993.

Acknowledgment

I thank John Riley for volunteering his time to monitor Sullivan Lake during 1993. Dick Vogel monitored the lake in 1990, and Terry Williams monitored the lake in 1989.

Sullivan Lake -- Pend Oreille County

1993 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	30
Mean Trophic State Index (Total Phosphorus):	39
Mean Trophic State Index (Chlorophyll *a*):	31

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (ft)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
25-May	0930	12.8	55.0	23.5		lt-green	10	none	calm	
11-Jun	1100	15.6	60.0	22.0		lt-green	90	light	calm	
25-Jun	1255	16.7	62.0	24.0		lt-green	25	none	breezy	
09-Jul	1225	18.9	66.0	25.0		lt-green	75	heavy	breezy	
23-Jul	1215	17.8	64.0	29.5		lt-green	50	moderate	light	Low water temp due to low ambient temperature.
03-Aug	1115	20.0	68.0	26.0		lt-green	10	none	light	
21-Aug	0915	20.0	68.0	27.7		lt-green	75		calm	Onsite visit.
03-Sep	1615	18.9	66.0	22.0		lt-green	25	none	calm	
17-Sep	1310	16.7	62.0	31.0		lt-green	10	trace	calm	
20-Oct	1430	13.3	56.0	30.0		lt-green	50	none	calm	

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Sullivan Lake rose 5' from May 25 to October 20.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/25	0.0	15.2	8.0	9.8	91
	2.0	13.9	8.0	10.2	90
	4.0	12.8	8.0	10.2	86
	6.0	10.8	8.0	10.7	84
	8.0	9.3	8.0	11.0	90
	10.0	8.3	7.9	10.9	87
	12.0	7.3	7.9	11.0	93
	14.0	6.7	7.9	10.9	93
	16.0	6.2	7.9	10.8	93
	18.0	5.9	7.8	10.7	96
	20.0	5.4	7.8	10.4	97
	25.0	4.8	7.8	10.0	99
	30.0	4.4	7.8	9.7	100
	35.0	4.2	7.7	9.7	100
	40.0	4.1	7.7	9.5	100
	45.0	4.1	7.7	9.1	101
	50.0	4.1	7.7	8.7	101
	55.0	4.0	7.5	8.5	101
	60.0	4.0	7.5	8.0	101
	65.0	4.0	7.5	7.8	102
08/21	0.0	19.8	8.2	8.3	95
	2.0	19.7	8.2	8.3	95
	4.0	19.3	8.2	8.5	95
	6.0	18.2	8.2	9.3	95
	7.0	16.7	8.2	9.6	95
	8.0	15.7	8.1	9.6	94
	9.0	14.7	8.1	9.8	94
	10.0	13.2	8.0	10.0	93
	11.0	12.0	8.0	10.2	93
	12.0	10.7	7.9	10.3	93
	14.0	8.6	7.9	10.2	95
	16.0	7.7	7.8	9.9	96
	18.0	6.7	7.7	9.7	98
	20.0	6.0	7.7	9.5	99
	25.0	5.2	7.6	9.1	101
	30.0	4.6	7.6	8.7	103
	35.0	4.4	7.5	8.6	104
	40.0	4.3	7.5	8.3	104
	45.0	4.2	7.5	8.2	105
	50.0	4.2	7.5	8.0	105
	55.0	4.2	7.4	7.7	105

Sullivan Lake -- Pend Oreille County

1993 Onsite Visit Data - Water Chemistry

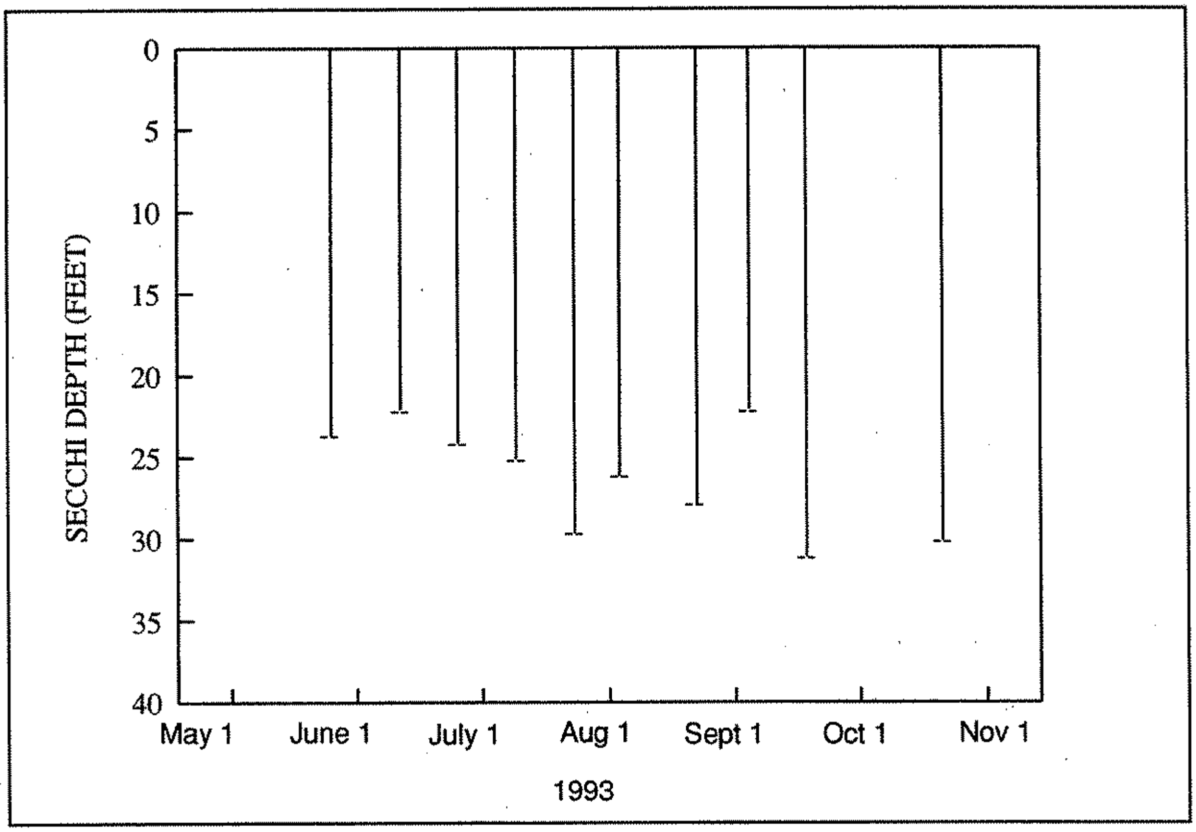
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 25							
Epilimnion	17	0.07	0.9	--	--	--	--
Hypolimnion	9	0.05	--	--	--	--	--
August 21							
Epilimnion	7	0.06	1.3	--	--	--	--
Hypolimnion	11	0.06	--	--	--	--	--

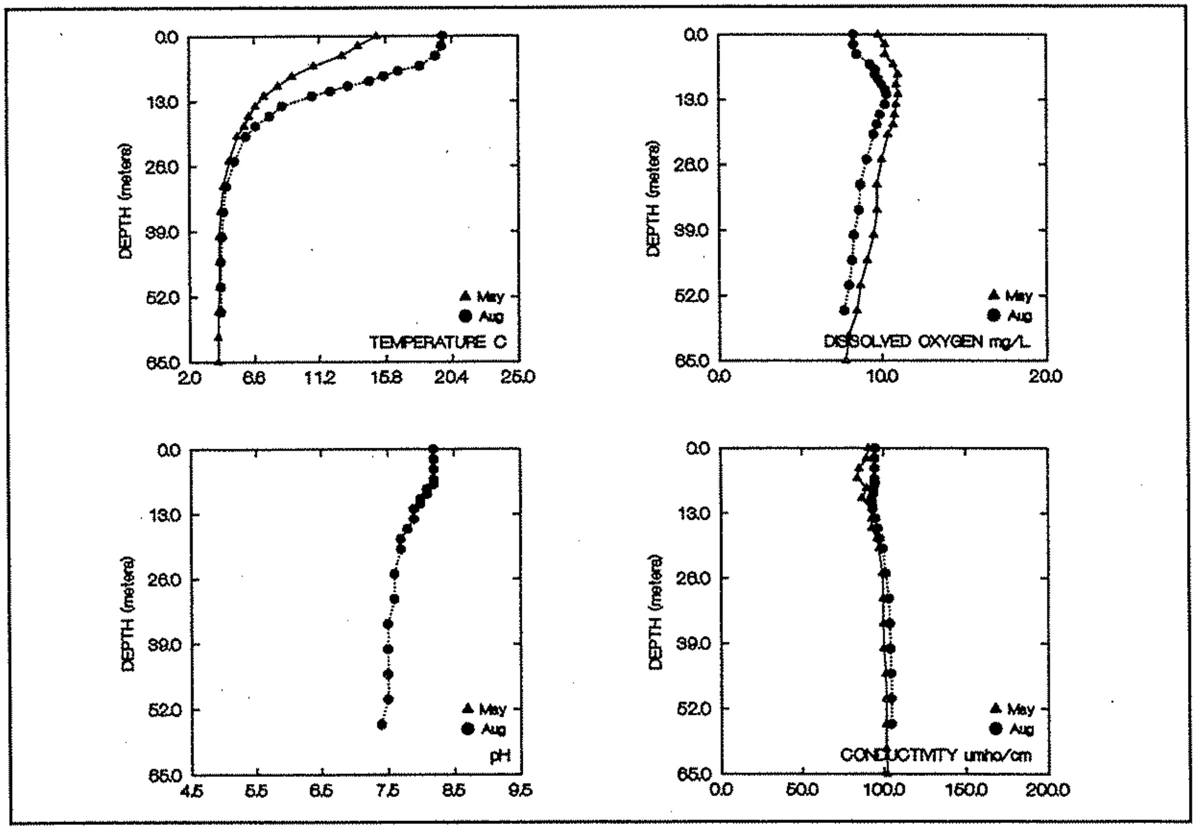
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/12/74[a]	7	--	--

a. Dion *et al.* (1976)

LAKE SULLIVAN (PEND ORIELLE COUNTY)





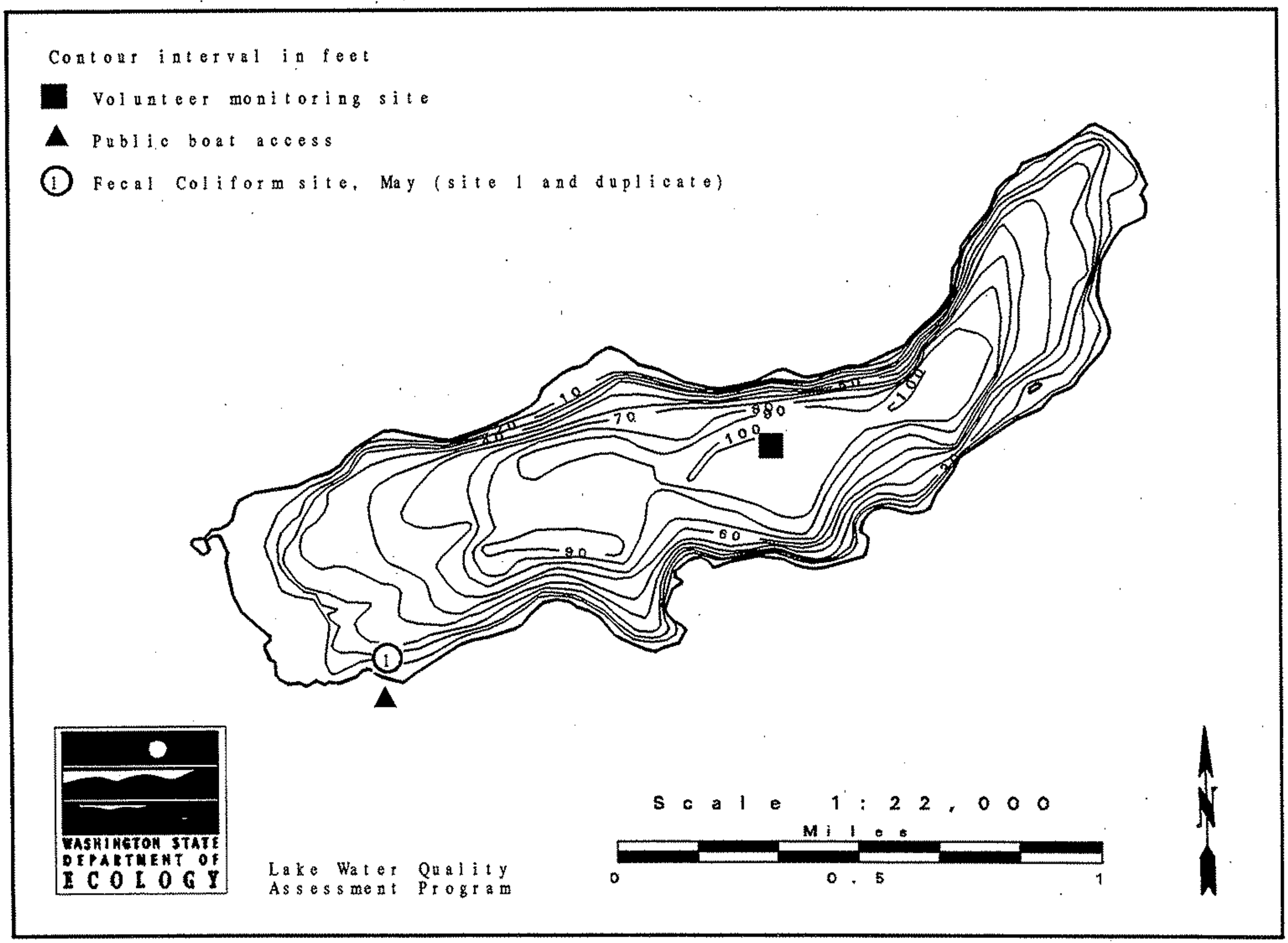
1993 Secchi Depth and Profile Data Graphs

Summit Lake -- Thurston County

Summit Lake is located in a steep forested valley nine miles west of Olympia. It is two miles long. Summit Lake is fed by intermittent streams, seeps, and springs, and drains via Kennedy Creek to Oyster Bay in Totten Inlet.

Size (acres)	530
Maximum Depth (feet)	100
Mean Depth (feet)	53
Lake Volume (acre-feet)	28,000
Drainage Area (miles^2)	2.8
Altitude (feet)	500
Shoreline Length (miles)	5.6

Data From Bortleson *et al.* (1976)



Overall Assessment

In 1993, Summit Lake was assessed as oligotrophic, based primarily on very good water clarity. In May, the lake had a moderately high concentration of total phosphorus, and at the time there was a moderately high density of algae. In September, the lake had low nutrient concentrations and a low density of algae.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depth
Water clarity in Summit Lake was good, as indicated by Secchi depths that ranged from 20.0 feet to 28.0 feet. Secchi depths greater than 13.0 feet indicate good water clarity and are typical for oligotrophic lakes.

Total Phosphorus
In May, the concentration of total phosphorus in the upper layer of water was moderately high (19 µg/L). The moderately high density of algae at the time of sampling (see Plants, below) was about what would be expected given this concentration of phosphorus.

In September, the total phosphorus concentration was low (8 µg/L). Total phosphorus concentrations less than 12 µg/L are typical for oligotrophic lakes.

Total Nitrogen
Concentrations of total nitrogen were moderately low on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. In May, the ratio of total nitrogen to total phosphorus was less than 17:1 (9:1), so algal growth was not limited by phosphorus at the time of sampling. In September, the concentration of total phosphorus was lower, resulting in a higher ratio of total nitrogen to total phosphorus (21:1). Thus, algae were not limited by nitrogen when the lake was sampled in September.

Profile Data
The lake was strongly stratified on both sampling dates. Below the thermocline, dissolved oxygen concentrations decreased with depth. By September, the dissolved oxygen was very low (less than 1.0 mg/L) in the bottom five meters of the lake. Low dissolved oxygen often results from bacteria, which use oxygen as they decompose aquatic plants and algae in the water and sediments. However, springs feed Summit Lake, and spring water is very low in oxygen; because the bottom layer of water does not mix with the upper layer of water during stratification, low-

oxygen spring water can be trapped in the lower layer until the lake mixes in early fall. It is not likely that low oxygen reduced fish habitat, because at a depth of around 10 meters, the water was cool and had moderately high oxygen concentrations that are preferred by trout species.

Fecal Coliform Bacteria

Two nearshore samples for fecal coliform bacteria were collected near the public access during May. Both results were very low. The state water quality standard for fecal coliforms in Lake Class waters is a geometric mean of 50 colonies/100 mL.

Solids

Results from solids samples are used to evaluate whether Secchi depths were affected primarily by algae, or if suspended sediments affected water clarity at the time of sampling. Both results for solids samples were below the analytical detection limit, indicating very low solids concentrations. This suggests that water clarity in Summit Lake was affected primarily by algae in the water, and not by suspended sediments, at the time of sampling.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the volume of algae in a volume of water. In May, the chlorophyll concentration indicated a moderately high density of algae, despite the heavy rains at the time of sampling. In September, the chlorophyll concentration was low and indicated a low density of algae.

Other Available Information

From Thurston County Public Health and Social Services Department (1993): In 1990, 409 sanitary systems around Summit Lake were surveyed. The survey was initiated because the lake shoreline is heavily developed, and when soils in the area are saturated, sewage is not properly treated by the systems. The survey found 27 failing systems, and 67 systems that were suspected of failing. Survey results were also used to establish a background level for fecal coliforms in the lake (5 colonies/100 mL). From February through June 1993, 113 properties were surveyed. The "suspect" systems found in 1990 were resampled, as well as properties in the block units associated with the suspected systems, and properties with suspected septic system or surface water runoff problems. Surveys consisted of onsite inspection of the systems, introducing fluorescent tracer dye into toilet/gray water systems, and placing activated charcoal packets in surface water. When dye was detected in the charcoal packets, bacteria samples were collected to confirm a failure, or to designate the system as a "suspected" failure. Of the 133 properties surveyed, 36 had failing systems, 6 were suspected to be failing, and 71 were not failing. Recommendations from the survey are to develop a long-term strategy for resolving the health issues that are inherent with a large number of failing septic systems, and to follow through on the second year of surveys.

Acknowledgment

I thank Bill Champion for volunteering his time to monitor Summit Lake during 1993. Larry Davis monitored the lake in 1989 and 1990.

Summit Lake -- Thurston County

1993 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	32
Mean Trophic State Index (Total Phosphorus):	40
Mean Trophic State Index (Chlorophyll *a*):	37

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
29-May	1010	20.0	68.0	28.0		clear	25	light	breezy	
13-Jun	1030	18.0	64.5	20.0	12.00	lt-green	25	moderate	light	
04-Jul	1230	20.0	68.0	25.0		clear	50	light	calm	
18-Jul	1130	20.0	68.0	26.0	16.00	lt-green	10	light	light	
07-Sep				20.5		lt-green	0			Algae particles visible.

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake level" refers to change in water level. Based on volunteer-collected data, the level of Summit Lake dropped 4" from June 13 to July 18.

Summit Lake -- Thurston County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/19	0.0	17.3	8.3	10.5	47
	1.9	17.2	8.4	10.3	47
	4.1	17.2	8.4	10.1	47
	5.9	16.3	8.4	9.8	47
	8.0	13.5	8.5	10.3	47
	10.0	12.3	8.4	9.8	46
	12.0	11.3	8.2	9.5	46
	14.1	9.9	8.2	9.2	46
	16.0	8.5	8.1	8.1	47
	18.1	8.2	8.0	7.4	47
	20.0	7.9	7.9	6.9	47
	25.0	7.9	7.7	6.4	48
09/07	0.0	20.7	7.6	9.7	48
	1.0	20.6	7.6	9.5	48
	2.0	20.6	7.5	9.4	48
	3.0	20.6	7.5	9.3	48
	4.1	20.4	7.5	9.3	48
	5.0	20.2	7.6	9.3	48
	6.0	20.0	7.6	9.1	48
	7.0	19.9	7.6	9.0	48
	8.0	19.3	7.6	8.8	48
	9.0	18.6	7.5	8.6	47
	10.0	17.1	7.4	8.0	47
	12.1	12.4	7.4	4.6	47
	14.1	10.3	7.2	2.3	48
	16.0	9.8	7.1	2.0	48
	18.1	9.2	7.1	1.3	49
	20.0	8.7	7.0	0.5	50
	24.5	8.6	6.9	0.1	52

Summit Lake -- Thurston County

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 19 Epilimnion	19	0.17	3.1	bdl	bdl	2	1
Hypolimnion	10	0.18	--	--	--	--	--
September 7 Epilimnion	8	0.17	1.2	--	--	--	--
Hypolimnion	12	0.17	--	--	--	--	--

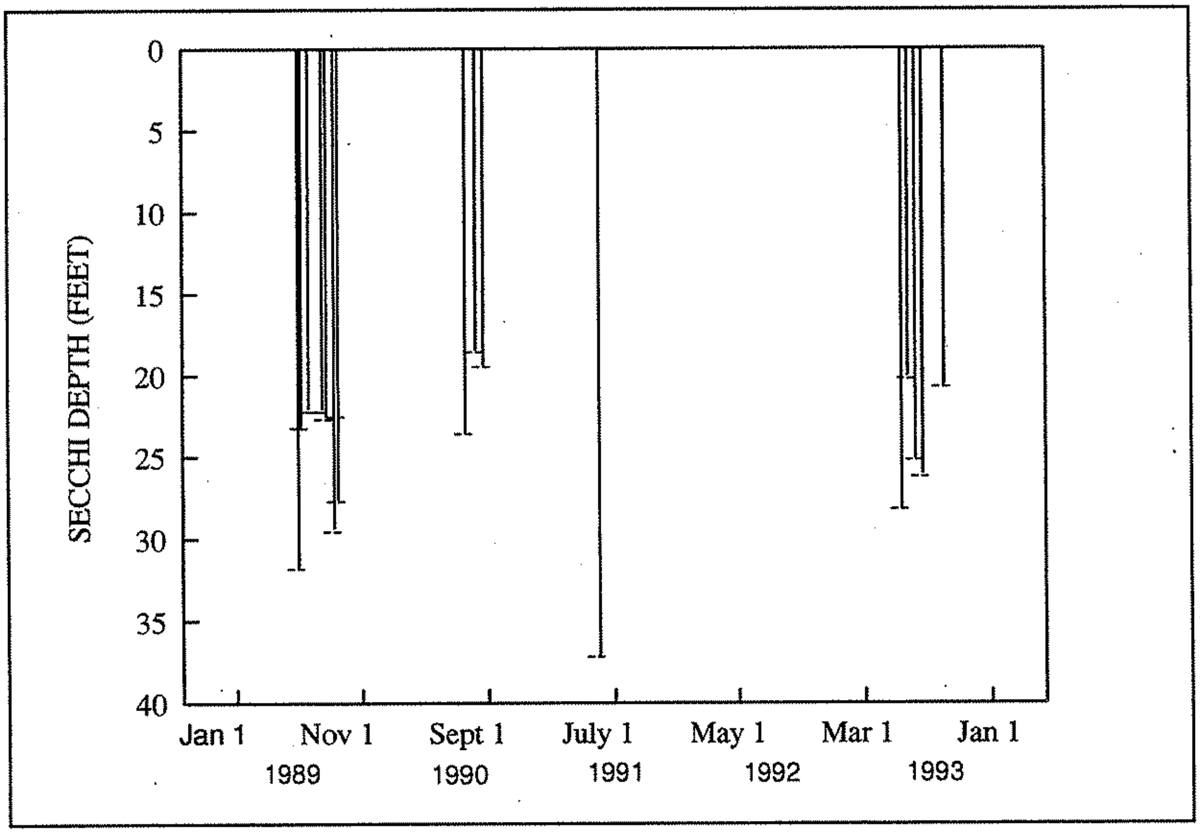
bdl = below analytical detection limit of 1 mg/L

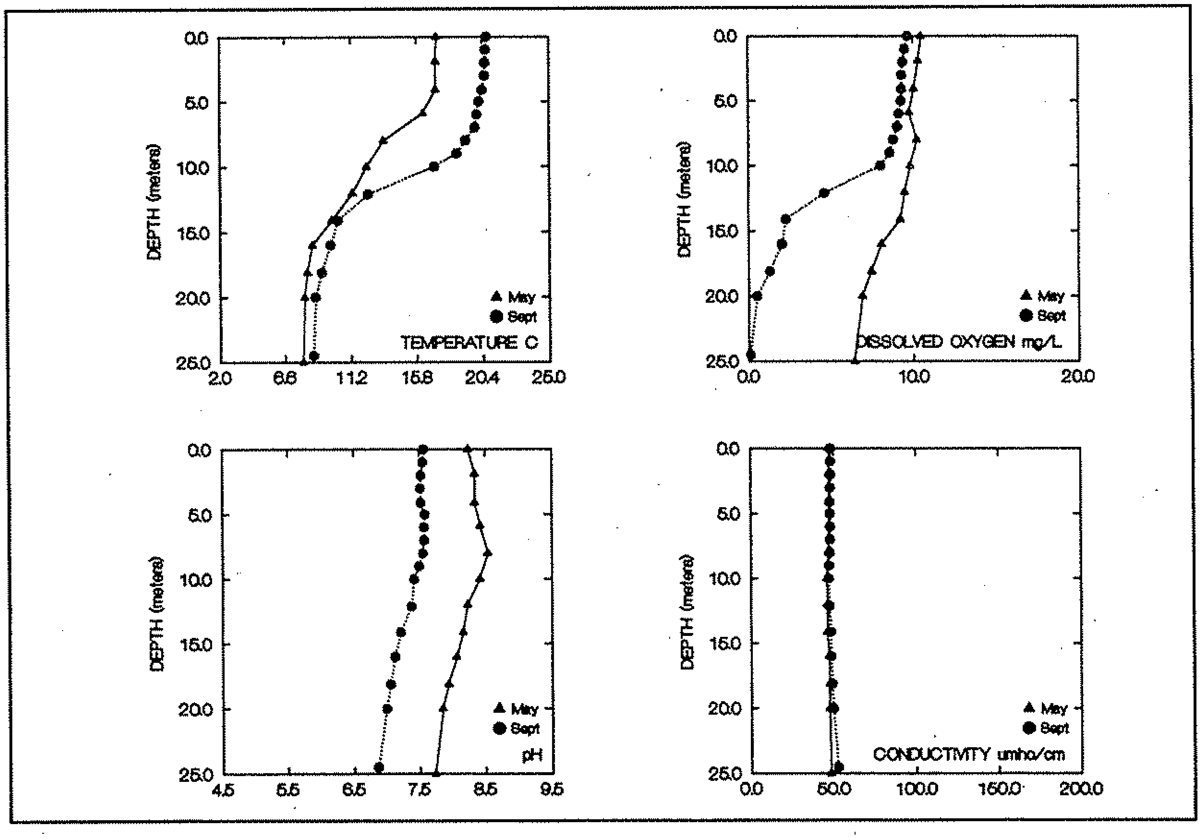
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/07/71[a]	10	--	--
06/07/89[b]	7	0.16	1.5
09/05/89[b]	6	0.15	1.5
05/31/90[c]	5	0.17	--
08/23/90[c]	15	0.21	--
05/23/91[d]	--	0.13	--

a. Bortleson *et al.* (1976)
b. Brower and Kendra (1990)
c. Rector (1991)
d. Washington's Citizen Lake Monitoring Program (unpublished data)

SUMMIT LAKE (THURSTON COUNTY)





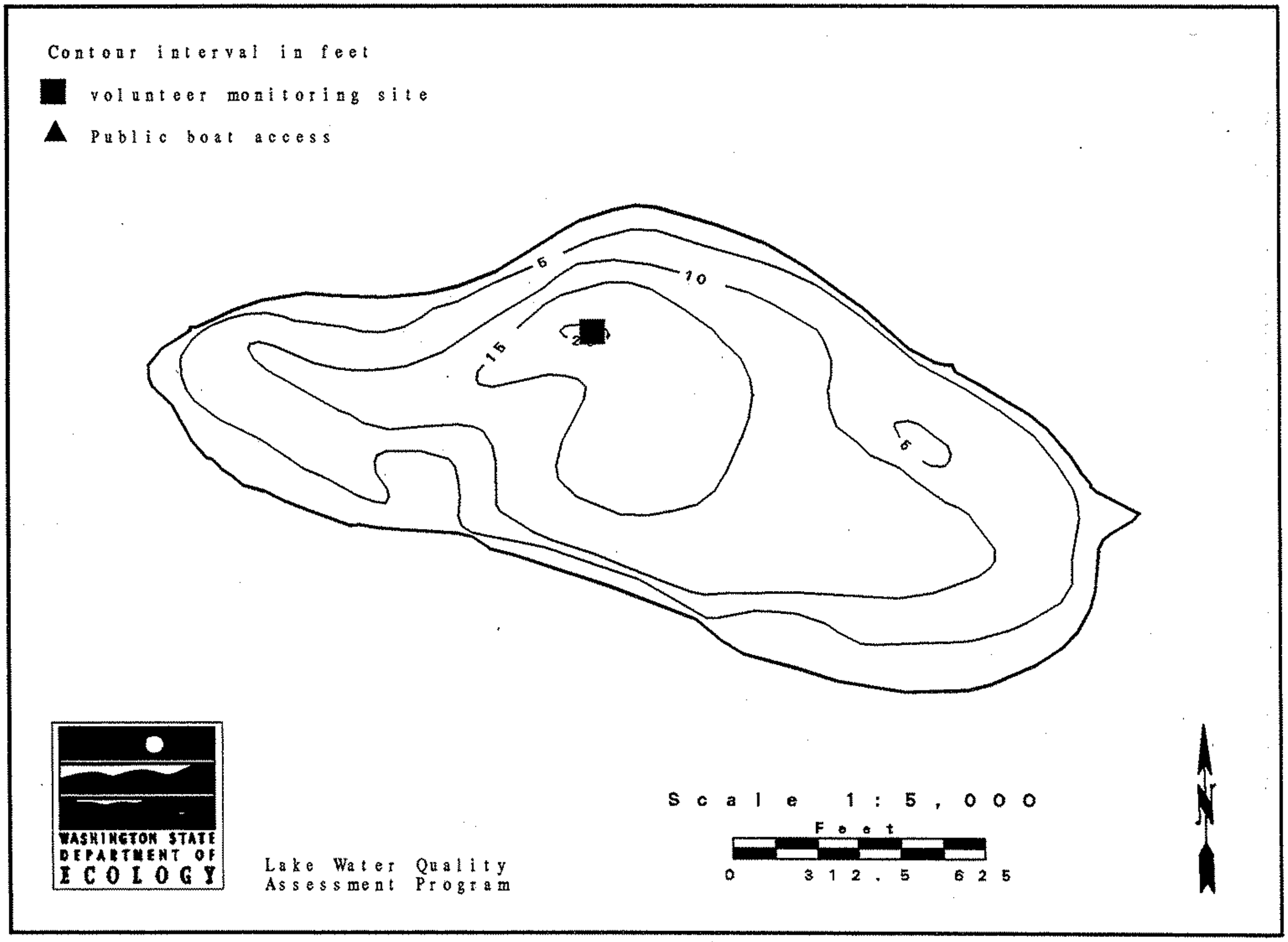
1993 Secchi Depth and Profile Data Graphs

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 ($miles^2$)	1.7
Altitude (feet)	211
Shoreline Length (miles)	1.3

Data From Bortleson *et al.* (1976)



Overall Assessment

In 1993, Sunday Lake was assessed as eutrophic, based on fair to poor water clarity, high nutrient concentrations, and moderately high to very high densities of algae and aquatic plants. Sunday Lake has been described as eutrophic each year since the lake was added to the program in 1990.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was poor to fair, as indicated by Secchi depths which ranged from 2.0 feet to 9.5 feet. Secchi depths measured in 1993 were very similar to those measured in 1992. Secchi depths less than 6.5 feet indicate poor water clarity, and are typical for eutrophic lakes.

Total Phosphorus

Concentrations of total phosphorus were high on both sampling dates (72 µg/L in May, and 44 µg/L in August). Concentrations greater than 24 µg/L can cause high densities of algae, and are typical for eutrophic lakes.

Total Nitrogen

In May, the concentration of total nitrogen was very high (1.61 mg/L), and was higher than concentrations measured in previous years for the program. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae usually need at least ten times the amount of nitrogen as phosphorus. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 (22:1 in May, and 19.5:1 in August), algae in Sunday Lake were not limited by nitrogen when the lake was sampled.

Profile Data

In May, both pH and dissolved oxygen were very high near the surface, most likely because of the algae bloom at the time. Below the surface, temperature, dissolved oxygen, and pH decreased with depth. The decrease in dissolved oxygen probably resulted from bacteria which use oxygen as they decompose aquatic plants and algae in the water and sediments. Profile data from May 1993 were very similar to data collected in May 1992.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. In May, the high chlorophyll concentration (57 µg/L) indicated a very high density of algae. At the time of sampling, numerous algae particles were visible, and the water was pea-green.

In August, the chlorophyll concentration indicated a moderately high density of algae. Although nutrient concentrations were also high in August, they were not as high as in May. Colonies of water net (*Hydrodictyon*), *Aphanizonmenon* and another filamentous green alga (possibly *Spirogyra*) were visible in the water at the time of sampling. Algae were more abundant and more of a nuisance in 1992 than in 1993. Lake Ketchum (Snohomish County) is the only other lake monitored for the program where Ecology staff observed water net (water net was very heavy in Lake Ketchum in 1992).

Aquatic plants identified by Ecology staff during the 1993 sampling visits were yellow-flowering lily (*Nuphar polysepalum*), cattails (*Typha* sp.), waterweed (*Elodea canadensis*), largeleaf pondweed (*Potamogeton amplifolius*), and coontail (*Ceratophyllum demersum*). Near shore there were duckweed, cinquefoil, bulrush and white-flowering water lily. In addition, quillwort (*Isoetes*) was growing out of the dock at the public access. In May, coontail was the most abundant plant.

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 1993.

> 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 in 1993. Currently the watershed is being logged and used for crop agriculture. The lakeshore is also being developed further for residences. In the past the watershed was logged and used for 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 one house per three acres. No plant or algae control occurred in 1993, but the lake has been chemically treated in the past to control weeds.
>
> Overall, the volunteer found that Sunday Lake had fair water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth, (2) algae, (3) odor from decaying algae, (4) decaying plants, (5) impaired fisheries, (6) water quality gradually degraded over years, (7) degraded aesthestics, (8) suspended sediments, (9) low water level, (10) fluctuating water level, (11) recently degraded water quality, and (12) bacteria. Possible sources of problems include septic

systems and over-fertilizing lawns. In 1993, there were fewer plants, less algae, and better water clarity than in 1992. Algae growth was lower in 1993 than in the previous two years.

Acknowledgment

I thank Darryl Johnson for volunteering his time to monitor Sunday Lake during 1990-1993.

Sunday Lake -- Snohomish County

1993 Trophic Status[1]

Estimated Trophic State:	Eutrophic
Mean Trophic State Index (Secchi):	48
Mean Trophic State Index (Total Phosphorus):	62
Mean Trophic State Index (Chlorophyll *a*):	58

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
29-May	1000	21.1	70.0	2.0		gr-brown	90	trace	calm	
12-Jun	1100	21.1	70.0	2.5		gr-brown	75	moderate	light	Need a new thermometer.
26-Jun	1100			6.0	44.00	gr-brown	25	trace	breezy	Starting to clear.
11-Jul	1200	19.0	66.2	9.0	42.00	clear	90	trace	light	Weeds appearing.
24-Jul	1030	18.0	64.5	9.0	23.00		50	none	light	Water color light brown to clear. Weeds appearing.
08-Aug	1100	20.0	68.0	8.5	21.00		25	none	calm	Water color light brown to clear. Weedy but still fairly clear.
22-Aug	1000	18.0	64.4	9.0		lt-brown	50	trace	light	
04-Sep	1100	18.0	64.4	8.5		lt-brown	50	trace	light	
18-Sep	1030	16.0	60.8	8.5		lt-brown	10	none	calm	Weed growth prevalent.
02-Oct	0930	15.0	59.0	9.5			0	none	calm	Water color light brown to clear. Water very clear.
16-Oct	1100	12.0	53.6	9.5			90	trace	light	Water color light brown-clear. Algae awash on shore.

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

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Sunday Lake dropped 23" from June 26 to August 8.

Sunday Lake -- Snohomish County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/25	0.0	22.3	9.7	12.5	100
	1.0	20.7	9.5	11.8	91
	1.1	19.4	9.0	7.1	85
	2.0	15.2	8.8	6.8	87
	3.1	13.8	8.4	4.0	88
	4.0	13.2	8.2	2.4	93
	4.3	13.2	8.1	1.6	93
08/18	0.0	22.1	7.4	6.8	87
	1.0	20.8	7.3	6.2	87
	2.0	19.6	7.2	4.5	86
	3.0	17.2	7.1	2.2	124
	4.0	14.3	7.0	1.1	206
	4.3	14.1	6.9	0.6	219

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 25							
Epilimnion	72	1.61	56.9	--	--	--	--
Hypolimnion*							
August 18							
Epilimnion	44	0.86	4.8	--	--	--	--
Hypolimnion	67	1.06	--	--	--	--	--

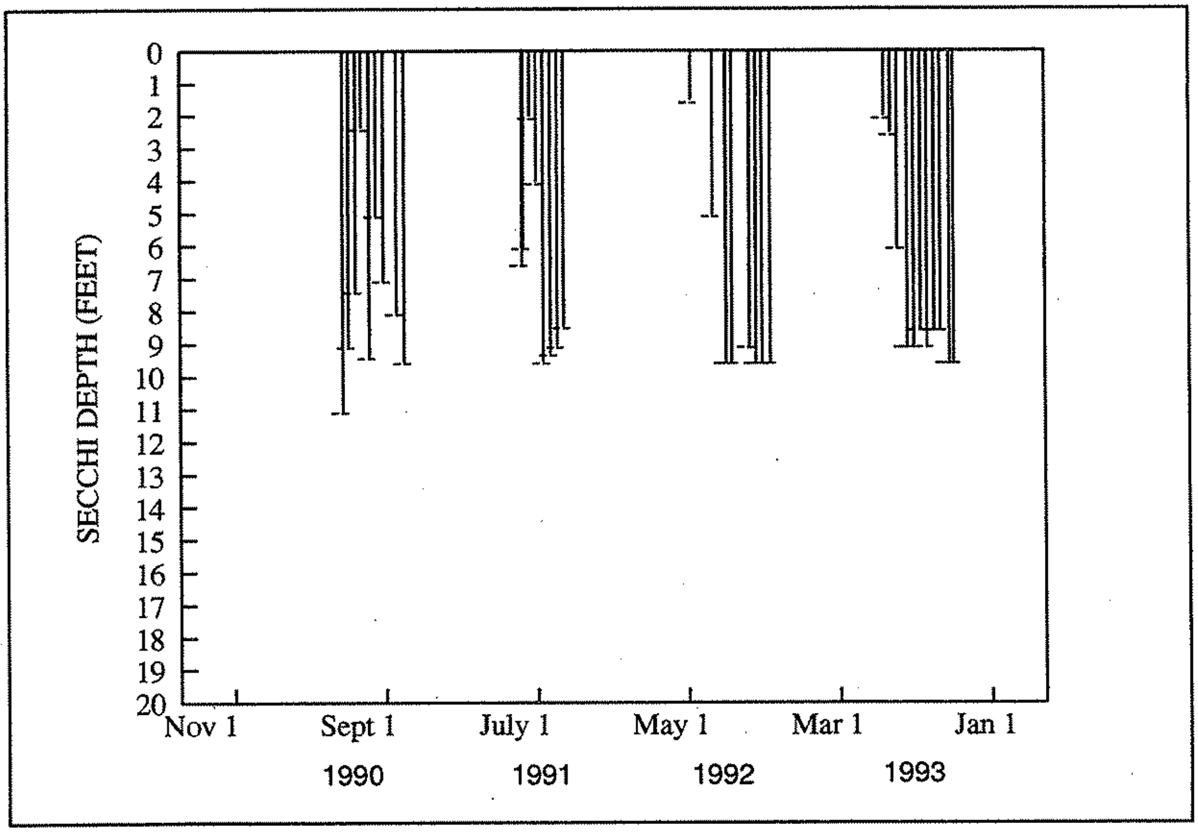
* The lake was not stratified at the time of sampling; only one set of samples was collected

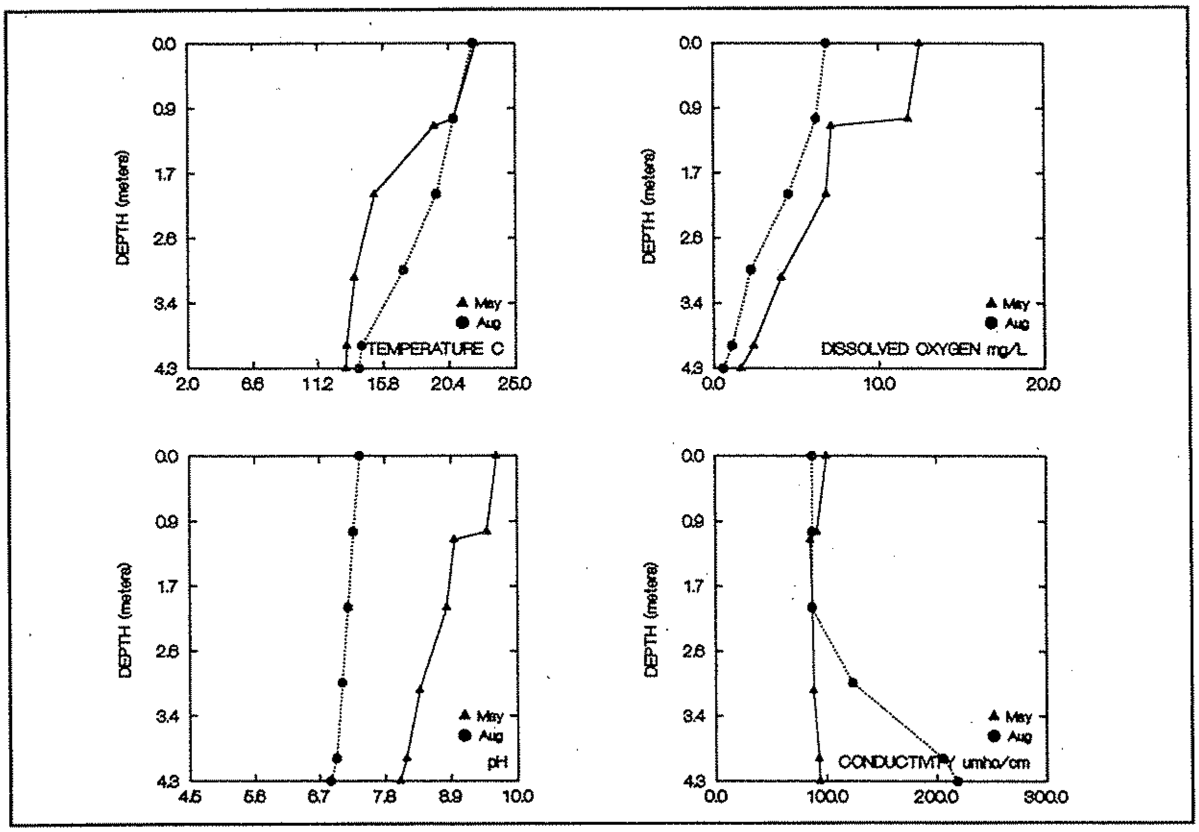
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)
07/26/73[a]	18	--	--
06/06/90[b]	151	--	--
08/28/90[b]	71	0.93	--
05/29/91[c]	--	0.61	--
05/18/92[d]	54	0.96	7.8
08/25/92[d]	44	0.74	4.3

a. Bortleson *et al.* (1976)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)

SUNDAY LAKE (SNOHOMISH COUNTY)





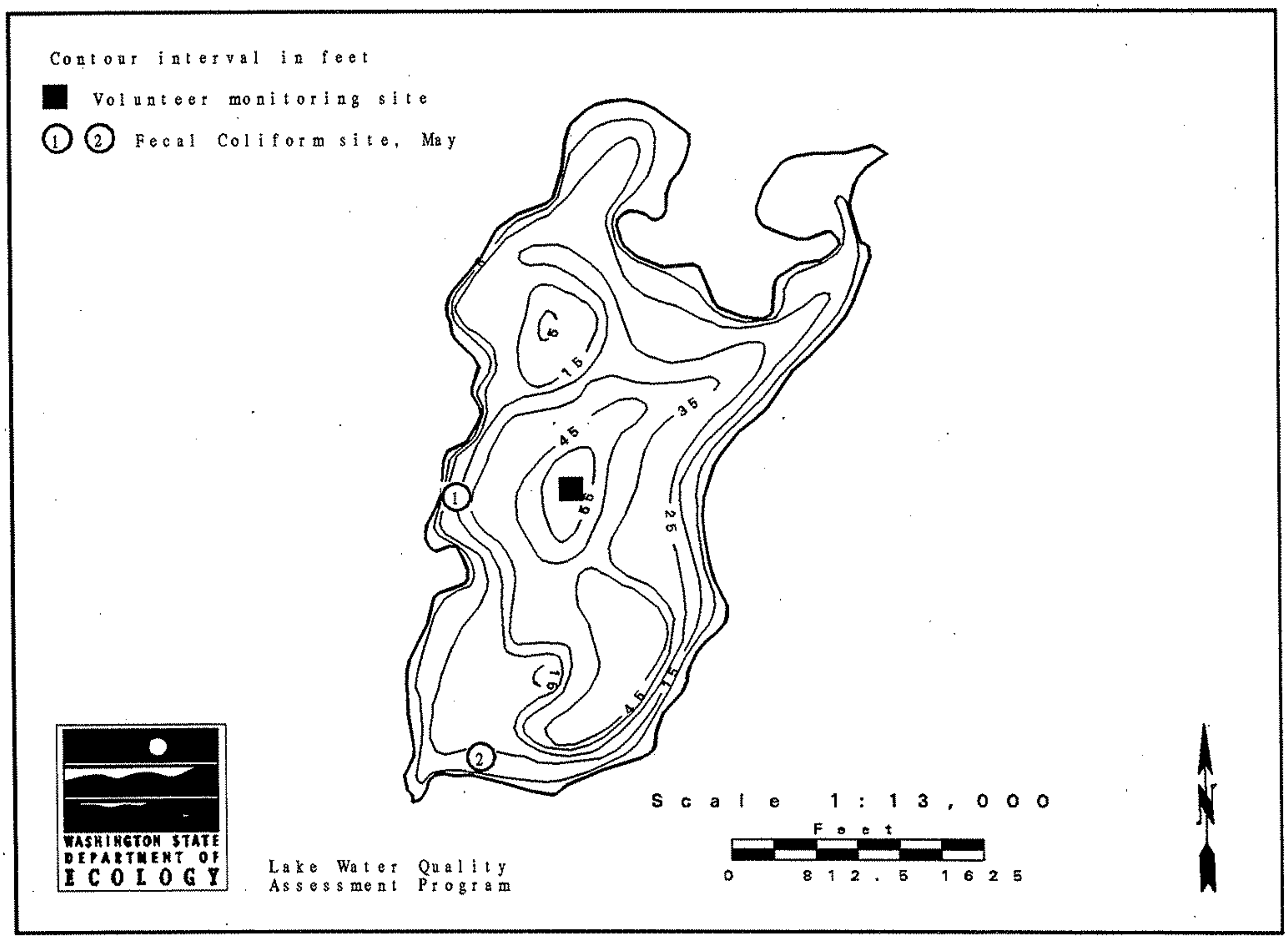
1993 Secchi Depth and Profile Data Graphs

Lake Thomas -- Stevens County

Thomas is located 17 miles northeast of Colville, and 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)



Overall Assessment

In 1993, Lake Thomas was assessed as oligo-mesotrophic, because it exhibited both oligotrophic and mesotrophic characteristics. Oligotrophic characteristics were the good water clarity, low nutrient concentrations, and low densities of algae at the time of sampling. However, dissolved oxygen concentrations were depleted throughout the hypolimnion in August, which was a mesotrophic characteristic. Lake Thomas was also described as oligo-mesotrophic in 1989, 1990, and 1992.

Eurasian water milfoil, an aggressive non-native aquatic plant, was introduced into the lake sometime prior to 1990. Eurasian water milfoil can out-compete other aquatic plants, and can create nuisance and safety problems in lakes. Eurasian water milfoil was also observed at the boat ramp on Lake Gillette, the lake immediately downstream of Lake Thomas in the Little Pend Oreille chain of lakes. Lake Leo, which is upstream of Lake Thomas and was also monitored for the program, did not appear to have milfoil in 1993. A grant from Ecology's Freshwater Aquatic Weeds Program will fund an aquatic plant survey of 28 lakes in Stevens County in 1994. Application for the grant by the Stevens County Noxious Weed Board was prompted, in part, by concern over milfoil in Lake Thomas.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in 1993 was good, as indicated by Secchi depths that ranged from 10.5 feet to 18.0 feet. Secchi depths greater than 13.0 feet indicate good water clarity, and are typical for oligotrophic lakes.

Secchi depth data collected since 1989 were analyzed for trend in water clarity. There was no statistically significant trend in water clarity from 1989 to 1993.

Total Phosphorus

Concentrations of total phosphorus in the upper layer of water were moderately low on both sampling dates (12 µg/L in May, and 11µg/L in August). Concentrations less than 12 µg/L are low and are typical for oligotrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were moderately low on both sampling dates, and were lower than those measured for the program in 1992 and 1990. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were moderately high, algae growth in Lake Thomas was not limited by nitrogen when the lake was sampled.

Fecal Coliform Bacteria
Samples for fecal coliforms were collected from two nearshore sites in May (see map). Site #1 was located due west of the volunteers' sampling site. Site #2 was located in a shallow area at the south end of the lake. Results for both samples were very low. The state water quality standard for fecal coliforms in Lake Class waters is a geometric mean of 50 colonies/100 mL.

Profile Data
On both sampling dates, the lake was thermally stratified. Below the thermocline, the concentrations of dissolved oxygen decreased considerably with depth. By August, there was no oxygen throughout the entire lower layer of water (the hypolimnion). Dissolved oxygen concentrations decrease because bacteria use oxygen as they decompose aquatic plants and algae in the water and sediments. Very low oxygen concentrations near sediments can create an environment that allows phosphorus, iron, and other compounds in sediment to be chemically reduced and released into the water column. This process probably caused the higher phosphorus concentrations and higher conductivity values in the hypolimnion.

There are no pH data for May because the probe was not functioning properly at the time.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Chlorophyll concentrations on both sampling dates indicated low densities of algae when the lake was sampled.

Aquatic plants observed by Ecology staff during the 1993 sampling visits included Eurasian water milfoil (*Myriophyllum spicatum*), and flatleaf pondweed (*Potamogeon robbinsii)*. In May 1992, Ecology staff observed Eurasian water milfoil, yellow-flowering water lily (*Nuphar polysepalum*) and muskgrass (*Chara*). During the September 1990 sampling visit, whitestem pondweed (*Potamogeton praelongus*), Eurasian watermilfoil, white-flowering water lily (*Nymphaea odorata.*), and the alga *Nitella* were observed.

Freshwater jellyfish (*Craspedacusta sowerbii*) were seen during the sampling visits in August 1992 and September 1990. The volunteer also reported seeing them during September 1991. Jellyfish were not reported in 1993. Freshwater jellyfish are relatively rare, and have unpredictable life cycles. Lake Thomas is the only volunteer-monitored lake in which they have been seen.

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 1993.

Lake Thomas is used for fishing, boating, swimming, rowing, jet skiing, and camping. There is a US 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 and rainbow trout were stocked in the lake in 1993. Bass and pumpkinseed were also introduced (illegally), and according to the volunteer, are starting to be problem.

There are 72 houses on the lakeshore, and none of the houses are connected to a sewer. A property owner's association is presently being organized for the lake. Currently the watershed is being logged, and the lakeshore is being developed further for residences. In the past, the watershed was logged and mined, and the shoreline was altered. No aquatic plant or algae control activities occurred in 1993, but the lake has been treated with chemicals in the past to control undesirable fish species.

Overall, the volunteer found that Lake Thomas had good water quality. Milfoil growth was the worst problem in the lake in 1993. In addition, fishing in the lake was impaired by milfoil. In 1992, the worst problem in the lake was low water level; 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, 1992.

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.

Acknowledgments

I thank Ray Hawk and Robert Strauss for volunteering their time to monitor Lake Thomas during 1989-1993.

Lake Thomas -- Stevens County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	37
Mean Trophic State Index (Total Phosphorus):	39
Mean Trophic State Index (Chlorophyll *a*):	34

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	Temp (°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
18-May	1240			14.0		green	10		calm	Onsite visit. 16.5' with view tube.
31-May	1300	20.0	68.0	16.8	2.75		100	light	calm	Yellow-green. Secchi readings using old shrunken rope.
15-Jun	1204	17.5	63.5	15.3	2.00		90	light	light	Yellow-green. Old rope.
29-Jun	1215	17.2	63.0	10.5	2.00		90	heavy	breezy	Yellow-green.
13-Jul	1130			12.0	5.00		20	heavy	light	Water color yellow-green.
27-Jul	1347	20.0	68.0	15.6	3.75		50	heavy		Water color yellow-green. New Secchi line arrived and used today.
10-Aug	1245	20.0	68.0	15.2	2.00		0	none	breezy	Water color yellow-green. Last rain was on 8/5/93, and was 0.57".
19-Aug	1210			14.0			0		light	Onsite visit. Water color yellow-brown. Second Secchi with view tube.
24-Aug	1210	17.8	64.0	16.2	1.75		50	none	strong	Water color yellow-green.
08-Sep	1135	21.1	70.0	16.4	0.25		0	none	calm	Water color yellow-green.
22-Sep	1415	15.6	60.0	16.3	-1.00		0	none		Water color yellow-green.
06-Oct	1230	15.0	59.0	17.0	-2.00		100	light		Water color yellow-green.
20-Oct	1230	12.2	54.0	18.0	-3.00		0	none	light	Water color yellow-green.

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Thomas dropped 5.75" from May 31 to October 20.

Lake Thomas -- Stevens County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/18	0.0	20.5	.	8.4	54
	1.0	20.0	.	8.6	55
	2.0	16.8	.	9.8	55
	3.0	12.4	.	10.2	55
	4.0	9.8	.	9.8	57
	6.0	7.6	.	5.2	61
	8.0	6.7	.	3.2	62
	10.0	6.2	.	2.3	62
	15.0	6.0	.	1.8	64
08/19	0.0	20.7	7.8	7.8	58
	1.0	20.1	7.8	7.7	58
	2.0	19.5	7.7	7.7	59
	3.0	19.2	7.7	7.7	58
	4.0	17.9	7.7	7.7	59
	5.0	13.9	7.3	2.9	64
	6.0	11.2	7.2	0.2	67
	7.0	9.4	7.1	0.1	70
	8.0	8.4	7.0	0.1	69
	9.0	7.6	7.0	0.1	73
	10.0	7.0	6.9	0.1	76
	12.0	6.7	6.9	0.1	78
	14.0	6.6	6.9	0.1	79
	16.0	6.5	6.8	0.1	81

Lake Thomas -- Stevens County

1993 Onsite Visit Data - Water Chemistry

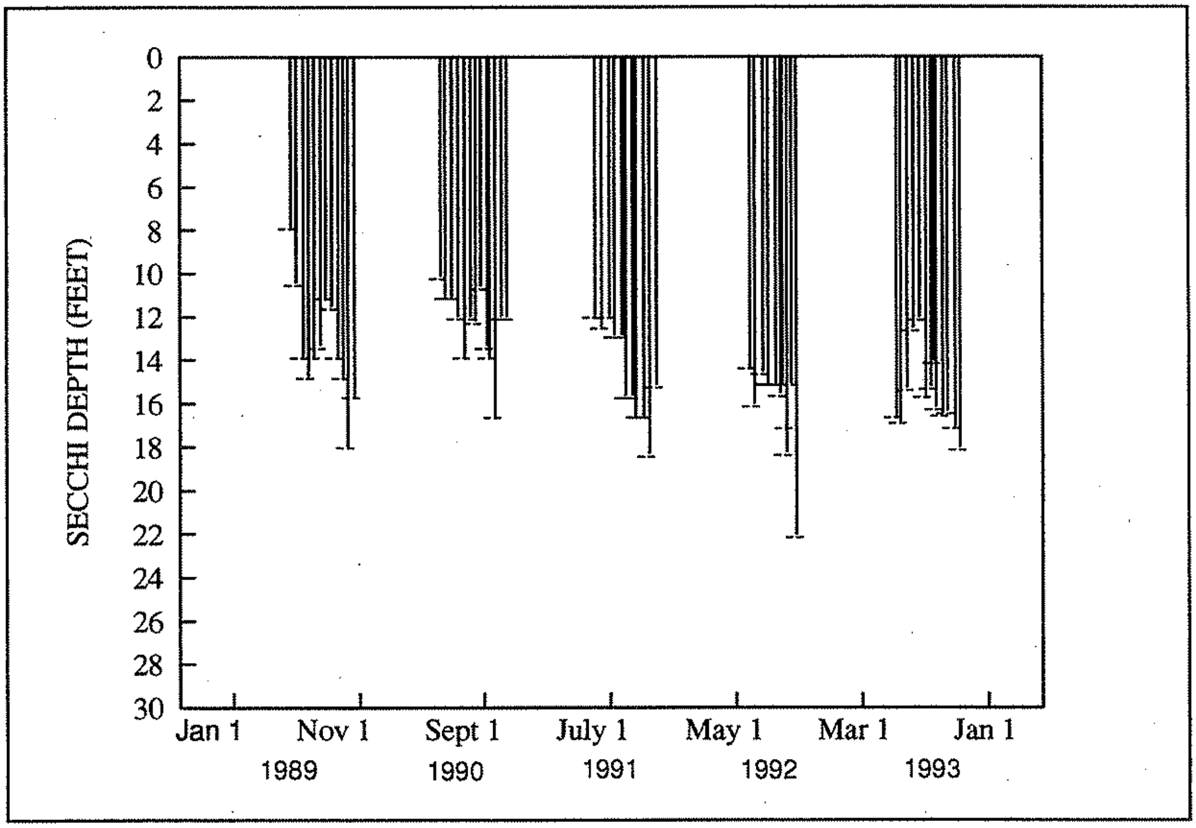
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 18							
Epilimnion	12	0.22	1.5	--	--	1	1
Hypolimnion	33	--	--	--	--	--	--
August 19							
Epilimnion	11	0.18	1.4	--	--	--	--
Hypolimnion	33	--	--	--	--	--	--

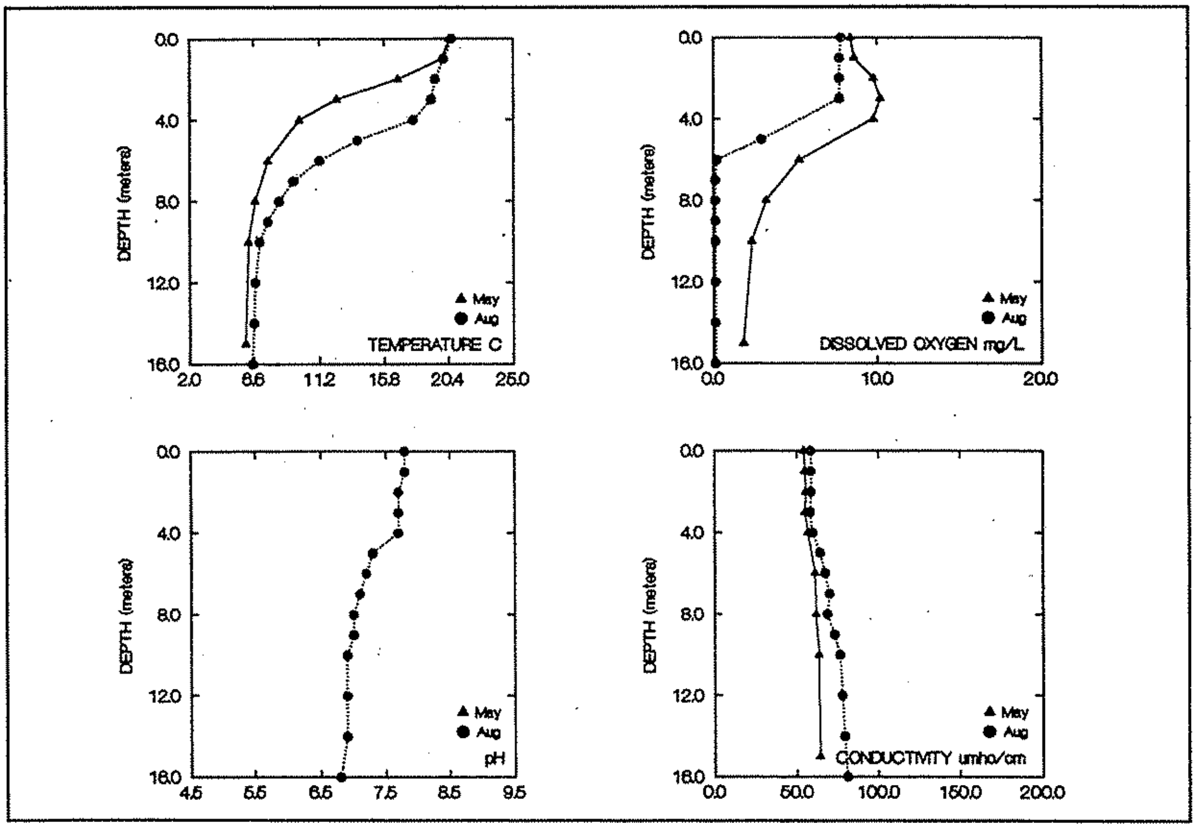
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)
08/16/72[a]	27	--	2.1
07/15/81[b]	20	0.69	3.0
05/25/90[c]	11	0.29	--
09/10/90[c]	7	0.27	--
06/13/91[d]	--	0.21	--
05/11/92[e]	13	0.33	3.1
08/27/92[e]	5	0.28	1.1

a. Dion *et al.* (1976), Bortleson *et al.* (1976)
b. Sumioka and Dion (1985)
c. Rector (1991)
d. Rector (1992)
e. Rector (1993)

THOMAS LAKE (STEVENS COUNTY)





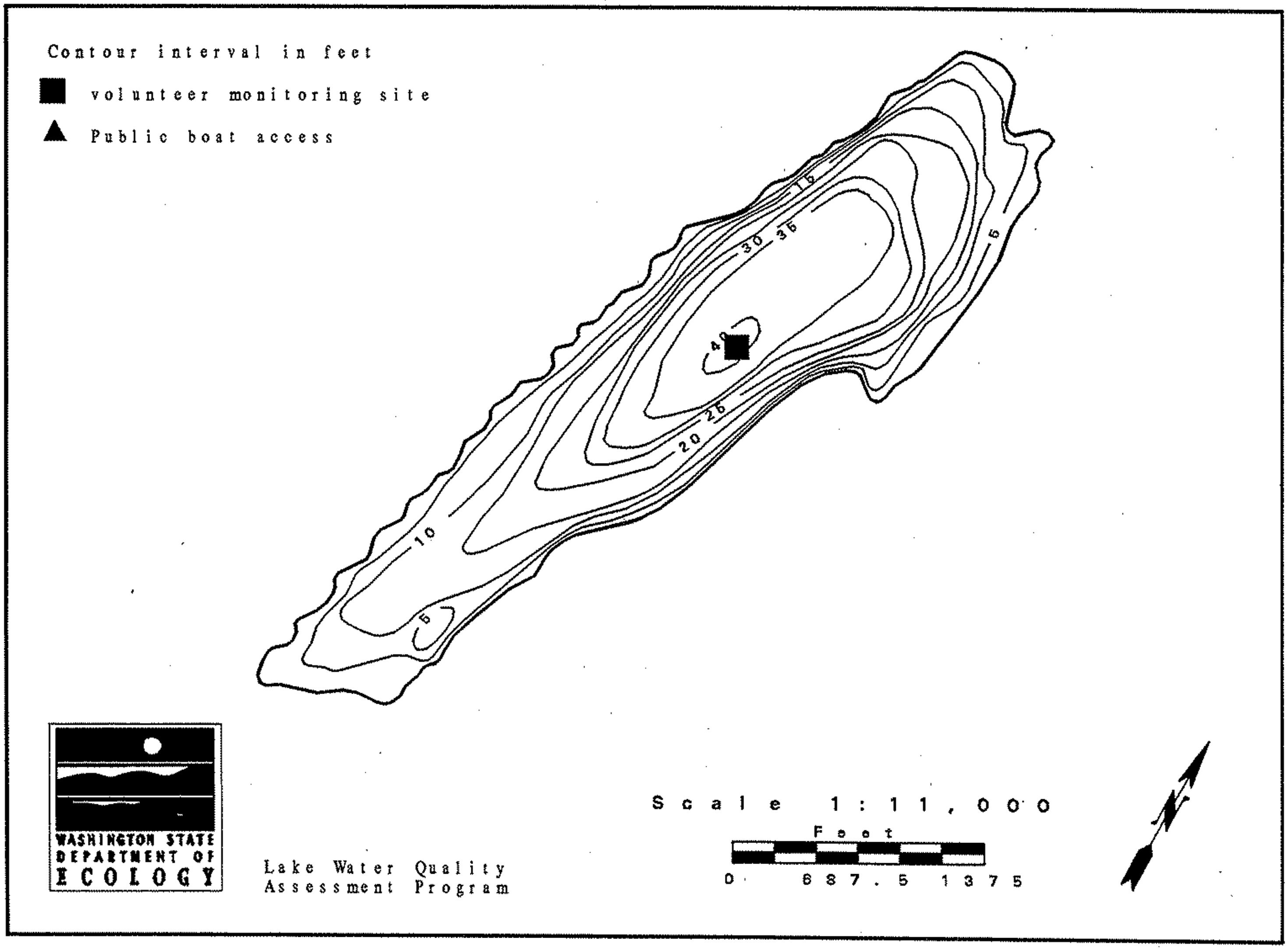
1993 Secchi Depth and Profile Data Graphs

Tiger Lake -- Kitsap/Mason Counties

Tiger Lake is located 9.5 miles southwest of Bremerton. Most of the lake (102.8 acres) is in Mason County, and the northern tip of the lake (6.3 acres) is in Kitsap County. Tiger Lake has no surface inlets, and drains via Mission Creek to Hood Canal.

Size (acres)	110
Maximum Depth (feet)	40
Mean Depth (feet)	19
Lake Volume (acre-feet)	2,100
Drainage Area (miles^2)	0.7
Altitude (feet) 496	
Shoreline Length (miles)	2.5

Data From Bortleson *et al.* (1976)



Overall Assessment

In 1993, Tiger Lake was assessed as oligotrophic, based on fair to good water clarity, low nutrient concentrations, and low densities of algae and aquatic plants. Tiger Lake was new to the Lake Water Quality Assessment Program in 1993.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was fair to good, as indicated by Secchi depths that ranged from 9.0 feet to 14.5 feet. Secchi depths from 6.5 feet to 13.0 feet are typical for mesotrophic lakes, and Secchi depths greater than 13.0 feet are typical for oligotrophic lakes.

Total Phosphorus

Concentrations of total phosphorus in the upper layer of water were low (8 µg/L on both sampling dates). Concentrations less than 12 µg/L are low and usually result in low densities of algae growth.

Total Nitrogen

Total nitrogen concentrations were moderately low on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 (29:1 in June, and 31:1 in August), algae in Tiger Lake were not limited by nitrogen when the lake was sampled.

Profile Data

On both sampling dates, the lake was weakly stratified with respect to temperature. Dissolved oxygen concentrations and pH values decreased in the bottom two meters of the lake. Dissolved oxygen concentrations usually decrease because bacteria use oxygen as they decompose aquatic plants and algae in the bottom water and sediments. However, Tiger Lake has no surface inlets and is probably fed by seeping groundwater or springs. Ground water has very low dissolved oxygen, which could also explain the very low dissolved oxygen content at the bottom of Tiger Lake.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Chlorophyll concentrations on both sampling dates indicated low densities of algae when the lake was sampled.

There were few aquatic plants in the lake during the sampling visits by Ecology staff. Plants observed were yellow-flowering water lily (*Nuphar polysepalum*) and cattails (*Typha* sp.). However, the volunteer's comments from October 11 indicate that rooted plants grow in deeper water areas of the lake. When the lake was sampled in 1973, there were few aquatic plants because of the sandy, gravely littoral zone (McConnell *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 the 1993 questionnaire on lake and watershed uses.

> Tiger Lake is used for fishing, swimming, motor boating, rowing, and jet skiing. There is one boat ramp on the lakeshore, and there are no restrictions for motor boat use on the lake. Trout were stocked in the lake in 1993. Currently, the watershed is being logged and used for crop agriculture. The lakeshore is also being developed further for residences. In the past, the watershed was logged.
>
> There are approximately 98 houses on the lakeshore, and none are connected to a sewer collection system. There is a lake association for the lake. No lake management activities occurred on the lake in 1993. Lake water was withdrawn for drinking and other domestic uses.
>
> Overall, the volunteer found that Tiger Lake had good water quality. Problems in the lake in 1993 were ranked as (1) shoreline erosion, and (2) degraded aesthetics. Possible sources of problems include clearcutting, unrestricted development (including shoreline alterations), and excessive power-boating (which limits other lake uses and erodes the shoreline). Presently there is a proposal to extensively develop one side of the lake; the development includes a community beach, and many lots are located in wetlands.

Acknowledgment

I thank Don Olson for volunteering his time to monitor Tiger Lake in 1993.

Tiger Lake -- Kitsap/Mason Counties

1993 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	41
Mean Trophic State Index (Total Phosphorus):	34
Mean Trophic State Index (Chlorophyll *a*):	33

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
03-Jun	0945	20.0	68.0	14.5			100			Onsite visit.
18-Jun	1115	21.1	70.0	13.0			10	none	light	Water color dark green.
06-Jul	1000	21.1	70.0	9.0	-6.00	gr-brown	0	heavy	breezy	Water has become milky in appearance.
17-Jul	1034	21.1	70.0	12.0	-8.00		90	light	breezy	Water color black-green. Because of inclement weather, there has been less jet ski activity since last reading.
29-Jul	1230	21.1	70.0	13.0	-9.00	black	75	heavy	breezy	
11-Aug	1000	22.8	73.0	13.0	-13.00	gr-brown	10	none	light	
27-Aug	1300	22.2	72.0	12.0	-16.00	gr-brown	50	trace	light	
31-Aug	1245			12.5			0			Water color dark green. Onsite visit.
16-Sep	1230	22.2	72.0	12.5	-21.00	lt-green	0	none	breezy	
28-Sep	0940	18.9	66.0	13.5	-28.00	green	0	none	calm	
11-Oct	1400	17.8	64.0	13.0	-26.00	lt-green	100	trace	light	The anchor brought up weeds of a different variety than we have seen before.
24-Oct	1430	16.1	61.0	12.0	-27.00	gr-brown	10	heavy	light	

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Tiger Lake dropped 21" from July 6 to October 24.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
06/03	0.0	19.1	8.1	8.8	16
	1.1	19.1	7.9	8.9	16
	2.0	19.1	7.8	8.9	16
	3.0	19.1	7.7	9.0	16
	4.1	19.1	7.7	9.0	16
	5.0	18.7	7.7	9.0	16
	6.1	16.8	7.6	9.1	15
	7.0	15.0	7.6	9.3	16
	8.1	14.2	7.4	7.6	16
	9.1	13.9	7.2	5.9	17
	10.1	13.7	7.1	4.0	19
08/31	0.0	21.1	7.2	8.9	16
	1.0	20.5	7.1	8.7	16
	2.0	20.4	7.0	8.5	16
	3.0	20.4	7.0	8.5	15
	4.0	20.3	7.0	8.4	16
	5.0	20.2	7.0	8.3	15
	6.1	20.1	6.9	8.2	16
	7.1	19.8	6.9	7.4	16
	8.1	19.1	6.6	3.8	17
	9.0	17.3	6.5	0.4	22
	9.6	16.6	6.5	0.2	27

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll a (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 3 Epilimnion	8	0.23	1.7	--	--	--	--
Hypolimnion	11	0.24	--	--	--	--	--
August 31 Epilimnion	8	0.25	1.0	--	--	--	--
Hypolimnion	9	0.23	--	--	--	--	--

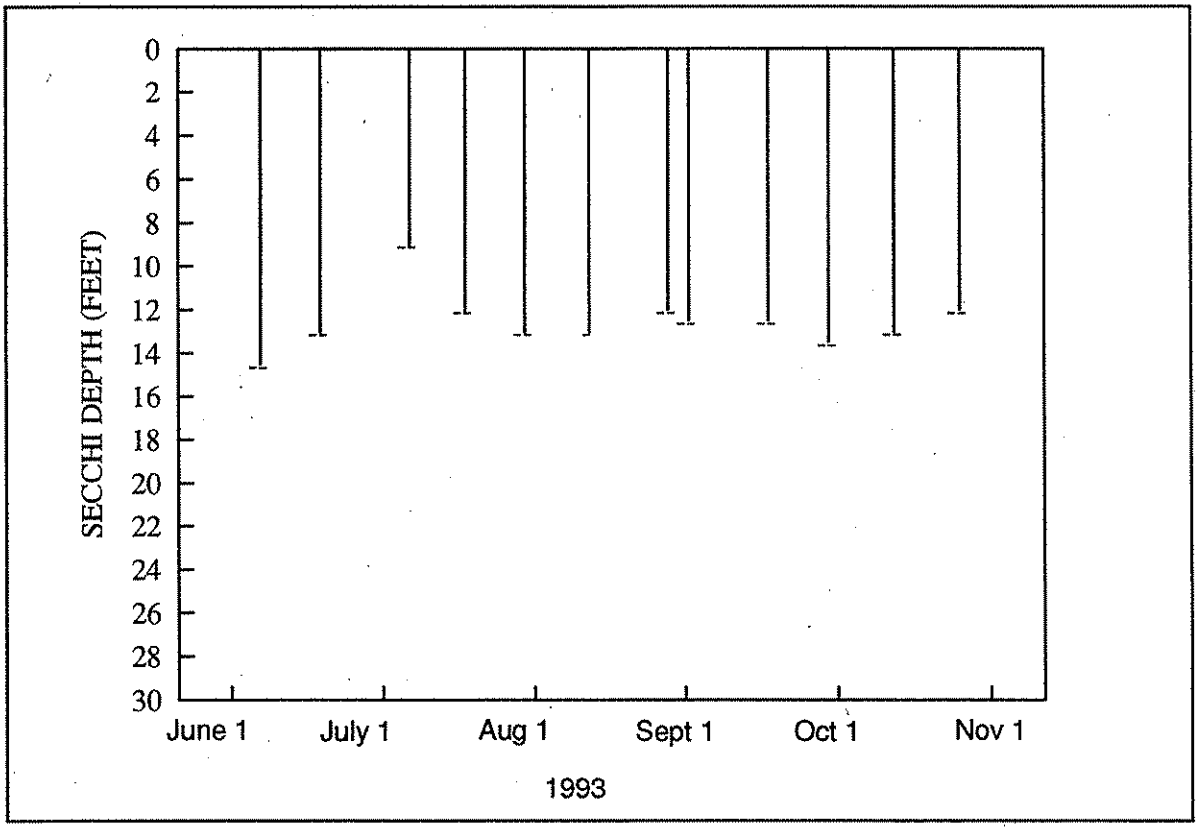
Tiger Lake -- Kitsap/Mason Counties

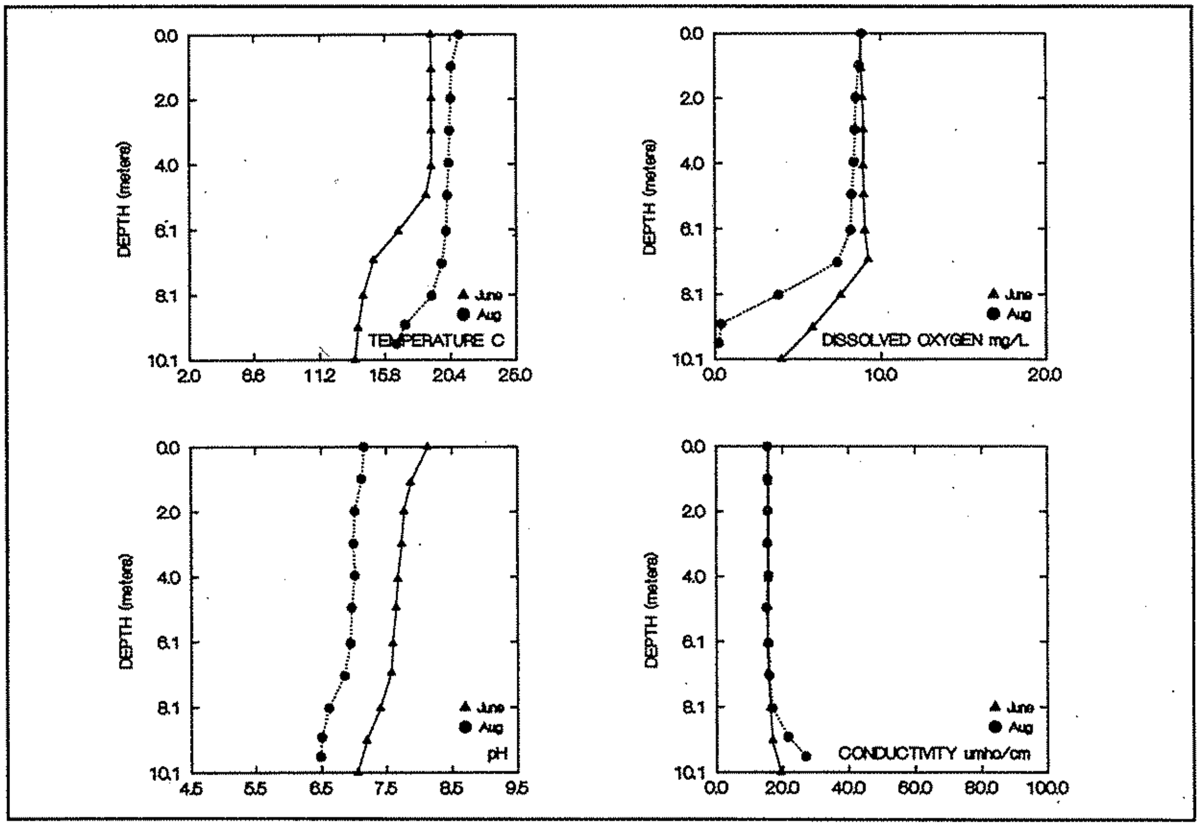
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)
06/20/73[a]	4	--	2.2
09/05/73[a]	11	--	6.0
06/28/89[b]	8	0.28	1.5
09/27/89[b]	13	0.27	1.6

a. McConnell *et al.* (1976)
b. Brower and Kendra (1991)

TIGER LAKE (KITSAP/MASON COUNTY)





1993 Secchi Depth and Profile Data Graphs

Big Twin Lake -- Okanogan County

Big Twin Lake is located two miles south of Winthrop. It has no surface inlets or outlet. It is located within the Methow River watershed.

Size (acres)	79
Maximum Depth (feet)	70
Mean Depth (feet)	24
Lake Volume (acre-feet)	1,900
Drainage Area (miles^2)	1.4
Altitude (feet)	1,799
Shoreline Length (miles)	1.5

Data From Dion *et al.* (1976)

No Data Available.

Overall Assessment

In 1993, Big Twin Lake was assessed as oligo-mesotrophic, because it exhibited both oligotrophic and mesotrophic characteristics. Oligotrophic characteristics were the good water clarity, and low densities of algae. Mesotrophic characteristics include the moderately high concentrations of total phosphorus, very low concentrations of dissolved oxygen throughout the lower layer of water (the hypolimnion), and the likelihood that sediments released phosphorus into the water column.

Big Twin Lake was new to the Lake Water Quality Assessment Program in 1993.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity in Big Twin Lake was good, as indicated by Secchi depths that ranged from 23.0 feet to 28.6 feet. Secchi depths greater than 13.0 feet indicate good water clarity, and are typical for oligotrophic lakes.

Total Phosphorus
Concentrations of total phosphorus were moderate on both sampling dates (12 μg/L in May, and 15 μg/L in August). Concentrations from 12 to 24 μg/L are typical for mesotrophic lakes.

In August, total phosphorus in the lower layer of water was much higher than in the upper layer of water, and could have resulted from sediment release. Sediment release can occur when dissolved oxygen concentrations near sediments are depleted, creating an environment that allows phosphorus, iron, and other compounds in sediments to be chemically reduced and released into the water column (see Profile Data, below). Sediment release is not characteristic of oligotrophic lakes, and can cause fall algal blooms after the lake turns over.

Total Nitrogen
Concentrations of total nitrogen were high on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae generally use at least ten times the amount of nitrogen as phosphorus. Because the ratios of total nitrogen to total phosphorus were much greater than 17:1 (60:1 in May, and 47:1 in August), algae in Twin Lake were not limited by nitrogen when the lake was sampled.

Profile Data
The lake was thermally stratified on both sampling dates. Below the thermocline, the concentrations of dissolved oxygen decreased considerably with depth and there was no oxygen in

the bottom six meters of the lake. Oxygen concentrations usually decrease because bacteria use oxygen as they decompose aquatic plants in the water and sediments. However, Twin Lake has no surface inlets, so it is likely that the lake is fed by groundwater as well as runoff. Groundwater, which is very low in dissolved oxygen, would be trapped in the lower layer of water while the lake is stratified. As a result, oxygen concentrations can be very low in the lower layer of water, yet high in the upper layer of water. In 1974, dissolved oxygen was depleted in the lower layer of water during stratification, so it is likely that low oxygen concentrations in summer have been occurring for many years.

There are no pH data from May because the probe was not functioning properly at the time.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Chlorophyll concentrations on both sampling dates (1.4 µg/L in May, and 2.0 µg/L in August) indicated low densities of algae when the lake was sampled. Chlorophyll concentrations less than 2.6 µg/L indicate low algal densities and are typical for oligotrophic lakes.

Aquatic plants observed by Ecology staff during the sampling visits include muskgrass (the alga *Chara*), sago pondweed (*Potamogeton pectinatus*), and variable pondweed (*Potamogeton gramineus*). Muskgrass was the most abundant plant in the lake.

Other Available Information
From Dion *et al.* (1976): In 1974, there were two nearshore homes. In 1974, there was a moderate amount of biological productivity; more than half of the lake bottom was covered with submersed aquatic macrophytes that extended from the shoreline to depths of about 25 feet.

Summary of Questionnaires Responses and Information from the Volunteer

The questionnaire on lake and watershed uses was not returned.

Acknowledgment

I thank Frank O. Johnson for volunteering his time to monitor Big Twin Lake in 1993.

Big Twin Lake -- Okanogan County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	30
Mean Trophic State Index (Total Phosphorus):	42
Mean Trophic State Index (Chlorophyll *a*):	35

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
23-May	1500			23.8		lt-green	15		calm	Onsite visit
08-Jun	1115	17.8	64.0	28.6	2.00	lt-green	25	light	breezy	
26-Jun	1003	20.0	68.0	27.8	4.50		0	none	calm	Water color light tan.
24-Aug	1455			23.0		green	70		breezy	Onsite visit. Water color bright green.

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

[2] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Big Twin Lake dropped 2.5" from June 8 to June 26.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/23	0.0	20.8	.	10.5	275
	1.0	20.5	.	10.5	274
	2.0	20.3	.	10.7	274
	3.0	19.5	.	10.6	274
	4.0	16.7	.	11.1	287
	5.0	14.8	.	11.5	290
	6.0	11.4	.	10.5	300
	7.0	8.8	.	11.1	306
	8.0	7.6	.	8.1	312
	9.0	6.3	.	2.3	318
	10.0	6.1	.	1.0	320
	11.0	5.7	.	0.3	318
08/24	0.0	20.8	9.0	8.1	257
	2.0	20.8	8.9	8.1	258
	4.0	20.8	8.9	8.0	257
	6.0	20.6	8.9	8.7	256
	7.0	19.5	8.8	8.9	285
	8.0	15.4	8.7	8.7	322
	9.0	12.5	8.2	4.8	332
	10.0	10.1	8.0	0.6	336
	12.0	7.8	7.7	0.1	342
	14.0	6.9	7.6	0.2	342
	16.0	6.6	8.5	0.1	348

1993 Onsite Visit Data - Water Chemistry

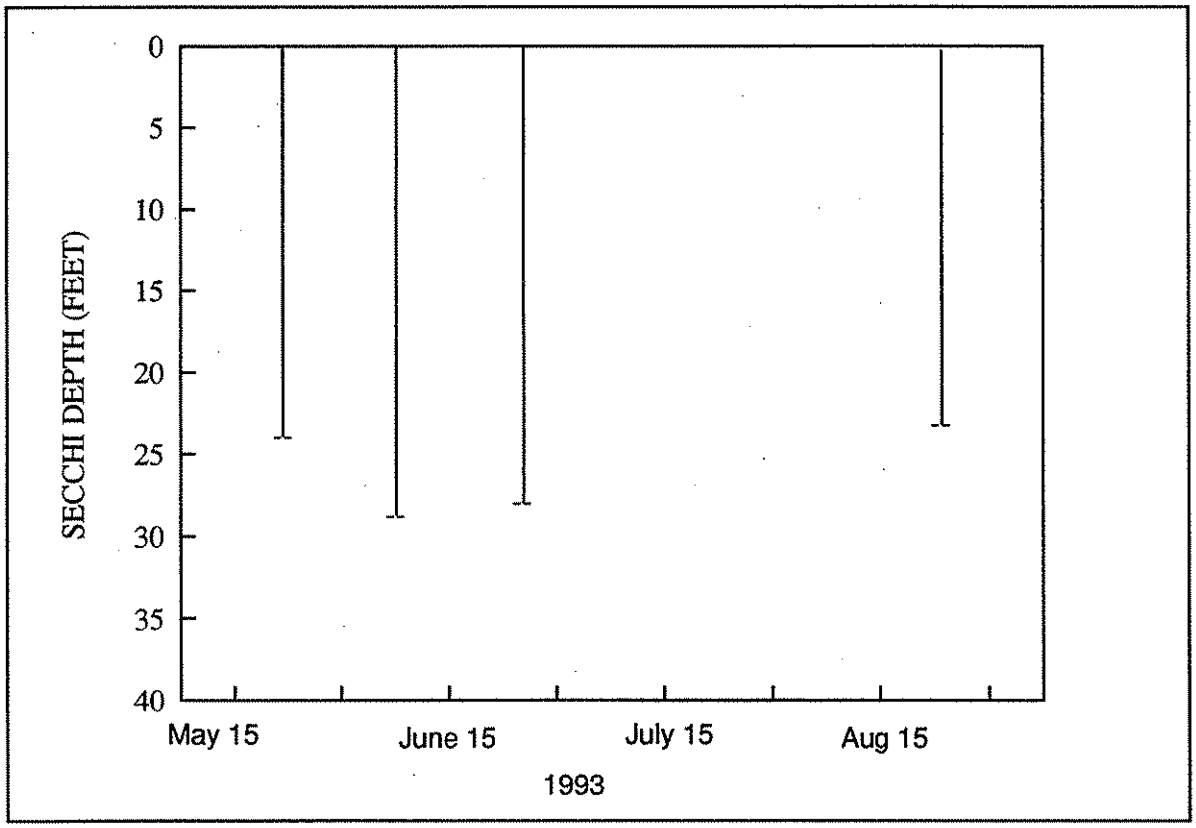
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL)	
						Site #1	Site #2
May 23							
Epilimnion	12	0.72	1.4	--	--	--	--
Hypolimnion	17	1.10	--	--	--	--	--
August 24							
Epilimnion	15	0.70	2.0	--	--	--	--
Hypolimnion	47	1.48	--	--	--	--	--

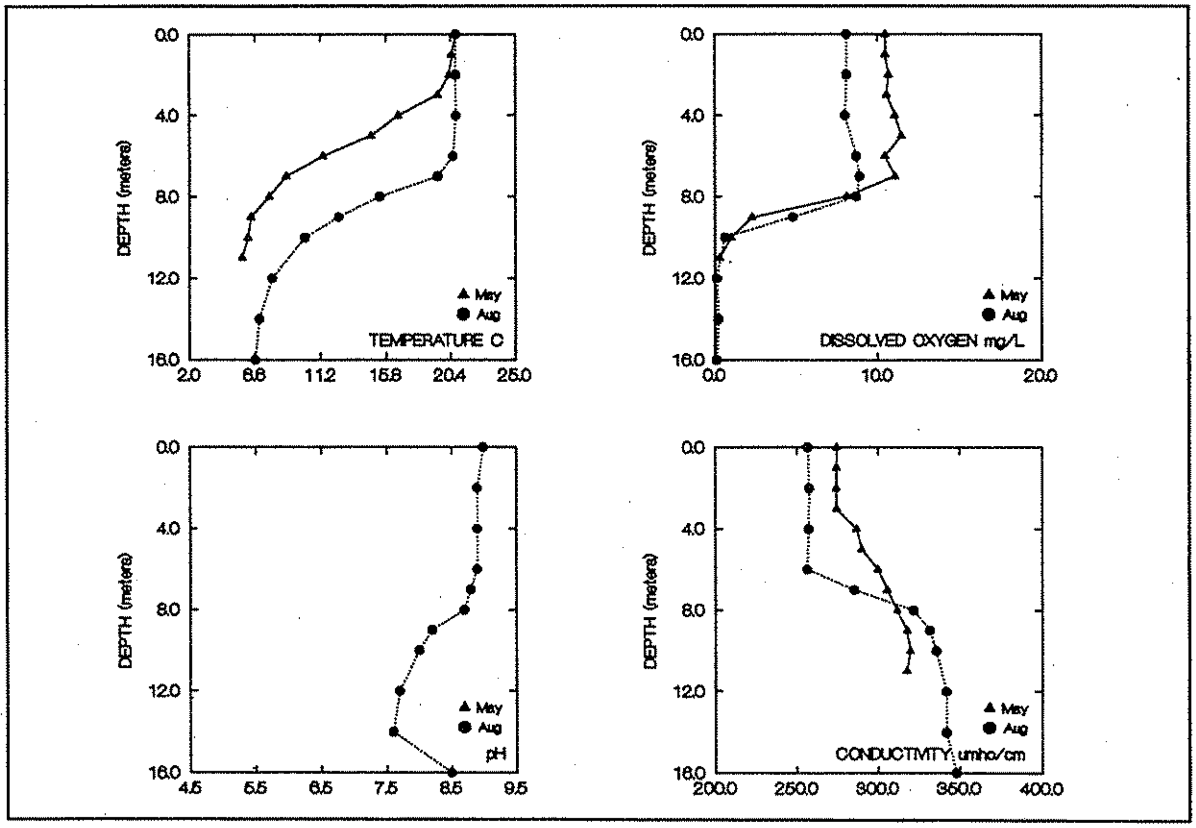
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)
05/21/74[a]	25	--	0.6
09/24/74[a]	10	--	2.1

a. Dion *et al.* (1976)

BIG TWIN LAKE (OKANOGAN COUNTY)





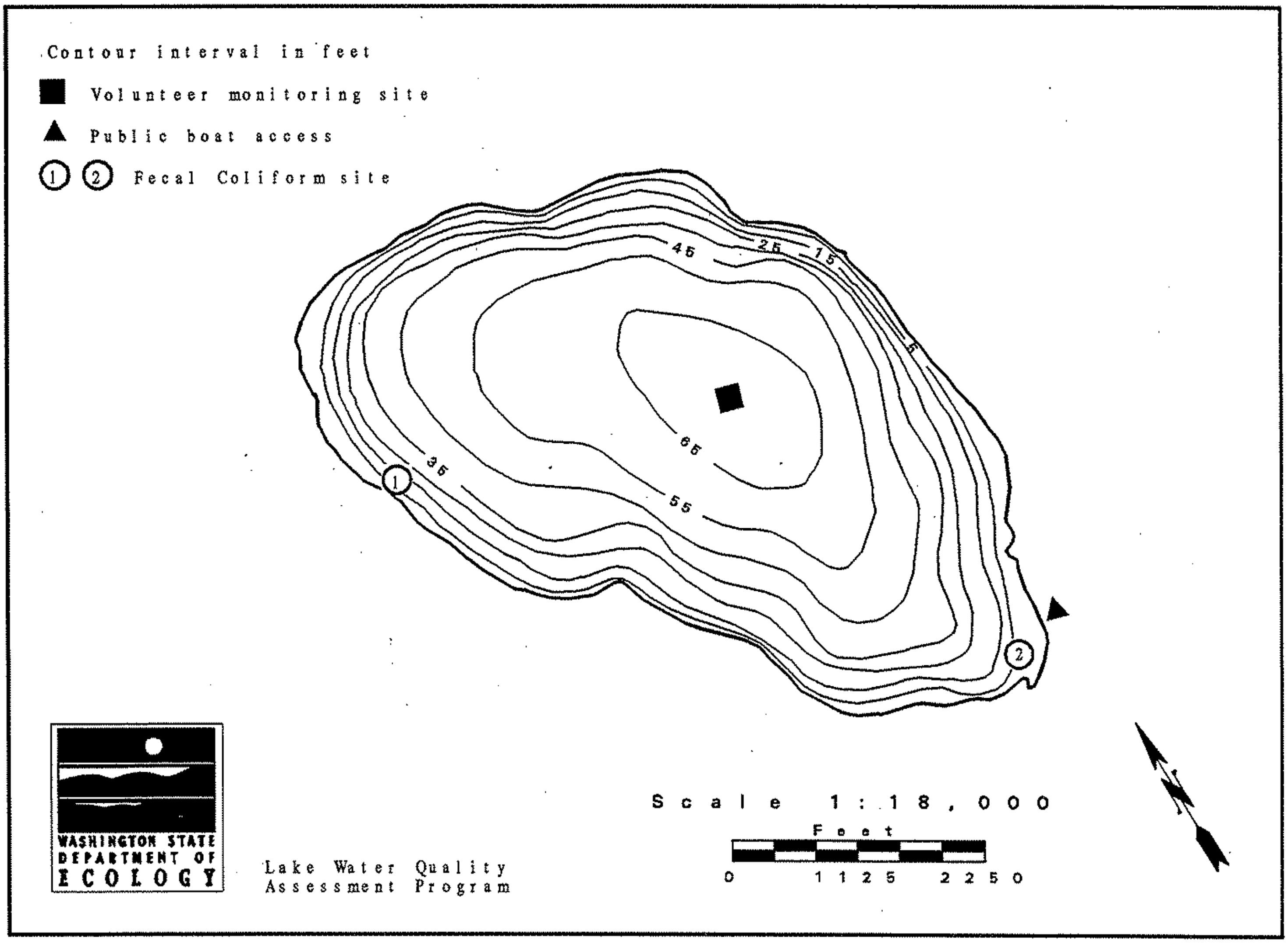
1993 Secchi Depth and Profile Data Graphs

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 that enters the Colvile River about two miles downstream.

Size (acres)	472
Maximum Depth (feet)	68
Mean Depth (feet)	40
Lake Volume (acre-feet)	18,784
Drainage Area (miles^2)	11.7
Altitude (feet)	1,946
Shoreline Length (miles)	3.3

Data From Dion *et al.* (1976)



Overall Assessment

In 1993, Waitts Lake was assessed as oligo-mesotrophic, because it exhibited both oligotrophic and mesotrophic characteristics. Oligotrophic characteristics were the very good water clarity and low densities of algae. Mesotrophic characteristics were the moderately high concentrations of total phosphorus, and very low concentrations of dissolved oxygen in the lower layer of water. Based on data collected for this program, Waitts Lake has been described as oligo-mesotrophic since 1990.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
In 1993, water clarity was very good, as indicated by Secchi depths that ranged from 19.0 feet to 31.0 feet. In general, Secchi depths from 1993 were deeper than in 1990-1992. Secchi depths greater than 13.0 feet indicate good water clarity, and are typical for oligotrophic lakes.

Total Phosphorus
Concentrations of total phosphorus were moderately high on both sampling dates (20 µg/L in May, and 17 µg/L in August). Concentrations measured in 1993 were somewhat higher than those measured in 1992 and 1990. Despite higher phosphorus concentrations, algal densities in the lake were low in 1993 (see Plants, below).

Total Nitrogen
Concentrations of total nitrogen were high on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. However, because the ratios of total nitrogen to total phosphorus were greater than 17:1 (24:1 in May, and 40:1 in August), algae in Waitts Lake were not limited by nitrogen when the lake was sampled.

Fecal Coliform Bacteria
Samples for fecal coliforms were collected from two nearshore sites on each sampling date. Site #1 was located on the northwest end of the lake, and Site #2 was located at the south end of the lake. On both sampling dates, results from both samples were very low. The state water quality standard for fecal coliforms in Lake Class waters is a geometric mean of 50 colonies/100 mL.

Profile Data
On both sampling dates, the lake was thermally stratified. Below the thermocline, concentrations of dissolved oxygen decreased considerably with depth. Dissolved oxygen concentrations usually

decrease from bacteria which use oxygen as they decompose aquatic plants and algae in the water and sediments. Low oxygen in the lower layer of water was also reported in 1992 and 1990. There are no pH data from May because the probe was malfunctioning at the time.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Chlorophyll concentrations in 1993 (1.6 µg/L on both sampling dates) indicated low densities of algae when the lake was sampled. Chlorophyll concentrations less than 2.6 µg/L are typical for oligotrophic lakes.

Aquatic plants observed by Ecology staff during the 1993 sampling visits included cattails (Typha latifolia), milfoil (*Myriophyllum* sp., but not the aggressive Eurasian species), Illinois pondweed (Potamogeton illinoensis), coontail (*Ceratophyllum demersum*), muskgrass (the alga *Chara*), and naiad (*Najas flexilis*). Except for coontail and naiad, which were observed for the first time in 1993, the other plants were also observed in 1992.

Summary of Questionnaire Results and Information from the Volunteer

The 1993 questionnaire on lake and watershed uses was not returned. 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 motor-boating in the lake. About 2 percent of the shoreline is publicly-owned. Rainbow and German brown trout were stocked in the lake in 1992. Currently, the watershed is being logged and used for animal grazing. In the past, the watershed was logged and used for crop agriculture and animal grazing, the shoreline was 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 found that in 1992 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 were no management measures used to control unwanted

plants or algae in the lake in 1992, but the lake was treated with chemicals in the past to control undesirable fish species. In 1993, the volunteer was concerned about garbage (and lack of a garbage can) at the public boat access.

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.

Acknowledgment

I thank Beth Pulliam for volunteering her time to monitor Waitts Lake during 1990-1993.

Waitts Lake -- Stevens County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index (Secchi):	33
Mean Trophic State Index (Total Phosphorus):	42
Mean Trophic State Index (Chlorophyll *a*):	35

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
19-May	0900	20.6	69.0	31.0	18.50	gr-brown	10	none	calm	
26-May	0900	16.7	62.0	23.0	19.50	green	100	none	light	
03-Jun	1020	18.3	65.0	25.0	21.25	green	25	light	calm	
09-Jun	1000	17.2	63.0	19.0	22.25	green	100	trace	breezy	Cooler temps than usual for June.
30-Jun	1850	17.8	64.0	21.5	24.00	green	50	light	breezy	Secchi with view tube.
14-Jul	0800	17.8	64.0	17.4	20.56	gr-brown	100	heavy	light	Massive rain and cool temps last 3 weeks.
19-Aug	0905	22.2	72.0	22.4	23.00	green	50	none	calm	
20-Aug	0910			22.5		green	50		calm	Onsite visit.
07-Sep	0900	20.0	68.0	22.4	25.19	green	0	none	calm	

1 Trophic State Indices calculated from Carlson (1977).
2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Waitts Lake dropped 6.7" from May 19 to September 7.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/19	0.0	20.6	.	9.4	280
	1.0	20.6	.	9.4	280
	2.0	19.9	.	9.5	280
	3.0	19.0	.	9.5	279
	4.0	14.7	.	9.7	276
	6.0	10.8	.	7.4	276
	8.0	7.8	.	3.4	276
	10.0	6.5	.	2.4	278
	15.0	4.9	.	0.2	285
08/20	0.0	22.2	8.7	8.4	287
	1.0	22.1	8.7	8.4	287
	2.0	21.3	8.7	8.5	286
	3.0	21.3	8.6	8.5	286
	4.0	21.0	8.6	8.5	286
	5.0	20.8	8.6	8.4	286
	6.0	18.5	8.4	7.0	294
	7.0	15.5	8.1	5.5	299
	8.0	11.3	7.9	2.7	298
	9.0	9.5	7.8	0.9	295
	10.0	8.5	7.7	0.5	294
	12.0	6.5	7.7	0.2	293
	14.0	5.5	7.5	0.1	302
	16.0	5.1	7.5	0.1	308

1993 Onsite Visit Data - Water Chemistry

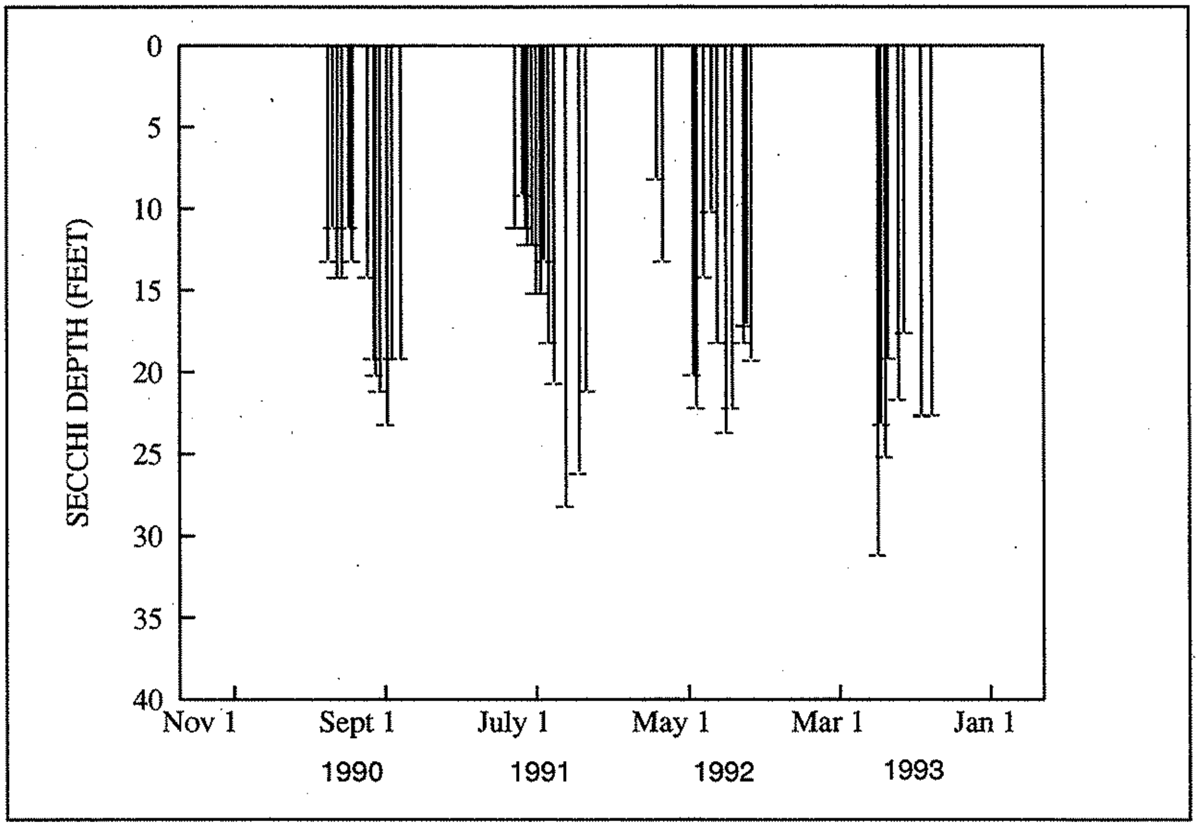
	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 19							
Epilimnion	20	0.47	1.6	--	--	1	1
Hypolimnion	24	0.50	--	--	--	--	--
August 20							
Epilimnion	10	0.40	1.6	--	--	1	1
Hypolimnion	27	0.44	--	--	--	--	--

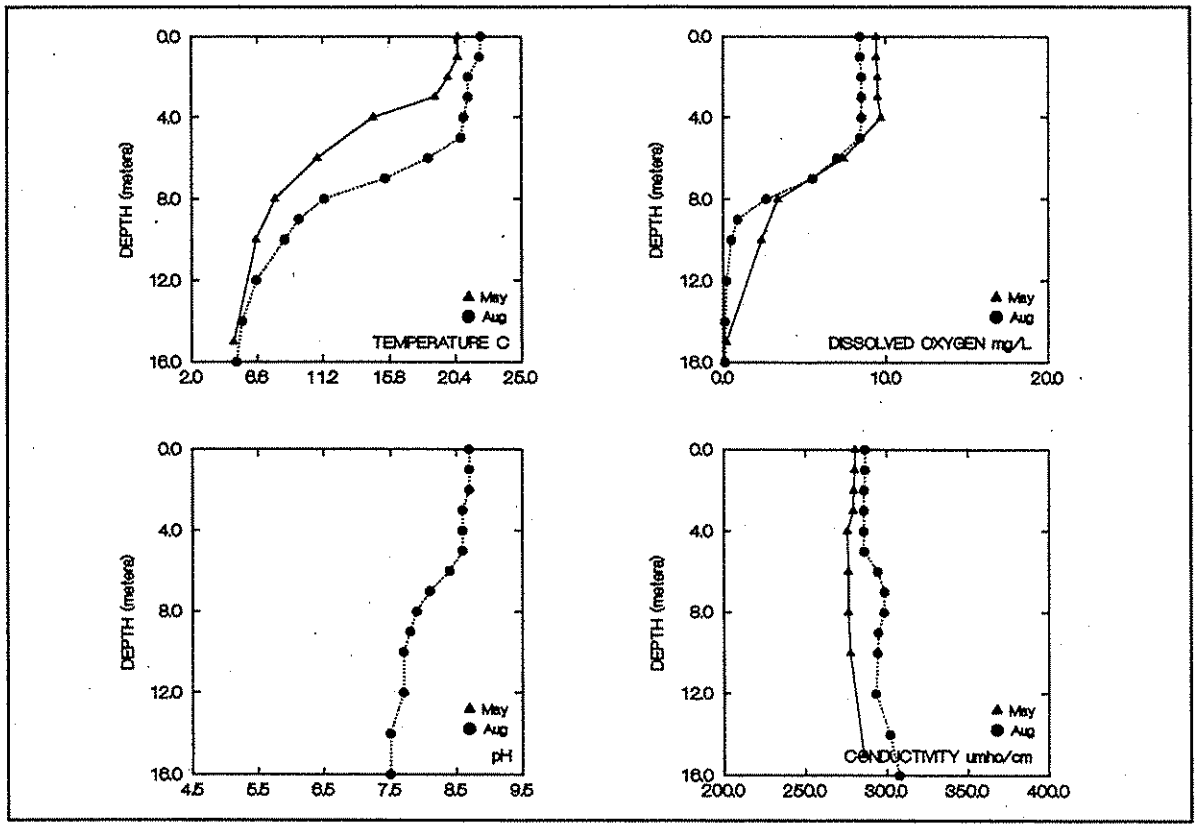
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)
07/08/74a	17	--	--
07/14/81b	20	0.7	1.5
06/26/90c	10	0.41	1.7
08/09/90d	16	0.47	--
09/25/90c	8	0.40	7.5
06/10/91e	--	0.40	--
05/12/92f	16	0.48	0.77
08/25/92f	10	0.46	2.1

a. Dion *et al.* (1976)
b. Sumioka and Dion (1985)
c. Coots (1991)
d. Rector (1991)
e. Rector (1992)
f. Rector (1993)

WAITTS LAKE (STEVENS COUNTY)





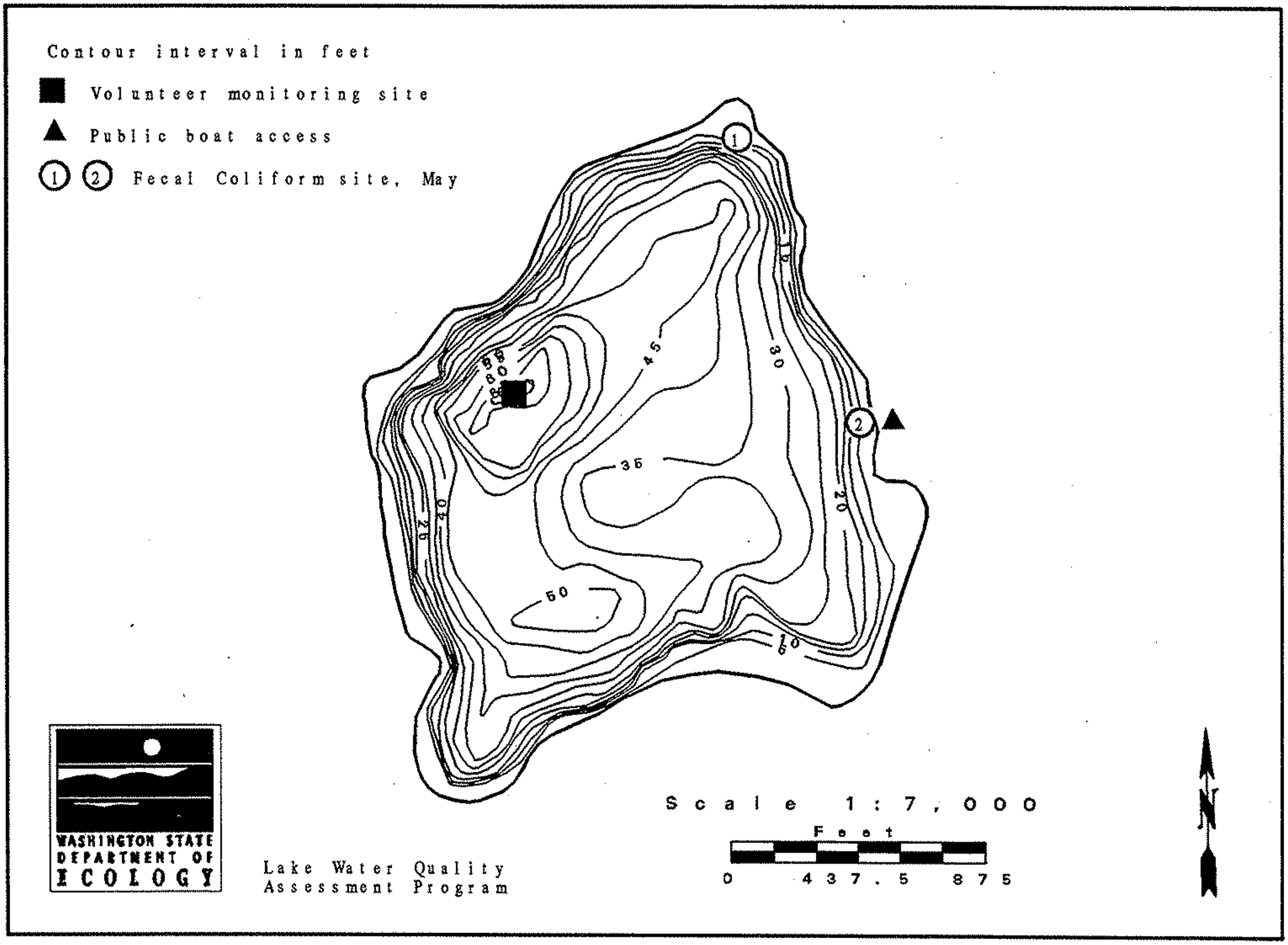
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, Ward Lake was assessed as oligo-mesotrophic, because it exhibited both oligotrophic and mesotrophic characteristics. Oligotrophic characteristics were the good water clarity and low densities of algae and aquatic plants. Mesotrophic characteristics include the moderately high concentration of total phosphorus in the upper layer of water during May, low concentrations of dissolved oxygen in the lower layer of water during August, sediment release of phosphorus, and the presence of hydrogen sulfide near the lake bottom. Ward Lake was classified as oligotrophic from 1990-1992.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
In 1993, water clarity was good, as indicated by Secchi depths that ranged from 12.0 feet to 22.5 feet. Water clarity was lowest in early July, from increased algae growth that made the water pea-green. Secchi depths greater than 13.0 feet indicate good water clarity, and are typical for oligotrophic lakes.

Total Phosphorus
In May, the concentration of total phosphorus in the upper layer of water was moderately high (21 µg/L). This concentration was higher than those measured for the program in 1992 and 1990. Despite the moderately high concentration, algal density at the time was low (see Plants, below).

In August, the total phosphorus concentration in the upper layer of water was very low (5 µg/L), and there was a very low density of algae at the time.

On both sampling dates, total phosphorus concentrations in the lower layer of water was higher than in the upper layer. It is likely that phosphorus was released from sediments into the water column. This process can occur when oxygen concentrations near sediments are very low, creating an environment that allows phosphorus, iron and other compounds in sediments to be chemically reduced and released into the water. Sediment release of phosphorus is not characteristic of oligotrophic lakes.

Total Nitrogen
On both sampling dates, the concentrations of total nitrogen were moderately low, although concentrations in Ward Lake were very low in comparison to concentrations found in other lakes in the program. Concentrations measured in 1993 were very similar to those measured from 1990-1992. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae generally use at least ten times the amount of nitrogen as phosphorus. In August, the ratio of total nitrogen to total phosphorus was

greater than 17:1 (39:1), algal growth was not limited by nitrogen when the lake was sampled in August. In May, the ratio of total nitrogen to total phosphorus was only 11:1, so algal growth may have been nitrogen-limited when the lake was sampled in May.

Profile Data

The lake was thermally stratified on both sampling dates. At the thermocline dissolved oxygen concentrations increased, most likely from a combination of decreased water temperature (because dissolved gases are more soluble in cold water than in warmer water) and from increased algae growth at these depths. Below the thermocline, concentrations of 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 dissolved oxygen.

Low oxygen concentrations in the lower layer of water probably caused phosphorus and other compounds in sediments to be released into the water column. In August, when oxygen concentrations were very low near the sediments, there was a high concentration of total phosphorus in the lower layer of water, and conductivity values increased in the bottom eight meters of the lake. The lack of oxygen also allowed hydrogen sulfide to be produced in the lower layer of water. Water samples collected from 16 meters in August smelled strongly of hydrogen sulfide ("rotten-egg" smell). Hydrogen sulfide is produced by bacteria, and is stable only in the absence of oxygen.

Fecal Coliform Bacteria

Two nearshore samples for fecal coliforms were collected in May. Site #1 was located at the north end of the lake near Holiday Hills, and Site #2 was located near the public access. Results for both samples were very low. The state water quality standard for fecal coliforms in Lake Class waters is a geometric mean of 50 colonies/100 mL.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants that is used to determine the amount of algae in a volume of water. On both sampling dates, chlorophyll concentrations indicated very low densities of algae when the lake was sampled. According to the volunteer's comments, though, algae growth appeared heaviest in April, when suspended particles were visible. Freshwater sponges have been observed growing on and near the volunteer's dock.

Aquatic plants identified by Ecology staff during the May 11, 1992, sampling visit were white-flowering water lily (*Nymphaea odorata*) and cattails (*Typha* sp.). Only about 50% of the shoreline had emergent plants, likely due to the many bulkheads, docks, and artificial beaches put in by lakeshore residents. The macroalga *Nitella* was also observed in 1993. In 1991, a submerged macrophyte was tentatively identified as water-starwort (*Callitriche* sp.). 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.

Other Available Information

From Serdar *et al.* (1994): Bottom sediment and fish tissue samples were collected from Ward Lake on June 10, 1992. Samples were analyzed for persistent organic compounds and trace metals. Arsenic concentrations from both sediment sampling sites were high (34 and 41 mg/Kg) and exceeded the recommended sediment quality guideline of 33 mg/Kg. Rainbow trout muscle tissue had PCB concentrations of 8 µg/L, which exceeds the EPA human health criterion of 1.4 µg/L. Concentrations of all other chemical contaminants were within acceptable ranges. Based on the PCB concentrations found in Rainbow trout muscle tissue, Ward Lake should be added to Ecology's 1994 "water quality limited" list. [This list identifies waterbodies that do not meet water quality standards. These waterbodies will be evaluated to address the source(s) of water quality violations.]

From Thurston County Health Department, 1992 (draft): Thurston County staff sampled Ward Lake six times in 1992: in February, May, July, September, October, and December. Secchi depths ranged from 3.3 meters to 6.1 meters (10.8 feet to 20.0 feet), with the lowest Secchi depth measured in February 1992. Total phosphorus concentrations in the epilimnion ranged from 7 to 39 µg/L; the highest concentration occurred in December 1992. Summer (May through October) total phosphorus concentrations ranged from 7 to 16 µg/L. Chlorophyll *a* results ranged from 1.0 to 12.3 µg/L; the highest concentrations occurred in May and July 1992. [Data evaluation methods used by Ecology's program would indicate that Ward Lake was oligotrophic in 1992, based on Secchi depth and total phosphorus data collected by Thurston County from May through October 1992. Chlorophyll samples were collected at depths within the metalimnion, so Ecology's data analysis method does not apply to these data.]

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 1993.

> 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 trout were stocked in the lake in 1993. 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 logged and used for 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

one acre in 1949 when the 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 37 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 no resident's organization for the lake, and no lake management activities occurred in 1993.

Overall, the volunteer found that Ward Lake had excellent water quality. The only problem in the lake in 1993 was the large population of local geese. Potential sources of problems include runoff from 42nd Street, Sten Village, Holiday Hills and the new cove on the west side. The volunteer is concerned about potential runoff from proposed development of the Briggs property.

Water lilies grow all around the lake, except where property owners pull them. White-flowering water 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.

Acknowledgment

I thank Kit Weaver for volunteering his time to monitor Ward Lake during 1990-1993.

Ward Lake -- Thurston County

1993 Trophic Status[1]

Estimated Trophic State:	Oligo-mesotrophic[2]
Mean Trophic State Index (Secchi):	36
Mean Trophic State Index (Total Phosphorus):	38
Mean Trophic State Index (Chlorophyll a):	<25[3]

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[4]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
01-Apr	1600	7.2	45.0	16.0	35.00		100	moderate		Water color gray green - suspended vegetation moss algae?
16-Apr	1330	12.2	54.0	15.0	39.00		100	moderate	breezy	Water color gray green. Suspended vegetation. Raining.
06-May	1400	15.6	60.0	17.0	41.00		25	moderate	breezy	Water color gray green. Suspended moss vegetation.
16-May	1330	17.8	64.0	18.0	38.50	lt-green	0	none	calm	Lots of boat traffic. Some swimmers. No birds.
04-Jun	1300	17.8	64.0	15.0	39.50		95	heavy	light	Water is gray concrete color. No swimmers or birds. Light fishing. Wind and rain very heavy.
16-Jun	1245	21.1	70.0	18.0	36.50		10	light	light	Water color gray green. Lake color due to construction on north end of lake? This area was filled in 1960-1963 - was a shallow swamp before.
02-Jul	1430	21.1	70.0	12.0	34.50	pea-green	90	moderate	calm	
18-Jul	1200	18.9	66.0	16.0			10	moderate	breezy	Water color gray-green. Add two houses to the '92 count.
02-Aug	1200	20.6	69.0	20.0	29.50	lt-green	0	none	breezy	Geese are back. Great kokanee fishing all of July. Construction started on northwest side (of lake).
14-Aug	1245	21.1	70.0	20.0	26.00	lt-green	100	none	calm	Noise makers in use to keep geese off. Cove construction site has bare earth to waters edge with no barrier.
25-Aug	1615	21.6	70.9	22.5			10		breezy	Water color pale green. Onsite visit.
01-Sep	1300	21.1	70.0	21.0	24.00	lt-green	0	none	light	
16-Sep	1330	20.6	69.1	22.0	19.50		0	trace	light	Water color clear green.
01-Oct	1400	17.8	64.0	22.0	17.50	lt-green	0	none	calm	Lake turned over. Water color clear - like 1930. The lake is about 26" higher than low of 10 years ago.
14-Oct	1300	15.6	60.1	19.0	17.00	lt-green	100	none	breezy	Water almost clear. No geese - noise devices in operation.

1 Trophic State Indices calculated from Carlson (1977).
2 See Overall Assessment.
3 The August concentration was below the analytical detection limit, so a mean value cannot be calculated.
4 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Ward Lake dropped 18" from April 1 to October 14.

Ward Lake -- Thurston County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/19	0.0	22.0	7.4	9.5	15
	1.0	20.5	7.3	9.5	15
	2.0	19.9	7.3	9.5	15
	3.0	17.4	7.5	10.1	15
	4.1	14.7	7.6	10.7	15
	5.1	12.2	7.6	11.0	15
	6.0	10.1	7.6	11.0	15
	7.1	7.8	7.5	10.0	15
	8.1	7.2	7.4	9.1	15
	10.1	6.5	7.2	7.4	17
	12.0	6.3	6.9	5.9	17
	14.1	6.1	6.8	5.2	17
	16.0	6.0	6.8	5.0	17
	18.1	5.9	6.6	4.4	17
	18.5	5.9	6.6	3.5	18
08/25	0.0	21.6	7.5	9.8	15
	1.0	21.5	7.3	9.2	15
	1.9	21.5	7.2	9.0	15
	3.3	21.2	7.1	8.8	15
	4.1	21.1	7.1	8.8	15
	5.0	21.1	7.0	8.8	15
	6.0	17.1	7.4	11.6	15
	7.9	11.2	7.5	9.6	15
	10.2	8.4	7.0	1.3	16
	12.2	7.3	6.9	0.6	25
	14.1	6.7	6.9	0.4	24
	16.0	6.4	6.8	0.3	31
	17.0	6.4	6.7	0.2	36

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll a (mg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 19 Epilimnion	21	0.23	0.8	--	--	bdl	3
Hypolimnion	45	0.37	--	--	--	--	--
August 25 Epilimnion	5	0.20	bdl	--	--	--	--
Hypolimnion	130	0.53	--	--	--	--	--

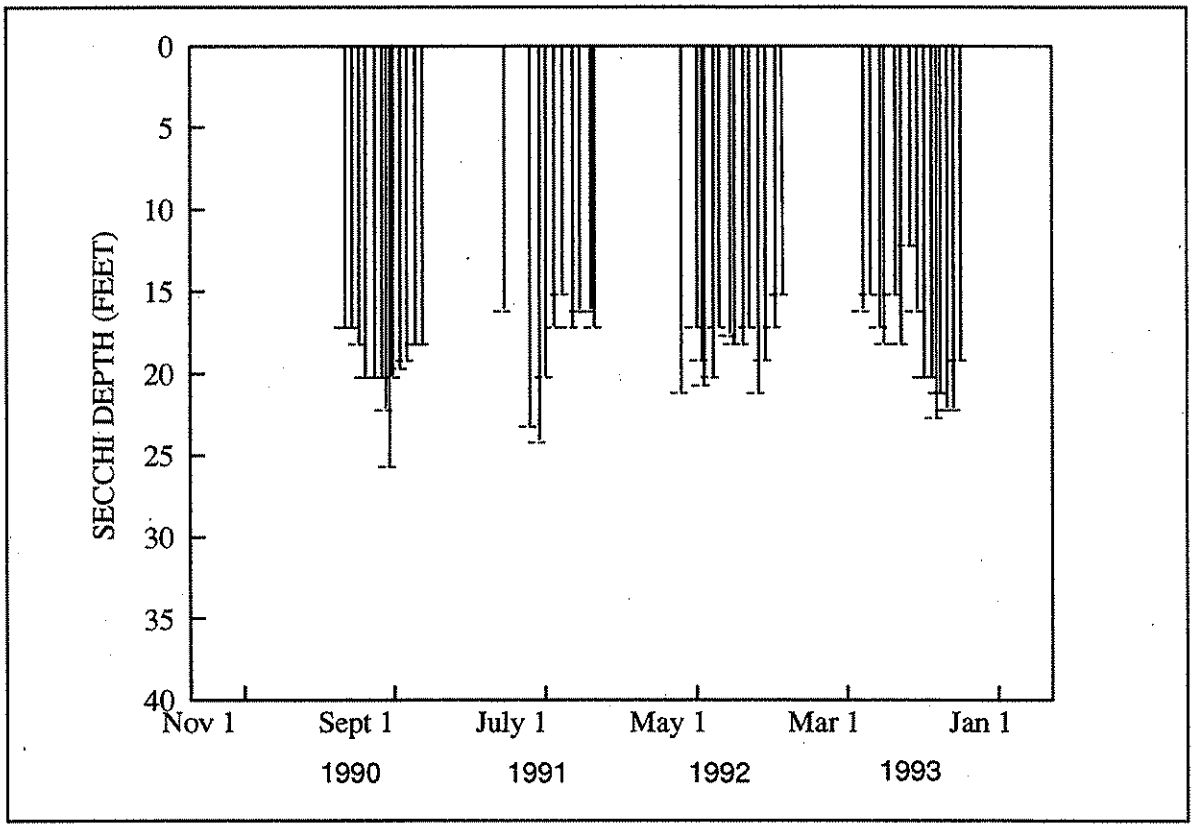
bdl = below analytical detection limit of 1 colony/100mL or 0.50 µg/L

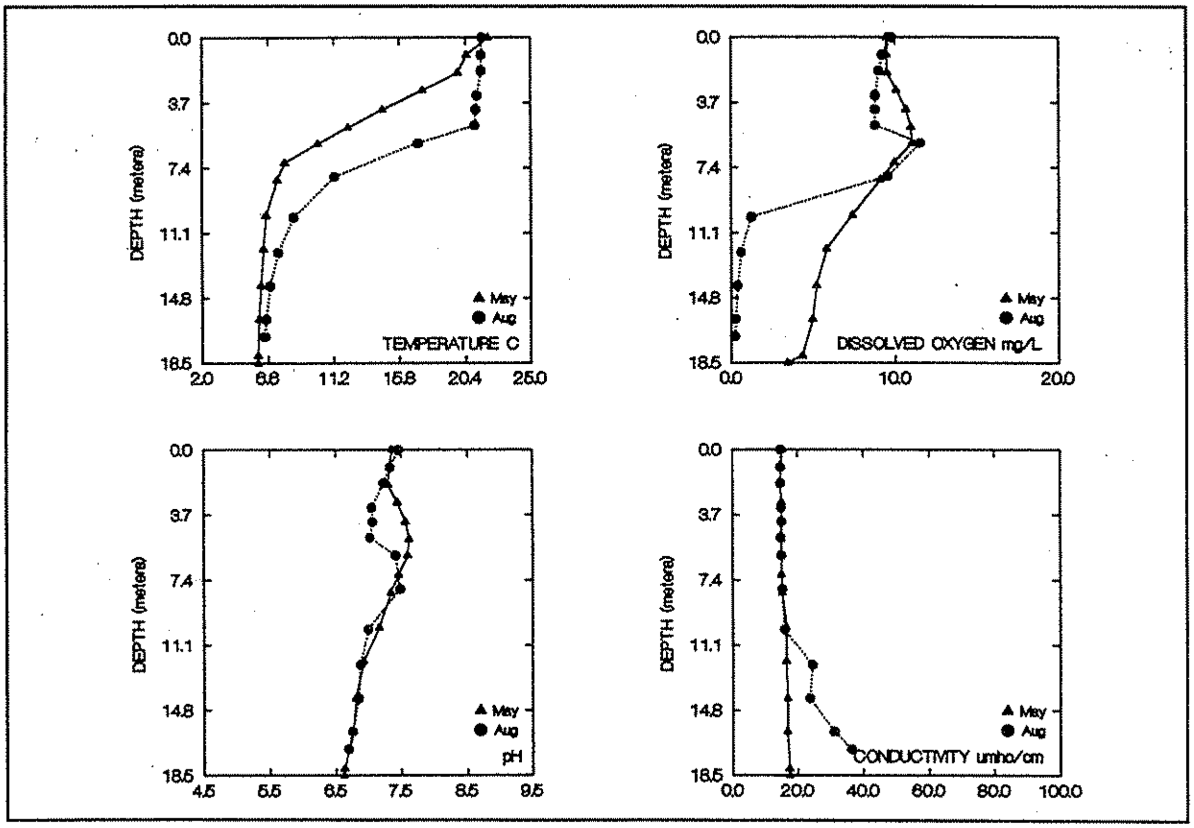
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll a (mg/L)
06/27/72[a]	10	--	7.8
10/03/72[a]	17	--	2.6
05/29/90[b]	10	0.26	--
08/21/90[b]	12	0.27	--
06/19/91[c]	--	0.19	--
05/11/92[d]	12	0.28	0.0
09/09/92[d]	8	0.27	0.6

a. Bortleson *et al.* (1976a)
b. Rector (1991)
c. Rector (1992)
d. Rector (1993)

WARD LAKE (THURSTON COUNTY)





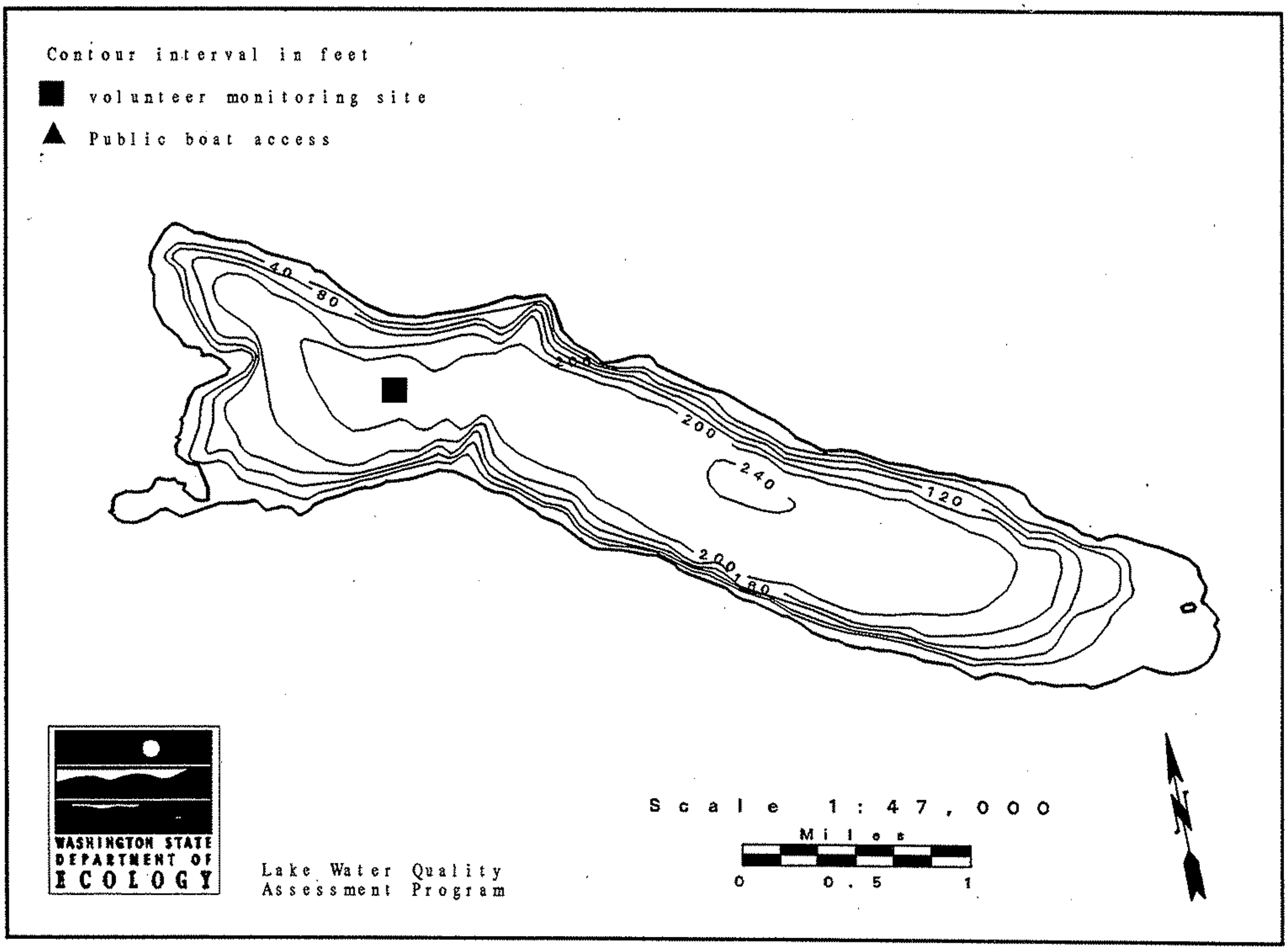
1993 Secchi Depth and Profile Data Graphs

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 (miles^2)	273
Altitude (feet)	1,875
Shoreline Length (miles)	13.3

Data From Dion *et al.* (1976)



Overall Assessment

In 1993, Lake Wenatchee was assessed as oligotrophic, based on good water clarity, low densities of algae and aquatic plants, low concentrations of total phosphorus (in August only) and total nitrogen, and high concentrations of dissolved oxygen in the water column. Although there was a moderately high concentration of total phosphorus in May, it was probably related to suspended sediments in the water following spring thaw.

Lake Wenatchee has been classified as oligotrophic since 1989.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

In 1993, water clarity was good, as indicated by Secchi depths that ranged from 15.0 feet to 18.0 feet. Although Secchi depths were not as deep as those measured from 1989-1992, there was not a statistically significant trend in water clarity from 1989-1993. All Secchi depths measured in 1993 were deep and indicated that the lake was oligotrophic.

Total Phosphorus

In May, the concentration of total phosphorus in the upper layer of water was very high (50 µg/L). Despite the high phosphorus concentration, there was very little algae at the time of sampling. The phosphorus may have been associated with suspended sediments from spring thaw runoff. In the past, the volunteer has noted that glacial meltwater is visible in the water, especially during spring.

In August, the concentration of total phosphorus in both the upper and lower layers of water were below the analytical detection limit.

Total Nitrogen

Concentrations of total nitrogen were very low on both sampling dates, and were similar to concentrations measured for the program in 1990, 1991, and 1992. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. In May, it is likely that phosphorus was adsorbed onto suspended sediments and would not have been available for uptake by algae, so it is not possible to determine which nutrient was responsible for limiting algae growth in May. In August, the concentration of total nitrogen was high relative to the concentration of total phosphorus, so algae growth was not limited by nitrogen when the lake was sampled in August.

Profile Data

Profile data were not collected to the lake bottom, because the cable on the profiling instrument was not long enough. As a result, profile data were measured down to 50-55 meters.

In May, the lake was not thermally stratified, so there was very little difference in values for profile parameters from the surface down to 50 meters. The high dissolved oxygen concentrations resulted from low water temperature, because dissolved gases are very soluble in cool water. In August, the lake was stratified with respect to temperature, and dissolved oxygen concentrations were high throughout the water column. High oxygen concentrations in the lower layer of water during stratification is characteristic of oligotrophic lakes.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants that is used to determine the amount of algae in a volume of water. In May, the chlorophyll concentration indicated a low density of algae when the lake was sampled. In August, the chlorophyll concentration was moderately high, and a surface scum was visible both nearshore and at the open-water sampling site. A sample of the scum contained detritus, the decomposing remains of organic material.

During the May 21, 1992, onsite visit with the volunteer, pieces of milfoil (*Myriophyllum* sp., but not the aggressive Eurasian variety) were seen floating at the monitoring site. Other aquatic plants observed were spikerush (*Eleocharis* sp.), waterweed (*Elodea* sp.), quillwort (*Isoetes* sp.), 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 1993 were analyzed for possible trends in flow and total phosphorus. Trend analysis was conducted using WQHYDRO (Aroner, 1990; data source: Washington State Department of Ecology Freshwater Ambient Monitoring Program). No significant trends in total phosphorus were detected, but for flow there was a significant decreasing trend of 18.9 cfs/yr ($P<0.10$).

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 whitefish tissues. These fish samples were well within levels considered acceptable for human consumption.

Summary of Questionnaire Results and Information from the Volunteer

The 1993 questionnaire on lake and watershed uses was not returned. 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 in 1992. Currently the watershed is being logged and used for animal grazing, and the lakeshore is being developed further for residences. In the past the watershed was logged and used for 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 found that Lake Wenatchee had excellent water quality in 1992, and that the only problem in the lake was from algae. Possible sources of problems are fish pens. There were no changes in the lake since the 1991 monitoring season, although sewers were being installed in 1992.
>
> 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 were 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.

Acknowledgment

I thank Gary Craig for volunteering his time to monitor Lake Wenatchee during 1989-1993.

Lake Wenatchee -- Chelan County

1993 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	37
Mean Trophic State Index (Total Phosphorus):	<40[2]
Mean Trophic State Index (Chlorophyll *a*):	33

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	Temp (°F)	Secchi (ft)	Lake Ht (in)[3]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
18-Jun	1145	10.0	50.0	15.0		lt-green	0	none	strong	Very windy conditions for past week.
04-Jul	1230	12.2	54.0	16.4		lt-green	25	trace	strong	Very windy conditions - cool days.
18-Jul	1130	15.0	59.0	18.0		lt-green	10	moderate		Fahrenheit thermometer broken. Windy last two weeks. Calm today, morning only.
02-Aug	1230	21.1	70.0	18.0			0	none	calm	Water color light green to moderate green. Fishing season, lots of boats. Calm and clear now and last few days.
17-Aug	1230	22.2	72.0	15.4		green	0	none	calm	Lake is changing. Calm and clear now and in past few days--water very green. Algae in lake.

[1] Trophic State Indices calculated from Carlson (1977).
[2] The August concentration was below the analytical detection limit, so a mean value could not be calculated.
[3] "Lake height" refers to change in water level. Lake height was not monitored in 1993.

Lake Wenatchee -- Chelan County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/28	0.0	8.4	.	11.3	22
	2.0	8.3	.	11.3	22
	4.0	8.1	.	11.3	22
	6.0	7.9	.	11.4	22
	8.0	7.8	.	11.3	22
	10.0	7.7	.	11.4	22
	15.0	7.5	.	11.3	22
	20.0	7.4	.	11.3	23
	25.0	7.0	.	11.4	23
	30.0	6.8	.	11.4	23
	35.0	6.7	.	11.4	24
	40.0	6.4	.	11.5	24
	45.0	6.4	.	11.4	24
	50.0	6.3	.	11.4	24
08/26	0.0	17.1	8.1	8.8	27
	1.0	16.0	7.9	9.0	26
	2.0	15.8	7.9	9.0	26
	3.0	15.8	7.9	9.0	26
	4.0	15.7	7.8	9.0	26
	6.0	15.7	7.8	9.0	26
	7.0	15.5	7.7	8.9	26
	8.0	15.5	7.7	8.9	26
	10.0	15.4	7.7	8.8	26
	12.0	15.2	7.6	8.8	26
	14.0	15.2	7.6	8.9	26
	16.0	15.1	7.6	8.8	26
	18.0	14.9	7.6	8.8	27
	20.0	14.6	7.6	8.7	26
	22.0	13.6	7.5	8.7	25
	24.0	12.4	7.5	8.7	24
	26.0	11.8	7.5	8.6	24
	28.0	10.8	7.4	8.7	24
	30.0	10.5	7.4	8.7	24
	35.0	8.9	7.4	8.7	24
	40.0	8.1	7.3	8.7	24
	45.0	7.8	7.2	8.6	24
	50.0	7.6	7.2	8.5	24
	55.0	7.3	7.1	8.5	25

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 27							
Epilimnion	50	0.13	0.6	--	--	--	--
Hypolimnion	14	0.13	--	--	--	--	--
August 26							
Epilimnion	bdl	0.09	2.9	--	--	--	--
Hypolimnion	bdl	0.09	--	--	--	--	--

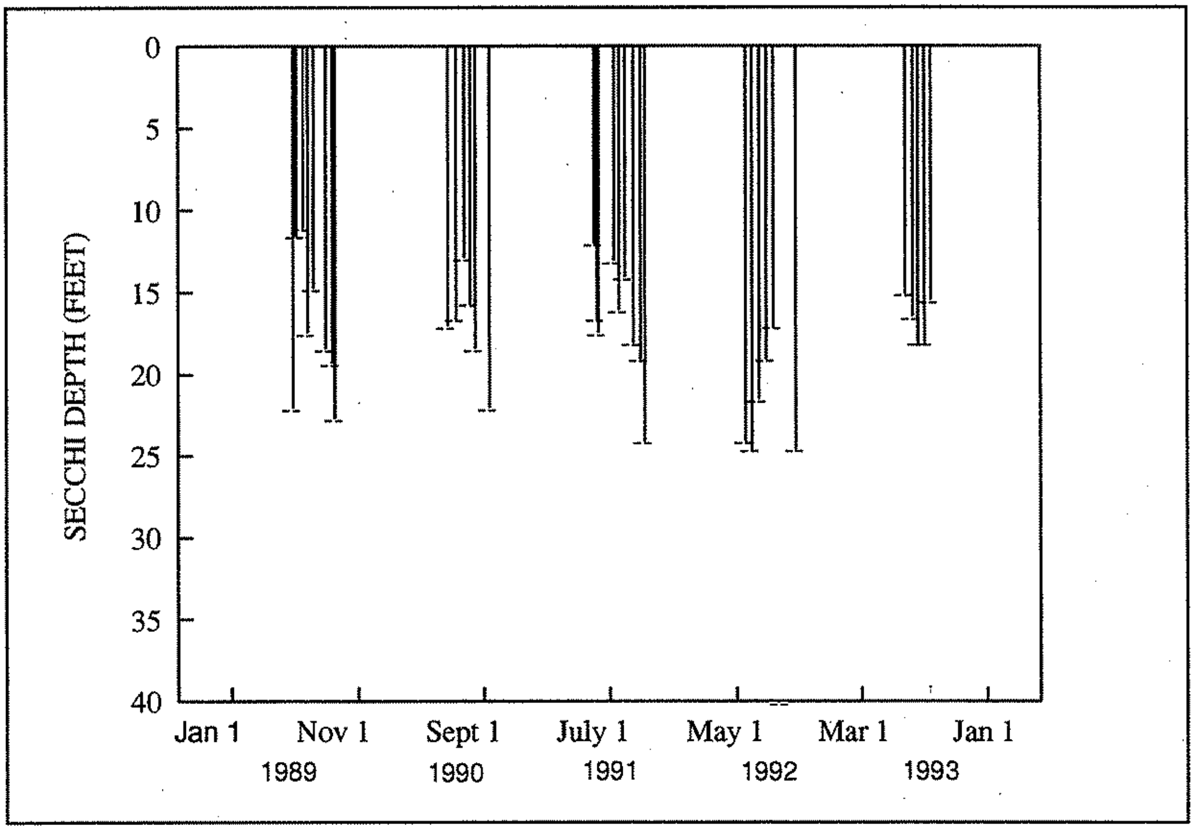
bdl = below analytical detection limit of 3 µg/L

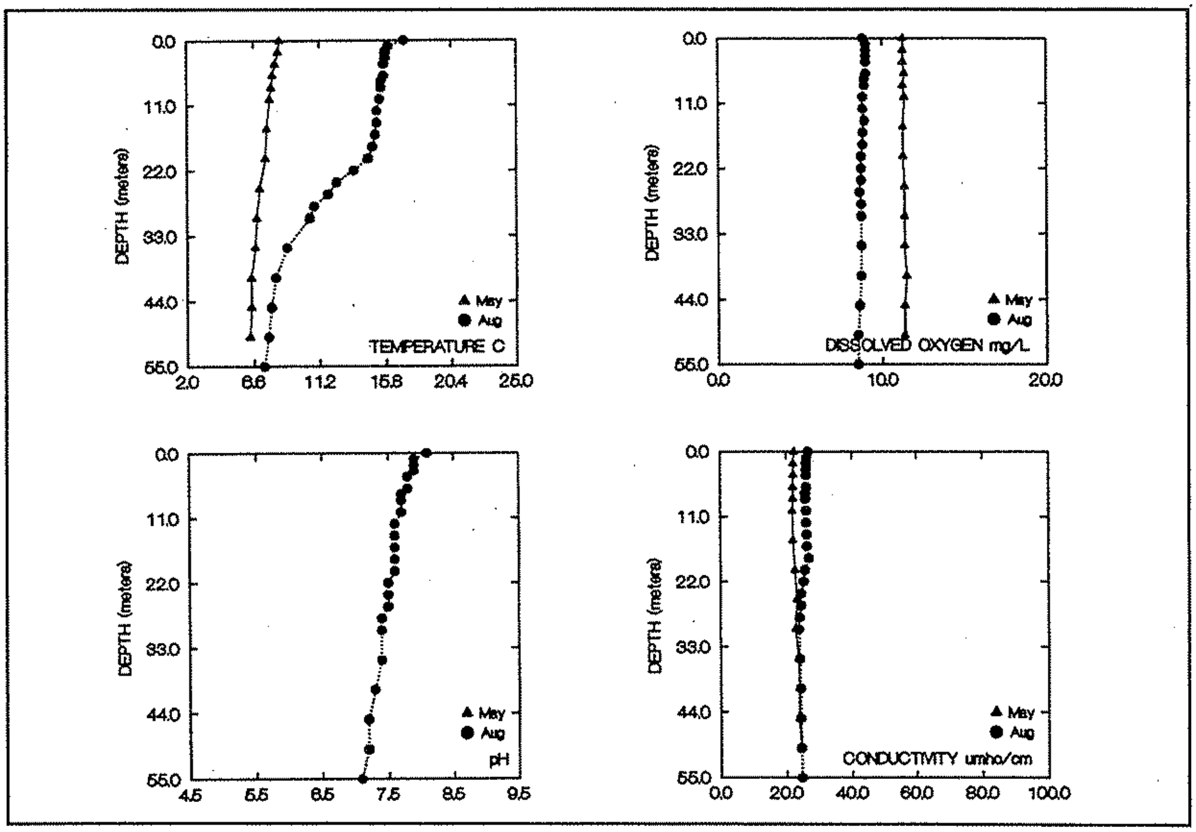
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)
05/22/74[a]	5	--	1.0
09/27/74[a]	5	--	2.1
06/06/89[b]	6	0.16	0.7
09/06/89[b]	7	0.07	6.9
06/04/90[c]	8	0.11	--
08/20/90[c]	12	0.17	--
06/06/91[d]	--	0.11	--
05/21/92[e]	3	0.21	0.2
09/03/92[e]	3	0.07	1.2

b. Brower and Kendra (1985)
c. Rector (1991)
d. Rector (1992)
e. Rector (1993)

LAKE WENATCHEE (CHELAN COUNTY)





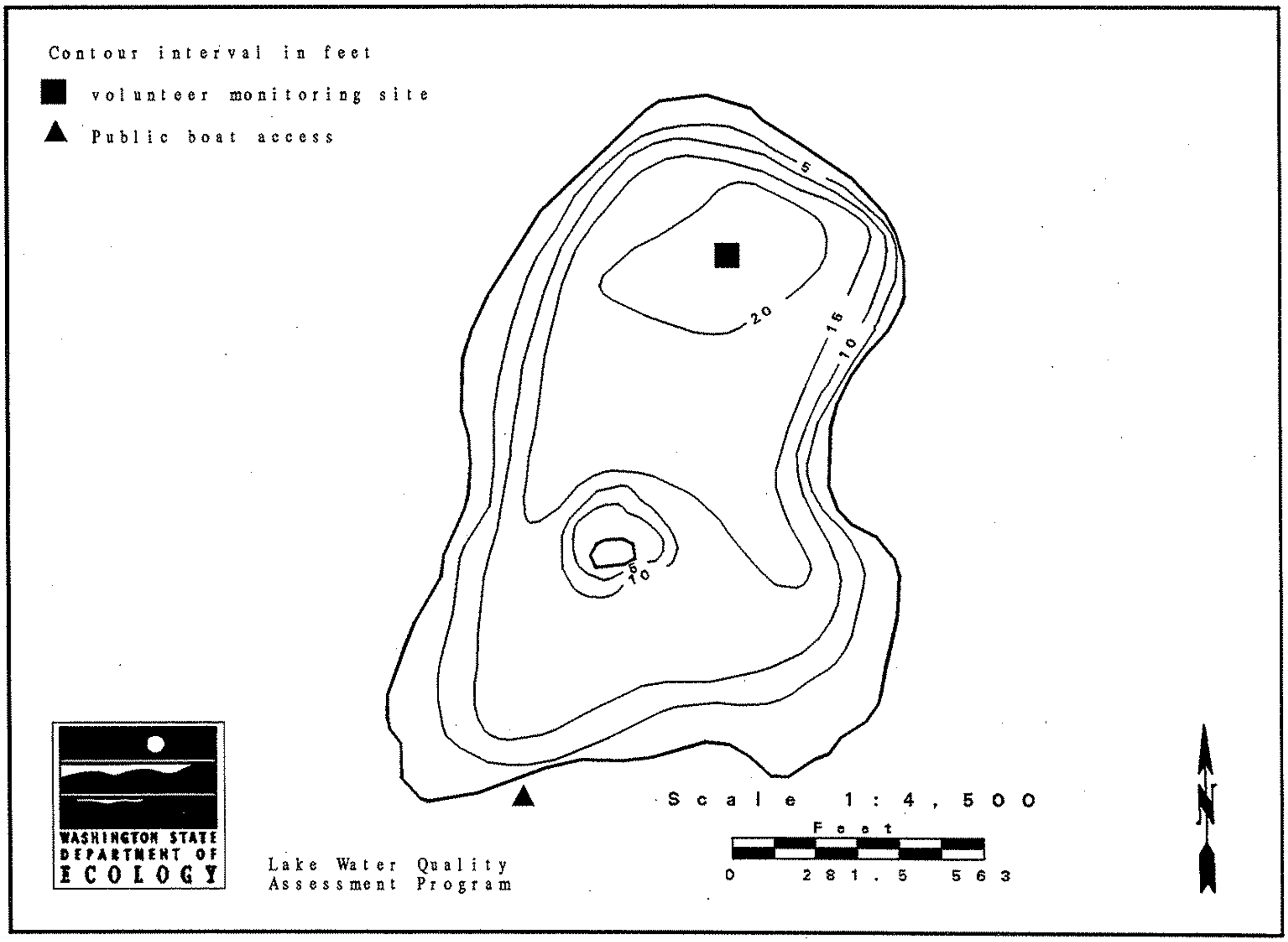
1993 Secchi Depth and Profile Data Graphs

Whitman Lake -- Pierce County

Whitman Lake is located 6.5 miles north of Eatonville. It is the largest of the Benbow group of lakes. It is fed by Twin Lakes, and drains to Tanwax Creek and the Nisqually River.

Size (acres)	30
Maximum Depth (feet)	20
Mean Depth (feet)	12
Lake Volume (acre-feet)	350
Drainage Area ($miles^2$)	1.0
Altitude (feet)	601
Shoreline Length (miles)	1.0

Data From Bortleson *et al.* (1976)



Overall Assessment

In 1993, Lake Whitman was assessed as mesotrophic, based on fair water clarity, moderately high concentrations of total phosphorus and total nitrogen, and moderately high to high densities of algae and aquatic plants. In addition, phosphorus was probably released from sediments into the water column, possibly causing the fall algae bloom reported by the volunteer in October.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was fair, as indicated by Secchi depths that ranged from 6.0 feet to 9.5 feet. Secchi depths from 6.5 to 13.0 feet are fair, and are typical for mesotrophic lakes.

Total Phosphorus

On both sampling dates, total phosphorus concentrations in the upper layer of water were moderately high (23 µg/L in June, and 18 µg/L in August). The concentration measured in May was very similar to the concentration measured in May 1990. Concentrations from 12 to 24 µg/L are moderately high, and are typical for mesotrophic lakes.

In August, the total phosphorus concentration in the lower layer of water was higher than in the upper layer. The phosphorus was probably released from sediments into the water column (see Profile data, below). Sediment release of phosphorus from sediments is characteristic of eutrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were moderately high on both sampling dates, and were similar to concentrations measured in 1990 and 1981. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae usually use at least ten times the amount of nitrogen as phosphorus. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 (21:1 in June, and 27:1 in August), algae growth in Lake Whitman was not limited by nitrogen when the lake was sampled.

Profile Data

The lake was weakly stratified with respect to temperature on both sampling dates. Concentrations of dissolved oxygen were very low in the bottom two meters of the lake, most likely from bacteria which use oxygen as they decompose aquatic plants and algae in the water and sediments. Low oxygen near lake sediments can create an environment that allows phosphorus, iron, and other compounds in sediments to be released into the water column. In August, there was a high phosphorus concentration in the lower layer of water, and conductivity values increased considerably in the bottom two meters of the lake. Increased conductivity values near sediments often indicate that compounds in sediments were reduced, and were released into the water column. Sediment release is characteristic of mesotrophic and eutrophic lakes.

Plants

Chlorophyll *a* is a plant pigment that is used to determine the amount of algae in a volume of water. In June, the chlorophyll concentration (7.0 µg/L) indicated a high density of algae when the lake was sampled. Algae particles were visible in the water at the time of sampling. In August, the chlorophyll concentration/algal density was moderately high. Chlorophyll concentrations from 2.6 to 6.5 µg/L are typical for mesotrophic lakes.

In October, the volunteer reported seeing algae particles and scum. Several lakes monitored for the program had fall algae blooms following lake turnover, which would mix high nutrient concentrations throughout the water column that could subsequently be taken up by algae.

Aquatic plants observed by Ecology staff during the sampling visits included white-flowering water lily (*Nymphaea odorata*), tapegrass (*Vallisneria americana*), waterweed (*Elodea canadenis*), Nuttall's waterweed (*Elodea nuttalli*), coontail (*Ceratophyllum demersum*), and cattails (*Typha*). An unidentified pondweed was also observed.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire on lake and watershed uses.

> Lake Whitman is used for fishing, swimming, and motor boating. There is one boat ramp on the lakeshore, and motor-boating is restricted so that only resident ski boats are allowed on the lake. Trout were stocked in the lake in 1993. Currently, the watershed is used for crop agriculture and animal grazing, although grazing animals do not have direct access to the lakeshore or inlet tributaries. The lakeshore is also being developed further for residences. In the past, the watershed was logged and used for animal grazing, and the shoreline was altered.
>
> There are 55 houses on the lakeshore, and none are connected to a sewer collection system. There are four culverts which drain into the lake. There is a lake association for the lake. Lake water was withdrawn for drinking and other domestic uses and irrigation, although withdrawals for both were minimal. No lake management activities occurred on the lake in 1993.
>
> Overall, the volunteer found that Lake Whitman had good water quality. Problems in the lake in 1993 were ranked as (1) excessive aquatic plant growth,

(2) water quality gradually degraded over years, (3) decaying plants, (4) degraded aesthetics, (5) algae, (6) recently degraded water quality, and (7) impaired fisheries. There is a potential for problems from septic systems, especially as shoreline development increases. The water level in 1993 was higher than normal for late fall. In addition, managing the flow through the chain of lakes has been difficult because landowners and Pierce County are not clearing out the inlets and outlets.

Acknowledgment

I thank Chuck Fink for volunteering his time to monitor Lake Whitman in 1993.

Whitman Lake -- Pierce County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	46
Mean Trophic State Index (Total Phosphorus):	48
Mean Trophic State Index (Chlorophyll *a*):	48

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
04-Jun	1515			8.0			100		calm	Onsite visit. Water color tea. Slight drizzle.
07-Jul	1915	20.0	68.0	9.0			0	none	light	Water color tea. Lake height slightly higher than normal. Lilies growing fairly rapidly.
09-Aug	1910	23.0	73.5	9.0			10	none	light	Water color tea.
27-Aug	1620			9.5			100	trace	calm	Onsite visit.
10-Oct	1700	17.0	62.5	6.0			75	none	calm	Water color greenish tea. Lake must be in bloom as water has lots of green suspended particles, some scum on north shore.

1 Trophic State Indices calculated from Carlson (1977).
2 "Lake height" refers to change in water level. Lake height was not monitored in 1993.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
06/04	0.0	20.1	7.5	8.8	76
	0.9	19.3	7.3	8.3	76
	2.0	16.0	7.1	3.5	81
	3.0	11.2	7.1	1.1	102
	4.0	9.2	7.1	0.7	104
	4.9	8.4	7.1	0.5	178
08/27	0.0	22.5	7.4	8.4	78
	0.9	20.2	7.5	8.5	78
	2.0	19.2	7.2	3.0	79
	3.0	15.0	7.1	0.6	113
	4.0	12.0	7.0	0.2	139
	5.1	10.2	7.2	0.1	248
	5.2	10.2	7.3	0.1	260

1993 Onsite Visit Data - Water Chemistry

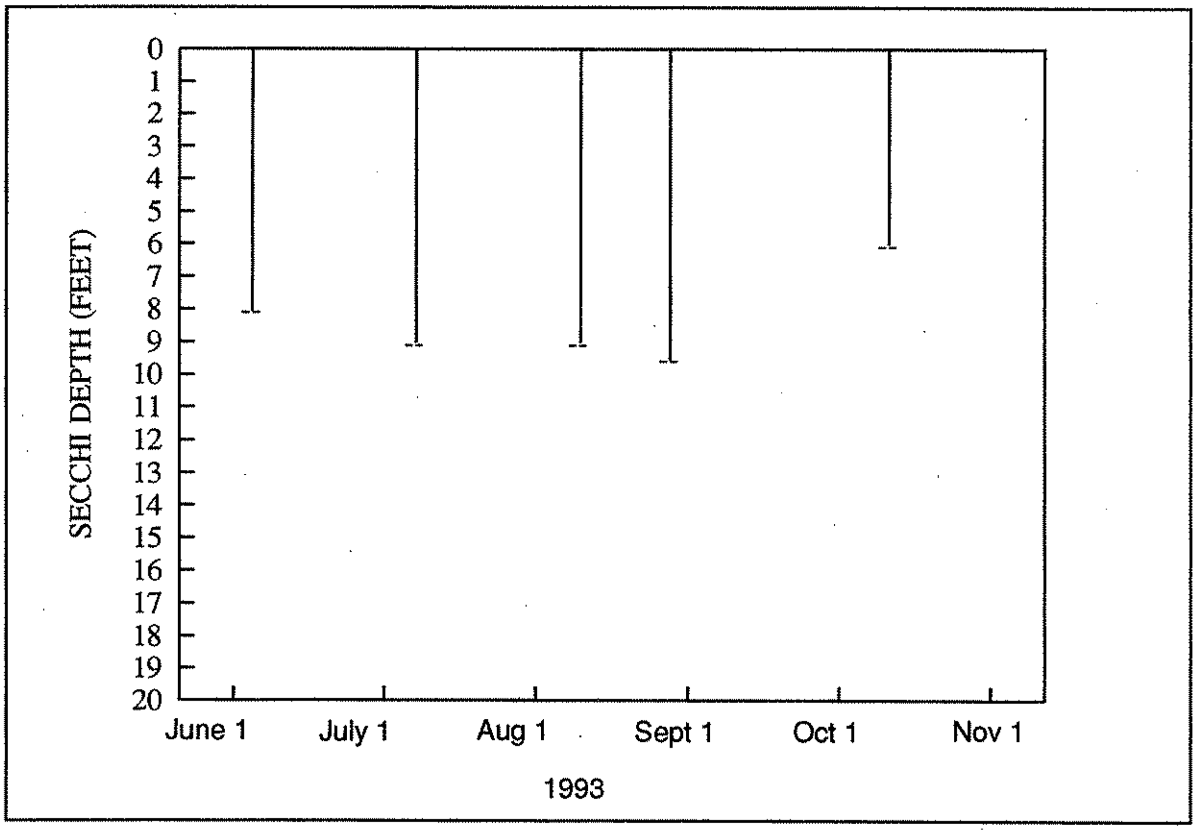
	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll a (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 4 Epilimnion	23	0.48	7.0	–	–	–	–
Hypolimnion	32	0.48	–	–	–	–	–
August 27 Epilimnion	18	0.48	5.1	–	–	–	–
Hypolimnion	132	0.65	–	–	–	–	–

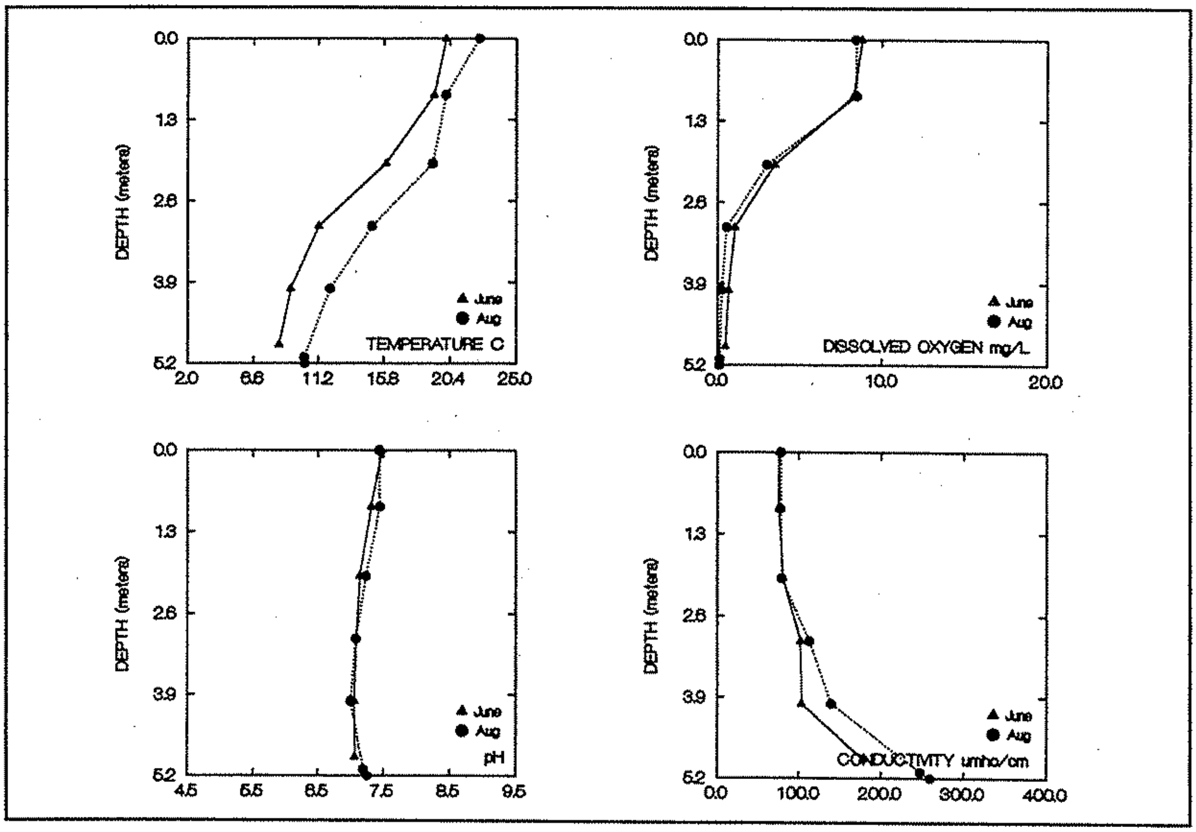
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll a (μg/L)
08/10/73[a]	13	–	–
06/23/81[b]	40	1.1	4.6
05/31/90[c]	26	0.42	–
08/23/90[c]	33	0.50	–

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

WHITMAN LAKE (PIERCE COUNTY)





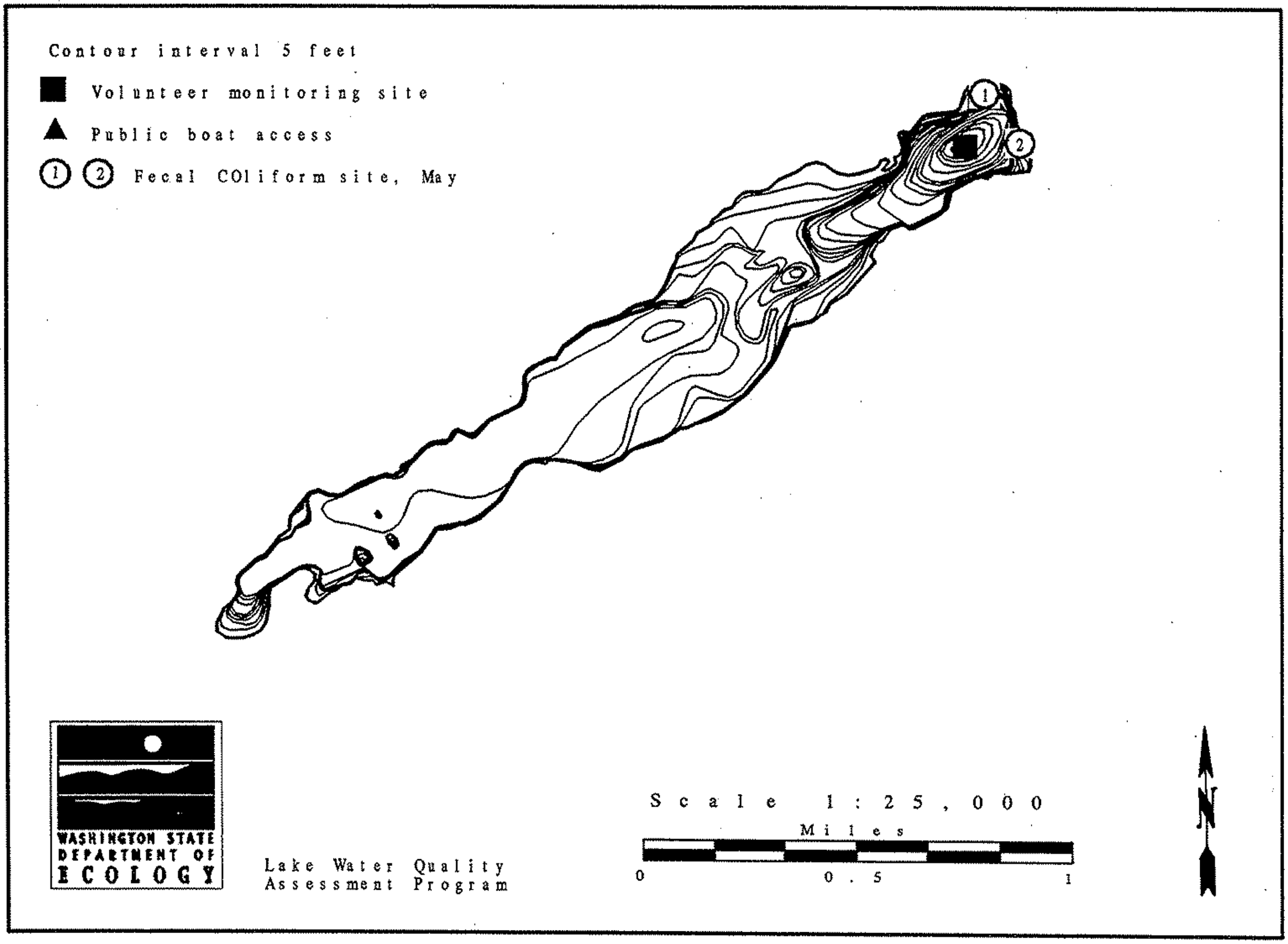
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, Williams Lake was assessed as mesotrophic, based on fair water clarity, moderately high densities of algae, and in May there was a moderately high concentration of total phosphorus. The lake also had very low concentrations of dissolved oxygen in the lower layer of water, particularly during August, that can lead to sediment release of phosphorus. Based on data collected for the program, Williams Lake has been described as mesotrophic each year since 1989.

In 1992, Williams Lake appeared to be severely affected by drought conditions. While low lake level was also a problem in 1993, the level did not drop as dramatically as in 1992. Continued monitoring of Williams Lake may track how water quality changes with time in response to climatic variations.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity in 1993 was fair, as indicated by Secchi depths that ranged from 6.5 feet to 13.1 feet. Secchi depths in this range are typical for mesotrophic lakes.

Although water clarity appears to vary from year to year, there was not a statistically significant trend in water clarity from 1989-1993.

Total Phosphorus

In May, the concentration of total phosphorus in the upper layer of water was high (30 μg/L), and there was a moderately high density of algae at the time of sampling (see Plants, below). The May concentration was much higher than concentrations measured for the program in 1989, 1990, and 1992. In August, the concentration of total phosphorus in the upper layer of water was moderate (12 μg/L), and algal density was moderately high.

On both sampling dates, concentrations of total phosphorus were high in the lower layer of water. Most likely, the phosphorus was released from sediments into the water column. This can occur when oxygen concentrations over sediments are very low, creating an environment that allows phosphorus, iron and other compounds in sediments to be chemically reduced and released into the water column (see Profile Data, below). Sediment release of phosphorus is characteristic of eutrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were moderately high on both sampling dates. The concentrations measured in 1993 were similar to concentrations measured in 1990. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 (19:1 in May, and 35:1 in August), algae growth was not limited by nitrogen when the lake was sampled.

Fecal Coliform Bacteria

In May, two nearshore samples for fecal coliforms were collected at the deep east end of the lake. Site #1 was located due north of the sampling site, and Site #2 was located due east of the sampling site. Results for both samples were very low. The state water quality standard for fecal coliforms in Lake Class waters is a geometric mean of 50 colonies/100 mL.

Profile Data

On both sampling dates, the lake was stratified with respect to temperature. Below the thermocline, the concentrations of dissolved oxygen decreased considerably with depth. During August, dissolved oxygen concentrations were depleted in the bottom 20 meters of the lake. Similar profiles were also measured in 1989 and 1992. Oxygen concentrations usually decrease in the lower layer of water from bacteria which use oxygen as they decompose aquatic plants and algae in the water and sediments.

When oxygen concentrations over sediments are very low, phosphorus, iron and other compounds in sediments can be released into the water column. This appeared to occur in Williams Lake, as indicated by the higher phosphorus concentrations in the lower layer of water, and the increasing conductivity values with depth below the thermocline. In the past (1992, 1989, and 1973), low oxygen concentrations in the lower layer of water have allowed hydrogen sulfide to be produced. Hydrogen sulfide ("rotten-egg" smell) is produced by bacteria in the absence of oxygen.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants that is used to determine the amount of algae in a volume of water. Chlorophyll concentrations on both sampling dates (5.1 µg/L in May, and 6.2 µg/L in August) indicated moderately high densities of algae when the lake was sampled. Chlorophyll concentrations from 2.6 to 6.5 µg/L are typical for mesotrophic lakes.

Aquatic plants identified by Ecology staff during the May 13, 1992, sampling visit 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 sampling visit, watermeal (*Wolffia* sp.) was also observed.

Other Available Information

Lake level data collected by the volunteer in 1992 indicated that the lake's level dropped 24 inches from June 16, 1992, to October 31, 1992. Although there are not enough data available to relate decreasing Secchi depths with decreasing lake level, it does appear that the lowest Secchi depths measured for the program since 1989 were measured in 1992, when lake level was lowest. If any further studies are planned for Williams Lake, sampling study design should consider the relationship between water budget and water quality.

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 1993.

> 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 one percent of the shoreline is publicly-owned. Currently the watershed is used primarily for animal grazing and crop agriculture. The lakeshore is also being developed further for residences. In the past the watershed was used for animal grazing and crop agriculture.
>
> There are more than 30 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 is a lake association for the lake. No lake management activities occurred on the lake in 1993.
>
> 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.
>
> Overall, the volunteer found that Williams Lake had poor water quality. Problems in the lake in 1993 were ranked as (1) water quality gradually degraded over years, and (2) low water level. Possible sources of problems include overloaded septic systems, especially during summer when up to 200 mobile homes and recreational vehicles are occupied. In 1992, the worst problem in the lake was low water level; the lake level dropped 24 inches from June 16 through October 31, and was the lowest it had been in many years.

Acknowledgments

I thank L.O. Kerlee and Brad McHenry for volunteering their time to monitor Williams Lake during 1993. Brad McHenry monitored the lake during 1989-1992.

Williams Lake -- Spokane County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index (Secchi):	44
Mean Trophic State Index (Total Phosphorus):	47
Mean Trophic State Index (Chlorophyll *a*):	47

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
15-Jun	2000			10.0	1.60	green	90	none	calm	See 1991 records for lake height.
20-Jul	0900	16.7	62.0	6.5	2.05	green	50	heavy	calm	Have had tremendous amount of rain. Lake has risen 4.5" since July 1.
10-Aug	1200	22.0	71.5	7.0	1.95	green	0	none	breezy	During calm winds there is dead algae scum from north end of lake.
22-Aug	1135			10.0		green	0			Onsite visit.
12-Sep	1030	19.0	66.2	13.1	1.61	green	50	none	gusty	
18-Oct	1000	14.0	57.2	11.8	1.36	green	0	trace	calm	Floating algae.

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Williams Lake dropped 0.24" from June 15 to October 18.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
05/26	0.0	18.2	8.6	10.5	289
	2.0	17.8	8.7	10.4	290
	4.0	17.7	8.7	10.4	289
	6.0	13.5	8.6	11.3	292
	8.0	10.9	8.5	7.9	291
	10.0	9.4	8.3	6.5	294
	12.0	7.2	8.4	4.9	295
	14.0	6.2	8.2	3.0	297
	16.0	5.3	8.1	0.8	299
	18.0	5.0	8.0	0.3	296
	20.0	4.9	7.9	0.2	300
	25.0	4.6	7.9	0.1	306
	30.0	4.5	7.8	0.2	304
08/22	0.0	21.4	9.1	9.4	300
	2.0	21.3	9.1	9.3	300
	4.0	21.1	9.1	9.1	300
	6.0	21.1	9.1	9.3	300
	8.0	16.4	8.5	1.1	310
	10.0	10.2	8.2	0.2	306
	12.0	8.5	8.1	0.1	306
	14.0	7.1	8.0	0.1	308
	16.0	6.1	7.9	0.1	306
	18.0	5.7	7.8	0.1	312
	20.0	5.4	7.8	0.1	308
	25.0	5.0	7.7	0.1	320
	30.0	4.9	7.6	0.1	334

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 26 Epilimnion	30	0.56	5.1	--	--	1	bdl
Hypolimnion	68	0.84	--	--	--	--	--
August 22 Epilimnion	12	0.43	6.2	--	--	--	--
Hypolimnion	75	0.64	--	--	--	--	--

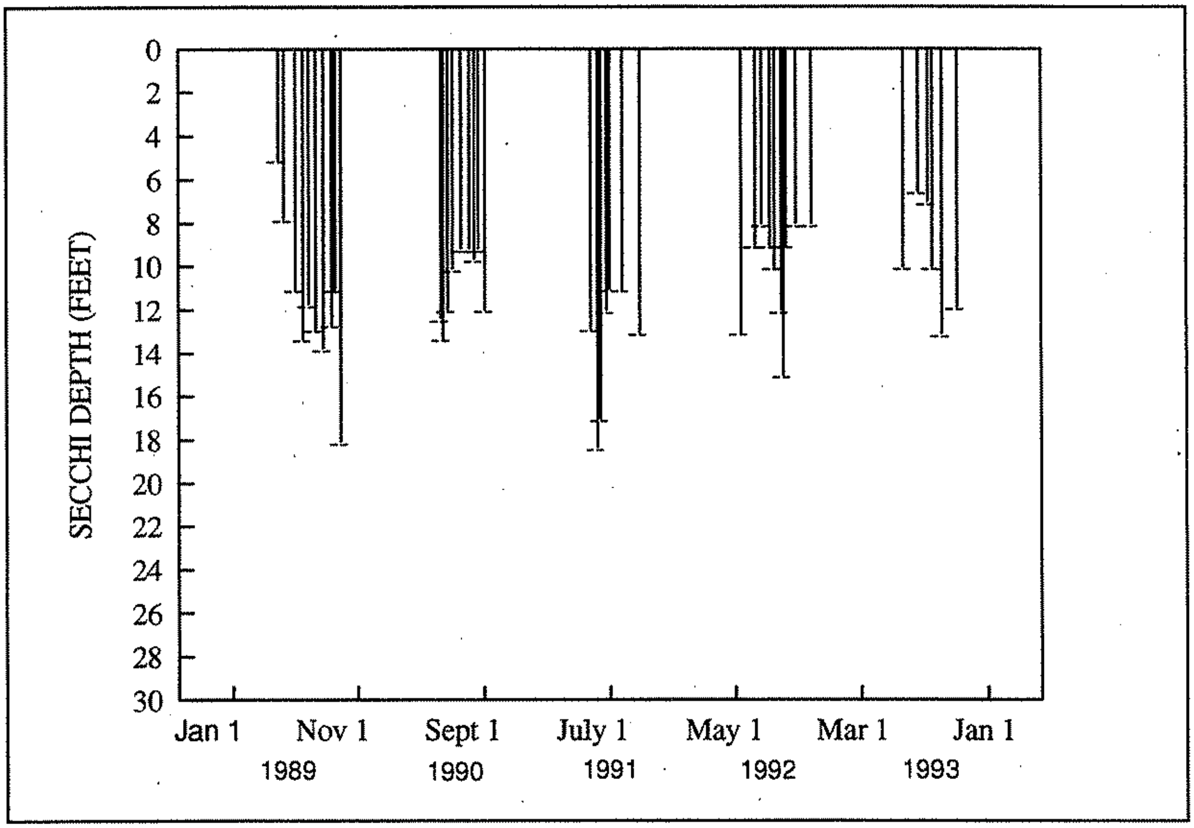
bdl = below analytical detection limit of 1 colony/100 mL

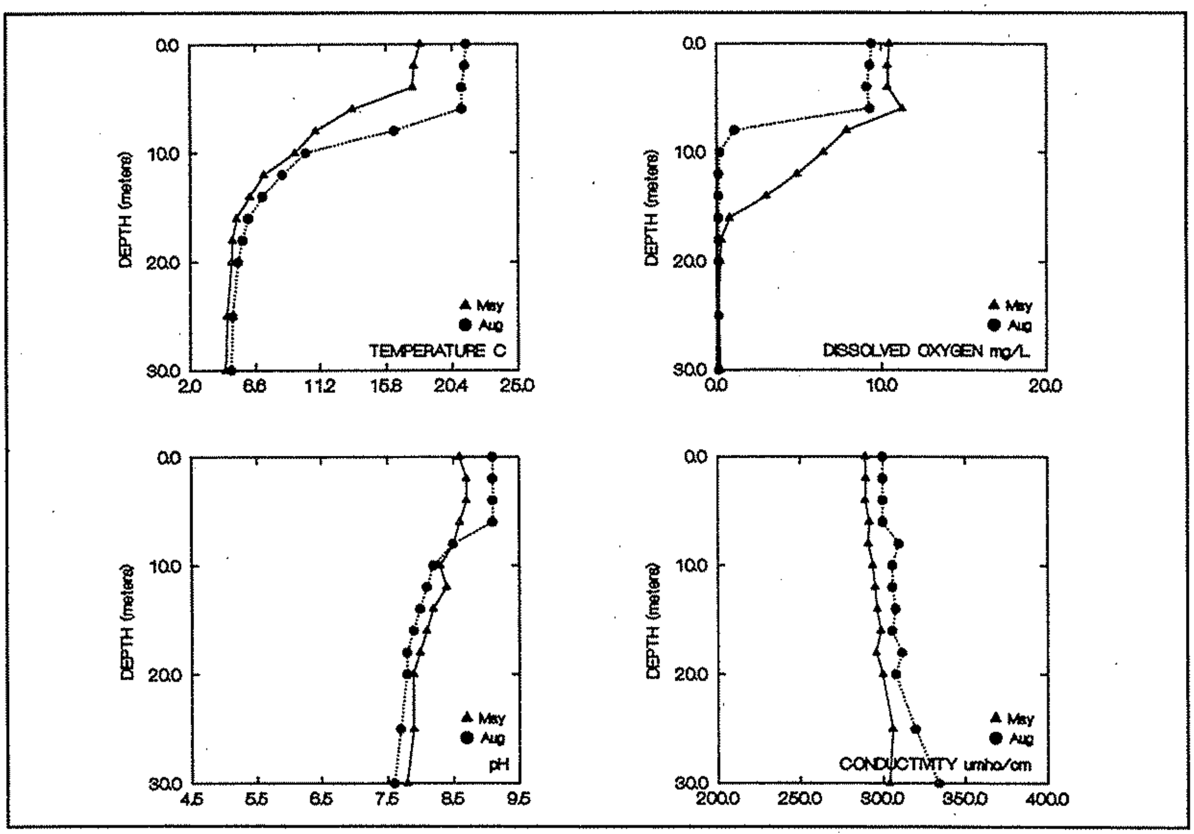
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)
07/10/73[a]	27	--	3.2
10/02/73[a]	16	--	3.8
06/21/89[b]	18	0.45	2.4
09/20/89[b]	15	0.74	2.6
05/23/90[c]	19	0.49	--
08/10/90[c]	17	0.52	--
06/10/91[d]	--	0.42	--
05/13/92[e]	18	0.57	2.0
08/26/92[e]	15	0.52	2.0

a. Dion *et al.* (1976), McConnell *et al.* (1976)
b. Brower and Kendra (1990)
c. Rector (1991)
d. Rector (1992)
e. Rector (1993)

WILLIAMS LAKE (SPOKANE COUNTY)





1993 Secchi Depth and Profile Data Graphs

Williams Lake -- Stevens County

Williams Lake is located 14.5 miles north of Colville, and 7.5 miles north of Echo. It has no surface inlets, and has an intermittent outlet which drains to Echo Valley and the Colville River.

Size (acres)	38
Maximum Depth (feet)	47
Mean Depth (feet)	26
Lake Volume (acre-feet)	980
Drainage Area (miles^2)	6.1
Altitude (feet)	1,980
Shoreline Length (miles)	1.0

Data From Dion *et al.* (1976)

No Map Available.

Overall Assessment

In 1993, Williams Lake was assessed as mesotrophic, based on moderately high densities of algae, and the lake has been aerated during winter for at least 20 years because of very low dissolved oxygen concentrations. Williams Lake was new to the Lake Water Quality Assessment Program in 1993.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

Water clarity was good, as indicated by Secchi depths that ranged from 15.3 feet to 22.5 feet. Secchi depths greater than 13.0 feet indicate good water clarity, and are typical for oligotrophic lakes. Given the other characteristics of the lake, water clarity was better than would be expected.

Total Phosphorus

In May, the concentration of total phosphorus in the upper layer of water was high (45 µg/L), and there was a moderately high density of algae at the time the lake was sampled. The density of algae was not as high as would be expected, given the high concentration of total phosphorus, suggesting that some of the phosphorus may have been adsorbed onto sediment particles (and would not have been available for uptake by algae). Results from solids samples indicate that there were some suspended sediments in the water when the lake was sampled in May. Many of the eastern Washington lakes sampled for the program have suspended sediments in the water in May, from spring thaw and lake mixing.

In August, the concentration of total phosphorus was low (10 µg/L), and there was a moderately low density of algae at the time of sampling.

Total Nitrogen

Concentrations of total nitrogen were high on both sampling dates, although the concentration in May was higher than in August. As with the phosphorus concentration, the higher May concentration may have resulted from suspended material in the water.

The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth. In August, the ratio of total nitrogen to total phosphorus was greater than 17:1 (59:1), so algae growth was not limited by nitrogen when the lake was sampled in August. In May, the interference from suspended sediments in the water makes it difficult to determine which nutrient was responsible for limiting algae growth at the time.

Profile Data
The lake was stratified with respect to temperature on both sampling dates.

Dissolved oxygen concentrations increased at four meters (in May) and six meters (in August), and probably resulted from increased algae growth at these depths. Like terrestrial plants, aquatic plants and algae produce oxygen when they are photosynthesizing. In May, the bottom of the lake was still being aerated (see Summary of Questionnaire Responses, below), so dissolved oxygen concentrations were high throughout the water column. In August, the aerator was not running and dissolved oxygen concentrations decreased considerably below the thermocline. Oxygen concentrations often decrease from bacteria which use oxygen as they decompose aquatic plants and algae in the water and sediments. When oxygen concentrations over sediments are low, phosphorus, iron and other compounds in sediments can be released into the water column. This probably occurred in Williams Lake in late summer, as indicated by the higher phosphorus concentration in the lower layer of water, and increased conductivity values below the thermocline. Oxygen concentrations in Williams Lake must have been low for many years, because Dion *et al.* (1976) reported that the lake was periodically aerated to raise the dissolved oxygen concentrations, and that hydrogen sulfide was detected in the lower layer of water. Hydrogen sulfide ("rotten-egg" smell) is only stable in the absence of oxygen. There are no pH data from May because the probe was malfunctioning at the time.

Solids
Results from solids samples are used to evaluate whether Secchi depths were affected primarily by algae, or if suspended sediments affected water clarity at the time of sampling. Results from solids samples indicated that there were more solids in the water during May than in August, and that some of the solids in May were due to inorganic material, as well as algae. As a result, Secchi depths from May could have been affected by suspended sediments (and as noted above, probably affected the nutrient concentrations). In August, solids results were low, and Secchi depths were affected primarily by algae.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants that is used to determine the amount of algae in a volume of water. Chlorophyll concentrations on both sampling dates indicated moderately high densities of algae when the lake was sampled.

Aquatic plants observed by Ecology staff during the sampling visits included muskgrass (the macroalga *Chara*), sago pondweed (*Potamogeton pectinatus*), red pondweed (*Potamogeton alpinus*), milfoil (*Myriophyllum* sp., but not the aggressive Eurasian variety), and rush (*Juncus* sp.). Muskgrass was the most abundant plant in the lake. In August 1993, tangled algae mats were visible on top of the muskgrass in areas of the lake; a sample of the algae contained the blue-green algae *Lyngbia*.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire on lake and watershed uses.

> Williams Lake is used for swimming, lakeshore camping, waterfowl hunting, and fishing (ice fishing only). Public facilities on the lakeshore include a day use park and a state park. Currently, the watershed is being logged and is used for animal grazing. In the past, the watershed was also logged and used for animal grazing.
>
> There are no houses on the lakeshore and no lake association for the lake. The lake is aerated during winter for ice fishing.
>
> Overall, the volunteer found that Williams Lake had good water quality. The worst problem in the lake in 1993 was algae. Possible sources of problems include excessive use by campers and swimmers, for the small size of the lake.

Acknowledgment

I thank Bob McGregor for volunteering his time to monitor Williams Lake in 1993.

Williams Lake -- Stevens County

1993 Trophic Status[1]

Estimated Trophic State:	Mesotrophic[2]
Mean Trophic State Index (Secchi):	34
Mean Trophic State Index (Total Phosphorus):	48
Mean Trophic State Index (Chlorophyll *a*):	42

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[3]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
01-Jun	0930	17.2	63.0	15.3	0.00	lt-green	90	light	light	Lake height 0" baseline. Brown flecks floating in water. Rained 2 inches Monday.
13-Jun	1342	20.0	68.0	18.3	0.50	lt-green	10	heavy	calm	
28-Jun	1100	17.8	64.0	19.0	1.00	lt-green	10	light	breezy	
15-Jul	1600	20.0	68.0	19.5	2.00	lt-green	90	moderate	light	
27-Jul	1000	21.1	70.0	22.5	3.00	lt-green	10	trace	light	
09-Aug	1000	22.2	72.0	22.5	1.00	lt-green	10	none	light	
18-Aug	0818	21.1	70.0	22.0	1.00	lt-green	90	heavy	calm	
27-Aug	1245	21.1	70.0	21.5		lt-green	10	none	calm	
16-Sep	1000	17.8	64.0	18.0	-2.25	lt-green	0	trace	light	Road construction pumping water for their use.
02-Oct	1330	16.1	61.0	17.8	-4.00		0	none	light	Water color light-moderate green.
17-Oct	1400	14.4	58.0	15.5	-4.75		10	light	light	Water color light-moderate green.

1 Trophic State Indices calculated from Carlson (1977).
2 See Overall Assessment.
3 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Williams Lake dropped 4.75" from June 1 to October 17.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
05/17	0.0	19.3	.	10.7	350
	2.0	18.4	.	12.0	348
	4.0	11.8	.	14.4	358
	6.0	7.5	.	12.0	376
	8.0	6.2	.	9.2	378
	10.0	5.7	.	7.1	376
08/18	0.0	20.8	8.8	8.9	342
	1.0	20.8	8.7	8.9	340
	2.0	20.8	8.7	8.8	340
	3.0	20.8	8.7	8.8	340
	4.0	20.8	8.7	8.7	340
	5.0	20.7	8.7	8.4	340
	6.0	17.7	8.5	12.6	390
	7.0	14.2	8.2	8.9	394
	8.0	11.6	8.0	4.3	396
	9.0	10.4	7.8	0.7	402
	10.0	8.9	7.6	0.3	404

1993 Onsite Visit Data - Water Chemistry

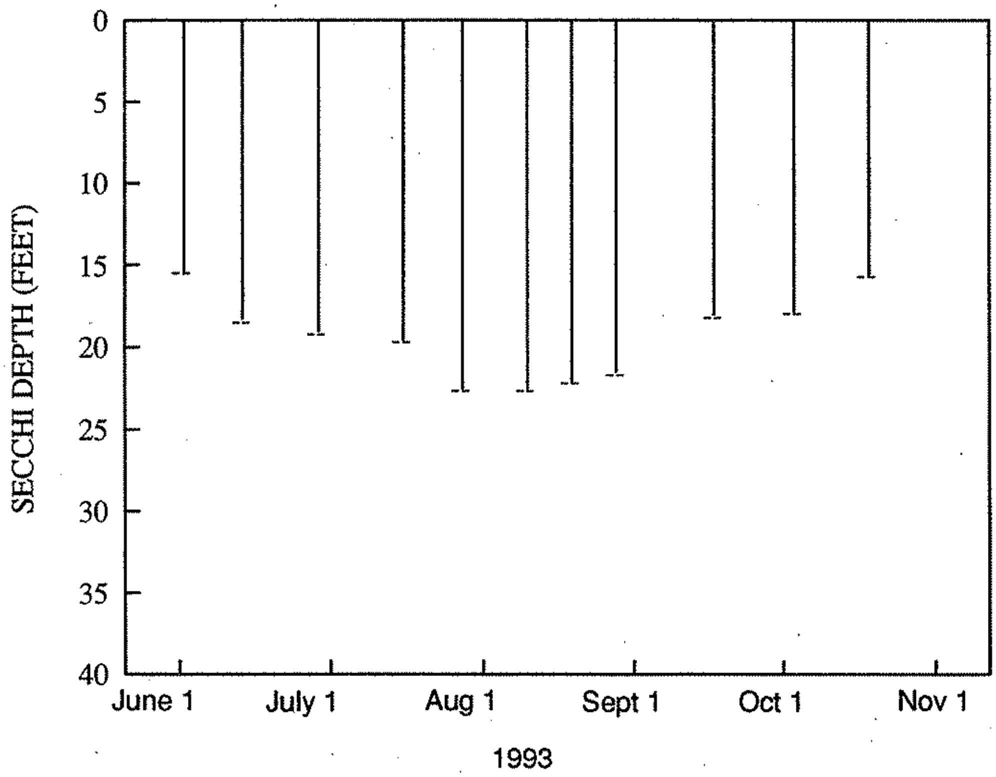
	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll a (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
May 17 Epilimnion	45	0.61	3.55	3	1	--	--
Hypolimnion	38	0.83	--	--	--	--	--
August 18 Epilimnion	10	0.59	2.67	1	<1	--	--
Hypolimnion	22	0.83	--	--	--	--	--

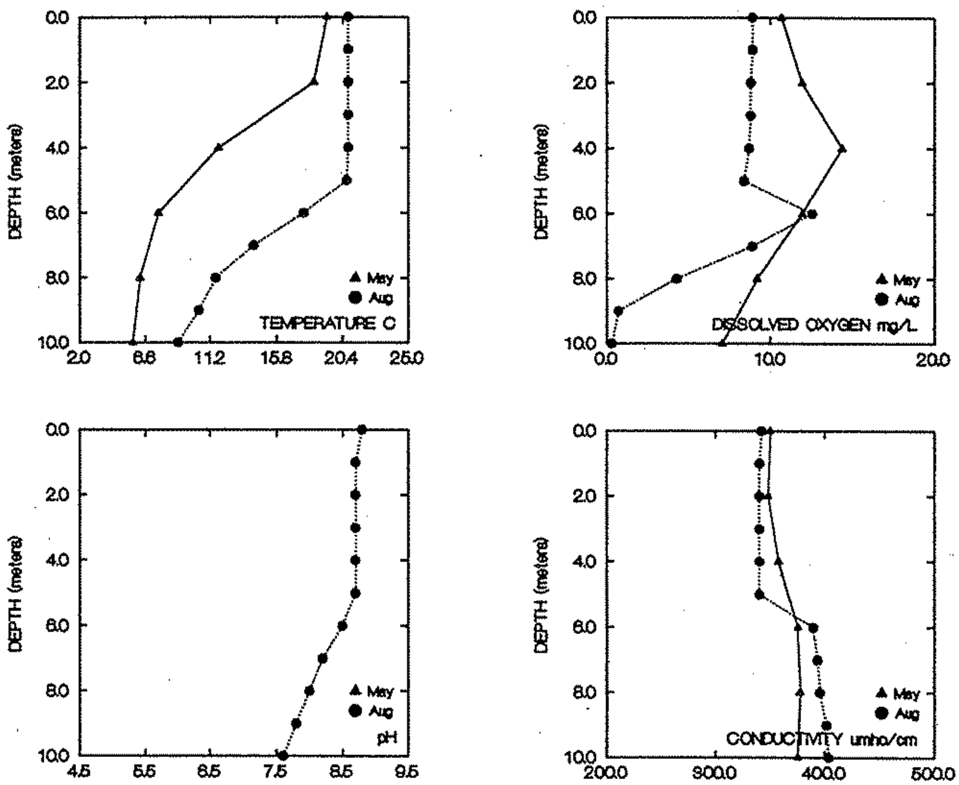
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll a (μg/L)
07/10/74[a]	22	--	--

a. Dion *et al.* (1976)

WILLIAMS LAKE (STEVENS COUNTY)





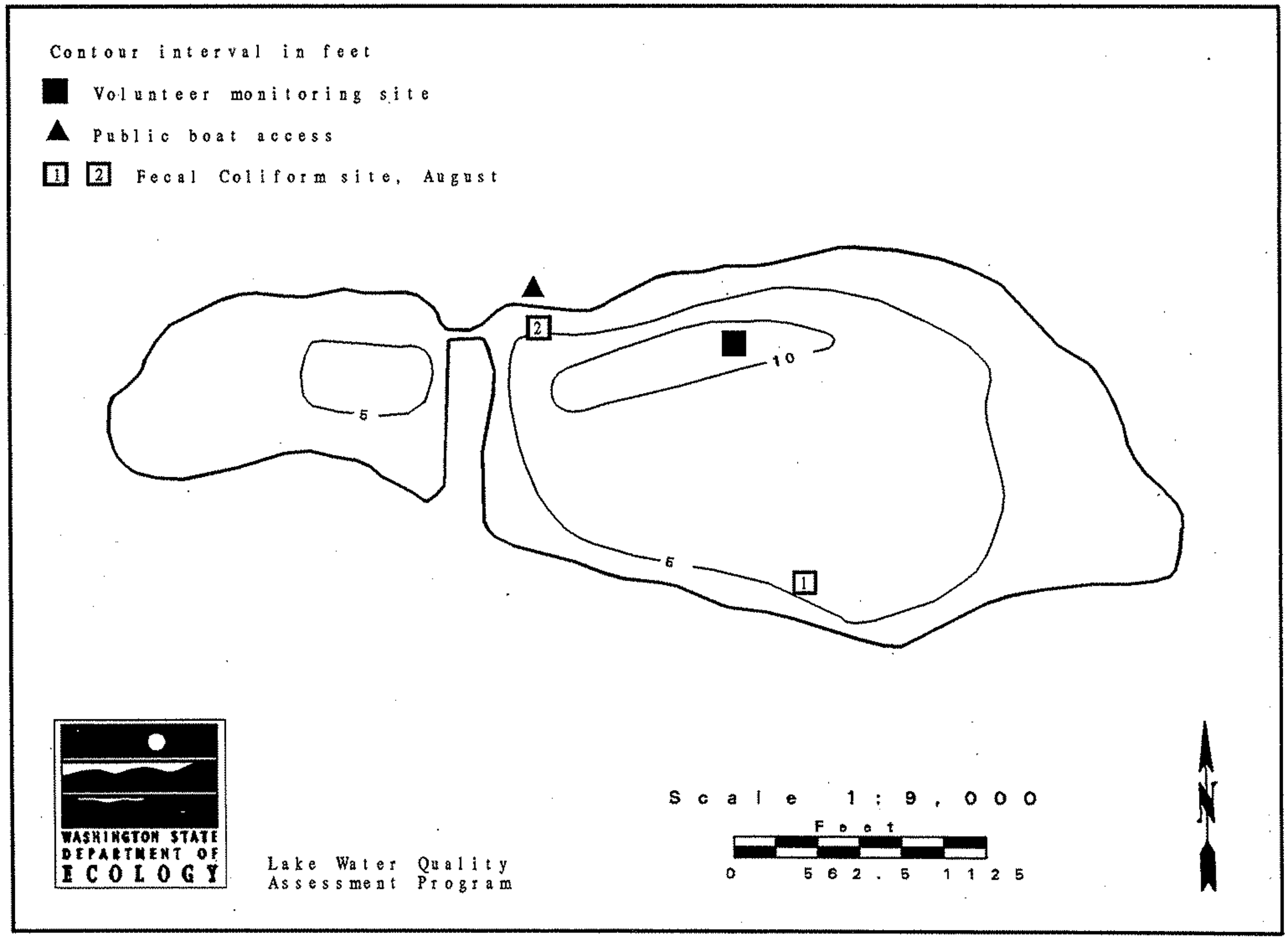
1993 Secchi Depth and Profile Data Graphs

Wiser Lake -- Whatcom County

Wiser Lake is located three miles southwest of Lynden. It consists of two basins, connected by a narrow isthmus, which is crossed by Meridian Road. The lake has no surface inlets, and drains via Wiser Lake Creek to the Nooksack River. The volunteer monitored the larger eastern basin.

Size (acres)	100
Maximum Depth (feet)	11
Mean Depth (feet)	6
Lake Volume (acre-feet)	610
Drainage Area (miles^2)	3.8
Altitude (feet)	50
Shoreline Length (miles)	2.3

Data From Bortleson *et al.* (1976)



Overall Assessment

In 1993, Wiser Lake was assessed as eutrophic, based on poor water clarity, high nutrient concentrations, and high densities of algae and aquatic plants.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths
Water clarity was poor, as indicated by Secchi depths that ranged from 2.0 feet to 2.5 feet. Secchi depths less than 6.5 feet indicate poor water clarity, and are typical for eutrophic lakes.

Total Phosphorus
Wiser Lake was not sampled in May. When the lake was sampled in August, the concentration of total phosphorus was very high (165 µg/L). Total phosphorus concentrations greater than 24 µg/L are high and are typical for eutrophic lakes.

Total Nitrogen
The concentration of total nitrogen was also high. The ratio of total nitrogen to total phosphorus can indicate which nutrient is likely to first become responsible for limiting algae growth. Because the ratio of total nitrogen to total phosphorus was less than 17:1 (it was 5:1), algae in Wiser Lake were not limited by phosphorus when the lake was sampled in August.

Profile Data
The lake was not stratified when it was sampled in August, and because the lake is so shallow, it may not have stratified for any significant length of time during summer. As would be expected from an unstratified lake, there was very little difference in profile parameter values from surface to bottom.

Fecal Coliform Bacteria
Two nearshore samples for fecal coliforms were collected. Site #1 was located nearshore on the south side of the lake, about in the middle of the basin. Site #2 was located at the public boat access. The result for site #1 was low, and was within state water quality standards for lake water. The result for site #2 at the public boat access was high (77 colonies/100 mL), and could have resulted from lake users or from waterfowl. Results from Wiser Lake were forwarded to Ecology's Northwest Regional office soon after they were received.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. The chlorophyll concentration was very high (30.8 µg/L), indicating that there was a very high density of algae when the lake was sampled. There was,

however, less algae than would be expected, given the very high concentration of total phosphorus. Some growth requirement other than phosphorus (such as nitrogen or light) limited algae growth in Wiser Lake.

Aquatic plants observed by Ecology staff during the sampling visit included coontail (*Ceratophyllum demersum*), Richard's pondweed (*Potamogeton richardsonii*), waterweed (*Elodea candensis*), naiad (*Najas flexilis*), curly-leaf pondweed (*Potamogeton crispus*), whitestem pondweed (*Potamogeon praelongus*), and a small-leaved pondweed (possibly *Potamogeton filiformis*). Waterweed was the most abundant plant in the lake.

Other Available Information

From Bortleson *et al.* (1976): In 1973, the lake had a heavy cover of submersed plants (waterweed and milfoil) over most of the lake bottom, especially in the small west bay. Emersed plants covered the shoreline. The lake was not stratified. There were 30 nearshore homes, and most land in the watershed was used for agriculture.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire on lake and watershed uses.

> Wiser Lake is used for fishing, swimming, motor boating, rowing, and jet skiing. There is one boat ramp on the lakeshore, and boat use on the lake is restricted to idling speed only from 8:00 a.m. to 12:00 p.m., and skiing is allowed from March 1 through October 15. No fish were stocked in the lake in 1993. Currently, the watershed is being used for crop agriculture and animal grazing, and grazing animals have direct access to the lakeshore or inlet tributaries. The lakeshore is also being developed further for residences. In the past, the watershed was also used for crop agriculture and animal grazing, and the shoreline was altered with bulkheads.
>
> There are approximately 35 houses on the lakeshore, and none are connected to a sewer collection system. There is a lake association for the lake, and in 1993 aquatic plants were controlled with a mechanical harvester. Lake water was withdrawn for irrigation.

Overall, the volunteer found that Wiser Lake had good water quality. Problems in the lake in 1993 were algae, fluctuating water level, and excessive aquatic plant growth. Possible sources of problems include excessive bottom sediment, and the lake becoming very shallow.

Acknowledgment

I thank Cindy Watt for volunteering her time to monitor Wiser Lake in 1993.

Wiser Lake -- Whatcom County

1993 Trophic Status[1]

Estimated Trophic State:	Eutrophic
Mean Trophic State Index (Secchi):	67
Trophic State Index (Total Phosphorus):	78[2]
Trophic State Index (Chlorophyll *a*):	64[2]

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	(°F)	Secchi (ft)	Lake Ht (in)[3]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
27-Jul	1015	13.0	55.4	2.5	15.00	gr-brown	0	none	light	Water color also yellow-greenish.
13-Aug	1045	17.0	62.6	2.0		gr-brown	25	none	breezy	Water color yellow.
17-Aug	1230			2.3			100		light	Onsite visit. Water color yellow to green brown.
25-Aug	1000	10.0	50.0	2.0	17.75		25	moderate	calm	Water color yellow/green brown.
10-Sep	1030	10.0	50.0	2.0	14.00		0	none	calm	Water color yellow green-brown. Lots of floating algae.

[1] Trophic State Indices calculated from Carlson (1977).
[2] From data collected in August only.
[3] "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Wiser lake dropped 1" from July 27 to September 10.

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
08/17	0.0	21.0	8.5	9.5	335
	0.6	20.3	8.0	7.7	337
	1.0	20.3	8.0	7.6	337
	1.3	20.2	7.9	7.4	336

1993 Onsite Visit Data - Water Chemistry

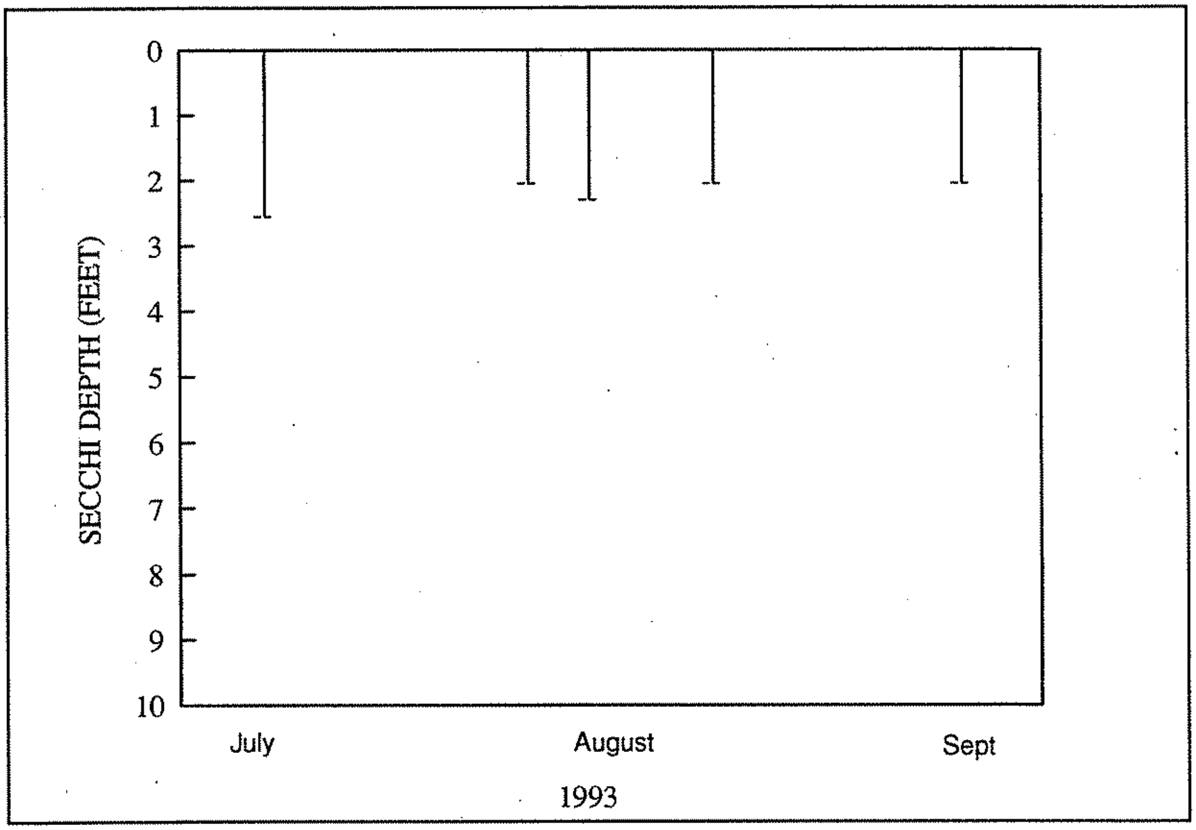
	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll a (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL)	
						Site #1	Site #2
August 17 Epilimnion	165	0.85	30.8	--	--	7	77
Hypolimnion	--	--	--	--	--	--	--

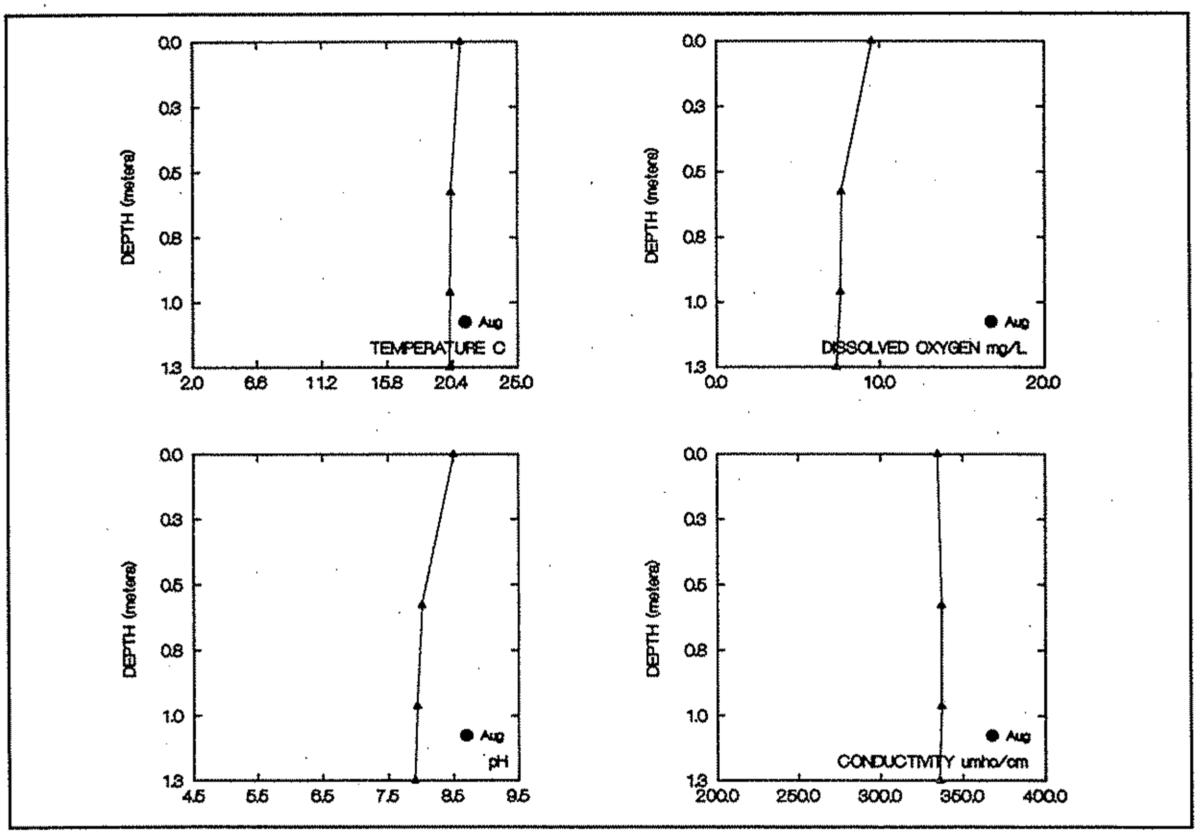
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll a (μg/L)
08/23/73[a]	41	--	--

a. Bortleson *et al.* (1976)

LAKE WISER (WHATCOM COUNTY)





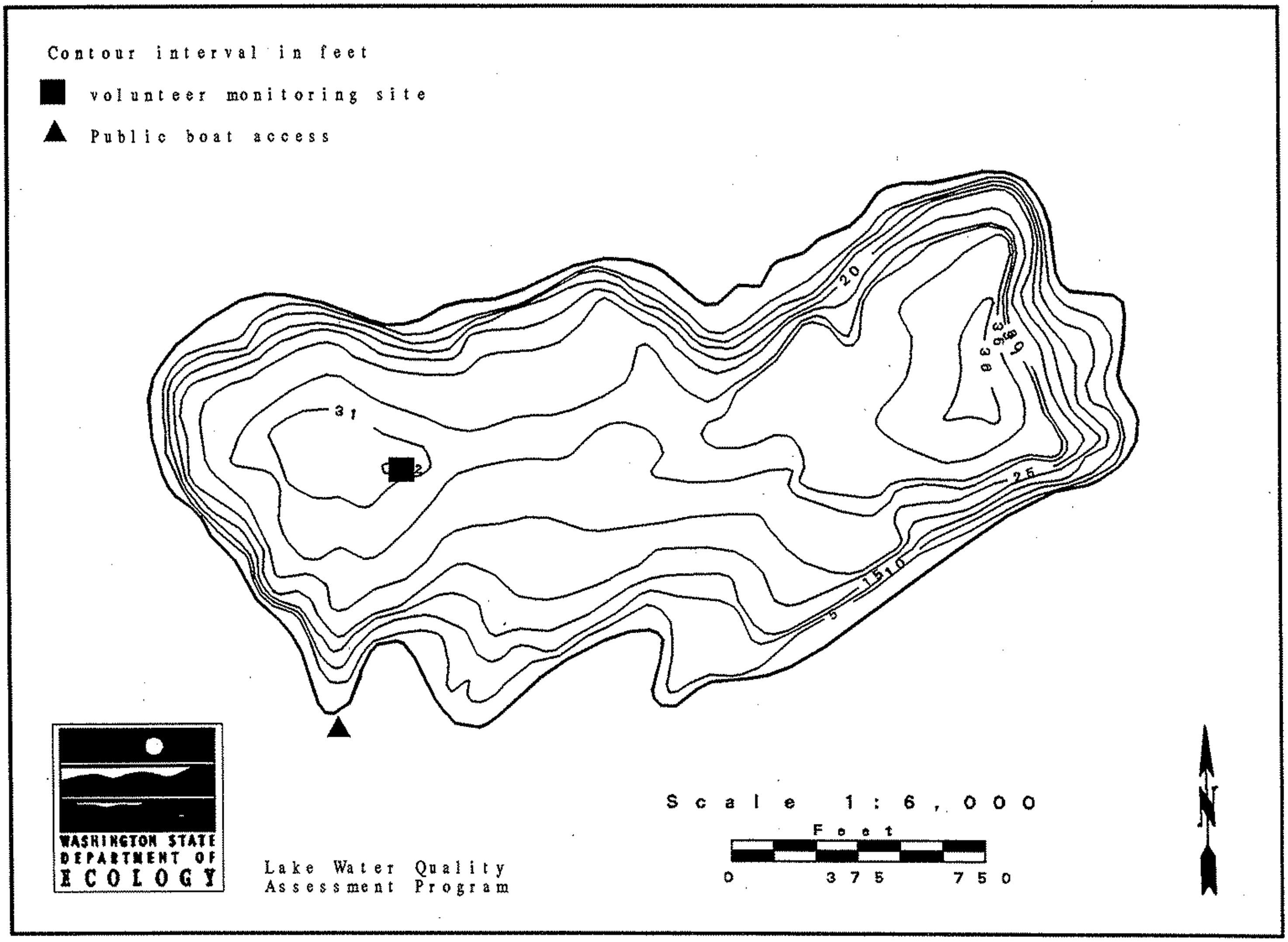
1993 Secchi Depth and Profile Data Graphs

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)



Overall Assessment

In 1993, Lake Wooten was assessed as oligotrophic, based on very good water clarity, low nutrient concentrations, and very low densities of algae and aquatic plants. Lake Wooten has been monitored for the Lake Water Quality Assessment Program since 1989; the lake was described as oligotrophic in 1989, 1991, and 1992.

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

In 1993, Lake Wooten had very good water clarity, as indicated by Secchi depths that ranged from 15.0 feet to 24.0 feet. Secchi depths greater than 13.0 feet indicate good water clarity, and are typical for oligotrophic lakes. Each year from 1989 to 1993, Secchi depths have typically been highest in May and lowest in October. Using seasonally adjusted Secchi depth data collected since 1989, there was no statistically significant trend in water clarity from 1989 to 1993.

Total Phosphorus

Concentrations of total phosphorus in the upper layer of water were very low on both sampling dates (4 µg/L in May, and 5 µg/L in August). Concentrations measured in 1993 were lower than those measured in 1992 and 1990. As would be expected from a lake with low phosphorus concentrations, algal densities were also low. Total phosphorus concentrations less than 12 µg/L are typical for oligotrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were moderately low on both sampling dates, and were lower than concentrations measured in 1992 and 1990. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae require at least ten times the amount of nitrogen as phosphorus. Because the ratios of total nitrogen to total phosphorus were greater than 17:1 (42:1 in June, and 36:1 in August), algae in Lake Wooten were not limited by nitrogen when the lake was sampled.

Profile Data

The lake was weakly stratified in May, but was destratified in August. As a result, only one set of water samples was collected in August.

Concentrations of dissolved oxygen decreased only at the very bottom of the lake, which often occurs as bacteria use oxygen when they decompose aquatic plants and algae in the water and sediments. Profile data from 1993 were very similar to profile data in 1989, 1990, 1991, and 1992.

Plants

Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. Chlorophyll concentrations on both sampling dates indicated low densities of algae when the lake was sampled. Chlorophyll concentrations were very similar to those measured in 1992.

Although some algae particles were visible when the lake was sampled in August, small amounts of blue-green algae are common in most lakes in late summer. The algae colonies appeared to be *Gloeotrichia*, which is a blue-green algae that has been observed in the lake in 1992 and 1989.

During the May and August 1992 sampling visits, a submerged aquatic plant in the vicinity of the outlet was seen for the first time. The sample was *Ludwigia palustris*, and was also observed in 1993. No other submerged macrophytes were observed.

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 1993.

> 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 1993. In the past the watershed was logged, and the shoreline was altered.
>
> There are 59 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 resident'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. No lake management activities occurred on the lake in 1993.
>
> 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.

Lake Wooten -- Mason County

Overall, the volunteer found that Lake Wooten had excellent water quality. The worst problem in the lake in 1993 was algae. Possible sources of problems include older septic systems which need to be updated. There were no changes in the lake since the 1992 monitoring season.

Acknowledgment

I thank Rusty Kidrick for volunteering her time to monitor Lake Wooten during 1989-1993.

Lake Wooten -- Mason County

1993 Trophic Status[1]

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index (Secchi):	33
Mean Trophic State Index (Total Phosphorus):	26
Mean Trophic State Index (Chlorophyll *a*):	34

Volunteer-Collected Data

Date 1993	Time	Temp (°C) (°F)	Secchi (ft)	Lake Ht (in)[2]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
20-May	1300	19.0 66.2	22.5		green	90	light	light	
03-Jun	1345		20.0		lt-green	95		light	Onsite visit.
17-Jun	1300	21.0 69.8	24.5	25.50	lt-green	10	none	calm	
29-Jun	140	20.0 68.0	22.5	25.50	green	90	light	breezy	
21-Jul	1000	19.0 66.2	23.8	24.75	green	100	moderate		
04-Aug	0930	22.0 71.6	23.3	26.00	green	0	none	calm	First showing of algae bloom.
18-Aug	1100	20.0 68.0	22.0	25.50	green	0	trace	light	
31-Aug	0945			20.3	green	100		light	Onsite visit. Some algae particles visible.
08-Sep	1300	22.0 71.6	22.5	23.50	green	0	none	calm	Algae bloom has increased with the hot weather. Not serious yet.
27-Sep	1500	19.0 66.2	16.0	20.75	green	10	none	light	
05-Oct	1330	18.0 64.4	20.0	21.00	green	100	trace	breezy	Algae bloom pretty much gone.
20-Oct	1030	15.0 59.0	15.0	19.25	green	10	none	light	Lot of suspended particles in the water. May be due to lack of rain to flush lake.

1 Trophic State Indices calculated from Carlson (1977).

2 "Lake height" refers to change in water level. Based on volunteer-collected data, the level of Lake Wooten dropped 6.25" from June 17 to October 20.

Lake Wooten -- Mason County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
06/03	0.0	19.7	7.8	9.1	25
	1.0	19.3	7.7	9.2	25
	2.0	19.2	7.6	9.2	25
	3.0	19.1	7.6	9.3	25
	4.0	18.4	7.7	10.4	25
	5.1	15.7	7.9	11.2	25
	6.1	14.1	7.9	11.5	25
	7.1	12.2	7.8	10.4	26
	8.0	11.5	7.6	8.5	27
08/31	0.0	20.4	7.6	9.3	26
	0.9	20.5	7.6	9.1	26
	2.0	20.5	7.6	9.0	26
	3.0	20.5	7.6	8.9	26
	4.0	20.5	7.6	8.9	26
	5.0	20.4	7.5	8.7	26
	6.0	20.4	7.5	8.5	27
	7.0	20.0	7.4	6.9	27
	8.0	19.0	7.2	2.4	33

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 3 Epilimnion	4	0.17	1.1	--	--	--	--
Hypolimnion	18	0.26	--	--	--	--	--
August 31 Epilimnion	5	0.18	1.8	--	--	--	--
Hypolimnion*							

* lake was not stratified at the time of sampling; only one set of water samples was collected

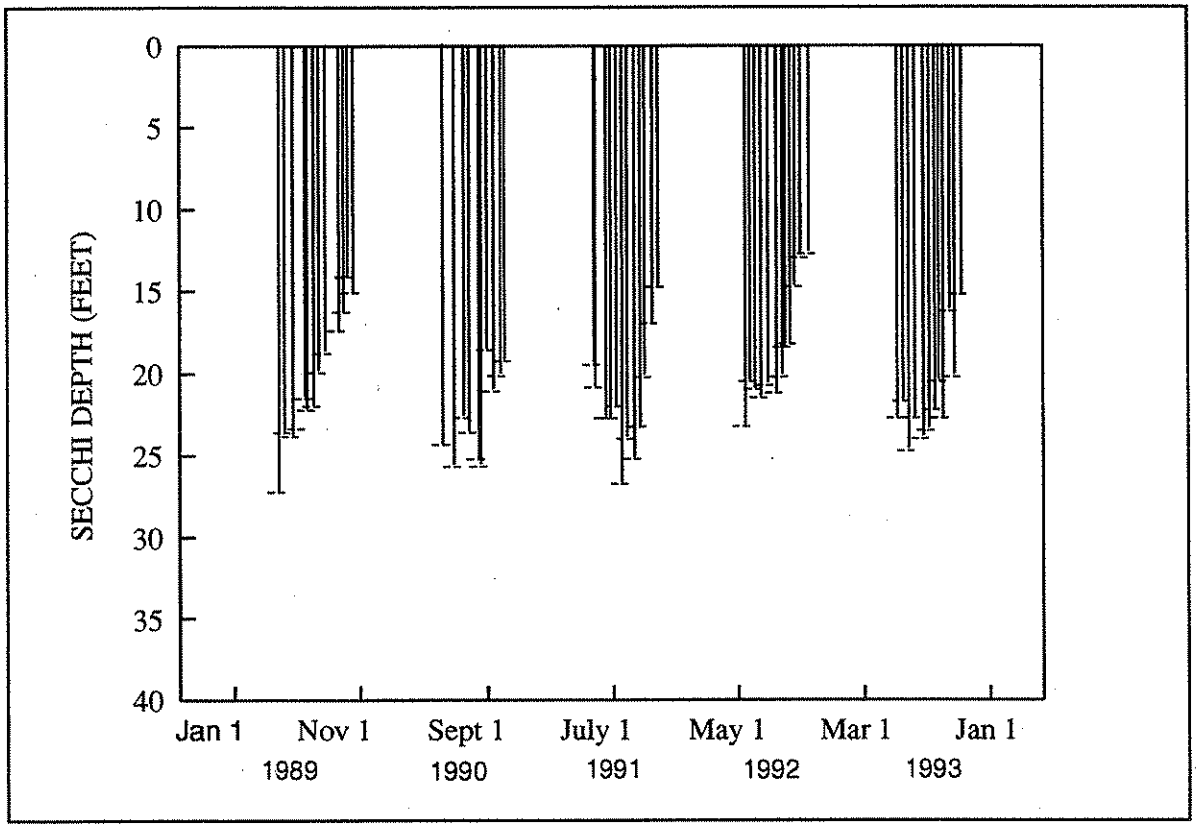
Lake Wooten -- Mason County

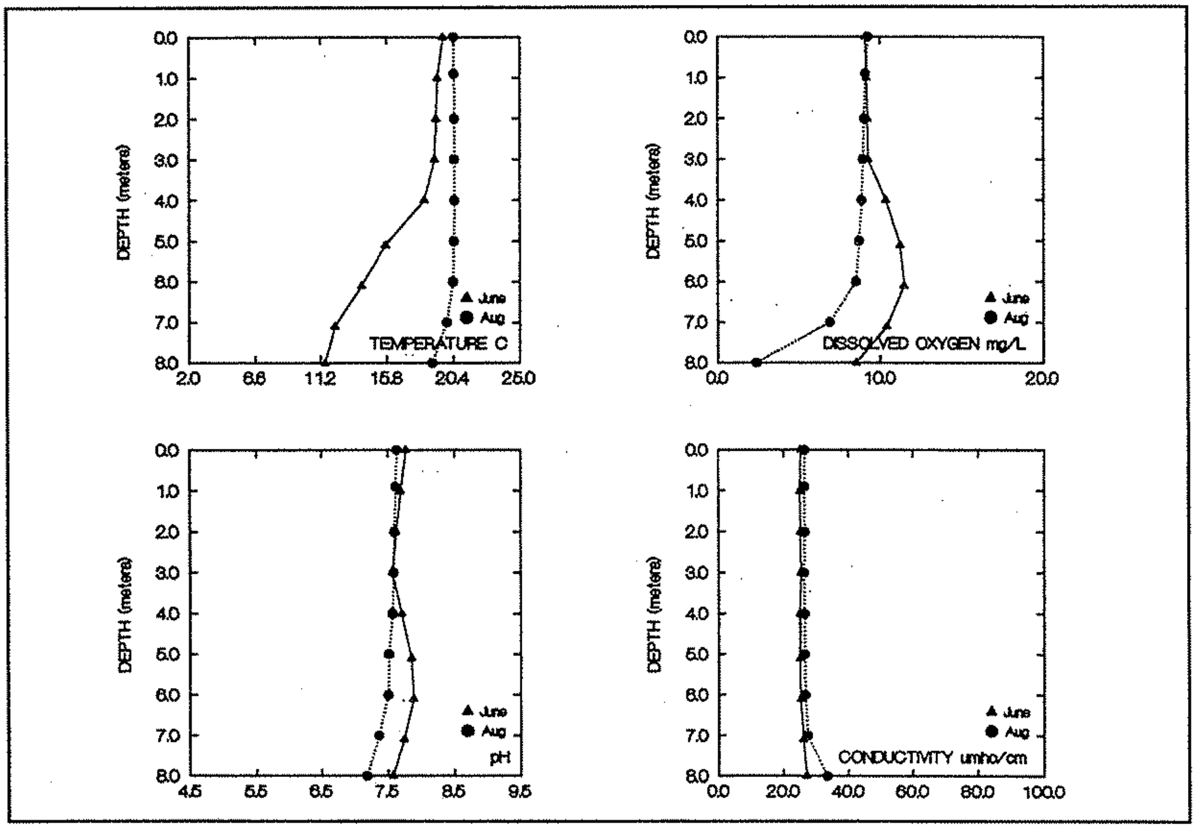
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll a (µg/L)
08/22/74[a]	5	--	--
06/28/89[b]	3	0.13	0.9
09/27/89[b]	10	0.20	9.7
08/14/90[c]	15	0.64	--
05/20/91[d]	--	0.13	--
05/13/92[e]	6	0.26	1.1
08/19/92[e]	8	0.21	1.7

a. Bortleson *et al.* (1976)
b. Brower and Kendra (1985)
c. Rector (1991)
d. Rector (1992)
e. Rector (1993)

LAKE WOOTEN (MASON COUNTY)





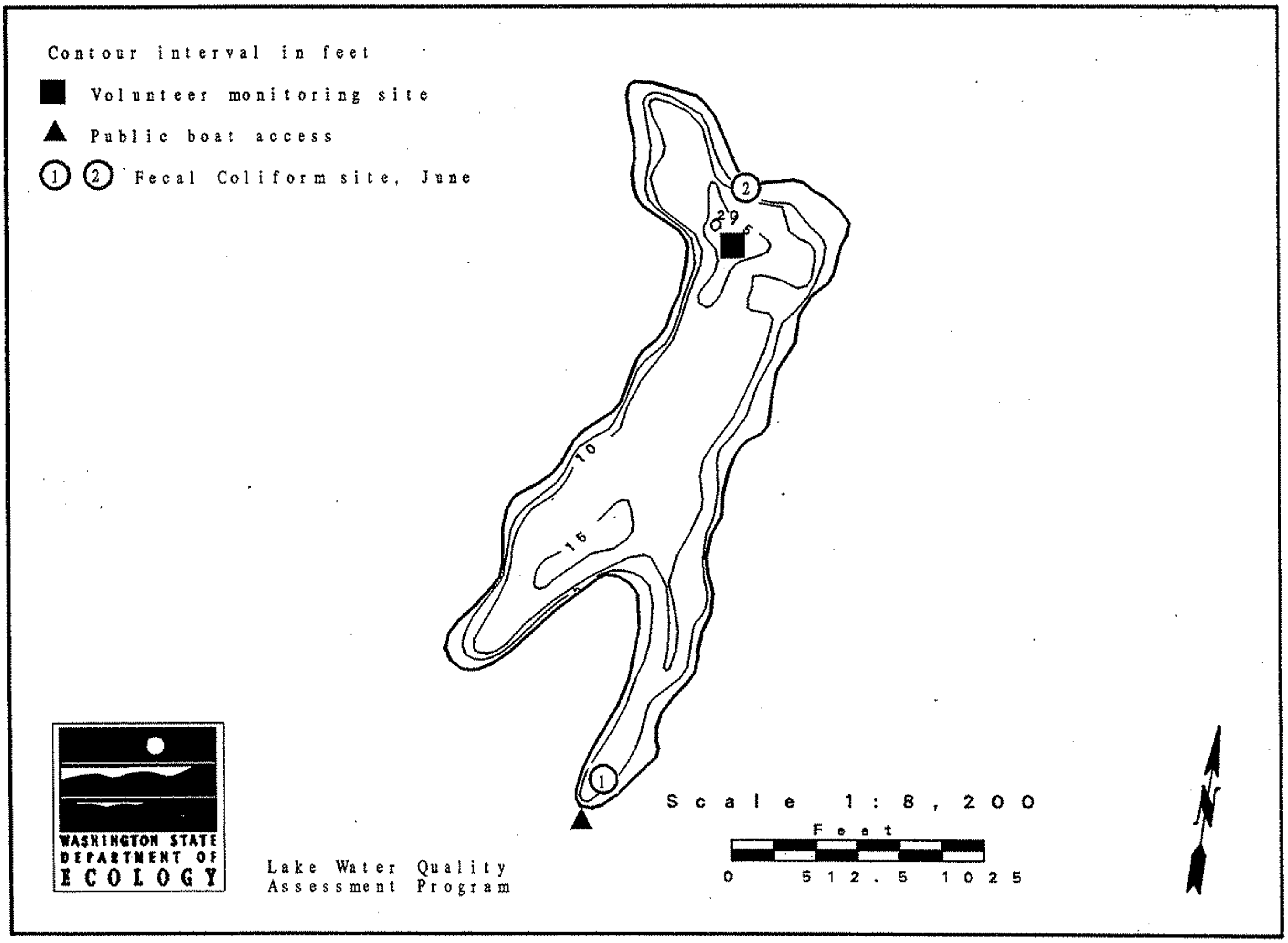
1993 Secchi Depth and Profile Data Graphs

Wye Lake -- Kitsap County

Wye Lake is located 3.5 miles southeast of Belfair. It is fed by about six intermittent inlets, and drains via an unnamed creek to Fern Lake, Rocky Creek and ultimately to Case Inlet.

Size (acres)	39
Maximum Depth (feet)	15
Mean Depth (feet)	10
Lake Volume (acre-feet)	370
Drainage Area (miles^2)	1.1
Altitude (feet)	300
Shoreline Length (miles)	1.7

Data From Bortleson *et al.* (1976)



Overall Assessment

Wye Lake was assessed as meso-eutrophic, because it exhibited both mesotrophic and eutrophic characteristics. Eutrophic characteristics were the high concentration of total phosphorus and high density of algae in June. However, by August both the total phosphorus concentration and the algal density were lower, in the range associated with mesotrophic lakes. Secchi depth data indicated good water clarity, although for most measurements the Secchi disk was visible on the bottom of the lake (referred to as "hitting bottom") which would give a low bias to the analysis of Secchi depth data. The density of aquatic plants was low. Wye Lake was new to the Lake Water Quality Assessment Program in 1993

1993 Monitoring Results/Summary of Other Available Information

Secchi Depths

The Secchi disk "hit bottom" on all sampling dates from June through August. As a result, only Secchi depths from September and October are full measurements of water clarity. Overall, water clarity was much better than would be expected, given the moderately high concentrations of total phosphorus and chlorophyll *a*.

Total Phosphorus

In May, the concentration of total phosphorus was high (28 µg/L), and there was a moderately high density of algae at the time of sampling. In August, the concentration of total phosphorus was moderate (15 µg/L). Concentrations from 12 to 24 µg/L are typical for mesotrophic lakes.

Total Nitrogen

Concentrations of total nitrogen were moderately low on both sampling dates. The ratio of total nitrogen to total phosphorus can indicate which nutrient may first become responsible for limiting algae growth, because algae usually use at least ten times the amount of nitrogen as phosphorus. In August, the ratio of total nitrogen to total phosphorus was greater than 17:1 (24:1), so it is likely that algae were not limited by nitrogen. Although the ratio of total nitrogen to total phosphorus was low in June (10:1), the concentration of chlorophyll was higher than would be expected given the phosphorus concentration.

Profile Data

The lake is very shallow, and it was not stratified on either sampling date. As would be expected from an unstratified lake, there was very little difference in profile parameters from surface to bottom. Higher pH values in June probably resulted from the high density of algae at the time of sampling.

Fecal Coliform Bacteria
Two nearshore samples were collected in June. Site #1 was located near the public boat access, and Site #2 was located off the dock of the community park. Results for both sites were moderate. The state water quality standard for fecal coliforms in Lake Class waters is a geometric mean of 50 colonies/100 mL.

Plants
Chlorophyll *a* is a pigment found in photosynthesizing plants, and is used to determine the amount of algae in a volume of water. In May, the chlorophyll concentration (15.0 µg/L) indicated a high density of algae at the time. The density was higher than would be expected given the concentration of total phosphorus. In August, the chlorophyll concentration was moderately high (2.8 µg/L) and was at the level expected given the nutrient concentrations.

An aquatic plant sample collected from the lake was identified as false loosestrife *(Ludwigia palustris)*. Few aquatic plants were observed along shore.

Other Available Information
From Bortleson *et al.* (1976): In 1972, there were 96 nearshore homes (mostly seasonal). The inlets were dry during summer, and the outlet was controlled by flashboards. There was low algal productivity, and sparse growth of aquatic plants because of sand and gravel littoral bottom. Rooted aquatic plants observed were sedge (*Cyperaceae*) and quillwort (*Isoetes* sp.). The lake was not stratified when it was sampled in March, May, June, and August 1972, and concentrations of dissolved oxygen were high throughout the water column.

Summary of Questionnaire Results and Information from the Volunteer

The following is a summary of the volunteer's remarks and responses to the 1993 questionnaire on lake and watershed uses.

> Wye Lake is used for fishing, swimming, rowing, and lakeshore camping. Public facilities on the lakeshore include a day use park and one boat ramp. No motor boats are allowed on the lake. Rainbow trout were stocked in the lake in 1993. Currently, the watershed is being used for tree farms, and the lakeshore is being developed further for residences. In the past, the watershed was logged and used for crop agriculture, and the shoreline was altered with bulkheads.
>
> There are 110 houses on the lakeshore, and none are connected to a sewer collection system. No culverts drain into the lake. There is a community association for the lake. Lake water was withdrawn for drinking and other domestic uses. No lake management activities occurred on the lake in 1993.

Overall, the volunteer found that Wye Lake had good water quality. The worst problem in the lake in 1993 was degraded aesthetics from lots cleared around the lake. Many of the lots being cleared will be developed for residences. There is a potential for water quality problems from septic systems because many summer cabins are being used as year-round residences.

Acknowledgment

I thank Sandra Gold for volunteering her time to monitor Wye Lake in 1993.

Wye Lake -- Kitsap County

1993 Trophic Status[1]

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index (Secchi):	<41[2]
Mean Trophic State Index (Total Phosphorus):	48
Mean Trophic State Index (Chlorophyll *a*):	49

Volunteer-Collected Data

Date 1993	Time	Temp (°C)	Temp (°F)	Secchi (ft)	Lake Ht (in)[3]	Water Color	% Cloud Cover	Recent Rain	Wind	Abbreviated Comments
07-Jun	1745			13.5b						
17-Jun	1300	21.2	70.2	13.5b	-3.00	lt-green	0	none	calm	hit bottom. All temperatures corrected by subtracting 1.8°C.
01-Jul	1705	21.2	70.2	13.0b	-8.00	lt-green	75	trace	light	hit bottom. Sprinkling.
16-Jul	1800	21.2	70.2	13.0b	-11.00		50	light	light	Water color light greenish-brown.
03-Aug	1700	23.2	73.8	13.0b	-16.00		0	none	calm	Water color light green-brown. Really hot weather last day or so. Top layer of water is hot!
17-Aug	1745	21.2	70.2	12.8b	-21.00		10	trace	light	Water color fairly light greenish-brown.
31-Aug	1715	21.7	71.1	12.0b	-24.00	gr-brown	0	none	light	hit bottom. Darker than previous weeks. Onsite visit.
21-Sep	1745	17.7	63.9	9.5	-29.00	gr-brown	0	none	light	Water color dark green-brown. Sun was noticeably lower. Light may be part difference in readings.
08-Oct	1600	16.7	62.1	10.0	-32.00	gr-brown	75	moderate	breezy	Earlier time for observation - better light than 09/21.
24-Oct	1500	14.2	57.6	11.0	-31.00	gr-brown	10	heavy	light	Lots of rain yesterday. Found a deeper point in the lake for next year!

b = Secchi disk hit bottom

1 Trophic State indices calculated from Carlson (1977).

2 Most Secchi depths hit bottom, so TSI is biased high.

3 "Lake height" refers to change in water level. Base don volunteer-collected data, the level of Wye Lake dropped 28" from June 17 to October 24.

Wye Lake -- Kitsap County

1993 Onsite Visit Data - Profile Data

Date 1993	Depth (meters)	Temp (°C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μmhos/cm)
06/07	0.0	20.2	7.2	9.3	18
	0.9	20.0	7.1	9.2	18
	2.0	19.8	7.2	9.3	18
	3.1	19.7	7.0	9.5	18
	3.1	19.7	7.1	9.4	18
	3.2	19.7	7.1	9.4	18
08/31	0.0	21.7	6.3	8.7	18
	1.0	21.1	6.1	8.6	18
	2.0	20.5	6.2	8.7	18
	2.8	20.4	6.3	8.6	18

1993 Onsite Visit Data - Water Chemistry

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll a (μg/L)	Total Suspended Solids (mg/L)	Total Nonvolatile Suspended Solids (mg/L)	Fecal coliform bacteria (colonies/100 mL) Site #1	Site #2
June 7							
Epilimnion	28	0.27	15.0	--	--	13	8
Hypolimnion*							
August 31							
Epilimnion	15	0.37	2.8	--	--	--	--
Hypolimnion*							

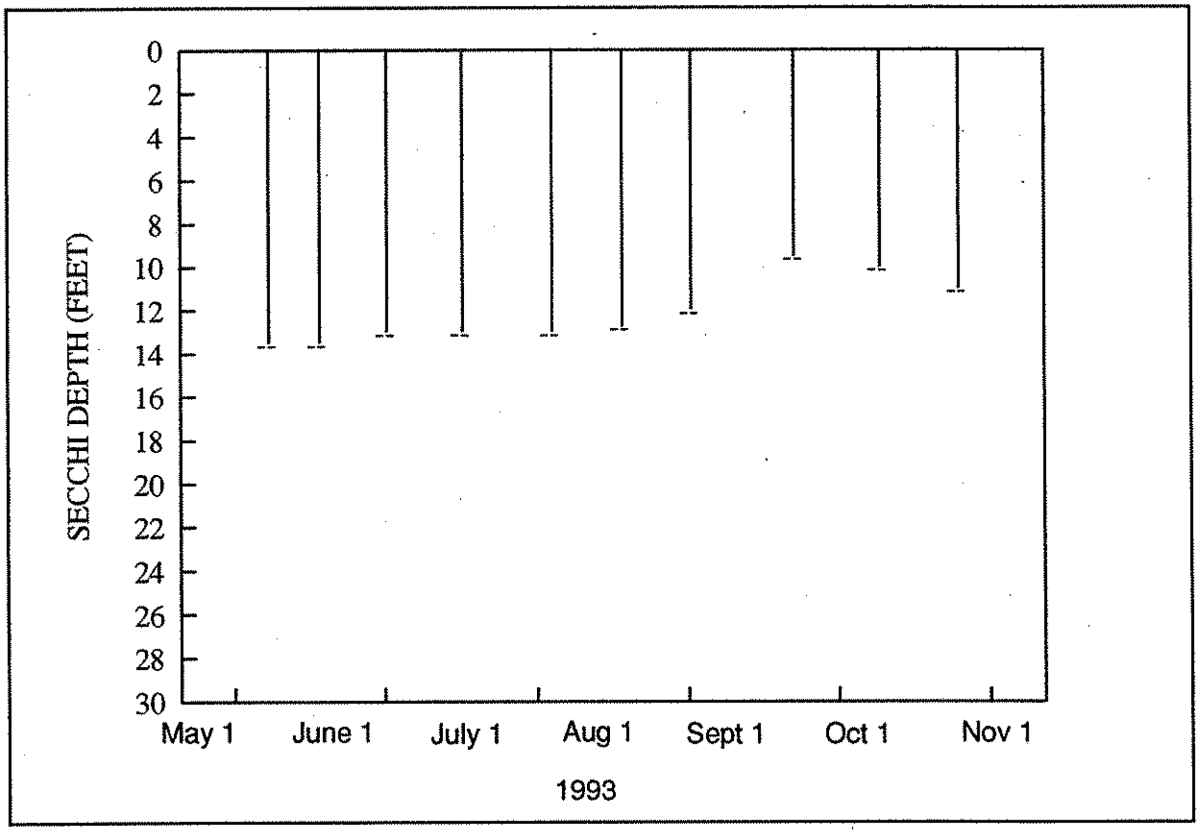
* lake was not stratified at the time of sampling; only one set of water samples was collected

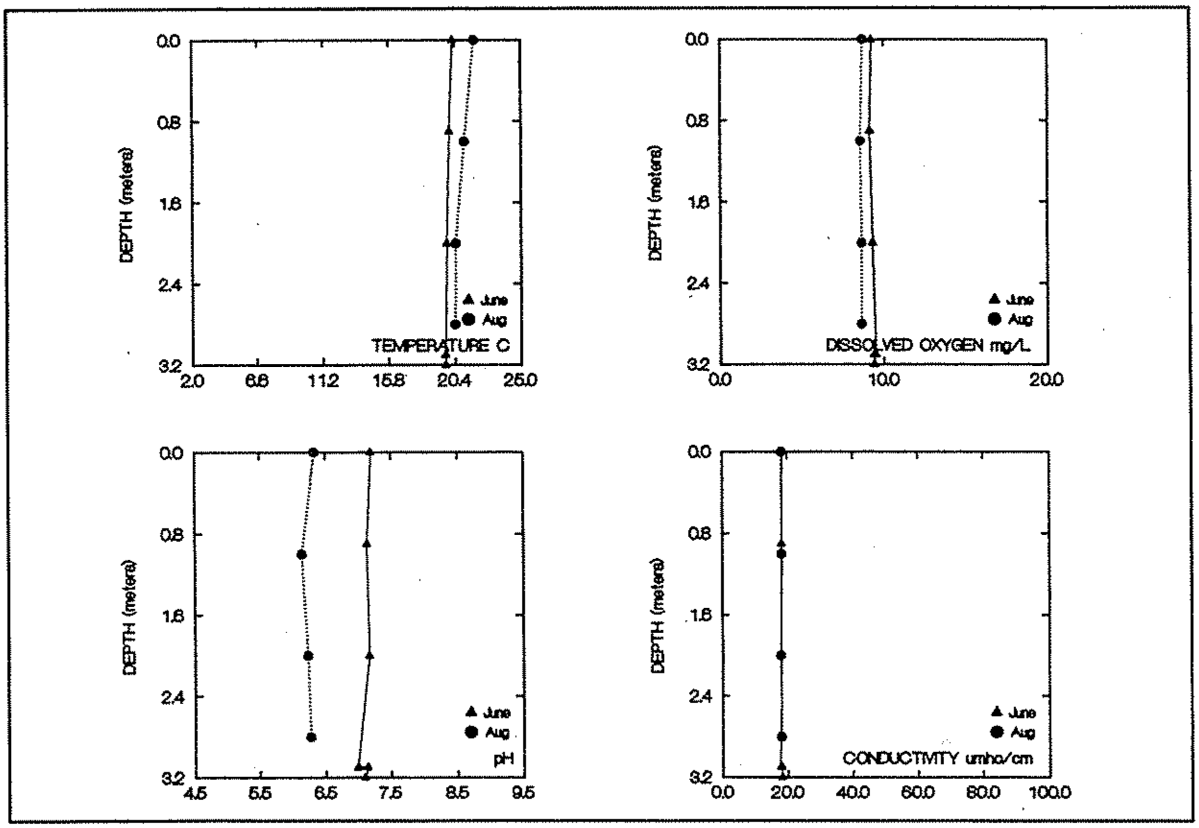
Historical Data From Ecology - Epilimnion Data Only

	Total Phosphorus (μg/L)	Total Nitrogen (mg/L)	Chlorophyll a (μg/L)
05/10/72[a]	2	--	1.1
08/24/72[a]	4	--	3.0

a. Bortleson *et al.* (1976)

LAKE WYE (KITSAP COUNTY)





1993 Secchi Depth and Profile Data Graphs

Water Quality Data from Lakes Monitored by Ecology Staff in 1993

Cle Elum Lake -- Kittitas County

Size (acres)	4800
Maximum Depth (feet)	258
Mean Depth (feet)	109
Lake Volume (acre-feet)	520000
Drainage Area (miles^2)	203.00
Altitude (feet)	2223
Shoreline Length (miles)	19.51

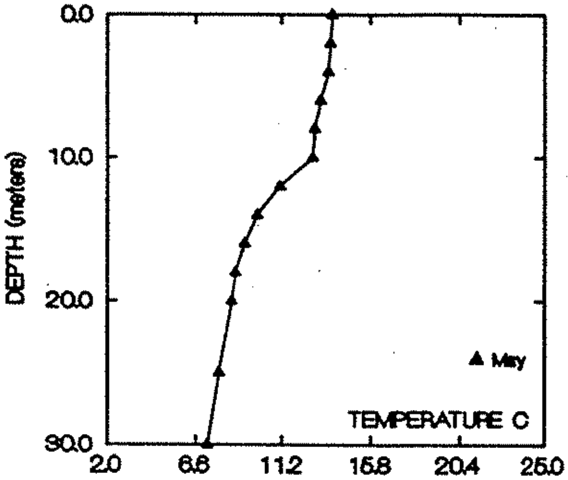
Data From Dion *et al.* (1976)

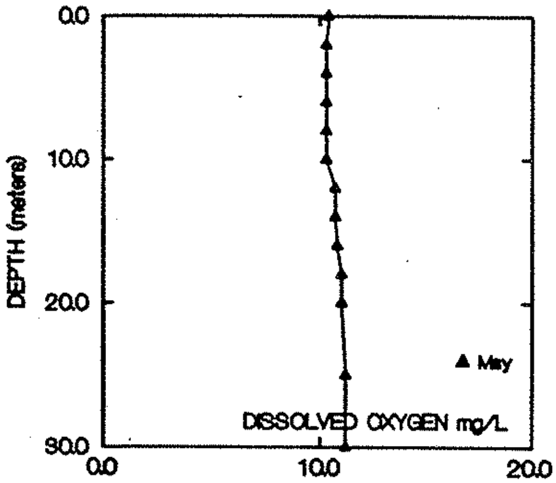
No Map Available.

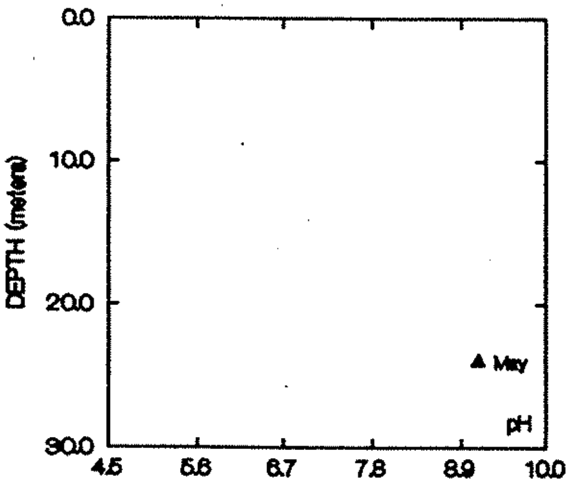
1993 Onsite Visit Data - Water Chemistry

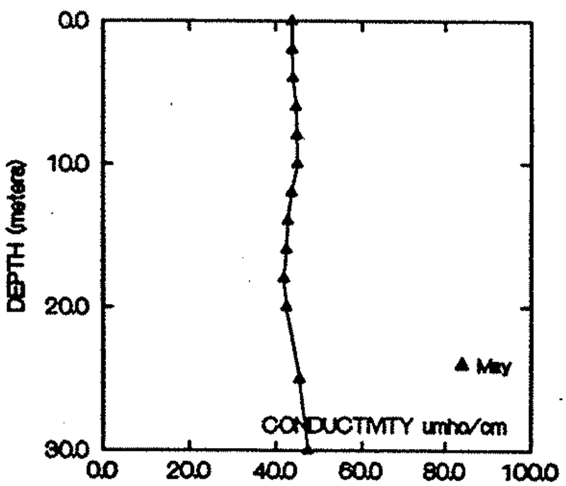
Date	Sta.	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/07/30		E	4	(Source: Water Supply Bulletin 43)					
89/06/06	1	E	5	0.06	1.0				
89/09/06	1	E	197	0.07	1.1				
93/06/01	1	E	3	0.05	1.7				
93/06/01	1	H	12	0.05					

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program





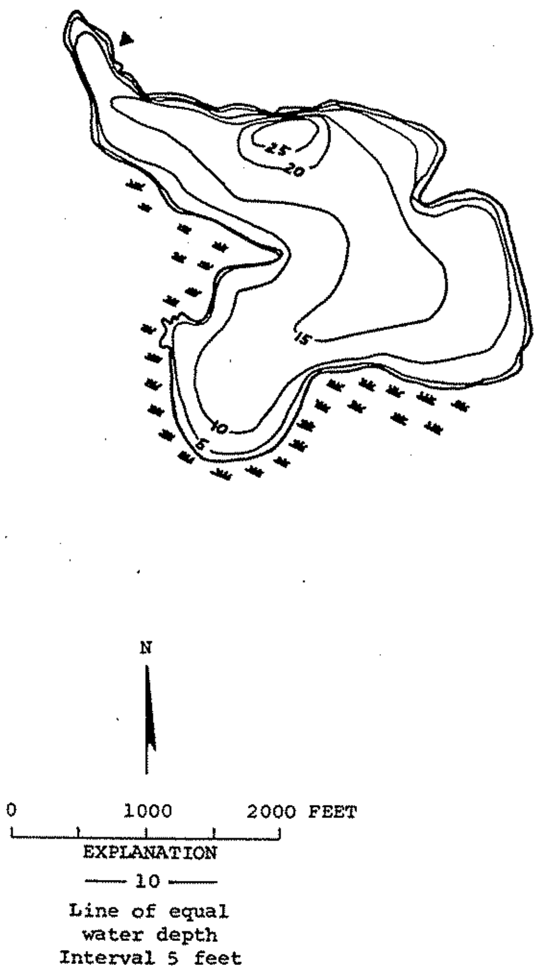




Cranberry Lake -- Island County

Size (acres)	125
Maximum Depth (feet)	25
Mean Depth (feet)	13
Lake Volume (acre-feet)	1576
Drainage Area (miles^2)	0.61
Altitude (feet)	20
Shoreline Length (miles)	2.84

Data From Dion *et al.* (1976)



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

Cranberry Lake -- Island County

1993 Onsite Visit Data - Water Chemistry

Date	Sta.	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/08/09		E	35		(Source: Water Supply Bulletin 43)				
81/07/09		E	30	8.2	(Source: Water Supply Bulletin 57)				
89/06/27	1	E	59	1.15	30.0				
89/09/26	1	E	107	1.16	16.8				
90/08/14	1	E	29	0.71					
91/05/28	1	E	0.79						
93/06/11	1	E	31	0.70	15.0				
93/06/11	2	E	37	0.67	9.7				
93/08/29	1	E	63	0.78	5.9	81	17		
94/05/29	1	E	55	0.35	5.1				
94/05/29	2	E	37	0.31	7.1				
94/05/29	1	H	89	0.34					
94/09/03	1	E	78	0.70J	10.4J				
94/09/03	2	E	85	0.77J	8.4J				
94/09/03	1	H	1272J	2.38J					

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
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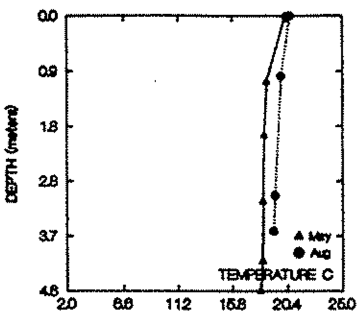

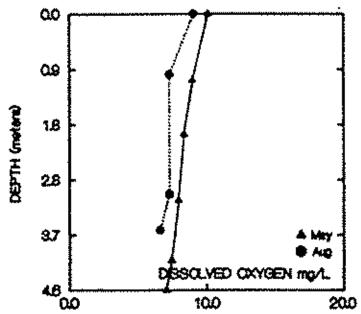

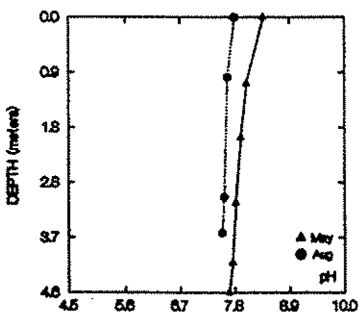

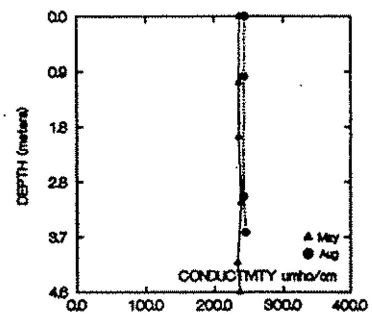

Deer Lake -- Stevens County

Size (acres)	1110
Maximum Depth (feet)	75
Mean Depth (feet)	52
Lake Volume (acre-feet)	57000
Drainage Area (miles^2)	18.20
Altitude (feet)	2474
Shoreline Length (miles)	8.62

Data From Dion *et al.* (1976)

No Map Available.

1993 Onsite Visit Data - Water Chemistry

Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
72/08/15		E	10		(Source: Water Supply Bulletin 43)				
81/07/14		E	10	1.0	(Source: Water Supply Bulletin 57)				
90/05/25	1	E	14						
90/08/09	1	E	17	0.34					
92/05/12	1	E	7	0.29	0.4				
92/05/12	1	H	10	0.30					
92/05/13	2	E	9						
92/08/25	1	E	8	0.33	1.3	1U	1		
92/08/25	1	H	15	0.33					
93/05/19	1	E	13	0.32	0.7				
93/05/19	1	H	15	0.31					
93/08/20	1	E	7	0.28	1.8				
93/08/20	1	H	26	0.27					

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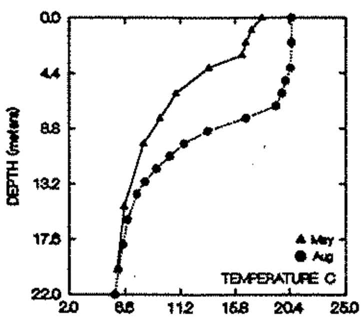

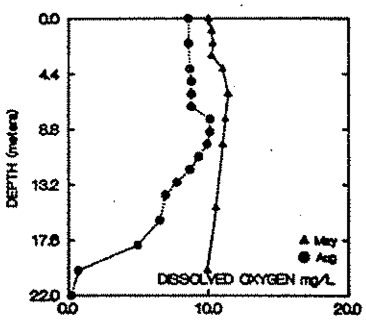

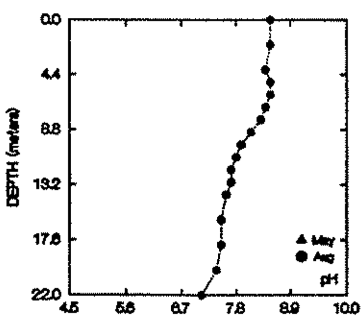

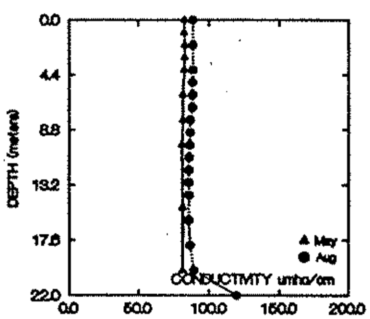

Easton Lake -- Kittitas County

Size (acres)	240
Maximum Depth (feet)	16
Mean Depth (feet)	17
Lake Volume (acre-feet)	3990
Drainage Area ($miles^2$)	188.00
Altitude (feet)	2180
Shoreline Length (miles)	2.54

Data From Dion *et al.* (1976)

No Map Available.

1993 Onsite Visit Data - Water Chemistry

Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/07/31		E	4	(Source: Water Supply Bulletin 43)					
93/06/01	1	E	3U	0.05	0.6	1	1U		
93/08/29	1	E	17	0.12	0.7	2	1U		

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
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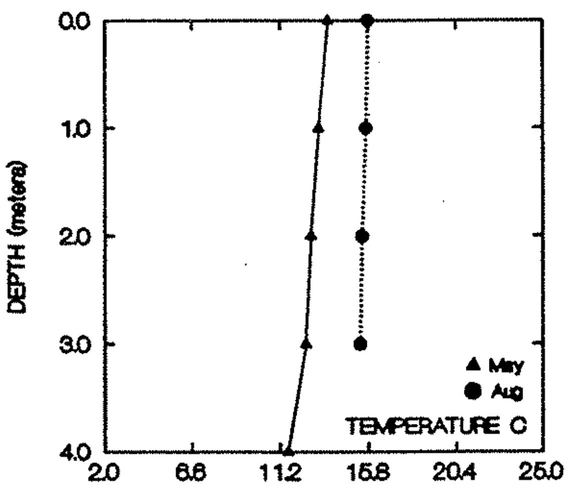
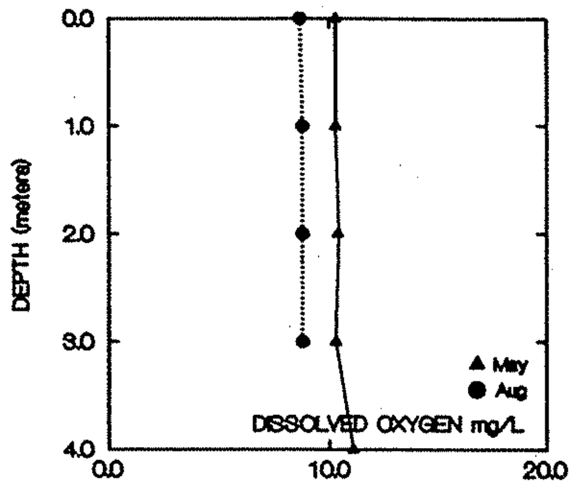
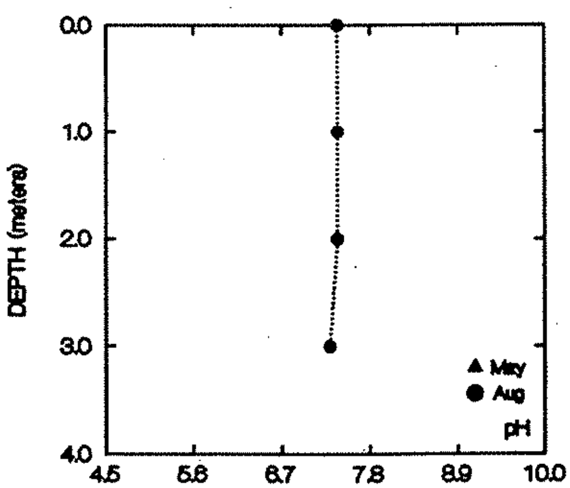
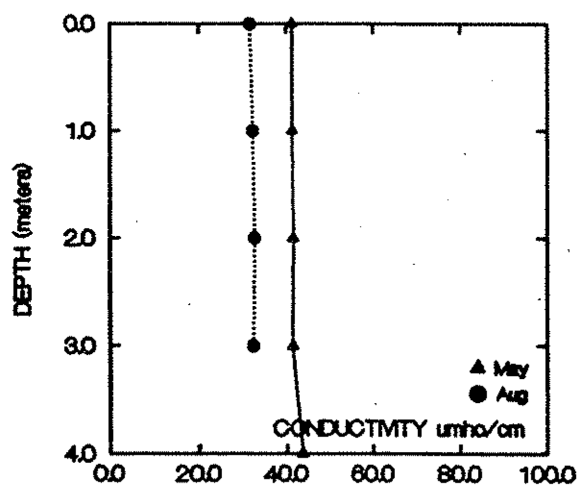




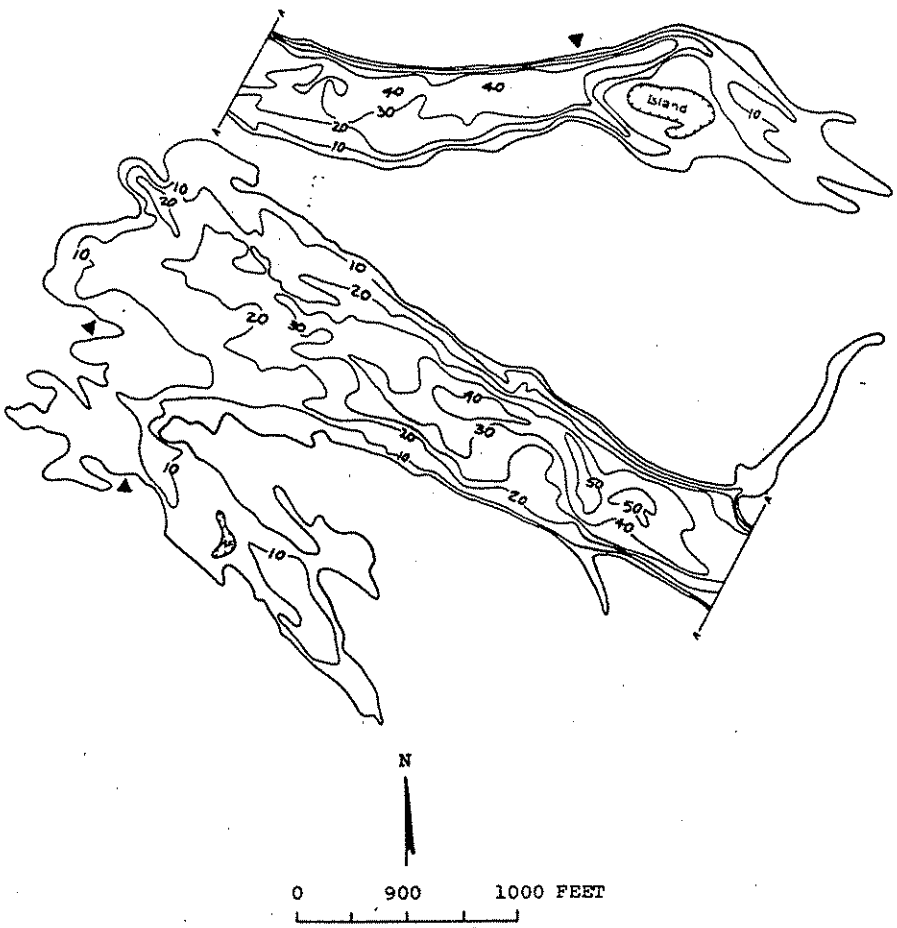




Evergreen Lake -- Grant County

Size (acres)	250
Maximum Depth (feet)	55
Mean Depth (feet)	19
Lake Volume (acre-feet)	4660
Drainage Area (miles^2)	**
Altitude (feet)	1198
Shoreline Length (miles)	8.05

Data From Dion *et al.* (1976)



EXPLANATION

—— 20 ——

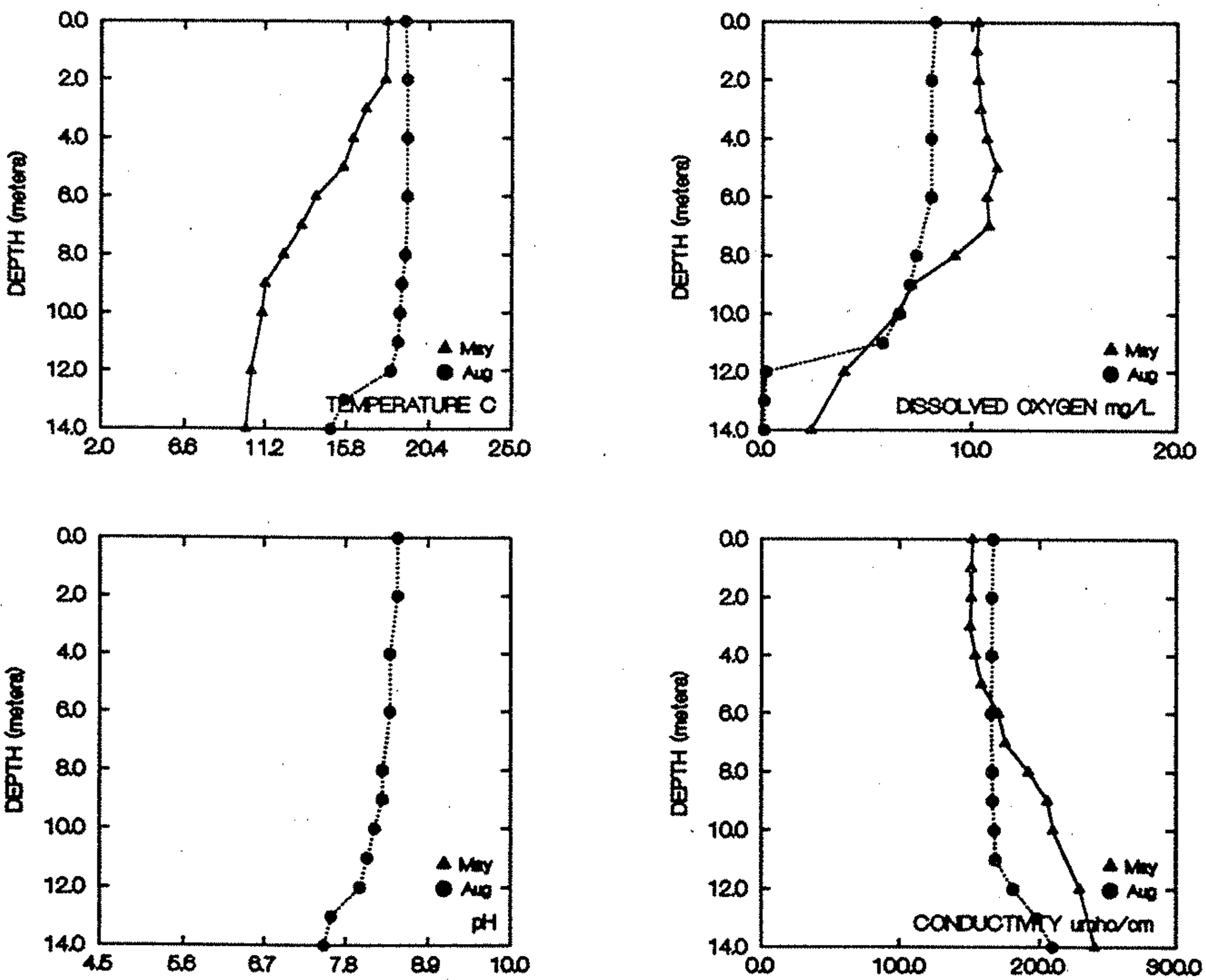
Line of equal
water depth
Interval 10 feet

Evergreen Lake, Grant County. From
U.S. Geological Survey, March 10, 1975.

1993 Onsite Visit Data - Water Chemistry

Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/06/11		E	36	(Source: Water Supply Bulletin 43)					
93/05/20	1	E	25	0.13	2.2				
93/05/20	1	H	28	0.29					
93/08/26	1	E	23	0.20	5.1				
93/08/26	1	H	188	0.64					

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program



Florence Lake -- Pierce County

Size (acres)	67
Maximum Depth (feet)	31
Mean Depth (feet)	19
Lake Volume (acre-feet)	1280
Drainage Area (miles^2)	0.40
Altitude (feet)	197
Shoreline Length (miles)	2.04

Data From Dion *et al.* (1976)

No Map Available.

1993 Onsite Visit Data - Water Chemistry

Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/08/21		E	10	(Source: Water Supply Bulletin 43)					
93/06/02	1	E	18	0.31	3.0	1			
93/06/02	1	H	61	0.32					

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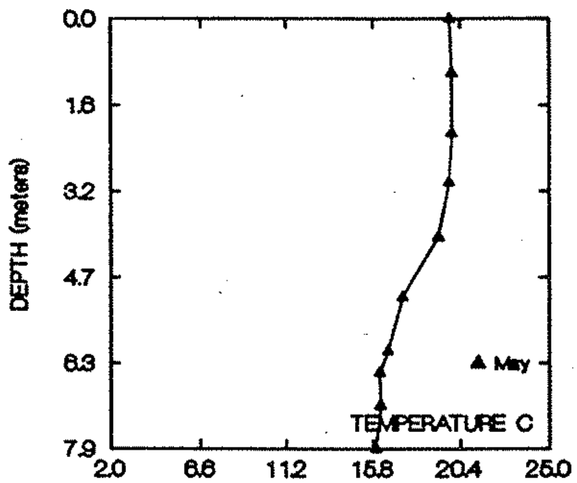
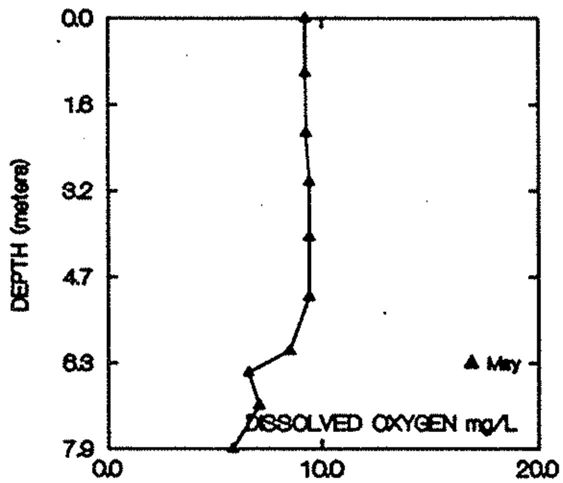
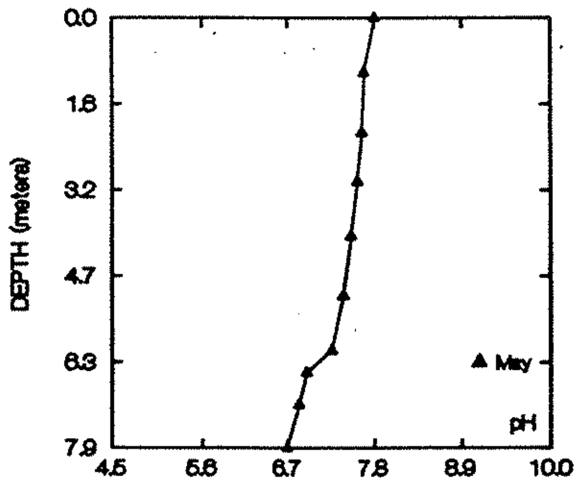
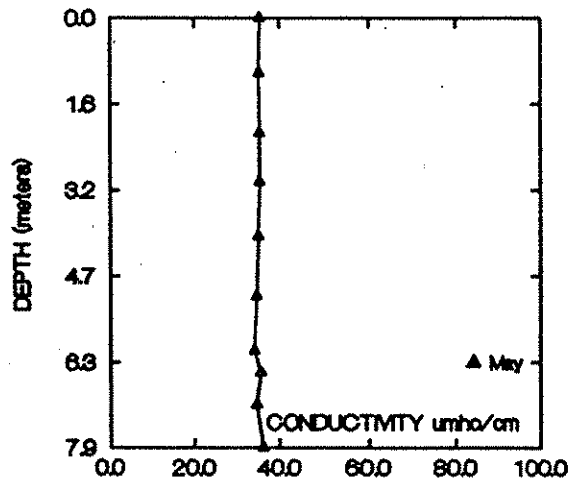
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program





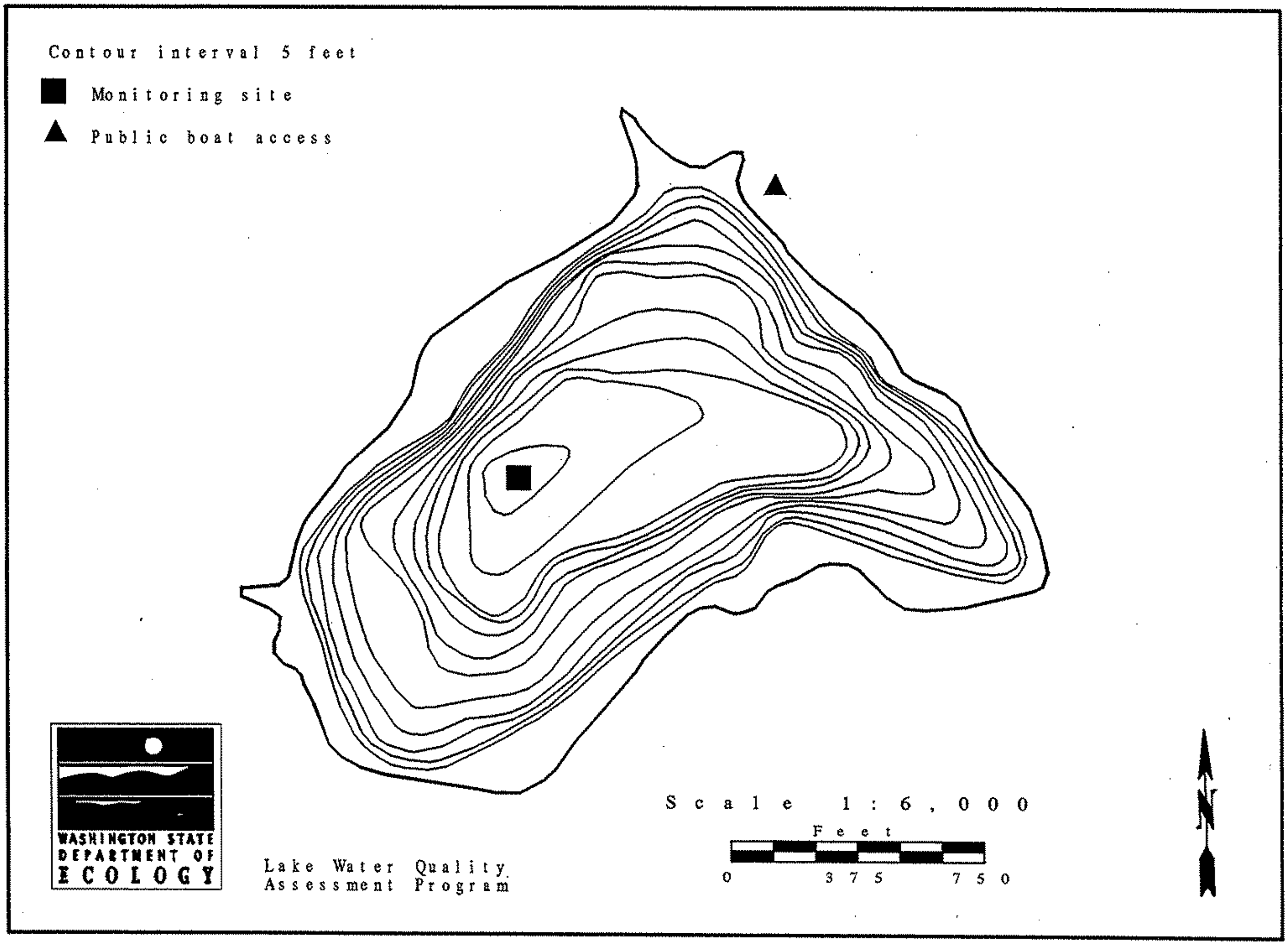




Goss Lake -- Island County

Size (acres)	47
Maximum Depth (feet)	60
Mean Depth (feet)	32
Lake Volume (acre-feet)	1500
Drainage Area (miles^2)	1.41
Altitude (feet)	130
Shoreline Length (miles)	1.19

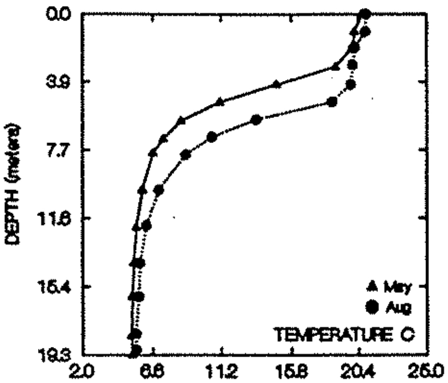
Data From Dion *et al.* (1976)

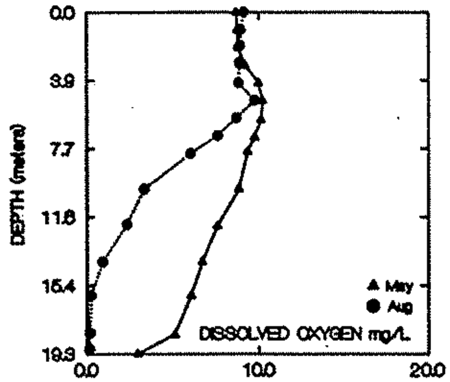


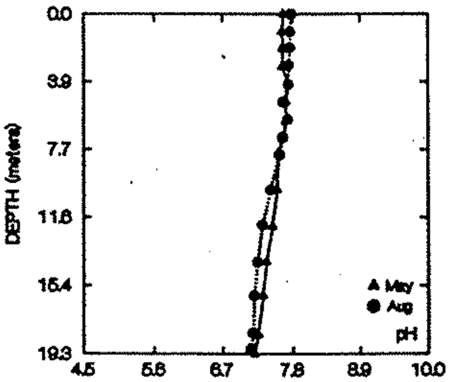
1993 Onsite Visit Data - Water Chemistry

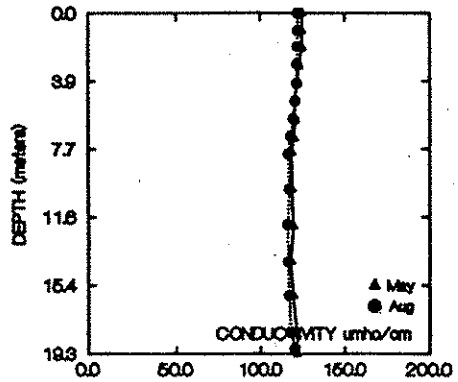
Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
73/06/26		E	11	(Source: Water Supply Bulletin 43)					
89/06/26	1	E	10	0.41	2.0				
89/09/25	1	E	10	0.48	1.1				
90/06/28	1	E	0.51						
91/05/28	1	E	0.69						
93/05/29	1	E	22	0.29	0.7				
93/05/29	1	H	14	0.38					
93/08/29	1	E	3U	0.29	1.8				
93/08/29	1	H	7	0.37					

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program





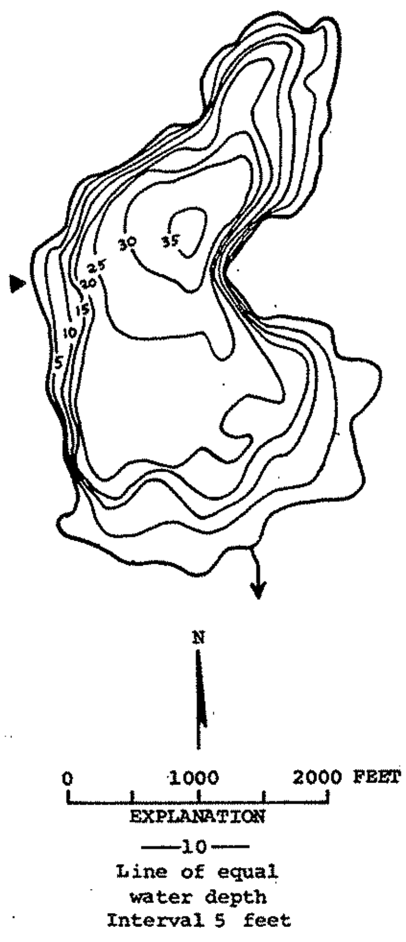




Hicks Lake -- Thurston County

Size (acres)	160
Maximum Depth (feet)	35
Mean Depth (feet)	18
Lake Volume (acre-feet)	2700
Drainage Area ($miles^2$)	1.80
Altitude (feet)	162
Shoreline Length (miles)	2.44

Data From Dion *et al.* (1976)

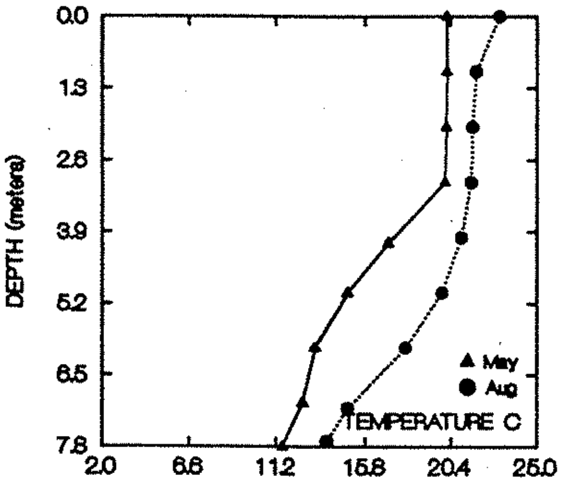


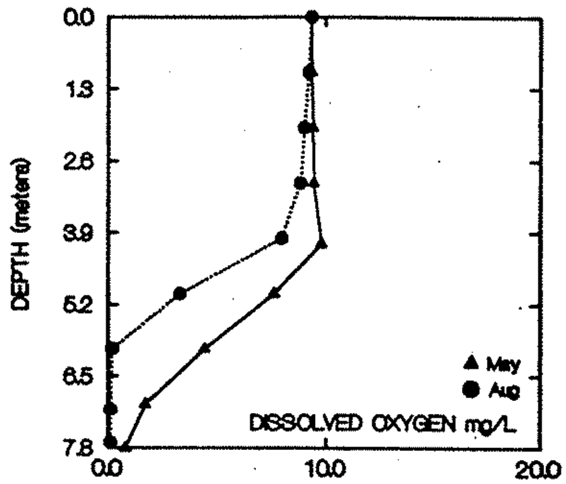
Hicks Lake, Thurston County. From Washington Department of Game, June 12, 1949.

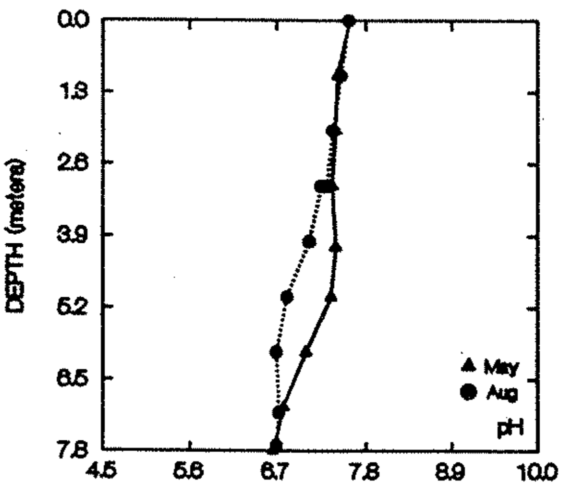
1993 Onsite Visit Data - Water Chemistry

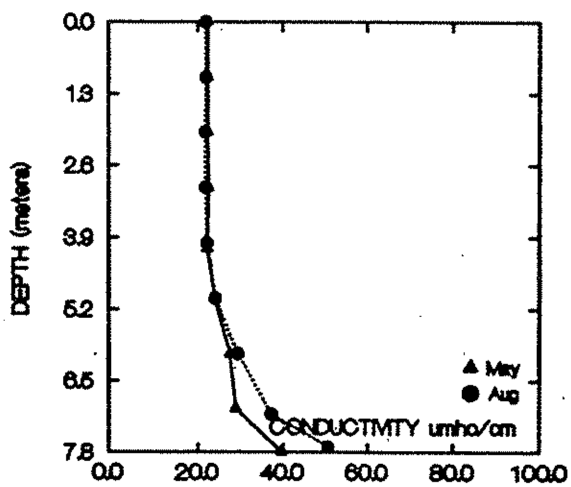
Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
72/06/27		E	20		(Source: Water Supply Bulletin 43)				
81/07/21		E	20	7.7	(Source: Water Supply Bulletin 57)				
90/06/07	1	E	14	0.28					
90/08/17	1	E	17	0.36					
93/06/01	1	E	23	0.40	5.2	3	14		
93/06/01	1	H	39	0.47					
93/09/07	1	E	20	0.38	3.3				
93/09/07	1	H	39	0.39					

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program





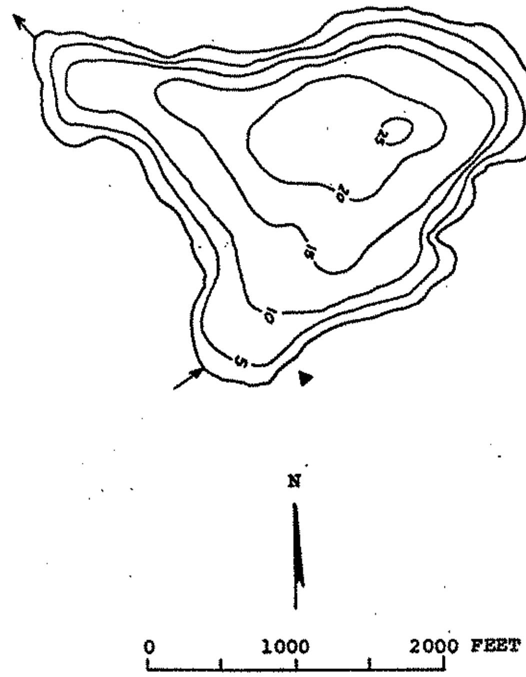




Jumpoff Joe Lake -- Stevens County

Size (acres)	110
Maximum Depth (feet)	25
Mean Depth (feet)	13
Lake Volume (acre-feet)	1420
Drainage Area (miles^2)	15.30
Altitude (feet)	2031
Shoreline Length (miles)	1.95

Data From Dion *et al.* (1976)



EXPLANATION

—— 10 ——

Line of equal water depth

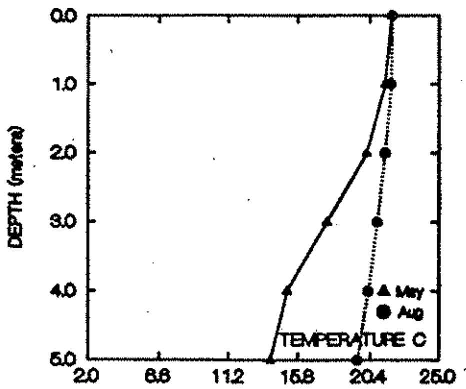
Interval 5 feet

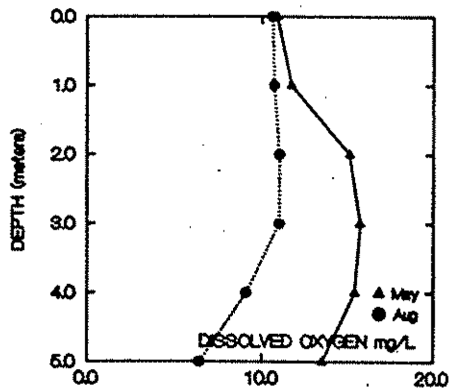
Jumpoff Joe Lake, Stevens County. From Washington Department of Game, date unknown.

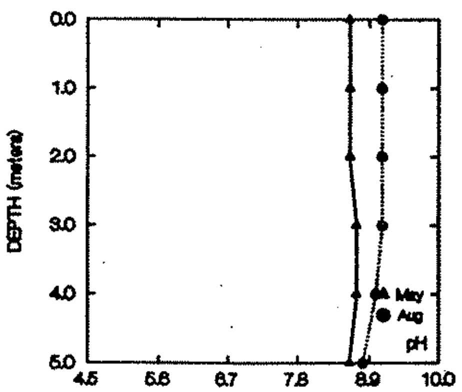
1993 Onsite Visit Data - Water Chemistry

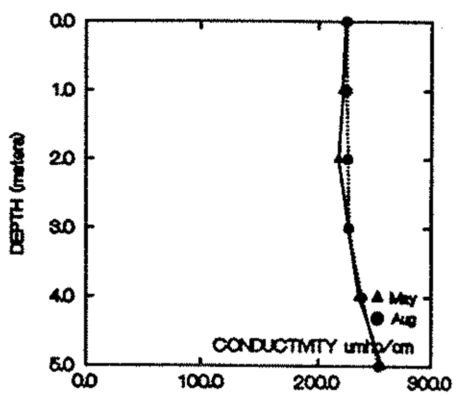
Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)	Color (Pt-Co)
74/07/08		E	14	(Source: Water Supply Bulletin 43)						
89/06/20	1	E	13	0.29	2.6					
89/09/19	1	E	17	0.44	4.6					
92/05/12	1	E	10	0.26	0.8	1U	1U	2	1	20
92/05/12	1	H								
92/08/25	1	E	19	0.55	5.6	1U	1U	5	2	10
92/08/25	1	H								
93/05/19	1	E	21	0.26	2.2	4	1U			
93/05/19	1	H	24							
93/08/20	1	E	21	0.27	5.9					

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program









Keechelus Lake -- Kittitas County

Size (acres)	2600
Maximum Depth (feet)	310
Mean Depth (feet)	96
Lake Volume (acre-feet)	249000
Drainage Area (miles^2)	54.70
Altitude (feet)	2517
Shoreline Length (miles)	14.3

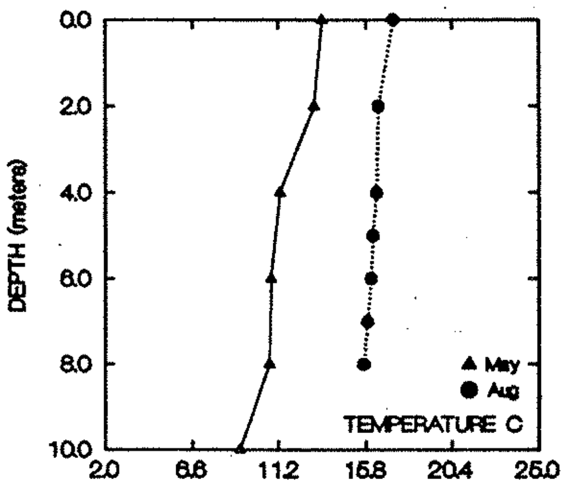
Data From Dion *et al.* (1976)

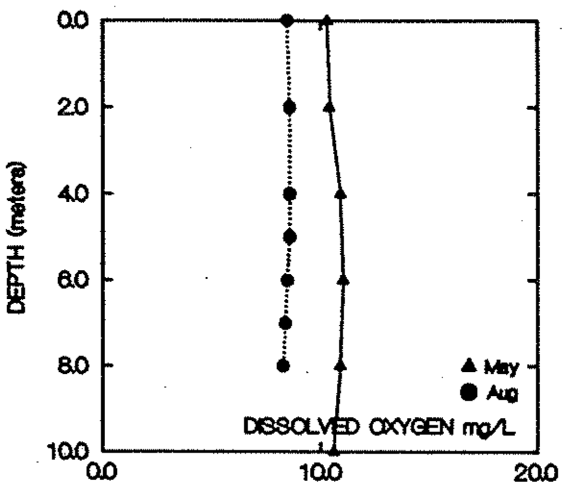
No Map Available.

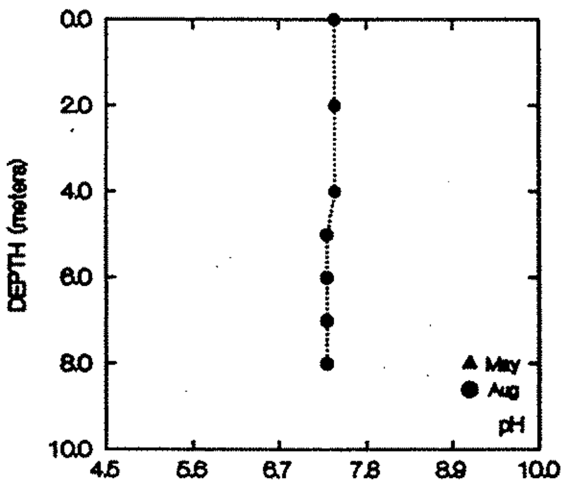
1993 Onsite Visit Data - Water Chemistry

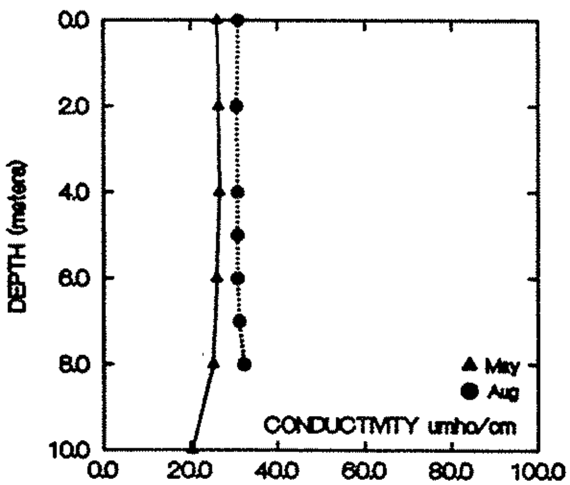
Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/07/30		E	2	(Source: Water Supply Bulletin 43)					
93/06/01	1	E	13	0.12	1.8	1U	1		
93/06/01	1	H	92	0.10					
93/08/29	1	E	8	0.11	2.6	1U	1U		
93/08/29	2	E							

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program









Leech Lake -- Yakima County

Size (acres)	41
Maximum Depth (feet)	15
Mean Depth (feet)	0
Lake Volume (acre-feet)	0
Drainage Area (miles^2)	
Altitude (feet)	4412
Shoreline Length (miles)	0

Data From Dion *et al.* (1976)

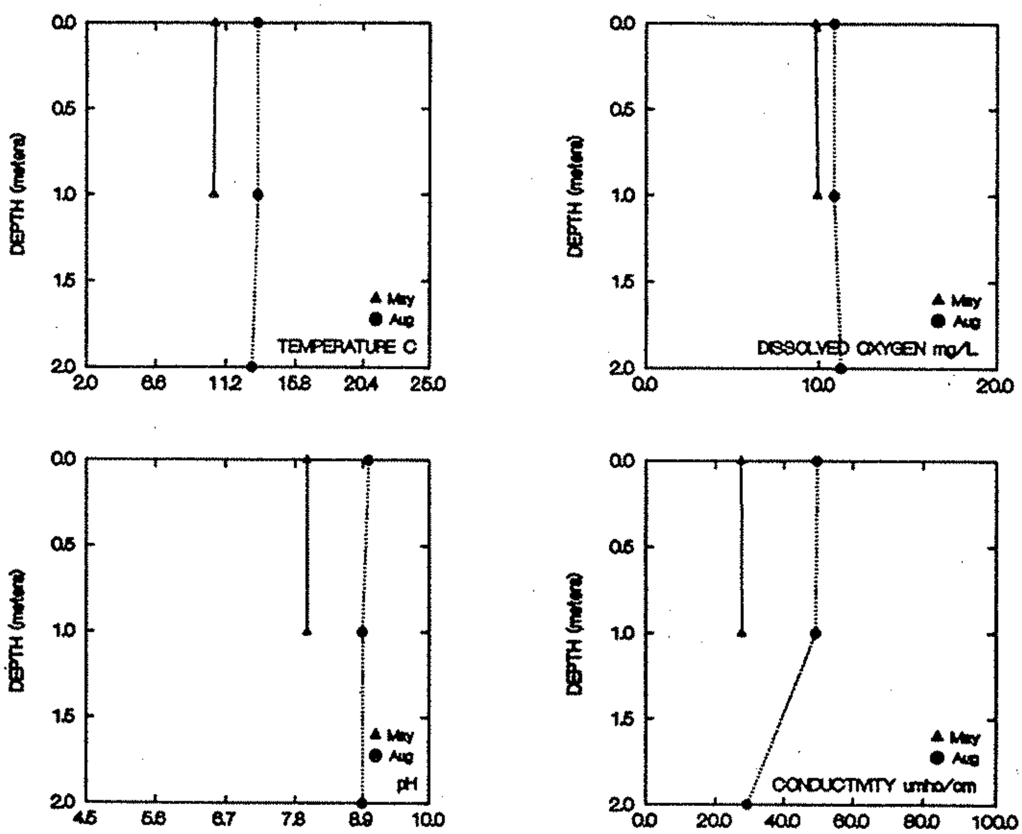
No Map Available.

Leech Lake -- Yakima County

1993 Onsite Visit Data - Water Chemistry

Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Fecal Coliform Bacteria (colonies/100 mL) Site 2	Suspended Solids Total (mg/L)	Suspended Solids Non-Volatile (mg/L)
90/06/08		E	11	0.16					
90/06/19	1	E	0.06	0.6					
90/08/31	1	E	19	0.35					
90/09/18	1	E	22	0.28	1.1				
92/04/30	1	E	12	0.17					
92/04/30	1	H							
92/08/23	1	E	12	0.26	0.8	1U	1		
92/08/23	1	E							
93/06/03	1	E	13	0.14	1.3				
93/08/30	1	E	16	3.9	1U	1			

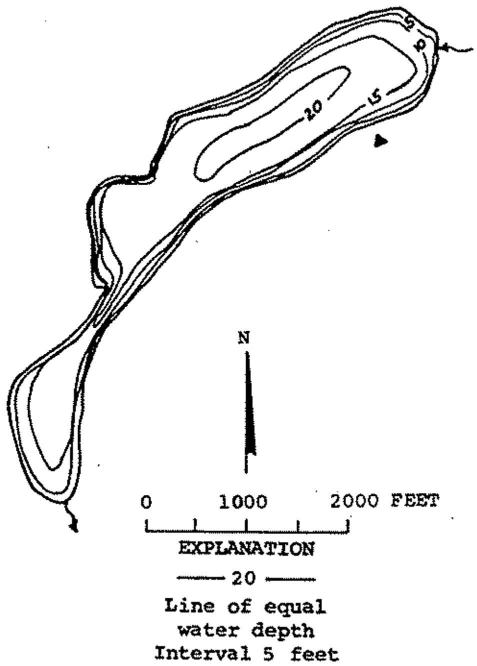
E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program



Leland Lake -- Jefferson County

Size (acres)	107
Maximum Depth (feet)	20
Mean Depth (feet)	13
Lake Volume (acre-feet)	1415
Drainage Area (miles^2)	5.71
Altitude (feet)	190
Shoreline Length (miles)	2.75

Data From Dion *et al.* (1976)

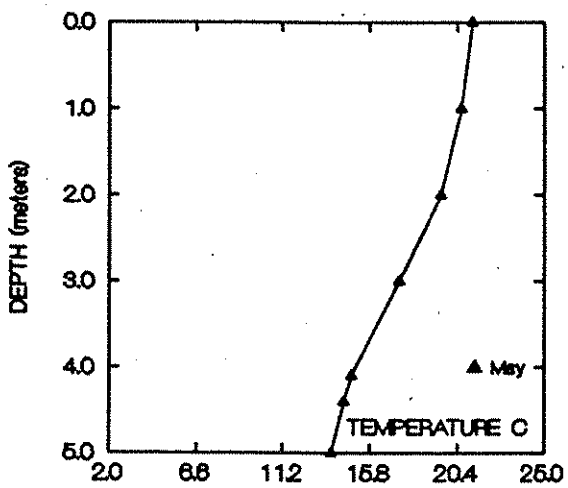


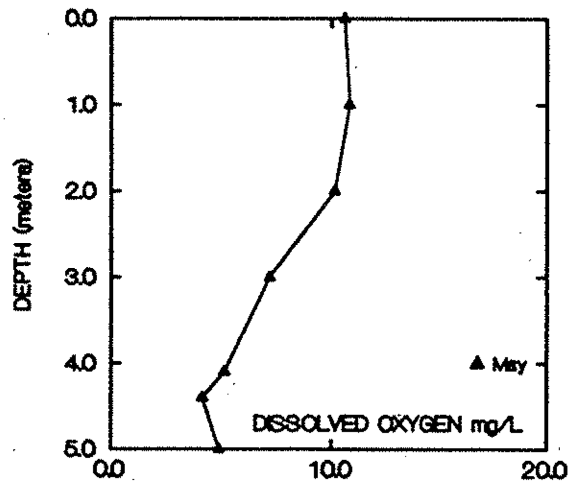
Leland Lake, Jefferson County. From Washington Department of Game, June 19, 1952.

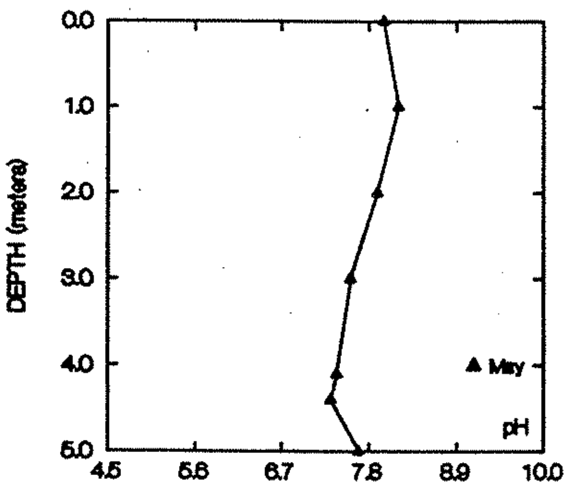
1993 Onsite Visit Data - Water Chemistry

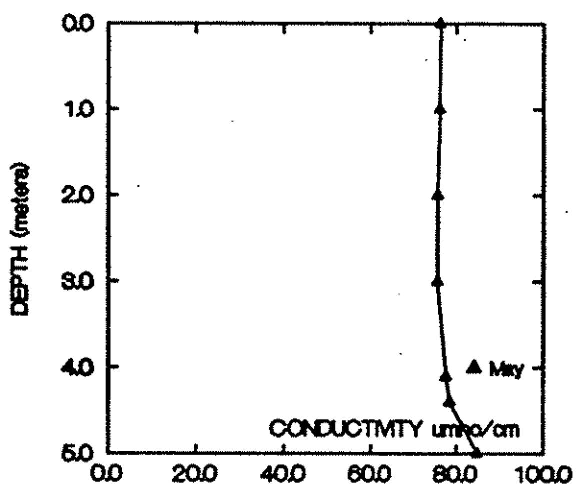
Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/08/05		E	61		(Source: Water Supply Bulletin 43)				
81/07/02		E	60	5.7	(Source: Water Supply Bulletin 57)				
93/05/30	1	E	40	0.69	27.2				
93/05/30	1	H	43	0.70					

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program





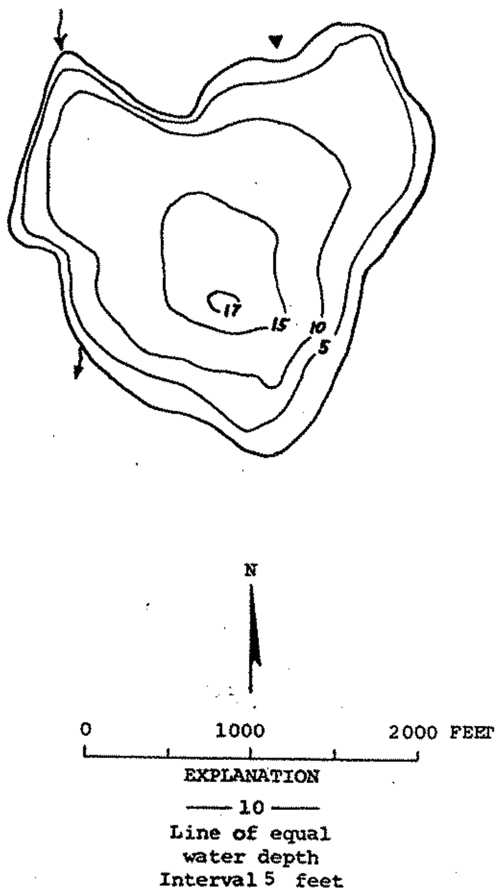




Lone Lake -- Island County

Size (acres)	101
Maximum Depth (feet)	17
Mean Depth (feet)	9
Lake Volume (acre-feet)	924
Drainage Area (miles^2)	2.80
Altitude (feet)	17
Shoreline Length (miles)	1.64

Data From Dion *et al.* (1976)

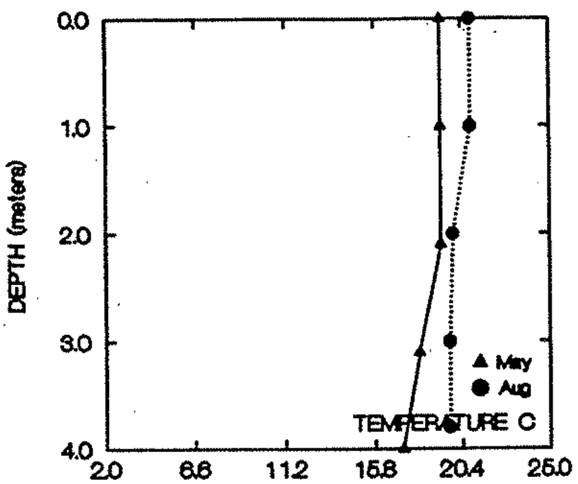


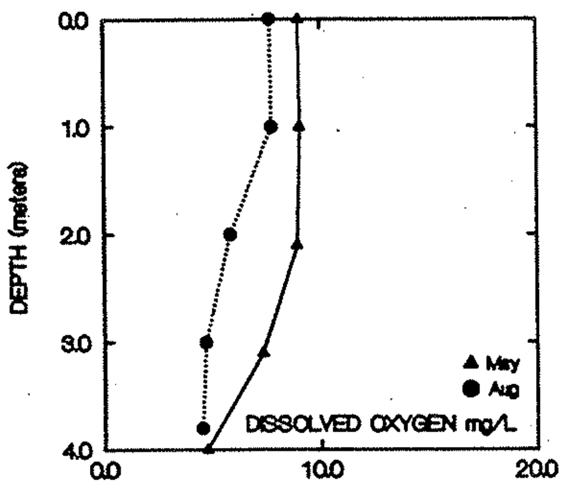
Lone Lake -- Island County

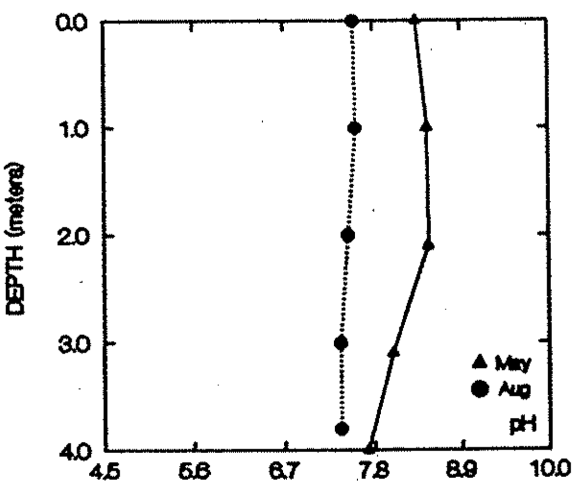
1993 Onsite Visit Data - Water Chemistry

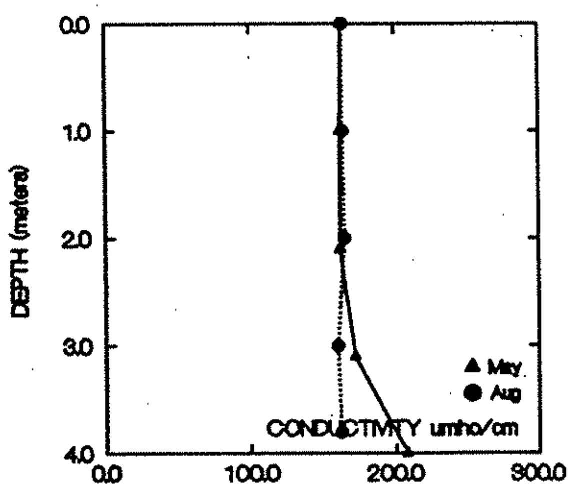
Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/08/05		E	75	(Source: Water Supply Bulletin 43)					
89/06/06	1	E	41	0.99	8.7				
89/09/05	1	E	61	1.07	21.3				
93/06/11	1	E	29	0.83	5.9				
93/08/29	1	E	41	0.88	4.4				

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program





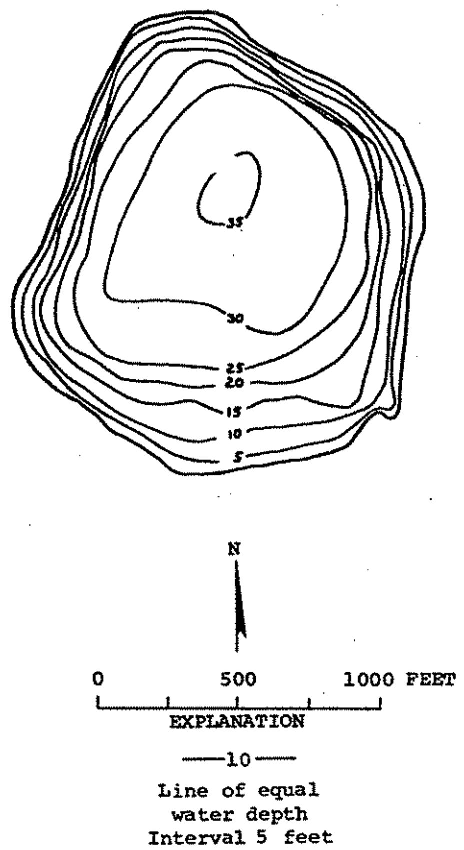




Lake Louise -- Pierce County

Size (acres)	39
Maximum Depth (feet)	35
Mean Depth (feet)	22
Lake Volume (acre-feet)	860
Drainage Area (miles^2)	0.34
Altitude (feet)	230
Shoreline Length (miles)	0.91

Data From Dion *et al.* (1976)

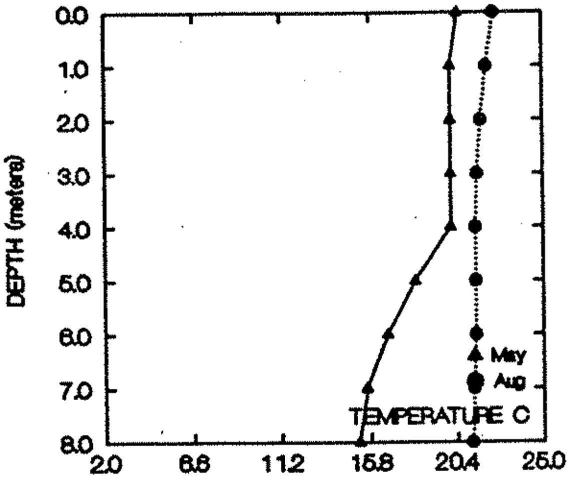


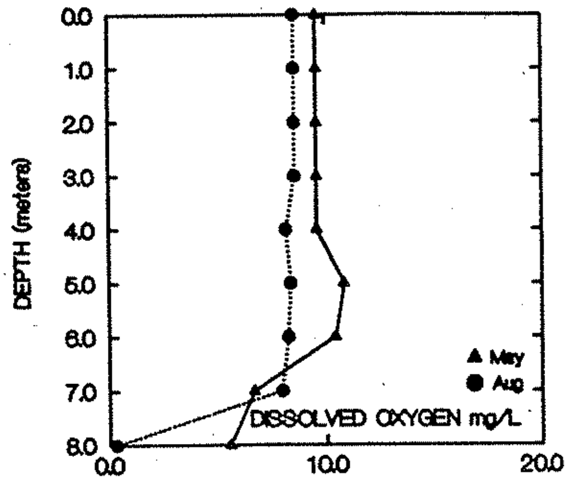
Louise Lake, Pierce County. From Washington Department of Game, June 5, 1950.

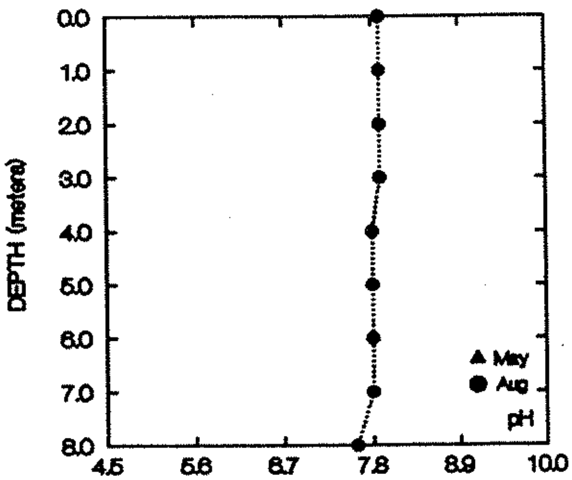
1993 Onsite Visit Data - Water Chemistry

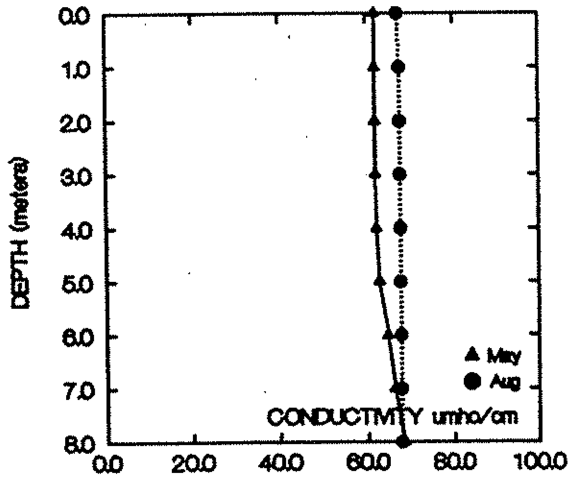
Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
73/06/18		E	9	(Source: Water Supply Bulletin 43)					
81/06/24		E	20	(Source: Water Supply Bulletin 57)					
90/06/01	1	E	15	0.42					
90/08/24	1	E	12	0.31					
93/06/05	1	E	11	0.18					
93/06/05	1	H	7	0.18					
93/08/31	1	E	13	0.25	2.7	4			
93/08/31	1	H	15	0.25					

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program









Mayfield Lake -- Lewis County

Size (acres)	2200
Maximum Depth (feet)	180
Mean Depth (feet)	61
Lake Volume (acre-feet)	134000
Drainage Area ($miles^2$)	1399.00
Altitude (feet)	450
Shoreline Length (miles)	33.52

Data From Dion *et al.* (1976)

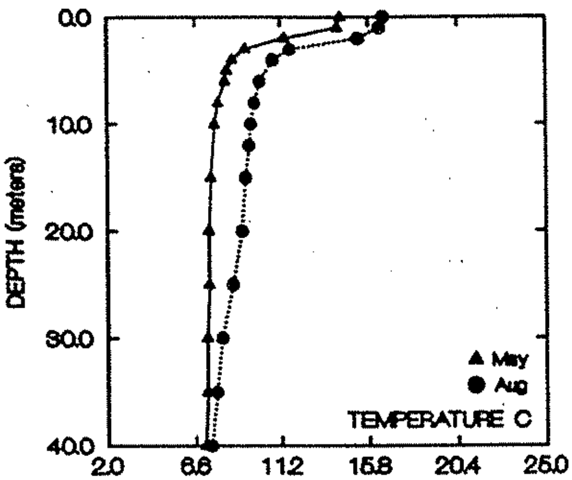
No Map Available.

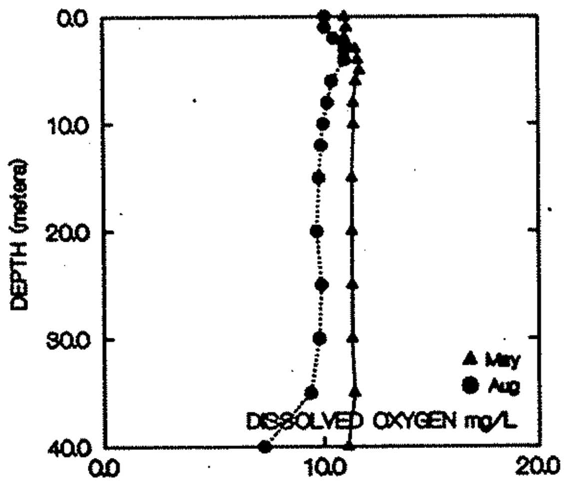
Mayfield Lake -- Lewis County

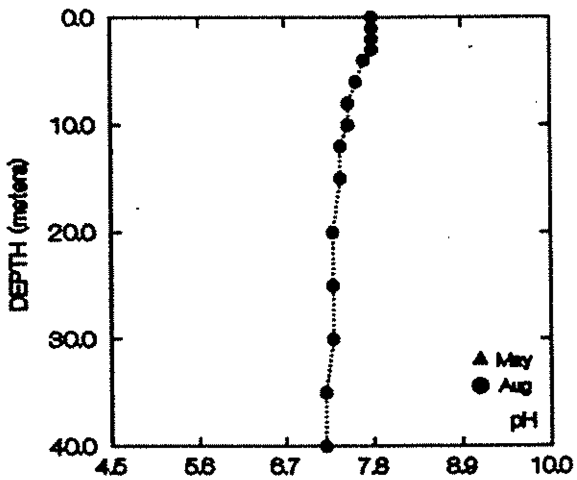
1993 Onsite Visit Data - Water Chemistry

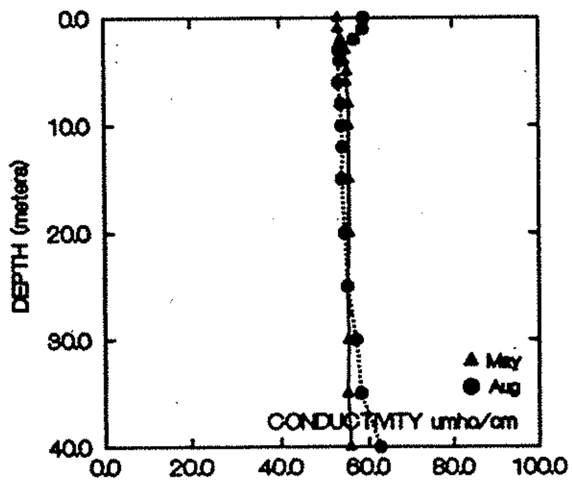
Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Fecal Coliform Bacteria (colonies/100 mL) Site 2	Suspended Solids Total (mg/L)	Suspended Solids Non-Volatile (mg/L)
74/09/09		E	4	(Source: Water Supply Bulletin 43)					
90/05/25	1	E	17	0.24					
93/06/04	1	E	31	0.19	3.5				
93/06/04	1	H	14	0.10					
93/08/30	1	E	5	0.13	2.6	9	2		
93/08/30	1	H	4	0.13					

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program





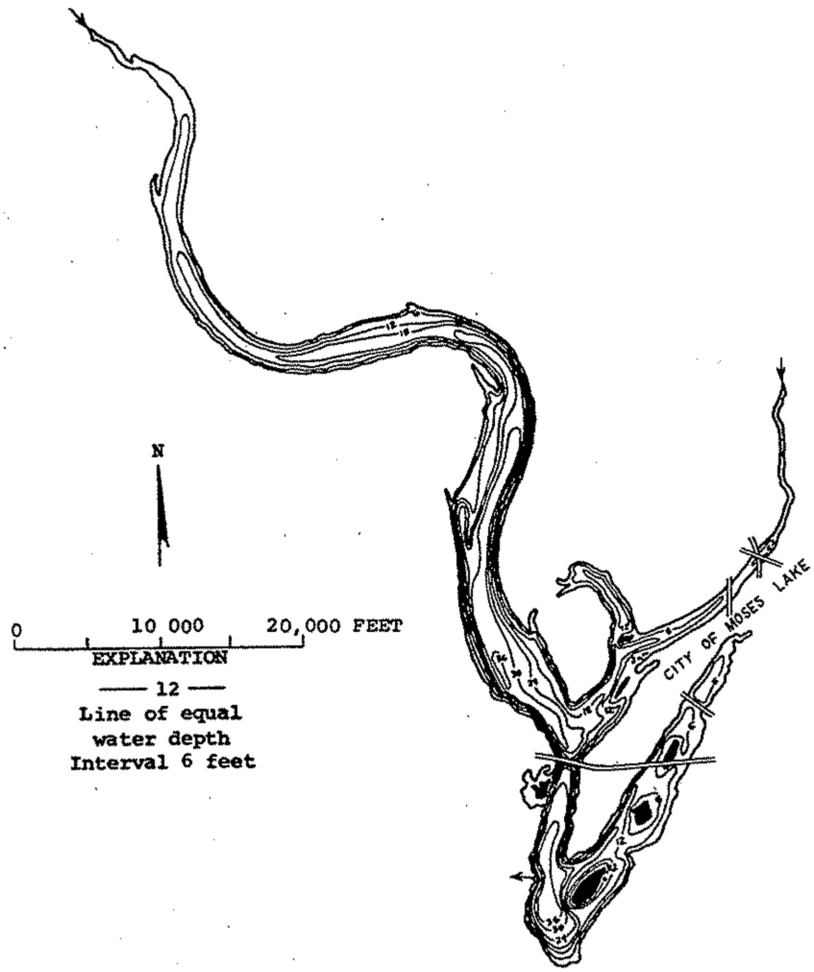




Moses Lake -- Grant County

Size (acres)	6800
Maximum Depth (feet)	38
Mean Depth (feet)	19
Lake Volume (acre-feet)	131000
Drainage Area (miles^2)	3080.00
Altitude (feet)	1046
Shoreline Length (miles)	62.31

Data From Dion *et al.* (1976)

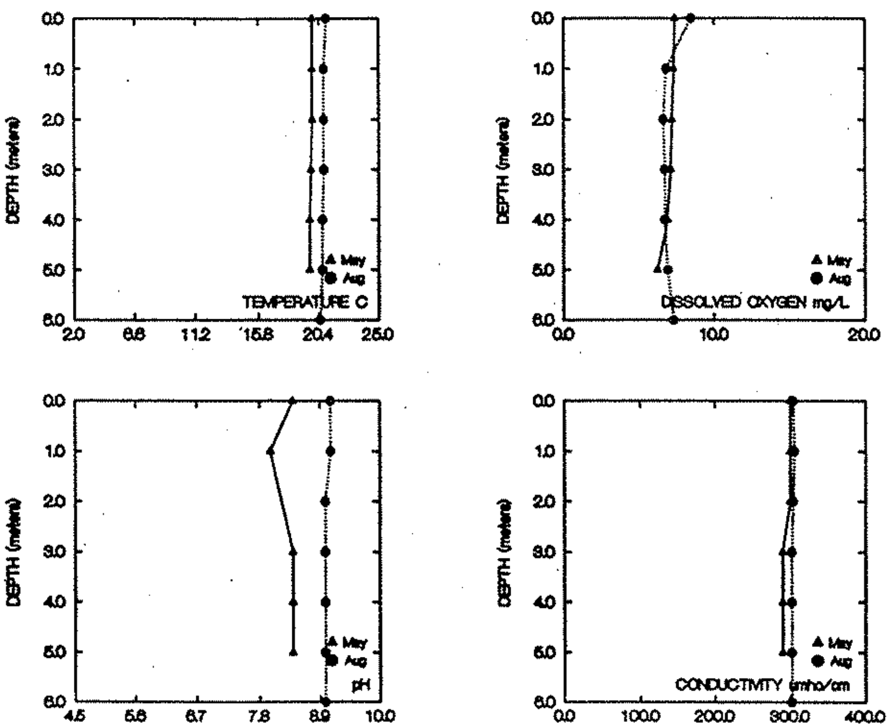


Moses Lake, Grant County. From University of Washington, August 1963.

1993 Onsite Visit Data - Water Chemistry

Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/06/12		E	120	(Source: Water Supply Bulletin 43)					
90/05/22	1	E	23	0.27					
90/08/23	1	E	66	0.61					
93/06/02	1	E	50	0.44	3.1	1U	1U		
93/06/02	2	E	47	0.34	3.3	6	5		
93/06/02	3	E	48	0.40	7.4	1	2		
93/06/02	1	H							
93/06/02	1	H							
93/06/02	1	H							
93/08/25	1	E	48	1.90	57.7				
93/08/25	2	E	151	1.34	57.9	1	1		
93/08/25	3	E	104	0.96	54.4				

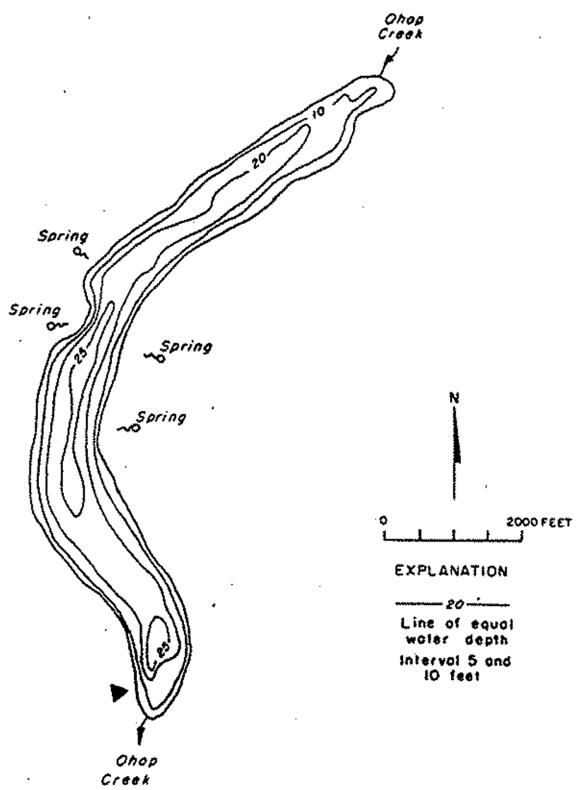
E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program



Ohop Lake -- Pierce County

Size (acres)	230
Maximum Depth (feet)	25
Mean Depth (feet)	17
Lake Volume (acre-feet)	3800
Drainage Area (miles^2)	17.30
Altitude (feet)	524
Shoreline Length (miles)	4.56

Data From Dion *et al.* (1976)



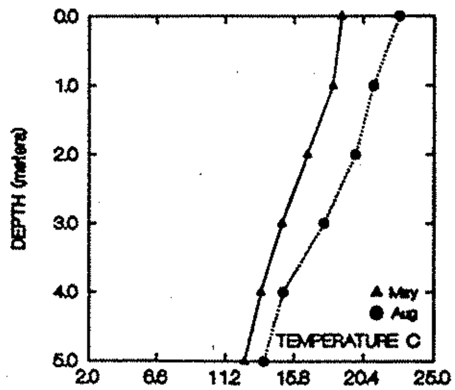
Ohop Lake, Pierce County. From Washington Department of Game, June 14, 1954.

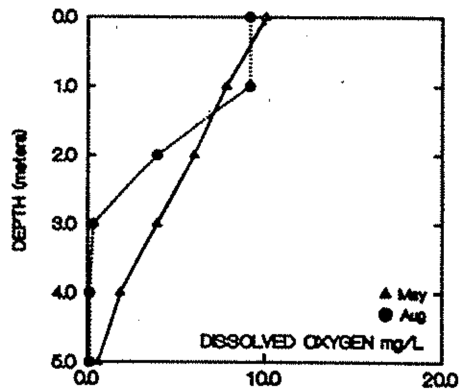
Ohop Lake -- Pierce County

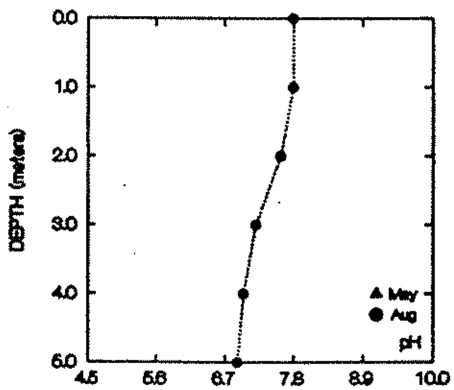
1993 Onsite Visit Data - Water Chemistry

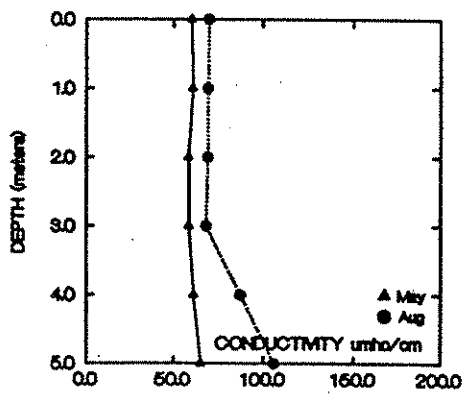
Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/08/26		E	30		(Source: Water Supply Bulletin 43)				
81/06/03		E	60	16.8	(Source: Water Supply Bulletin 57)				
90/06/02	1	E	31						
90/08/17	1	E	37	0.39					
93/06/03	1	E	34	0.66	7.1	4	3		
93/08/31	1	E	36	0.46	15.9	5	5		
93/08/31	1	H	152	0.65					

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program





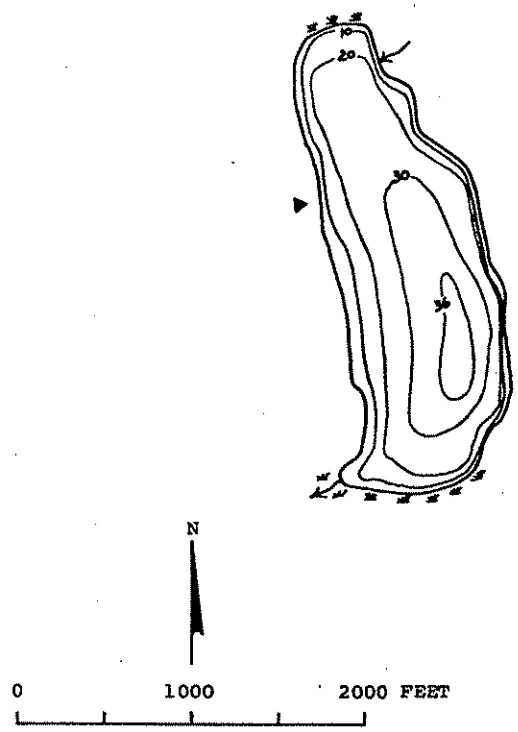




Panther Lake -- Snohomish County

Size (acres)	48
Maximum Depth (feet)	36
Mean Depth (feet)	23
Lake Volume (acre-feet)	1101
Drainage Area (miles^2)	0.82
Altitude (feet)	455
Shoreline Length (miles)	1.27

Data From Dion *et al.* (1976)



EXPLANATION

—— 20 ——

Line of equal
water depth
Interval 10 feet

Panther Lake, Snohomish County. From Washington Department of Game, January 24, 1949.

Panther Lake -- Snohomish County

1993 Onsite Visit Data - Water Chemistry

Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
73/08/03		E	13	(Source: Water Supply Bulletin 43)					
90/06/06	1	E	13	0.67					
90/08/30	1	E	17	0.37					
93/05/26	1	E	11	0.59	1.5				
93/05/26	1	H	9	0.65					
93/08/19	1	E	11	0.39	4.7				
93/08/19	1	H	17	0.42					

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program

Potholes Lake -- Grant County

Size (acres)	28000
Maximum Depth (feet)	142
Mean Depth (feet)	18
Lake Volume (acre-feet)	500000
Drainage Area (miles^2)	**
Altitude (feet)	1046
Shoreline Length (miles)	0

Data From Dion *et al.* (1976)

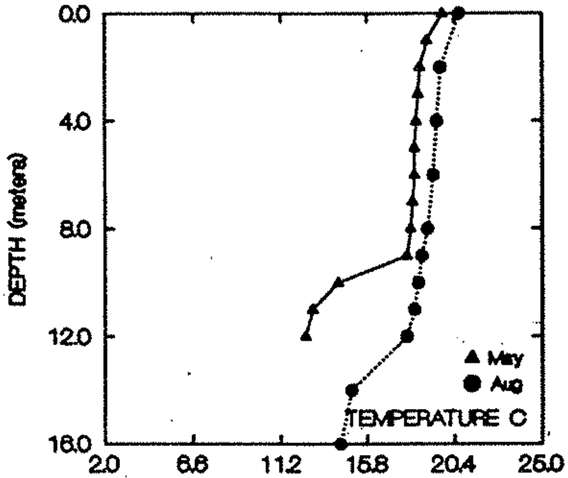
No Map Available.

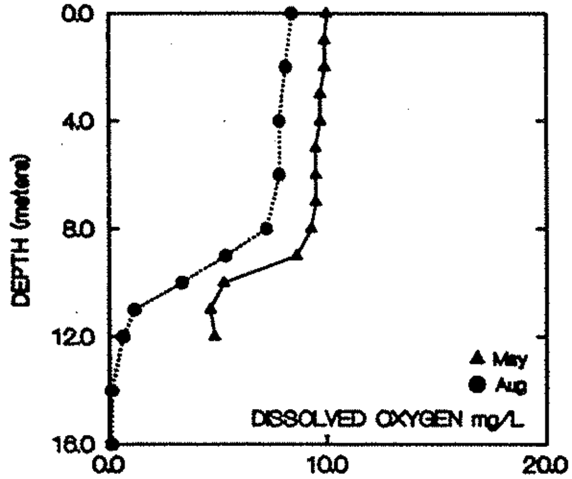
Potholes Lake -- Grant County

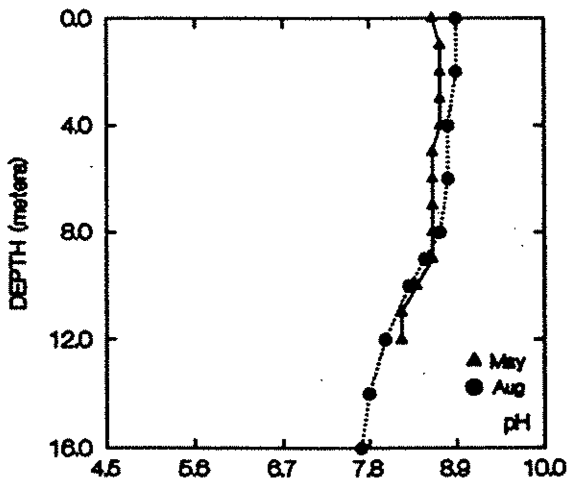
1993 Onsite Visit Data - Water Chemistry

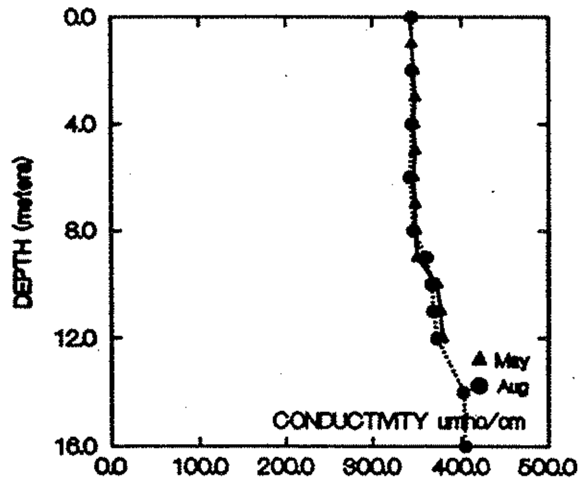
Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/06/12		E	67	(Source: Water Supply Bulletin 43)					
93/06/02	1	E	37	1.17	5.1	3	1		
93/06/02	2	E	39	1.16	4.4				
93/08/25	1	E	37	0.85	19.1	4	3		
93/08/25	1	H	210	1.67	4	1U			

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program





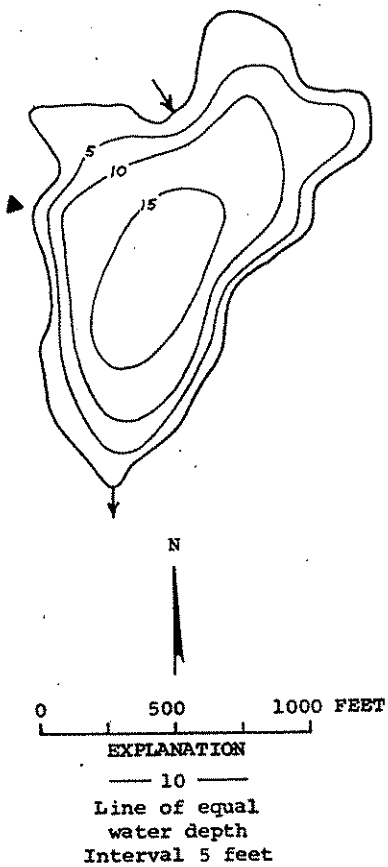




S. Skookum Lake -- Pend Oreille County

Size (acres)	33
Maximum Depth (feet)	15
Mean Depth (feet)	9
Lake Volume (acre-feet)	296
Drainage Area (miles^2)	6.04
Altitude (feet)	3525
Shoreline Length (miles)	0.97

Data From Dion *et al.* (1976)

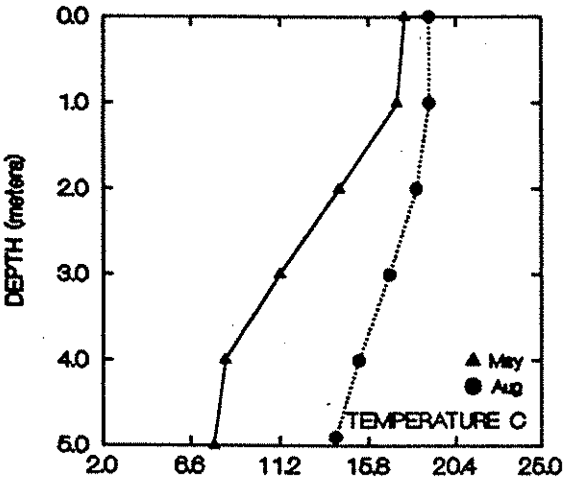


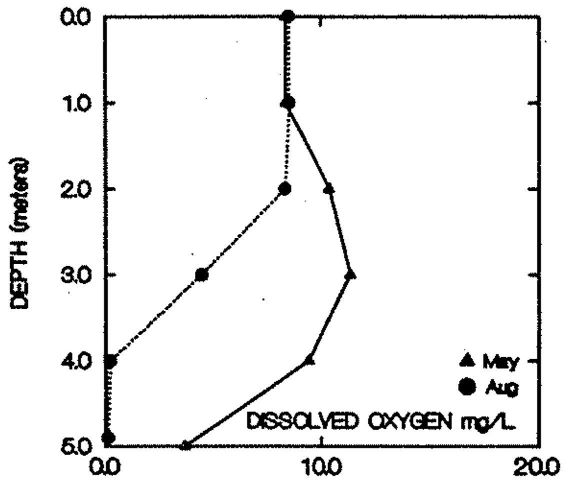
Skookum, South Lake, Pend Oreille County. From Washington Department of Game, December 29, 1956.

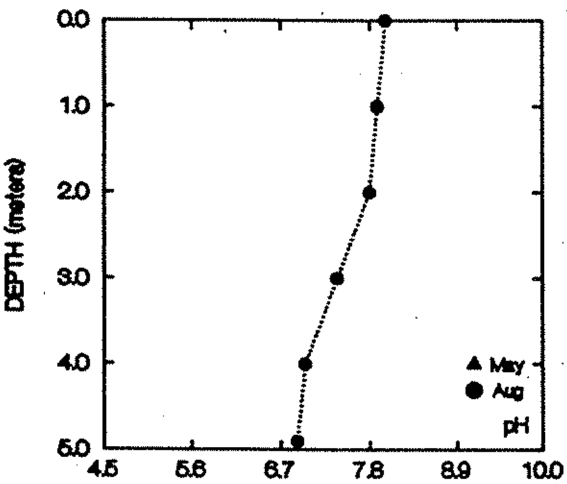
1993 Onsite Visit Data - Water Chemistry

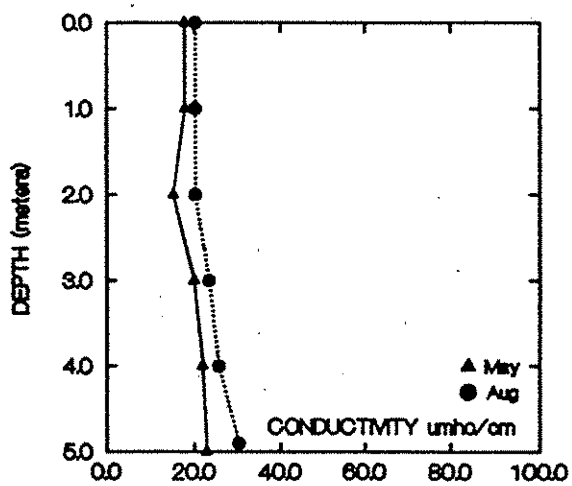
Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/07/10		E	17	(Source: Water Supply Bulletin 43)					
93/05/25	1	E	25	0.19	1.6	1	1		
93/05/25	1	H	42	0.51					
93/08/21	1	E	27	0.24	4.4	2	1U		
93/08/21	1	H	26	0.35					

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program





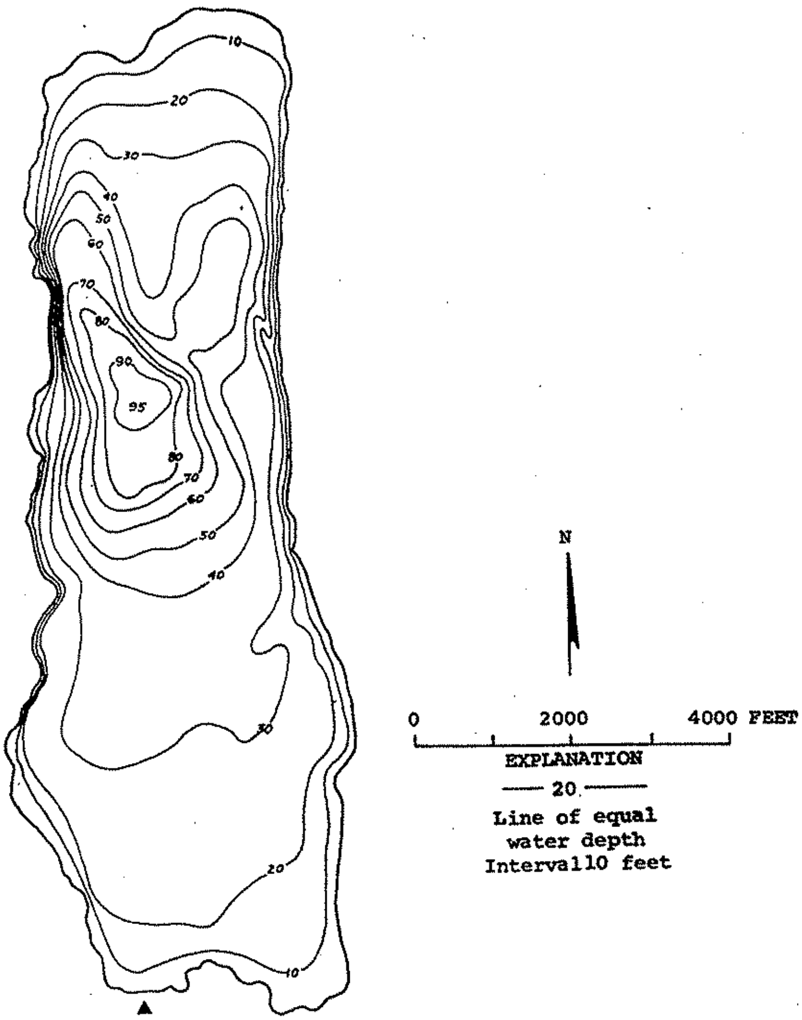




Soap Lake -- Grant County

Size (acres)	860
Maximum Depth (feet)	95
Mean Depth (feet)	33
Lake Volume (acre-feet)	28500
Drainage Area (miles^2)	413.00
Altitude (feet)	1076
Shoreline Length (miles)	5.68

Data From Dion *et al.* (1976)

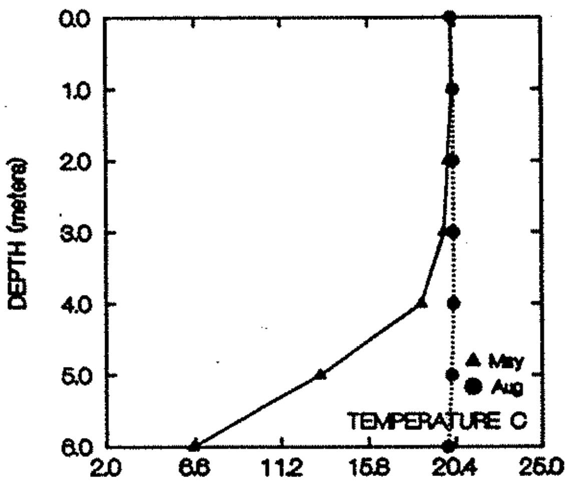


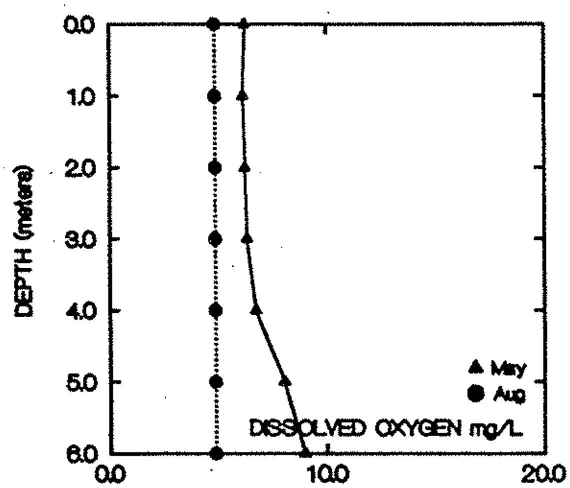
Soap Lake, Grant County. From
U.S. Bureau of Reclamation, August 1955.

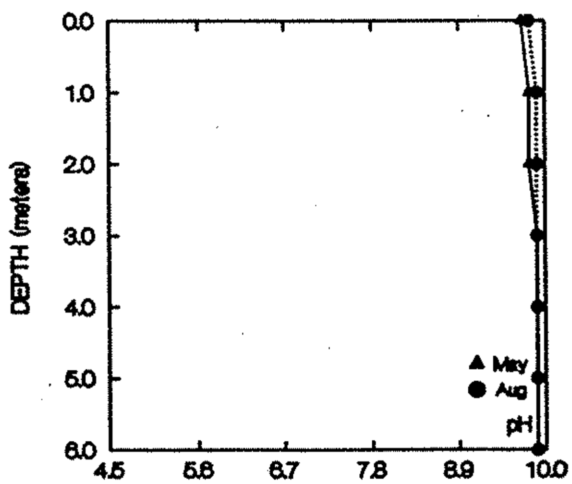
1993 Onsite Visit Data - Water Chemistry

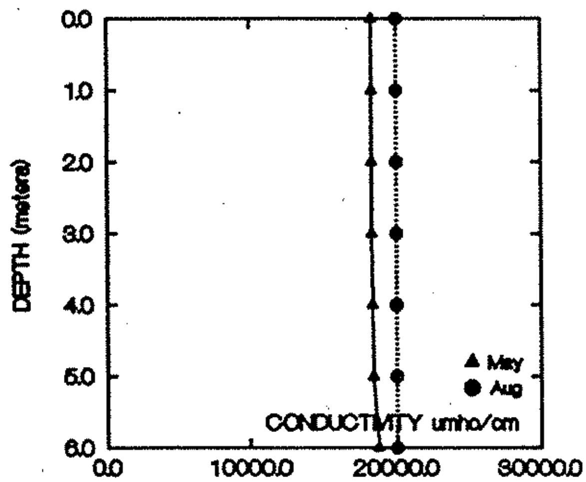
Date	Sta	Strata	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Fecal Coliform Bacteria (colonies/100 mL) Site 1	Site 2	Suspended Solids Total (mg/L)	Non-Volatile (mg/L)
74/06/06		E	520	(Source: Water Supply Bulletin 43)					
93/05/20	1	E	514	1.75	1.3	1U	1U		
93/05/20	1	H	540	1.71					
93/08/25	1	E	559	0.48	0.8	1U			
93/08/25	2	E							

E=epilimnion composite, H=hypolimnion composite
Remarks codes: U = Below detection limits; J = Estimate.
Unless source is specified, data are from Ecology's Lake Water Quality Assessment Program









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Appendix A

Data Reporting Cards Used by Volunteers

Appendix A. Data Reporting Cards Used by Volunteers

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

Appendix B

Materials and Methods Used to Build Viewing Tubes

Materials and Methods Used to Make View Tubes

MATERIALS

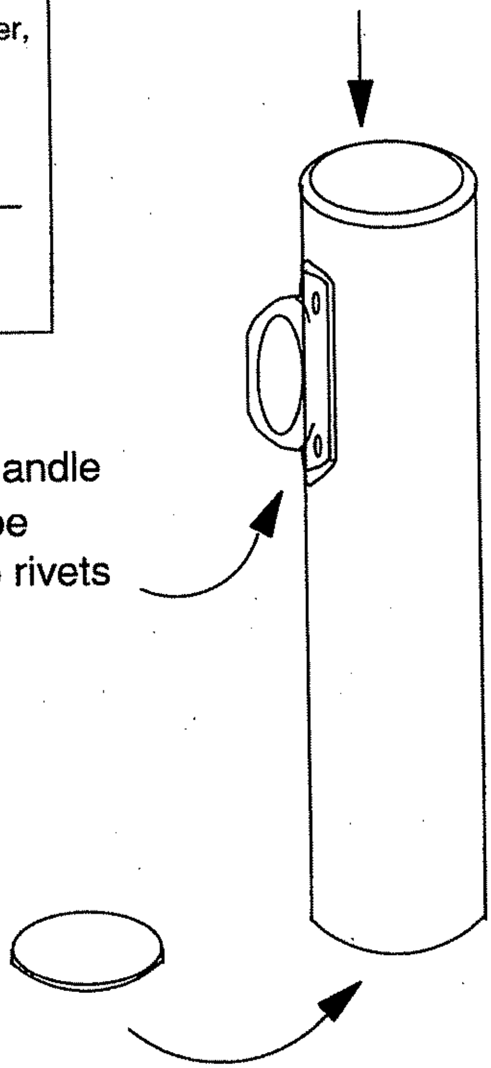
1. 4" diameter black PVC pipe*
   cut into 28" lengths
2. drawer pulls with holes for rivets
3. pop rivets (to fit holes in handles)
   and rivet gun
4. sandpaper
5. 1/4" clear plastic disks, 3 15/16" diameter,
   edge unfinished (order from plastic
   supply store)
6. silicone caulk and caulking gun

---

* if white PVC is used, paint inside of tube
evenly with flat black paint.

Sand rough ends
of PVC pipe

(wipe off plastic dust)



fasten handle
to tube
with pop rivets

use silicone caulk
to fasten acrylic disk
to bottom of tube

allow 1-2 weeks to dry

Appendix C

1993 Questionnaire on Lake and Watershed Uses

WASHINGTON'S CITIZEN LAKE MONITORING PROJECT
1993 QUESTIONNAIRE

Your Name ______________________ Date ______________

Lake/County ______________________

- o Please complete and return this questionnaire by October 29, 1993. If you will be late returning this questionnaire, please mail it to the new address listed below.
- o Remember to continue collecting Secchi data, every two weeks, until mid-October
- o If you aren't sure how to answer a question, contact Julie at (206) 586-5496.
- o **Thanks for your time spent on this!**

<u>NOTE:</u> Ecology employees in Olympia will be moving to a new building, so addresses and phone numbers will be changing. As of November 1, 1993, Julie's phone number will be (206) 407-6680, and all mail for Washington's Citizen Lake Monitoring Project should be addressed to

Julie Rector
Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600.

General Lake Information

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. Was the lake treated with any chemicals this year?
   - ☐ Yes, for weed control
   - ☐ Yes, for algae control
   - ☐ Yes, for eliminating non-game fish
   - ☐ No
   - ☐ Don't Know

3. Did any lake management activities occur on your lake this year?
   - ☐ Yes, a mechanical harvester has been used
   - ☐ Yes, the lake has been chemically treated
   - ☐ Yes, the lake has been dredged this year
   - ☐ Yes, the lake was drawn down last winter
   - ☐ No management activities were pursued this year

4. Were fish stocked in the lake this year?
   - ☐ Yes (What species? ______________________________________)
   - ☐ No
   - ☐ Don't know

Lake Water Quality

5. 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

6. 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

7. Were there days when the lake had poor aesthetics?
   - ☐ Yes (About how many days out of the year? ____________)
   - ☐ No

8. 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

9. What have been the worst water quality problems on your lake in 1993? 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. Use "0" to indicate if any of the below were not an important problem in your lake.

____ Algae bloom
____ Odor from decaying algae
____ Aesthetics degraded
____ Excessive aquatic plant growth
____ Decaying plants
____ Bacteria
____ Hazardous substance
____ Eye/skin problems after swimming
____ Swimmer's itch
____ Beach closure
____ Other ______________________________

____ High water level
____ Low water level
____ Fluctuating water level
____ Suspended sediments
____ Shoreline erosion
____ Water quality gradually degraded over years
____ Recently degraded water quality
____ Fish kill
____ Impaired fisheries

10. What do you see as the predominant source(s) of actual or potential water quality problems in your lake (if a problem or potential problem exists)? Use the back of Page 3 if you need more room.

____
____
____

11. Have there been any changes in your lake since last year's monitoring season?

____
____
____

12. Is there any other information that you would like to pass on about your lake?
____
____
____

Lake Organizations

13. Are there any lake groups for your lake?
- ☐ Lake Association
- ☐ Lake Management District
- ☐ Sewer District
- ☐ Community Association
- ☐ Other(s) ____________________________

Monitoring/Training

14. 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)

15. Do you have any suggestions for improving the data reports you have received from this program (if you've monitored your lake long enough to receive one)?
____
____
____

16. Did you enjoy participating in this project? (Please comment.)
____
____
____

17. 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 __________________________

18. Suggestions for improving the program for the 1994 sampling season:
____
____
____

19. Each year, we get requests from local reporters, county agencies, and other volunteers who want to talk to some of the volunteers in this program. May we have your permission to provide your name and phone number to these people?
- ☐ Yes
- ☐ No

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE!

Volunteers who entered the program prior to 1993 have already answered the following questions which appear on both sides of this page. Volunteers new in 1993: 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 D

Laboratory Quality Assurance/Quality Control Data for 1993

Appendix D. Laboratory Quality Assurance/Quality Control Data for 1993.

1993 Total Phosphorus Data (all results in µg/L)

Total Phosphorus Lab Splits

May

Lab Number	Results		CV%
219008	9	9	0
219064	42	42	0
219022	18	17	4
229007	15	15	0
229014	28	27	2.6
229031	11	12	6.1
229049	41	41	0
239028	45	44	1.6
249005	32	33	2.2
249011	37	36	1.9

RMS = 2.7%
Acceptable level = < 7.5%

August

Lab Number	Result 1		CV%
348704	6	5	12.9
348719	13	13	0
348775	3U	3U	--
348780	3U	3U	--
348790	20	20	0
348715	7	6	10.9
358726	20	20	0
358727	37	37	0
358756	12	13	5.7
358782	3U	3U	--
368720	5	6	12.9
378708	4	4	0
378709	12	12	0
378710	15	16	4.6
378711	160	159	0.4

RMS = 6.5%
Acceptable level = < 7.5%

Total Phosphorus Field "Duplicates"

May

Lake	Site 1	Site 2	CV%
Summit	19	9	50.5
Black	7	42	101.0
Bosworth	21	15	23.6
Nahwatzel	7	11	31.4
Leland	40	41	6.7
Williams	30	33	6.7
Wenatchee	50	20	60.6
Whitman	23	45	45.7
Buck	38	32	12.1
Cranberry	31	37	12.5
Samish	22	18	14.1
Potholes	37	39	3.7

RMS = 41.5%
Acceptable level = < 14%

August

Lake	Site 1	Site 2	CV%
Samish	8	6	20.2
Williams	12	20	35.4
Sullivan	7	3U	--
Killarney	33	37	8.1
Ward	5	7	23.6
L. Martha	12	13	5.7
Whitman	18	20	7.4
Osoyoos	10	12	12.9
Mason	6	5	12.9
Wenatchee	3U	3U	--
Summit	8	4	47.1
Spanaway	14	17	13.7

RMS = 24.3%
Acceptable level = < 14%

Appendix D. Continued.

Total Phosphorus Lab Check Standards

May

Std vlue	3 µg/L	13 µg/L	24.5 µg/L
	3	13	25
	3	13	24
	3	12	24
	3	14	24
	3	13	25
	3	13	24
	3	13	24
	relative error = 0%	relative error = 0%	relative error = -0.9%
		acceptable level = < 2.5%	

August

Std value	3 µg/L	13 µg/L	24.5 µg/L
	3	13	26
	3	13	26
	3	12	24
	3	13	24
	3	13	23
	3	13	24
	3	14	24
	3		25
	relative error = 0%	relative error = 0%	relative error = 0%
		acceptable level = < 2.5%	

Matrix spikes - Recoveries

May
92%, 95%, 103%, 100%. 102%, 90%, 109%, 90%, 90%, 109%, 100%, 92%, 97%, 109%, 95%, 107%, 104%
Range = 99% - 109 %; mean = 99.6%

August
106%, 96%, 92%, 93%, 102%, 96%, 97%
Range 92% - 106%; mean = 97.4%

Appendix D. Continued.

1993 Total Persulfate Nitrogen Data (all results in mg/L)

Total Persulfate Nitrogen Lab Duplicates

no lab duplicate data were provided

Total Persulfate Nitrogen Field Duplicates

May

Lake	Result 1	Result 2	CV%
Samish	0.567	0.612	5.4
Nahwatzel	0.170	0.228	20.6
Leland	0.693	0.765	7.0
Williams	0.551	0.563	1.5
Osoyoos	0.294	0.334	9.0
Whitman	0.507	0.476	4.5
Potholes	1.17	1.16	0.6
Buck	0.716	0.715	0.1
Cranberry	0.701	0.673	2.9

RMS = 8.3%
Acceptable level not specified in draft QAPP

August

Lake	Result 1	Result 2	CV%
Howard	0.323	0.338	3.2
Williams	0.425	0.406	3.2
Osoyoos	0.252	0.292	10.4
Island	0.225	0.230	1.6
Chambers	0.824	0.850	2.2

RMS = 5.2%
Acceptable level not specified in draft QAPP

Total Nitrogen Lab Check Standards

no lab check standard data were provided

Total Nitrogen Matrix Spike Recoveries

no data from matrix spikes were provided

Total Nitrogen Lab Blanks

no data for lab blanks were provided

Blind Reference Standards

TP (µg/L)	Actual Value	May Value	August Value	CV%	95% CI
	7.5	10	12	20, 33	0.7 - 45.4
	15.0	16	15	4.5, 0	6.9 - 53.8
	150.0	148	160	0.9, 4.6	118.4 - 206.2

TN (mg/L)	Actual Value	May Value	August Value	CV %	95% CI
	0.025	--	0.029	10.5	0.021 - 0.29
	0.050	--	0.051	1.4	0.042 - 0.058
	0.500	0.476	0.504	3.5, 0.6	0.406 - 0.562

Appendix D. Continued.

1993 Chlorophyll *a* Data (all results in µg/L)

Chlorophyll *a* Field Duplicates

May

Lake	µg/L CV%	µg/L	CV%
Black (St)	2.16	0.05U	--
Nahwatzel	1.88	2.40	17.2
Leland	27.17	22.16	14.4
Williams	5.05	5.01	0.6
Osoyoos	4.69	2.92	32.9
Potholes	5.09	4.44	9.6
Buck	9.40	4.67	47.5
Cranberry	15.02	9.66	30.7

RMS = 26.4%
Acceptable level = < 10%

August

Lake	µg/L	µg/L	
Howard	1.62	2.32	25.1
Williams	6.17	8.66	23.7
Chambers	6.31	4.71	20.5
Osoyoos	4.28	4.78	7.8
Island	2.09	1.95	4.9

RMS = 18.4%
Acceptable level = < 10%

1993 Fecal Coliform Bacteria Data (all results in colonies/100 mL)

Fecal Coliform Bacteria Field Duplicates

May

Lake	Result 1	Result 2	CV%
Black	1U	1U	--
Buck	5	6	12.9

August

Lake	Result 1	Result 2	CV%
Chambers	35	35	0

1993 Total Suspended Solids and Total Nonvolatile Solids (TSS and TNVSS) Data (all results in mg/L)

Solids Field Duplicates

Lake	TSS			TNVSS	
	Result 1	Result 2		Result 1	Result 2
May					
Black	1	1		1U	1U
August					
Chambers	1U	1U		1U	1U
Potholes 4	4	3	1U		

Appendix E

Hydrolab Postcalibration Data for 1993

Appendix E. Hydrolab Postcalibration Data for 1993

Date 1993	Parameter	Comparison Value	Hydrolab Value	Postcalibration for the following lakes
05/17	D.O.	10.5 mg/L	10.6 mg/L	Ellen
	pH	7.0	7.0	
	pH	10.0	10.0	
05/18	D.O.	8.7 mg/L	8.8 mg/L	Williams (Stevens), Deep, Big Meadow
	pH	7.0	7.0	
	pH	10.0	10.0	
05/19	D.O.	9.0 mg/L	8.8 mg/L	Leo, Thomas, Black
	pH	7.0	6.9	Leo, Thomas, Black
	pH	10.0	10.1	Leo, Thomas, Black
	D.O.^{f}	8.4 mg/L	8.5 mg/L	Black, 1 m
	pH	7.0	6.9	Offutt, St. Clair
	D.O.^{f}	8.8 mg/L	8.8 mg/L	Offutt, St. Clair (surface)
05/20	D.O.	10.0 mg/L	10.0 mg/L	Waitts, Jumpoff Joe, Deer
	pH	7.0	6.9	Waitts, Jumpoff Joe, Deer
	pH	10.0	10.0	Waitts, Jumpoff Joe, Deer
	D.O.^{f}	8.4 mg/L	8.5 mg/L	Ward, Summit, Alice (surface)
	pH	7.0	6.9	Ward, Summit
	pH	10.0	10.0	Ward, Summit
05/21	D.O.^{f}	10.4 mg/L		Alice, Sawyer, S. Pattison (surface)
	pH	7.0	6.9	Alice, Sawyer
	pH	10.0	10.0	Alice, Sawyer
05/23	D.O.	12.3 mg/L	12.0 mg/L	Soap, Evergreen
	pH	7.0	7.1	Soap, Evergreen
	pH	10.0	10.0	Soap, Evergreen
	D.O.^{f}	10.0 mg/L	10.2 mg/L	Evergreen, 1 m
	D.O.^{f}	9.7 mg/L	9.3 mg/L*	Blackmans, surface. Flag D.O. for Samish, Toad, Blackmans.
05/24	D.O.	10.1 mg/L	10.5 mg/L	Twin, Osoyoos
	pH	7.0	7.0	Twin, Osoyoos
	pH	10.0	10.0	Twin, Osoyoos
	D.O.	9.4 mg/L	9.4 mg/L	Bosworth, Roesiger, Martha L.
	D.O.^{f}	1.4 mg/L	1.7 mg/L	Roesiger, 29 m
	pH	7.0	7.0	Bosworth, Roesiger, Martha L.
	pH	10.0	10.0	Bosworth, Roesiger, Martha L.
05/25	D.O.	9.6 mg/L	9.6 mg/L	Curlew, Pierre
	pH	7.0	7.0	Curlew, Pierre
	pH	10.0	10.0	Curlew, Pierre
	D.O.^{f}	9.6 mg/L	9.6 mg/L	Howard, surface
	D.O.	9.4 mg/L	9.4 mg/L	Martha Lake, Roesiger, Bosworth
	pH	7.0	7.0	Martha Lake, Roesiger, Bosworth

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 E. Continued.

Date 1993	Parameter	Comparison Value	Hydrolab Value	Postcalibration for the following lakes
05/26	D.O.	9.4 mg/L	9.3 mg/L	Sullivan, Skookum, Eloika
	pH	7.0	6.9	Sullivan, Skookum, Eloika
	pH	10.0	10.0	Sullivan, Skookum, Eloika
	D.O.[f]	9.1 mg/L	9.2 mg/L	Eloika, 3 m
05/27	D.O.	10.3 mg/L	10.3 mg/L	Silver, Williams (Spokane)
	pH	7.0	7.0	Silver, Williams (Spokane)
	pH	10.0	10.1	Silver, Williams (Spokane)
05/28	D.O.	11.0 mg/L	11.0 mg/L	Pearrygin, Conconully
	pH	7.0	7.0	Pearrygin, Conconully
	pH	10.0	10.0	Pearrygin, Conconully
	D.O.[f]	10.5 mg/L	10.4 mg/L	Conconully, 1 m
	D.O.[f]	9.3 mg/L	9.2 mg/L	Mason, 16 m
06/01	D.O.	10.0 mg/L	10.0 mg/L	Wenatchee
	pH	7.0	6.8	Wenatchee
	pH	10.0	10.0	Wenatchee
06/02	D.O.	8.8 mg/L	8.8 mg/L	Keechelus, Cle Elum
	pH	7.0	7.2	Keechelus, Cle Elum
	pH	10.0	10.0	Keechelus, Cle Elum
	D.O.[f]	9.0 mg/L	8.6 mg/L	Florence, 6 m
06/03	D.O.	10.0 mg/L	9.9 mg/L	Moses, Potholes
	pH	7.0	7.1	Moses, Potholes
	pH	10.0	9.9	Moses, Potholes
	D.O.[f]	9.7 mg/L	9.6 mg/L	Wooten, surface
06/04	D.O.	10.4 mg/L	10.5 mg/L	Ohop, Leech
	pH	7.0	7.0	Ohop, Leech
	pH	10.0	10.0	Ohop, Leech
	D.O.[f]	12.7 mg/L	12.8 mg/L	Lacamas, 1 m
	D.O.[f]	8.7 mg/L	8.6 mg/L	Whitman, surface
06/05	D.O.[f]	1.8 mg/l	1.8 mg/L	Rapjohn, 4 m
06/07	D.O.	9.5 mg/L	9.6 mg/L	Mayfield, Merwin, Lacamas, Louise
	pH	7.0	7.0	Mayfield, Merwin, Lacamas, Louise
	pH	10.0	10.0	Mayfield, Merwin, Lacamas, Louise

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 E. Continued.

Date 1993	Parameter	Comparison Value	Hydrolab Value	Postcalibration for the following lakes
08/18	D.O.	7.0 mg/L	7.0 mg/L	Ellen
	pH	7.0	7.0	
	pH	10.0	10.0	
	D.O.[f]	8.8 mg/L	8.5 mg/L	Deep, 1 m
08/17	D.O.	9.6 mg/L	9.9 mg/L	Samish
	pH	7.0	7.0	
	pH	10.0	10.0	
08/18	D.O.	9.9 mg/L	9.7 mg/L	Toad, Wiser
	pH	7.0	7.1	
	pH	10.0	9.9	
	D.O.[f]	9.7 mg/L	9.5 mg/L	Wiser, surface
08/19	D.O.	9.2 mg/L	9.5 mg/L	Flowing, Ki, Panther
	pH	7.0	6.9	
	pH	10.0	10.0	
08/19	D.O.	8.1 mg/L	8.0 mg/L	Williams (St), Deep, Big Meadow
	pH	7.0	7.0	
	pH	10.0	10.0	
08/20	D.O.	9.1 mg/L	8.9 mg/L	Bosworth, L. Martha, Howard, Stevens, Sunday
	pH	7.0	6.9	
	pH	10.0	10.0	
	D.O.[f]	9.0 mg/L	8.7 mg/L	Flowing, surface
08/20	D.O.	8.3 mg/L	8.2 mg/L	Black, Thomas, Leo
	pH	7.0	7.0	
	pH	10.0	10.0	
08/21 a.m.	D.O.	9.7 mg/L	9.5 mg/L	Roesiger
	pH	7.0	7.2	
	pH	10.0	10.0	
	D.O.[f]	9.2 mg/L	8.9 mg/L	Roesiger, surface
08/21 p.m.	D.O.	8.8 mg/L	9.0 mg/L	Loma, Blackmans
	pH	7.0	7.0	
	D.O.[f]	8.8 mg/L	9.0 mg/L	Blackmans, surface
08/21	D.O.	8.5 mg.L	8.4 mg/L	Waitts, Jumpoff Joe, Deer
	pH	7.0	7.0	
	pH	10.0	10.1	
08/22	D.O.	9.1 mg/L	9.1 mg/L	Sullivan, Skookum, Eloika
	pH	7.0	6.9	
	pH	10.0	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 E. Continued.

Date 1993	Parameter	Comparison Value	Hydrolab Value	Postcalibration for the following lakes
08/23	D.O.	8.4 mg/L	8.5 mg/L	Silver, Williams (Sp)
	pH	7.0	7.1	
	pH	10.0	10.0	
08/24	D.O.	10.7 mg/L	10.6 mg/L	Killarney, Alice, Sawyer
	pH	7.0	6.9	
	pH	10.0	10.2	
		cond	105 µmho/cm	110 µmho/cm
08/24	D.O.	7.8 mg/L	7.8 mg/L	Pierre, Curlew
	pH	7.0	7.1	
	pH	10.0	10.2	
08/25	D.O.	9.1 mg/L	9.2 mg/L	Chambers
	pH	7.0	7.0	
	pH	10.0	9.9	
	pH	4.1	4.4	
	D.O.[f]	4.2 mg/L	4.3 mg/L	Chambers, surface
08/25	D.O.	8.4 mg/L	8.3 mg/L	Osoyoos, Conconully, Pearrygin, Twin
	pH	7.0	7.0	
	pH	10.0	10.1	
08/26	D.O.	8.0 mg/L	8.0 mg/L	Long, Black, Ward
	pH	7.0	6.9	
	pH	10.0	9.9	
08/26	D.O.	9.0 mg/L	9.0 mg/L	Soap, Moses, Potholes
	pH	7.0	6.9	
	pH	10.0	10.1	
08/27	D.O.	9.9 mg/L	10.3 mg/L	S. Pattison
	pH	7.0	7.1	
	pH	10.0	10.0	
	D.O.[f]	10.0 mg/L	10.2 mg/L	S. Pattison, surface
08/28	D.O.	9.9 mg/L	9.7 mg/L	Spanaway, Whitman
	pH	7.0	7.0	
	pH	10.0	10.0	
	pH	4.1	4.3	
	D.O.[f]	11.5 mg/L	11.1 mg/L	Spanaway, surface
08/29	D.O.	10.7 mg/L	10.5 mg/L	Rapjohn
	pH	7.0	6.9	
	pH	10.0	10.1	
	D.O.[f]	8.3 mg/L	8.6 mg/L	Rapjohn, 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
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 E. Continued.

Date 1993	Parameter	Comparison Value	Hydrolab Value	Postcalibration for the following lakes
08/29	D.O.	8.4 mg/L	8.3? mg/L	Evergreen, Wenatchee
	pH	7.0	6.9	
	pH	10.0	10.3	
08/30	D.O.	8.1 mg/L	8.0 mg/L	Martha L., Cranberry, Lone, Goss, Gravelly
	pH	7.0	6.8	
	pH	10.0	10.0	
	cond	105 µmho/cm	106 µmho/cm	
	D.O.[f]	2.4 mg/L	2.3 mg/L	Goss, 12 m
	D.O.[f]	9.4 mg/L	9.0 mg/L	Cranberry, surface
08/30	D.O.	8.5 mg/L	8.5 mg/L	Keechelus, Easton, Cle Elum
	pH	7.0	7.2	
	pH	10.0	10.0	
08/31	D.O.	8.4 mg/L	8.5 mg/L	Long, Buck, Wooten, Mission, Tiger, Kitsap
	pH	7.0	7.3	new pH 7 (hi ionic strength)
	pH	10.0	9.8	
08/31	D.O.	7.9 mg/L	8.0 mg/L	Leech, Mayfield, Merwin
	pH	7.0	7.1	
	pH	10.0	10.0	
09/01	D.O.	8.0 mg/L	8.0 mg/L	Wye, Mason, Limerick, Nahwatzel
	pH	7.0	7.1	
	pH	10.0	10.0	
	D.O.[f]	9.0 mg/L	8.8 mg/L	Nahwatzel, surface
09/02	D.O.	9.7 mg/L	9.7 mg/L	Island, Spencer, Phillips, Lost
	pH	7.0	7.0	
	pH	10.0	10.0	
09/03	D.O.	8.5 mg/L	8.3 mg/L	Lacamas, Ohop, Louise
	pH	7.0	7.0	
	pH	10.1	10.0	
09/07	D.O.	7.9 mg/L	7.8 mg/L	Summit, St. Clair, Hicks, Offut
	pH	7.0	6.9	
	pH	10.0	9.9	
	pH	4.1	3.9	
	cond	105 µmho/cm	104 µmho/cm	

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