WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Lake Water Quality Assessment Project

1990

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

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EXECUTIVE SUMMARY

The objectives of Ecology's lake monitoring 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 1990, Ecology's lake monitoring program consisted of a statewide volunteer lake monitoring program, and a conventional parameter water quality survey which was conducted by Ecology staff. This report presents results from the volunteer monitoring program, evaluates water quality trends and the relationships between volunteer-collected Secchi depth data with Ecology-collected phosphorus and chlorophyll *a* data, discusses water quality anomalies within ecoregions, and ranks the monitored lakes according to their need for eutrophication management. Individual lake assessments, which were written to summarize data for volunteers in the program, are compiled and included in this report.

Volunteers participating in Washington's Citizens Lake Monitoring Project measured Secchi disk transparency and surface water temperature bi-monthly for six months. From May through October 1990, 73 lakes were monitored by 82 volunteers. To supplement volunteer collected data, Ecology staff met with each of the volunteers during May and August to collect epilimnetic water samples and profile data. Water samples were analyzed for total phosphorus and total nitrogen. Additional data for lakes assessments were collected by Ecology staff from 15 lakes during June and September 1990. Although data from this survey are used in this report for data comparisons and to assess lakes, detailed methods and results from this survey are presented in Coots (1991).

Carlson's Trophic State Index (1977) was used to evaluate volunteer-collected Secchi depth data and Ecology-collected phosphorus and chlorophyll data. Trophic state estimations are based primarily on volunteer-collected Secchi depth data and the total phosphorus data collected during the onsite visits. Of the 73 volunteer-monitored lakes, 24 were characterized as oligotrophic or oligo-mesotrophic, 30 were characterized as mesotrophic or meso-eutrophic, and 19 lakes were characterized as eutrophic. There were not enough data available to assess water quality trends in individual lakes.

Analysis of data collected for the program indicated that total phosphorus and chlorophyll *a* were strongly correlated with Secchi depth, but when Secchi depth, total phosphorus, and chlorophyll *a* were transformed to trophic state indices, the relationships were often inconsistent. Ecoregion analysis identified two lakes with deeper than expected Secchi depths which may be good candidates for protective lake management (Curlew Lake and Twin lake, both in Ferry County) and one lake with higher than expected total phosphorus concentrations (Sunday Lake in Snohomish County). This lake would be a good candidate for determining nutrient sources and developing a lake management plan.

The ranking of lakes according to their need for eutrophication management was based on a computerized procedure that uses monitoring data, physical characteristics, information on lake and watershed use, and water quality trends. From this procedure, lakes with high priority for eutrophication management are more likely to have a high susceptibility to eutrophication, poor water quality, high public value, and a declining trend in water quality.

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INTRODUCTION

In 1990, Washington State Department of Ecology's (Ecology) ambient lake monitoring program consisted of volunteer monitoring on 73 lakes, and a supplemental water quality survey (conducted by Ecology staff) on 15 lakes. The purpose of this report is to describe the 1990 ambient lake monitoring program, to present results from the volunteer-monitored lakes, and to compare volunteer-collected data with data collected from the supplemental water quality survey. This report also proposes a ranking of the monitored lakes in order of management priority, and includes 73 data summary reports which were prepared for the volunteers who collected data for the program. Each volunteer originally received their summary report in December 1991.

This introductory section describes the background and objectives of the overall lake monitoring program, provides an overview of the 1990 program, and gives general descriptions of the lakes which were monitored by volunteers in 1990.

Background

The volunteer monitoring program, which is known as Washington's Citizen Lake Monitoring Project, was established in early 1989 to gather general water quality information from "significant, publicly-owned lakes." Significant, publicly-owned lakes are defined as:

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

Data collected from the program are used primarily to assess each monitored lake for the state's biennial Water Quality Assessment (305 (b)) Report. Lake water quality assessments are required under Section 314 (a)(2) of the Clean Water Act, as amended by the Water Quality Act of 1987. Funding for establishing and implementing Washington's 1989 lake monitoring program was obtained through a Federal 314 Water Quality Assessment Grant. Ecology intends to assess as many of Washington's significant, publicly-owned lakes as funds and the availability of volunteers allow. However, because of the large number of lakes involved, and our reliance on volunteers to collect data, no formal schedule for assessing significant publicly-owned lakes has been developed.

The 1989 lake monitoring program consisted of the volunteer lake monitoring program on 48 lakes, a supplemental water quality survey, and a toxics study. The water quality survey was conducted on 25 lakes which were scheduled to be monitored by volunteers. The toxics study surveyed chemical contaminants in fish tissues and sediments from 10 Washington lakes.

Volunteer-collected data for each of the 48 monitored lakes were reported in individual data summaries written for the volunteers. These summaries are compiled in Rector and Hallock (1991); the latter also compares volunteer-collected data with data collected for the water quality survey. Reports prepared as a result of the 1989 lake monitoring program include:

Brower, C. and W. Kendra, 1990. Water Quality Survey of 25 "Citizen-Volunteer" Lakes from Washington State. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, 114 pp.

Johnson, A. and D. Norton, 1990. 1989 Lakes and Reservoir Water Quality Assessment Program: Survey of Chemical Contaminants in Ten Washington Lakes. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, 30 pp.

Rector, J. and D. Hallock, 1991. Water Quality Assessment Project, 1989. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, 209 pp.

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 to collect water samples and vertical profile (surface-to-bottom) data during both May and August. However, there was no toxics component in the 1990 program, and the water quality survey was conducted on only 15 lakes. Results of this survey are reported in:

Coots, R., 1991. Water Quality Survey of 15 "Volunteer-Monitored" Lakes in Washington State. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, 95 pp.

Project Objectives

The goal of the Lake Water Quality Assessment Project is to assess the current water quality of publicly-owned lakes in Washington, and to develop and implement a potentially long-term volunteer monitoring program. Specific objectives were as follows:

1) Determine the trophic status of monitored lakes.
2) Assess water quality in lakes not evaluated in the last five years, and determine the degree to which beneficial uses are supported.
3) Promote public awareness of lake processes and lake protection measures, and foster a conservation ethic.
4) Separate 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.

The objectives of the water quality survey on 15 lakes are listed in Coots (1991). Although the objectives of this survey were very similar to the objectives of the overall monitoring program, one additional objective of the survey was to gather data which could be compared with volunteer-collected data in order to validate the use of volunteer-collected data to assess lakes. Data collected by volunteers and by Ecology staff are compared in the Results Section of this report.

Overview of 1990 Program

There were two major components to the 1990 Lake Water Quality Assessment Project. The first was the continuation and expansion of a volunteer monitoring program. The second component consisted of a water quality survey by Ecology staff of 15 lakes which were scheduled to be monitored by volunteers. Monitoring methods for each component are described under the Methods Section.

Volunteer Monitoring Program

All Washington lakes that cover at least 20 acres and have a public access are eligible for inclusion in the volunteer monitoring program. Lakes which are monitored for the Municipality of Metropolitan Seattle's (METRO) volunteer lake monitoring program were excluded from the state's monitoring program in order to avoid duplication of effort. Volunteers, either recruited for the program or referred by other sources, are accepted if they indicate that 1) they want to monitor an eligible lake, 2) they are willing and able to collect monitoring data for the six-month monitoring period, and 3) they have access to a boat to use while collecting data.

Volunteers collected Secchi disk transparency and surface temperature data every two weeks from mid-May through mid-October. In addition, the volunteers were asked to complete a questionnaire on lake and watershed uses. Training of the volunteers took place during evening public meetings. New volunteers were provided with an updated lake monitoring manual along with the monitoring equipment. Except for illustrations, the 1990 manual was not appreciably different from the 1989 manual. The 1989 lake monitoring manual, and a description of the evening training sessions, may be found in Rector and Hallock (1991). A sample of the questionnaire used for the 1990 program is in Appendix A. Questionnaire results are summarized in Appendix B.

Compared to the 1989 program, the 1990 volunteer monitoring program was expanded. In 1990, additional volunteers/lakes were recruited into the program, pH was included as a volunteer-monitored parameter (see the Field Methods Section), and Ecology staff collected water samples and profile data with the volunteers during both May and August 1990. The latter are referred to as "onsite visits" with the volunteers.

The onsite visits with the volunteers were intended to supplement data collected by the volunteers, and to provide an opportunity for evaluating the quality of volunteer-collected Secchi depth data. During these onsite visits, Ecology staff collected profile (surface-to-bottom) data for temperature, pH, dissolved oxygen and conductivity; water samples were collected from the epilimnion of each lake (analyzed for total phosphorus and total nitrogen), and both Ecology staff and the volunteers took Secchi depth readings which were later compared as part of the quality assurance evaluation.

Additional volunteers were recruited into the 1990 program primarily through press releases to newspapers and radio stations throughout the state. Although some volunteers were referred to the program from other volunteers, Ecology Offices, or other agencies, about 65-70 people contacted us, and 37 were accepted as volunteers, as a result of the press releases. Of those who contacted us, many wanted to monitor lakes which were not eligible for the program.

Water Quality Survey

The water quality survey had the same study objectives, lake selection criteria and methods as the 1989 water quality survey (Brower and Kendra, 1990). Different lakes were sampled for the 1990 survey in order to increase the number of lakes assessed using data collected by Ecology staff.

Lakes sampled for the 1990 water quality survey were:

Aeneas (Okanogan County)
Big (Skagit County)
Davis (Pend Oreille County)
Flowing (Snohomish County)
Kahlotus (Franklin County)
Kitsap (Kitsap County)
Leech (Yakima County)
Loomis (Pacific County)*
Merrill (Cowlitz County)*
Nahwatzel (Mason County)
Nunnally (Grant County)*
Sidley (Okanogan County)
St. Clair (Thurston County)
Tanwax (Pierce County)
Waitts (Stevens County)

* Loomis Lake, Merrill Lake, and Nunnally Lake were not actively monitored by volunteers.

Locations and Physical Characteristics of Monitored Lakes

Locations of the 73 volunteer-monitored lakes are shown in Figure 1. Physical characteristics of the lakes are listed in Table 1.

FIELD METHODS

There were three separate field data collection efforts for the program: 1) data collected by the volunteers, 2) data collected by Ecology staff during "onsite visits" with the volunteers, and 3) data collected for the water quality survey of 15 of the volunteer-monitored lakes. Methods for each of the data collection efforts are discussed separately.

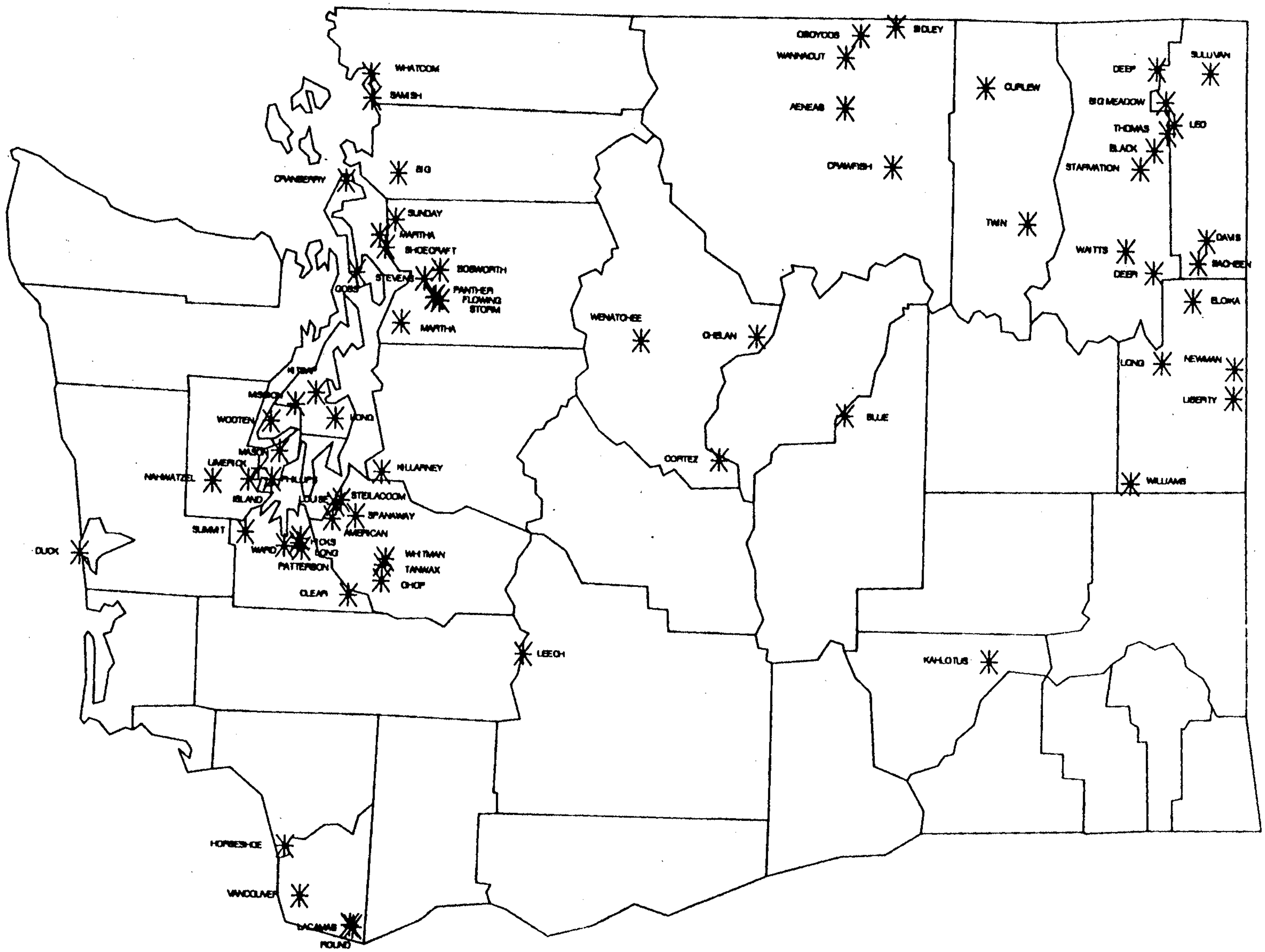


Figure 1. Locations of lakes monitored by volunteers in 1990.

Table 1. Physical characteristics of lakes monitored by volunteers in 1990.

Lake	County	Area (Acres)	Volume (Ac-Ft)	Shore-Length (Mi)	Max Depth (Ft)	Mean Depth (Ft)	Drainage Area(Mi^2)	Altitude (Ft)
AENEAS	OKANOGAN	62	1820	1.3	62	29	32.4	1350
AMERICAN	PIERCE	1100	60000	11.8	90	53	25.4	235
BIG	SKAGIT	520	7470	6.2	23	14	22.4	81
BIG MEADOW	PEND OREILLE	512			23	7		3450
BLACK	STEVENS	70	1863	2.0	45	27	0.9	3701
BLUE	GRANT	532	21318	7.0	69	40	334.0	1093
BOSWORTH	SNOHOMISH	105	3671	2.0	79	35	1.4	563
CLEAR	THURSTON	170	3200	2.7	25	19	2.6	518
CORTEZ	CHELAN	44	794	1.2	28	18	0.3	871
CRANBERRY	ISLAND	125	1576	2.8	25	13	0.6	20
CRAWFISH	OKANOGAN	80			36			4475
CURLEW	FERRY	921	39519	15.8	130	43	64.5	2333
DAVIS	PEND OREILLE	152	12622	2.7	146	83	17.8	2150
DEEP	STEVENS	210	7203	3.5	49	34	48.1	2025
DEER	STEVENS	1110	57000	8.6	75	52	18.2	2474
DUCK	GRAYS HARBOR	278	3000	11.3	30	11	1.4	10
ELOIKA	SPOKANE	662	6018	5.9	15	9	111.0	1905
FLOWING	SNOHOMISH	134	3790	2.2	69	28	0.8	526
GOSS	ISLAND	47	1500	1.2	60	32	1.4	130
HICKS	THURSTON	160	2700	2.4	35	18	1.8	162
HORSESHOE	COWLITZ	85	473	3.0	16	6	0.4	20
ISLAND	MASON	108	2246	1.7	31	21	0.3	230
KAHLOTUS	FRANKLIN	380	5140	5.3	24	14	167.0	880
KILLARNEY	KING	24	230	1.3	15	9	0.2	385
KITSAP	KITSAP	250	4500	2.7	29	18	2.7	156
LACKAMAS	CLARK	315	7489	5.3	65	24	64.3	179
LEECH	YAKIMA	41			8			4412
LEO	PEND OREILLE	43	740	1.3	37	17	2.9	3290
LIBERTY	SPOKANE	710	16000	4.8	30	23	13.3	2053
LIMERICK	MASON	129	1210	4.4	24	9	13.0	220
LONG	SPOKANE							1536
LONG	THURSTON	330	3900	7.1	21	12	8.3	153
LONG	KITSAP	339	2180	5.1	12	6	9.4	118
LOUISE	PIERCE	39	860	0.9	35	22	0.3	230
MARTHA LAKE	SNOHOMISH	57	1346	1.4	48	24	0.8	450
LAKE MARTHA	SNOHOMISH	62	2034	1.8	70	33	1.6	186
MASON	MASON	1000	49000	10.9	90	48	20.2	194
MISSION	KITSAP	88	1000	1.9	25	12	1.8	516
NAHWATZEL	MASON	269	4642	2.9	25	17	6.2	440
NEWMAN	SPOKANE	1200	23000	9.7	30	19	28.6	2124
OHOP	PIERCE	230	3800	4.6	25	17	17.3	524
OSOYOOS	OKANOGAN	5800	266000	29.7	208	46	3150.0	911
PANTHER	SNOHOMISH	48	1101	1.3	36	23	0.8	455
N. PATTERSON	THURSTON	81	1120	1.7	22	14	2.9	154
S. PATTERSON	THURSTON	190	2540	4.6	19	13	3.8	154

Table 1. Continued.

Lake	County	Area (Acres)	Volume (Ac-Ft)	Shore-Length (Mi)	Max Depth (Ft)	Mean Depth (Ft)	Drainage Area(Mi^2)	Altitude (Ft)
PHILLIPS	MASON	110	1800	2.6	25	16	0.5	188
ROUND	CLARK	30	786	1.1	55	26	64.7	179
SACHEEN	PEND OREILLE	317	7615	6.3	40	24	42.8	2234
E. SAMISH	WHATCOM	680	24000	6.3	75	31	9.2	273
W. SAMISH	WHATCOM	130	9100	1.8	140	71	3.7	273
SHOECRAFT	SNOHOMISH	130	2400	2.4	35	18	6.0	324
SIDLEY	OKANOGAN	116	1725	2.5	22	15	2.5	3675
SPANAWAY	PIERCE	280	4600	4.4	28	16	17.0	320
SPENCER	MASON	230	5152	4.3	36	22	1.7	170
ST.CLAIR	THURSTON	180	5100	7.5	70	28	6.4	73
STARVATION	STEVENS	30	233	0.9	14	8	3.0	2375
STEILACOOM	PIERCE	320	3500	5.7	20	11	89.4	210
STEVENS	SNOHOMISH	1000	65000	7.1	155	63	6.8	210
STORM	SNOHOMISH	79	1777	1.7	46	22	0.4	528
SULLIVAN	PEND OREILLE	1380	267000	8.9	332	193	51.2	2583
SUMMIT	THURSTON	530	28000	5.6	100	53	2.8	500
SUNDAY	SNOHOMISH	46	365	1.3	20	8	1.7	211
TANWAX	PIERCE	170	3300	2.8	30	20	4.1	600
THOMAS	STEVENS	170	4000	3.3	55	23	12.7	3147
NORTH TWIN	FERRY	744						50
VANCOUVER	CLARK	2858						9
WAITTS	STEVENS	455	19000	3.3	68	40	11.7	1946
WANNACUT	OKANOGAN	410	22500	5.4	158	55	20.0	1850
WARD	THURSTON	65	2100	1.4	67	33	1.0	123
WENATCHEE	CHELAN	2480	360000	13.3	244	147	273.0	1875
WHATCOM	WHATCOM	5000	767700	26.5	330	154	55.9	315
WHITMAN	PIERCE	30	346	1.0	20	12	1.0	601
WILLIAMS	SPOKANE	320	12000	5.3	120	37	21.8	2052
WOOTEN	MASON	68	1530	1.5	36	23	0.3	407

Volunteer-Collected Data

Volunteers collected Secchi disk transparency, surface temperature and surface pH data. Data were collected approximately every two weeks from mid-May through mid-October. For consistency of methods and to maximize available sunlight for the Secchi depth readings, the volunteers were instructed to collect data between 10 a.m. and 2 p.m.

Each volunteer used their own boat to get to their monitoring site. At most lakes, the site was located at the deepest part of the lake. After anchoring at their sampling site, the volunteers measured water clarity by lowering a 20 cm diameter limnological style Secchi disk from the shady side of the boat 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 repeated during each sampling trip so that consistency between readings could be evaluated by Ecology staff (see Quality Assurance Section). If the Secchi disk hit the lake bottom and was still visible, or was obscured by macrophyte growth, this was indicated on the data reporting card. Secchi disks used by the volunteers were made by Ecology staff (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 6-8 inches below the water surface and waiting one to two minutes for the reading to equilibrate. The temperature was then quickly read, and recorded on the data sheet to the nearest 0.5 degree. All Fahrenheit data were corrected to the Celsius scale after they were entered into the database.

For measuring pH, volunteers were provided with ColorpHast® pH strips (range 5-10, with 0.5 unit increments). Because the strips came in containers of 100 strips each, each volunteer was given a small plastic container holding 20-24 strips, and a color reproduction of the color comparator scale. The strips were held in surface lake water for one to two minutes, and after waiting for the color strips to stabilize, were compared to the comparator charts.

Data Collected During Onsite Visits with the Volunteers

Ecology staff accompanied most of the volunteers in the field during late May/early June, and late August/early September 1990. The purpose of these "onsite visits" was to 1) observe the volunteer's Secchi disk reading technique, and if needed, to offer suggestions for improving technique; 2) have both Ecology staff and volunteers collect Secchi disk readings, for later comparisons; 3) collect profile data and water samples from the volunteers' sampling sites; 4) collect macrophyte and/or algae samples for identification; and 5) answer questions or discuss lake issues with each of the volunteers.

Timing and Logistics

The visits were intended to occur over a three-week timeframe, so that seasonal effects would be reduced when data were compared between lakes. To accomplish this, two Ecology staffpersons each visited 1-4 lakes per day from May 21 to June 11, 1990, and from August 9 to September 4, 1990. During the onsite visits, a total of 76 lakes were sampled, and 55 of these lakes were sampled during both sampling periods.

Profile Data

Each volunteer took the Ecology staffperson to their monitoring site, and if possible, anchored. Temperature, pH, dissolved oxygen, and conductivity profile data were collected using a Hydrolab Surveyor II.

During May, profile data for Summit Lake and Island Lake were collected with a Seabird CTD/profiling instrument package instead of a Hydrolab. With the exception of the conductivity data, the data met the quality control criteria. Also, during August there was no Hydrolab available for some of the Eastern Washington lakes sampled. These lakes were Big Meadow, Black, Curlew, Deep, Eloika, Leo, Starvation, Thomas, and Twin. Dissolved oxygen samples were collected from the surface and bottom of those lakes, and were titrated using the azide-modified Winkler method (APHA, 1985). Although temperature profile data were also collected for those lakes, equipment problems were encountered and the data are not reported here. Goss Lake in Western Washington was also sampled in this manner, while one Hydrolab was being repaired.

Water Chemistry Data

Water samples were collected from the epilimnion of each lake. Temperature profile data were used to determine the thermocline, and three depths within the epilimnion were chosen for compositing the sample. Water samples were collected using a Kemmerer or Van Dorn style water sampler. Samples were composited by filling approximately 1/3 of each sample bottle with water from each composite depth. Immediately upon returning to shore, the total phosphorus samples were preserved by adding 2 drops of concentrated sulfuric acid, in order to bring the sample pH below 2. The preserved total phosphorus samples and the total nitrogen samples were either kept on ice, or stored refrigerated at 4°C until the samples were delivered to the lab. Maximum allowable holding time for preserved total phosphorus and total nitrogen samples was 28 days.

Weather conditions, water color, and general observations about the lake were recorded. If an obvious algal bloom was occurring at 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. Keys used for algal identifications were Smith (1950), Edmondson (1959), and Prescott (1962;

1978). Keys used for macrophyte identifications were Hitchcock and Cronquist (1973), Tarver *et al.* (1978), and Prescott (1980). It should be noted that algae and macrophyte samples were collected for qualitative purposes only, and results are not inclusive of all species present.

Total phosphorus samples were analyzed using the persulfate digestion and ascorbic acid reduction method (EPA method 365.3), modified by using a 10 cm absorbance cell to lower the detection limit to about 2 μg/L. Total nitrogen samples were analyzed using the persulfate digestion cadmium reduction method (D'elia *et al.*, 1977). The limit of detection for this method is 0.10 mg/L.

Water Quality Survey of 15 Lakes

Profile data and water samples (from both the epilimnion and the hypolimnion) were collected from each lake during June and September 1990. Water samples were analyzed for nutrients (total phosphorus, total nitrogen, orthophosphorus, nitrate+nitrite nitrogen, and ammonia-nitrogen), turbidity, chlorophyll *a*, and fecal coliform bacteria. Plant and algae samples were also collected and identified. Details of the methods and results from this survey are reported in "Water Quality Survey of 15 'Volunteer-Monitored' Lakes From Washington State" (Coots, 1991).

METHODS USED FOR DATA QUALITY ASSURANCE AND DATA ANALYSIS

The following describe the methods used to evaluate data collected for the volunteer program. Quality assurance for the water quality survey of 15 lakes is in Coots (1991), and is not repeated in this report.

Quality Assurance of Volunteer-Collected Secchi Data

Some of the volunteer-collected Secchi data needed to be corrected before data analysis. To assure the quality of all Secchi data collected by volunteers, the two Secchi readings collected on each sampling date, and the Secchi data collected during the onsite visits, were evaluated.

Correcting Secchi Depths for Line Shrinkage

In 1989, we discovered that the ropes attached to the Secchi disks had shrunk about 1 inch per original foot of line (Rector and Hallock, 1991). As a result, all 1989 Secchi data were corrected. In 1990, preshrunk lines were used on most of the Secchi disks. Measurements of the lines during the onsite visits indicated that the lines did not shrink appreciably after they were preshrunk, so data collected using the preshrunk lines were not corrected. Some of the older lines from the 1989 program were not replaced in 1990, so these data were corrected using the same correction factor used in 1989.

Evaluating the Volunteers' Abilities to Reproduce Their Readings

Volunteers collected two Secchi depth readings on each sampling date. Each set of duplicate Secchi depth readings were evaluated using the coefficient of variation (CV). The CV is the standard deviation of two Secchi depth values divided by their mean, multiplied by 100. Because the duplicate readings were not collected independently of each other, they were biased and cannot be used to evaluate the volunteers' precision. Independently-collected readings are not practical for the volunteer program, so instead we evaluated the abilities of the volunteers to reproduce their readings.

Acceptable values of CV for three ranges of Secchi depths were created to determine whether replication was acceptable. Ranges of Secchi depths were chosen because duplicate readings of shallow Secchi depths need to be almost identical to have a low CV, whereas when Secchi depths are greater than 20 feet, duplicate readings can differ by more than 2 feet and still have a small CV. To emphasize our preference for good replication even for Secchi depths greater than 20 feet, acceptable ranges of CV were identified for Secchi depths between 0-10 feet, 10-20 feet, and greater than 20 feet. For the shallow range, the acceptable value of CV ensures replication within 0.25-0.50 feet. For the deeper ranges, replication within about 0.0-1.0 feet will be within the accepted CV range. Acceptable CV values for each of these ranges are listed in Table 2.

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

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

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

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

The CV for each data pair, and the root mean square for each lake, are listed in Appendix C.

Comparing Secchi Data Collected by Volunteers and Ecology Staff

During each onsite visit, both the volunteer and Ecology staff collected Secchi depth readings. A paired t-test was used to analyze the variability of the difference between each data pair. Secchi data were evaluated within each range of Secchi depths listed in Table 2.

The calculated value of *t* for each data range was determined as

$$\frac{\bar{D}}{\left(\frac{s}{\sqrt{n}}\right)}$$

Where

$\bar{D}$ = the mean of the differences between pairs
s = the standard deviation of the differences between pairs
n = the number of pairs

Calculated values of *t* were then compared to tabulated values from Student's *t* distribution. Calculated values which exceed the tabulated values ($\alpha = 0.05$) indicate a significant difference.

Quality Assurance of Onsite Visit Data

In addition to collecting Secchi depth data with the volunteers, profile data and water samples were collected during the onsite visits. Quality assurance methods for the profile data and water samples are described below.

Profile Data

The Hydrolabs were pre- and post-calibrated frequently (often daily). Hydrolab pH readings were checked against pH 7 and pH 10 buffers. Postcalibration readings within 0.1 pH unit of the standard buffer values were considered acceptable. Dissolved oxygen was checked against azide-modified Winkler titrations. At least two samples were collected either from surface lake water and titrated in the field, or were collected from large aerated vats located in Ecology's wet lab. Postcalibration data within 0.3 mg/L were acceptable. Conductivity, a more stable parameter on the Hydrolab, was checked approximately once per week. Postcalibration values within 5 μmhos/cm were considered acceptable.

When postcalibration data were not within acceptable limits for any parameter, that parameter's profile data were flagged for those lakes which were monitored since the last time the Hydrolab was calibrated.

All Hydrolab postcalibration data are compiled in Appendix D.

Water Chemistry Data

Laboratory quality assurance consisted of lab duplicates, lab check standards, matrix spikes, and lab blanks.

Total precision was evaluated using the root mean square of lab duplicates. Total precision was acceptable if the root mean square was < 7.5%. For total phosphorus, the most critical parameter measured, this provides a total precision of at least 15% at the 95% confidence level. Relative bias was evaluated using the mean percent recoveries of the lab check standards and matrix spikes. Mean recoveries of 80-120% were considered acceptable.

Because analysis of the water samples from the onsite visits overlapped analyses of samples collected for the water quality survey, one set of EPA standard reference materials for nutrients (WP987) were submitted along with samples for the water quality survey. The average measured value of 5 laboratory replicates was compared against the 95% confidence interval provided in the literature with the samples. A more detailed description of the standard reference materials is in Coots (1991). Results from the total phosphorus and total nitrogen reference materials only were used for the volunteer program.

Graphing Data

Secchi depth graphs and TSI plots were created from Lotus spreadsheets, and enhanced using Freelance Plus version 3.0. Profile data were graphed using SYSTAT version 5.0 with a command file written by Jim Cubbage of Ecology's Environmental Investigations Program. These graphs aided in interpreting the profile data, and are presented in the individual lake assessments.

Regressions were calculated and plotted using the statistical analysis and graphing software, WQHYDRO version 2010 (Aroner, 1990).

Estimating Trophic States

Carlson's (1977) trophic state indices for Secchi depth (TSI_{SD}) and total phosphorus (TSI_{TP}), tempered with some professional judgment, were used to estimate the trophic status of the monitored lakes. The trophic state index for chlorophyll *a* (TSI_{CHL}) was also used for trophic state comparisons. Chlorophyll data are from Coots (1991).

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

$$TSI_{SD}=10[6-\frac{lnSD}{ln2}]$$

$$TSI_{TP}=10[6-\frac{ln\frac{48}{TP}}{ln2}]$$

$$TSI_{CHL}=10[6-\frac{2.04-0.68lnCHL}{ln2}]$$

Where

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

TSI_{SD} were calculated for lakes with at least three Secchi depth readings collected by volunteers from June through September 1990. Secchi data for these four months only were used because the majority of the data were collected during these months, and because algal growth, water quality problems and recreational use of lakes are usually heaviest during these months. The mean of the TSI values for June through September is the mean TSI_{SD} used in the data evaluations.

In general, TSIs of 40 or less indicate oligotrophy, TSIs greater than 40 indicate mesotrophy, and TSIs greater than 50 indicate eutrophy (Carlson, 1979). However, several lakes exhibited characteristics of more than one trophic state (e.g., mean summer Secchi depth in the upper region of the oligotrophic range, but hypolimnetic anoxia was measured during an onsite visit). To describe lakes which appeared to be between trophic states, the terms "oligo-mesotrophic" and "meso-eutrophic" were used. In general, oligo-mesotrophy was assigned to lakes with TSI_{SD} values between 38 - 41, and meso-eutrophy was assigned to lakes with TSI_{SD} between 48 - 51.

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

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

RESULTS AND DISCUSSION

Eighty-two volunteers collected 644 data points from 73 lakes during 1990. Three lakes, Mason Lake, Patterson Lake, and Lake Samish, had more than one lake station monitored by volunteers; Mason Lake had five lake stations, and both basins of Patterson Lake and Lake Samish were monitored by separate volunteers. Big Lake, Ward Lake, and Lake Whatcom had two volunteers who monitored the same lake station. Seventy-six lakes were monitored during the onsite visits, and 55 of those lakes were sampled during both onsite visits. Of the 15 lakes sampled during the supplemental survey (Coots, 1991), 9 were also monitored by volunteers and data from the survey were compared with volunteer-collected data.

Monitoring results and data analysis in this section is broken up into several subsections: Quality Assurance; Trophic State Estimations; Secchi:TP:Chlorophyll Relationships; Water Quality Trends; and Ecoregion Analysis.

Quality Assurance

Quality assurance of the volunteer-collected Secchi depths are discussed separately from the quality assurance of water quality data collected during the onsite visits.

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

Because the Secchi test is affected by individual eyesight, we decided not to use the Ecology staff readings as the "standard" against which to compare volunteer-collected readings. Rather, one purpose of the onsite visits was to evaluate the technique used by the volunteers to conduct the test, and to offer suggestions for improving technique, if needed. As such, a greater emphasis was placed on the volunteers' abilities to reproduce their Secchi readings.

Poor replication was indicated when the coefficient of variation (CV) for each pair of data for one sampling date exceeded the values listed in Table 2. Of 644 data pairs collected in all, 58 data points (9%) had poor replication and those data were excluded from comparisons with other data. Twenty of the poor data points were from one lake, Mason Lake, which had five stations monitored by volunteers.

The quality of the volunteer-collected Secchi depths indicated that, based on the duplicate readings collected on each sampling date, most of the volunteers had good replication. There were exceptions, though. Volunteer-collected data from Lake Bosworth, Lake Louise, and Mason Lake Stations 1 and 5 had poor overall replication, based on the root mean square of the coefficient of variation for each pair of Secchi readings. Replication from these four data sets was greater than the acceptable values listed in Table 2. As a result, these data were excluded from comparisons with other lake data and the individual data points are flagged in the data summaries. Trophic state indices for Lake Bosworth and Lake Louise were calculated, though, for use in the individual lake assessments to the volunteers. In this report, those assessments are flagged. Because the trophic state estimation for Mason Lake was based on data collected from Station 4, the Mason Lake trophic state index was not affected by the quality assurance evaluation.

During the onsite visits, Secchi data were collected by both the volunteer and Ecology staff at 40 lakes. When the data for these 40 lakes were plotted (Figure 2), it appeared that at most lakes, the volunteer's Secchi depth was not as deep as the Secchi depth collected by Ecology staff. Also, as Secchi depth increased, the differences between the two readings for each lake also tended to increase. For the ranges of Secchi depths of 10-20 feet and for 20+ feet, there was no significant difference ($p < 0.05$) between the volunteers' readings and readings collected by Ecology staff. For these two data populations, the two readings could differ by more than 1.5 feet and still be considered acceptable. However, for Secchi depths within the 0-10 feet range, there was a significant difference between the volunteer-collected and the Ecology-collected values. When two sets of readings with differences greater than 1.5 feet were eliminated from the t-test ($n=15$), there was no longer a statistically significant difference between the two sources of Secchi readings. This is important because the TSI_{SD}:Secchi depth relationship is not linear; changes of Secchi depths shallower than 5 feet will have a much greater affect on TSI_{SD} than the same change at Secchi depths deeper than 10 feet. This further supports our concern for having good replication of Secchi depths, particularly when Secchi depth is less than 10 feet.

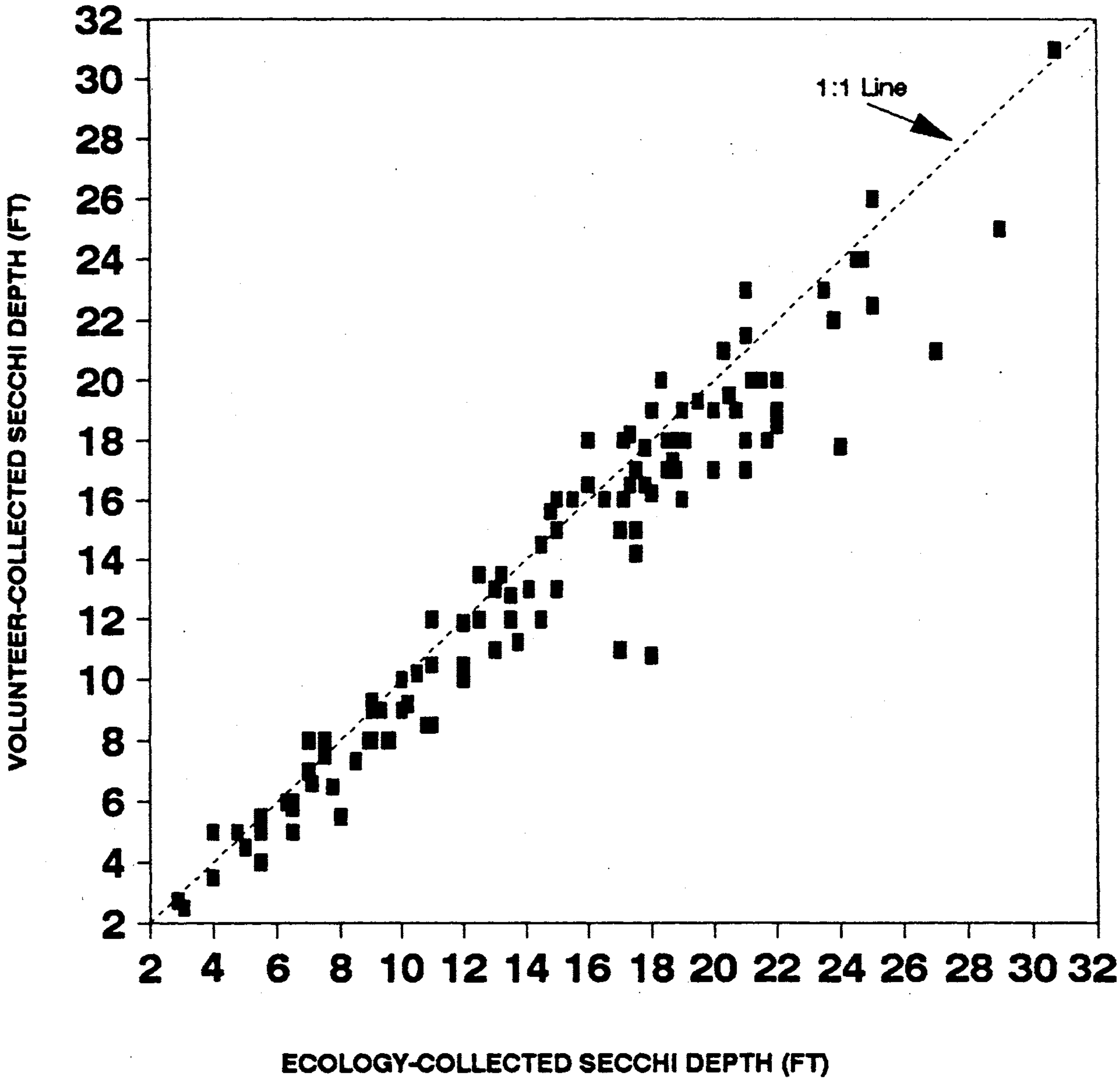


Figure 2. Secchi data collected by volunteers and Ecology staff during onsite visits, 1990-1992.

Water Quality Data from the Onsite Visits

Hydrolab postcalibration data from the May onsite visits indicated that some pH and dissolved oxygen data were unacceptable. The pH data were flagged for the following lakes: Bosworth, Stevens, Williams, Deep, Deer, Leo, Thomas, Ohop, Tanwax, Flowing, Lake Martha, Limerick, Nahwatzel, Phillips, Spencer, Panther, Shoecraft, Storm, and Sunday. Dissolved oxygen data from the May onsite visits were flagged for lakes Crawfish, Twin, Wenatchee, and Stevens. All postcalibration data for August were within acceptable limits, so no August data were flagged.

The total phosphorus and total nitrogen data from both the May and August onsite visits were of acceptable quality. Laboratory quality assurance is summarized in Table 3. Results of the EPA standard reference materials are summarized in Coots (1991), and indicate that the standard reference materials were well within the 95% confidence intervals.

Table 3. Laboratory QA of total phosphorus and total nitrogen from onsite visits.

Survey	$\bar{x}$ method blanks	$\bar{x}$ recoveries check stds (n)	$\bar{x}$ recoveries matrix spikes	root mean square lab duplicates
May TP	1.2 μg/L	99% (4)	95% (50 μg/L)	3.4
Aug TP	1.8 μg/L	100% (4)	103% (50 μg/L)	3.3
May TN	-0.014 mg/L	100% (4)	93% (0.33 mg/L)	3.3
Aug TN	-0.005 mg/L	102% (5)	101% (0.33 mg/L)	2.9

Trophic State Estimations

Lakes monitored by volunteers, their assigned trophic states, and the TSI_{SD} calculated for each lake are listed in Table 4. Fourteen lakes were oligotrophic, 10 lakes were oligo-mesotrophic, 26 lakes were mesotrophic, 4 lakes were meso-eutrophic, and 19 lakes were eutrophic. A ranking of the lakes in order of their TSI_{SD} is shown in Figure 3. Lake Kahlotus, Leech Lake, Starvation Lake and the south basin of Patterson Lake had most of their Secchi data "entering weeds." These lakes, and lakes with Secchi data which did not pass the quality assurance evaluation (Lake Bosworth and Lake Louise), do not have TSI_{SD} listed in Table 4 or Figure 3.

TSI_{SD} was the main basis for the trophic state estimation for 43 of the lakes monitored during 1990. Comparisons with TSI_{TP} and other data (if any were available) confirmed the use of Secchi data for estimating trophic status. Five lakes did not have sufficient or valid Secchi data that could be used to calculate TSI_{SD}, but there were other data (onsite visit data) which were used to estimate the trophic status. At the remaining 25 lakes, comparisons of TSI_{SD} and TSI_{TP}

Table 4. TSI_{SD}, TSI_{TP}, and trophic state for volunteer-monitored lakes, 1990.

Lake	TSI (SD)	TSI(TP) May	TSI(TP) Aug	Trophic Status	Lake	TSI (SD)	TSI(TP) May	TSI(TP) Aug	Trophic Status
Aeneas	37	--	--	mesotrophic	Martha L.	37	--	43	mesotrophic
American	32	46	38	mesotrophic	Mason	29	33	33	oligotrophic
Big	60	61	51	eutrophic	Mission	*	43	43	mesotrophic
Big Meadow	47	54	53	meso-eutrophic	Nahwatzel	38	40	40	oligotrophic
Black	39	46	39	mesotrophic	Newman	36	49	51	mesotrophic
Blue	45	48	45	mesotrophic	Ohop	49	54	56	eutrophic
Bosworth	*	32	--	oligotrophic	Osoyoos	48	--	--	mesotrophic
Chelan	21	--	29	oligotrophic	Panther	48	41	45	mesotrophic
Clear	37	--	55	eutrophic	Patterson (N)	39	47	43	mesotrophic
Cortez	53	47	59	eutrophic	Phillips	38	41	42	oligo-mesotrophic
Cranberry	45	--	53	eutrophic	Round	48	58	53	eutrophic
Crawfish	36	38	40	oligo-mesotrophic	Sacheen	40	46	51	mesotrophic
Curlew	36	--	43	mesotrophic	Samish (E)	39	41	37	oligo-mesotrophic
Davis	37	39	46	oligo-mesotrophic	Shoecraft	40	40	39	oligo-mesotrophic
Deep	41	53	41	mesotrophic	Sidley	45	--	55	meso-eutrophic
Deer	37	42	45	oligo-mesotrophic	Spanaway	42	48	43	mesotrophic
Duck	61	--	--	eutrophic	Spencer	40	36	41	oligotrophic
Eloika	52	--	62	eutrophic	St. Clair	49	55	50	eutrophic
Flowing	45	43	40	mesotrophic	Starvation	*	55	57	eutrophic
Goss	36	--	--	oligotrophic	Steilacoom	51	45	--	eutrophic
Hicks	39	42	45	mesotrophic	Stevens	34	36	40	oligotrophic
Horseshoe	57	57	55	eutrophic	Storm	47	42	38	mesotrophic
Island	36	38	39	oligotrophic	Sullivan	30	--	--	oligotrophic
Kahlotus	*	--	78	eutrophic	Summit	34	28	43	oligotrophic
Killarney	49	58	--	eutrophic	Sunday	48	77	66	eutrophic
Kitsap	--	46	55	mesotrophic	Tanwax	51	57	53	eutrophic
Lacamas	54	56	54	eutrophic	Thomas	40	39	31	oligo-mesotrophic
Leech	*	47	--	mesotrophic	Twin (N)	31	47	32	mesotrophic
Leo	39	40	41	oligo-mesotrophic	Vancouver	73	65	--	eutrophic
Liberty	37	--	--	mesotrophic	Waitts	36	--	44	oligo-mesotrophic
Limerick	44	45	43	mesotrophic	Wannacut	42	--	--	mesotrophic
Long (Kitsap)	61	63	65	eutrophic	Ward	31	38	40	oligotrophic
Long (Spokane)	46	52	56	meso-eutrophic	Wenatchee	36	34	40	oligotrophic
Long (Thurston)	49	47	52	mesotrophic	Whatcom	35	29	32	oligotrophic
Louise	*	43	40	mesotrophic	Whitman	45	51	55	meso-eutrophic
L. Martha	40	34	40	oligotrophic	Williams	44	46	45	mesotrophic
					Wooten	32	--	43	oligo-mesotrophic

*TSI_{SD} could not be calculated due to insufficient or invalid data.

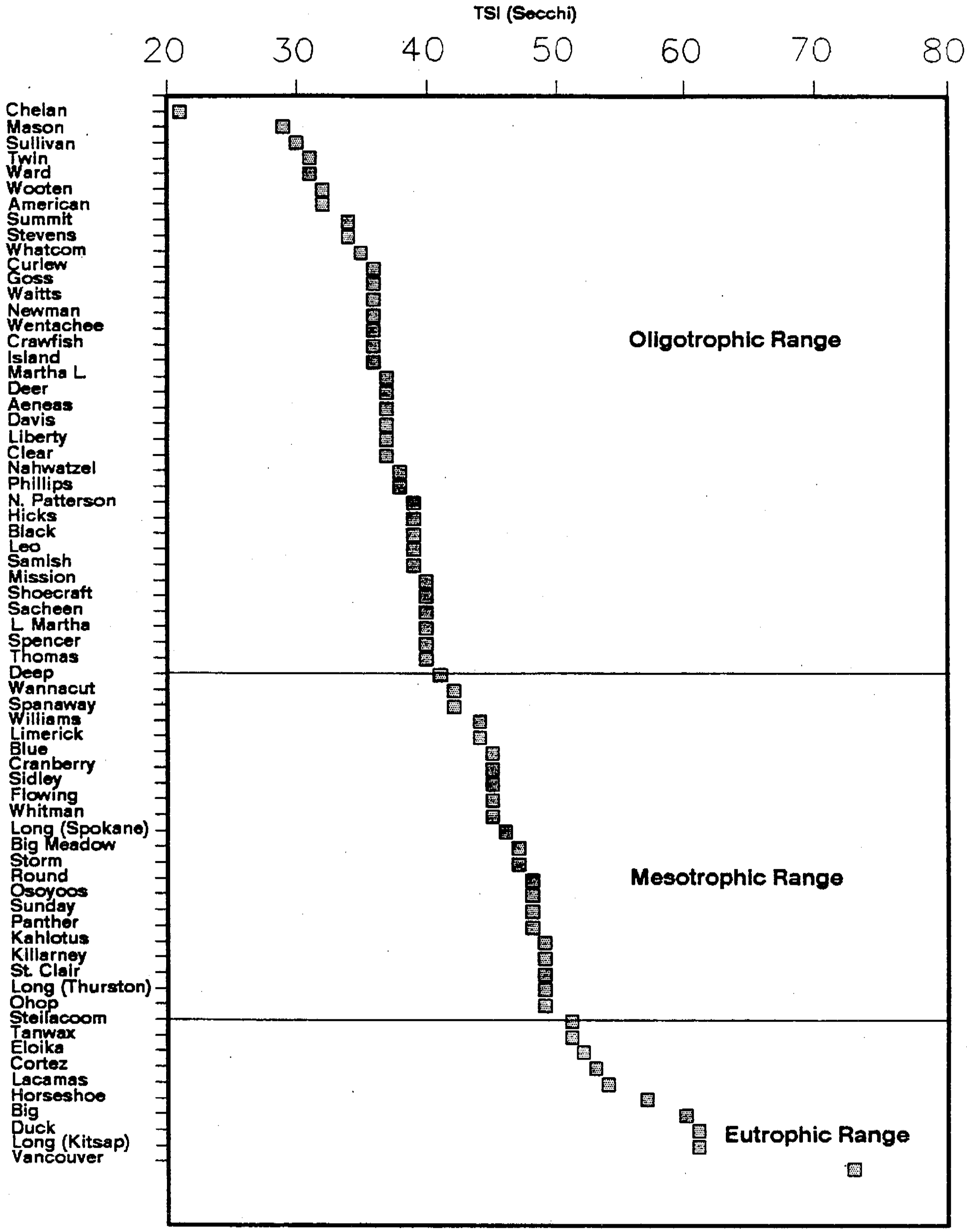


Figure 3. Lakes ranked in order of 1990 TSI_{SD}.

(and other data, if available) indicated that Secchi was not the best indicator of trophic status. Explanations of the basis for each lake's trophic state assignment are listed with "Comments" for each lake's assessment within the Individual Lake Assessments Section of this report.

Comparisons of Trophic States Assigned in 1990 and 1989

Thirty-nine lakes were monitored by volunteers in both 1990 and 1989 (Table 5). Of those lakes, 23 (59%) were assigned the same trophic status during both years, 14 (36%) were estimated to be more eutrophic in 1990, and 2 (5%) were estimated to be less eutrophic in 1990.

The 1990 trophic states of the 14 "more eutrophic" lakes were based mainly on total phosphorus data (which were not available in 1989) that indicated a more eutrophic state than Secchi depth. These lakes also had mean Secchi depths which were either borderline between two trophic states, or did not agree with other trophic characteristics. The differences in assessments between 1989 and 1990 should not be considered a "trend." (See the Water Quality Trends Section.)

The two lakes which were "less eutrophic" in 1990 than in 1989 are Liberty Lake and Phillips Lake. Liberty Lake's assessments were based primarily on Secchi depth data during both years and other available reports, since no onsite visits were made to this lake. The 1989 assessment for Phillips Lake was based on four readings collected during August and September only, whereas the 1990 assessment was based on 11 Secchi readings which indicated a TSI_{SD} that was borderline between oligotrophy and mesotrophy (Table 5).

Although a paired t-test indicated that there was a significant difference ($p < 0.01$) between the TSI_{SD} values calculated in 1990 and 1989, TSI_{SD} values at the majority of lakes (24) differed by 3 or fewer units. Only 4 lakes had TSI_{SD} values differ by more than 5 units from 1989 to 1990. Overall, TSI_{SD} values did not appear to be higher, or lower, during either year; for the 39 lakes monitored during both years, mean TSI_{SD} was 42 for 1990 data and 43 for 1989 data, and 18 lakes had a higher TSI_{SD} in 1990 than in 1989.

Secchi:TP:Chlorophyll Relationships

Our water quality assessments are based largely on volunteer-collected Secchi data evaluated with Carlson's (1977) trophic state index (TSI). It is, therefore, important to evaluate the empirical relationships between Secchi disk depth and both chlorophyll *a* and total phosphorus, which are more direct measures of trophic state. The theoretical relationships between Secchi depth, chlorophyll, and phosphorus are discussed in detail in Rector and Hallock (1991). Specifically, this section a) compares TSIs based on Secchi, chlorophyll, and phosphorus data, b) evaluates the mathematical relationship between the three variables, and c) identifies lakes where the relationship is inconsistent with that observed at other lakes.

Table 5. Trophic states assigned in 1990 and 1989. Changes in trophic state from 1989 to 1990 may be due to the availability of TP data in 1990; TP was not collected from all lakes in 1989.

Lake	1990 TSI (SD)	1990 Trophic Status	1989 TSI (SD)	1989 Trophic Status
Big	60	eutrophic	44	mesotrophic
Big Meadow	47	meso-eutrophic	49	meso-eutrophic
Black	39	mesotrophic*	38	oligotrophic
Blue	45	mesotrophic	44	mesotrophic
Clear	37	eutrophic*	41	mesotrophic*
Cranberry	45	eutrophic*	54	eutrophic
Crawfish	36	oligo-mesotrophic	38	oligo-mesotrophic
Curlew	36	mesotrophic*	39	oligo-mesotrophic*
Davis	37	oligo-mesotrophic	38	oligo-mesotrophic
Deep	41	mesotrophic	36	oligo-mesotrophic
Deer	37	oligo-mesotrophic	34	oligotrophic
Duck	61	eutrophic	65	eutrophic
Eloika	52	eutrophic	50	meso-eutrophic
Flowing	45	mesotrophic	43	mesotrophic
Goss	36	oligotrophic	35	oligotrophic
Island	36	oligotrophic	37	oligotrophic
Kahlotus	--	eutrophic	54	eutrophic
Killarney	49	eutrophic*	49	meso-eutrophic
Kitsap	43	mesotrophic	35	oligotrophic
Lacamas	54	eutrophic	57	eutrophic
Liberty	37	mesotrophic*	47	meso-eutrophic
Long (Kitsap)	61	eutrophic	56	eutrophic
Long (Thurston)	49	mesotrophic	44	mesotrophic
Louise	--	mesotrophic*	34	oligotrophic*
Mason	29	oligotrophic	33	oligotrophic
Newman	36	mesotrophic*	44	mesotrophic
Osoyoos	48	mesotrophic	47	mesotrophic
Phillips	38	oligo-mesotrophic	42	mesotrophic
Samish	39	oligo-mesotrophic	41	mesotrophic
St. Clair	49	eutrophic	46	mesotrophic
Starvation	--	eutrophic*	43	mesotrophic
Steilacoom	51	eutrophic	52	eutrophic
Sullivan	30	oligotrophic	30	oligotrophic
Summit	34	oligotrophic	31	oligotrophic
Thomas	40	oligo-mesotrophic	40	oligo-mesotrophic
Twin	31	mesotrophic*	35	oligotrophic
Wenatchee	36	oligotrophic	37	oligotrophic
Williams	44	mesotrophic	40	oligo-mesotrophic
Wooten	32	oligo-mesotrophic*	34	oligotrophic

* Trophic State based on data besides Secchi depth

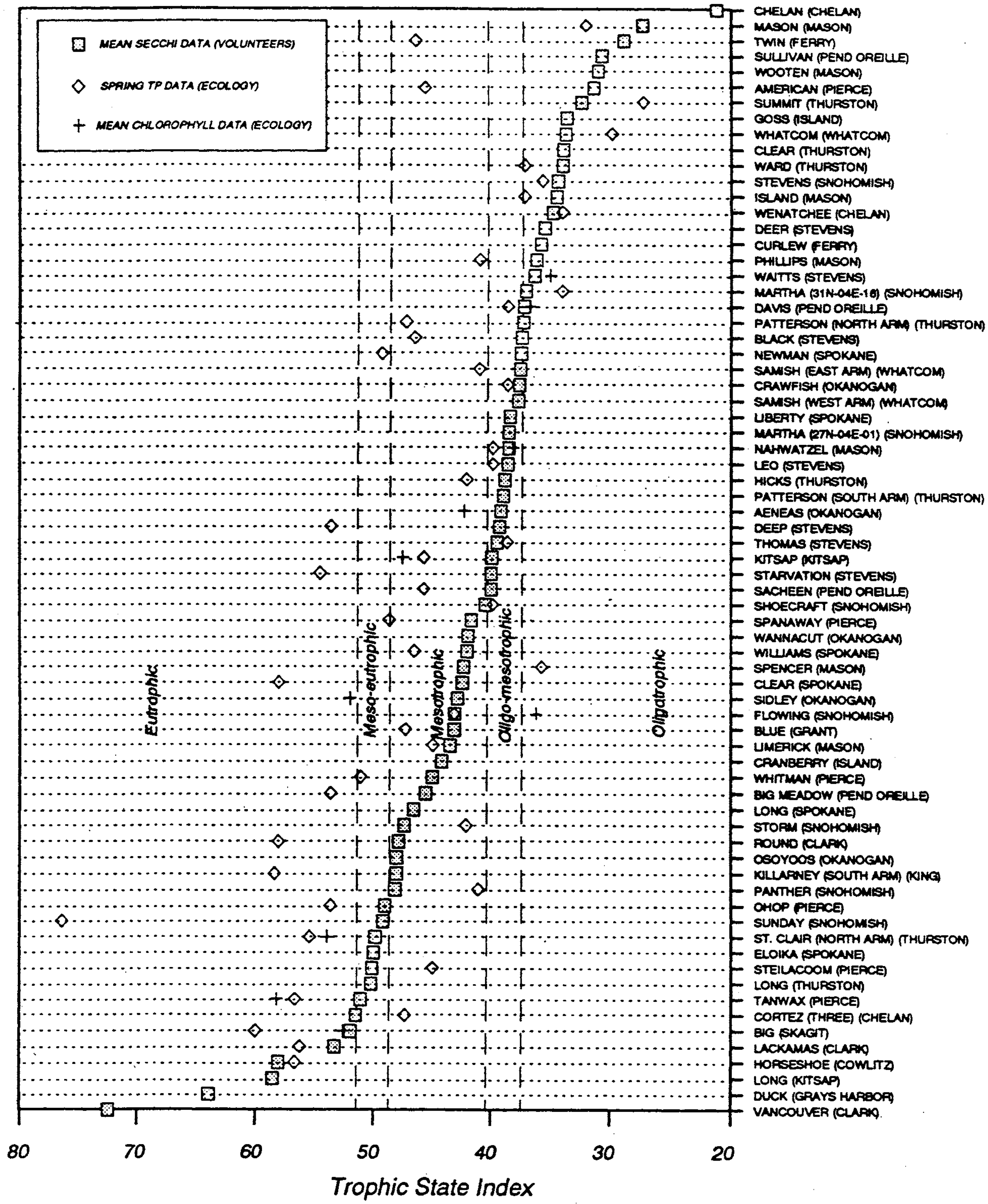


Figure 4. Trophic state indices for lakes monitored in 1990. Lakes are in order of increasing Secchi-based trophic state.

Trophic State Comparisons

Trophic states based on Secchi depth (TSI_{SD}), phosphorus (TSI_{TP}), and chlorophyll *a* (TSI_{CHL}) were often not consistent (Figure 4). This lack of agreement could result from low-quality Secchi data or problems inherent in the theoretical relationships between the three parameters (for example, the effects of water color on Secchi depth). However, the inconsistency could also result from basing TSI_{TP} and TSI_{CHL} on only one and two samples, respectively. The lack of agreement between indices may also be caused by anomalous characteristics in particular lakes, for example, nitrogen rather than phosphorus limitation. Examining the inconsistencies between TSIs can be a useful step in assessing lake water quality.

TSI_{SD} and TSI_{TP} differed by more than 10 units at 9 of the 48 lakes with phosphorus data available. TSI_{TP} was greater than TSI_{SD} in all cases. Three or fewer Secchi readings were available at four of the nine lakes (American, Clear, Starvation, and Twin Lakes). These lakes were either not assessed, or TSI_{SD} was qualified in the assessment. Another four lakes had total phosphorus to total nitrogen ratios between 10 and 14 indicating possible nitrogen limitation (Deep, Sunday, Killarney, and Newman Lakes). Also, Newman Lake was treated with alum in August, 1989, which could affect the Secchi:phosphorus relationship. We are unable to explain the discrepancy between TSI_{SD} and TSI_{TP} in Round Lake.

Mathematical Relationships

The differences between TSIs notwithstanding, both total phosphorus and chlorophyll *a* (from Coots, 1991) were strongly correlated with Secchi depth (Table 6). Mean chlorophyll explained about 70% of the variability in Secchi depths between the lakes evaluated (Figure 5). However, the slope of the regression line was steeper in both 1989 and Carlson's (1977) study than in 1990 (Table 7). In other words, Secchi depth was less sensitive in these lakes to differences in chlorophyll. As a result, lakes with similar trophic states cannot be differentiated as clearly.

Average non-algal light attenuation (k_w) at the 10 lakes where both Secchi and chlorophyll data were available was a moderate 0.30, higher than the k_w found in 1989 (0.14 and 0.20 in the spring and fall, respectively). A higher k_w indicates more light attenuation by non-algal turbidity. The more transparency is affected by factors other than algae, the less Secchi depth is able to accurately assess trophic state. Like the shallower regression slope discussed in the previous paragraph, the higher non-algal light attenuation results in reduced ability to differentiate trophic state using Secchi data alone, between the 10 lakes evaluated. Of course, non-algal light attenuation at any particular lake cannot be inferred from the average k_w discussed above. (See Lorenzen, 1980, and Rector and Hallock, 1989, for a more detailed discussion of k_w.)

Total phosphorus is usually the factor limiting production in freshwater lakes and is therefore correlated with chlorophyll. In 1990, total phosphorus explained 69% of the variability in mean chlorophyll concentrations (chlorophyll data from Coots, 1991) in the spring and 56% in the fall (Figure 6). The regression equation was very similar to that found by Carlson (1977) (Table 7).

Table 6. Significant Pearson correlation coefficients (r) for mean volunteer-collected Secchi disk data and total phosphorus and chlorophyll *a* data collected by Ecology staff. Data were log-transformed prior to calculating coefficients. N = 9 for correlations involving chlorophyll, otherwise, n = 44. (N.S. = not significant, * = $p<0.10$, ** = $p<0.01$, *** = $p<0.001$)

	Mean Volunteer Secchi	Total Phosphorus Spring	Total Phosphorus Fall	Chlorophyll Spring	Chlorophyll Fall
Secchi	1.000				
TP Spring	-0.668***	1.000			
TP Fall	-0.712***	0.753***	1.000		
Chl Spring	-0.785**	0.737*	N.S.	1.000	
Chl Fall	-0.756*	0.870**	0.771*	0.586*	1.000
Chl Mean	-0.832**	0.829**	0.750*	0.807**	0.942***

Table 7. Regression coefficients from the 1990 Citizen Lake Monitoring Program (CLMP), the 1989 CLMP (Rector and Hallock, 1991), and Carlson (1977).

Study	a	b	r^2	n
Log(mean Secchi (m)) = a + b Log(mean Chlorophyll (μg/L))				
1990	0.76	-0.39	0.69	10
1989	0.85	-0.53	0.75	24
Carlson	0.89	-0.68	0.86	147
Log(mean Chlorophyll *a* (μg/L)) = a + b Log(spring Total Phosphorus (mg/L))				
1990	3.23	1.58	0.69	9
1989	2.67	1.14	0.49	25
Carlson	3.28	1.45	0.85	43
Log(mean Secchi (m)) = a + b Log(spring Total Phosphorus (mg/L))				
1990	-0.42	-0.56	0.45	47
1989	-0.50	-0.56	0.66	19
Carlson	-1.26	-0.98	--	--

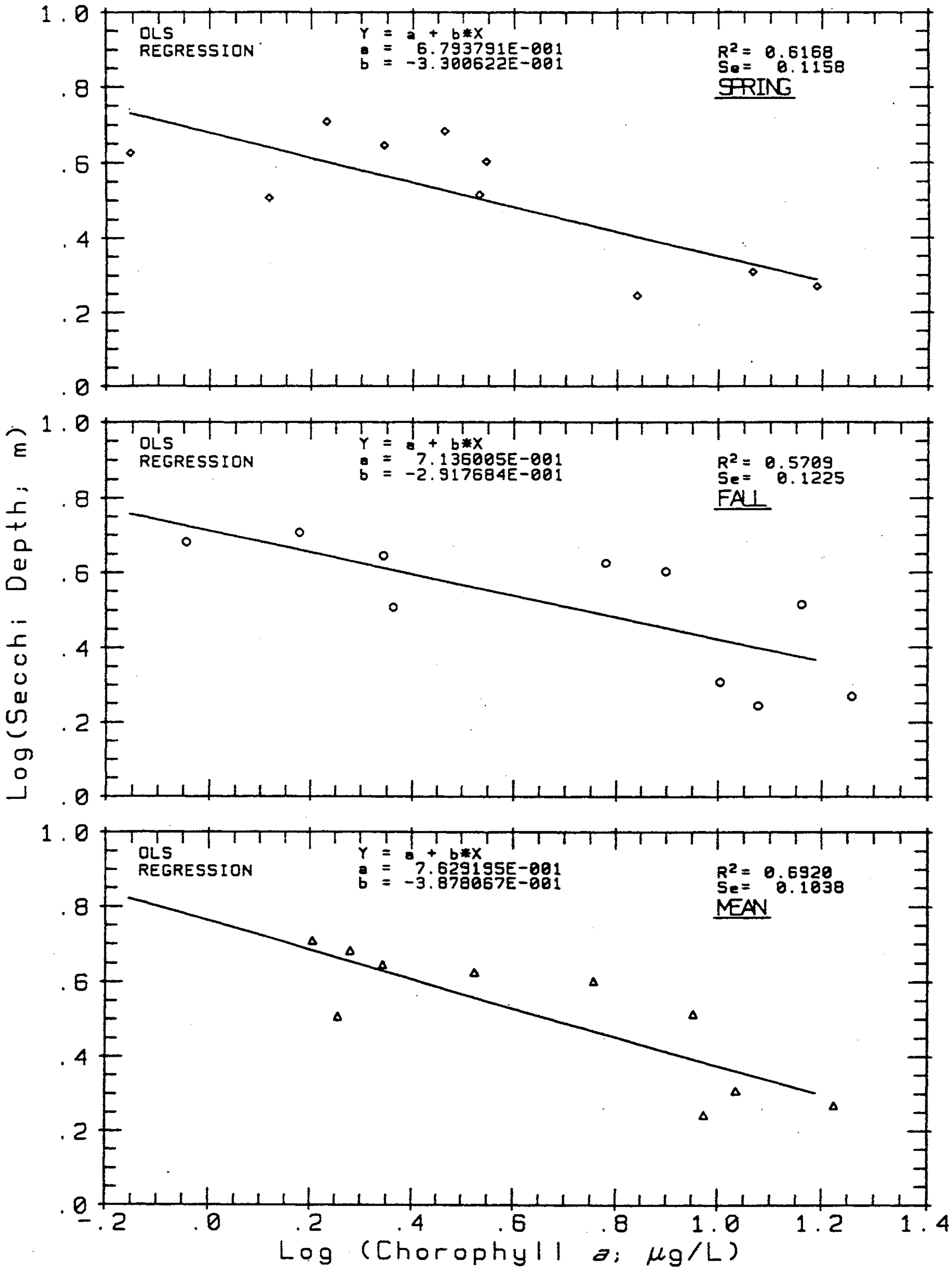


Figure 5. Regression of volunteer-collected Secchi depths (average) and spring, fall, and mean chlorophyll *a* from conventional monitoring by Ecology (Coots, 1991).

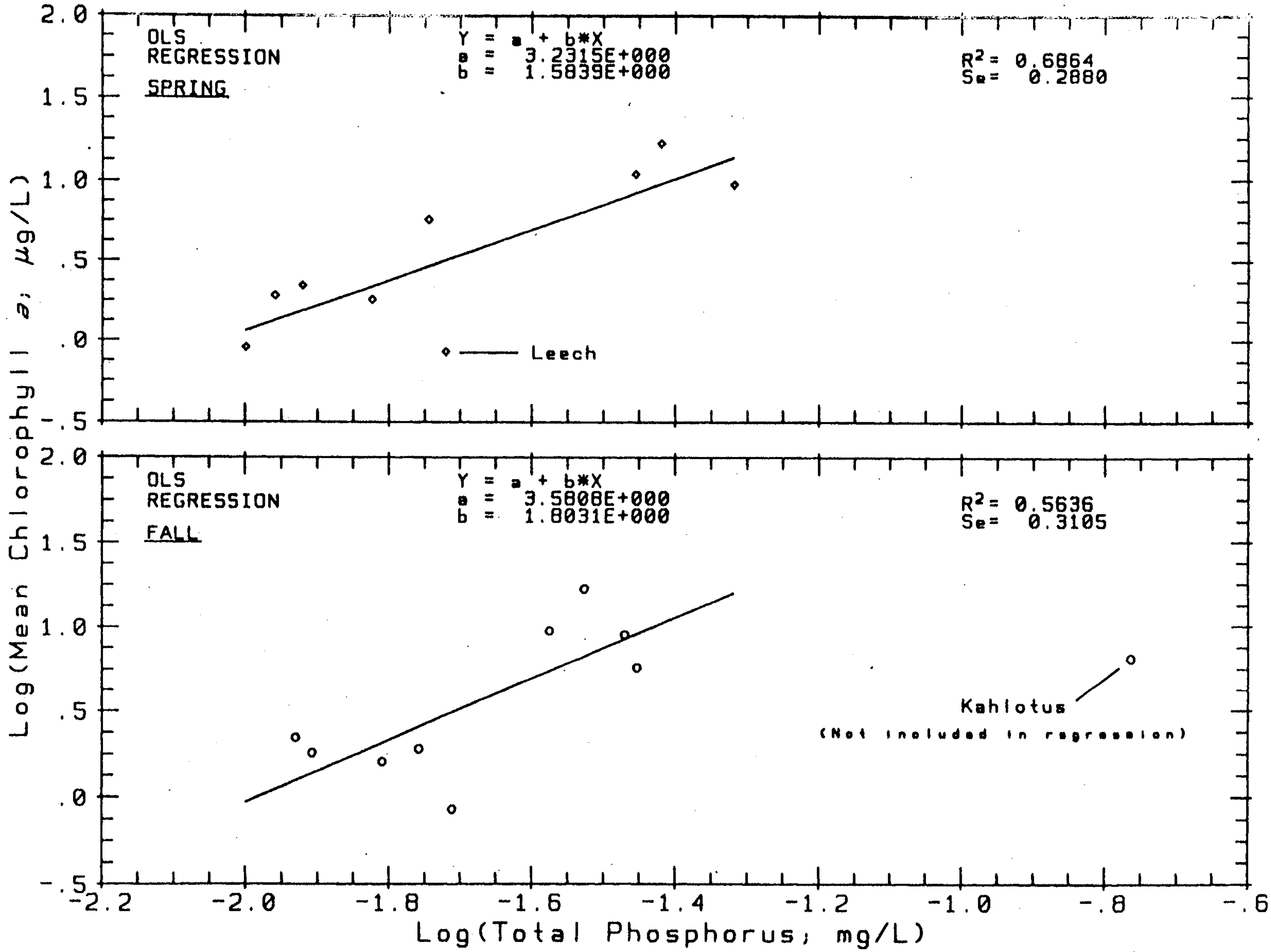


Figure 6. Regression of mean chlorophyll *a* from conventional monitoring by Ecology (Coots, 1991) and spring and fall total phosphorus from onsite visits with the volunteers.

Total nitrogen in a multiple regression was not significant ($p > 0.05$). Based on this analysis, nitrogen was not an important limiting factor in the determination of chlorophyll concentrations in the 10 lakes for which both chlorophyll and nutrient data are available.

Secchi depth is indirectly related to phosphorus because both are related to chlorophyll. Total phosphorus explained about 50% of the variability in Secchi depths between lakes (Figure 7). (Sunday Lake, which had unusually high phosphorus concentrations, was excluded from the analysis.) The regression equation was nearly identical to that found in 1989, but had a shallower slope than reported by Carlson (1977) (Table 7). This is consistent with the Secchi:chlorophyll and chlorophyll:phosphorus relationships discussed above.

Outlier Lakes

Only in the regression of mean chlorophyll against fall total phosphorus was an unusual data point apparent (Figure 6). Lake Kahlotus had much higher total phosphorus concentrations than the other nine lakes in the regression (Kahlotus was not sampled in the spring). In addition, the chlorophyll concentration was much lower than expected, given the phosphorus concentration.

Lake Kahlotus, the only monitored lake in an arid, eight-county area of southeast Washington, is also a geographical outlier (See Ecoregion Analysis section). Lake Kahlotus is fed by sub-surface irrigation returns. Chlorophyll may be lower than expected because of competition for nutrients or shading by an extensive population of the pondweed, *Potamogeton pectinatus*.

Water Quality Trends

Five years is often cited as the minimum period of record required to conduct meaningful statistical trend analyses (e.g., Taylor and Loftis, 1989). Ten years or more of consistent data collection may be required to assess trends with confidence. Lakes require particularly long data sets for the evaluation of trends because of large variability, both seasonal and annual, in water quality measurements. Lakes are also sensitive to climatic variations, which can obscure trends in water quality resulting from watershed changes.

While we cannot evaluate lake-specific trends, we can comment on overall differences in water quality between this study and earlier studies. Seventy-seven of the lakes monitored in 1990 were sampled in the early 1970s (Bortleson, *et al.*, 1976a-d; Dion, *et al.*, 1976a-c), 24 were sampled in 1981 (Sumioka and Dion, 1985) and 40 were monitored in 1989 (Rector and Hallock, 1991). Only 13 lakes were sampled in all four periods.

Secchi depth and total phosphorus trophic state indices (TSI_{SD} and TSI_{TP}) from 77 lakes, having both 1990 data and data from earlier years, were compared using a paired t-test.

Differences between 1990 and earlier years indicated no overall pattern or trend, although there were differences between specific years. TSI_{SD} was lower (*i.e.*, water clarity was better) in 1990

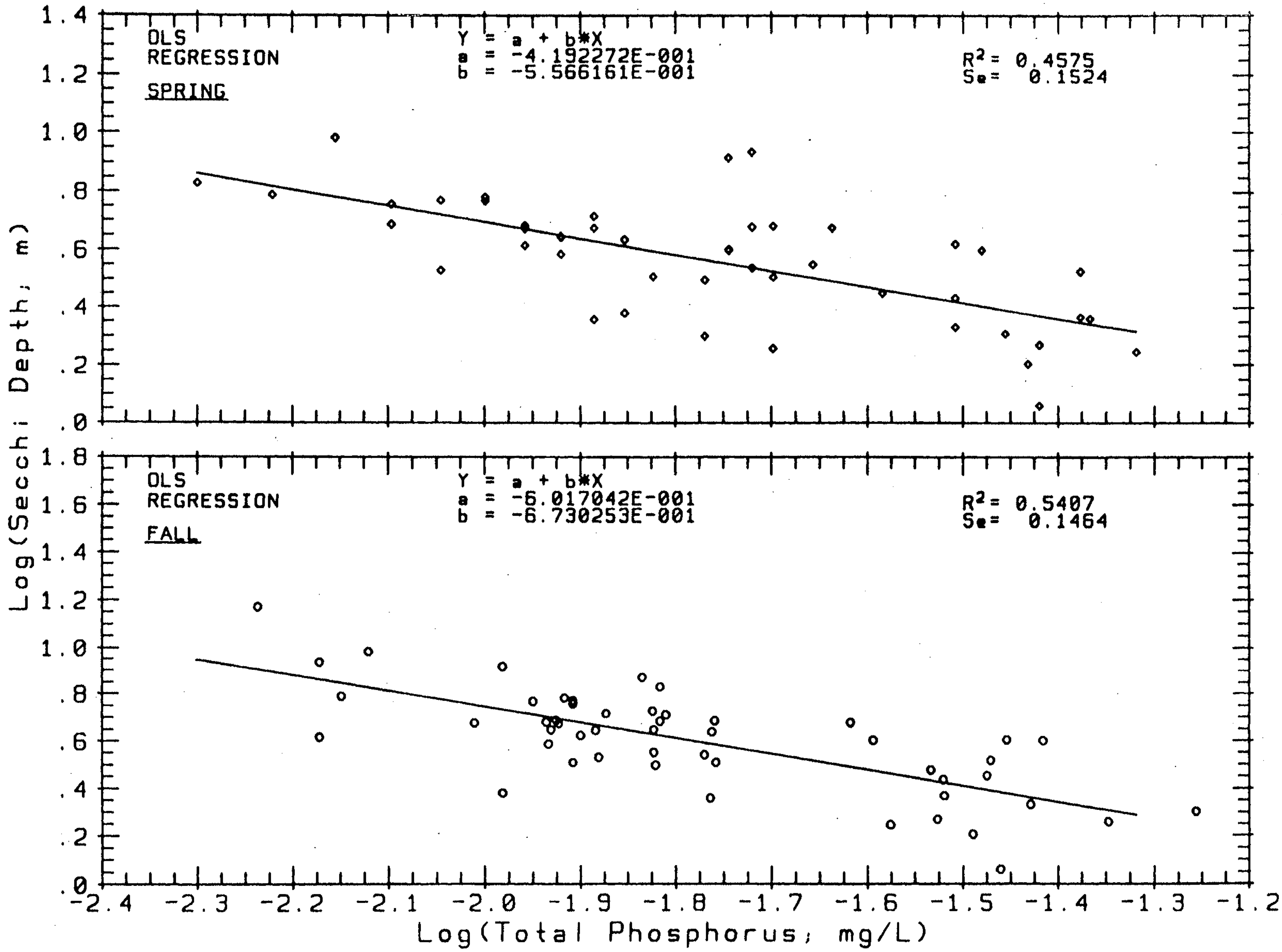


Figure 7. Regression of volunteer-collected Secchi depths (average) and spring and fall total phosphorus from onsite visits with the volunteers. Sunday Lake was excluded from the regressions.

than in the 1970's ($p<0.01$). Fifty-four percent of Eastern Washington lakes and 61% of Western Washington lakes had better Secchi visibility in 1990 than in the 1970's. However, there were no significant differences between 1990 and other years ($p>0.10$). Although a paired t-test showed phosphorus-based trophic states were slightly better in 1990 than in 1981 ($p<0.01$), they were slightly worse in 1990 than in the 1970's ($p<0.10$). Charges in total phosphorus concentrations may have been affected by changes in analytical methods and reporting. No overall trend in the monitored lakes was evident in either TSI_{SD} or TSI_{TP} (Figure 8).

The above analysis is meant to compare water quality in specific years, and to provisionally assess overall trends. There are insufficient data to even tentatively assess trends in individual lakes. Although the effects of lake-specific variability are made less important by evaluating overall changes, factors affecting all lakes may still obscure actual trends. Observed change (or lack of change) in water quality based on only a few years of data may be merely a response to assessment methods (the earlier studies are based on only two to four samples) or climatic variations. For example, total precipitation varied between the different studies (Table 8) and was about 20% above the 30-year average in 1990. In spite of higher than normal precipitation, lake levels are reported to be well below normal, and water clarity better than normal, in Eastern Washington. Other important factors, such as solar radiation, growing season temperature, timing of precipitation events, etc., were not evaluated.

Ecoregion Analysis

This section discusses differences in Secchi depth and total phosphorus concentration between ecoregions and identifies lakes with unusual Secchi depths or total phosphorus concentrations compared to other lakes within the same ecoregion. Omernik and Gallant (1986) divided the Pacific Northwest into 15 ecoregions (8 in Washington) based on similarities in land use, land surface form, potential natural vegetation, and soils. In theory, water bodies within an ecoregion would have similar water quality or potential water quality. One important proposed use of ecoregions is in the development of water quality criteria. Minnesota has used ecoregion differences in both total phosphorus concentrations and public perceptions of acceptable water quality to develop ecoregion-specific criteria (NALMS, 1992). Another use of ecoregions is to identify waterbodies with unusual water quality. By comparing a lake to others in the same ecoregion, rather than a statewide comparison, anomalous conditions can be more readily detected.

Figure 9 shows the lakes monitored in 1990 and their corresponding ecoregions, and data collected in 1990 (this study) is displayed in Figures 10 and 11. Figures 10 and 11 also show regression residuals after using several morphometric variables to predict Secchi depth. The much larger data set from a statewide survey conducted in the 1970s (Bortleson *et al.*, 1976a-d; Dion *et al.*, 1976a-b) is shown in Figure 12. Although very few lakes were monitored in 1990 in the Coast Range, the Willamette Valley, and the Cascades ecoregions, the two studies show similar patterns for all ecoregions. No lakes were monitored in the Eastern Cascades in 1990 and neither study included lakes in the Blue Mountains ecoregion. Data in Figure 12 exceeds the scale shown; the scale was adjusted to correspond to 1990 data.

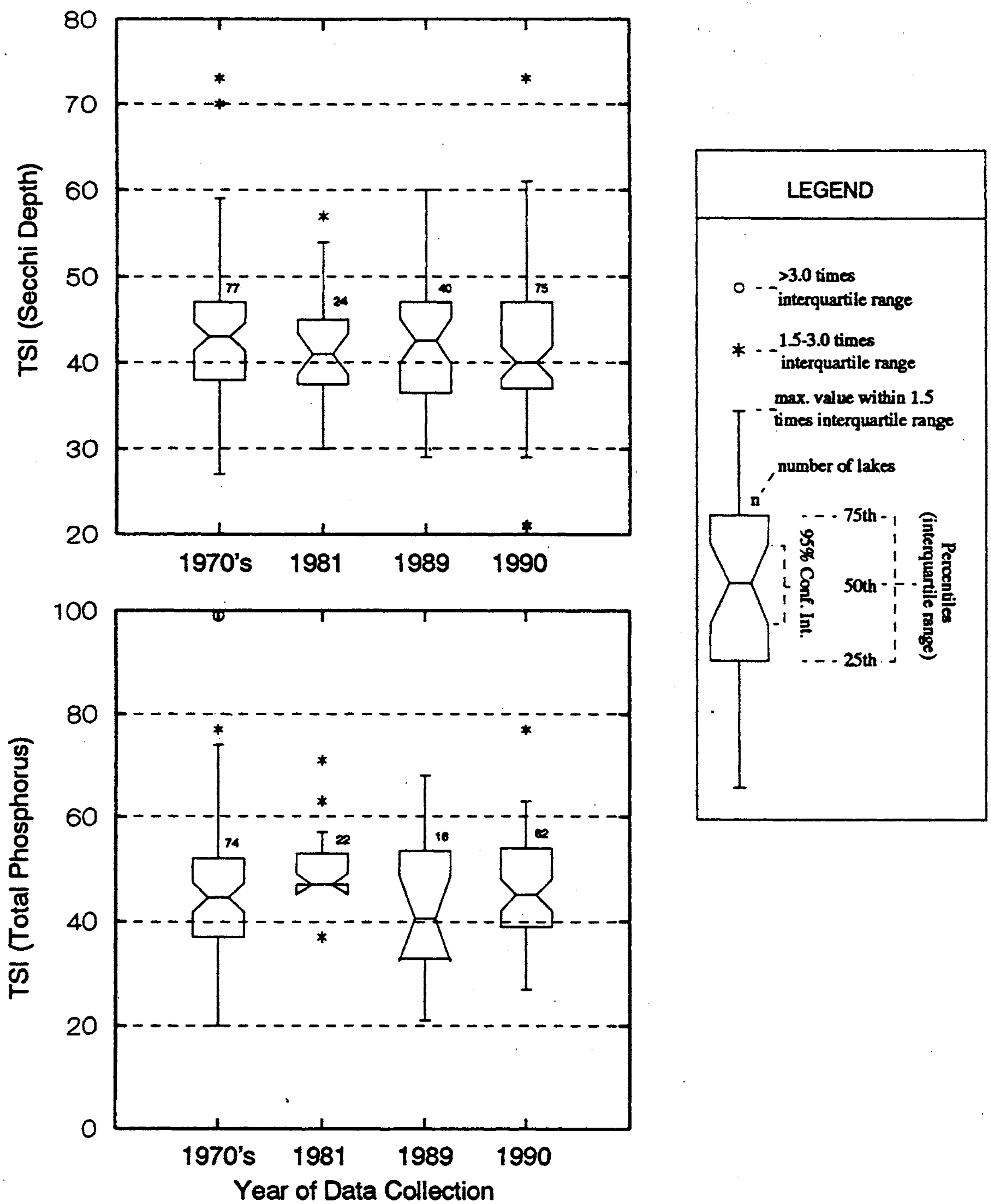


Figure 8. Box plots of Secchi- and phosphorus-based trophic state indices (TSI) from studies conducted in the early 1970's (Bortleson *et al.*, 1976a,b,c,d; Dion *et al.*, 1976a,b,c), 1981 (Sumioka and Dion, 1985), 1989 (Rector and Hallock, 1991), and 1990.

Table 8. Climatic data from Seattle and Spokane (EarthInfo, Inc., 1992). Temperatures are daily averages, snow and precipitation are annual totals.

Parameter	30-Year Average	1971	1972	1973	1974	1981	1989	1990
Station: SEATTLE TAC WSCMO AP								
Temp, Min (°F)	43.9	44	44	44	45	45	45	45
Temp, Max (°F)	59.1	57	58	59	60	60	60	60
Snow (in.)	12.61	25.8	22.2	4.0	13.5	1.1	14.2	13.6
Precip. (in.)	38.20	43.21	48.36	35.04	37.87	35.40	34.69	44.75
Station: SPOKANE WSO AP								
Temp, Min (°F)	38.1	37	37	39	37	38	37	38
Temp, Max (°F)	58.0	57	57	59	58	58	57	58
Snow (in.)	41.93	54.4	31.3	44.0	39.6	20.0	45.2	49.9
Precip. (in.)	16.04	18.48	13.53	17.11	16.04	14.91	14.71	19.61

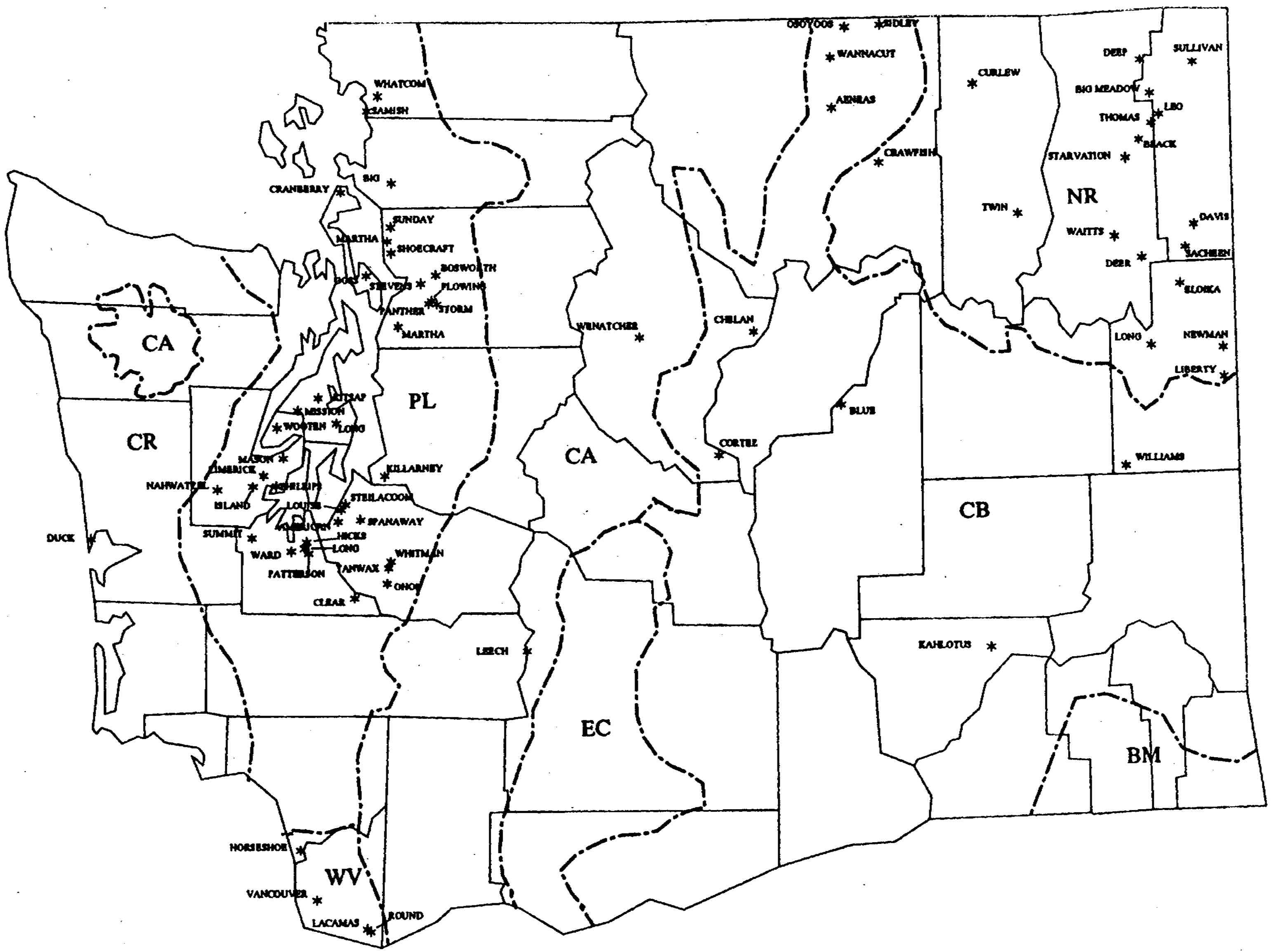


Figure 9. Ecoregion map. (CR = Coast Range, PL = Puget Lowland, WV = Willamette Valley, CA = Cascades, CB = Columbia Basin, and NR = Northern Rockies.)

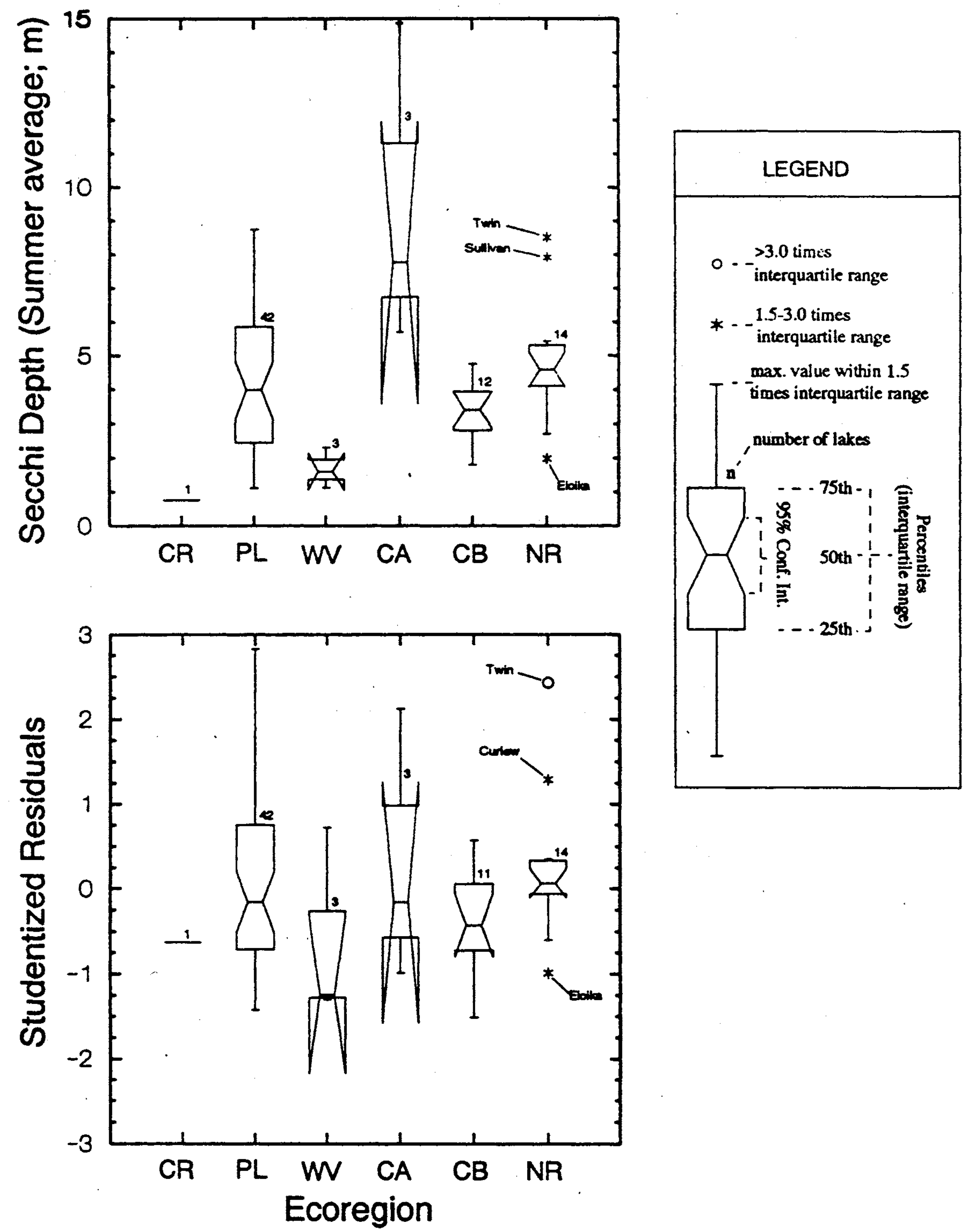


Figure 10. Box plots of volunteer-collected summer-average Secchi depths (top) and regression residuals after using several morphometric variables to predict Secchi depth (bottom) by Ecoregion. (CR = Coast Range, PL = Puget Lowland, WV = Willamette Valley, CA = Cascades, CB = Columbia Basin, and NR = Northern Rockies.)

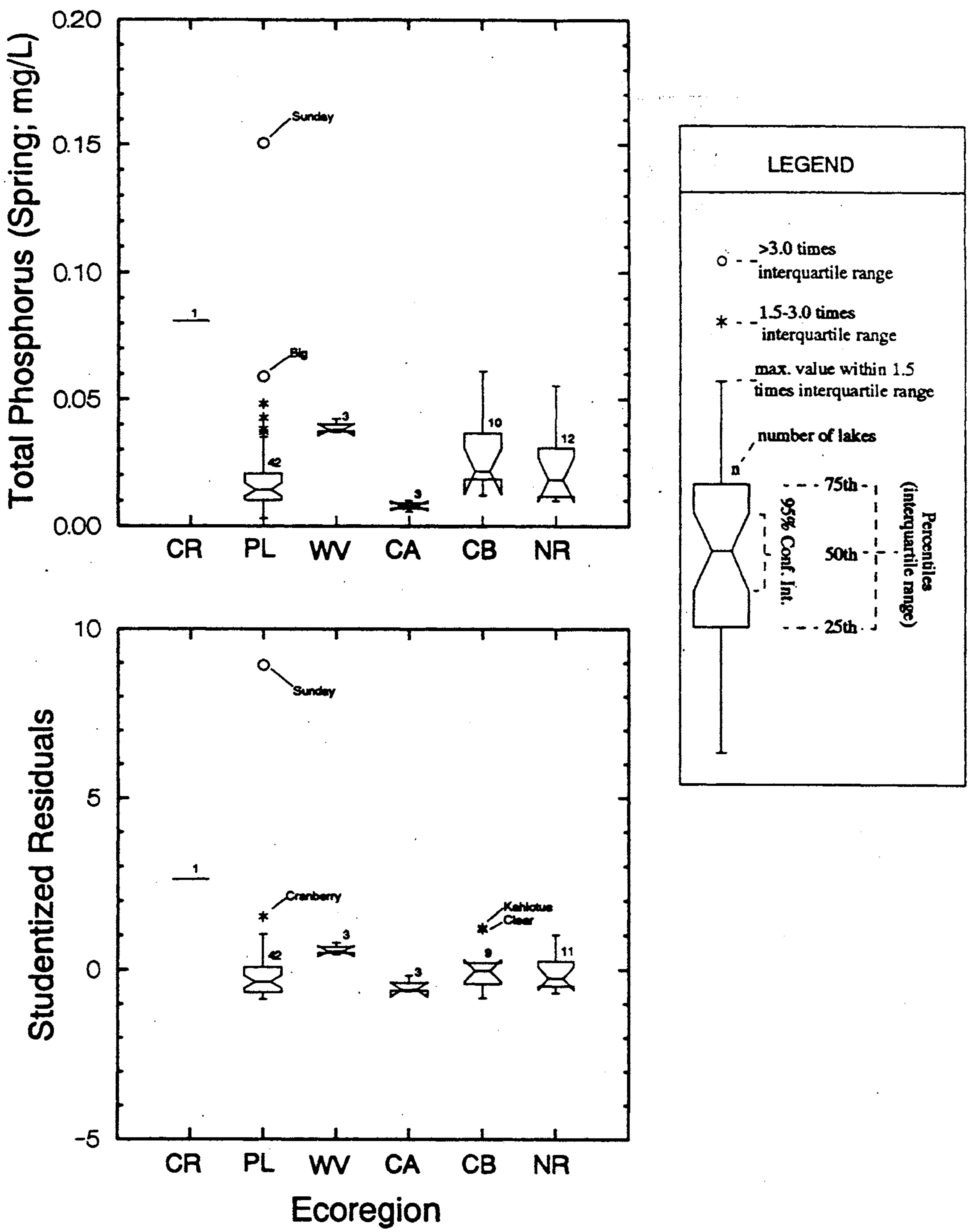


Figure 11. Box plots of spring total phosphorus concentration (top) and regression residuals after using several morphometric variables to predict total phosphorus (bottom) by Ecoregion. (CR = Coast Range, PL = Puget Lowland, WV = Willamette Valley, CA = Cascades, CB = Columbia Basin, and NR = Northern Rockies.)

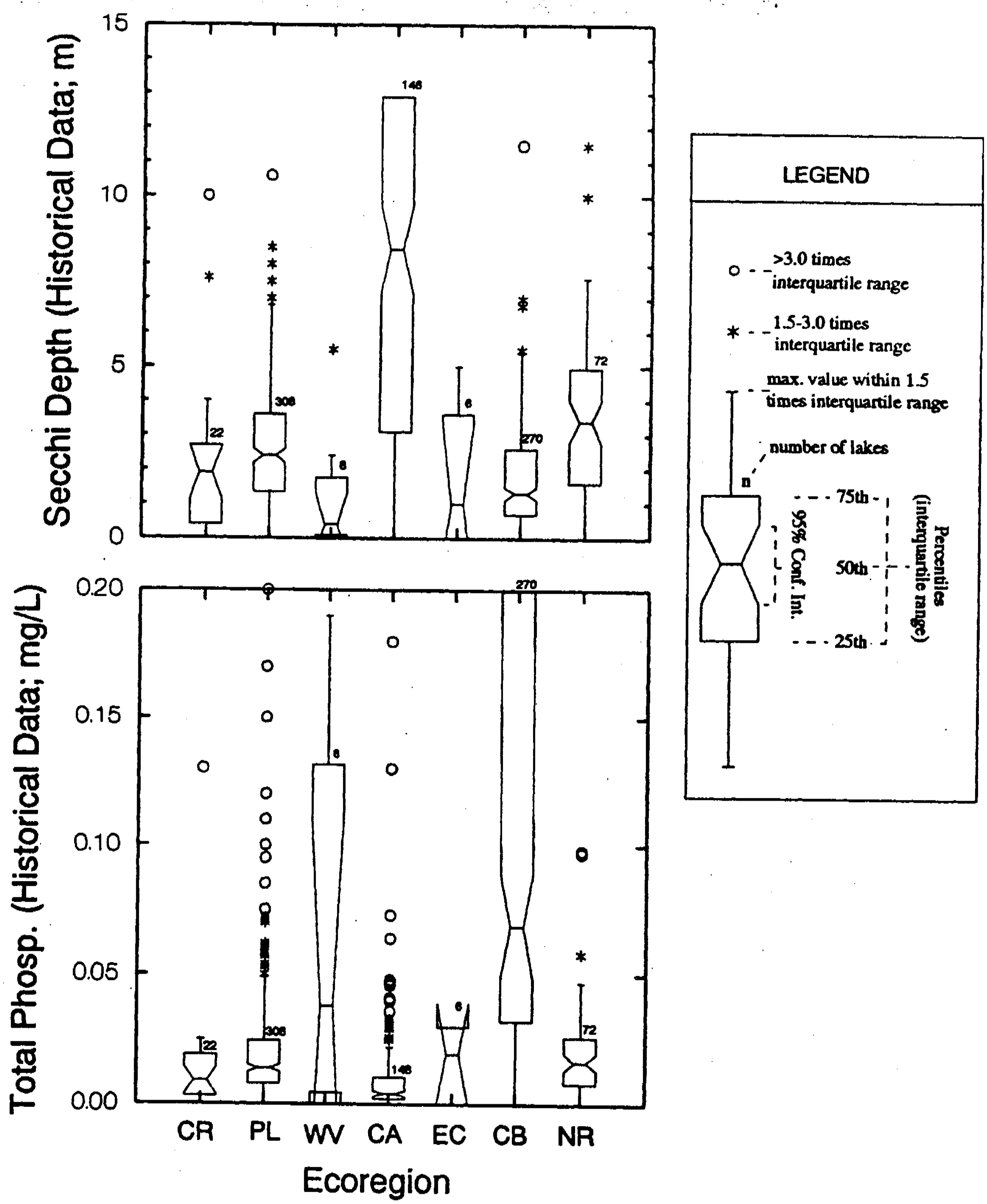


Figure 12. Box plots of Secchi depths (top) and total phosphorus (bottom) from the early to mid-1970s by Ecoregion. (CR = Coast Range, PL = Puget lowland, WV = Willamette Valley, CA = Cascades, EC = Eastern Cascades, CB = Columbia Basin, and NR = Northern Rockies.)

Some differences in Secchi depths and total phosphorus concentrations were evident between ecoregions in the older data set. Secchi depths tend to be shallower in the Willamette Valley, the Eastern Cascades, and the Columbia Basin, and deeper in the Cascades and the Northern Rockies. Total phosphorus was low in the Cascades ecoregion and most lakes fell within a very narrow range, although there were a number of exceptions in the older data set. Lakes in the Willamette Valley and Columbia Basin ecoregions tended to have higher total phosphorus concentrations than other ecoregions.

Three lakes had somewhat unusual Secchi depths in 1990 (indicated by '*' in Figure 10, top), all in the Northern Rockies ecoregion. Twin Lake (Ferry County) and Sullivan Lake (Pend Oreille County) had deeper than typical Secchi depths, and Eloika Lake (Spokane County) had shallower than typical depths. When the effects of a number of physical variables on Secchi depth were removed by a stepwise multiple linear regression (see below), Twin Lake and Eloika Lake were still atypical, but instead of Sullivan Lake, Curlew Lake was identified as unusual (Figure 10, bottom). The shallower than expected Secchi depths in Eloika Lake were not necessarily caused by phytoplankton, but may have resulted from sediment from natural erosion in the watershed observed by Soltero, *et al.* (no date). The deeper than expected Secchi depths at Curlew and Twin Lakes suggest that those lakes might be good candidates for protective management.

Several lakes in the Puget Lowland ecoregion had higher than usual total phosphorus concentrations, most notably Sunday Lake (Snohomish County) and Big Lake (Skagit County) (Figure 11, top). The effects of a number of physical variables on total phosphorus were removed by a stepwise multiple linear regression (see below). This procedure identified Sunday and Cranberry Lakes in the Puget Lowland ecoregion and Clear Lake (Spokane County) and Kahlotus Lake in the Columbia Basin ecoregion as unusual (Figure 11, bottom). Cranberry and Kahlotus Lakes are both undeveloped, highly productive lakes (see the Individual Lake Assessments Section). Clear Lake, on the other hand, has several resorts and is used heavily for recreation. Sunday Lake is much more eutrophic than it was in 1973 (Bortleson *et al.*, 1976b) and might be a good candidate for additional study to identify nutrient sources and develop a management plan.

The stepwise multiple regressions mentioned above were performed to removed the effects of significant physical variables on Secchi depth and total phosphorus in order to better identify atypical lakes within an ecoregion. The physical parameters evaluated were altitude, area, volume, shoreline length, maximum depth, mean depth, drainage area, shoreline development index (a measure of how windy a shoreline is), watershed area to surface area ratio, and relative depth (depth as a function of surface area). A significance probability of 0.2 to enter the regression and 0.2 to remove was specified. Significant variables in the regression to predict Secchi depth were watershed area to surface area ratio, mean depth, and shoreline development index (standard error (SE) = 1.66, $r^2 = 0.508$, and $p<0.01$). Significant variables in the regression to predict total phosphorus were watershed area:surface area, and relative depth (SE = 0.21, $r^2 = 0.11$, and $p=0.02$).

PRIORITY RANKING OF LAKES

This section discusses the methods used to rank Citizen Lake Monitoring Program (CLMP) lakes according to need for management of conventional water quality-related problems, or potential problems. Methods used by other states are discussed, followed by an overview of the methods we used, and a discussion of the specific variables used in the ranking process.

The purpose of this priority ranking is to assist, in part, EPA's Clean Lakes Program objective to "provide maximum recreational and environmental benefits to as many people as possible" (EPA, 1988). The water quality of the lake is one factor to consider in determining which lakes most urgently need management. In addition, EPA urges states to consider criteria such as public access, the number of people that will benefit, and the degree to which high-quality lakes may be threatened in the future. These factors are incorporated into the ranking scheme presented here.

The priority ranking presented here will not be used directly by Ecology, but rather is intended to be used as supporting documentation in applications for lake management grants. As discussed in Rector and Hallock (1991), Ecology is unable to use a prioritized list to seek out and fund high-priority projects directly because of Ecology's lake management funding process and the small number of lakes evaluated. However, because grant requests are initiated at the local level, local governments should consider high priority lakes as potential candidates for grant applications. The following prioritized list of lakes considers neither the source of eutrophication (natural or cultural) nor the likelihood of successful management.

Methods Used by Other States

Adler and Smolen (1989) discusses the prioritization methodology used by six different states. These six states were considered representative of the different methodologies being used. Five of the states assign points and calculate a numerical score based on several criteria. For example, Ohio assigns five points to lakes between 5 and 10 m deep. One state, New Mexico, uses a decision tree where the flow is guided by answers to yes/no questions.

The basic approach differs between states. Some states prioritize all lakes for which data are available. Others prioritize only those lakes where a grant application has been made and matching funds are available. New York and Colorado prioritize waterbodies based on impairment of beneficial uses. Illinois and Ohio assess water quality using Carlson's Trophic State Index (Carlson, 1977). Rhode Island assesses threat to waterbodies based on watershed measures (such as change in the number of building permits issued).

All six states include an evaluation of public value in their ranking. Variables such as public access, recreational facilities, proximity to metropolitan areas, and uniqueness of the waterbody were considered. Some states included a subjective assessment of likelihood of success, though this is not always a part of the prioritization process. Other states used morphometric measurements to assess the potential for restoration. For example, a small watershed was considered more readily managed than a large watershed.

Washington's Prioritization Method

We elected to use a ranking approach. This approach prioritized lakes based on an average of the ranks for 15 variables, which are within four descriptive categories. The four categories are susceptibility to eutrophication, current water quality, public value, and trend in water quality. By ranking lakes rather than assigning points (*i.e.*, x points when a variable is between y and z), subjective determination of boundary values (y and z) is avoided. An advantage of averaging ranks within categories is that lakes can be ranked even if some data are missing. A disadvantage of ranking is that the score for a given lake cannot be determined independently; all lakes must be evaluated together.

We developed a dBASE IV* computer program which prioritized lakes using the following steps:

1) Lakes were ranked by each of the 15 variables in Table 9. Most variables were ranked in descending order, that is, the higher the variable, the lower (closer to one) the priority. (A lake with a low rank has a higher priority for protection.)

2) Each of the ranks of the one to six variables descriptive of a category were multiplied by a weighting factor (Table 9) and the results summed across all variables within that category. Weighting factors were used to adjust the relative importance of the different variables. This was repeated for each of the four categories.

3) The lakes were ranked by each of the category sums, thereby reducing the 15 variable ranks to four category ranks.

4) The four category ranks were multiplied by weighting factors and summed.

5) Lakes were then ranked by the sum of category ranks.

The ordered list was divided into high, medium, and low priority lakes. High priority lakes were defined as those in the upper 15th percentile, excluding lakes in the bottom half of the "Public Value" category. This exclusion was applied on the assumption that limited management funds should not be expended on lower-value lakes, regardless of their ranking.

The list of variables in Table 9 was refined and weighting factors were determined for categories and variables by a Delphi process. The Delphi technique, as used here, consisted of a survey sent to local resource managers and aquatic scientists, followed by a statistical summary, followed by interviews with the Delphi panel (participants in the survey). This three-step

Table 9. Variables and weighting factors used in assigning lake management priorities to monitored lakes. '*' indicates the variable was ranked in ascending order, that is, a low result corresponds to a low rank (high priority).

Weighting Factor	Variable
MAIN CATEGORIES	
0.34	Susceptibility to Eutrophication
0.26	Current Water Quality
0.20	Public Value
0.20	Trend in Trophic State
SUSCEPTIBILITY to eutrophication	
0.18	Flushing index (1, 2, or 3 for river, creek, or intermittent inlets, respectively)[1]
0.18	Population density (adjusted for sewered homes by considering two sewered homes equivalent to one un-sewered home)[1]
0.17	*Relative depth (from Wetzel, 1983)[2]
0.17	Watershed area/lake area[2]
0.17	*Mean depth[3]
0.13	Shoreline development index (high index = windy shore)[2]
CURRENT WATER QUALITY	
0.46	Subjective assessment[1]
0.34	Total phosphorus (from 1990 spring samples)[1]
0.20	Clean Water Act Goals (1 pt. for each goal not met)[4]
PUBLIC VALUE of the lake	
0.32	Use as drinking water source (yes/no)[1]
0.20	Number of lakeshore homes[1]
0.22	Population within 30 miles[5]
0.16	Lake area[1]
0.10	*Other lakes within 30 miles, >20 acres, with access[6]
TREND in trophic state	
1.00	Narrative assessment minus 1974 assessment[1 and 3]

Source of data:

[1] - Citizen Lake Monitoring Program
[2] - calculated, WSB 42 and 43 (Bortleson, *et al.* (1976 a-d), Dion, *et al.* (1976 a-c), and Sumioka and Dion, (1985))
[3] - WSB 42 and 43
[4] - 305(b) Report (Ecology, 1992)
[5] - ARC/INFO tabular database of 1990 decennial census data; 30 mile radius centered on point representing the lake.
[6] - ARC/INFO database from USGS 1:100,000 hydrographic data. 30 mile radius centered on point representing the lake.

process was repeated three times with each survey used to refine the questions in previous surveys. Survey responses were compiled and weighting factors determined with a computer software program developed by Horner *et al.* (1986) using a method proposed by Saaty (1977).

Priority Ranking of Lakes

Results of the Delphi survey, the lake prioritization, and suggested improvements for future rankings are presented here.

Results of the Delphi Survey

A survey of local resource managers and aquatic scientists indicated susceptibility to eutrophication was the most important factor in prioritizing lakes according to need for water quality management. Current water quality, public value, and trend in trophic state, in that order, were of lesser importance (Table 10). In other words, preserving lakes susceptible to eutrophication was considered more important than managing/restoring already eutrophic lakes. Trend in trophic state was considered less important by most respondents because only two years of data were available. This category may be weighted more heavily when trends can be assessed with more confidence.

Some states (see above) refer to the "susceptibility to eutrophication" category as "potential water quality" and assign points in reverse order to the order used here (although no two states use quite the same list of variables). Those states use this category to assess manageability, presumably on the assumption that eutrophic lakes that are not ordinarily susceptible to eutrophication will be more easily managed. For example, while a small watershed may indicate a lowered susceptibility to eutrophication, a small watershed is also more easily managed than a large one.

Some survey respondents felt that priority should be given to lakes susceptible to eutrophication with *good* water quality. The emphasis using this method would be *protection* rather than *restoration*. It is less expensive to protect a lake through education, watershed management, etc., than to restore a culturally eutrophic lake. Lakes were ranked a second time after reversing the order of the "Current Water Quality" category (so high-quality lakes would be given higher priority than lower-quality lakes). Results are discussed in the following section.

A computerized procedure has the advantage of allowing weighting factors and ranking order to be easily varied to meet requirements of regional lake managers. The program and data are available from the authors on request.

Table 10. Rankings of 1990 Citizen Lake Monitoring Program lakes according to need for eutrophication management, with poor water quality considered a high priority characteristic. High priority lakes were required to be in the top half of the "public value" category. The lower the rank, the higher the priority. (Management status: 'A' = Phase I, 'B' = Phase II, 'H' = herbicide treatment; uppercase = completed, lowercase = in progress/pending.)

Lake (County)	Management Status	Public Value	Suscep to Eutrop	Curren Water Qual	Trnd	Ovr Rnk
High Priority Lakes						
LONG (KITSAP)	AB	1.0	1.0	5.0	41.5	1.0
STEILACOOM (PIERCE)	H	23.0	2.0	16.0	10.0	2.0
BIG (SKAGIT)	A	22.0	9.0	9.0	10.0	3.0
CLEAR (SPOKANE)	H	33.0	14.0	4.0	.	5.0
OHOP (PIERCE)	H	12.0	8.0	21.0	41.5	7.0
SACHEEN (PEND OREILLE)	A H	17.0	13.0	28.0	23.0	8.0
LIBERTY (SPOKANE)	AB	25.0	23.0	27.0	10.0	9.0
MISSION (KITSAP)		13.0	34.0	31.0	10.0	12.5
ST. CLAIR (THURSTON)	H	8.0	46.0	19.0	10.0	12.5
NEWMAN (SPOKANE)	Ab	2.0	10.0	32.0	65.0	14.0
Medium Priority Lakes						
BANKS (GRANT)	H	41.0	6.0	6.0	.	4.0
KAHLOTUS (FRANKLIN)		69.0	3.0	2.0	10.0	6.0
PATTERSON (SOUTH) (THURSTON)	ABH	46.0	15.0	22.0	10.0	10.0
ELOIKA (SPOKANE)	Ab	45.0	19.0	8.0	23.0	11.0
DUCK (GRAYS HARBOR)	H	39.0	11.0	7.0	59.0	15.0
TANWAX (PIERCE)	H	43.0	3.0	12.5	10.0	16.0
KILLARNEY (SOUTH) (KING)	H	57.0	32.0	10.0	10.0	17.5
LIMERICK (MASON)	H	50.0	4.0	42.0	23.0	17.5
DEER (STEVENS)		6.0	20.0	56.0	23.0	19.0
AMERICAN (PIERCE)	a H	24.0	30.0	41.0	10.0	20.0
LONG (THURSTON)	ABH	30.0	5.0	46.5	41.5	21.0
SUNDAY (SNOHOMISH)		70.0	35.0	1.0	10.0	22.0
SIDLEY (OKANOGAN)		74.0	21.0	17.5	10.0	23.0
MAYFIELD (LEWIS)	H	26.0	27.0	34.0	.	24.0
DEEP (STEVENS)		32.0	45.0	24.0	10.0	25.0
PHILLIPS (MASON)		19.0	12.0	53.0	41.5	26.0
SPANAWAY (PIERCE)	H	31.0	7.0	33.0	65.0	27.0
CLEAR (THURSTON)	H	56.0	49.0	14.5	1.0	28.0
WANNACUT (OKANOGAN)		51.0	24.0	46.5	10.0	29.0
KITSAP (KITSAP)	A	27.0	28.0	37.0	41.5	30.0
WILLIAMS (SPOKANE)	H	11.0	25.0	39.0	65.0	31.0
STARVATION (STEVENS)		76.0	16.0	20.0	41.5	32.0
WHITMAN (PIERCE)		65.0	31.0	25.0	23.0	33.5

Table 10. Continued.

Lake (County)	Management Status	Suscep to Eutrop	Curren Trophi Status	Public Value	Trnd	Ovr Rnk
HICKS (THURSTON)	H	40.0	17.0	48.0	41.5	33.5
CRANBERRY (ISLAND)		72.0	37.0	3.0	41.5	35.0
HORSESHOE (COWLITZ)	a	67.0	33.0	12.5	41.5	36.0
PATTERSON (NORTH) (THURSTON)	H	60.0	22.0	35.5	41.5	37.0
LACAMAS (CLARK)	Ab	59.0	41.0	14.5	41.5	38.0
NAHWATZEL (MASON)		20.0	29.0	63.0	41.5	39.0
SHOECRAFT (SNOHOMISH)	A	36.0	18.0	54.5	59.0	40.0
LOUISE (PIERCE)	H	53.0	52.0	29.5	23.0	41.0
FLOWING (SNOHOMISH)		15.0	63.0	45.0	23.0	42.0
SAMISH (WEST) (WHATCOM)		16.0	75.0	43.0	10.0	43.0
BLUE (GRANT)	H	55.0	40.0	35.5	.	44.0
Low Priority Lakes						
BLACK (STEVENS)		44.0	64.0	39.0	10.0	45.0
SAMISH (EAST) (WHATCOM)		9.0	70.0	49.5	23.0	46.5
OSOYOOS (OKANOGAN)		35.0	48.0	44.0	41.5	46.5
MASON (MASON)	H	3.0	36.0	72.5	59.0	48.5
SPENCER (MASON)		18.0	26.0	69.5	65.0	48.5
STORM (SNOHOMISH)		62.0	67.0	26.0	10.0	50.0
WOOTEN (MASON)		29.0	50.0	64.0	23.0	51.0
CURLEW (FERRY)	AbH	38.0	65.0	29.5	41.5	52.0
SUMMIT (THURSTON)		7.0	51.0	75.0	41.5	53.0
WENATCHEE (CHELAN)		10.0	54.0	71.0	41.5	54.5
THOMAS (STEVENS)	H	28.0	39.0	58.5	65.0	54.5
WHATCOM (WHATCOM)	Ab	4.0	60.0	74.0	41.5	56.0
ROUND (CLARK)		73.0	69.0	11.0	41.5	57.0
CHELAN (CHELAN)		5.0	66.0	62.0	.	58.0
TWIN (FERRY)	Ab	61.0	53.0	39.0	.	59.0
MERRILL (COWLITZ)		34.0	56.0	57.0	.	60.0
PANTHER (SNOHOMISH)		49.0	59.0	49.5	41.5	61.0
AENEAS (OKANOGAN)		52.0	58.0	51.0	41.5	62.0
LEO (PEND OREILLE)		77.0	42.0	54.5	41.5	63.0
MARTHA LAKE (SNOH)	a	47.0	47.0	60.0	59.0	65.0
CORTEZ (CHELAN)		71.0	73.0	23.0	41.5	66.0
BOSWORTH (SNOHOMISH)		14.0	72.0	72.5	41.5	67.0
BIG MEADOW (PEND OREILLE)		75.0	71.0	17.5	.	68.0
WARD (THURSTON)		54.0	55.0	66.0	41.5	69.0
WAITTS (STEVENS)		42.0	57.0	61.0	59.0	70.0
STEVENS (SNOHOMISH)		21.0	76.0	69.5	41.5	71.0

Table 10. Continued.

Lake (County)	Management Status	Suscep to Eutrop	Curren Trophi Status	Public Value	Trnd	Ovr Rnk
ISLAND (MASON)		63.0	44.0	66.0	59.0	72.0
GOSS (ISLAND)		58.0	62.0	66.0	41.5	73.5
LAKE MARTHA (SNOH)	A	66.0	68.0	52.0	41.5	73.5
DAVIS (PEND OREILLE)		37.0	74.0	58.5	59.0	75.0
BENSON (MASON)		48.0	61.0	76.0	.	76.0
SULLIVAN (PEND OREILLE)		64.0	77.0	68.0	41.5	77.0

Results of the Lake Prioritization

Lakes monitored by volunteers in 1990 are prioritized according to need for eutrophication management in Table 10. A high priority lake is more likely to have high susceptibility to eutrophication, poor water quality, high public value, and a declining trend in water quality. Fifty percent of the "high priority" lakes have received some form of management attention other than herbicide application. Only 23% and 15% of the medium and low priority lakes, respectively, have received management attention. This ranking scheme seems to be in general agreement with past management funding decisions.

The lakes in Table 10 were ranked a second time, except that *good* (rather than poor) water quality was considered a high-priority characteristic. The top ten lakes (and counties), susceptible to eutrophication but with good current water quality are listed in Table 11. Lakes not in the top third of the "Current Water Quality" category were excluded to ensure priority lakes using this methodology have good water quality.

When ranked this way, five of the ten high-priority lakes are in Mason County. In addition to good water quality, the Mason County lakes tended to have higher than average public value. Two other lakes, Twin Lake (Ferry County) and Curlew Lake (Ferry County), were identified in the Ecoregion Analysis Section as having unusually good water quality compared to other lakes in their ecoregion.

Suggested Improvements for Future Rankings

The ranking procedures used here incorporate a number of the recommendations made in Rector and Hallock (1991), most notably the inclusion of a trend category and the use of weighting factors. There are still a number of weaknesses in the methods, however. Future improvements to the procedure may include the following:

1) An assessment of management potential. Lakes should be removed from the 'high priority' list where management is less likely to be successful. For example, management with the intent of reducing eutrophication in naturally eutrophic lakes may not be desirable, and may be less likely to be successful than management of culturally eutrophic lakes.

2) Further refinements to the list of variables. Several "Public Value" variables are intended as surrogates of actual lake use; some more direct measures may be found. A "recreational facilities" variable could also be included in this category. The "Suscepti-bility to Eutrophication" category could be improved by including expected growth in the watershed and land use information.

3) A meaningful evaluation of macrophyte problems. Some lakes have low phosphorus concentrations and good Secchi depth measurements, yet have serious macrophyte problems. This is particularly true of lakes infested with eurasian milfoil (*Myriophyllum*

Table 11. The ten highest ranking lakes in the 1990 Citizen Lake Monitoring Program lakes according to need for eutrophication management, with good water quality considered a high priority characteristic. High priority lakes were required to be in the top third of the "current water quality" category. The lower the rank, the higher the priority. (Management status: 'A' = Phase I, 'B' = Phase II, 'H' = herbicide treatment; uppercase = completed, lowercase = in progress/pending.)

Lake (County)	Management Status	Public Value Eutrop	Suscep to Qual	Curren Water	Trnd	Ovr Rnk
Deer (Stevens)		6.0	20.0	21.0	23.0	1
Phillips (Mason)		19.0	12.0	24.0	41.5	2
Mason (Mason)	H	3.0	36.0	4.5	59.0	7
Nahwatzel (Mason)		20.0	29.0	14.0	41.5	8
Spencer (Mason)		18.0	26.0	7.5	65.0	11
Summit (Thurston)		7.0	51.0	2.0	41.5	13
Wenatchee (Chelan)		10.0	54.0	6.0	41.5	20
Whatcom (Whatcom)	Ab	4.0	60.0	3.0	41.5	21
Wooten (Mason)		29.0	50.0	13.0	23.0	23
Shoecraft (Snohomish)	A	36.0	18.0	22.5	59.0	24

spicatum). These lakes may be in desperate need of management but are unlikely to be near the top of Table 10. An example is Lake Osoyoos, which was ranked "Low Priority," yet has continuing problems with milfoil.

4) Inclusion of ecoregion influences in the "Current Water Quality" category. A lake with better than average water quality compared to other lakes statewide, may have poor water quality when compared to other lakes in the same ecoregion. (See the preceding section, "Ecoregion Analysis.") One solution would be to divide "Current Water Quality" variables for each lake by the mean for that lake's ecoregion.

5) Use of a parametric procedure, rather than a non-parametric ranking. Ranking removes information about the magnitude of the difference between adjacent lakes. One solution would be to transform all variables to an approximately standard uniform distribution. The actual value of the variable could then be used to determine an overall score, rather than a rank.

INDIVIDUAL LAKE ASSESSMENTS

The individual lake summaries presented here were written primarily for the volunteers who participated in the 1990 Citizen Lake Monitoring Project. As a result, layperson's terms are used and many of the basic limnological concepts are discussed or described. The original data summaries were mailed to the volunteers in December 1991. Individual summaries have also been provided upon request. Accompanying each individual report were materials that explain the sources of the data included, the methods used for interpreting the data, and a glossary of terms. An example of these accompanying materials is in Appendix E.

Aeneas Lake -- Okanogan County

Aeneas Lake is located 3.7 miles southwest from Tonasket. It is fed by an intermittent inlet from Horse Springs Coulee, and it has no surface outlet.

Size (acres)	62
Maximum Depth (feet)	62
Mean Depth (feet)	29
Lake Volume (acre-feet)	1820
Drainage Area (miles^2)	32.4
Altitude (feet)	1350
Shoreline Length (miles)	1.3

Estimated Trophic State:	Mesotrophic*
Mean Trophic State Index** (Secchi):	37

* See Comments Section
** From Carlson (1977)

Summary of Questionnaire Results and Information from the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Aeneas Lake is used for fishing, swimming, and waterfowl hunting. Recreational facilities on the lakeshore include a camping area, a beach, and one boat ramp. Lake water is withdrawn for drinking and irrigation. Currently the watershed is used for logging, animal grazing, crop agriculture, and the lakeshore is being developed further for residences. In the past, the watershed was used for logging, crop agriculture, and mining, and the shoreline was altered. There are four houses on the lakeshore, and all are occupied year-round. The lakeshore is not sewered, and there are no storm drains that empty into the lake. Trout are stocked in the lake. Presently there is no citizen's lake protection organization for the lake. The worst problems in the lake, in the opinion of the volunteer, are 1) aquatic plants, 2) floating debris, and 3) water level. Overall, the volunteer finds that Aeneas Lake has good recreational water quality, and suggested that orchard runoff, cattle, and homes on the shore may have the potential to affect water quality.

According to the volunteer, the lake has no natural inlets or outlets. The lake is filled by water pumped from the Okanogan River. There are water rights for irrigation. The entire lake is ringed with submerged plants, and willows and reeds grow along areas of the shoreline. No algae blooms occurred in 1990. There are irrigation pipes on the west shore of lake, and submerged trees in both the north and south areas of the lake.

Aeneas Lake -- Okanogan County

Monitoring Results/Summary of Other Available Information

Volunteer-collected Secchi disk transparency data show that water clarity was lowest during May, and improved somewhat over the course of the summer. Aeneas Lake was also sampled by Ecology staff during June and September 1990. Although the lake was as clear as oligotrophic lakes, 1990 data collected by Ecology showed that the lake had several eutrophic characteristics, such as high concentrations of ammonia-nitrogen in the hypolimnion, depleted dissolved oxygen concentrations near the bottom of the lake, hydrogen sulfide (rotten-egg smell) in the hypolimnion, considerable aquatic plant growth covering the bottom of the lake, and blue-green algae species growing in the lake (Coots, 1991). Concentrations of total phosphorus and total nitrogen in the epilimnion were moderately high (0.012 mg/L and 0.315 mg/L, respectively), and were in the range associated with mesotrophic lakes.

Compared to data collected in 1974 by the USGS (Dion *et al.*, 1976), some parameters in Aeneas Lake were very similar during both 1974 and 1990. In 1974, hydrogen sulfide was detected in the hypolimnion, dissolved oxygen was 0.3 mg/L near the bottom of the lake, the concentration of total phosphorus near the surface was 0.019 mg/L, and Secchi visibility was ten feet. However, there was much more aquatic plant growth reported in 1990 (Coots, 1991) than in 1974. In 1974, no aquatic plants reported in the lake, although algal density was relatively high.

Comments

Aeneas Lake was estimated as mesotrophic, although the lake exhibits oligotrophic, mesotrophic, and eutrophic characteristics. Because Secchi disk transparency data tend to underestimate the trophic state of Aeneas Lake, future estimations of trophic state for this lake should be based on concentrations of total phosphorus. Secchi data are still useful, though, and may best be used to evaluate the occurrence and severity of algal growth in the lake.

Because the lake has only intermittent inflow and no outflow to dilute and flush nutrients from the lake, it is likely that any nutrient loading to the lake will fertilize additional plant and algae growth. Rooted aquatic plants, such as the ones identified in Aeneas Lake, need a nutrient-rich sediment in order to thrive. The larger aquatic plant population in 1990 compared to 1974 could mean that nutrients are accumulating in the sediments of Aeneas Lake.

Other Okanogan County lakes monitored for the program in 1990 were Lake Wannacut, Crawfish Lake, Sidley Lake and Lake Osoyoos. Like Aeneas Lake, Sidley Lake and Crawfish Lake have no permanent inlets or outlets and have moderate to high amounts of aquatic plant growth. Sidely Lake had the highest trophic state of these three lakes, based on high concentrations of nutrients in the water and low water clarity. Aeneas Lake had more aquatic plant growth and lower concentrations of dissolved oxygen near the lake bottom, compared to the other monitored Okanogan County lakes.

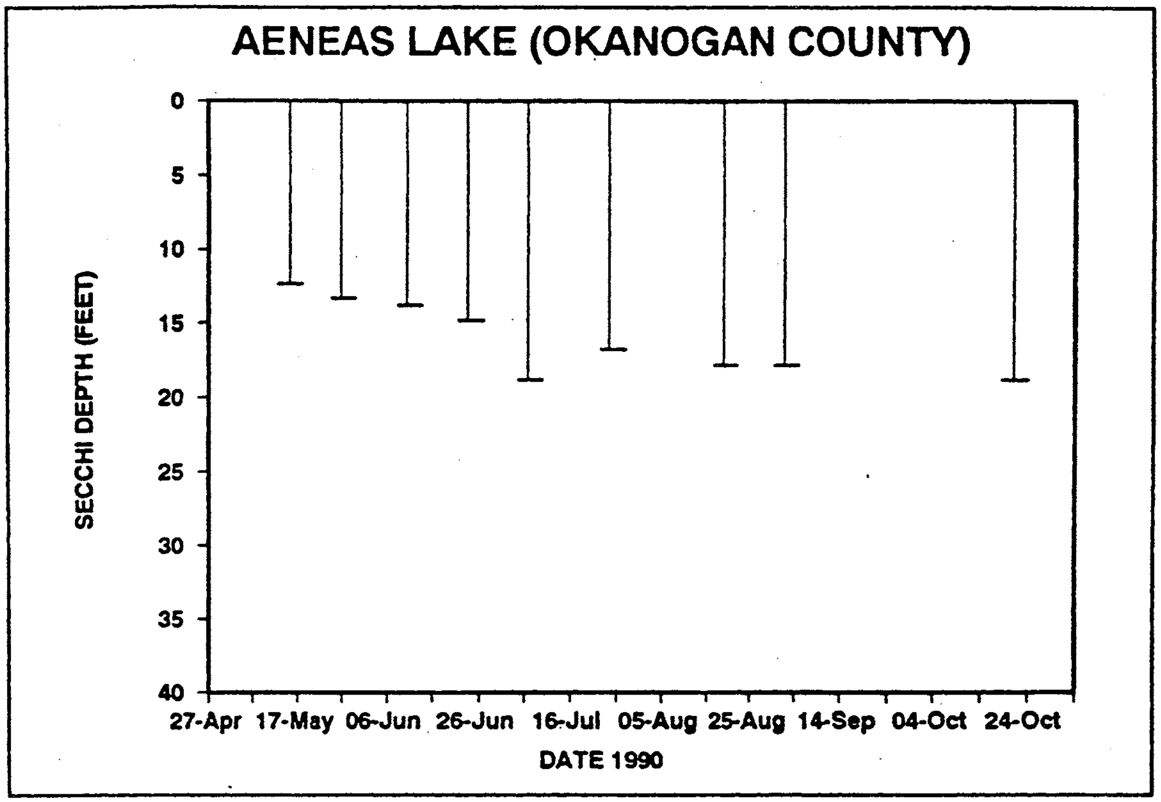
Acknowledgement

I thank Diane Richardson for volunteering her time to monitor Aeneas Lake during 1990.

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
16-May	15.6	60.1	6.5	Gr-Brown	50	Heavy	Breezy	11.5	3.3	inches of rain this month.
28-May	15.8	60.4	6.5	Lt-Green	100	Heavy	Calm	12.5*	2.0	
12-Jun	21.1	70.0	6.5	Lt-Green	25	Trace	Light	13.0		No lake height, marker moved.
25-Jun	23.3	73.9	6.5	Lt-Green	90	None	Calm	14.0		
08-Jul	25.6	78.1	6.5	Lt-Green	10	Trace	Calm	18.0	1.0	
26-Jul	26.1	79.0	6.5	Lt-Green	100	None		16.0	1.0	
20-Aug	27.8	82.0	6.5	Lt-Green	100	None		17.0	0.0	
03-Sep	25.5	77.9	6.5	Lt-Green	100	None		17.0		
22-Oct	9.4	48.9	6.5	Lt-Green	100	None		18.0		

* There was high variability between the first and second Secchi depths collected; this data point may not be used in data comparisons


AENEAS LAKE (OKANOGAN COUNTY)
SECCHI DEPTH (FEET)
0
5
10
15
20
25
30
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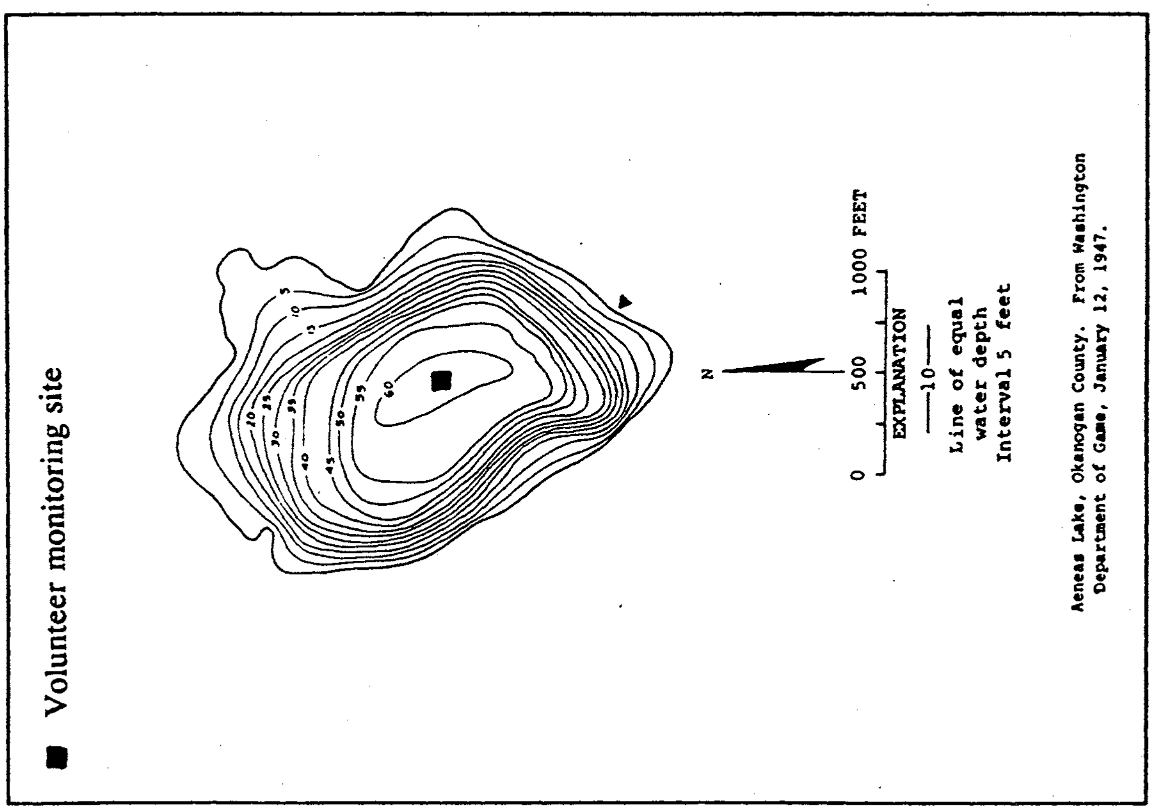
14-Sep
04-Oct
24-Oct
DATE 1990


Volunteer monitoring site
N
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—10—
Line of equal
water depth
Interval 5 feet
Aeneas Lake, Okanogan County. From Washington
Department of Game, January 12, 1947.

American Lake -- Pierce County

American Lake is located eight miles southwest from Tacoma. It is fed primarily by Murray Creek, which drains through the Fort Lewis Military Reservation. Fort Lewis borders part of the lake. No natural outlet exists; in 1956 a box culvert was installed which overflows to Sequallitchew Creek (Brower and Kendra, 1990). The lake is 3.5 miles long.

Size (acres)	1100
Maximum Depth (feet)	90
Mean Depth (feet)	53
Lake Volume (acre-feet)	60,000
Drainage Area (miles^2)	25.4
Altitude (feet)	235
Shoreline Length (miles)	11.8

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index** (Secchi):	32*
Mean Trophic State Index** (Total Phosphorus):	43

* See Comments Section
** From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The questionnaire on lake watershed uses was not returned by the volunteer.

Monitoring Results/Summary of Other Available Information

There were not enough Secchi data collected in 1990 to evaluate patterns in algal growth. The profile data collected in August 1990 show that dissolved oxygen concentrations were depleted in the bottom 10 meters (about 33 feet) of the lake. The increase in dissolved oxygen concentrations at 9 meters during August could be from a combination of decreased water temperatures (dissolved oxygen has a higher solubility in colder temperatures) and increased algae growth at this depth. A subsurface bloom of blue-green algae occurred at 9.2 meters in 1989 (Brower and Kendra, 1990) and resulted in a similar dissolved oxygen profile as the one measured in 1990. Concentrations of dissolved oxygen below 1.0 mg/L near the bottom of American Lake were also reported in 1968 (Lee, 1969) and 1971 (Bortleson *et al.*, 1976).

Concentrations of total phosphorus and total nitrogen in 1990 were moderately high. Total phosphorus concentrations were similar to concentrations found in 1989 by Ecology (Brower and Kendra, 1990), but were much higher than concentrations found during 1971 (0.0 mg/L; Bortleson *et al.*, 1976). Concentrations of total nitrogen were much higher in 1990 than in 1989.

American Lake -- Pierce County

From December through January 1989, natural toxins from a severe bloom of the blue-green algae *Anabaena flos-aquae* were released into American Lake. The deaths of five cats and several waterfowl, as well as the illnesses of some dogs and cats, were attributed to the ingestion of these toxins (Tacoma-Pierce County Health Department, pers. comm.). This was the first reported instance of a toxic algae bloom west of the Cascades (Tacoma News Tribune, 1989) and it is also unusual in that the toxicity occurred during cooler winter months. The lake was treated with 400 pounds of copper sulfate on December 10, 1989, to kill the algae bloom. According to newspaper reports, the algae bloom subsided by February 1990. Causes of algae toxicity are still unknown, but the issue is presently under investigation by a private consulting firm. The *Anabaena* species may have been present in the lake for many years, since an *Anabaena* species was reported to be the dominant alga in the lake during 1920s (Lee, 1969). Because *Anabaena* is indicative of a eutrophic lake, the fact that it was reported so long ago suggests that the lake has had high nutrient concentrations for many years.

Comments

American Lake exhibits both oligotrophic and eutrophic characteristics. An oligotrophic characteristic of the lake is the water clarity found in 1989-1990; however, very few Secchi depth measurements were collected during both years so it is difficult to assess trophic state based on Secchi depth data alone. Eutrophic characteristics of the lake include the depletion of dissolved oxygen concentrations near the bottom of the lake and severe blue-green algae blooms. American Lake is estimated as mesotrophic, rather than oligotrophic, primarily because of the blue-green algal toxicity that occurred in 1989. No severe algal blooms or associated toxicity were reported during the winter of 1990.

Because of the large surface area of the lake, winds can localize algae growth in nearshore areas. As a result, algae growth may be minimal in the open water areas of the lake and Secchi data collected from these areas will underestimate the trophic state of the lake. Because of this, future estimations of trophic status should be based on chemical data. If Secchi data from American Lake are to be collected in the future, it may be worthwhile to locate stations closer to shore and to use the data to evaluate the occurrence and severity of algal growth in these areas.

Acknowledgement

I thank the David G. Anderson family for volunteering their time to monitor American Lake during 1990.

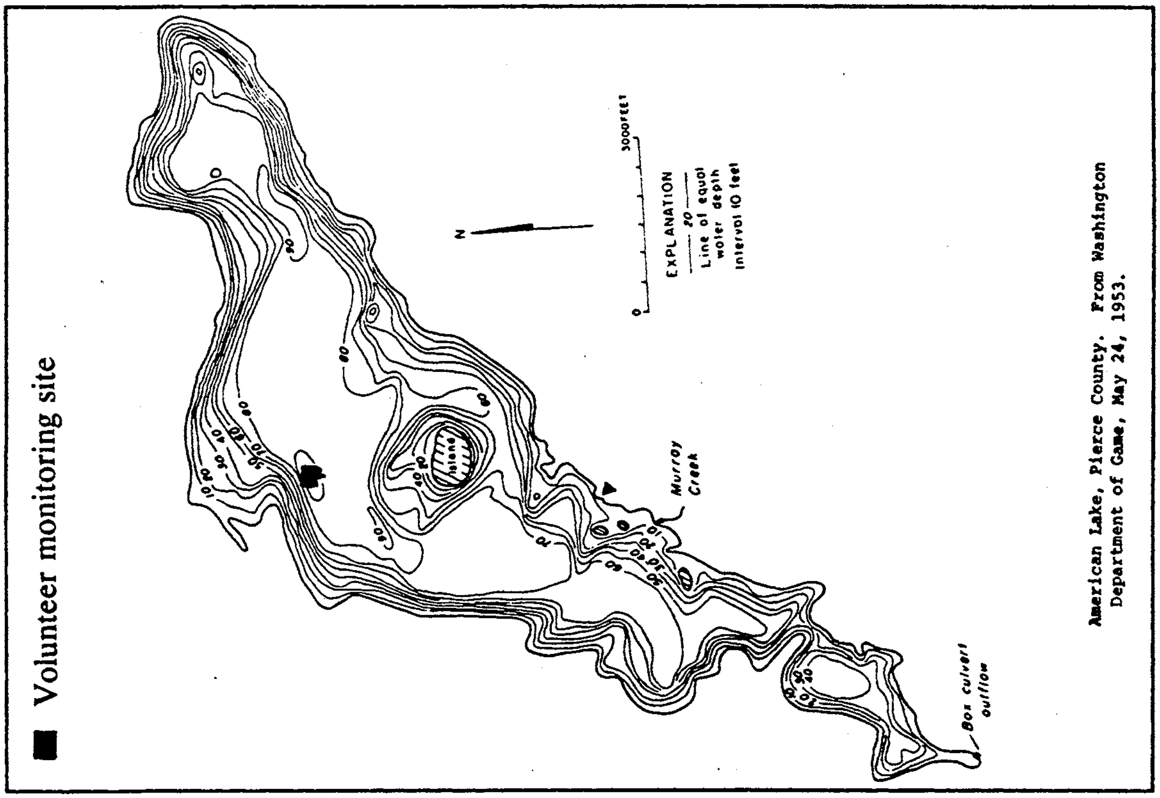
American Lake -- Pierce County

Volunteer-Collected Data

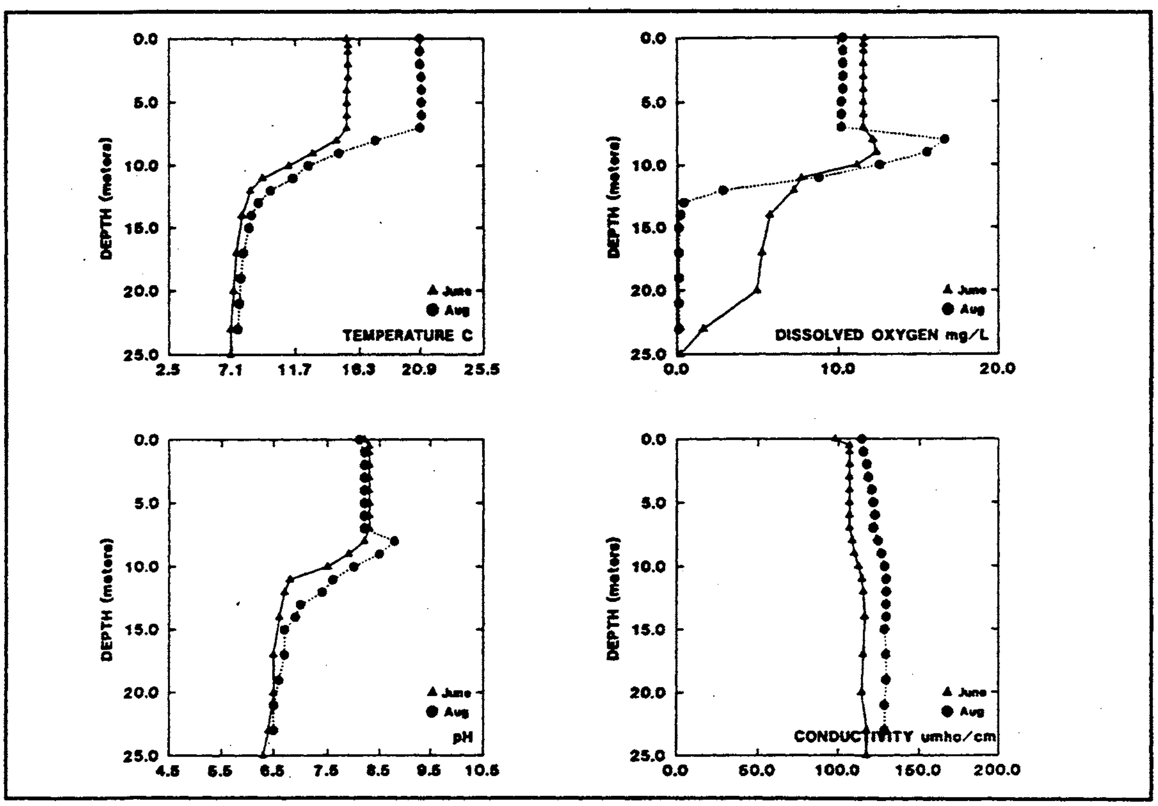
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
01-Jun								18.0		Taken during onsite visit
16-Aug	23.3	73.9	6.5	Lt-Green	50	Calm	Strong	27.0		
24-Aug								23.0		Taken during onsite visit

Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/01	0.0	15.4	8.2	11.7	98	1,3,7	0.018	0.401
	0.5	15.5	8.3	11.6	107			
	1.0	15.5	8.3	11.6	107			
	2.0	15.5	8.3	11.6	107			
	3.0	15.5	8.3	11.6	107			
	4.0	15.4	8.3	11.6	107			
	5.0	15.4	8.3	11.6	107			
	6.0	15.4	8.3	11.6	107			
	7.0	15.4	8.3	11.6	107			
	8.0	14.6	8.2	12.2	109			
	9.0	12.9	7.9	12.4	110			
	10.0	11.2	7.5	11.2	113			
	11.0	9.3	6.8	7.7	115			
	12.0	8.4	6.7	7.2	116			
	14.0	7.8	6.6	5.7	117			
	17.0	7.4	6.5	5.2	116			
	20.0	7.2	6.5	4.9	115			
	23.0	7.0	6.4	1.6	118			
	25.0	7.0	6.3	0.2	118			
08/24	0.0	20.9	8.1	10.3	115.0	1,3,6	0.0104	0.397
	1.0	20.9	8.2	10.3	116.0			
	2.0	20.9	8.2	10.3	118.0			
	3.0	21.0	8.2	10.3	119.0			
	4.0	21.0	8.2	10.3	121.0			
	5.0	21.0	8.2	10.2	122.0			
	6.0	21.0	8.2	10.2	133.0			
	7.0	20.9	8.2	10.2	122.0			
	8.0	17.5	8.8	16.6	125.0			
	9.0	14.8	8.5	15.5	127.0			
	10.0	12.6	8.0	12.6	129.0			
	11.0	11.5	7.6	8.8	130.0			
	12.0	9.9	7.4	2.8	130.0			
	13.0	9.0	7.0	0.4	130.0			
	14.0	8.5	6.9	0.2	130.0			
	15.0	8.3	6.7	0.1	129.0			
	17.0	7.9	6.7	0.1	130.0			
	19.0	7.7	6.6	0.1	130.0			
	21.0	7.6	6.5	0.1	129.0			
	23.0	7.5	6.5	0.1	129.0			



American Lake, Pierce County. From Washington Department of Game, May 24, 1953.



Big Lake -- Skagit County

Big Lake is located five miles southeast from Mount Vernon. It is 2.7 miles long. The lake is fed by Nookachamps Creek, and drains via Nookachamps Creek to the Skagit River.

Size (acres)	520
Maximum Depth (feet)	23
Mean Depth (feet)	14
Lake Volume (acre-feet)	7470
Drainage Area (miles^2)	22.4
Altitude (feet)	81
Shoreline Length (miles)	6.2

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi) Volunteer #1	54
Mean Trophic State Index* (Secchi) Volunteer #2	60
Mean Trophic State Index* (Total Phosphorus)	56

* From Carlson (1977)

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

The following are from the volunteer's remarks and responses to the 1990 questionnaire. Big Lake is used for fishing, boating, swimming, rowing, and jet skiing. (Responses to the 1989 questionnaire also included floatplanes as a use of the lake.) Recreational facilities on the lakeshore include one resort and one boat ramp, and there is a speed restriction of 40 mph for motorboats. Lake water is withdrawn for drinking and other domestic uses. Currently the watershed is used for logging, crop agriculture, and the lakeshore is being developed further for residences. In the past, the watershed was used for logging and crop agriculture. There are approximately 250 houses on the lakeshore. The lakeshore is partially sewered, and there are five storm drains that empty into the lake. Fish were not reported as being stocked in the lake. Presently there is a lake association and a sewer district for the lake. The worst problems in the lake, in the opinion of the volunteer, are 1) aquatic plants, 2) algae, 3) floating debris, and 4) water level. Overall, the volunteer finds that Big Lake has good recreational water quality, and that the lake is fairly clean and moderately green. However, people, boats, sewer runoff, and garbage debris may affect the water quality of the lake. The volunteer also noted that people need to wear shoes while swimming because of glass in the lake.

A Public Utility District has been approved and hook-up of residences to the sanitary sewer should be available near end of next year. There are docks around the entire lake, with lily pads and cattails between. There are wetlands at the south end of the lake. Submerged plants grow especially on the east side of the lake and in shallow areas, and growth is thick by the end of summer (August and September).

Big Lake -- Skagit County

The following are from the 1989 survey responses. There was local concern in 1989, that the wetlands need to be protected from development. Weed growth in the lake was thick, particularly at the north end of the lake, near the public boat launch, and the wetland area at the south end of the lake (near the inlet). In some areas, weeds grew to the water surface. There were yellow-flowering lilies, white-flowering lilies, and pink-flowering lilies in the lake, mostly at the south end. In the wetlands there were cattails, reeds, grasses and willows.

Monitoring Results/Summary of Other Available Information

Big Lake was monitored at the same deepwater site by two different volunteers. Secchi readings collected by both volunteers indicate that Big Lake was eutrophic. The eutrophic classification was confirmed by the high concentrations of total phosphorus found during the onsite visits.

Big Lake was one of 15 lakes sampled by Ecology during June and September 1990 as part of a statewide lakes survey to supplement volunteer-collected data. Low Secchi disk transparency and high concentrations of chlorophyll *a* (an indicator of the volume of algae growing in water) from this survey also show that the lake was eutrophic. In 1973, total phosphorus and Secchi disk transparency data indicated that Big Lake was mesotrophic (Bortleson *et al.*, 1976). However, in October 1968 Big Lake was not stratified, concentrations of dissolved oxygen were high from surface to bottom, the Secchi disk transparency was six feet, clumps of algae were present, and the lake was described as "a shallow eutrophic lake" (Lee, 1969). One explanation of these different evaluations of the lake is that trophic state evaluations can depend on the time of year the lake is sampled, and whether the lake is stratified during sampling.

Profile data collected during both the onsite visit and during the Ecology survey show that instead of being thermally stratified throughout the summer, Big Lake was stratified occasionally during 1990. During the August 1990 onsite visit with the volunteer, the lake was stratified and concentrations of dissolved oxygen were low near the bottom of the lake. The decrease in pH and the increase in conductivity with depth is likely related to the decrease in dissolved oxygen concentrations. During the September Ecology survey, the lake was destratified (temperature data was constant from surface to bottom) and the concentrations of total phosphorus and dissolved oxygen were high and fairly constant throughout the water column (Coots, 1991). It is most likely that the large surface area and the relatively shallow depth of the lake make the lake susceptible to wind mixing. As a result, the lake "turns over" repeatedly during the summer. During turnover, concentrations of total phosphorus and dissolved oxygen will be fairly constant from surface to bottom. Usually, when greater amounts of phosphorus are available, more algae can grow. A bloom of blue-green algae was occurring during the September Ecology survey (Coots, 1991).

Big Lake -- Skagit County

Residential development along the shore of Big Lake has increased since 1973; in 1973 there were 179 nearshore homes (Bortleson et al., 1976), compared to approximately 250 homes reported by the volunteer in 1990.

During the June onsite visit, the lake level was high and the lake was very turbid because of recent flooding in the area. The plant sample collected during the onsite visit was identified as *Elodea densa*. During the August onsite visit, the white-flowering lily (*Nymphaea odorata*) was also noted. These plants were identified along with several other plants during the 1990 Ecology Survey (Coots, 1991).

Comments

Based on 1989 Secchi depth data, Big Lake was estimated as mesotrophic. Comparisons of Secchi depth data collected during 1989 and 1990 show that the water clarity of Big Lake was noticeably lower during 1990. However, several more years of data are needed to document whether a trend is occurring.

Acknowledgements

I thank Joyce Curry for volunteering her time to monitor Big Lake during 1989-1990, and Toby Allen for being the second volunteer monitor on Big Lake during 1990.

Big Lake -- Skagit County

Volunteer-Collected Data

Volunteer #1

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
27-Jun	20.0	68.0	6.5	Green	100	None	Light	5.5	24.0	
13-Jul	25.0	77.0	6.5	Green	10	None	Breezy	5.4	24.0	
31-Jul	23.0	73.4	6.5	Green	0	None	Light	4.4	23.0	
24-Aug	23.0	73.4	6.5	Green		None	Light	4.6	20.0	
09-Sep	20.0	68.0	6.5	Green	100		Calm	4.6		

Volunteer #2

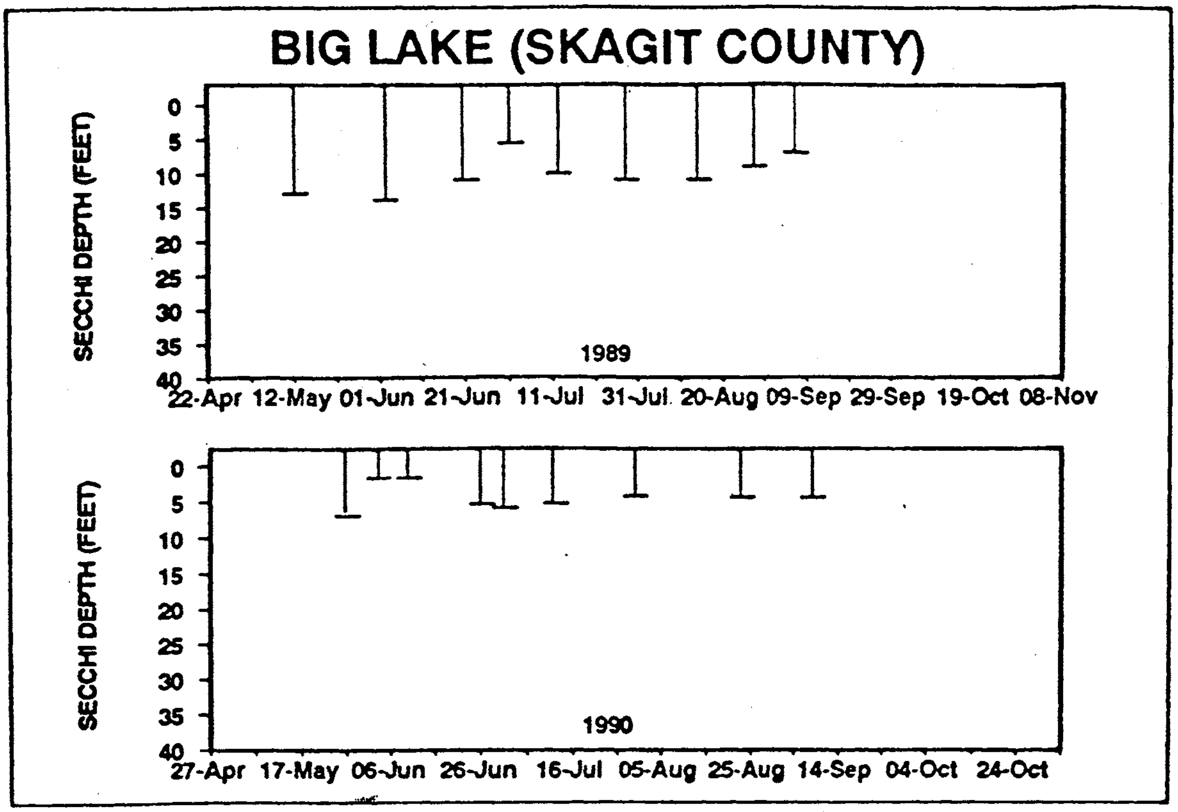
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
28-May	15.8	60.4	7.0	Green	100	Light	Calm	7.0		
11-Jun	16.1	61.0			100	Moderate	Breezy	2.0 b	3.5	
25-Jun	16.7	62.1	7.0		75	Light	Strong	3.0 b	2.0	
02-Jul	18.9	66.0	7.0	Green-Br	10		Strong	6.0		
14-Aug								2.0		

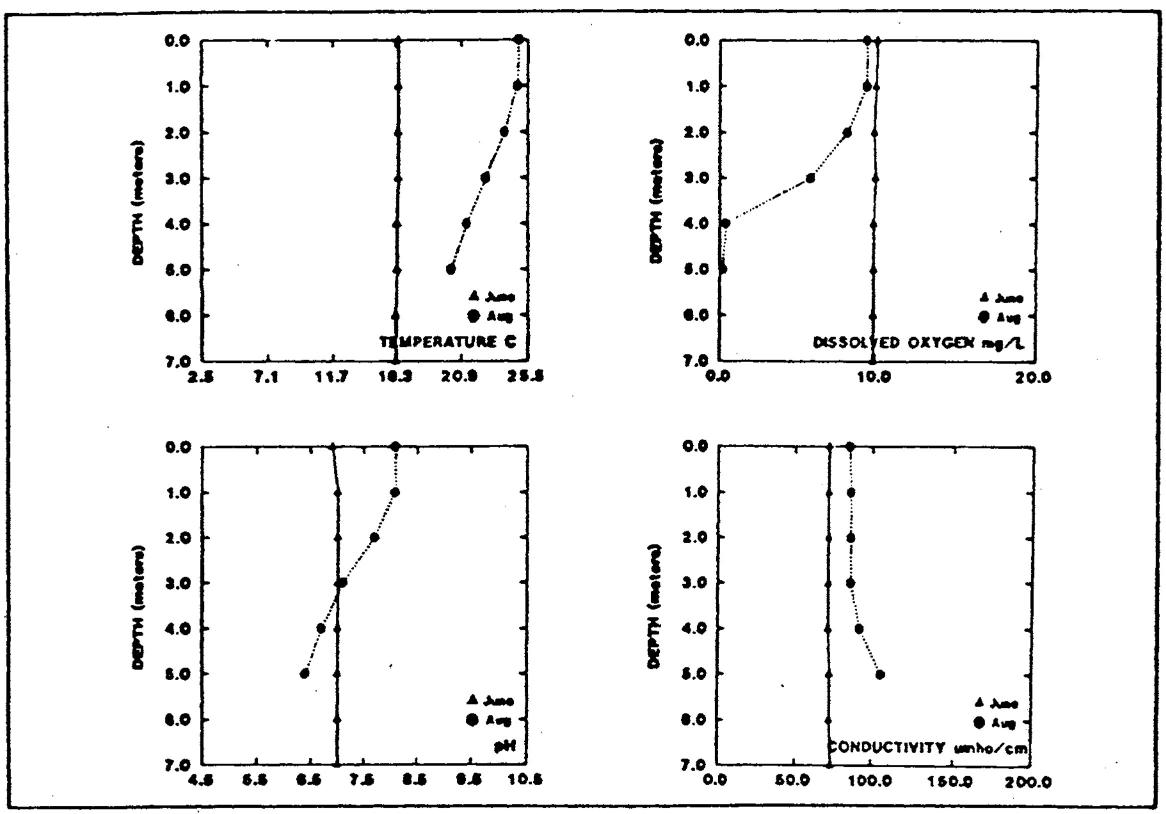
* Secchi data corrected for rope shrinkage
b Secchi hit bottom

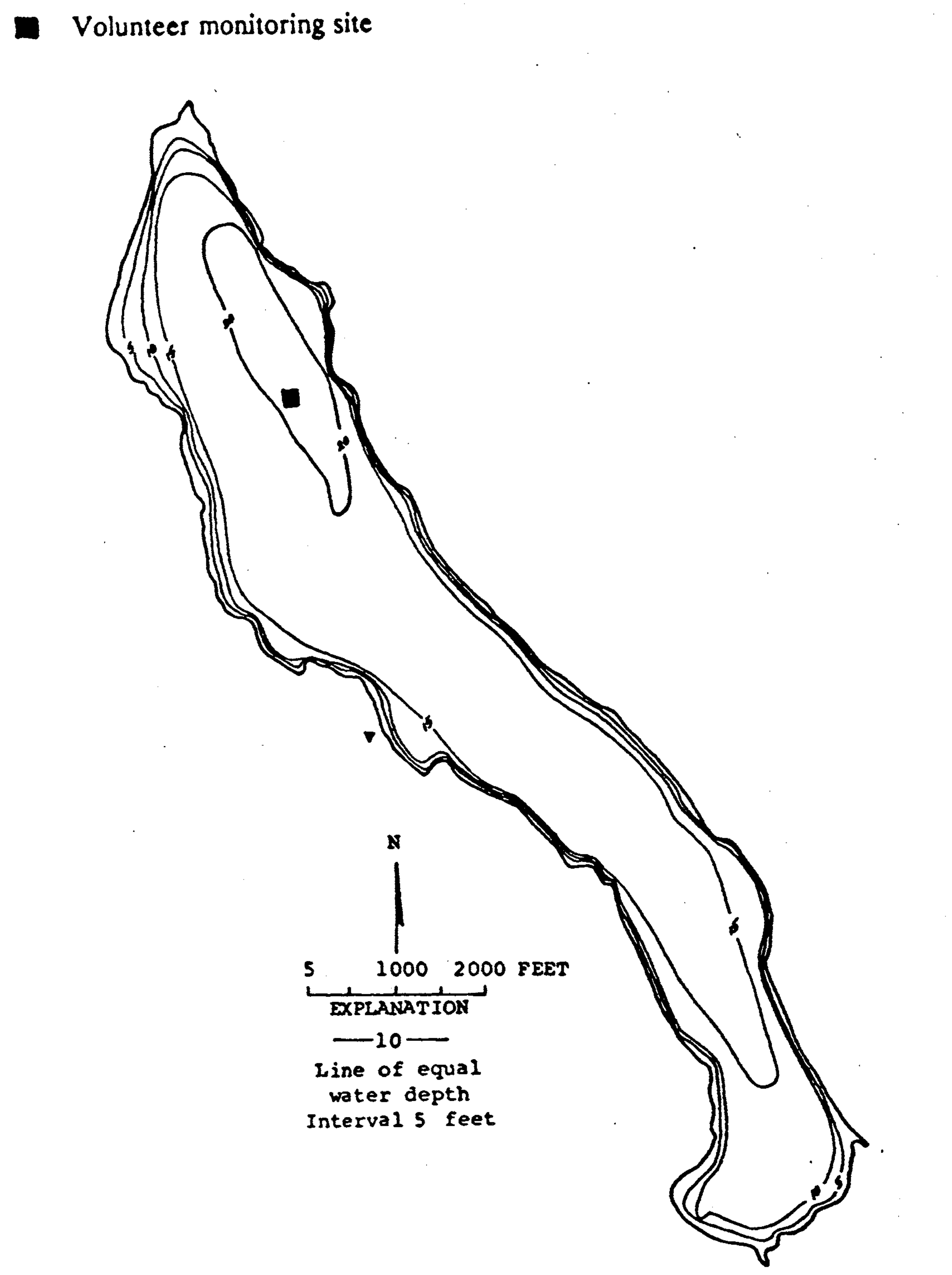
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/04	0.0	16.5	6.9	10.1	72	3	0.048	0.518
	1.0	16.5	7.0	10.0	72			
	2.0	16.5	7.0	9.9	72			
	3.0	16.5	7.0	10.0	72			
	4.0	16.4	7.0	9.9	72			
	5.0	16.4	7.0	9.9	73			
	6.0	16.3	7.0	9.9	73			
	7.0	16.3	7.0	9.9	74			
08/14	0.0	24.9	8.1	9.4	85	1, 2	0.027	0.442
	1.0	24.8	8.1	9.4	86			
	2.0	23.9	7.7	8.2	86			
	3.0	22.6	7.1	5.8	86			
	4.0	21.3	6.7	0.4	92			
	5.0	20.2	6.4	0.2	106			

Secchi Depth and Profile Data Graphs







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

Big Meadow Lake -- Pend Oreille County

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

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

* information not available

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index* (Secchi):	47
Mean Trophic State Index* (Total Phosphorus):	53

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The 1990 questionnaire on lake and watershed uses was not returned by the volunteer. The following are from the volunteer's responses to the 1989 questionnaire. Big Meadow Lake is used for fishing, picnicking, camping and waterfowl habitat. There are no houses on the lake. The Forest Service is developing a campground at the lake. Fish are stocked in the lake. The worst problem in the lake, in the opinion of the volunteer, was the winter kill of fish that occurred from January to February. The Department of Wildlife installed an aeration system on August 25, 1989, to prevent the fish kills. The entire lake has submerged weeds except for the area that was part of the original lake. Open areas about seven feet deep have floating-leaved type weeds.

Monitoring Results/Summary of Other Available Information

Based on volunteer-collected Secchi depth data, Big Meadow Lake was meso-eutrophic during the summer of 1990. Compared with Secchi depth data collected during 1989, the average summer trophic state index was somewhat improved in 1990. During both years, the same general pattern was documented: there was lower water clarity during May and midsummer, followed by increased water clarity in late September. Periods of increased algae growth during the summer had similar effects on water clarity during both years.

Big Meadow Lake -- Pend Oreille County

Temperature profile data collected during May and September 1990 show that on both sampling dates the lake was stratified. During May, the concentration of dissolved oxygen was very low near the bottom of the lake (dissolved oxygen profile data were not collected during September). Low dissolved oxygen concentrations probably resulted from the decomposition of organic matter (such as algae, aquatic plants and woody debris) in the water and sediments, a process which consumes dissolved oxygen.

The concentrations of total phosphorus and total nitrogen were high on both sampling dates. Compared with the other 78 lakes sampled during onsite visits, only 12 lakes had a higher average concentration of total phosphorus than Big Meadow Lake.

During the September 1990 onsite visit with the volunteer, the anchor was dragged about 200 yards to collect plants from the bottom of the lake. Plants on the anchor consisted mostly of the algae *Nitella*. Two other plants, a pondweed (*Potamogeton* species) and bur-reed (*Sparganiaceae* family), were also noted. Decomposing blue-green algae were found along the shoreline. The volunteer noted that floating islands (chunks of lake bottom brought to the surface by gases) are common in the lake.

Comments

Big Meadow Lake was one of four Pend Oreille County lakes monitored for the program in 1990. Compared to the other monitored lakes (Davis, Sacheen, and Sullivan Lakes), Big Meadow Lake was much more eutrophic. Nutrients leached from the soils and vegetation when Big Meadow Lake was enlarged, as well as nutrient loading from the watershed, have probably contributed to the eutrophy of the lake.

Acknowledgement

I thank Terry Williams for volunteering his time to monitor Big Meadow Lake during 1989-1990.

Big Meadow Lake -- Pend Oreille County

Volunteer-Collected Data

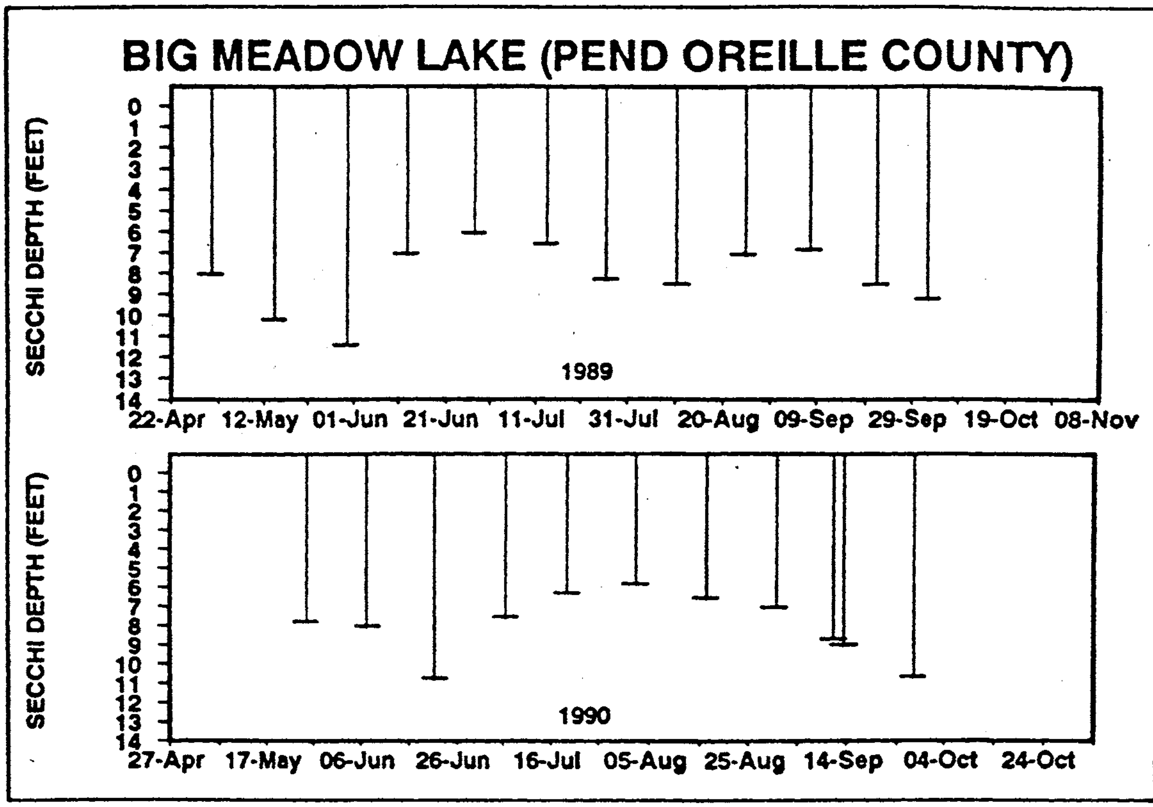
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
26-May	13.0	55.4	6.5	Gr-Brown	10	Moderate	Breezy	7.6	-5.0	Lake height measured 5" from top. Looked like lots of organic matter in the water
08-Jun	13.5	56.3	7.0	Gr-Brown	100	Trace	Light	7.8	-3.0	Lake height measured 3" from top. Cloudy-fog visibility about 1 mile. Very light rain.
22-Jun	20.5	68.9	7.0	Dk-Green	100	None	Breezy	10.3	-6.0	
07-Jul	20.0	68.0	7.0	Dk-Green	90	Light	Light	7.3	-8.0	Lost my secchi disk, using a home made one which is not the best.
20-Jul	25.0	77.0	7.0	Gr-Brown	25	None	Light	6.2	-14.0	Found my old Secchi disk and am using it.
03-Aug	25.0	77.0	7.0	Gr-Brown	20	None	Light	5.7	-14.0	
17-Aug	22.5	72.5	7.0	Dk-Brown	50	None	Light	6.4		Water brown with green tinge. Slight haze in sky.
31-Aug	18.0	64.4	6.5	Gr-Brown	50	Light	Breezy	6.9	-16.0	
12-Sep								8.4		Taken during onsite visit.
14-Sep	20.0	68.0	6.5	Gr-Brown	0	Trace	Breezy	8.7		
28-Sep	17.5	63.5	7.0	Gr-Brown	75	None	Light	10.3	-16.0	Very thin clouds.
11-Oct	9.0	48.2	7.0	Green	75	Light	Breezy	13.3	-20.0	Very thin clouds. Last report this year

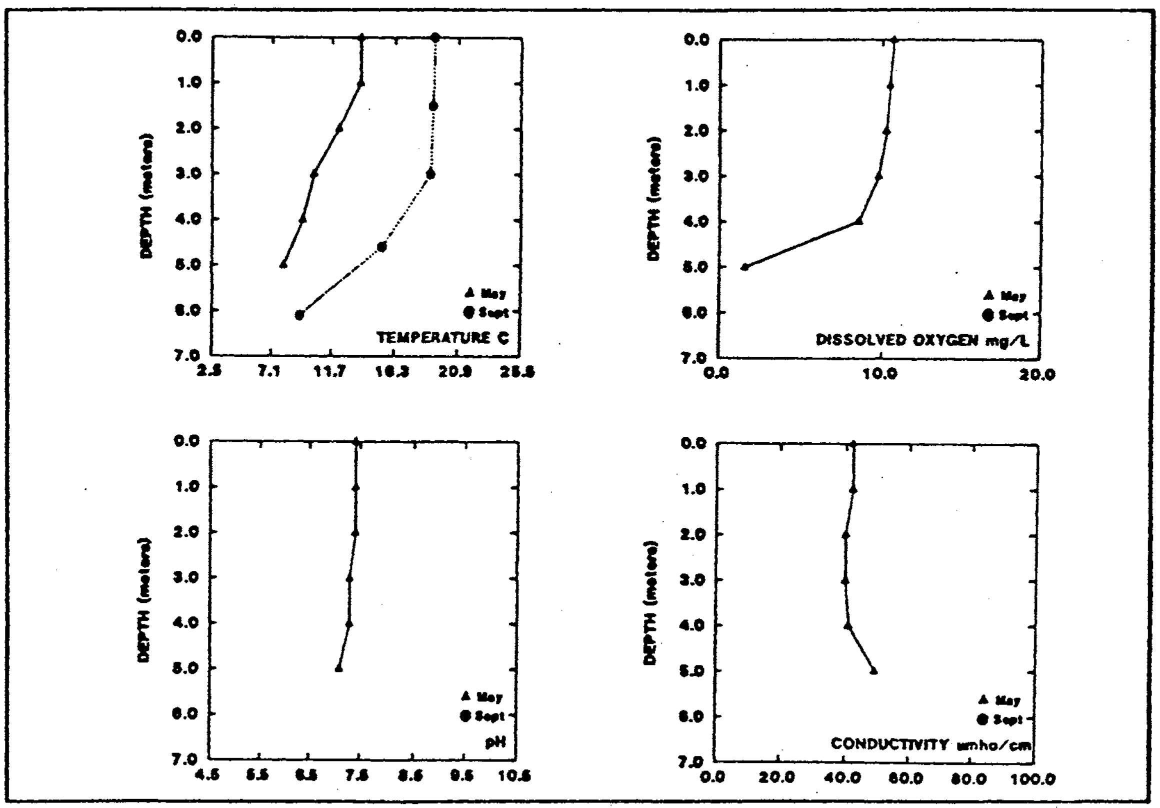
* Secchi data corrected for rope shrinkage

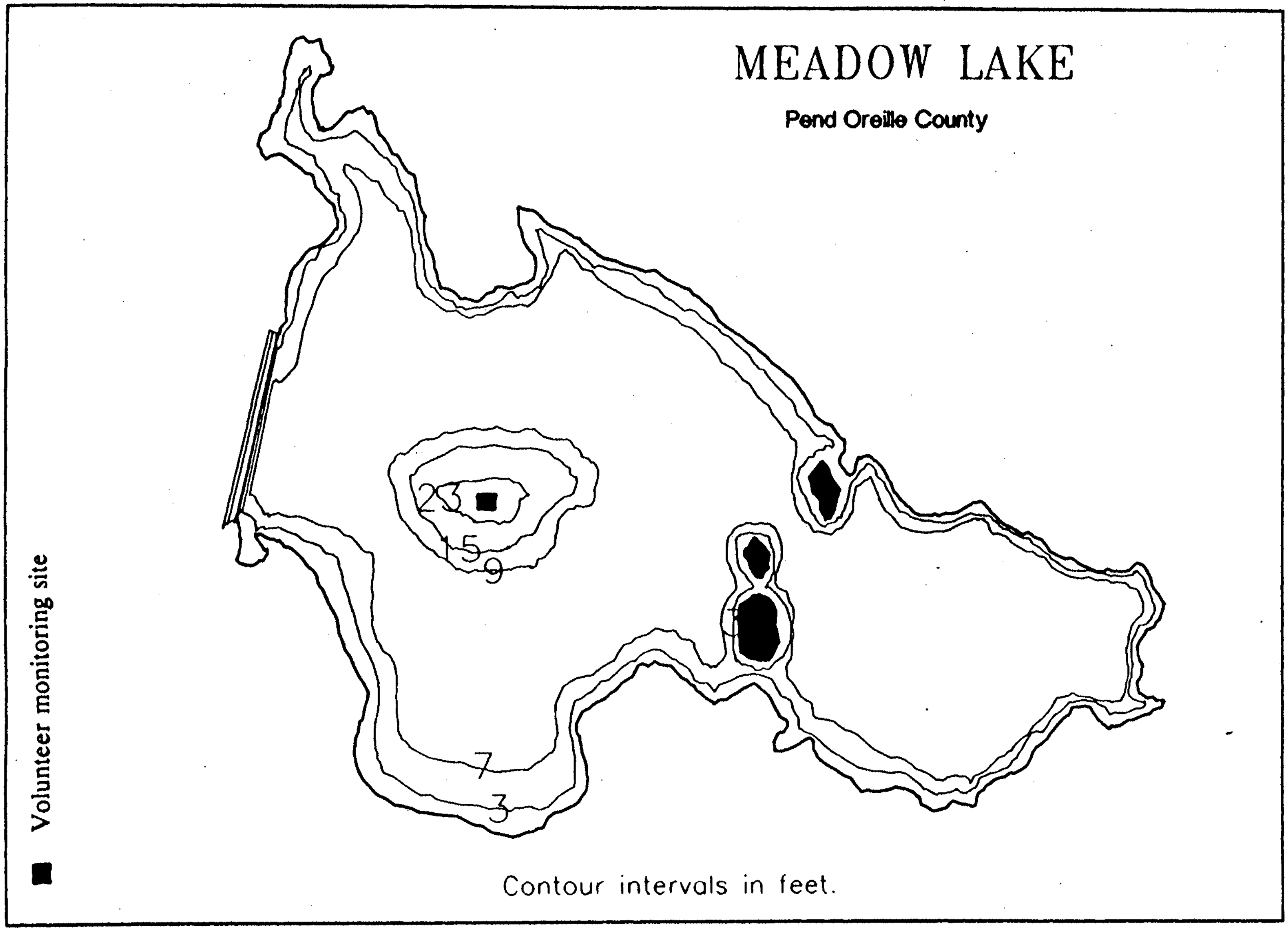
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/29	0.0	13.8	7.4	10.7	42	0.5, 1	0.031	0.699
	1.0	13.8	7.4	10.5	42			
	2.0	12.2	7.4	10.3	40			
	3.0	10.3	7.3	9.8	40			
	4.0	9.4	7.3	8.6	41			
	5.0	8.0	7.1	1.6	49			
09/12	0.0	19.1	.	.	.	1, 2, 3	0.030	0.911
	15.0	19.0	.	.	.			
	10.0	18.8	.	.	.			
	15.0	15.4	.	.	.			
	20.0	9.2	.	.	.			

Secchi Depth and Profile Data Graphs






MEADOW LAKE
Pend Oreille County
23
15
9
7
3
Volunteer monitoring site
Contour intervals in feet.

Black Lake -- Stevens County

Black Lake is located about 12.5 miles east from Colville. It is 4800 feet long. The main inflow is intermittent into the north end 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)	1863
Drainage Area (miles^2)	0.9
Altitude (feet)	3701
Shoreline Length (miles)	2.0

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	39
Mean Trophic State Index* (Total Phosphorus):	43

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Black Lake is used for fishing, swimming, rowing, camping, and during the winter, skating and skiing. Recreational facilities on the lakeshore include a picnic area, a camping area, a beach, one resort and one boat ramp. Lake water is withdrawn for drinking and other domestic uses. Currently the lakeshore is being developed further for residences. In the past the watershed was used for logging, and crop agriculture. There are 25 houses on the lakeshore; of these, four are occupied year-round. The lakeshore is not sewered, and there are no storm drains that empty into the lake. Fish (eastern brook and rainbow trout) are stocked in the lake. Presently there is no citizen's lake protection organization for the lake. The lake has been chemically treated in the past to control fish species. Ducks were noted by the volunteer as being the worst problem in the lake. Overall, the volunteer finds that Black Lake has excellent recreational water quality.
There were no visible algae in the lake during 1990. However, aquatic plants grow in 6-10 feet of water, with some reaching to the surface. There were scattered areas of reed growth and patches of lily pads. There are wetland areas near both inlets. The volunteer wants the program to include sampling for drinking water quality.

Responses to the 1989 questionnaire included that there was a beaver dam and a wetland area at the north end of the lake at the inlet. The worst problem in the lake, in the opinion of the volunteer, was the increasing amount of aquatic plant growth during the summer. The volunteer was also concerned about fecal coliform bacteria and giardia. Most of the shoreline was ringed with reeds and grasses, and scattered aquatic plants reached to the surface up to 20-40 feet offshore. Photos and aquatic weed descriptions were sent in by the volunteer in 1989.

Photos showed submerged species of aquatic plants (*Elodea*), floating-leaved pondweeds (*Potamogeton*), yellow-flowering pond lily (*Nuphar*), and emergent species of cattail, reeds, and grasses.

Monitoring Results/Summary of Other Available Information

Based solely on volunteer-collected Secchi depth data, Black Lake was near the borderline between oligotrophy and mesotrophy. Secchi data collected during 1989 also indicated that the lake was borderline between these two trophic states. Although the average Secchi disk reading over the summer was similar between 1989 and 1990, there was less variability among the 1990 readings compared to the 1989 readings. Less variability and less severe algal blooms were also documented from several nearby lakes that were monitored in both 1989 and 1990 (including Crawfish Lake in Okanogan County and Deer Lake in Stevens County).

Last year, the lake was estimated as oligotrophic based on relatively low nutrient and chlorophyll *a* concentrations from a 1989 Ecology survey (Brower and Kendra, 1990). In 1990, the nutrient data collected during the onsite visits showed that concentrations of total phosphorus in Black Lake were somewhat higher in 1990 than in 1989.

During May and September 1990, the concentrations of dissolved oxygen near the bottom of the lake were very low. Low dissolved oxygen concentrations (0.4 mg/L at 30 feet) were also reported in 1974 (Dion *et al.*, 1976), indicating that dissolved oxygen depletion near the bottom of the lake may have been occurring for many years. Low dissolved oxygen concentrations can result from the bacterial decomposition of organic material (such as vegetation and woody debris) in the water and sediments. Decaying vegetation could also result in the dark water color that is probably the namesake of the lake. Aquatic plants covered 90-95% of the shoreline with scattered patches offshore.

During the September onsite visit, there was little aquatic plant growth near the sampling area, except in small coves. Yellow-flowering lily (*Nuphar* species), pondweeds (*Potamogeton amplifolius*, *P. berchtoldii*, and *P. epihydrus*), and *Elodea* were identified during the visit.

Comments

Black Lake exhibits several mesotrophic characteristics, such as moderately high concentrations of total nitrogen and total phosphorus, depleted concentrations of dissolved oxygen near the bottom of the lake, and moderate growth of submerged and emergent aquatic plants. Based on these characteristics, Black Lake was estimated as mesotrophic. The water clarity of Black Lake was much better than would be expected considering its concentrations of total phosphorus and total nitrogen. Because of this, future estimations of tropic status should be based on chemical data, and Secchi disk data would be best used to document the occurrence and severity of algal growth. Compared to other lakes monitored in the program, the water quality of Black Lake is very good considering its size, amount of plant growth, and lack of dissolved oxygen in the hypolimnion.

Fecal coliform bacteria samples were collected by Ecology during June and September 1989, and the results did not indicate a bacteria problem in the lake. However, samples were collected from the surface at the center of the lake, and not from nearshore areas.

Acknowledgement

I thank Norman S. LaVigne for volunteering his time to monitor Black Lake during 1989-1990.

Black Lake -- Stevens County

Volunteer-Collected Data

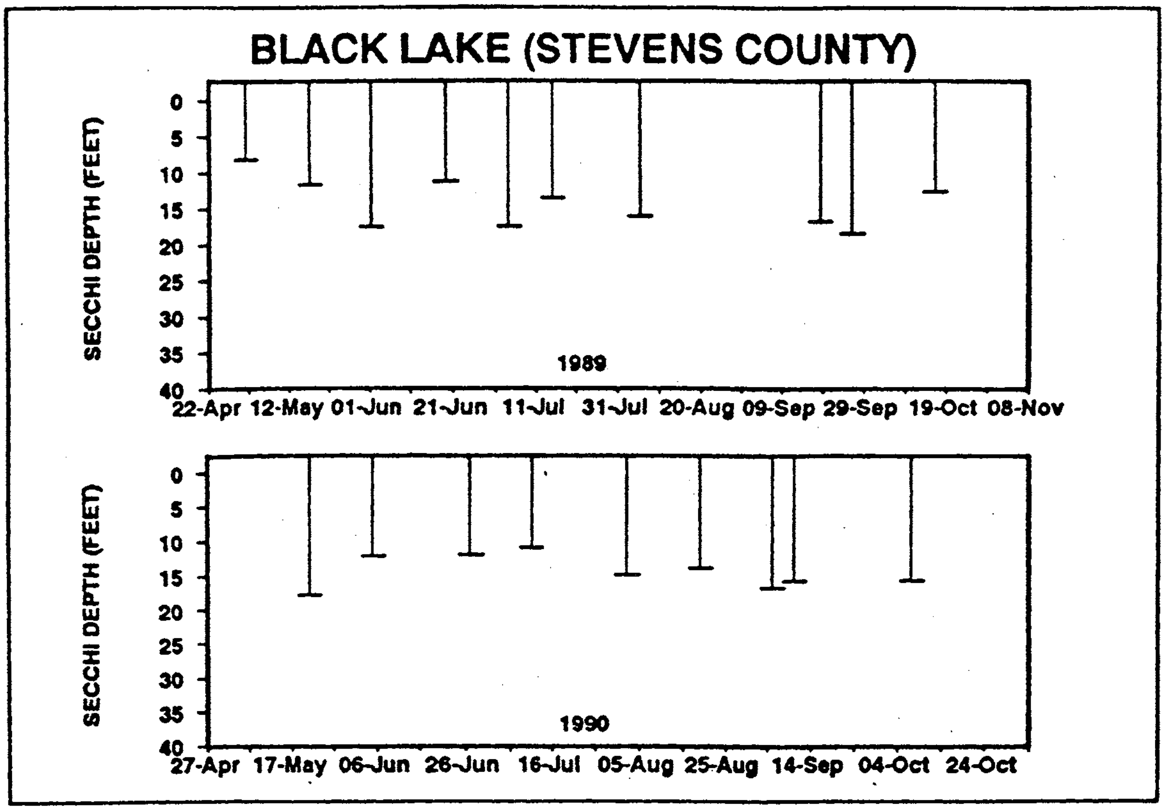
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
22-May	12.8	55.0	6.5	Clear	50	Light	Calm	17.4		Lake depth 42' at test point. New kit just arrived so this is the first report.
06-Jun	13.3	55.9	6.5	Lt-Brown	90	Light	Calm	12.1	24.3	Lake color remark, clear. Heavy rain in the past two weeks raised the lake 5.25 inches.
28-Jun	19.4	66.9	6.5	Clear	50	None	Light	11.9	18.3	
12-Jul	24.4	75.9	6.5	Clear	10	None	Breezy	11.0	16.3	Water color brownish clear.
03-Aug	22.2	72.0	6.5	Clear	0	None	Light	14.7	14.7	Water color clear-brownish.
20-Aug	21.7	71.1	6.5	Clear	50	Moderate	Light	13.7	13.5	Water color clear-brownish.
06-Sep	19.4	66.9	6.5	Clear	0	None	Calm	16.5		Water color clear brownish.
11-Sep	19.4	66.9	6.5	Clear	0	None	Light	15.6		Water color clear-brownish.
08-Oct	10.6	51.1	6.5	Clear	0	None	Light	15.6	9.3	Water color clear brownish.

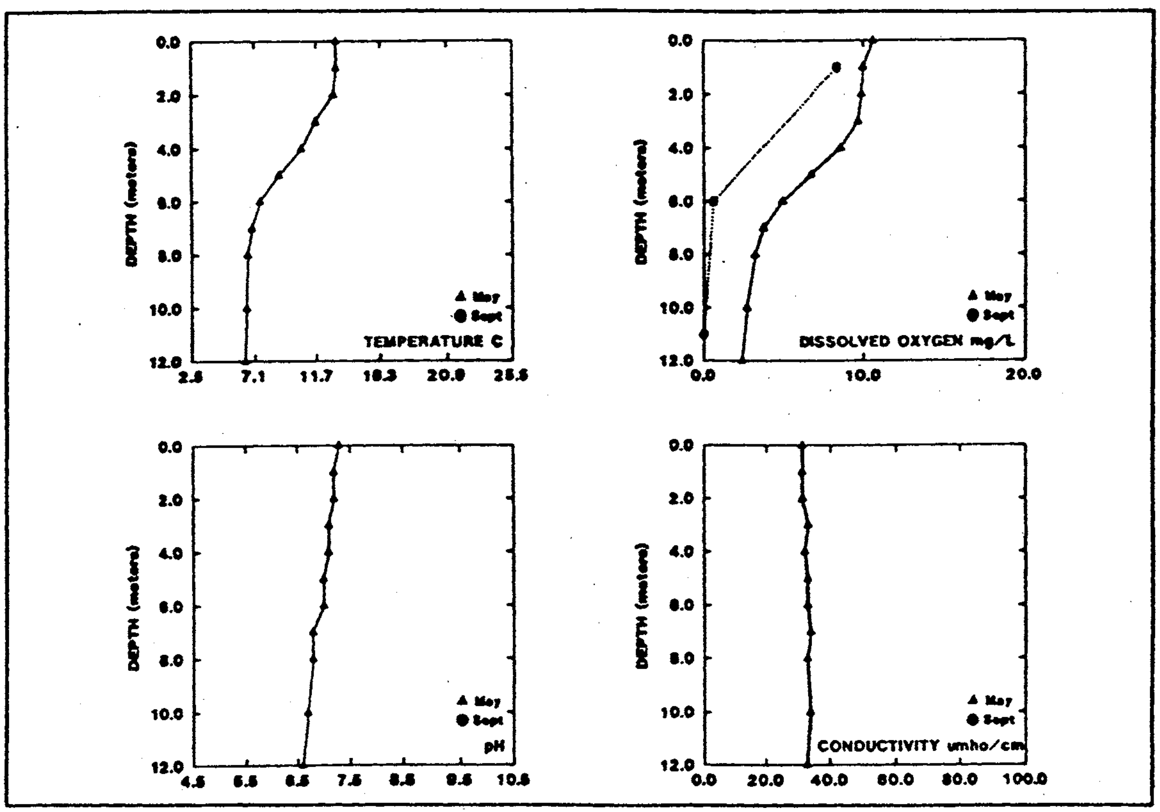
* Secchi data corrected for rope shrinkage

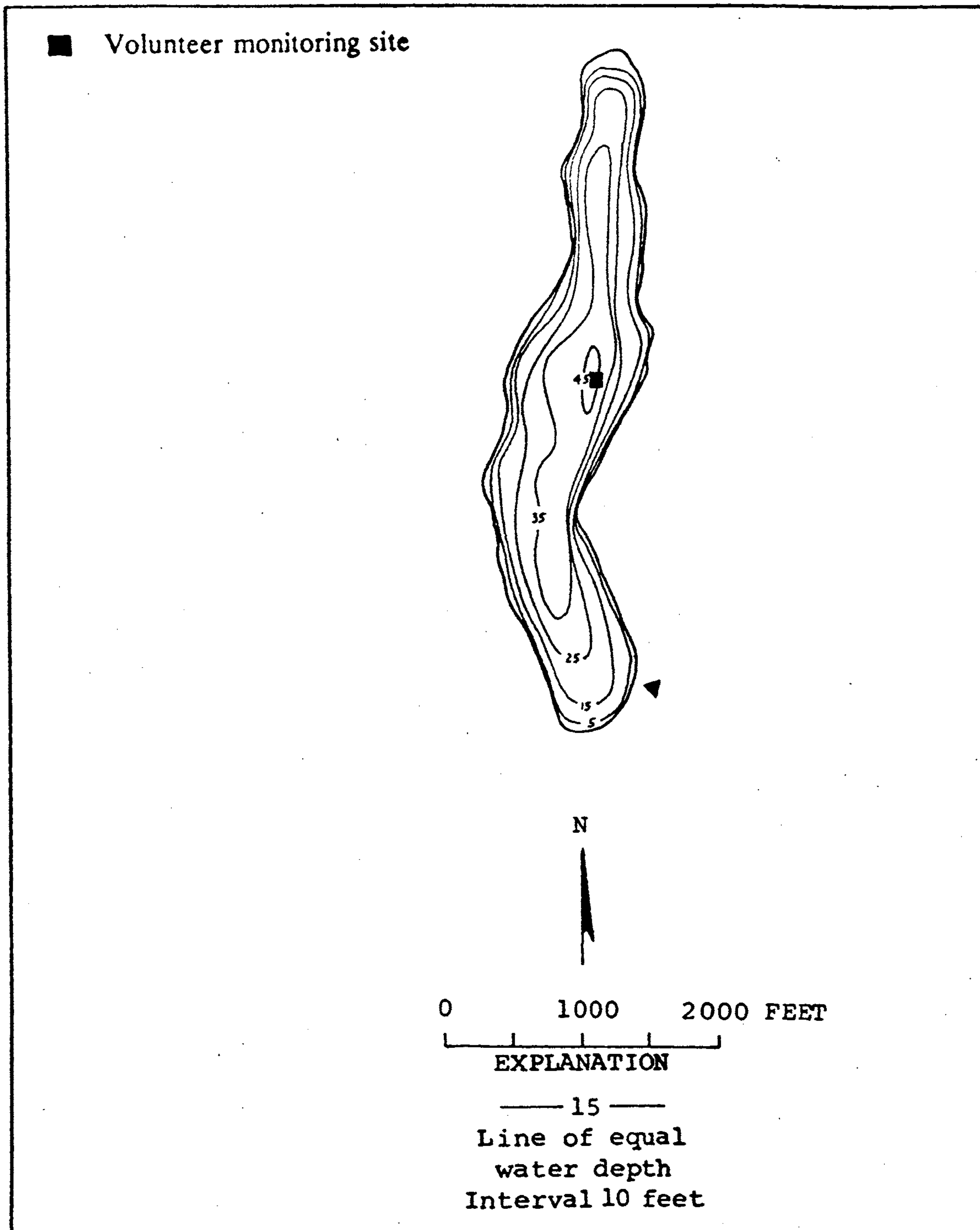
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/29	0.0	13.1	7.3	10.6	31	0.5, 1, 2	0.019	0.345
	1.0	13.1	7.2	10.0	31			
	2.0	12.9	7.2	9.9	31			
	3.0	11.6	7.1	9.7	33			
	4.0	10.6	7.1	8.6	32			
	5.0	8.9	7.0	6.8	33			
	6.0	7.5	7.0	5.0	33			
	7.0	6.9	6.8	3.8	34			
	8.0	6.6	6.8	3.3	33			
	10.0	6.5	6.7	2.8	34			
	12.0	6.4	6.6	2.5	33			
09/11	1.0	.	.	8.4	.	1, 2, 3	0.012	0.301
	6.0	.	.	0.6	.			
	11.0	.	.	0.0	.			

Secchi Depth and Profile Data Graphs







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

Blue Lake -- Grant County

Blue Lake is located about 11 miles north of the town of Soap Lake, and adjacent to and southwest from Park Lake. It is fed by Park Lake via Park Lake Creek and drains to Lenore Lake. The inflow is intermittent. Blue Lake is a natural lake in the lower Grand Coulee. It receives heavy recreational use. There is a wetland at the south end of the lake.

Size (acres)	532
Maximum Depth (feet)	69
Mean Depth (feet)	40
Lake Volume (acre-feet)	21,318
Drainage Area (miles^2)	334
Altitude (feet)	1093
Shoreline length (miles)	7.0

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	45
Mean Trophic State Index* (Total Phosphorus):	47

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The 1990 questionnaire on lake and watershed uses was not returned by the volunteer. The following are the volunteer's responses to the 1989 questionnaire. Blue Lake is used for fishing, boating, jet skiing, picnicking, camping, and hiking. There are three resorts, a park, and 18 houses on the lakeshore. All the houses are occupied year-round and use on-site wastewater disposal systems. The lake water is used for irrigation only. Currently the watershed is used for animal grazing, and the lakeshore is being developed further for residences. The shoreline has been altered in the past. There are some restrictions on water skiing. The lake has been treated in the past with rotenone; the last time was in 1987. Fish are stocked in the lake. The worst problems in the lake, in the opinion of the volunteer, are 1) weeds, and 2) algae blooms that are especially a concern during June and July. The volunteer is also concerned about RV trailers illegally camped along the highway for long periods (emptying tanks into the lake, spreading garbage on the roadside, and having open fires), and septic systems adjacent to the lake.

Monitoring Results/Summary of Other Available Information

The volunteer-collected Secchi disk readings and concentrations of total phosphorus indicate that in 1990, Blue Lake was mesotrophic. In 1989, the lake was estimated as mesotrophic based on the moderately high Secchi disk readings collected by the volunteer and moderately high concentrations of total phosphorus and chlorophyll *a* that were collected during the 1989 Ecology survey (Brower and Kendra, 1990). Lake quality was very similar during 1989 and 1990 with respect to Secchi disk transparency, pH, concentrations of total phosphorus and total nitrogen, and concentrations of dissolved oxygen near the bottom of the lake when the lake was stratified.

In 1974, the USGS surveyed Blue Lake at its deep site, and reported Secchi disk transparency and concentrations of total phosphorus that are characteristic of mesotrophic lakes (Dion *et al.*, 1976). The USGS also observed very few emergent plants .

During the August onsite visit, pondweed (*Potamogeton richardsonii*) was identified in the lake. According to the volunteer, pondweed grows extensively in southern shallow bays at certain times of the year. Other aquatic plants in the lake are not extensive. Plant leaves were covered with marl (a calcium carbonate deposit) which indicates that Blue Lake is a very hardwater lake (note the high conductivity in the profile data). Other plant species identified in the lake included *Chara*, another pondweed (*P. pectinatus*), milfoil (*Myriophyllum* species; not the aggressive Eurasian species that causes problems in lakes and rivers), and naiad (*Najas flexilis*).

Comments

Secchi disk transparency appears to be a good indicator of lake quality for Blue Lake. Continued Secchi disk monitoring is recommended to document the trophic status of the lake.

The water clarity of Blue Lake was comparable to the water clarity of other Eastern Washington lakes located in areas with similar land uses and geology such as Williams Lake and Newman Lake.

Acknowledgement

I thank Robert Baucke for volunteering his time to monitor Blue Lake during 1989-1990.

Blue Lake -- Grant County

Volunteer-Collected Data

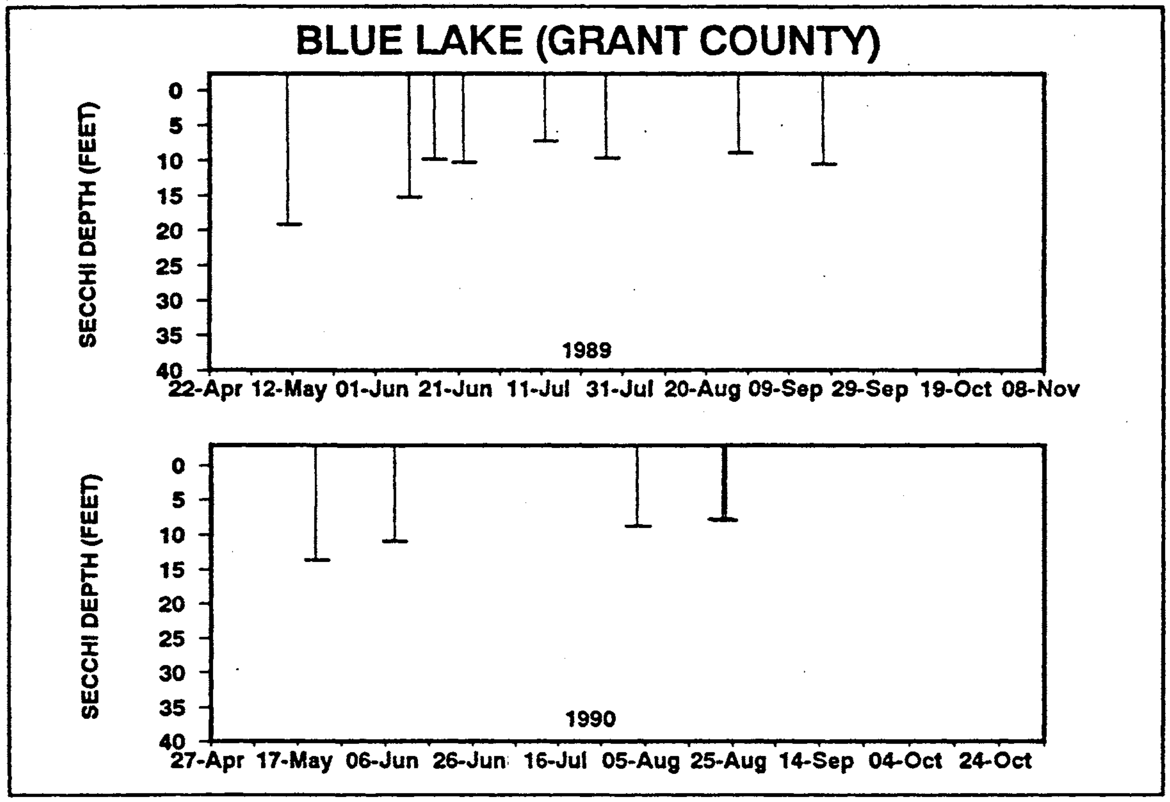
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
22-May								13.7		Taken during onsite visit
09-Jun	18.0	64.4	7.5	Lt-Green	50	Moderate	Light	11.3		
04-Aug	23.0	73.4	8.0	Lt-Green	0	None	Calm	9.2		
23-Aug								8.3		Taken during onsite visit
24-Aug	22.0	71.6	7.8	Lt-Green	0	Heavy	Gusty	8.4	-2.0	

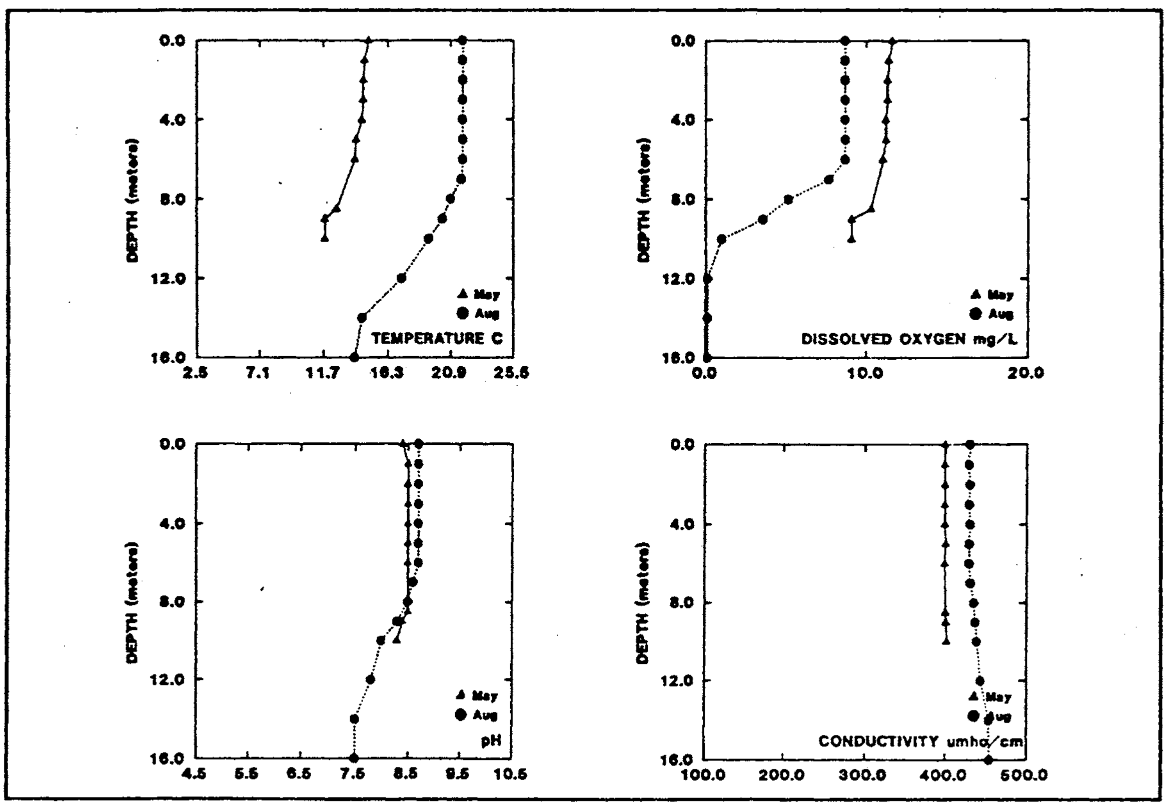
* Secchi data corrected for rope shrinkage

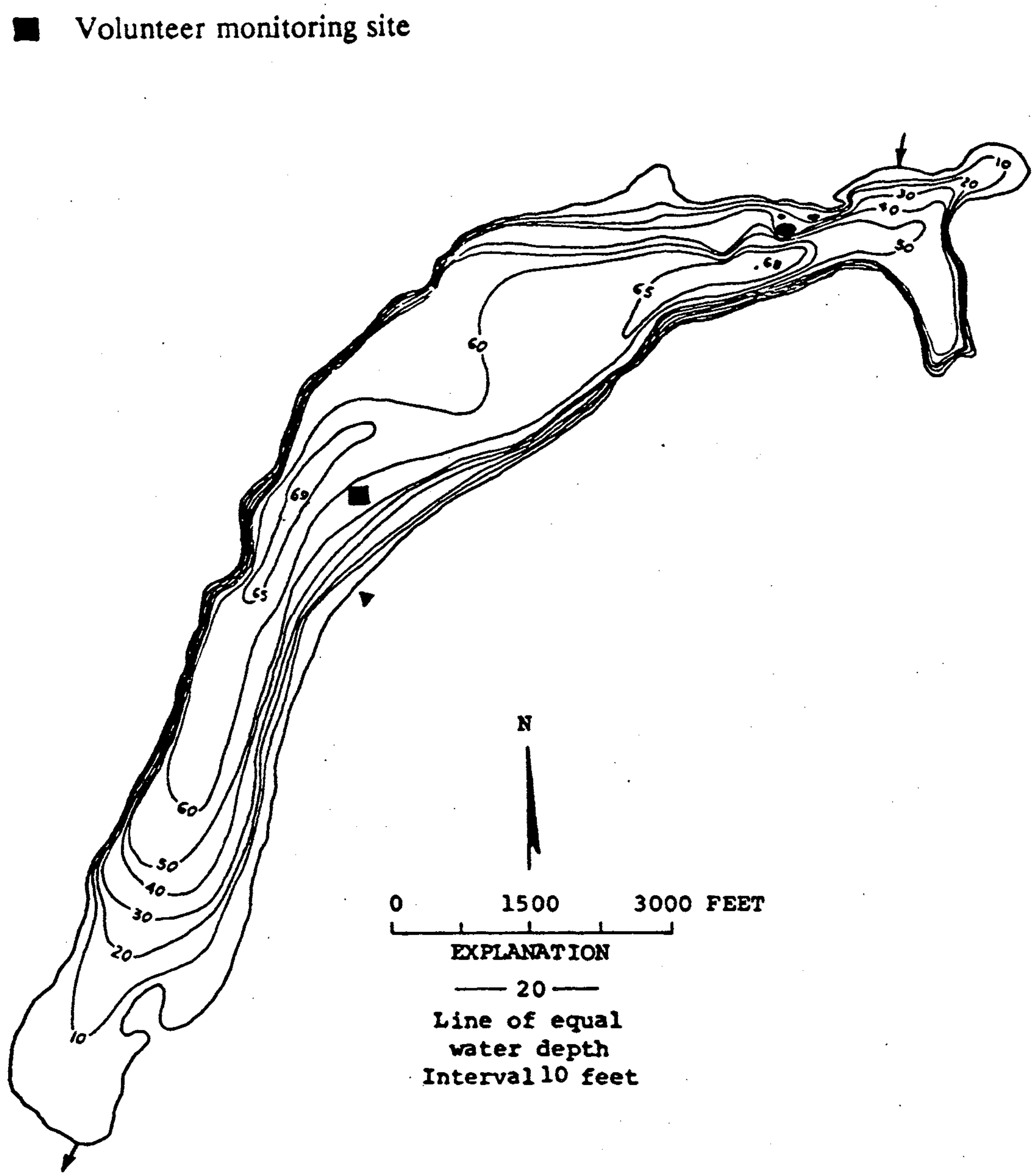
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/22	0.0	14.9	8.4	11.6	399	1, 2, 5	0.020	0.358
	1.0	14.6	8.5	11.4	399			
	2.0	14.5	8.5	11.3	399			
	3.0	14.5	8.5	11.3	399			
	4.0	14.4	8.5	11.2	399			
	5.0	14.0	8.5	11.2	400			
	6.0	13.9	8.5	11.0	399			
	8.5	12.6	8.5	10.3	400			
	9.0	11.8	8.4	9.1	401			
	10.0	11.8	8.3	9.1	402			
08/23	0.0	21.8	8.7	8.7	430	2, 4, 6	0.018	0.594
	1.0	21.8	8.7	8.7	429			
	2.0	21.8	8.7	8.7	430			
	3.0	21.8	8.7	8.7	429			
	4.0	21.8	8.7	8.7	430			
	5.0	21.8	8.7	8.7	429			
	6.0	21.8	8.7	8.7	429			
	7.0	21.7	8.6	7.7	431			
	8.0	20.9	8.5	5.2	435			
	9.0	20.3	8.3	3.6	437			
	10.0	19.3	8.0	1.0	439			
	12.0	17.3	7.8	0.1	444			
	14.0	14.4	7.5	0.1	454			
	16.0	13.9	7.5	0.1	455			

Secchi Depth and Profile Data Graphs







Blue Lake, Grant County. From Washington
Department of Game, January 10, 1949.

Lake Bosworth -- Snohomish County

Lake Bosworth is located 2.33 miles south from Granite Falls. It is fed by two unnamed inlets, and drains northeast to the Pilchuk River.

Size (acres)	105
Maximum Depth (feet)	79
Mean Depth (feet)	35
Lake Volume (acre-feet)	3671
Drainage Area (miles^2)	1.4
Altitude (feet)	563
Shoreline length (miles)	2.0

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	41**
Trophic State Index* (Total Phosphorus):	32

* From Carlson (1977)
** See Comments Section

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Bosworth is used for fishing, swimming, and rowing. Recreational facilities on the lakeshore include one boat ramp, and there is a speed restriction of 6 mph. Motor boats are restricted to electric motors only. Lake water is withdrawn for drinking and other domestic uses. Currently the watershed is used for logging, and the lakeshore is being developed further for residences. In the past, the watershed was used for logging and the shoreline was altered. There are 111 houses on the lakeshore; of these, 36 are occupied year-round. The lakeshore is not sewered, and there are five storm drains that empty into the lake. Fish (rainbow trout, cutthroat trout and bass) are stocked in the lake. Presently there is no citizen's lake protection organization for the lake. The lake has been chemically treated in the past to control fish species. The worst problems in the lake, in the opinion of the volunteer, are 1) aquatic plants (in some areas), and 2) fish species. Overall, the volunteer finds that Lake Bosworth has excellent water quality, and suggested that outhouses, septic tanks, and fertilizing may affect the water quality.

Lily pads are located in cove areas. There are weeds at the south end of the lake.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that there was very little variability in the water clarity of the lake.

Lake Bosworth -- Snohomish County

Profile data collected during June 1990 show that the lake was stratified with respect to temperature. The increase in the concentration of dissolved oxygen at 5-6 meters is probably due to a combination of decreased water temperatures (dissolved oxygen is more soluble in cooler water), and increased algae growth at these depths. In August 1973, the concentration of dissolved oxygen near the bottom of the lake was 1.0 mg/L (Bortleson *et al.*, 1976), so it is probable that in late summer months the concentration of dissolved oxygen gets very low near the bottom of the lake.

The volunteer-collected Secchi disk readings and low concentration of total phosphorus indicate that Lake Bosworth was oligotrophic. The concentration of total phosphorus was very low compared to other lakes monitored for the program in 1990; only 4 of the 79 lakes sampled had lower concentrations. In 1973, the concentration of total phosphorus in Lake Bosworth was 0.004 mg/L (Bortleson *et al.*, 1976).

Comments

Because there was high variability between the two volunteer-collected Secchi depths on each sampling date, these Secchi depths will not be compared with Secchi depths collected by other volunteers. Based on total phosphorus data, though, the quality of Lake Bosworth is very good compared to other lakes monitored for the program. Lake Martha in Snohomish County (near Warm Beach) is somewhat smaller than Lake Bosworth but is another lake which is relatively deep compared to its surface area. Compared with Lake Martha, Lake Bosworth had a much lower concentration of total phosphorus. Compared with nearby Panther, Storm and Flowing Lakes in Snohomish County, Lake Bosworth had lower concentrations of total phosphorus.

Acknowledgement

I thank Robert and Delores Maxwell for volunteering their time to monitor Bosworth Lake during 1990.

Lake Bosworth -- Snohomish County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)*	Lake Ht(in)	Abbreviated Comments
15-May	13.3	55.9	6.0	Gr-Brown	100	Heavy	Calm	12.0	3.0	Lake color very light.
05-Jun	15.6	60.1	6.5	Green	10	Heavy	Calm	13.0	0.7	Very windy and rainy the last week.
19-Jun	18.9	66.0	6.0	Lt-Green	100	Heavy	Light	13.0	4.7	Water color yellow green.
04-Jul	21.1	70.0	6.5	Pea-Green	25	Heavy	Breezy	11.5		Water color pea-soup green/yellow.
16-Jul	25.6	78.1	6.0	Pea-Green	0	None	Strong	12.0	5.5	Water color yellow/pea-soup green.
01-Aug	23.3	73.9	6.5	Pea-Green	0	None	Calm	12.0	9.0	
15-Aug	23.3	73.9	6.5	Pea-Green	75	None	Light	12.0	11.0	Water color also noted as green-yellow
04-Sep	21.1	70.0	7.5	Pea-Green	0	None	Breezy	12.0	11.7	Water color pea-soup green-yellow.
17-Sep	21.1	70.0	6.0	Pea-Green	10	Trace	Calm	10.5	12.3	Sunny - haze.
01-Oct	17.8	64.0	6.0	Pea-Green	25	None	Breezy	14.0	13.3	

* There was high variability between the two Secchi depths collected on each sampling date; all Secchi data from this lake were not included in data comparisons

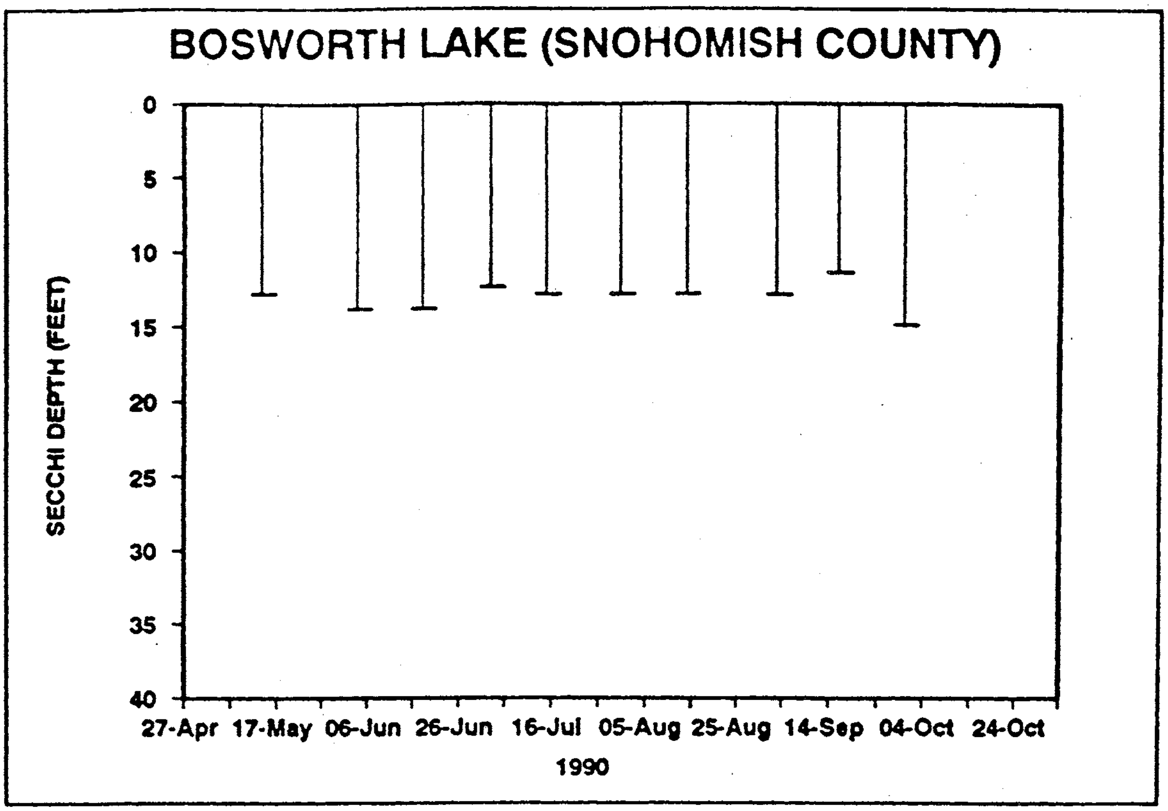
Onsite Visit Data

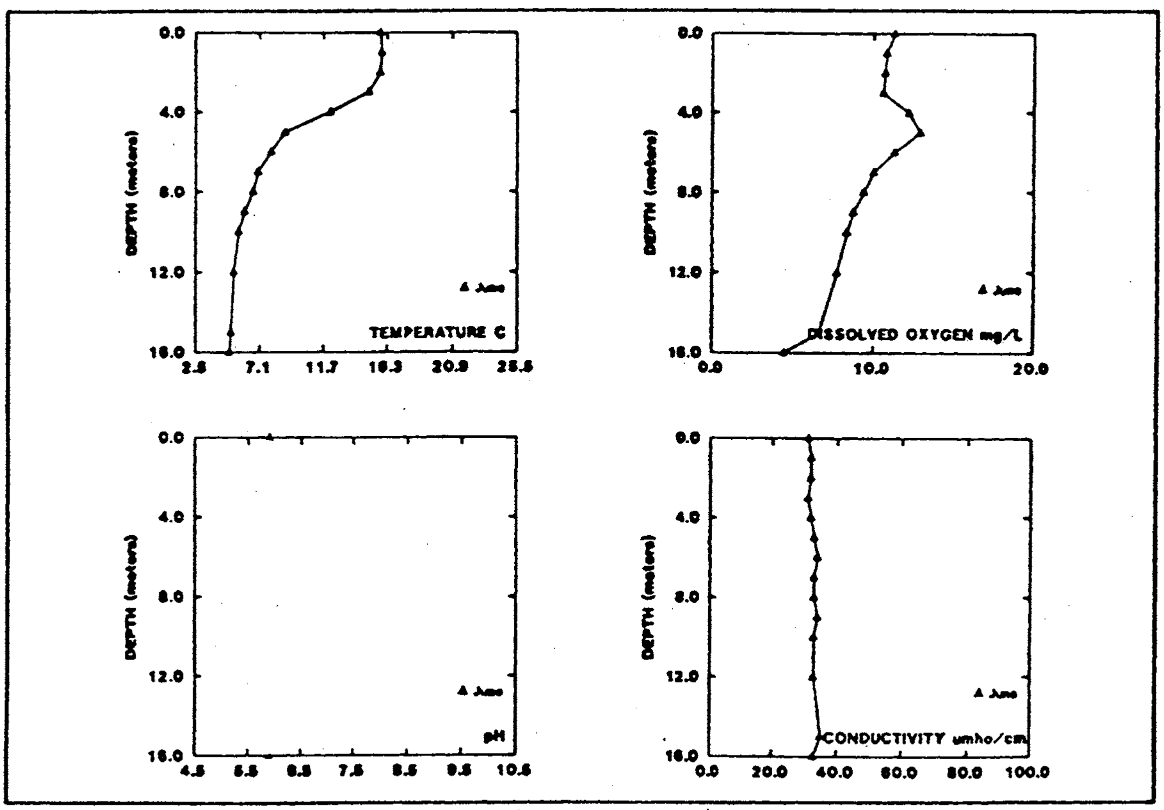
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/06	0.0	15.8	.*	11.3	31	1, 2, 3	0.007	NA
	1.0	15.9	.	10.8	32			
	2.0	15.8	.	10.7	32			
	3.0	15.0	.	10.6	31			
	4.0	12.2	.	12.2	32			
	5.0	8.9	.	12.9	33			
	6.0	7.9	.	11.3	34			
	7.0	7.0	.	10.0	33			
	8.0	6.6	.	9.4	33			
	9.0	6.0	.	8.8	34			
	10.0	5.6	.	8.4	33			
	12.0	5.2	.	7.8	33			
	15.0	5.0	.	6.7	35			
	16.0	4.9	.	4.6	33			

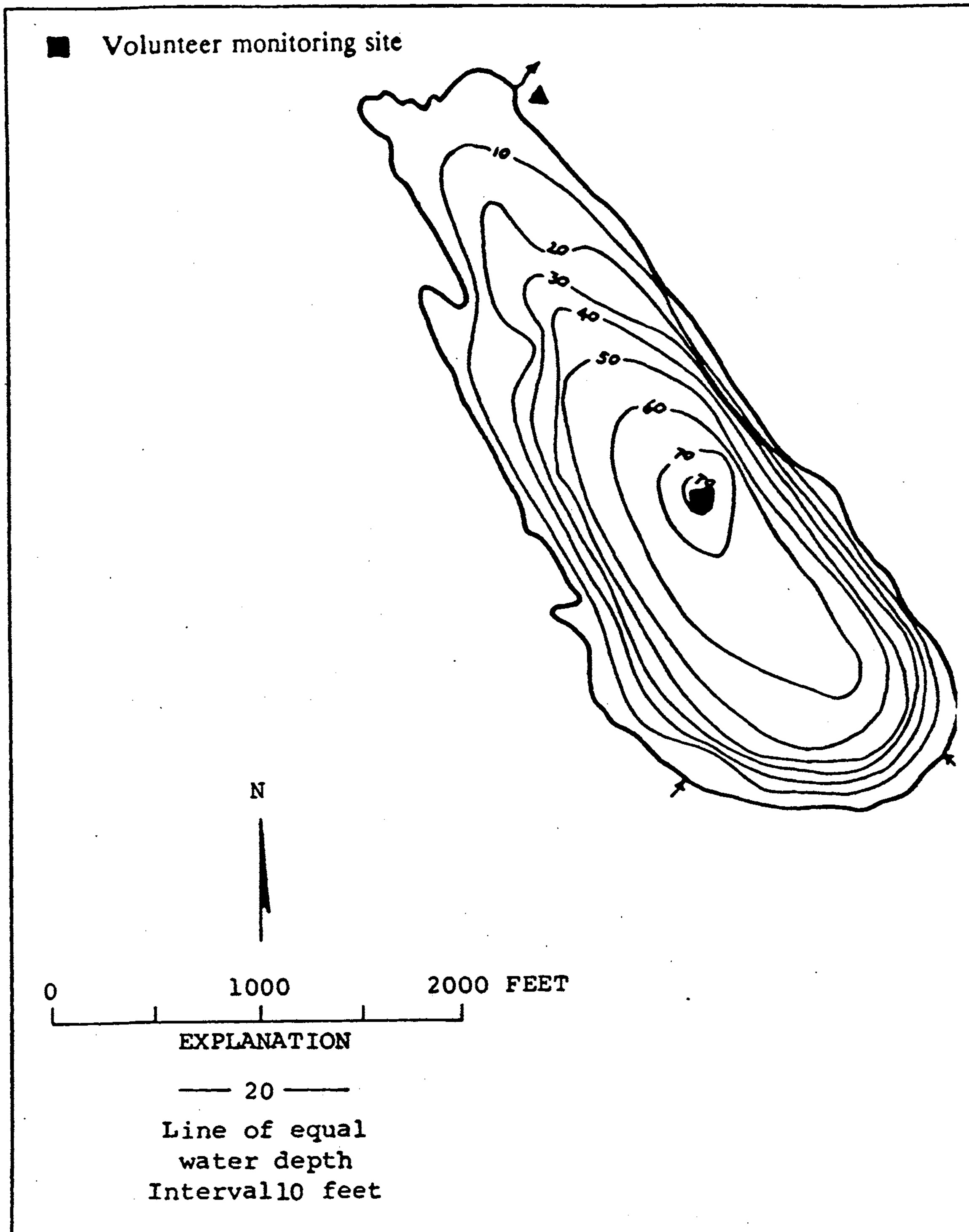
* See Quality Assurance section of this report.

NA Data not available; sample was not analyzed by the laboratory

Secchi Depth and Profile Data Graphs







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

Lake Chelan -- Chelan County

The outlet of Lake Chelan is located at the city of Chelan. It is the longest and deepest natural lake in the state. It extends 50.4 miles northwest from the dam at the outlet to the mouth of the Stehekin River. The dam at the outlet was built in 1928 and the water level is controlled by Chelan County PUD No. 1. There are numerous inlets along the west and east sides, and the Stehekin River at the head of the lake is the principal inlet tributary. It drains via the Chelan River to the Columbia River.

Size (acres)	33,300
Maximum Depth (feet)	1486
Mean Depth (feet)	474
Lake Volume (acre-feet)	1,756,198.
Drainage Area (miles^2)	924
Altitude (feet)	1110
Shoreline length (miles)	109.2

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	21
Trophic State Index* (Total Phosphorus):	29

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Chelan 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, eight resorts, and seven boat ramps, and there are no restrictions for motorboat use on the lake. Lake water is withdrawn for drinking, municipal use, and irrigation. Currently the watershed is used for logging, animal grazing, crop agriculture, and the lakeshore is being developed further for residences. Grazing animals have direct access to the lakeshore and inlet tributaries. In the past, the watershed was used for animal grazing, crop agriculture, and mining, and the shoreline was altered. There are approximately 400 houses on the lakeshore; of these, 200 are occupied year-round. The lakeshore is about 70% sewered. Fish were not reported as being stocked in the lake. Presently there is a sewer district, yacht and boat clubs, and a sports council for the lake. The worst problem in the lake, in the opinion of the volunteer, was algae growing along the shore in areas where it wasn't 10 years ago. Overall, the volunteer finds that Lake Chelan has excellent recreational water quality, and suggested that agricultural runoff and the large number of large boats that use the lake for long periods, may contribute to the water quality of the lake. The volunteer also noted that last year the health department closed the city park because of ducks.

Lake Chelan -- Chelan County

Monitoring Results/Summary of Other Available Information

The volunteer monitored Lake Chelan at the center of the lake between 25 Mile Creek and Dutch Harbor. Because high winds frequently make the water surface choppy, a viewing tube was loaned to the volunteer to improve his ability to see the Secchi disk through the water. None of the other volunteers used viewing tubes.

Both the Secchi disk readings and the total phosphorus concentrations in the water indicate that Lake Chelan was oligotrophic.

From Patmont *et al.* (1989): Lake Chelan was monitored from November 1986 through December 1987, for an Ecology-funded study. The purpose of the study was to provide baseline information on the lake, to evaluate the existing and potential nutrient sources to the lake and their impacts, and to use the gathered information to provide recommendations for preserving the high water quality of the lake. Several aspects of the lake were evaluated, including groundwater, circulation patterns of the lake, lake productivity (phytoplankton and periphyton), bacteriological conditions in the lake, lake sediments and fish tissue. With respect to phosphorus concentrations, Lake Chelan was classified as ultra-oligotrophic, meaning that the lake was extremely unproductive and low in nutrients. The main water quality concern at the lake is with regards to nearshore water quality, because the lake is used for recreation and for drinking. Recommendations from the study included limiting development along the lakeshore so that phosphorus loading to the lake is minimized, maintaining the lake as ultra-oligotrophic. This may limit further development to 500 or fewer dwellings in the lower basin. Recommendations also address agricultural runoff to the tributaries and loading from septic systems. In order to maintain the lake at an ultra-oligotrophic classification, the mean annual concentration of total phosphorus should not exceed 4.5 μg/L; during the 1986-1987 study the concentration of epilimnetic total phosphorus in the upper basin of the lake was 3.0 (+/-0.2) μg/L.

Comments

Lake Chelan consistently had the greatest water clarity of all the lakes monitored for the program during 1990. Only Lake Crescent, monitored for the program during 1989, had greater water clarity, having a mean summer average water clarity of 79 feet in 1989. Lake Chelan also had the lowest concentration of total phosphorus of the lakes monitored during 1990.

Acknowledgement

I thank Keith S. Marney, for volunteering his time to monitor Lake Chelan during 1990.

Lake Chelan -- Chelan County

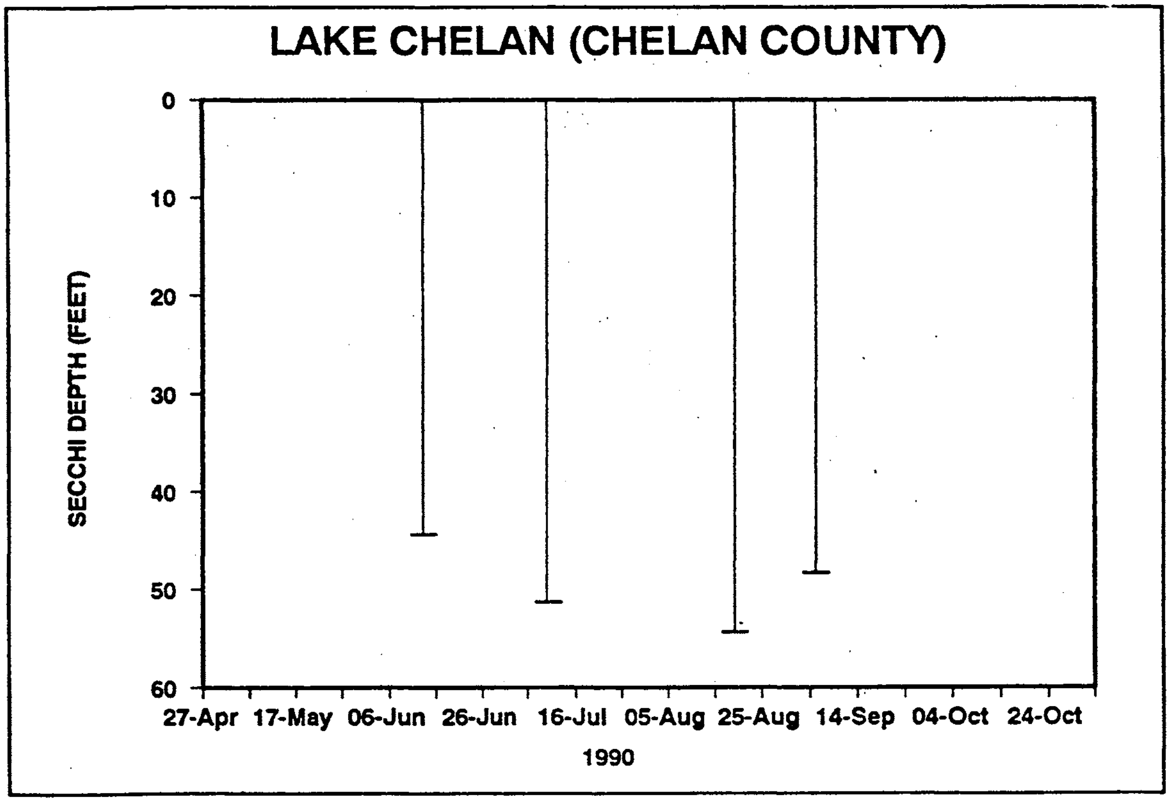
Volunteer-Collected Data

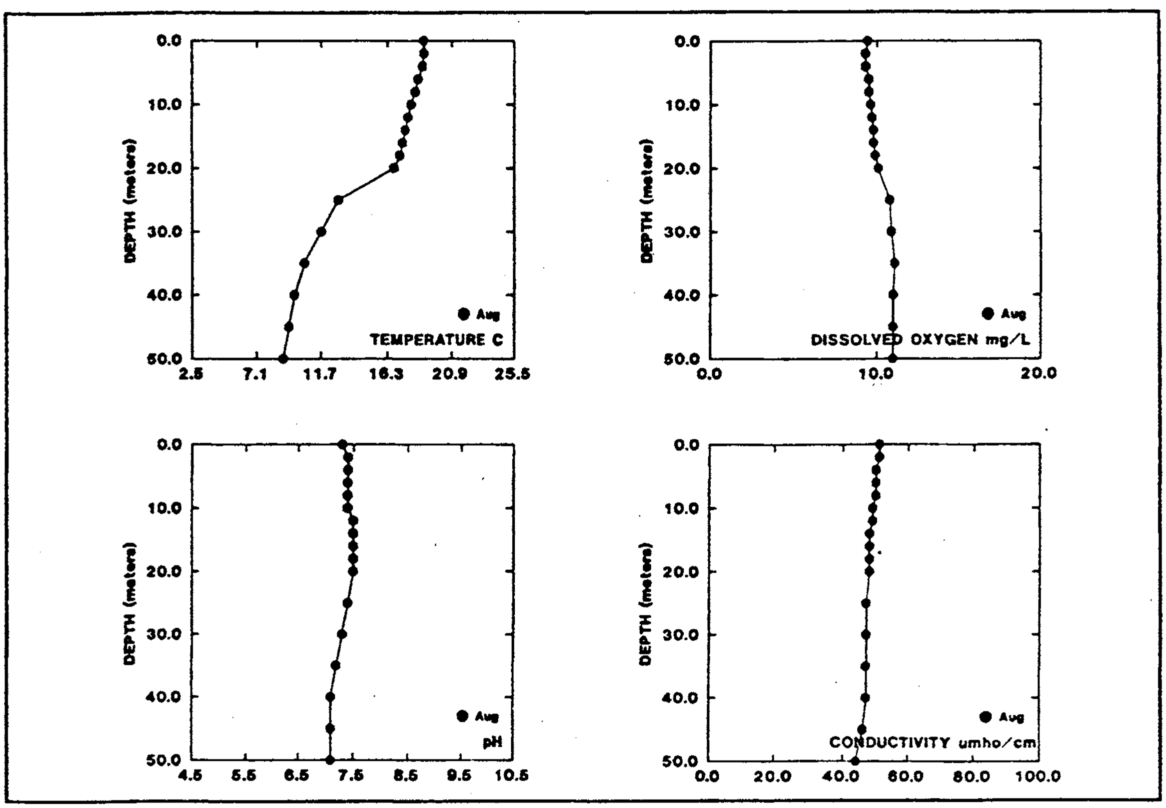
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
14-Jun	13.3	55.9	6.5	Clear	25	Light	Calm	43.0	95.6	Lots of rain but not much runoff last 10 days.
11-Jul	17.2	63.0	6.0	Bl-Green	0	None	Calm	50.0	100.0	
20-Aug	17.2	63.0	6.5	Blue	25	Light	Strong	53.0	100.0	White caps; used view tube with Dave or would have been too rough to see Secchi.
06-Sep	17.8	64.0	6.0	Blue	25	None	Calm	47.0	99.0	Lots of boat use over Labor Day weekend!

Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
08/20	0.0	18.9	7.3	9.4	51	5, 10, 15	0.006	112.0
	2.0	18.9	7.4	9.3	51			
	4.0	18.8	7.4	9.3	50			
	6.0	18.5	7.4	9.5	50			
	8.0	18.3	7.4	9.5	50			
	10.0	18.0	7.4	9.6	49			
	12.0	17.8	7.5	9.7	49			
	14.0	17.6	7.5	9.8	48			
	16.0	17.4	7.5	9.8	48			
	18.0	17.2	7.5	9.9	48			
	20.0	16.8	7.5	10.1	48			
	25.0	12.9	7.4	10.8	47			
	30.0	11.7	7.3	10.9	47			
	35.0	10.5	7.2	11.1	47			
	40.0	9.8	7.1	11.0	47			
	45.0	9.4	7.1	11.0	46			
	50.0	9.0	7.1	11.0	44			

Secchi Depth and Profile Data Graphs





Clear Lake -- Thurston County

Clear Lake is located 10 miles southeast from Yelm, in the Bald Hill region. It drains northerly to Toboton Creek and the Nisqually River. The inflow is perennial.

Size (acres)	170
Maximum Depth (feet)	25
Mean Depth (feet)	19
Lake Volume (acre-feet)	3200
Drainage Area (miles^2)	2.6
Altitude (feet)	518
Shoreline length (miles)	2.7

Estimated Trophic State:	Eutrophic*
Mean Trophic State Index** (Secchi):	37
Trophic State** (Total Phosphorus):	55

* See Comments Section
** From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The 1990 questionnaire on lake and watershed uses was not returned by the volunteer. The following are the volunteer's responses to the 1989 questionnaire. Clear Lake is used for fishing, swimming, canoeing/rowing, sailing/wind surfing, picnicking, camping, and hiking. There is one resort and five boat ramps along the lakeshore. There is a speed limit (5 MPH) for motor boats. Currently the watershed is used for logging and tree farming, and residential development is occurring on the lakeshore. There are seven houses directly on the lakeshore; all the rest are located behind a buffer strip 100-150 feet from the shore. All houses use on-site wastewater disposal systems. The lake has been treated with chemicals since the 1960s to control weeds and algae. Copper sulfate, rotenone, Endothall and Sonar have been used. The lake was chemically treated in 1989 to control weeds and algae. Fish are stocked in the lake. In the opinion of the volunteer, the worst problems in the lake, are 1) algae growing over the entire lake, and 2) weeds. Blue-green algal blooms were especially bad in early July. The weeds were not viewed as a problem when they are controlled in the swimming areas. Master's thesis work done by the 1989 volunteer concluded that internal loading of phosphorus from sediments triggers the blue-green algae blooms.

Monitoring Results/Summary of Other Available Information

Secchi readings collected from May through August 1990 show that the water was very clear throughout July. During 1989, the lowest water clarity occurred from late August through

October. No Secchi readings were taken during this period in 1990. No pattern in algal growth was apparent in 1990.

Profile data collected during May and August 1990 showed that the lake was not thermally stratified, although concentrations of dissolved oxygen decreased noticeably near the lake bottom. Very low dissolved oxygen concentrations in Clear Lake were also reported in 1968 (Lee, 1969) and 1971 (Bortleson *et al.*, 1976). The May 1990 total phosphorus sample was accidentally destroyed before it could be analyzed; the August sample had a high concentration of total phosphorus (0.0330 mg/L) indicating that Clear Lake was eutrophic. In 1971, the concentration of total phosphorus was 0.010 mg and the concentration of total nitrogen was 0.19 mg/L (Bortleson *et al.*, 1976). The lower concentrations of total phosphorus indicate that based on this nutrient, Clear Lake was oligotrophic in 1971.

The dissolved oxygen and pH profiles and the epilimnetic concentrations of total phosphorus were very similar during August 1990, and June 1989 (Brower and Kendra, 1990). However, during September 1989, the concentration of total phosphorus quadrupled in the epilimnion and a surface bloom of the blue-green alga *Anabaena* occurred.

The ratio of total nitrogen to total phosphorus was low (10:1) in 1990, suggesting that nitrogen may be the nutrient limiting the amount of algae growth in Clear Lake. Low ratios of total nitrogen to total phosphorus were also found in Clear Lake during 1989 (Brower and Kendra, 1990). The possibility of nitrogen limitation makes it difficult to use total phosphorus data to assess the trophic state of the lake. Also, the chemical treatment of the lake makes it difficult to use Secchi data to estimate the trophic status of the lake.

Water quality variance records with Ecology show that on June 6 and 21, 1989, Clear Lake was treated with Aquathol, Endothall, and Sonar to control pondweed and milfoil. On July 6, 7, and 13, the lake was treated with copper sulfate to control algae. Water quality variance records with Ecology state that in 1990 the lake was treated on May 21, June 5 and 27, July 16, and August 20, 1990. Copper sulfate was used on most treatment days to control algae. Aquathol K was used to control *Elodea*.

Comments

As mentioned above, it is difficult to assess the trophic state of Clear Lake based on total phosphorus or Secchi depth data. However, because the lake has a high frequency of blue-green algal blooms, the lake was estimated as eutrophic.

Lake Steilacoom in Pierce County is about the same size as Clear Lake and also has received long-term chemical treatments to control aquatic plants and algae. In 1990, the June concentration of total phosphorus in Lake Steilacoom was only 0.0167 mg/L. In 1989, both Clear Lake and Lake Steilacoom were sampled by Ecology, and the data showed that

Clear Lake -- Thurston County

Clear Lake had much better water clarity but considerably higher total phosphorus concentrations than Lake Steilacoom. Lake Steilacoom receives urban and residential runoff, whereas Clear Lake is probably affected more by logging, tree farms, and residential runoff. The total phosphorus concentrations in Clear Lake were sufficient to support an even greater algal population than was seen during the 1989 sampling season.

The chemical treatment of the lake directly affects water clarity by altering the amount of algae that grow in the water. Because of this, the Secchi disk data collected by the volunteer underestimate the trophic state of the lake and future estimates of trophic status should be based on chemical as well as transparency data. However, a long-term Secchi disk data record can be used to document and compare the severity of the algal blooms that occur in the lake.

Acknowledgements

I thank Mark Swarthout for volunteering his time to monitor Clear Lake during 1989-1990, and Bill Owen for volunteering to take over for Mark in 1990.

Clear Lake -- Thurston County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
31-May	16.0	60.8	7.1	Clear	50	Light	Breezy	20.2	0.0	
20-Jun	22.0	71.6		Lt-Green	100	Trace	Light	11.9	0.0	
28-Jun	23.0	73.4		Lt-Green	100	Light	Light	18.3	2.1	
11-Jul	24.0	75.2		Clear	25	None	Calm	23.8 b	2.0	
18-Jul	25.0	77.0	6.5	Clear	0	None	Light	22.9 b	1.9	
25-Jul	25.0	77.0	6.5	Clear	100	None	Calm	22.9 b	1.9	
01-Aug	24.0	75.2	6.5	Clear	90	None	Light	22.0	1.8	
08-Aug	26.0	78.8	6.7	Clear	75	None	Light	22.9 b	1.8	
21-Aug								17.4		Taken during onsite visit

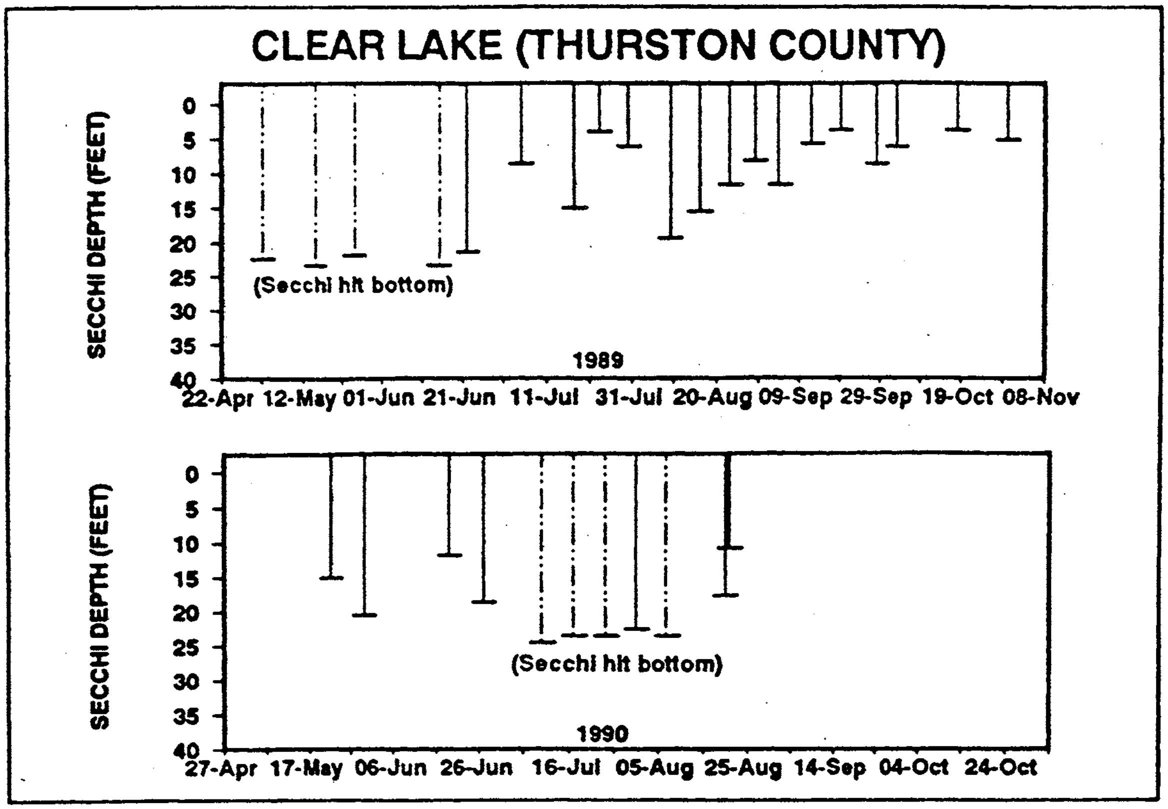
* Secchi data corrected for rope shrinkage
b Secchi hit bottom

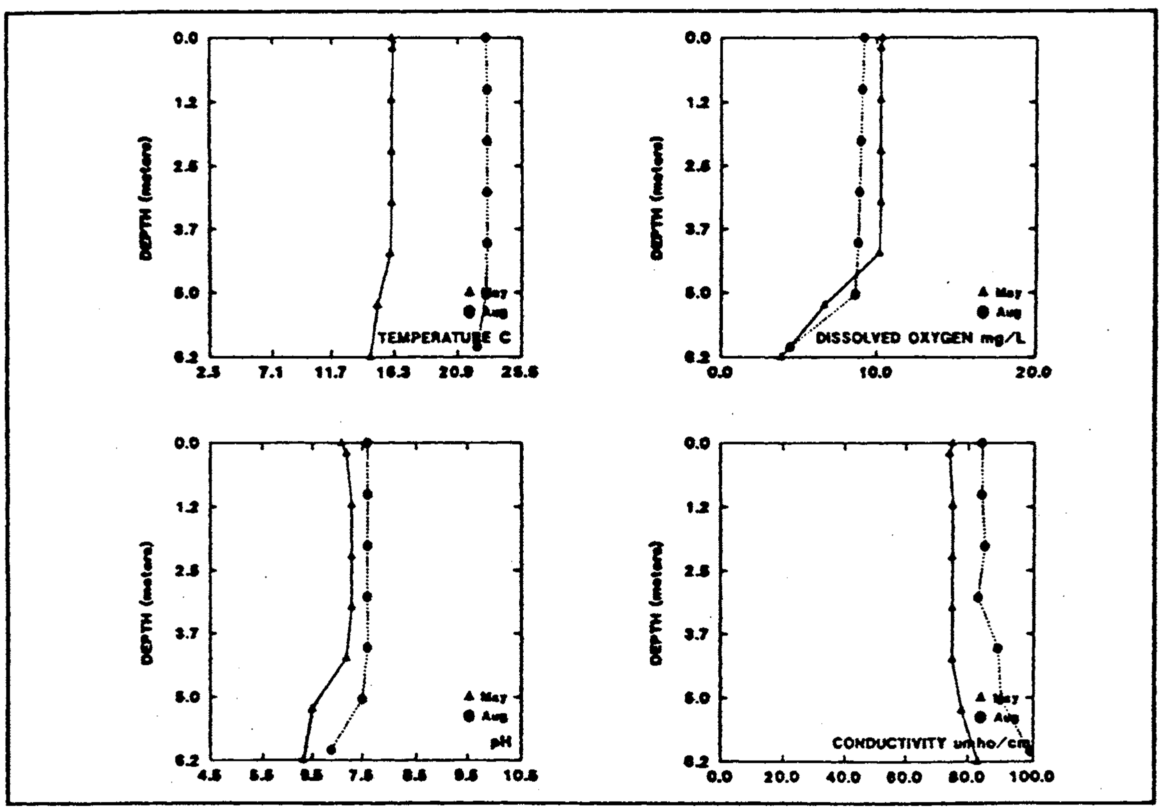
Onsite Visit Data

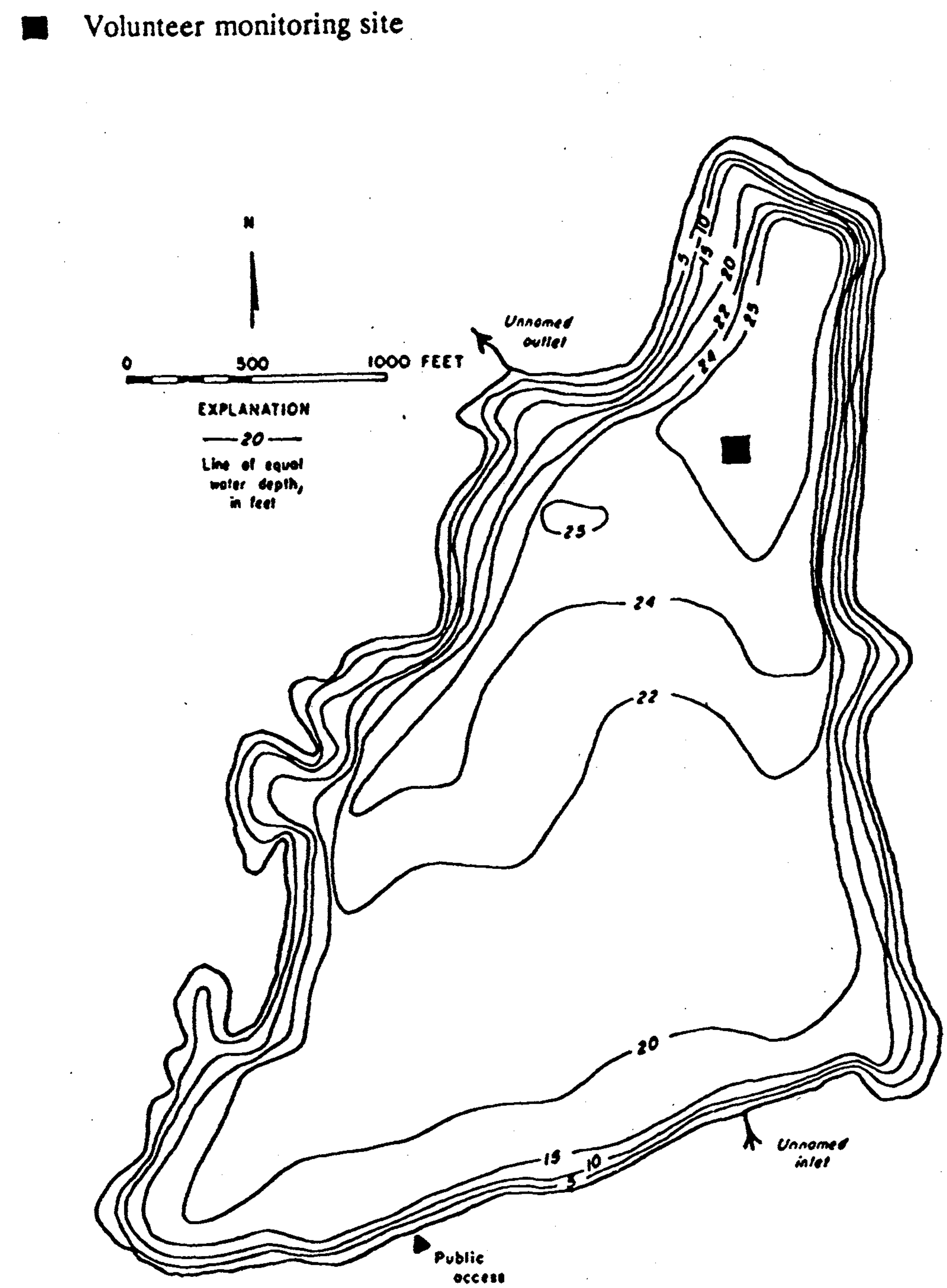
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/31	0.0	16.1	7.1	10.4	75	1, 4	NA	0.450
	0.2	16.2	7.2	10.3	74			
	1.2	16.1	7.3	10.3	75			
	2.2	16.1	7.3	10.3	75			
	3.2	16.1	7.3	10.3	75			
	4.2	16.0	7.2	10.2	75			
	5.2	15.1	6.5	6.6	78			
	6.2	14.6	6.3	3.8	83			
08/21	0.0	23.0	7.6	9.2	84	1, 3, 5	0.033	0.330
	1.0	23.1	7.6	9.1	84			
	2.0	23.1	7.6	9.0	85			
	3.0	23.1	7.6	8.9	83			
	4.0	23.1	7.6	8.8	89			
	5.0	23.0	7.5	8.6	90			
	6.0	22.4	6.9	4.4	99			

NA data not available; sample accidentally destroyed during shipment to laboratory.

Secchi Depth and Profile Data Graphs







Clear Lake, Thurston County. From Washington Department of Game, February 19, 1952.

Cortez Lake -- Chelan County

Cortez Lake is located 5.7 miles southeast from Wenatchee and 1.3 miles southwest from Malaga. It is an irrigation reservoir fed by diversions from Stemilt Creek and drainage from Meadow Lake. It has no outlet, but seeps to the Columbia River. Its size varies widely with seasons. Cortez Lake is called Three Lakes Reservoir in older literature.

Size (acres)	44
Maximum Depth (feet)	28
Mean Depth (feet)	18
Lake Volume (acre-feet)	794
Drainage Area (miles^2)	0.3
Altitude (feet)	871
Shoreline length (miles)	1.2

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	53
Mean Trophic State Index* (Total Phosphorus):	54

* From Carlson (1977)

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

The following are from the volunteer's remarks and questionnaire responses. Cortez Lake is used for fishing, swimming, and rowing. There are no recreational facilities on the lakeshore, and no motors are allowed on the lake. Lake water is withdrawn for irrigation. Currently the watershed is used for logging, animal grazing, and residential development is occurring on the lakeshore. Grazing animals have direct access to the lakeshore or inlet tributaries. In the past, the watershed was used for crop agriculture. There are 24 houses on the lakeshore; of these, 22 are occupied year-round. The lakeshore is not sewered, and there are no storm drains that empty into the lake. Fish were not reported as being stocked in the lake. The lake is drawn down by irrigation until October, and then refilled. The worst problems in the lake, in the opinion of the volunteer, are 1) sediment suspended in the water, and 2) aquatic plants. Overall, the volunteer finds that Cortez Lake has fair recreational water quality, and suggested that "weed and feed", ducks and geese, possible septic tank failure and spraying beaches to kill knapp weed may affect the water quality. The volunteer is mainly concerned about swimming water quality.

A diversion from Stemilt Creek fills the lake from October 15 through April 15. There are marshes on the southeast shallow end and the northeast end of the lake. Algae grow along the shores of these marshy areas.

Cortez Lake -- Grant County

Monitoring Results and Summary of Other Available Information

Secchi disk readings collected during 1990 show that the water clarity in Lake Cortez decreased over the course of the summer, and the lowest water clarity occurred during late August and September. This decrease in water clarity was likely due to agal growth, and occurred at the same time that the water level decreased.

Profile data collected during May and August 1990 show that the lake was strongly stratified during May, and on both sampling dates the concentrations of dissolved oxygen near the bottom of the lake were virtually depleted. The decrease in pH with depth on both sampling dates most likely occurred in response to the lower dissolved oxygen concentrations. Concentrations of dissolved oxygen in 1974 also decreased with depth, and were reported to be 3.4 mg/L at 16 feet, which was about three feet above the bottom of the lake (Dion *et al.*, 1976).

The concentrations of total phosphorus and total nitrogen were high, especially during August. In 1974, the concentration of total phosphorus in the epilimnion was 0.024 mg/L (Dion *et al.*, 1976), which is similar to the concentration found during May 1990.

During the May 1990 onsite visit with the volunteer, algae were visible but were not in bloom proportions. During the August onsite visit, pondweed (*Potamogeton pectinatus*) and rush (*Spirea*) were present at the northeast end of the lake. Pieces of coontail (*Ceratophyllum demersum*) were also seen.

In 1974, there were seven nearshore homes (compared with the 24 nearshore homes counted by the volunteer in 1990), and most of the shoreline was covered with aquatic plants (Dion *et al.*, 1976).

Comments

Of the 74 lakes monitored for the program in 1990, only 15 lakes had higher concentrations of total phosphorus than Cortez Lake.

Acknowledgement

I thank Iris Rose Hahn for volunteering her time to monitor Cortez Lake during 1990.

Cortez Lake -- Grant County

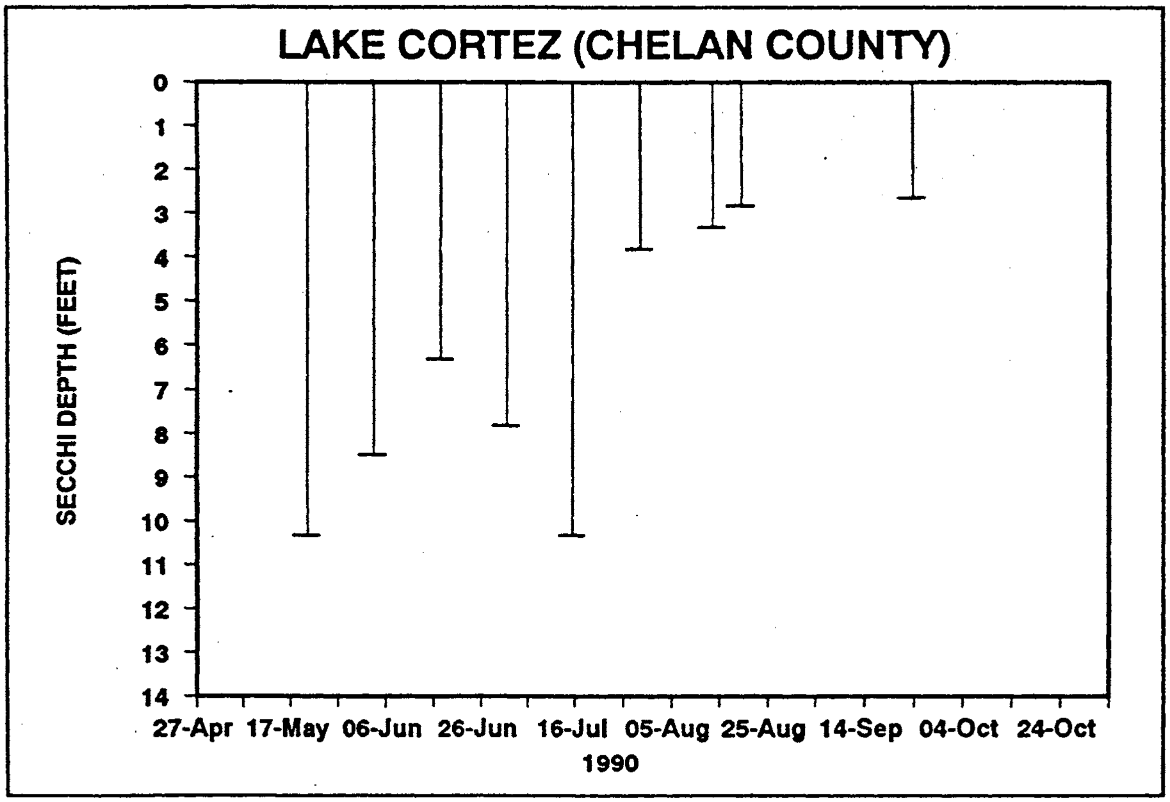
Volunteer-Collected Data

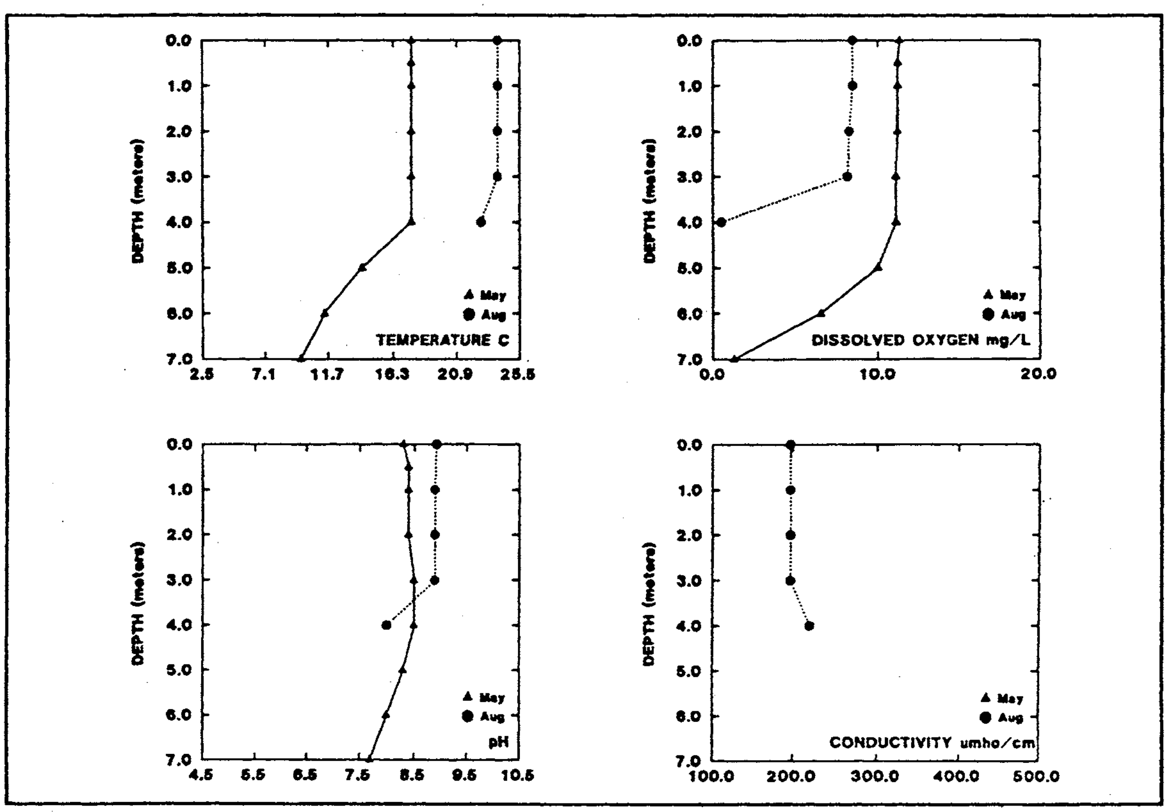
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(ft)	Abbreviated Comments
21-May	17.8	64.0	7.5	Green	10	Heavy	Breezy	10.0		
04-Jun	17.8	64.0	8.0	Green	25	Light	Breezy	8.2	25.	
18-Jun	21.1	70.0	8.0	Green	0	None	Gusty	6.0	24.	
02-Jul	22.8	73.0	8.0	Dk-Green	100	Trace		7.5	22.5	
16-Jul	26.7	80.1	8.0	Clear-Gr	10	None	Breezy	10.0	21.	Last few days water looks a little clearer and cleaner.
30-Jul	27.8	82.0	8.5		75	None	Calm	3.5	19.	Water color murky green.
14-Aug	26.7	80.1	8.0	Pea-Green	10	None	Calm	3.0	17.5	Am sending in sample of algae/weeds.
20-Aug	25.6	78.1	8.5	Green	90			2.5		
24-Sep	23.3	73.9	8.5	Green	0	None	Calm	2.3	14.5	

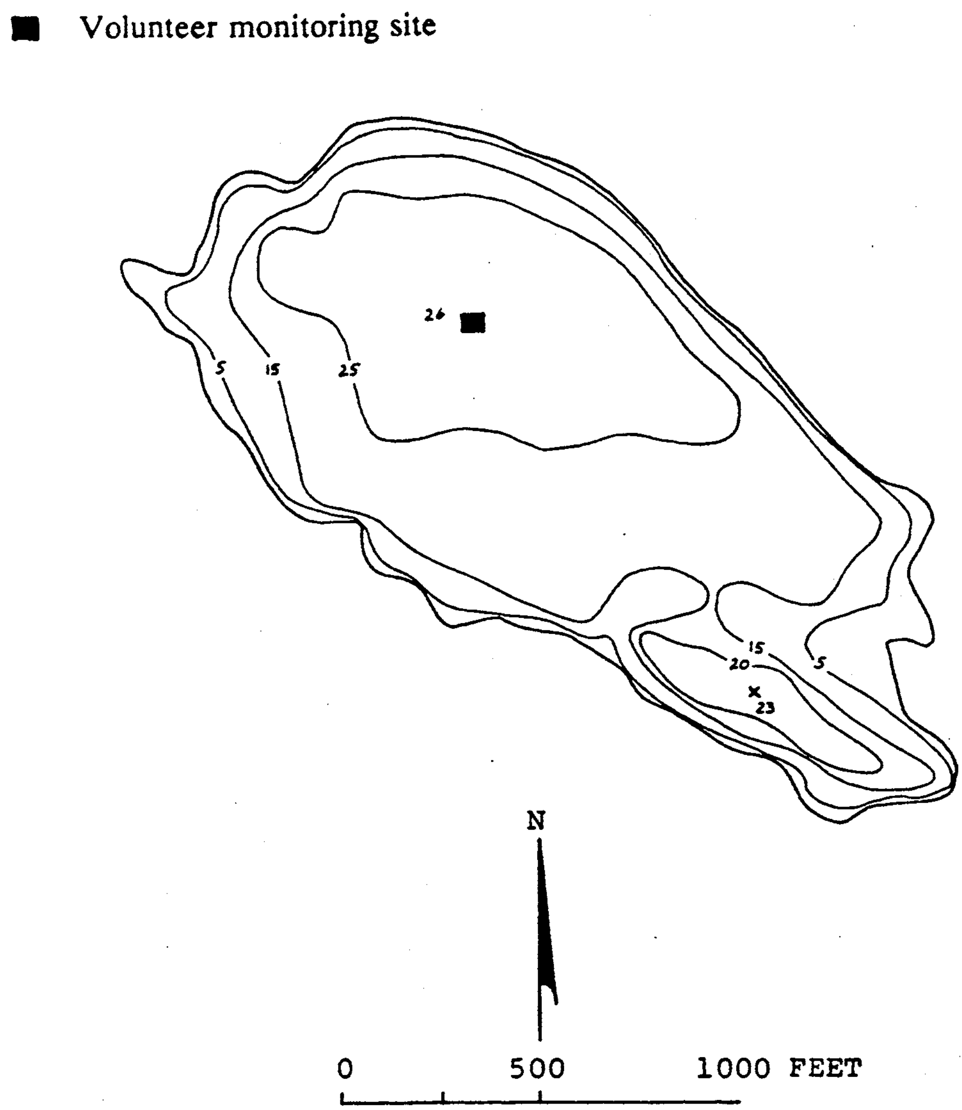
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/21	0.0	17.6	8.3	11.3	.	0.5	0.020	0.329
	0.5	17.6	8.4	11.2	.			
	1.0	17.6	8.4	11.2	.			
	2.0	17.6	8.4	11.2	.			
	3.0	17.6	8.5	11.1	.			
	4.0	17.6	8.5	11.1	.			
	5.0	14.1	8.3	10.0	.			
	6.0	11.4	8.0	6.6	.			
	7.0	9.7	7.7	1.3	.			
08/20	0.0	23.9	8.9	8.5	197	1, 2, 3	0.045	0.664
	1.0	23.9	8.9	8.5	197			
	2.0	23.9	8.9	8.3	197			
	3.0	23.9	8.9	8.2	197			
	4.0	22.7	8.0	0.5	220			

Secchi Depth and Profile Data Graphs







EXPLANATION

— 15 —

Line of equal
water depth
Interval 5 feet

Cortez (Three) Lake, Chelan County. From Washington Department of Game, December 1948.

Cranberry Lake -- Island County

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

Size (acres)	125
Maximum Depth (feet)	25
Mean Depth (feet)	13
Lake Volume (acre-feet)	1576
Drainage Area (miles^2)	0.6
Altitude (feet)	20
Shoreline Length (miles)	2.8

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	45
Trophic State Index* (Total Phosphorus):	53

* From Carlson (1977)

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

The following are from the volunteer's remarks and questionnaire responses. Cranberry Lake is used for fishing, swimming, rowing, and camping. Recreational facilities on the lakeshore within the state park include a picnic area, a camping area, a beach, and one boat ramp. Currently the watershed is used for animal grazing, crop agriculture, and residential development is occurring on the lakeshore. In the past, the watershed was used for animal grazing and crop agriculture. There are no houses on the lakeshore, and there is one storm drain that empties into the lake. Fish were not reported as being stocked in the lake. Presently there is no citizen's organization for the lake. The worst problems in the lake, in the opinion of the volunteer, are 1) aquatic plants, and 2) algae. In 1989, the volunteer noted that the worst problems in the lake were suspended sediments and algae blooms. Overall, in 1990 the volunteer finds that Cranberry Lake has good recreational water quality.

There is a culvert at the south end of the lake that has been dammed by beavers. The volunteer reports that Park rangers are concerned because this has raised the lake level over the last few years.

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

Cranberry Lake -- Island County

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

Monitoring Results/Summary of Other Available Information

Secchi disk readings collected during 1990 are noticeably deeper than Secchi readings collected during 1989. However, Cranberry Lake still exhibits several eutrophic characteristics such as high epilimnetic concentrations of total phosphorus, depleted dissolved oxygen concentrations near the bottom of the lake, considerable aquatic plant growth along the shoreline and in the water, and reports of a blue-green algae species (the "grass clipping" algae noted by the volunteer on September 9, 1990, was probably the easily recognizable alga *Aphanizomenon*, a blue-green alga that was also reported in the lake in 1989 by Brower and Kendra, 1990).

The Secchi data, profile data, and nutrient data collected during 1990 are more similar to data collected in 1981 (from Sumioka and Dion, 1985) than the 1989 data. Many other Western Washington Lakes monitored for the program, including Cranberry Lake, had more algae growth and worse water clarity in 1989 than in 1990. The greater water clarity and lower total phosphorus concentrations, and the less severe algae growth in 1990, does not necessarily reflect an improvement in water quality; rather, it probably reflects the differences in weather conditions during 1990 compared to 1989. To evaluate whether any changes have actually occurred in the lake quality, at least five consecutive years of data are needed.

The plant sample collected from the public access during the August 1990 onsite visit with the volunteer was identified as a milfoil species (*Myriophyllum*), but was not thought to be the aggressive Eurasian milfoil variety.

Comments

Duck Lake was the only other coastal lake monitored for the program in 1990. Like Cranberry Lake, Duck Lake is shallow, eutrophic, and has been shown to have high nutrient concentrations and a high amount of blue-green algae growth. Compared with Duck Lake, Cranberry Lake has better water clarity. In 1989, Cranberry Lake had similar concentrations of total phosphorus as Duck Lake, higher concentrations of total nitrogen, but less algae growth and fewer aquatic plants. Sidley Lake in Okanogan County has similar physical characteristics (size and mean depth) as Cranberry Lake, and in 1990 had very similar trophic state values from Secchi depth and total phosphorus data. Sidley Lake also has fish kills that are most likely due to low concentrations of dissolved oxygen in the water, but this occurs during the winter when the lake is iced over.

Cranberry Lake -- Island County

In 1989, the ratio of total phosphorus to total nitrogen concentrations in Cranberry Lake suggested that algae growth in the lake may have been limited by the concentration of nitrogen in the water. In 1990, the concentration of total phosphorus was lower than in 1989 and the ratio of total nitrogen to total phosphorus did not indicate that nitrogen was the limiting nutrient.

During both 1989 and 1990, Secchi disk data underestimated the trophic state of Cranberry Lake somewhat. However, other characteristics of the lake indicate that Cranberry Lake is eutrophic. Secchi data will be best used to document the occurrence and severity of algae growth in the lake.

Acknowledgement

I thank Terri Thomas for volunteering her time to monitor Cranberry Lake during 1989-1990.

Cranberry Lake -- Island County

Volunteer-Collected Data

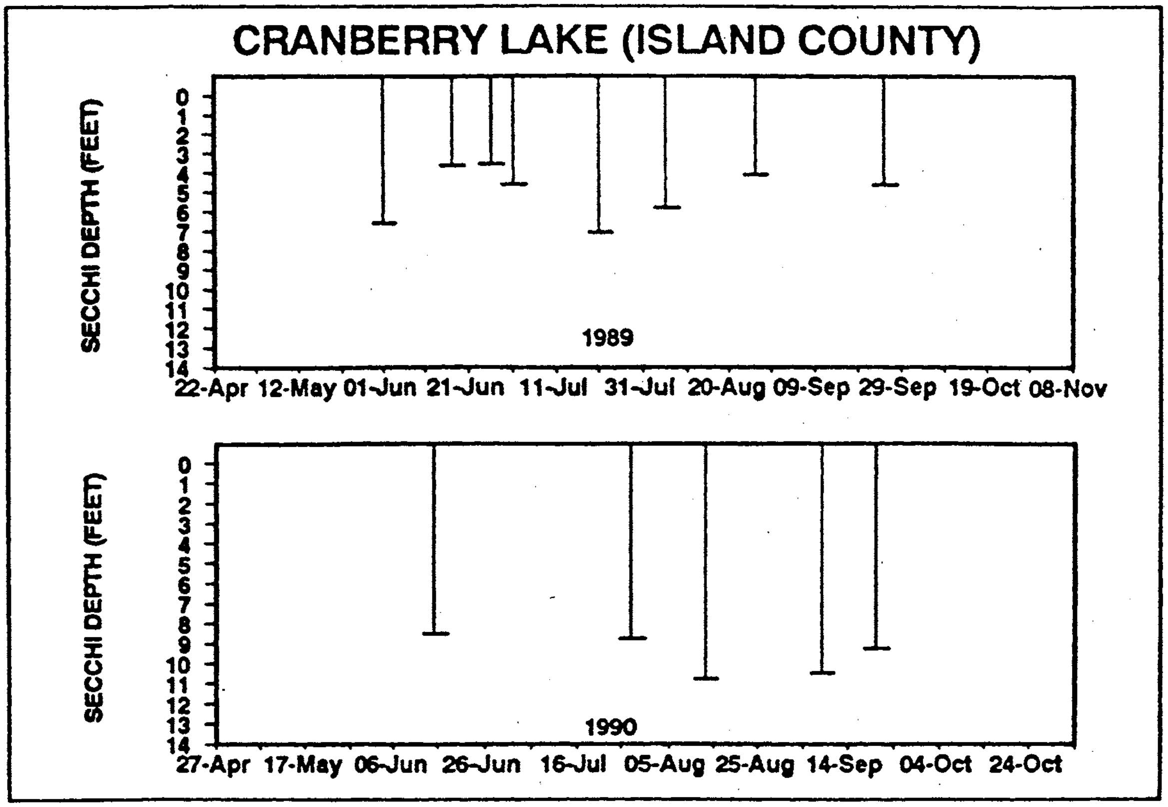
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
16-Jun			6.5	Lt-Brown	100	Trace	Calm	8.3		Thermometer is broken - need new one. Algae particles suspended in water.
29-Jul	23.5	74.3	7.0	Lt-Brown	0	None	Calm	8.5	-6.5	Small (1") algae strands near shore. Clear to 10' out. Water is looking good compared to last year -my kids even swam without complaining about dirty water!
14-Aug								10.4		Taken during onsite visit
09-Sep	21.0	69.8	6.5	Lt-Brown	100	None	Calm	10.1	-10.0	New white/pale green scum around lake - at first glance it looked like oil slick, up close looked more like soap scum. Very thin sheet on surface. "Grass clipping" algae still present but less than before.
21-Sep	21.5	70.7	6.5	Lt-Brown	0	None	Calm	8.9	-11.0	Too dark to be accurate with readings.

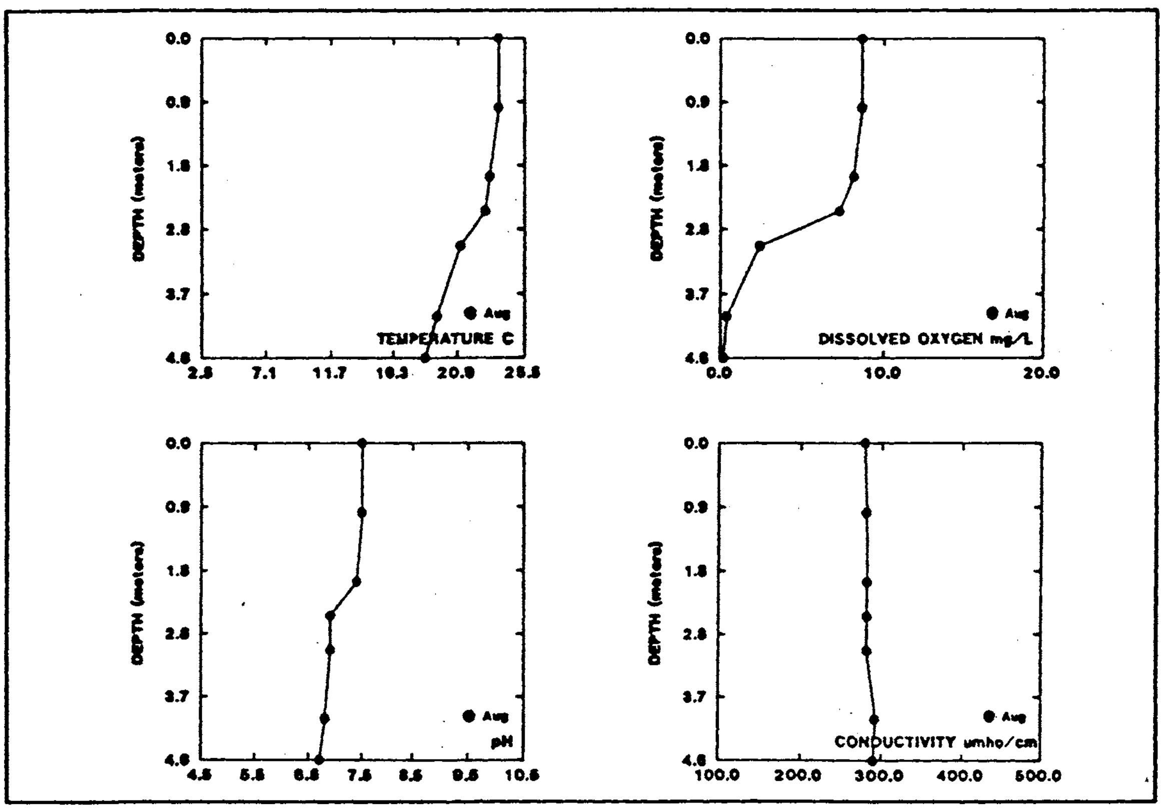
* Secchi data corrected for rope shrinkage

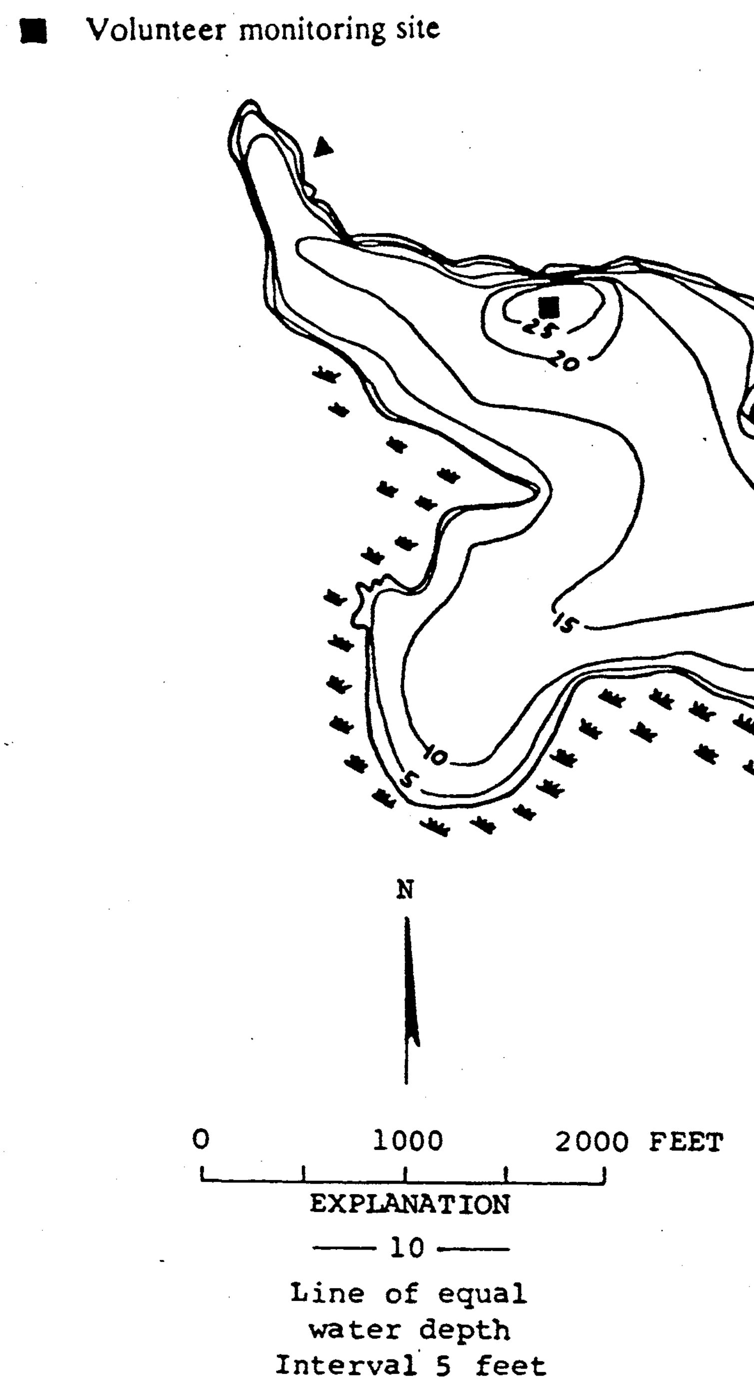
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
08/14	0.0	23.7	7.5	8.7	280	1, 2	0.029	0.707
	1.0	23.7	7.5	8.7	282			
	2.0	23.1	7.4	8.2	283			
	2.5	22.8	6.9	7.3	283			
	3.0	21.1	6.9	2.4	283			
	4.0	19.5	6.8	0.4	293			
	4.6	18.7	6.7	0.2	291			

Secchi Depth and Profile Data Graphs







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

Crawfish Lake -- Okanogan County

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

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

*information not available

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

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Crawfish Lake is used for fishing, swimming, rowing, and camping. Recreational facilities on the lakeshore include a picnic area, a state park, a camping area, and two boat ramps, and there are no restrictions for motorboat use on the lake. There is ice on the lake from October through April. Currently the watershed is used for logging. In the past, the watershed was also used only for logging. There are 41 houses on the lakeshore although none of these are occupied year-round. The lakeshore is not sewered. Fish (rainbow and eastern brook trout) are stocked in the lake. A lake association was formed this year for the lake. The lake was treated with rotenone in 1988 to control fish species. In 1989, the volunteer noted that there were dead fish in the lake during April and May 1989, following winterkill. Overall, the volunteer finds that Crawfish Lake has excellent recreational water quality. According to the volunteer, the crawfish population has decreased considerably in recent years.

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

Crawfish Lake -- Okanogan County

Monitoring Results/Summary of Other Available Information

Secchi disk readings collected during 1990 show less of a pattern in algal growth and greater overall water clarity than in 1989. Many other lakes monitored for the program during both years 1989 and 1990 also had better, but less variable, water clarity in 1990.

Profile data collected during June and August 1990 show that the lake was not thermally stratified during June. During August, the lake was stratified and dissolved oxygen decreased with depth. The similar profile shapes of the temperature, pH and dissolved oxygen data illustrate nicely the differences between the upper and lower water layers that may occur because of thermal stratification. The lower concentrations of dissolved oxygen near the bottom of the lake most likely resulted from the bacterial decomposition of organic material such as algae, aquatic plants and woody debris at the bottom of the lake. Dissolved oxygen can be depleted from the bottom layer of water yet remain high in the upper layer because the lower layer of water does not mix with the upper layer during thermal stratification. This is apparent in the profiles of the August data.

The concentrations of total phosphorus and total nitrogen during June and August were low to medium-high, respectively.

Comments

Although the Secchi readings suggest that the lake is oligotrophic, the concentrations of total phosphorus are moderately high, and confirm that the lake is approaching mesotrophy. The low concentrations of dissolved oxygen near the bottom of the lake also indicate that the lake is no longer oligotrophic. However, the data suggest that the lake has fairly good water quality compared to other lakes monitored for the program in 1990. Although Secchi disk transparency may underestimate the trophic state for Crawfish Lake somewhat, the readings can be used to document the occurrence and severity of algae blooms in the lake.

Only eight other lakes monitored for the program in 1990 had lower mean summer concentrations of total phosphorus than Crawfish Lake.

Acknowledgement

I thank Barry Nelson for volunteering his time to monitor Crawfish Lake during 1989-1990.

Crawfish Lake -- Okanogan County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
12-May	12.0	53.6	5.5	Green	90	Moderate	Light	10.1		
01-Jun								17.4		taken during onsite visit
17-Jun	14.0	57.2		Lt-Green	10	Moderate	Light	15.6		
08-Jul	18.0	64.4	5.5	Green	10	Moderate	Light	18.3**	31.0	
01-Aug	22.0	71.6	5.5	Lt-Green	0	None	Calm	19.3	30.0	
03-Sep	18.0	64.4	5.5	Lt-Green	0	None	Breezy	16.5		
23-Sep	18.0	64.4	5.5	Lt-Green	0	None	Light	15.6**		

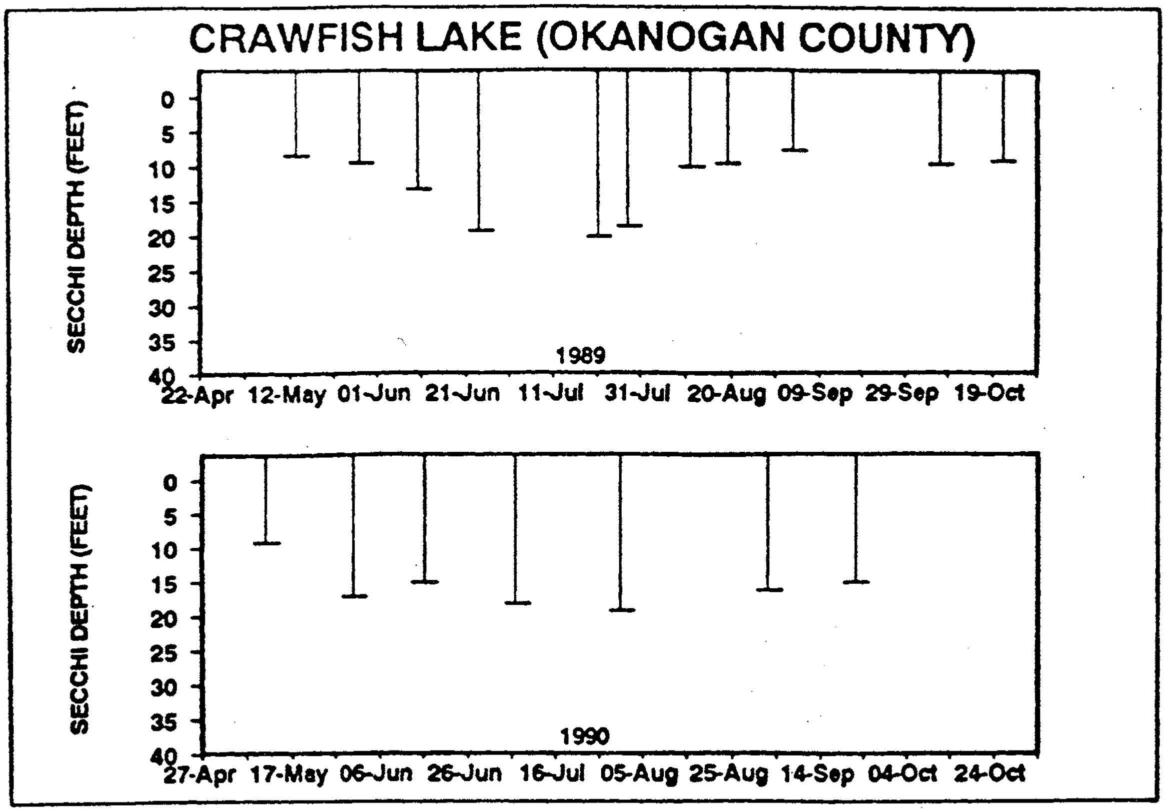
* Secchi data corrected for rope shrinkage
** There was high variability between the first and second Secchi depths collected; this data point may not be used in data comparisons

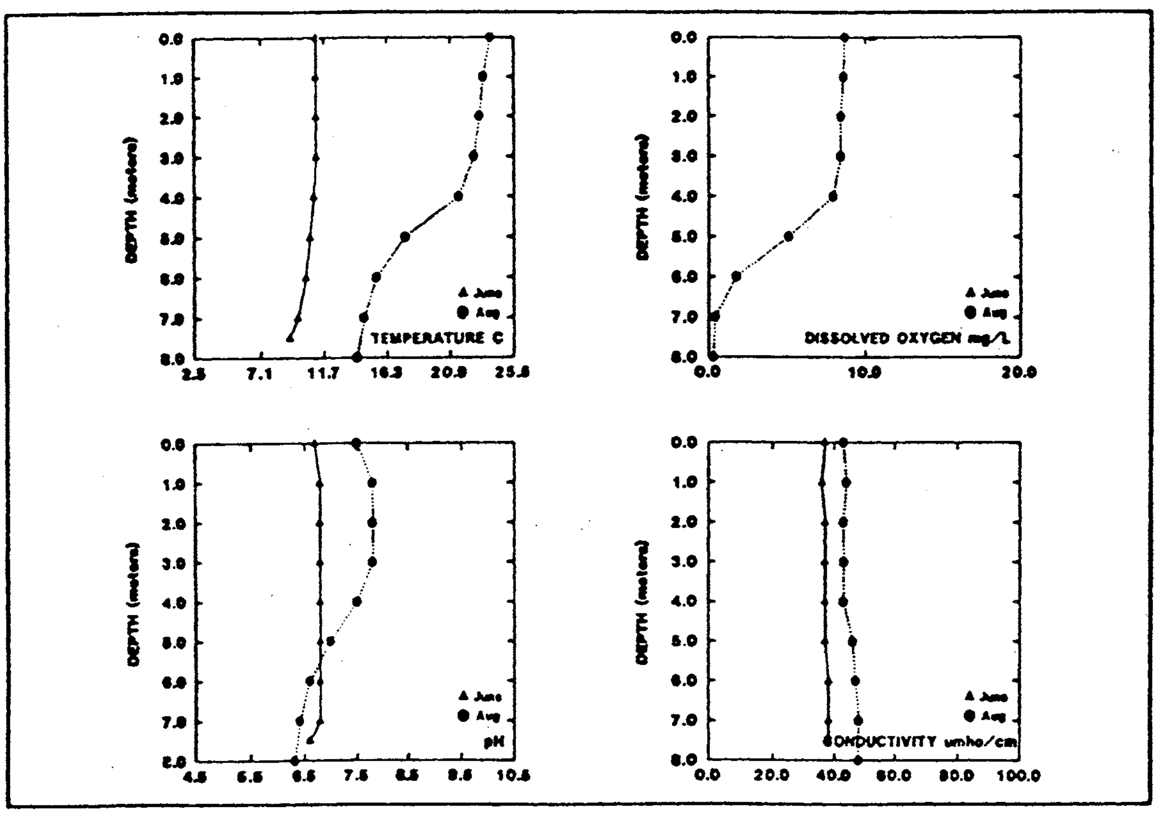
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/01	0.0	11.1	6.7	.*	37	2, 3, 5	0.011	0.362
	1.0	11.1	6.8	.	36			
	2.0	11.1	6.8	.	37			
	3.0	11.1	6.8	.	37			
	4.0	10.9	6.8	.	37			
	5.0	10.6	6.8	.	37			
	6.0	10.3	6.8	.	38			
	7.0	9.7	6.8	.	38			
	7.5	9.1	6.6	.	38			
08/13	0.0	23.8	7.5	8.7	43	1, 2, 3	0.012	0.392
	1.0	23.3	7.8	8.6	44			
	2.0	23.0	7.8	8.4	43			
	3.0	22.6	7.8	8.4	43			
	4.0	21.5	7.5	7.9	43			
	5.0	17.7	7.0	5.0	46			
	6.0	15.5	6.6	1.7	47			
	7.0	14.6	6.4	0.4	48			
	8.0	14.1	6.3	0.3	48			

* See Quality Assurance section of this report.

Secchi Depth and Profile Data Graphs





Crawfish Lake -- Okanogan County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
12-May	12.0	53.6	5.5	Green	90	Moderate	Light	10.1		
01-Jun								17.4		taken during onsite visit
17-Jun	14.0	57.2		Lt-Green	10	Moderate	Light	15.6		
08-Jul	18.0	64.4	5.5	Green	10	Moderate	Light	18.3**	31.0	
01-Aug	22.0	71.6	5.5	Lt-Green	0	None	Calm	19.3	30.0	
03-Sep	18.0	64.4	5.5	Lt-Green	0	None	Breezy	16.5		
23-Sep	18.0	64.4	5.5	Lt-Green	0	None	Light	15.6**		

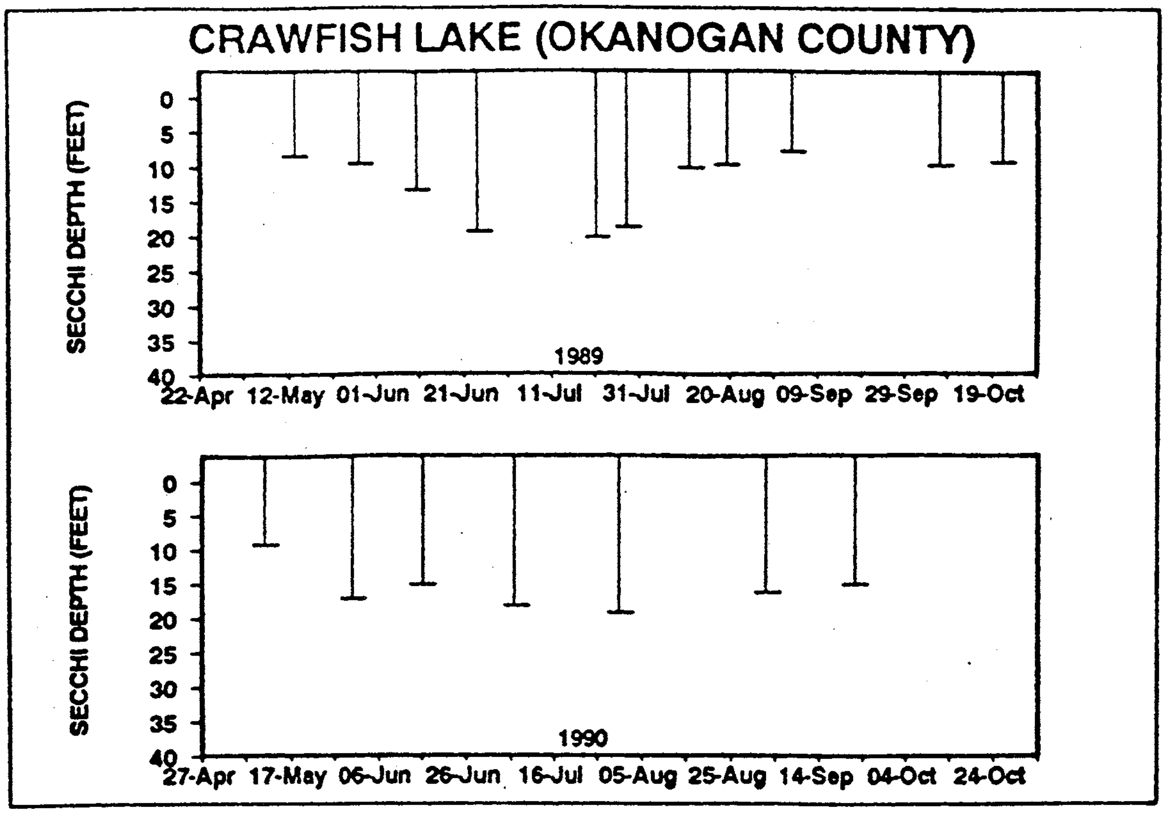
* Secchi data corrected for rope shrinkage
** There was high variability between the first and second Secchi depths collected; this data point may not be used in data comparisons

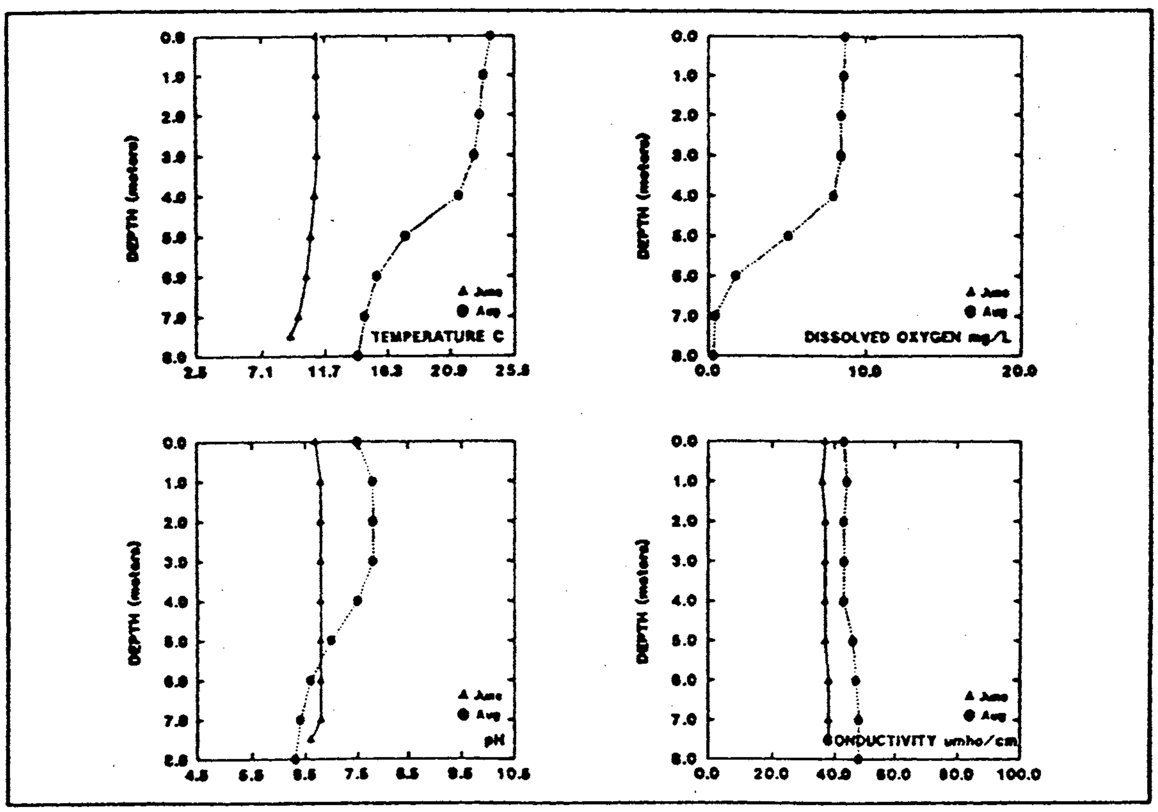
Onsite Visit Data

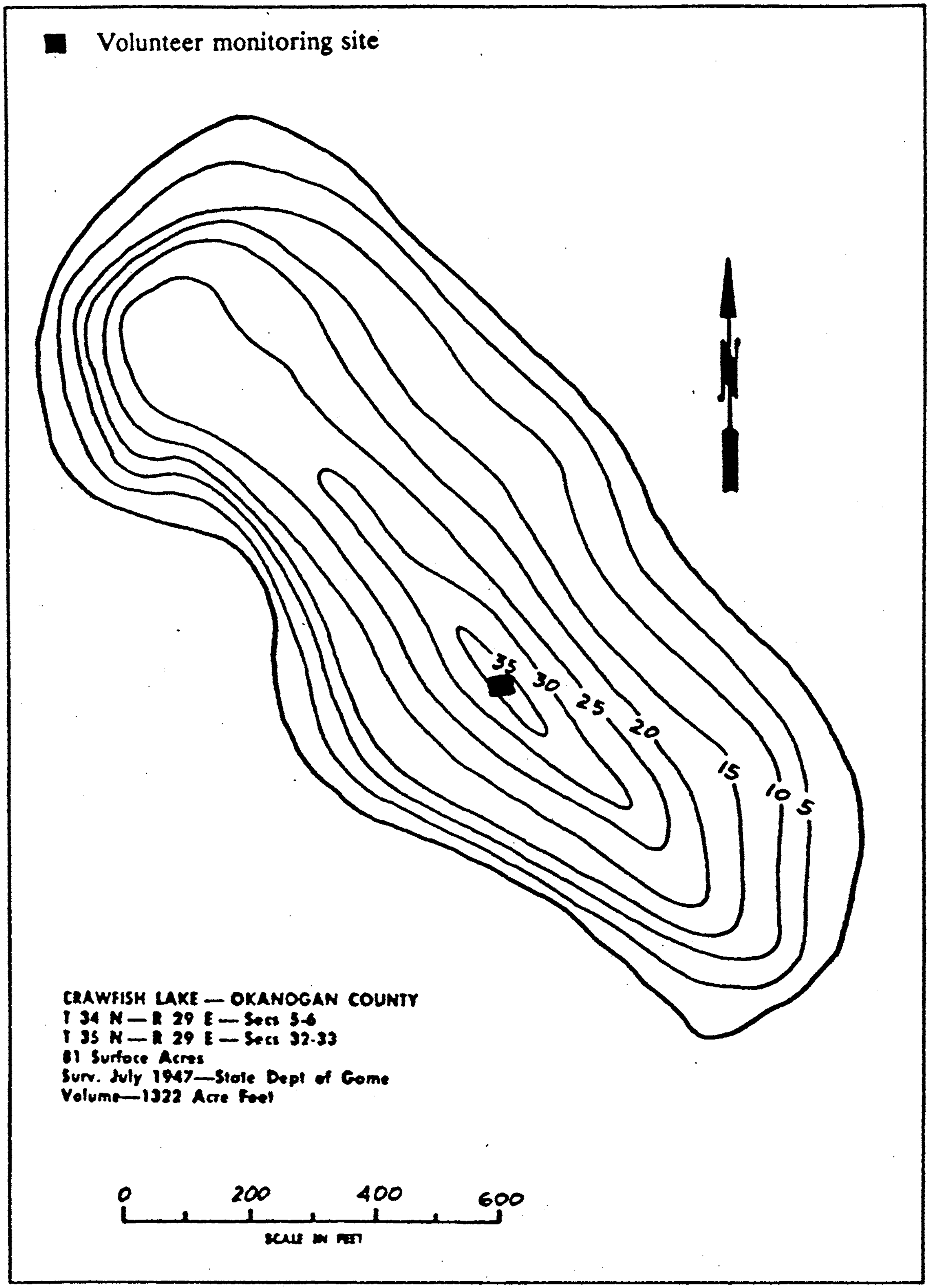
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/01	0.0	11.1	6.7	.*	37	2, 3, 5	0.011	0.362
	1.0	11.1	6.8	.	36			
	2.0	11.1	6.8	.	37			
	3.0	11.1	6.8	.	37			
	4.0	10.9	6.8	.	37			
	5.0	10.6	6.8	.	37			
	6.0	10.3	6.8	.	38			
	7.0	9.7	6.8	.	38			
	7.5	9.1	6.6	.	38			
08/13	0.0	23.8	7.5	8.7	43	1, 2, 3	0.012	0.392
	1.0	23.3	7.8	8.6	44			
	2.0	23.0	7.8	8.4	43			
	3.0	22.6	7.8	8.4	43			
	4.0	21.5	7.5	7.9	43			
	5.0	17.7	7.0	5.0	46			
	6.0	15.5	6.6	1.7	47			
	7.0	14.6	6.4	0.4	48			
	8.0	14.1	6.3	0.3	48			

* See Quality Assurance section of this report.

Secchi Depth and Profile Data Graphs







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

Curlew Lake -- Ferry County

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

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)	2333
Shoreline Length (miles)	15.8

Estimated Trophic State:	Mesotrophic*
Mean Trophic State Index** (Secchi):	36
Trophic State Index** (Total Phosphorus):	43

* See Comments Section
** From Carlson (1977)

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

The following are from the volunteer's remarks and questionnaire responses. 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, four resorts, and five ramps, and there are no restrictions for motorboat use on the lake. Lake water is withdrawn for irrigation. Currently the watershed is used for logging, animal grazing, and residential development is occurring on the lakeshore. Grazing animals have direct access to the lakeshore or inlet tributaries, and animal wastes from agriculture drain into the lake or inlet tributaries. In the past the watershed was used for logging, animal grazing, crop agriculture, and mining, the lake was dredged and the shoreline was altered. There are 211 houses on the lakeshore; of these, about 150 are occupied year-round. The lakeshore is not sewered, and there are six storm drains that empty into the lake. Fish (rainbow trout) are stocked in the lake. Presently there is a lake association and a sewer district for the lake. The lake has been chemically treated in the past to control weeds and algae. Watershed surveys are underway. The worst problems in the lake, in the opinion of the volunteer, are 1) water odors (rotten egg), and 2) "light pollution". In 1989, the worst problems in the lake according to the volunteer were 1) weeds, 2) algae blooms, 3) lake level, 4) rough fish, and 5) odor (described as a rotten egg smell along shallows in the spring). Overall, the volunteer finds that Curlew Lake has good recreational water quality, and suggested that the quality of the lake may by affected by internal nutrient loading, surface runoff from the watershed, increased number of homes on the lake with septic tanks, abandoned tanks and pit toilets that flood during high water, and the increased amount of scrap fish. The WSU Cooperative Extension Service and the Ferry County Conservation District were in the process of studying the west watershed in 1990, and a grant from Ecology was allocated for a study of the east watershed beginning in 1991.

There used to be a lumber mill at the north end of the lake and in the past the lake was 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 an old sawmill. Swimmers itch has been reported in early summer. The volunteer has a weather station on the lake for measuring precipitation.

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

Monitoring Results/Summary of Other Available Information

Secchi disk readings show that there was less variability in water clarity during 1990 compared to 1989. Highest water clarity occurred during May of both years. Not enough readings were taken during 1990 to determine temporal patterns in algae growth.

Profile data show that during September the lake was thermally stratified, and concentrations of dissolved oxygen were depleted near the surface and bottom of the lake. The concentration of total phosphorus in the eplimnion was moderate compared to other lakes monitored for the program. In 1974, dissolved oxygen was depleted near the lake bottom, and large amounts of epiphytic algae were observed (Dion *et al.*, 1976). Trophic state indices calculated from Secchi disk transparency, total phosphorus and chlorophyll *a* data collected in 1981 show that Curlew Lake was mesotrophic (Sumioka and Dion, 1985).

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 there have been floating mats of algae 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 algae *Anabaena*, floating mats of algae, a heavy scum, and a strong smell of rotting plants.

Curlew Lake -- Ferry County

Residential development along the lakeshore has apparently increased; 95 nearshore homes were reported in 1974 (Dion *et al.*, 1976) whereas the volunteer reports that there are now 211 houses on the lakeshore.

During the 1990 onsite visit with the volunteer, four fish pens operated by the Washington Department of Wildlife were seen on the lake. Aquatic plants identified in the lake included *Chara* (according to the volunteer, this plant creates the biggest problem in the lake), milfoil (*Myriophyllum* species; this was not the aggressive Eurasian species), and pondweeds (*Potamogeton pectinatus* and *P. richardsonii*). The blue-green alga *Gloeotrichia* was also present. This alga appears as green fuzzy balls floating in the water.

Comments

Although water clarity in the lake is relatively good, the concentration of total phosphorus in the epilimnion of the lake and the depletion of dissolved oxygen in the hypolimnion of the lake indicate that Curlew Lake was mesotrophic. As stated in the summary of volunteer-collected 1989 data, future estimates of trophic state should be based on chemical as well as physical data. Secchi data from Curlew Lake can be used to document the occurrence and severity of algae growth in the lake.

Deer Lake has similar physical characteristics (altitude, lake volume, lake area, and mean and maximum depths) as Curlew Lake, and was monitored for the program during 1989 and 1990. In 1989, Deer Lake was estimated as oligotrophic based on Secchi depth data. In 1990, the mean water clarity and mean concentration of total phosphorus of both Deer Lake and Curlew Lake were very similar. However, Deer Lake has fewer water quality problems than Curlew Lake. The differences in water quality between these lakes is most likely the result of different land uses within each watershed. For example, animal grazing is not a major land use in the Deer Lake watershed.

Acknowledgement

I thank Marion Dammann for volunteering her time to monitor Curlew Lake during 1989-1990.

Curlew Lake -- Ferry County

Volunteer-Collected Data

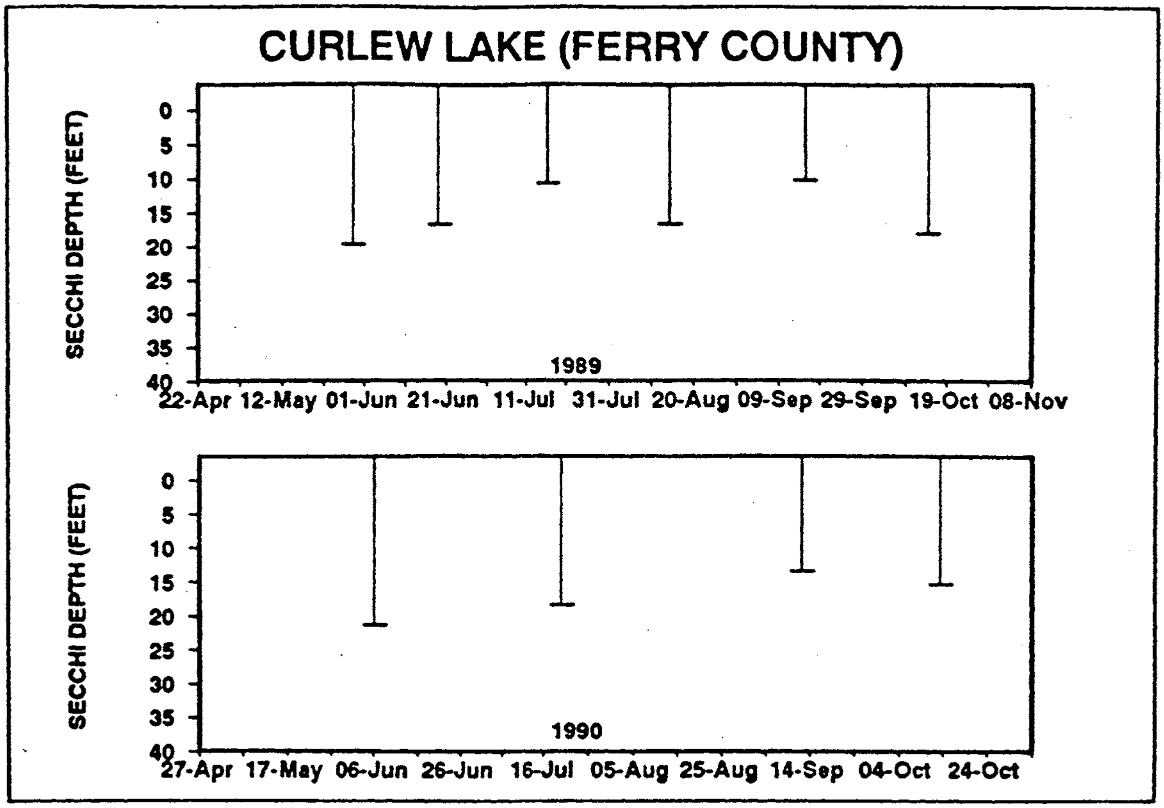
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
07-Jun	15.0	59.0	7.5	Green	50	Moderate	Light	21.1	4.3	Small suspended particles throughout the water column. Lake height measured by gage at N. end of lake under trestle. One gage under water. Water still rising. Higher than usual. Small suspended particles throughout water column.
21-Jul	26.0	78.8	6.5	Gr-Brown	0	None	Calm	18.3	2.9	High water reached 4.00 on gage 6/25.
13-Sep	22.0	71.6	6.5	Green	0	None	Light	14.7	2.5	Bloom.
14-Oct			7.0	Dk-Brown	75	None	Calm	15.6	2.5	The way the weather looks this may be my last report. Nov. may not be possible.

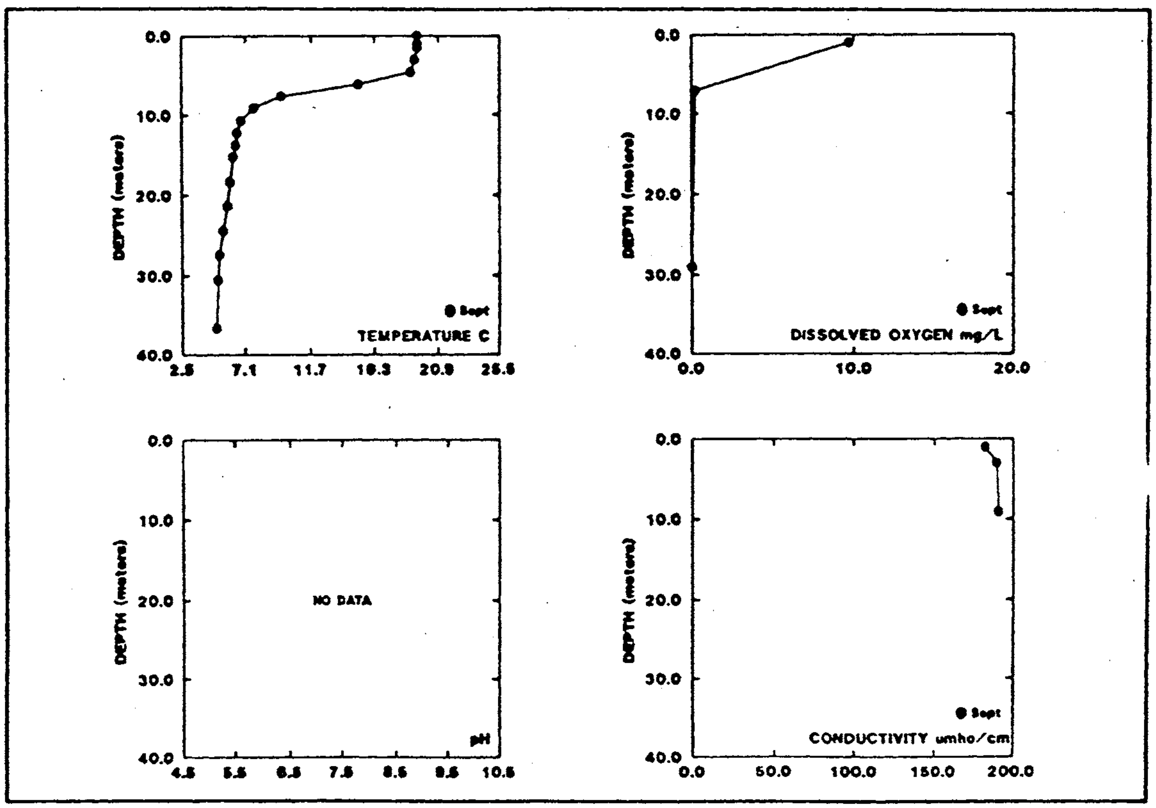
* Secchi data corrected for rope shrinkage

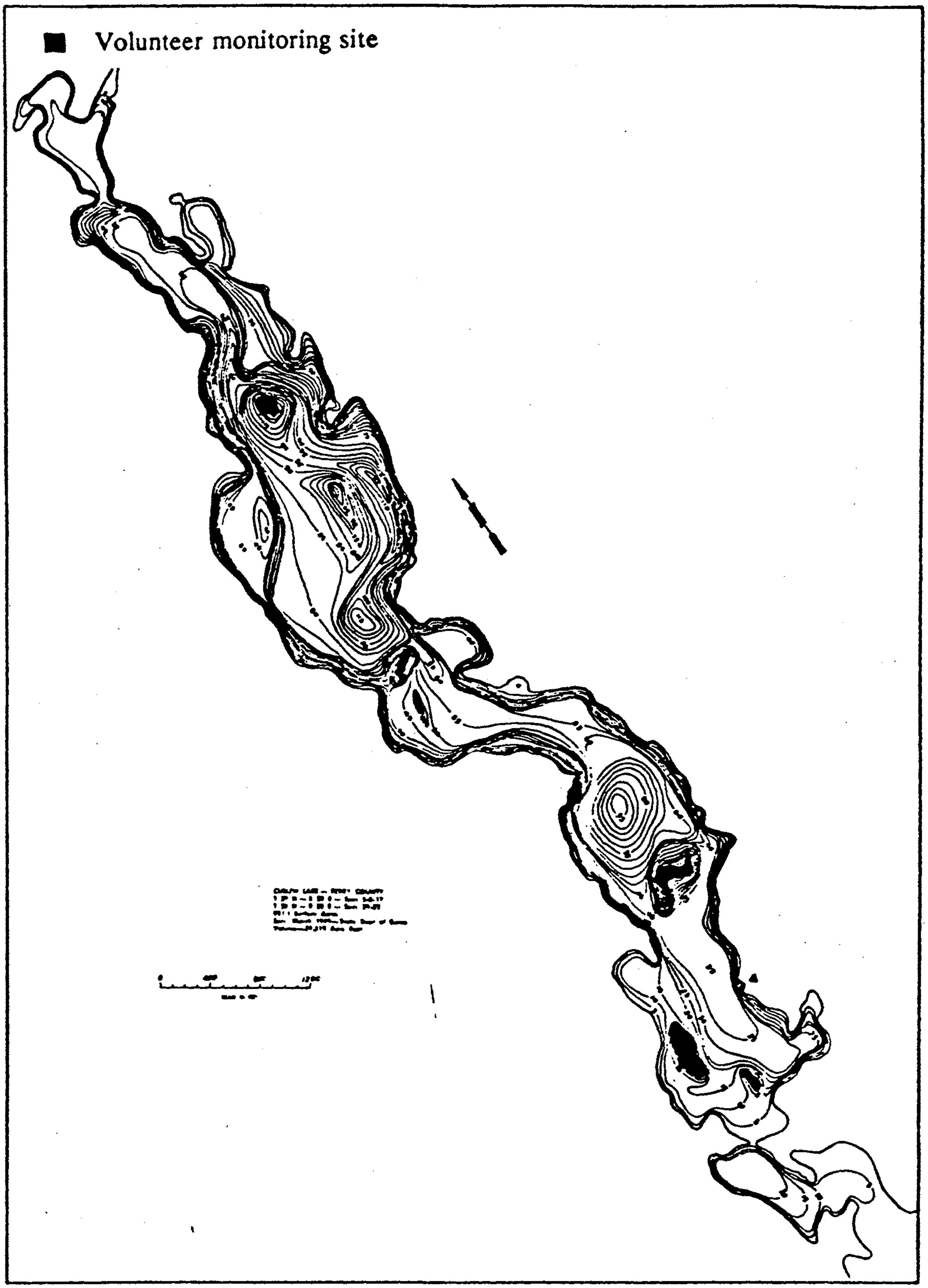
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
09/13	0.0	19.4	.	.		1, 3, 5	0.015	0.597
	1.0	19.4	.	9.7	183			
	5.0	19.4	.	.	.			
	7.0	.	.	0.2	190			
	10.0	19.2	.	.	.			
	15.0	18.9	.	.	.			
	20.0	15.2	.	.	.			
	25.0	9.6	.	.	.			
	29.0	.	.	0.0	191			
	30.0	7.7	.	.	.			
	35.0	6.8	.	.	.			
	40.0	6.5	.	.	.			
	45.0	6.4	.	.	.			
	50.0	6.2	.	.	.			
	60.0	6.0	.	.	.			
	70.0	5.8	.	.	.			
	80.0	5.5	.	.	.			
	90.0	5.2	.	.	.			
	100.0	5.1	.	.	.			
	120.0	5.0	.	.	.			

Secchi Depth and Profile Data Graphs






Volunteer monitoring site

Davis Lake -- Pend Oreille County

Davis Lake is located about 5.7 miles south from Usk, and 2.7 miles southwest from Dalkena. Deer Creek is the perennial inlet. Davis Lake is stabilized by a small dam at the outlet and drains via Davis Creek to the Pend Oreille River. It is weedy and shallow at the south end of lake. Highway 211 runs along the east shore of the lake.

Size (acres)	152
Maximum Depth (feet)	147
Mean Depth (feet)	83
Lake Volume (acre-feet)	12,622
Drainage Area (miles^2)	17.8
Altitude (feet)	2150
Shoreline Length (miles)	2.7

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

* From Carlson (1977)

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

The following are from the volunteer's remarks and questionnaire responses. Davis Lake is used for fishing, swimming, rowing, and a minor amount of diving. Recreational facilities on the lakeshore include a picnic area, a beach, and one boat ramp, and there is a speed restriction of 5 mph. Lake water is withdrawn for irrigation. Currently the watershed is used for logging, animal grazing, and residential development is occurring on the lakeshore. Grazing animals have direct access to the lakeshore or its tributaries. In the past, the watershed was used for logging and crop agriculture, and the shoreline was altered. There are 45 houses on the lakeshore; of these, 12 are occupied year-round. The lakeshore is not sewered, and there are two storm drains that empty into the lake. Fish (kokanee and rainbow trout) are stocked in the lake. Presently there is no citizen's organization for the lake. The worst problems in the lake, in the opinion of the volunteer, are 1) sediments suspended in the water, and 2) aquatic plants. Overall, the volunteer finds that Davis Lake has excellent recreational water quality, and suggested that livestock in the watershed, auto waste products, and runoff, may affect the water quality of the lake.

The volunteer reported that curly-leaf pondweed (*Potamogeton crispus*) was growing in a cove on the west end of the lake. There are wetlands at the south end of the lake near the inlet. The shoreline is rocky along much of the west and east shores. There are large populations of osprey and kingfishers at the lake.

Davis Lake -- Pend Oreille County

<u>Monitoring Results/Summary of Other Available Information</u>

Secchi readings collected during 1990 show that water clarity was lowest during June, when the water color was green-brown. No pattern in algae growth was evident from Secchi readings collected in 1989 and 1990, but the data does indicate that the lake was oligotrophic, and approaching mesotrophic. Profile data collected with the volunteer during May and August 1990 show that on both sampling dates, the lake was thermally stratified. The unusual dissolved oxygen profile of the August data also occurred during September 1990, when Davis Lake was sampled by Ecology as part of a statewide lakes survey to supplement volunteer-collected data (Coots, 1991). The very strong density gradient created by the extreme temperature differences between the top and bottom layers of water probably trapped algae or zooplankton in the bottom of the upper layer. Either bacterial decomposition of algae or respiration of zooplankton, or both, may have contributed to the decrease in dissolved oxygen concentrations at the thermocline during both August and September (Coots, 1991).

Of the four total phosphorus samples collected from the epilimnion of Davis Lake during 1990 (two collected during onsite visits with the volunteer, and two samples collected during the Ecology survey), the highest concentration occurred during August. However, the concentrations from all the samples were very similar and were all within the mesotrophic range. In 1974, the concentration of total phosphorus in Davis Lake was 17 μg/L (Dion *et al.*, 1976), which is also in the mesotrophic range. Nevertheless, for the 1990 Ecology survey, Davis Lake was classified as oligotrophic based on two Secchi disk readings and two chlorophyll *a* samples collected during June and September 1990 (Coots, 1991).

<u>Comments</u>

For the volunteer lake monitoring program, the oligo-mesotrophic classification of Davis Lake is based on the volunteer-collected Secchi data and the concentrations of total phosphorus found during the four lake sampling trips to the lake in 1990. The oligotrophic characteristics of the lake include the high water clarity and the relatively low concentrations of chlorophyll *a* (used as an indicator of the volume of algae growing in water). Mesotrophic characteristics of the lake include water color, the presence of wetland areas with prolific submerged aquatic plant growth, and the moderate concentrations of total phosphorus.

Compared with Sacheen Lake, Davis Lake had better overall water clarity and lower concentrations of total phosphorus. Concentrations of total nitrogen were similar in both lakes during May, but during August the concentration of total nitrogen was 0.435 mg/L in Sacheen Lake compared to 0.257 mg/L in Davis Lake. Of the lakes monitored for the program in 1990, Davis Lake had one of the greatest mean depths; the majority of the monitored lakes had mean depths of less than 40 feet. The high overall depth and mean depth of Davis Lake helps maintain better water quality than would be seen in a shallower lake with similar nutrient content.

Acknowledgements

I thank Ray Huffman for volunteering his time to monitor Davis Lake during 1989, and David Hebb for monitoring during 1990.

Volunteer-Collected Data

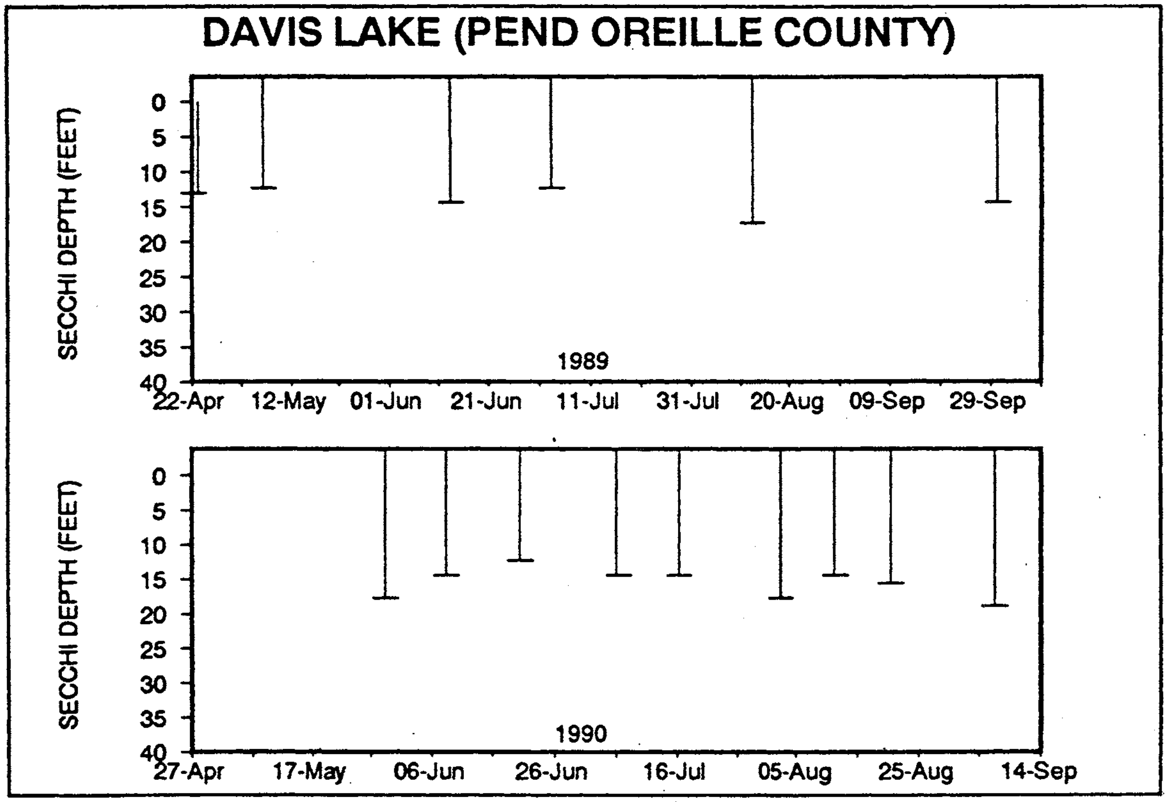
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
30-May								18.0		
09-Jun	15.8	60.4		Gr-Brown	75	Moderate	Calm	15.0	-5.5	Probably too late in the day.
21-Jun	17.2	63.0	6.5	Gr-Brown	10	None	Light	13.0	-2.0	Visibility not as good; light was bright strong and high.
07-Jul	23.3	73.9	6.5	Gr-Brown	0	None	Light	15.0		
17-Jul	23.9	75.0	6.5	Lt-Brown	10	Trace	Breezy	15.0		
03-Aug	23.3	73.9	7.0	Lt-Brown	0	None	Calm	18.0		Very calm, very clear.
12-Aug	23.3	73.9	6.5	Lt-Brown	10	Trace	Breezy	15.0		
21-Aug	20.0	68.0	6.5	Gr-Brown	100	Heavy	Calm	16.0		Lots of rain previous day. Reading taken with Dave.
07-Sep	20.0	68.0	7.0	Yellow-Br	0	None	Calm	19.0		Water color light yellow-brown. Very clean very calm. No clouds!

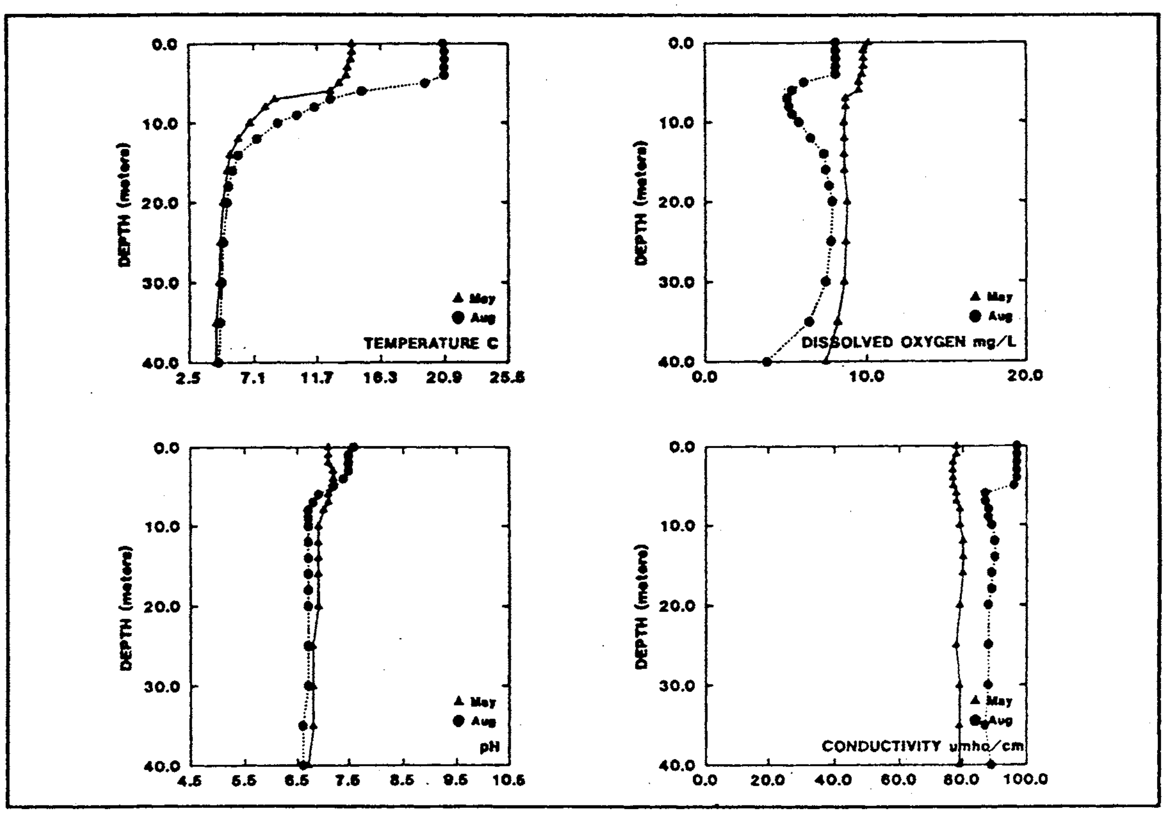
Davis Lake -- Pend Oreille County

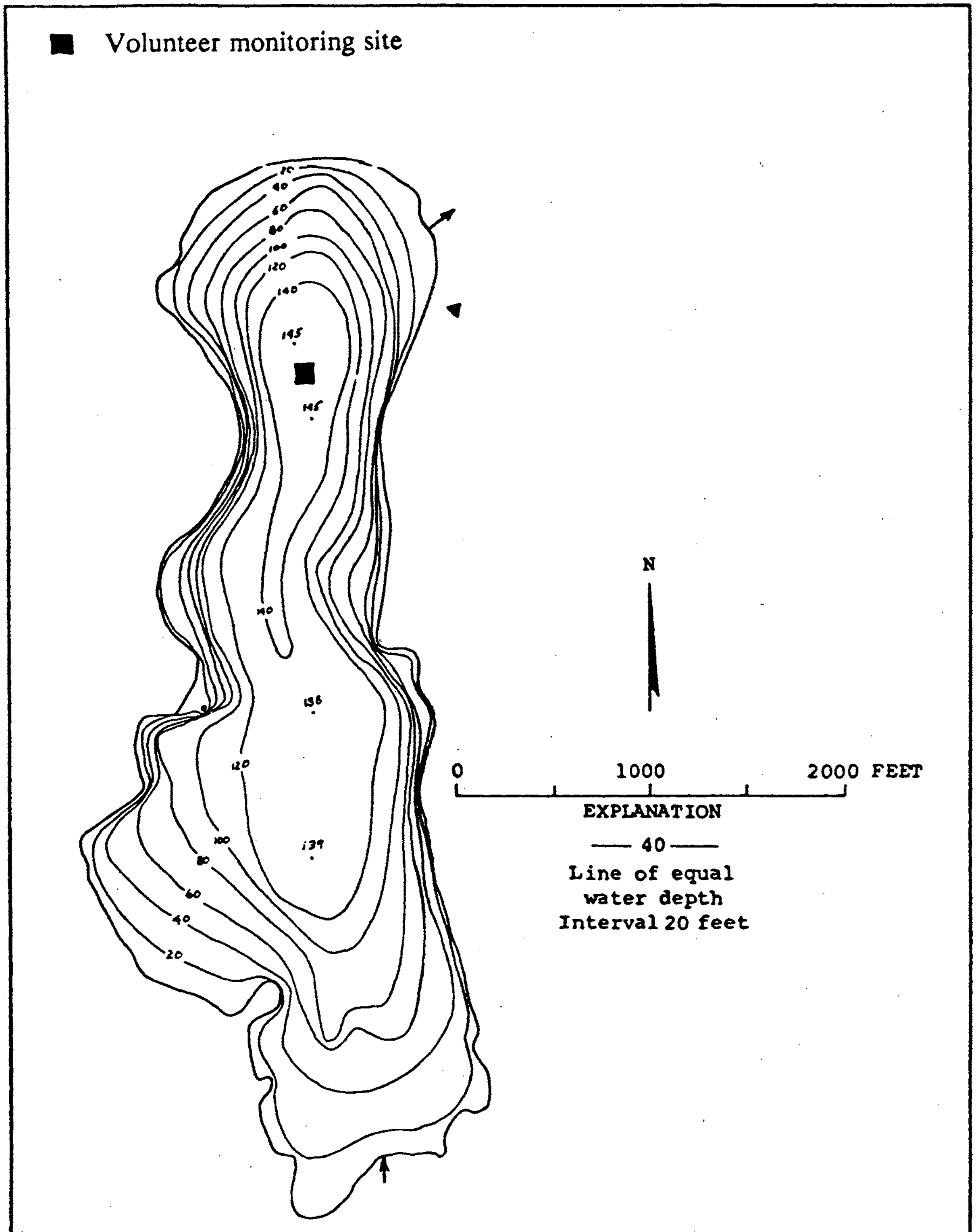
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/30	0.0	14.3	7.1	10.1	78	1, 2, 4	0.011	0.338
	1.0	14.3	7.1	9.8	78			
	2.0	14.2	7.1	9.8	77			
	3.0	14.0	7.2	9.8	77			
	4.0	13.9	7.2	9.7	77			
	5.0	13.4	7.2	9.5	77			
	6.0	12.7	7.1	9.5	78			
	7.0	8.6	7.1	8.7	78			
	8.0	7.9	7.0	8.7	79			
	10.0	6.8	6.9	8.6	79			
	12.0	6.0	6.9	8.6	80			
	14.0	5.4	6.9	8.6	80			
	16.0	5.2	6.9	8.6	80			
	20.0	4.9	6.9	8.8	79			
	25.0	4.7	6.8	8.7	78			
	30.0	4.6	6.8	8.6	79			
	35.0	4.4	6.8	8.2	79			
	40.0	4.4	6.7	7.5	79			
08/21	0.0	20.8	7.6	8.1	97	1, 2.5, 4	0.017	0.257
	1.0	20.9	7.5	8.1	97			
	2.0	20.9	7.5	8.1	97			
	3.0	20.9	7.5	8.1	97			
	4.0	20.9	7.4	8.1	97			
	5.0	19.5	7.2	6.2	96			
	6.0	15.0	6.9	5.5	87			
	7.0	12.7	6.8	5.2	87			
	8.0	11.5	6.7	5.3	88			
	9.0	10.2	6.7	5.5	88			
	10.0	8.8	6.7	5.9	89			
	12.0	7.3	6.7	6.6	90			
	14.0	6.0	6.7	7.4	90			
	16.0	5.6	6.7	7.5	89			
	18.0	5.3	6.7	7.7	89			
	20.0	5.2	6.7	7.9	88			
	25.0	4.9	6.7	7.8	88			
	30.0	4.8	6.7	7.5	88			
	35.0	4.7	6.6	6.5	87			
	40.0	4.6	6.6	3.9	89			

Secchi Depth and Profile Data Graphs







Davis Lake, Pend Oreille County. From Washington Department of Game, January 1949.

Deep Lake -- Stevens County

Deep Lake is located nine miles south from Northport, and 25 miles northeast from Colville. The lake is 1.4 miles long and the shoreline is steep. Both the inlet and the outlet are the north fork of Deep Creek, which drains ultimately to the Columbia River (FDR Lake).

Size (acres)	210
Maximum Depth (feet)	49
Mean Depth (feet)	34
Lake Volume (acre-feet)	7203
Drainage Area (miles^2)	48.1
Altitude (feet)	2025
Shoreline Length (miles)	3.5

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	41
Mean Trophic State Index* (Total Phosphorus):	48

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The 1990 questionnaire on lake and watershed uses was not returned by the volunteer. The following are the volunteer's responses to the 1989 questionnaire. Deep Lake is used for fishing, swimming, boating, jet skiing, picnicking, camping, hiking, and waterfowl hunting. There is one resort and two boat ramps on the lakeshore. Lake water is withdrawn for drinking and other domestic uses. Currently the watershed is used for logging and agriculture (both crop and animal grazing), and the lakeshore is being developed further for residences. In the past, both logging and mining occurred in the watershed. There are about 52 houses on the lakeshore, and 17 of these are occupied year-round. All the residences use on-site wastewater disposal systems. Fish are stocked in the lake. There is a wetland at the south end of the lake near the outlet. Weeds are especially thick in the shallow areas at the north and south ends of the lake. The worst problems in the lake, in the opinion of the volunteer, were 1) weeds, 2) fish kill, 3) odor, and 4) lake level. These problems are worst during July and August. The volunteer suggested that cattle grazing close to the lake, failing and older septic systems, and residential development may contribute to the water quality of the lake.

The volunteer mentioned during the September onsite visit that zinc mines in the watershed will be opening in the fall, and that 500-800 cows graze in the valley near the inlet tributary.

Deep Lake -- Stevens County

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity gradually increased over the summer. Although the mean trophic state index for 1990 is somewhat higher than the trophic state index calculated from 1989 data, there is only a short period where Secchi data were collected during the same months in 1989 and 1990. As a result, it is difficult to compare data between the two years. However, the mean trophic state index values between the two years are very similar and the data do suggest that lake quality was similar in 1989 and 1990. Profiles of the 1990 data, especially of temperature, dissolved oxygen and conductivity, were very similar to profile data reported in 1989 by Brower and Kendra (1990). The dissolved oxygen profile data were also similar to data collected in 1974 (Dion *et al.*, 1976).

The concentrations of total phosphorus and total nitrogen in the epilimnion were high during May and were moderately high during September. In September, the concentrations of both nutrients were similar to concentrations found during 1989 (Brower and Kendra, 1990) and during 1974 (Dion *et al.*, 1976).

As in 1989, the water clarity of Deep Lake was relatively good. However, the lake exhibited several characteristics that were the basis of the mesotrophic classification. These mesotrophic characteristics include the moderately high concentrations of total phosphorus found in 1990, and the depletion of dissolved oxygen and presence of hydrogen sulfide (rotten-egg smell) near the bottom of the lake in both 1989 and 1990. Also, in 1989 there was a high concentration of ammonia in the hypolimnion and blue-green algae (*Anabaena* species) were present in the lake (Brower and Kendra, 1990).

During the September 1990 onsite visit with the volunteer, aquatic plants growing in the water included coontail (*Ceratophyllum demersum*), watershield (*Bresenia schreberi*), yellow-flowering lily (*Nuphar polysepalum*), naiad (*Najas* species), water buttercup (*Ranunculus aquatilis*) and sago pondweed (*Potamogeton pectinatus*). The alga *Chara*, which looks like an aquatic macrophyte and is often associated with hard water, was also present.

Comments

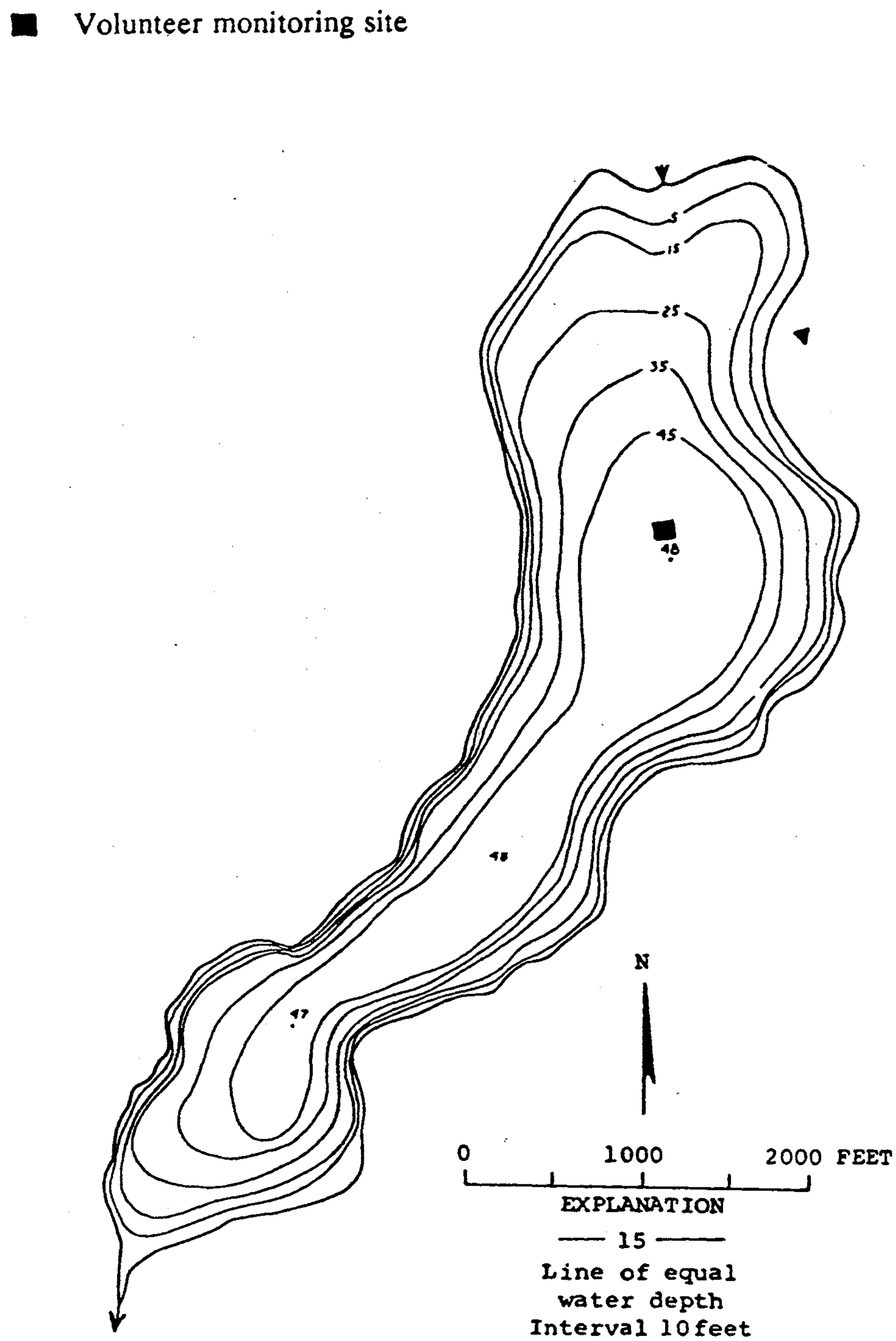
Although the Secchi data were barely in the mesotrophic range, the total phosphorus data clearly indicate that Deep Lake was mesotrophic.

The considerable increase in conductivity with depth was documented in both 1989 (Brower and Kendra, 1990) and 1990. Although several other lakes monitored for the program had conductivities that increased with depth, only two other lakes (Lake Whitman and Spanaway Lake, both located in Pierce County) had conductivities that increased around 100 μmhos/cm from surface to bottom. The reason for this increase is unknown. Marl, a calcium carbonate deposit, was found on aquatic plant leaves during the September onsite visit and further supports the conclusion that Deep Lake is a hardwater lake.

Several other lakes monitored for the program in 1990 had relatively good water clarity and moderately high concentrations of total phosphorus. The discrepancies between these two parameters may indicate some unexplained phenomenon in the ecosystem of Deep Lake. For example, some factor other than total phosphorus may be limiting algae growth in Deep Lake.

Acknowledgement

I thank Dave Daniel for volunteering his time to monitor Deep Lake during 1989-1990.



Deep Lake, Stevens County. From Washington
Department of Game, January 23, 1948.

Deep Lake -- Stevens County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
15-Jun	13.0	55.4	7.0					8.3		
07-Jul	15.0	59.0	6.5					11.0		
18-Jul	18.0	64.4	6.5					11.9		
01-Aug	22.0	71.6	6.0					11.9		
20-Aug	24.0	75.2	6.0					13.7		
12-Sep	18.0	64.4	6.5					18.3		

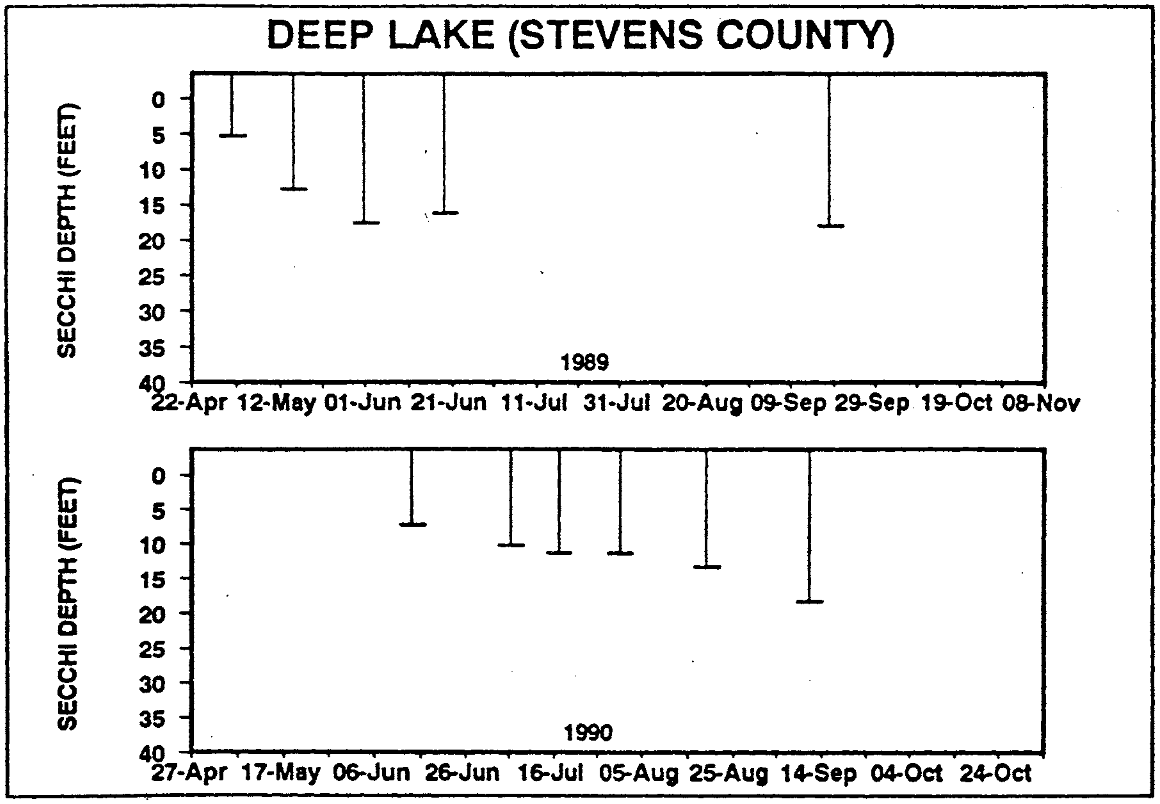
* Secchi data corrected for rope shrinkage

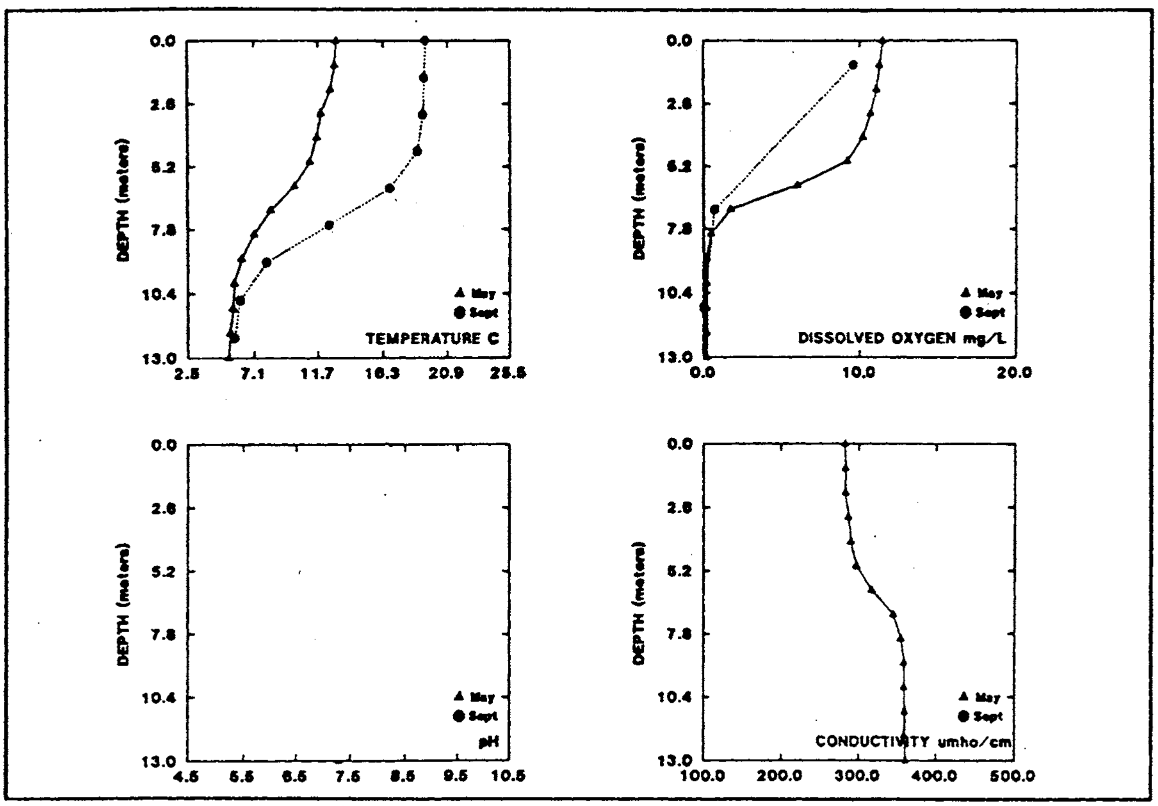
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/25	0.0	13.0	.*	11.5	282	1, 3, 5	0.031	0.314
	1.0	12.9	.	11.3	283			
	2.0	12.6	.	11.1	283			
	3.0	11.9	.	10.7	287			
	4.0	11.6	.	10.2	290			
	5.0	11.1	.	9.2	297			
	6.0	10.0	.	6.0	317			
	7.0	8.3	.	1.7	345			
	8.0	7.1	.	0.5	355			
	9.0	6.2	.	0.2	359			
	10.0	5.7	.	0.2	359			
	11.0	5.6	.	0.2	360			
	12.0	5.4	.	0.2	360			
	13.0	5.3	.	0.2	361			
09/12	0.0	19.3	.	.	.	1, 3, 5	0.013	0.231
	1.0	.	.	9.6	.			
	1.5	19.2	.	.	.			
	3.1	19.1	.	.	.			
	4.6	18.7	.	.	.			
	6.1	16.8	.	.	.			
	7.0		.	.	0.7			
	7.6	12.5	.	.	.			
	9.1	8.0	.	.	.			
	10.7	6.1	.	.	.			
	11.0	.	.	0.0	.			
	12.2	5.7	.	.	.			

* See Quality Assurance section.

Secchi Depth and Profile Data Graphs





Deer Lake -- Stevens County

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

Size (acres)	1110
Maximum Depth (feet)	75
Mean Depth (feet)	52
Lake Volume (acre-feet)	57,000
Drainage Area (miles^2)	18
Altitude (feet)	2474
Shoreline Length (miles)	8.6

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

* From Carlson (1977)

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

The 1990 questionnaire on lake and watershed uses was not returned by the volunteer. The following are the volunteer's responses to the 1989 questionnaire. Deer Lake is used for fishing, swimming, boating, jet skiing, picnicking, camping, hiking, and waterfowl hunting. There are two resorts and three boat ramps on the lakeshore. There is a speed limit for motor boats. Lake water is withdrawn for drinking and other domestic uses. Currently the watershed is used for logging and animal grazing, and lakeshore is being developed further for residences. There are about 700 houses on the lakeshore. All houses use septic systems, and about 100 of the houses are occupied year-round. Individual homeowners rake weeds from their lakeshore areas. Fish are stocked in the lake, and there is a wetland on the north part of the lake. The worst problems in the lake, in the opinion of the volunteer, are 1) algal blooms, 2) weeds, 3) sediments suspended in the water in spring, and 4) hydrogen sulfide ("rotten egg") odor in the fall and winter. The algae is worst during August. The volunteer suggested that septic systems, logging, and runoff from residential lawns may affect the water quality of the lake.

It has been proposed that the Deer Lake lakeshore be sewered. The lake has been studied by Eastern Washington University. The volunteer noted that ten years ago one could see the bottom of the lake (40-50 feet down) and now that is not possible. Algae blooms now occur all over the lake.

Deer Lake -- Stevens County

Monitoring Results/Summary of Other Available Information

There were not enough Secchi readings taken during 1990 to evaluate patterns in algae growth. Compared to readings taken during the same months in 1989, water clarity in 1990 was less variable but not as good.

Profile data collected during 1990 show that the lake was thermally stratified and concentrations of dissolved oxygen decreased with depth. During August, concentrations of dissolved oxygen and pH increased considerably at 7-9 meters in depth. This increase most likely occurred from either increased algae growth or decreased temperatures, or both, at these depths. Below the thermocline, the concentrations of dissolved oxygen were virtually depleted near the bottom of the lake. Dissolved oxygen is usually consumed at the bottom of a lake through bacterial decomposition of organic material (such as algae, aquatic plants and woody debris) in the water and sediments.

The concentrations of total phosphorus in 1990 were moderately high and indicate that the lake was mesotrophic. Other mesotrophic characteristics of Deer Lake include algae blooms, considerable plant growth in some areas of the lake, and the depletion of dissolved oxygen concentrations near the bottom of the lake.

Data collected in 1972 (Dion *et al.*, 1976) and 1981 (Sumioka and Dion, 1985) indicate that Secchi disk transparency and nutrient concentrations in Deer Lake were at levels characteristic of oligotrophic lakes. However, total phosphorus concentrations in 1981 were somewhat higher than would be expected given the Secchi disk transparency and the concentration of chlorophyll *a*. Deer Lake was surveyed by Ecology in 1978, and it was concluded that the lake was mesotrophic (Singleton *et al.*, 1980). However, the Secchi disk transparency and chlorophyll *a* data collected during this 1978 survey would suggest an oligotrophic lake condition (Carlson, 1977).

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

In 1972, Deer Lake had 358 nearshore homes (Dion *et al.*, 1976), compared with the 700 nearshore homes reported by the volunteer in 1989. It is apparent that shoreline development has increased significantly.

Deer Lake -- Stevens County

Comments

Compared with other lakes monitored for the program, the water clarity of Deer Lake was very good, and the concentration of total phosphorus was average. Waitts Lakes, also in Stevens County, had virtually the same mean summer water clarity and concentration of total phosphorus. Waitts Lake is considerably smaller (455 acres) than Deer Lake and is somewhat shallower than Deer Lake. Because the volunteer reported that the clarity of the lake has noticeably decreased with time and that algae clumps are seen in the water, monitoring should be continued so that subsequent changes may be documented. Sewering of the lakeshore has been proposed, so long-term monitoring data may be used to document changes in water quality after the area is sewered.

Acknowledgement

I thank Wesley Wagoner for volunteering his time to monitor Deer Lake during 1989-1990.

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
19-Jun	16.7	62.1	7.0	Green	90	Trace	Breezy	16.5		
06-Jul	17.2	63.0	7.0	Green	90		Gusty	15.6		
20-Jul	24.4	75.9	7.0	Green	10	None	Light	15.3		
31-Jul	24.4	75.9	7.0	Green	10		Gusty	15.6		
09-Aug	23.3	73.9	7.0	Green	90		Calm	18.3		

* Secchi data corrected for rope shrinkage

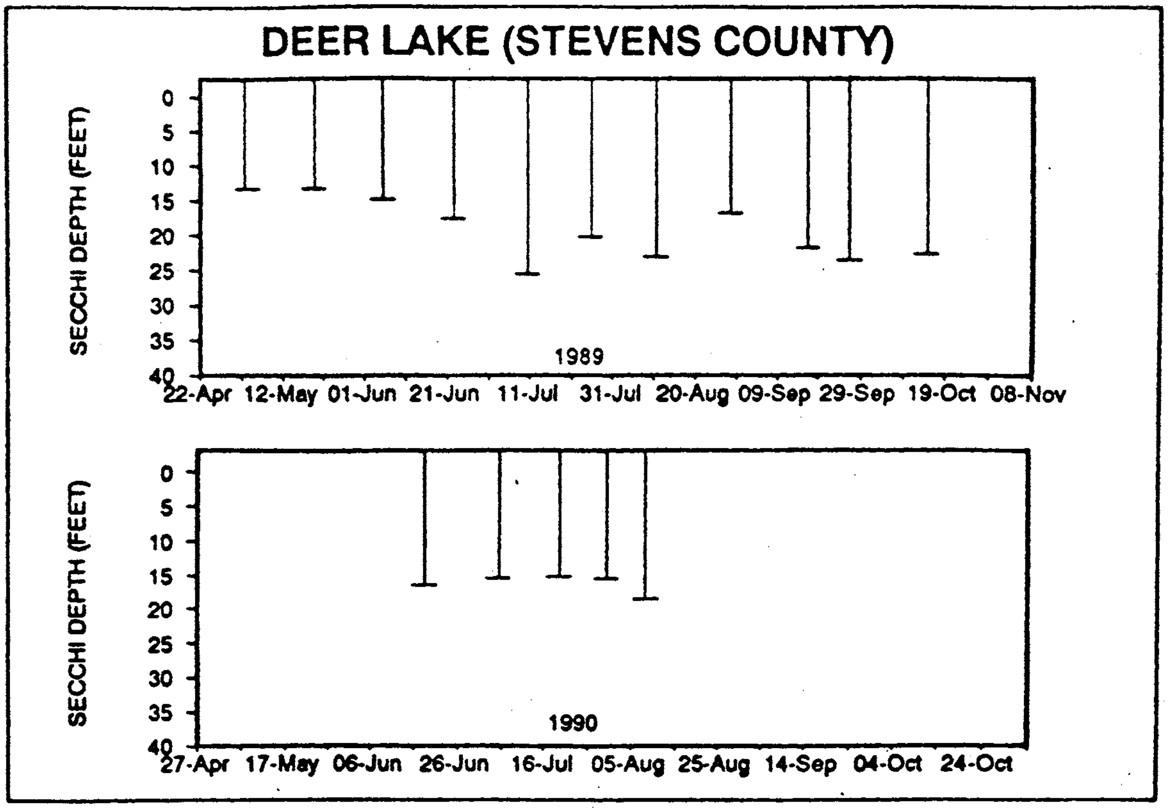
Deer Lake -- Stevens County

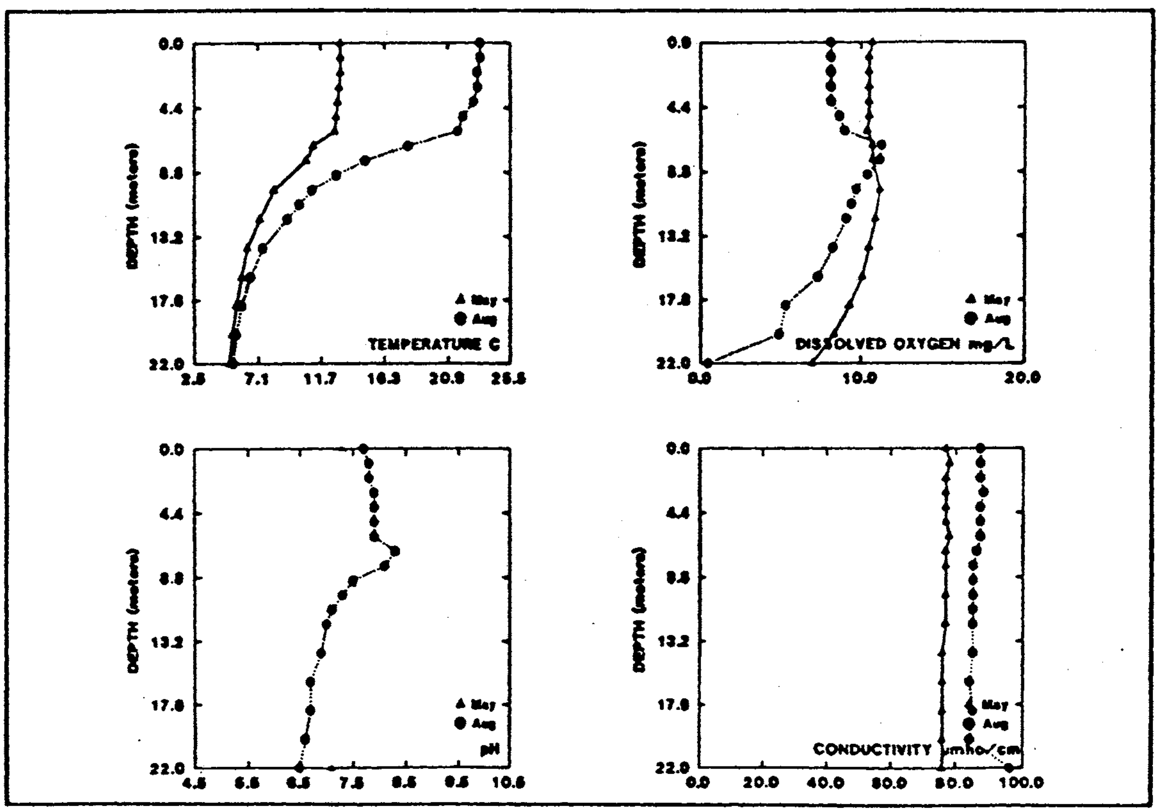
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/25	0.0	13.1	.*	10.7	77	1, 3, 6	0.014	NA
	1.0	13.1	.	10.5	78			
	2.0	13.1	.	10.5	77			
	3.0	13.0	.	10.5	77			
	4.0	12.9	.	10.5	77			
	5.0	12.8	.	10.5	77			
	6.0	12.7	.	10.4	78			
	7.0	11.1	.	10.7	77			
	8.0	10.6	.	10.7	77			
	10.0	8.2	.	11.2	77			
	12.0	7.2	.	10.9	77			
	14.0	6.3	.	10.5	76			
	16.0	5.9	.	10.1	76			
	18.0	5.5	.	9.3	76			
	20.0	5.2	.	8.4	76			
	22.0	5.0	.	7.1	76			
08/09	0.0	23.3	7.7	8.2	87	1, 3, 5	0.017	0.336
	1.0	23.3	7.8	8.2	87			
	2.0	23.1	7.8	8.2	87			
	3.0	23.1	7.9	8.2	88			
	4.0	22.8	7.9	8.2	87			
	5.0	22.0	7.9	8.7	87			
	6.0	21.6	7.9	9.0	87			
	7.0	18.0	8.3	11.3	86			
	8.0	14.9	8.1	11.2	85			
	9.0	12.8	7.5	10.4	85			
	10.0	11.0	7.3	9.7	85			
	11.0	10.1	7.1	9.4	85			
	12.0	9.2	7.0	9.1	85			
	14.0	7.4	6.9	8.3	85			
	16.0	6.5	6.7	7.4	84			
	18.0	5.9	6.7	5.4	85			
	20.0	5.5	6.6	5.0	84			
	22.0	5.3	6.5	0.5	96			

* See Quality Assurance section of this report.
NA data not available; sample not analyzed by laboratory

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site

EXPLANATION

— 15 —
Line of equal
water depth
Interval 10 feet

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

Duck Lake -- Grays Harbor County

Duck Lake is located on a peninsula directly southeast of Ocean Shores. Once a wetland, the lake has been extensively dredged and filled for residential and recreational development. Duck Lake is marshy with numerous small islands, and is part of a canal system that runs through the city of Ocean Shores. It drains to Grays Harbor.

Size (acres)	278
Maximum Depth (feet)	30
Mean Depth (feet)	11
Lake Volume (acre-feet)	3000
Drainage Area (miles^2)	1.4
Altitude (feet)	10
Shoreline Length (miles)	11.3

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	61

* From Carlson (1977)

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

The 1990 questionnaire was not returned by the volunteer. The following are questionnaire results from 1989. Duck Lake is used for fishing, swimming, boating, jet skiing, and picnicking. There are two boat ramps on the lakeshore. There is a speed limit for motor boats. Lake water is withdrawn for irrigation. Lakeshore development for residences is the main activity within the watershed. There are about 120 houses on the lakeshore (compared with 14 reported in 1974; Bortleson *et al.*, 1974), and 95-98% of these are occupied year-round. The lakeshore area is not sewered. The lake was treated with diquat and copper sulfate from 1987-1989 to control weeds and algae, and individual homeowners rake weeds from their lakeshore areas. Fish are stocked in the lake. In the early 1960's, a series of lakes were dredged, resulting in filling and draining of wetland areas and creating land suitable for development (Kramer, Chin and Mayo, 1989). The worst problems in the lake, in the opinion of the volunteer, were 1) weeds and 2) algae, which occur in the summer from May through September. The volunteer suggested that septic systems in poor soils (the soils around the lake are sandy) and the large waterfowl population at the lake may contribute to the water quality of the lake.

The lake has much natural wildlife: beaver, herons, ducks, geese, and otters. Duck Lake and another lake, Lake Minard, are directly connected to a large canal system. Aquatic plants are a problem throughout the lake especially from May through September. About 90% of the homes have a natural buffer strip separating them from the lakeshore. About 98% of the lakeshore is covered with emergent plants.

Duck Lake -- Grays Harbor County

Monitoring Results/Summary of Other Available Information

There were not enough Secchi readings taken in 1990 to evaluate patterns in algal growth. However, the low Secchi disk readings clearly indicate the lake was eutrophic.

In 1989, low Secchi disk readings and high epilimnetic concentrations of total phosphorus and chlorophyll *a*, also indicated that the lake was eutrophic (Brower and Kendra, 1990). Dense algae blooms occurred at the surface during both sampling dates of 1989, which is probably why the turbidity was higher at the surface than at the bottom of the lake. Dissolved oxygen concentrations were depleted near the bottom of the lake during both sampling periods. In 1989, the higher ammonia concentrations, higher specific conductance and lower pH near the bottom of the lake were most likely related to the decreased concentrations of dissolved oxygen. Dissolved oxygen is usually depleted by bacteria which use oxygen when decomposing organic material (such as algae, aquatic plants and woody debris) in the water and sediments.

In 1989, Duck Lake had high concentrations of total nitrogen and total phosphorus (Brower and Kendra, 1990). Because concentrations of phosphorus are usually lower than concentrations of total nitrogen relative to the physiological requirements of algae, the concentration of available phosphorus usually limits the amount of algal growth in a lake. However, phosphorus concentrations in Duck Lake are so high that nitrogen or other factors may actually be limiting algal growth in the lake. As a result, if additional nitrogen enters the water (such as from animal wastes or failing septic systems), the lake may be able to support even more algal growth.

Presently, property owners are concerned about the algae and aquatic plants that grow in the canals and the lakes. In 1986, the extent of weed growth was investigated and was found to be primarily limited to shoreline areas, due to steep slopes of the dredged canals and lakes; the use of herbicides was recommended to control plants growing in shallow boating and swimming areas (Kramer, Chin and Mayo, Inc., 1989).

Before the City of Ocean Shores was sewered, high levels of bacteria were found in one of the canals that is associated with the lake (Kramer, Chin and Mayo, Inc., 1989). After construction of the sewers, fecal coliform bacteria levels dropped. Recent (1989) data from the Grays Harbor Health Department indicate that fecal coliform bacteria range from 4-50 colonies/100 mL in the canals, ditches, and a few of the lake sites. Fecal coliform bacteria data collected by Ecology in 1989, did not indicate a bacteria problem in Duck Lake (Brower and Kendra, 1990). However, fecal coliform bacteria samples were collected in mid-channel over the deepest site of the lake, and not from a nearshore area.

Water quality variance records with Ecology indicate that Duck Lake was chemically treated on June 25, 1990, with Aquathol K and Komeen to control pondweeds and algae.

Duck Lake -- Grays Harbor County

Comments

In 1989, Duck Lake had the lowest water clarity of all the lakes monitored by volunteers, and it was the only volunteer-monitored lake with a trophic state index value over 60. In 1990, based on the trophic state indices, two lakes monitored for the program had worse water quality than Duck Lake. Long Lake in Kitsap County had the same average Secchi reading as Duck Lake, and Vancouver Lake in Clark County had a trophic state index value (from Secchi disk data) of 73. Duck Lake is probably becoming hypereutrophic, meaning that the lake will continue to have severe algae blooms with large areas grown over with aquatic plants. Chemical treatment of the weeds and algae are not preventing the lake from being eutrophic, but may alleviate some aesthetic problems. However, because the concentrations of nitrogen and phosphorus are high enough in the lake to support large populations of plants and algae, chemical treatment of the water is only a short-term solution.

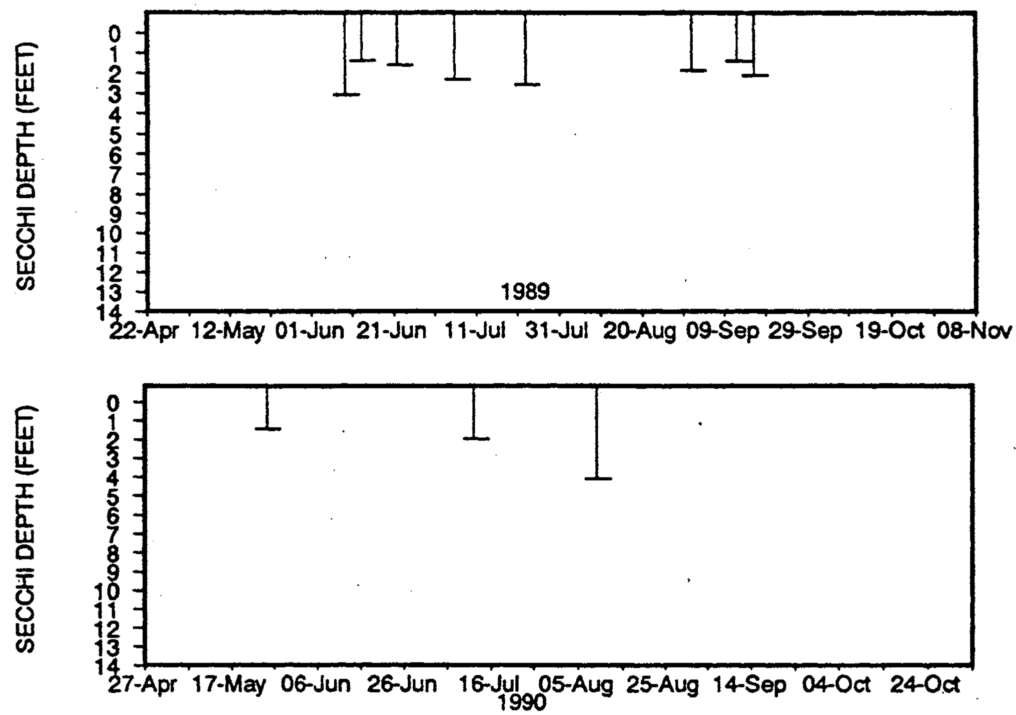
Acknowledgements

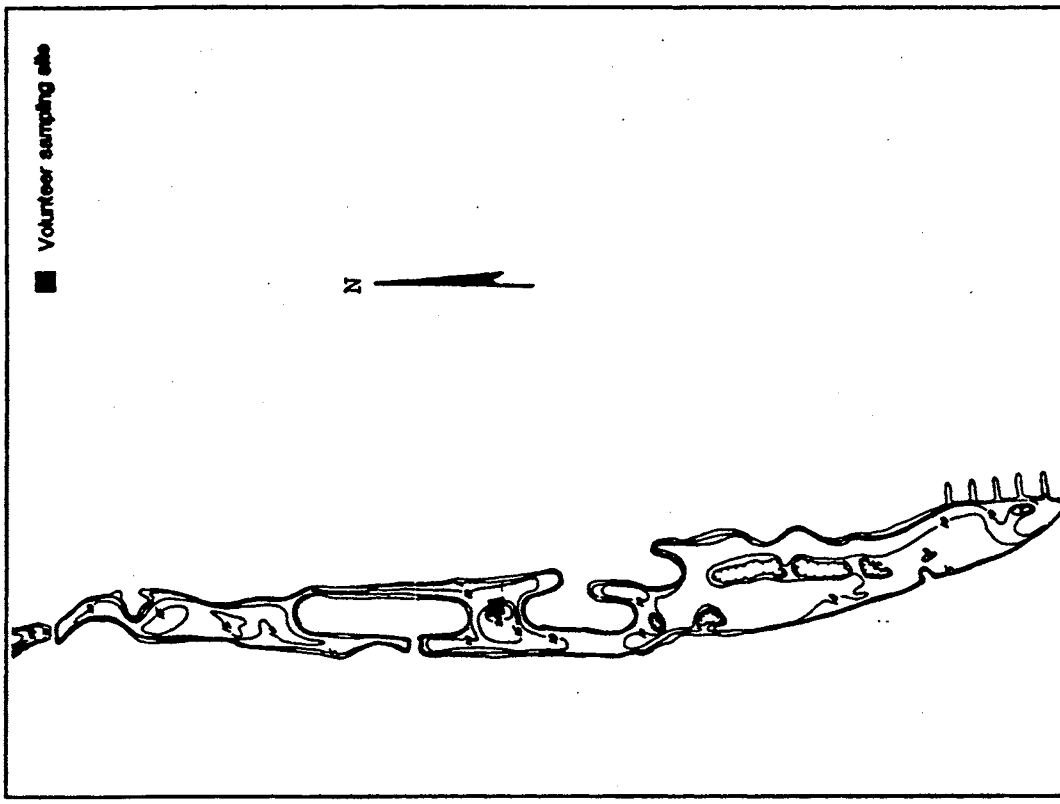
I thank Rita Wilson for volunteering her time to monitor Duck Lake during 1989, and Bruce Smith for monitoring the lake in 1990.

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
26-May	15.6	60.1	6.5	Lt-Brown	10	Trace		1.5	192.0	Lake height measured with secchi disk.
13-Jul	21.1	70.0	6.5	Lt-Brown	0	None		2.0	192.0	
10-Aug	17.8	64.0	6.5	Gr-Brown	100			4.0	198.0	

DUCK LAKE (GRAYS HARBOR COUNTY)





Duck Lake, Grays Harbor County. From U.S. Geological Survey, March 6, 1974.

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)	6018
Drainage Area (miles^2)	111
Altitude (feet)	1905
Shoreline Length (miles)	5.9

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	52
Trophic State Index* (Total Phosphorus):	62

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Eloika Lake is used for fishing, rowing, camping, and waterfowl hunting. Recreational facilities on the lakeshore include two resorts and one boat ramp, and there are no restrictions for motorboat use on the lake. Lake water is withdrawn for irrigation. Currently the watershed is used for logging, animal grazing, and residential development is occurring on the lakeshore. Grazing animals have direct access to the lakeshore or inlet tributaries, and animal wastes from agriculture drain into the lake or inlet tributaries. In the past, the watershed was used for logging and crop agriculture, the lake was dredged, and the shoreline was altered. There are 48 houses on the lakeshore; of these, 25 are occupied year-round. The lakeshore is not sewered, and there are six storm drains that empty into the lake. German brown trout are stocked in the lake. Presently there is a community association for the lake. The lake has been chemically treated in the past to control weeds. This year a Phase II project was implemented. The worst problems in the lake, in the opinion of the volunteer, were 1) aquatic plants, 2) algae, and 3) sediments suspended in the water. In 1989, the worst problems in the lake, identified and ranked by the volunteer in order of severity, were 1) sediments suspended in the water, 2) weeds, 3) algae blooms, and 4) odor after algae blooms. Overall, the volunteer finds that Eloika Lake has fair recreational water quality.

Lake Eloika -- Spokane County

Much of the shoreline is wetlands, especially at the north and south ends of the lake, and during spring high water. 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 the wetland area and it has since been sprayed and removed. Patches of large-leafed plants grow in the water and protrude above the surface.

During the August 1990 onsite visit with the volunteer, blue-green clumps about 2-6 inches in diameter were floating along the shore. The clumps consisted primarily of filaments of the blue-green alga *Oscillatoria*. Plants identified during the onsite visit included fairly extensive patches of watershield (*Bresenia schreberi*), bladderwort (*Utricularia vulgaris*), coontail (*Ceratophyllum demersum*), two pondweeds (including *Potamogeton robbinsii*), duckweed (*Lemna minor*), and waterweed (*Elodea canadensis*). High winds during the previous evening could have destratified the lake and stirred up sediments.

The following is a summary of comments the volunteer included with the 1990 questionnaire map:

- Underwater weeds cover all of the areas shallower than 12 feet. Some underwater weed masses protrude even into the edges of the 12 foot depth areas. For most of the year only the area within the 12 foot depth can be used by motorized boats. Even small electric trolling motors quickly get fouled by weeds. After a heavy algae bloom, the underwater weeds loose their vigor and "lay down," allowing motorized boats to penetrate the north and south areas of the lake. There was an increase this year in the number of areas with lilies that protrude above the water. However, a surprise freeze (20°F) caused all of that species to "burn" to the water level.

- There are large floating islands on the lake, which are comprised of dirt and aquatic plants. The very soft sediment holds gases produced by decomposition.

- The narrow finger at the north end was dredged for peat until a few years ago. The water color in this area has a "tea" appearance.

- There is a considerable amount of wildlife associated with the lake. A study of the lake included a waterfowl population count and looked at the possible effects of raising and lowering the lake water level. The study data will be used to model impact of watershed activity on northwest lakes. Residents of the area have always considered the lake as predominately a wildlife and fishing lake.

The volunteer also noted in 1989, that a 1987 study conducted by Eastern Washington University found that phosphorus is the limiting nutrient and that upstream lakes and watersheds contribute more than 75% of the total phosphorus to the lake.

Lake Eloika -- Spokane County

Monitoring Results/Summary of Other Available Information

Secchi depth data collected during 1990 show that water clarity during July and August was much better in 1990 than in 1989, but during September the water clarity was much worse in 1990 than in 1989. Algae growth during September 1990 was noted by the volunteer to be much worse near shore than in open water.

Profile data collected from Eloika Lake in 1990 show that during August, the lake was not stratified and concentrations of dissolved oxygen were not depleted near the bottom of the lake. In July 1974, the algal density was moderately high, the lake bottom was completely covered with submerged aquatic plants (coontail, Elodea, and pondweed), and dissolved oxygen concentrations were very high (17.2 mg/L) in water ten feet deep (Dion *et al.*, 1976). The high dissolved oxygen concentrations at ten feet probably resulted from photosynthesis by the dense submerged plant community. Data collected in 1981 (Sumioka and Dion, 1985) show that dissolved oxygen concentrations decreased, but were not depleted, near the bottom of the lake.
Concentrations of total phosphorus were considerably higher in 1990 (0.0553 mg/L) compared to data collected in 1974 (0.028 mg/L; Dion *et al.*, 1976) and 1981 (0.02 mg/L; Sumioka and Dion, 1981). In contrast, the concentration of total nitrogen was considerably higher in 1981 (0.98 mg/L; Sumioka and Dion, 1981) than in 1990 (0.678 mg/L).

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

Residential development of the lakeshore has not increased significantly since 1974, when there were 41 homes along the shore (Dion *et al.*, 1976).

A Water Quality Assessment and Restoration Feasibility Study conducted by Eastern Washington University 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 to reduce internal phosphorus recycling in the lake (Soltero *et al*).

In 1990, Centennial Clean Water Funds were awarded to study the nutrient loading from the watershed and to investigate designs for a water level control structure at the lake (Soules, 1989). The work was to be done by EWU. Presently, there is a proposal to install a dam at the lake outlet to prolong the water level at the natural spring high level throughout most of the year. Water level drawdown during the winter is 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; some plants are needed for fish habitat.

Lake Eloika -- Spokane County

Comments

Although both the Secchi depth and total phosphorus data from 1990 indicate that Eloika Lake was eutrophic, overall the mean water clarity was better than would be expected, given the high concentrations of total phosphorus in the epilimnion.

It is difficult to compare Eloika Lake with other lakes in the program because Eloika Lake is very shallow. The most comparable lake to Eloika Lake is Long Lake in Kitsap County, which also has logging and animal grazing within its watershed and has a shallow maximum and mean depth. Eloika Lake has slightly lower concentrations of total phosphorus and somewhat better water clarity than Long Lake.

Acknowledgement

I thank Victor H. Soules for volunteering his time to monitor Eloika Lake during 1989-1990.

Lake Eloika -- Spokane County

Volunteer-Collected Data

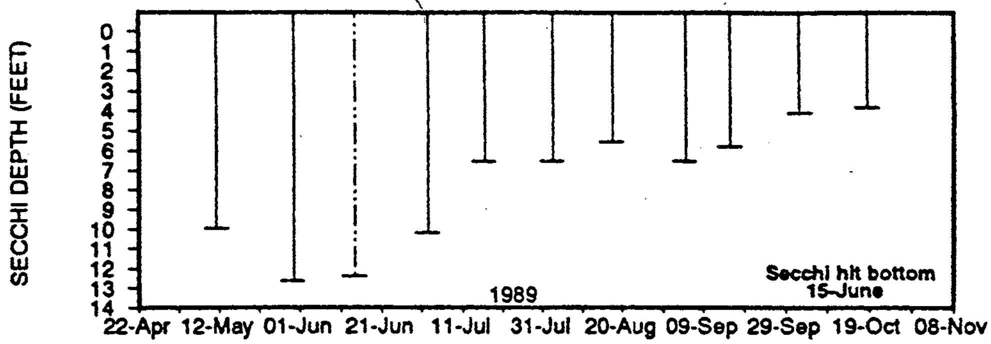
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(ft)	Abbreviated Comments
19-May	15.6	60.1	6.0	Gr-Brown	50	Light	Light	7.3	1906.	Lake height measured as feet above sea level.
09-Jun	16.7	62.1	6.5	Lt-Brown	25	Heavy		6.9	1905.	
19-Jun	20.0	68.0	6.0	Gr-Brown	0	Moderate	Light	6.9	1907.7	Between storms.
03-Jul	21.1	70.0	6.0	Gr-Brown	25	Trace	Breezy	5.5	1906.6	Lake depth is approx. 15' when surface is 1906 feet above sea level. Trout fishing good near shore.
17-Jul	25.0	77.0	6.0	Gr-Brown	0	None	Light	8.2	1906.	Underwater weeds near shore are much thicker than previous years.
03-Aug	24.4	75.9	6.0	Gr-Brown	0	None	Calm	9.2	1906.	
16-Aug	24.4	75.9	6.0	Gr-Brown	25	None	Light	7.4	1906.	Locally very severe electrical storm 8/10/90; several inches rain in few hours.
21-Aug	22.2	72.0	6.0	Gr-Brown	100	Heavy	Calm	4.7	1906.	Storm yesterday - severe winds stirred water.
06-Sep	21.1	70.0	6.5	Pea-Green	0	None	Calm	2.3	1906.1	Smooth as glass.
18-Sep	17.8	64.0	6.0	Green	0	None	Light	2.6	1905.9	Algae worse near shore.
30-Sep	20.0	68.0	6.0	Green	10	None	Calm	4.6	1905.6	
19-Oct	8.9	48.0	6.0	Gr-Brown	90	Moderate	Light	6.6 b	1904.7	

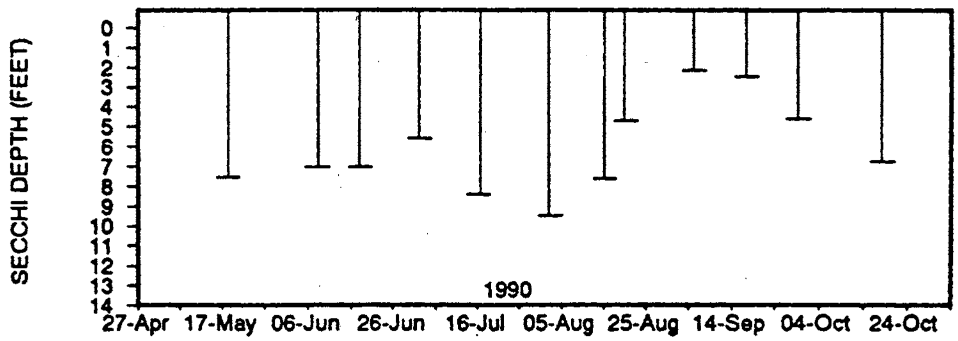
* Secchi corrected for rope shrinkage
b Secchi hit bottom

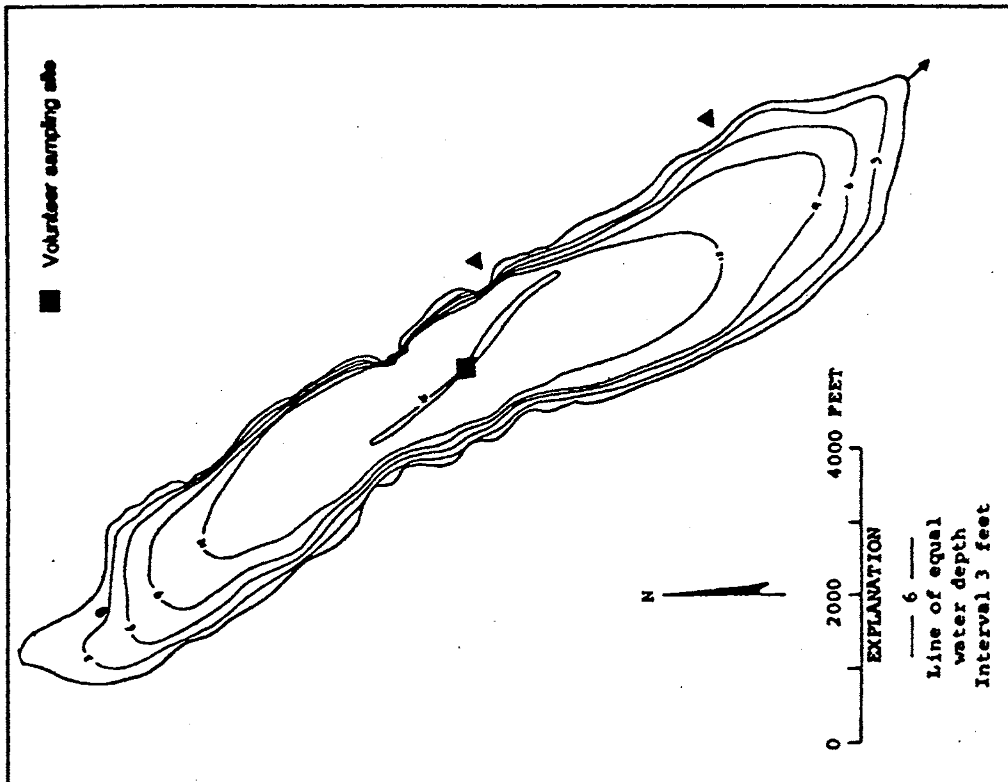
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
08/21	0.0	21.6	7.9	8.8	98	1, 2	0.055	0.678
	1.0	21.6	7.7	8.7	98			
	2.0	21.6	7.7	8.7	98			
	3.0	21.6	7.7	7.3	98			

ELOIKA LAKE (SPOKANE COUNTY)







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

Flowing Lake -- Snohomish County

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

Size (acres)	134
Maximum Depth (feet)	69
Mean Depth (feet)	28
Lake Volume (acre-feet)	3790
Drainage Area (miles^2)	0.8
Altitude (feet)	526
Shoreline Length (miles)	2.2

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

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Flowing Lake is used for fishing, boating, swimming, rowing, jet skiing and camping. Recreational facilities on the lakeshore include a county park, a state park, a camping area, a beach, and one boat ramp. There is a speed restriction of 8 mph for motorboats, however, it does not apply to water skiing. Lake water is withdrawn for drinking and irrigation. Currently the watershed is used for crop agriculture and residential development is occurring on the lakeshore. In the past, the watershed was used for logging and animal grazing. There are 94 houses on the lakeshore (there were 92 houses reported by the volunteer in 1989); of these, 61 are occupied year-round. The lakeshore is not sewered, and there are 15 storm drains that empty into the lake. Rainbow trout are stocked in the lake. Presently there is a ski association, and a water association (serves three lakes) for the lake. The lake has been chemically treated in the past to control fish species. The volunteer reports that the lake has no water quality problems. Overall, the volunteer finds that Flowing Lake has excellent recreational water quality, and suggested that motor boats may affect the water quality of the lake.

Flocks of cormorants come to the lake in droves after the lake is stocked in the spring. They roost on the ski float and eat fish, and leave in April after the fishing season opens.

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

Flowing Lake -- Snohomish County

Monitoring Results/Summary of Other Available Information

There was much more variability in water clarity during 1990 than in 1989. During 1990, algal growth appeared to increase during August. Profile data collected during June, August, and September 1990, show that on all sample dates the lake was thermally stratified and that concentrations of dissolved oxygen decreased considerably with depth. During September, however, concentrations of dissolved oxygen were extremely low throughout the entire hypolimnion of the lake (Coots, 1991). Dissolved oxygen is depleted by bacterial decomposition of organic material (such as algae and aquatic plants and woody debris) in the water and sediments. Low dissolved oxygen concentrations near the bottom of the lake (1.0 mg/L) were also documented in 1973 (Bortleson *et al.*, 1976). The lake has been used in the past as a log holding/transportation pond (Bortleson *et al.*, 1976).

The Ecology Lakes Survey conducted in 1990 showed that concentrations of total phosphorus in the lake were very low, and were similar to concentrations found in 1974 (Bortleson *et al.*, 1976).

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

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

Comments

Flowing Lake showed several mesotrophic characteristics in 1990, including moderately low Secchi disk transparency readings collected by the volunteer, very low concentrations of dissolved oxygen in the hypolimnion, presence of a blue-green algae species (*Gloeotrichia*) noted during the Ecology survey, and frequent green-brown water color noted by the volunteer. These characteristics are the basis for the mesotrophic estimation in this report.

Flowing Lake had better overall water clarity in 1990 than nearby Panther and Storm Lakes, although total phosphorus concentrations in all three lakes were very similar, and all three lakes were classified as mesotrophic.

Acknowledgements

I thank Betty Williams and Kim Williams for volunteering their time to monitor Flowing Lake during 1989-1990, and Kurt Gibbons for assisting with water sampling during May and August 1990.

Flowing Lake -- Snohomish County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
17-May	14.0	57.2	6.0	Lt-Br	100	Trace	Calm	12.4	13.7	Lake height measured from beginning dock mark.
31-May	15.0	59.0	6.0	Lt-Br	100	Moderate	Calm	12.4	13.5	Increased activity due to Memorial Day weekend.
06-Jun									10.0	Taken during onsite visit with Kurt Gibbons.
14-Jun	18.0	64.4	6.5	Lt-Br	0	Heavy	Calm	10.5		Lake activity less due to constant rain.
28-Jun	22.0	71.6	6.5	Lt-Br	50	Light	Light	9.9	14.7	
12-Jul	25.0	77.0	6.5	Lt-Br	10	None	Calm	9.2	16.0	
26-Jul	23.0	73.4	6.5	Lt-Br	100	Light	Calm	11.0	18.5	Preceding 2 weeks very warm and heavy weekend boating, swimming, ski boats.
09-Aug	25.0	77.0	6.5	Lt-Br	0	None	Breezy	8.3	20.0	Heavy motor boat activity and swimming due to hot period.
23-Aug	22.0	71.6	6.5	Lt-Br	10	Light	Calm	6.0	21.5	
06-Sep	23.0	73.4	6.5	Lt-Br	0	None	Calm	8.3	22.3	Less lake activity with holidays over and schools starting.
20-Sep	21.0	69.8	6.5	Lt-Br	0	None	Light	10.1	23.0	Moderate lake activity.
07-Oct	14.0	57.2	6.5	Lt-Br	10	Light	Breezy	8.3	21.0	

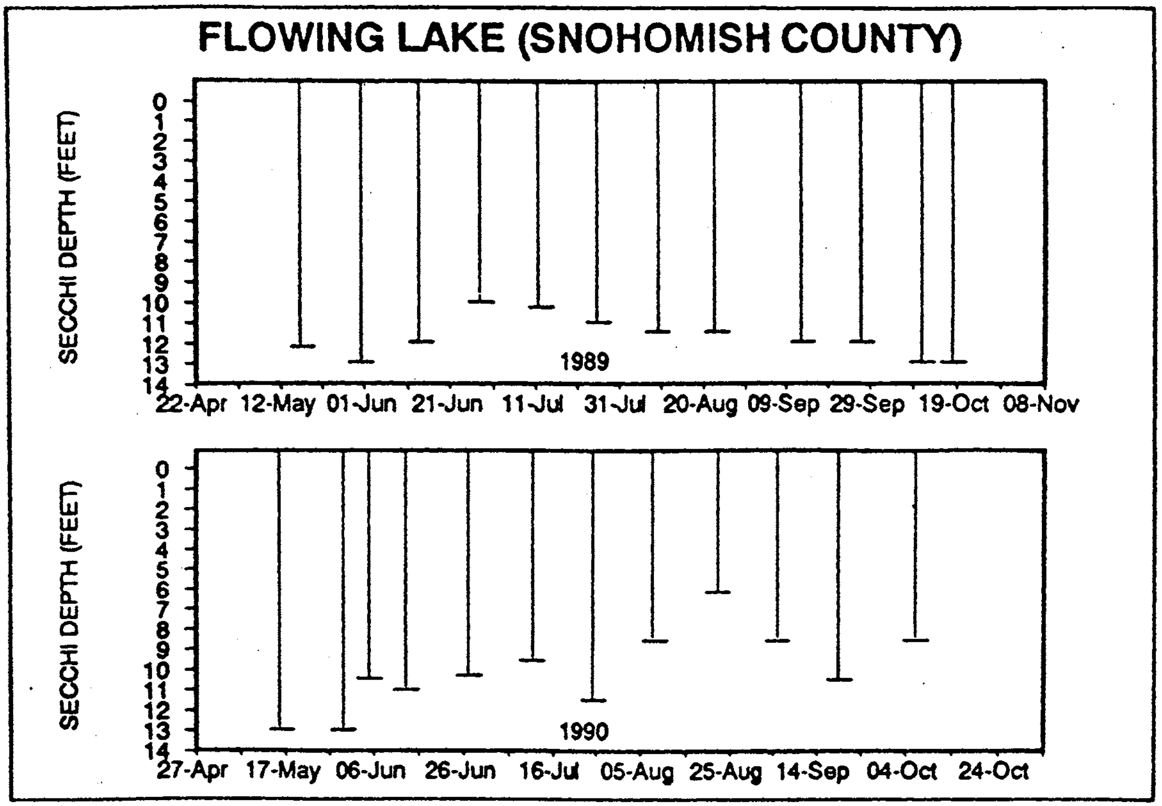
* Secchi data corrected for rope shrinkage.

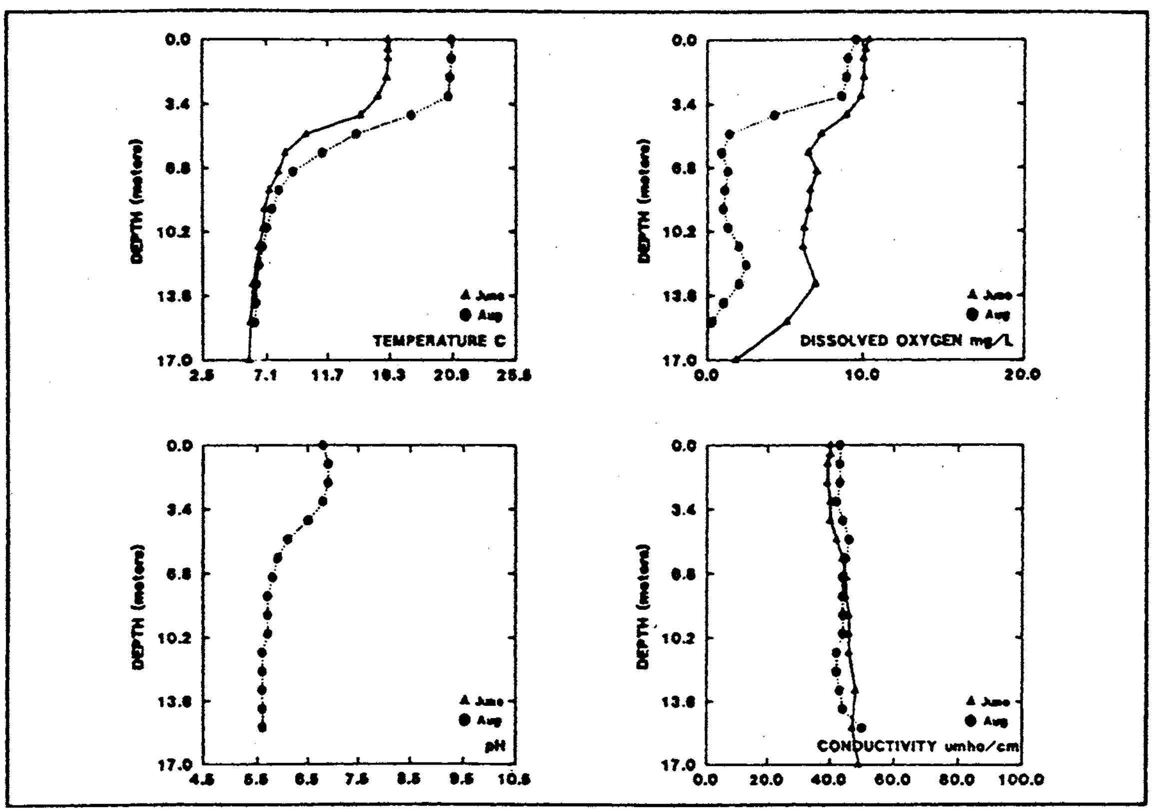
Onsite Visit Data

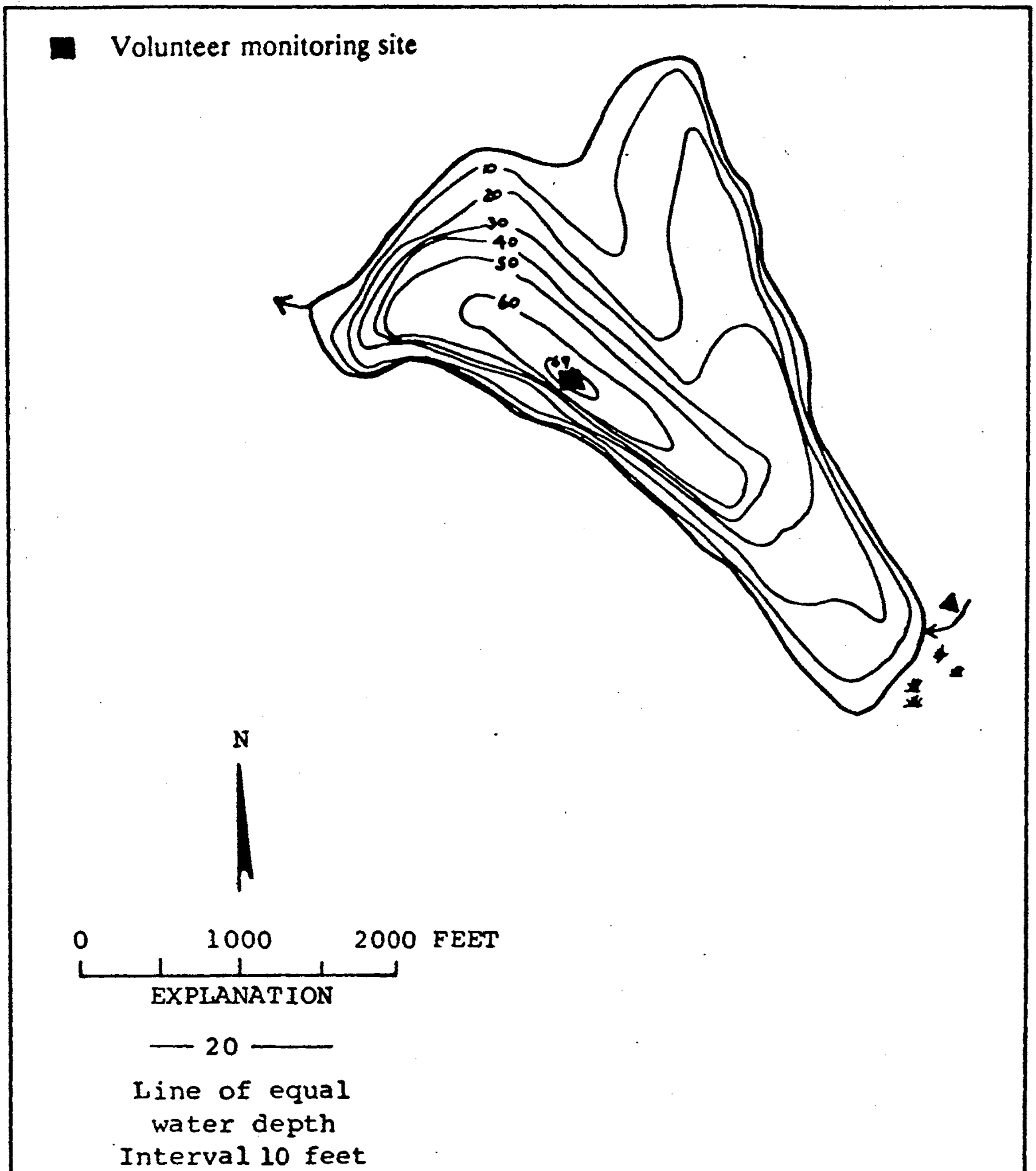
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total hosphorus (mg/L)	Total nitrogen (mg/L)
06/06	0.0	16.2	.*	10.4	40	1, 4	0.015	0.537
	0.5	16.2	.	10.2	40			
	1.0	16.2	.	10.1	39			
	2.0	16.1	.	10.1	39			
	3.0	15.5	.	9.9	40			
	4.0	14.2	.	9.0	40			
	5.0	10.1	.	7.4	42			
	6.0	8.5	.	6.6	44			
	7.0	8.0	.	7.1	45			
	8.0	7.3	.	6.7	45			
	9.0	6.9	.	6.6	46			
	10.0	6.8	.	6.3	46			
	11.0	6.5	.	6.2	46			
	13.0	6.1	.	7.0	48			
	15.0	5.9	.	5.2	47			
	17.0	5.8	.	1.8	49			
08/30	0.0	20.8	6.8	9.6	43	1, 2, 3	0.012	0.420
	1.0	20.8	6.9	9.1	43			
	2.0	20.7	6.9	9.0	43			
	3.0	20.6	6.8	8.7	42			
	4.0	17.9	6.5	4.4	44			
	5.0	13.9	6.1	1.4	46			
	6.0	11.3	5.9	0.9	45			
	7.0	9.1	5.8	1.3	44			
	8.0	8.0	5.7	1.1	44			
	9.0	7.5	5.7	1.0	44			
	10.0	7.1	5.7	1.3	44			
	11.0	6.8	5.6	2.0	42			
	12.0	6.5	5.6	2.5	42			
	13.0	6.3	5.6	2.0	43			
	14.0	6.3	5.6	1.0	44			
	15.0	6.2	5.6	0.3	50			

* See Quality Assurance section of this report.

Secchi Depth and Profile Data Graphs







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

Goss Lake -- Island County

Goss Lake is located on Whidbey Island, three miles west of Langley. Three intermittent streams contribute minor inflow early in the year. There is no outlet. No gasoline-powered boats are allowed on the lake.

Size (acres)	47
Maximum Depth (feet)	60
Mean Depth (feet)	32
Lake Volume (acre-feet)	1500
Drainage Area (miles^2)	1.4
Altitude (feet)	130
Shoreline Length (miles)	1.9

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	36

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Goss Lake is used for fishing and swimming. Recreational facilities on the lakeshore include a park, a beach, and two boat ramps. Currently the lakeshore is being developed further for residences. In the past, the watershed was used for logging. There are approximately 36 houses on the lakeshore; of these, 12 are occupied year-round. The lakeshore is not sewered. Trout are stocked in the lake. Presently there is a lake association for the lake. The volunteer noted no water quality problems in the lake. Overall, the volunteer finds that Goss Lake has excellent recreational water quality. In 1989, the volunteer stated that the "Lake (is) remarkably clean and unspoiled; hope to keep it that way. Threats (to the lake include): clearing of building lots, abuse of shoreline, (and) malfunctioning septic tanks." The volunteer noted there are some cattails on the east shore, and the lake depth was 68-70 feet.

Monitoring Results/Summary of Other Available Information

Secchi depth data show that the fluctuations in water clarity were a bit different during 1989 and 1990. However, during both years the average summer water clarity was essentially the same and the lake was oligotrophic. Water samples collected from Goss Lake in 1990 show that the concentration of total nitrogen was somewhat higher than epilimnetic concentrations measured in 1989 (Brower and Kendra, 1990). Unfortunately, the total phosphorus sample was lost due to laboratory error so there are no total phosphorus results for Goss Lake.

In 1989, Goss Lake had high Secchi disk transparency and low epilimnetic concentrations of total phosphorus and chlorophyll *a* (Brower and Kendra, 1990). However, dissolved oxygen concentrations were depleted near the bottom of the lake by June, which is not characteristic of an oligotrophic lake. Increases in dissolved oxygen concentrations at five meters (during June) and six meters (during September) probably resulted from algal photosynthesis at these depths (Brower and Kendra, 1990). Very little aquatic plant growth was noted, including sparse patches of cattails (*Typha* spp.) on the east and west ends of the lake and smartweed (*Polygonum* spp.) on the north end. The water was "tea" colored, probably from humic materials released from the decomposition of woody debris in the water and watershed. Nutrient concentrations in 1989 were similar to concentrations detected in 1973 (Bortleson *et al.*, 1976). Dissolved oxygen concentrations near the bottom of the lake were not depleted in 1973.

Comments

In addition to having good water clarity, the low amount of aquatic plant growth in the lake shows that Goss Lake had very good water quality compared with many other lakes monitored for the program.

Acknowledgement

I thank M. W. Kirkwood for volunteering his time to monitor Goss Lake during 1989-1990.

Goss Lake -- Island County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
28-Jun								16.0		
12-Jul	18.0	64.4	6.0	Clear	10	None	Calm	20.9	62.7	
26-Jul	21.0	69.8	6.0	Clear	10	Trace	Calm	22.5		Percent cloud cover noted as 10 to 25%.
09-Aug	23.0	73.4	6.0	Clear	10		Light	17.1	55.0	
23-Aug	21.0	69.8	6.0	Clear	25	Light	Light	11.5	53.7	Would like figures on first test.
08-Sep	19.0	66.2	6.0	Clear	100	None	Calm	18.6	49.5	High fog.
25-Sep	18.0	64.4	6.0	Clear	10	None	Light	17.9	46.7	

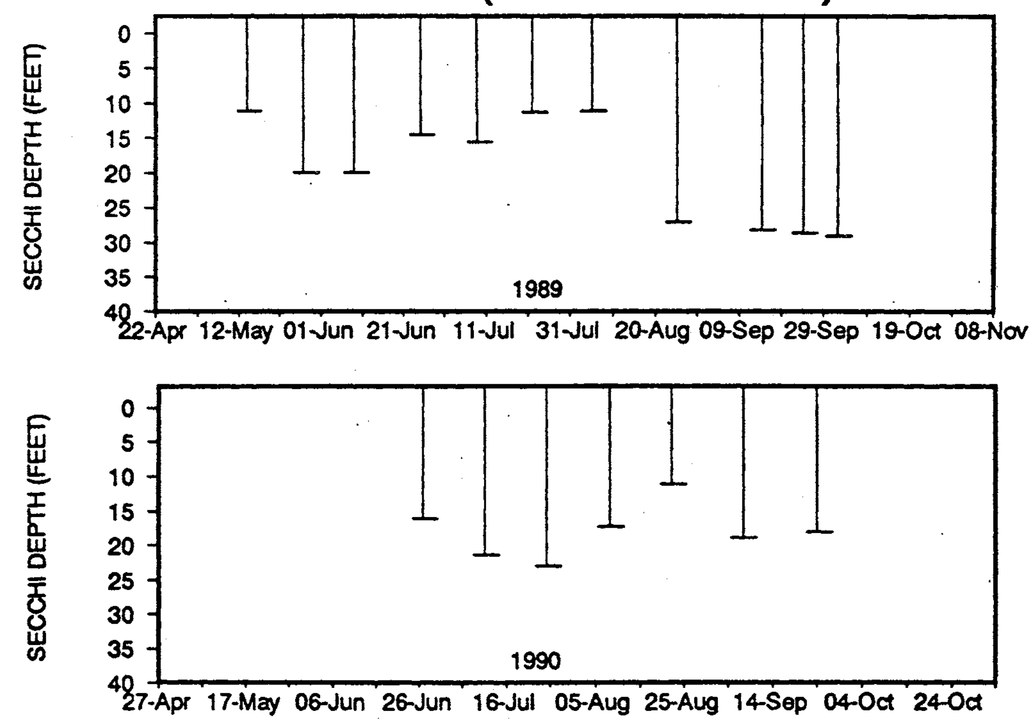
* Secchi data corrected for rope shrinkage

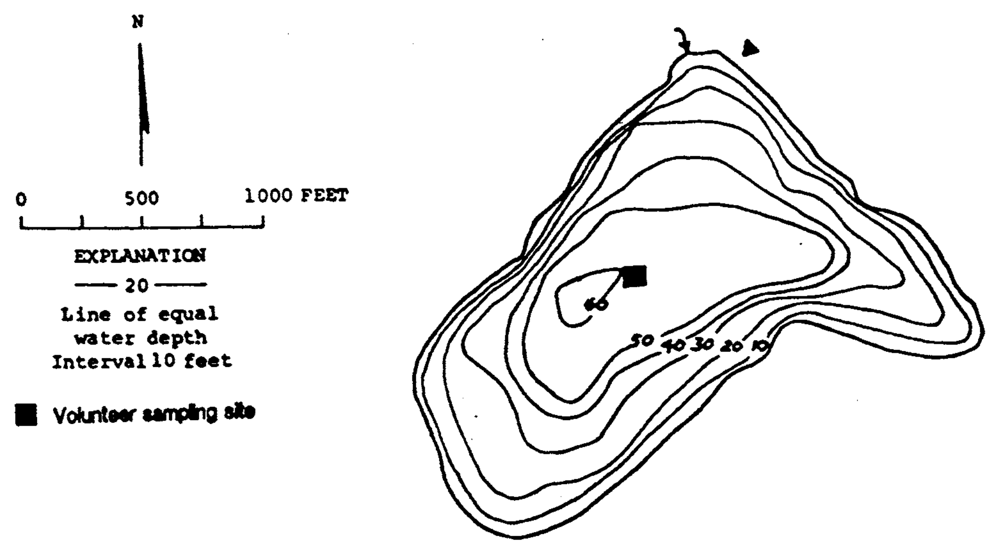
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (μg/L)	Total nitrogen (mg/L)
06/28	0.0	19.5	.	.	.	1, 2	NA	0.510
	1.0	19.0	.	.	.			
	2.0	18.5	.	.	.			

NA data not available; sample not analyzed by laboratory

GOSS LAKE (ISLAND COUNTY)





Goss Lake, Island County. From Washington Department of Game, January 23, 1949.

Hicks Lake -- Thurston County

Hicks Lake is located five miles east from Olympia. It has no inflow channels, but is springfed. The lake is the first in a chain of three lakes; it drains south to Patterson Lake, which in turn drains to Long Lake.

Size (acres)	160
Maximum Depth (feet)	35
Mean Depth (feet)	18
Lake Volume (acre-feet)	2700
Drainage Area (miles^2)	1.8
Altitude (feet)	162
Shoreline Length (miles)	2.4

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	39
Mean Trophic State Index* (Total Phosphorus):	44

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The questionnaire on lake and watershed uses was not returned.

Monitoring Results/Summary of Other Available Information

Secchi disk readings did not indicate any patterns in algae growth in the lake. Profile data collected during June and August show that the lake was thermally stratified and concentrations of dissolved oxygen were depleted near the bottom of the lake on both sampling dates. The increase in dissolved oxygen at five feet during August could be from either decreased temperatures, or increased algae growth at this depth, or both. Very low concentrations of dissolved oxygen near the bottom of the lake were also reported in 1981 (Sumioka and Dion, 1985) and 1972 (Bortleson *et al.*, 1976). Concentrations of total phosphorus and total nitrogen in the epilimnion of the lake were lower than the values reported in both 1972 and 1981. Concentrations of total nitrogen in 1981 were particularly high (1.8 mg/L; Sumioka and Dion, 1985). Based on 1981 data, the lake appeared to be meso-eutrophic. However, in 1990 the trophic state indices calculated from both Secchi disk data and total phosphorus data indicate that Hicks Lake was mesotrophic.

In 1972, it was reported that there was a heavy cover of submerged and emergent plants near the marshy south end of the lake (Bortleson *et al.*, 1976).

Acknowledgement

I thank Clay Curtiss for volunteering his time to monitor Hicks Lake during 1990.

Hicks Lake -- Thurston County

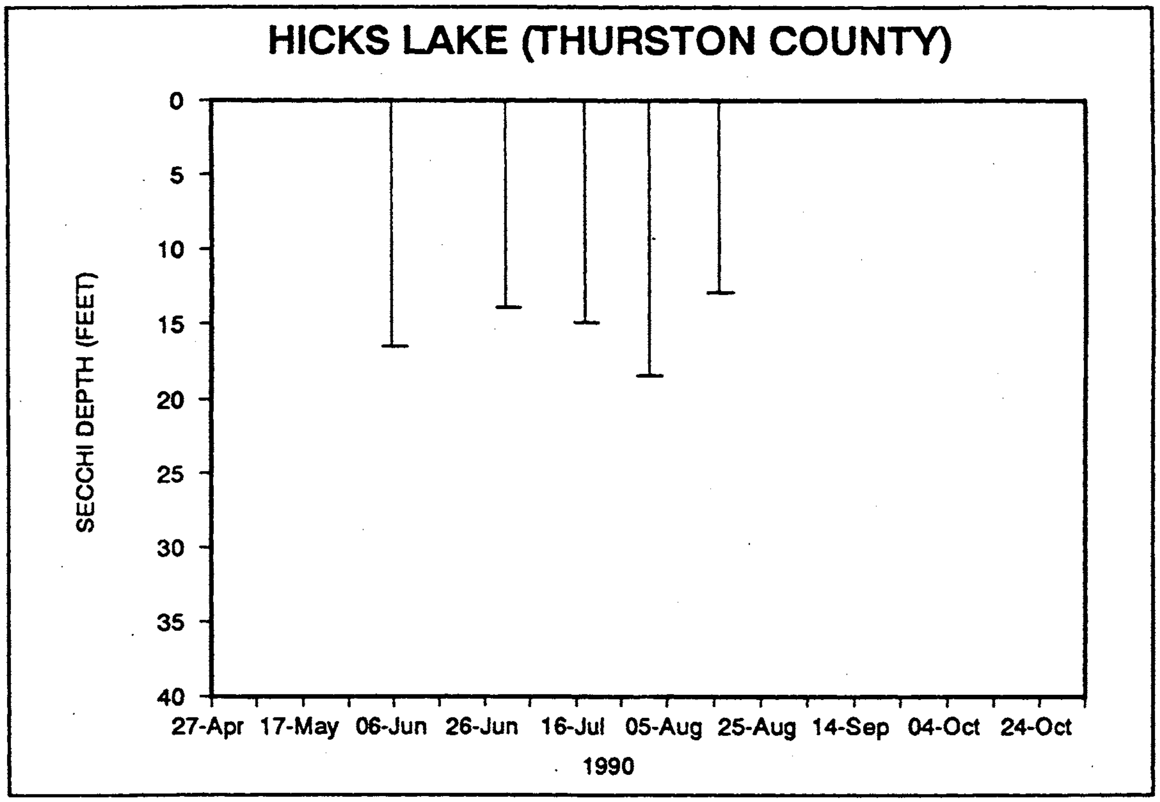
Volunteer-Collected Data

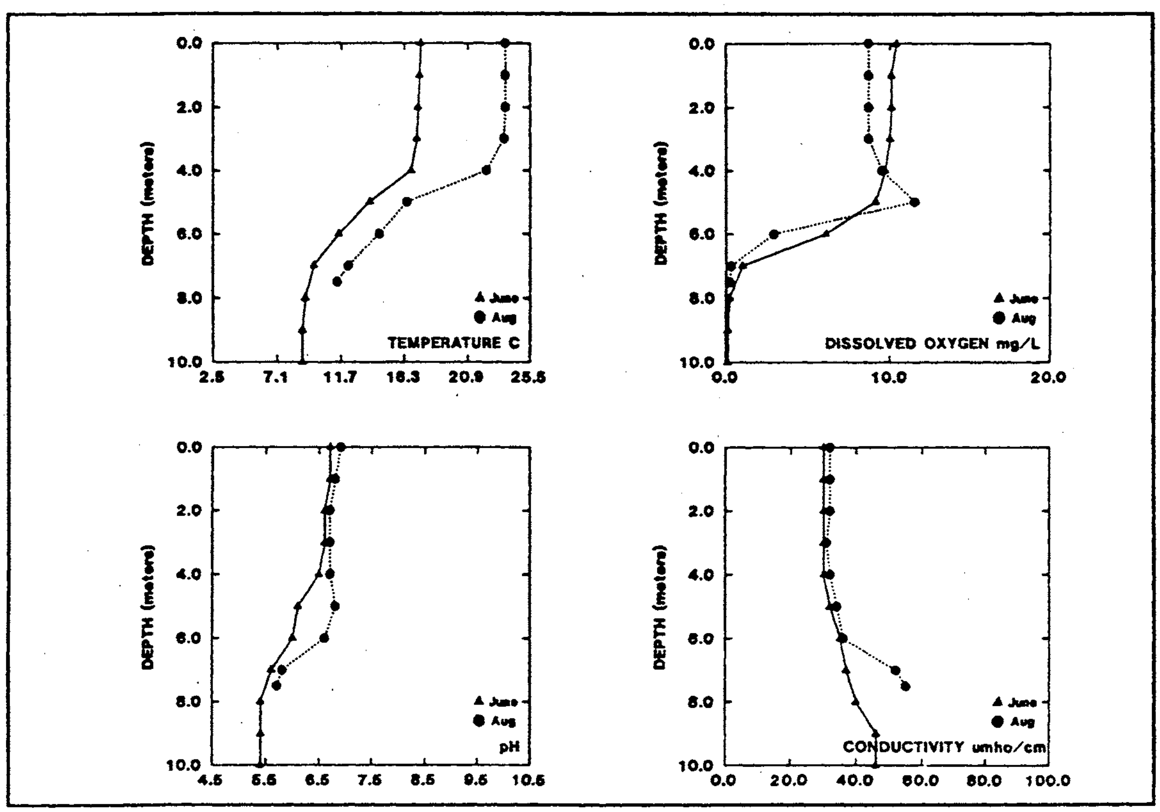
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(ft)	Abbreviated Comments
07-Jun								15.6		
02-Jul	20.6	69.1	6.5	Lt-Green	90	Trace	Breezy	13.0		
19-Jul	25.0	77.0	6.5	Lt-Green	0	None	Light	4.0	13.5	
02-Aug	22.8	73.0	6.5	Lt-Green	0	None	Light	7.5	12.7	
17-Aug	22.2	72.0	6.3	Lt-Green	75	Light		12.0	12.5	

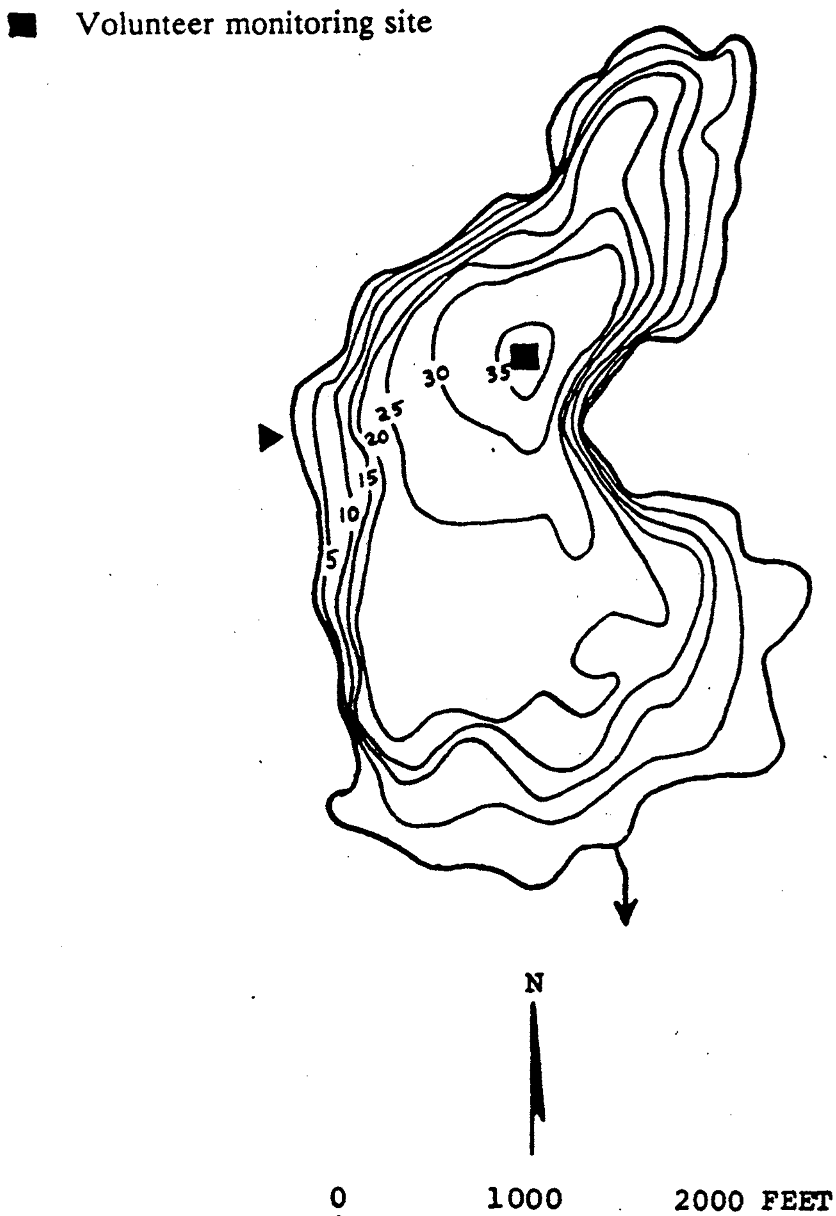
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/07	0.0	17.5	6.7	10.4	30	1, 2, 4	0.014	0.280
	1.0	17.4	6.7	10.1	30			
	2.0	17.3	6.6	10.1	30			
	3.0	17.2	6.6	10.0	30			
	4.0	16.8	6.5	9.7	30			
	5.0	13.8	6.1	9.1	32			
	6.0	11.5	6.0	6.1	35			
	7.0	9.7	5.6	1.0	37			
	8.0	9.1	5.4	0.2	40			
	9.0	8.9	5.4	0.1	46			
	10.0	8.9	5.4	0.1	46			
08/17	0.0	23.7	6.9	8.7	32	1, 2, 3	0.017	0.357
	1.0	23.7	6.8	8.7	32			
	2.0	23.7	6.7	8.7	32			
	3.0	23.6	6.7	8.7	31			
	4.0	22.3	6.7	9.5	32			
	5.0	16.5	6.8	11.5	34			
	6.0	14.5	6.6	2.9	36			
	7.0	12.2	5.8	0.3	52			
	7.5	11.4	5.7	0.2	55			

Secchi Depth and Profile Data Graphs







EXPLANATION

—10—
Line of equal
water depth
Interval 5 feet

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

Horseshoe Lake -- Cowlitz County

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

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

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	57
Mean Trophic State Index* (Total Phosphorus):	56

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Horseshoe Lake is used for fishing, boating, swimming, and rowing. Recreational facilities on the lakeshore include a park, a picnic area, a beach, and one boat ramp. Water skiing is restricted to specific times, and no jet skis are allowed on the lake. Lake water is withdrawn for irrigation. Currently the watershed is used for animal grazing and crop agriculture. In the past, the watershed was used for animal grazing and crop agriculture, the lake was dredged and the shoreline was altered. There are 19 houses on the lakeshore, and all are occupied year-round. The lakeshore is 50% sewered, and there are five storm drains that empty into the lake. Rainbow trout are stocked in the lake. Presently there is a community association for the lake. The worst problem in the lake, in the opinion of the volunteer, was water odor (noxious smell-sulfur). Overall, the volunteer finds that Horseshoe Lake has fair recreational water quality, and suggested that agricultural runoff, storm drains, and water stagnation may affect the water quality of the lake.

There is a slaughterhouse, a trucking company, and a welding shop on the lakeshore. There were no submerged weeds or lily pads growing in the lake. Algae blooms were not localized in any area. The lake depths on the 1947 Department of Game map are not accurate. A water quality study was conducted in 1988-89 by the Cowlitz County Conservation District.

Horseshoe Lake -- Cowlitz County

Monitoring Results/Summary of Other Available Information

Secchi data and total phosphorus data, collected from Horseshoe Lake during 1990, indicate that the lake was eutrophic. Variations in Secchi depth show that water clarity was worst during March, July, and September.

Profile data collected with the volunteer during May and August 1990, show that the lake was not thermally stratified on either sampling date. Under mixing conditions, one would expect that all physical and chemical parameters would be essentially the same from the top to the bottom of the lake. However, the dissolved oxygen and pH were higher at one meter than at the surface, and decreased with depth from one meter to the bottom. These unusual profiles could result from either increased algal growth at one meter, or from winds and wave action circulating oxygen from the super-saturated surface waters to the deeper waters (the saturation level was 120% at the surface and 130% at one meter). The lower concentrations of dissolved oxygen near the bottom of the lake probably result from the bacterial decomposition of organic material (such as algae, aquatic plants, or woody debris) in the water and sediments.

Data collected in 1974 showed that concentrations of total phosphorus were much higher in 1973 (0.073 mg/L; Bortleson *et al.*, 1976) than in 1990 (highest value was 0.0378 mg/L). The ratio of total nitrogen to total phosphorus concentrations was relatively low, indicating that (relative to each other) the nitrogen concentrations are unusually low, or the phosphorus concentrations are unusually high. Low ratios of nitrogen to total phosphorus concentrations also occurred during 1974.

During the August 1990 onsite visit, large particles and clumps of algae were observed in the water. A water sample sent in by the volunteer (date unknown) was badly decomposed, but was tentatively identified as *Aphanocapsa*, a genus of blue-green algae.

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

From Somers (1989): In 1981, the pump was replaced with one that had a greater pumping capacity. The pump was running during 1988-1989 when the Cowlitz County Conservation District studied the lake.

During the study period, none of the Lewis River stations exceeded state Class A standards, although two stations near Horseshoe Lake Park, a stormwater station (during rain events), a station near the cattle lot, and other south end lake stations had high fecal coliform bacteria counts that exceeded state standards. Secchi depth measured from the North Arm of the lake during 1988-1989 ranged from 2.25-4.5 feet, indicating that the lake was eutrophic. The lowest readings were in September 1988 and April 1989, and highest readings were in August 1988 and February 1989.

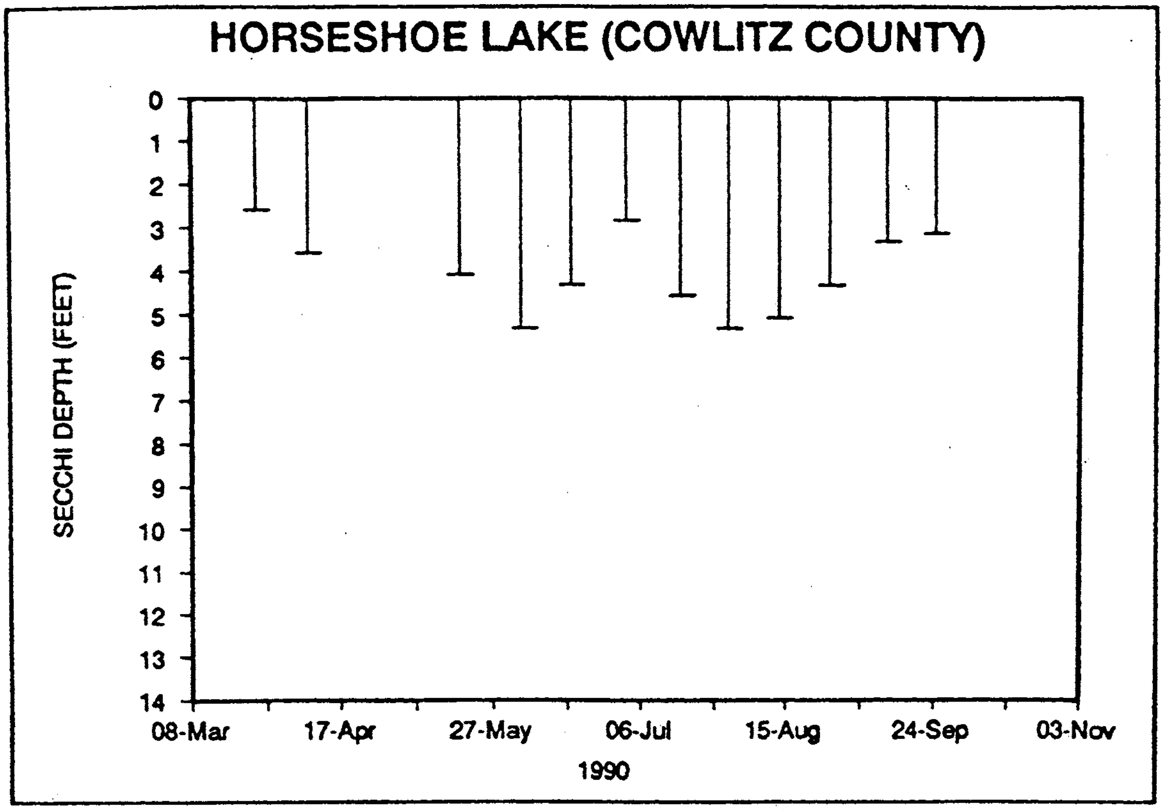
Comments

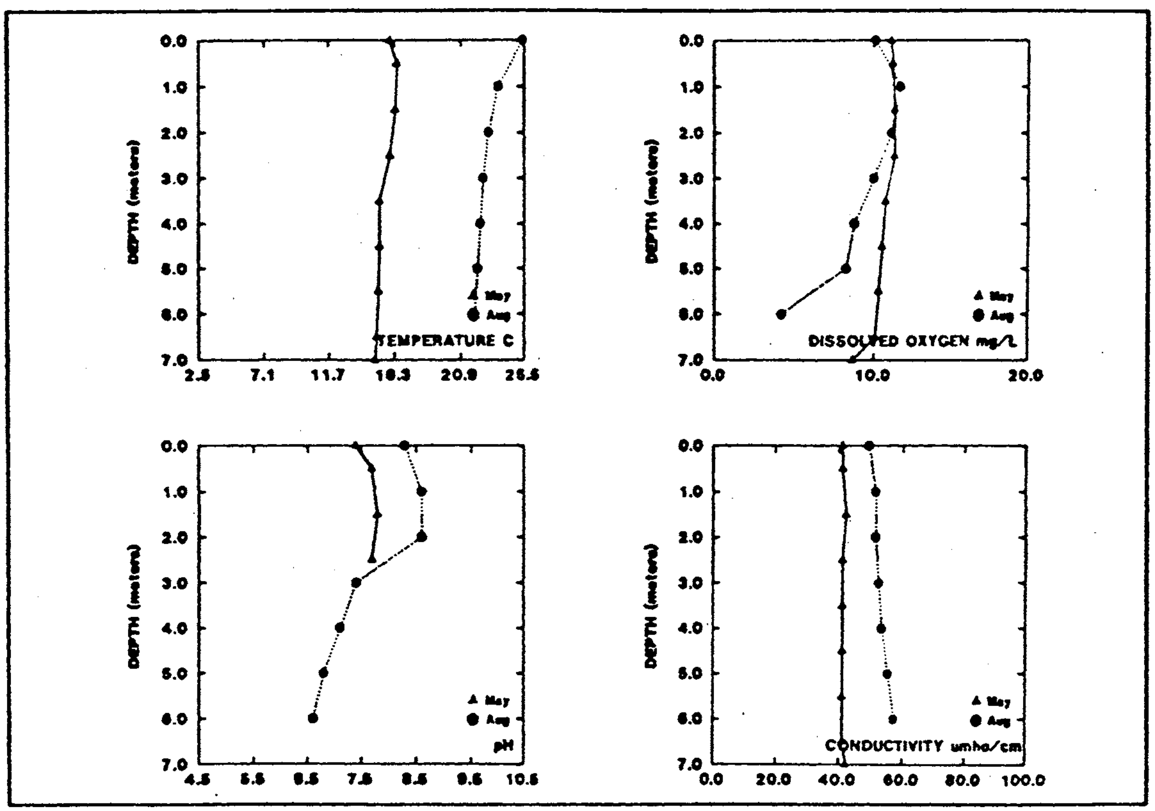
Compared to other lakes monitored for the program, Horseshoe Lake was very unusual in its physical shape and dependence on pumped river water for maintaining its lake level. Because the lake receives unfiltered Lewis River water, some suspended solids from the river will settle in the lake. In this respect, the lake serves as a settling pond for solids from the Lewis River. Concerns among the local users of the lake include high fecal coliform levels, bad odors that occur during certain times of the year, fluctuating lake levels, the quality of the Lewis River water pumped into the lake, and maintaining satisfactory water quality for contact recreation. Although there are conflicting reports over whether or not the lake violates water quality standards, it appears that the lake was eutrophic. Presently, local governments are working with support groups to reduce loading from stormwater, to educate the public about reducing nonpoint source pollution within the lake's watershed, and to improve the shoreline near the cattle lot.

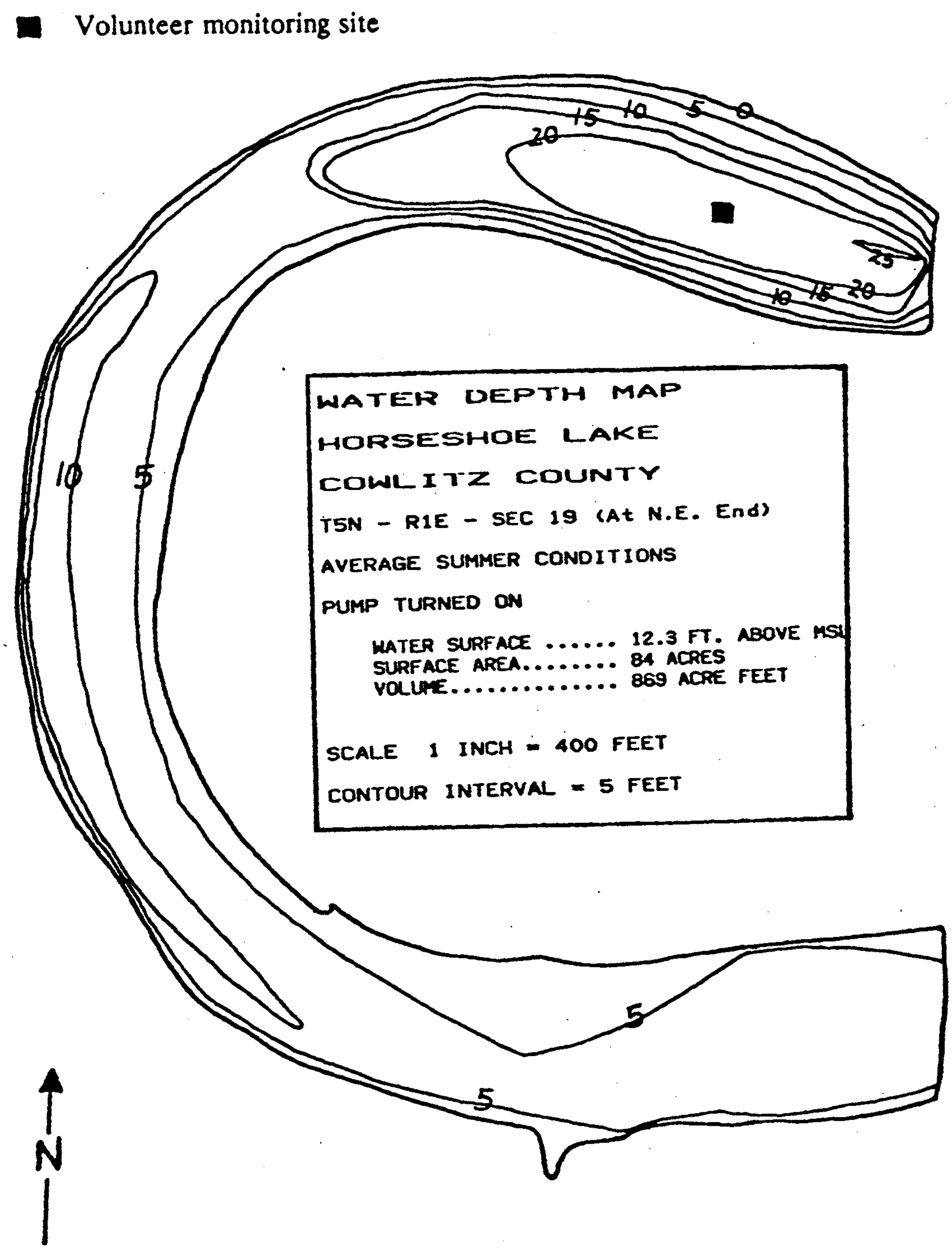
Acknowledgement

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

Secchi Depth and Profile Data Graphs







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

Horseshoe Lake -- Cowlitz County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
26-Mar	12.0	53.6						2.3	0.0	Lake depth 12.5'. Recent animal activity on shore of lake denuding foilage (cows).
09-Apr	16.0	60.7						3.3*	0.0	
19-May	16.5	61.7	7.5	Green	90	Heavy	Light	3.7		
05-Jun	20.0	68.0	6.5	Pea-Green	100	Light	Calm	5.0	8.5	Lots of cottonwood bloom.
18-Jun	21.0	69.8	6.5	Pea-Green	0	None	Light	4.0	8.4	Cottonwood still blooming.
03-Jul	22.5	72.5	6.5	Milky-Gr	25	None	Light	2.5	7.5	40 people swimming, 4 ski boats, and 2 fishing boats.
18-Jul	24.0	75.2	6.5	Gr-Brown	0	None	Breezy	4.3	6.3	125 people using park, 45 people in lake.
31-Jul	22.5	72.5	7.5	Pea-Green	100	None	Calm	5.0	5.5	Four nesting pair of herons.
14-Aug	25.0	77.0	8.0	Pea-Green	75	None	Light	4.7	5.2	25+ ducks in sample area. Smell has returned - bloom may be starting.
28-Aug	23.0	73.4	7.5	Pea-Green	10	Light	Calm	4.0	5.8	
12-Sep	20.0	68.0	6.5	Gr-Brown	90	Light	Calm	3.0	6.0	Bloom still going on. Large duck population - 200 estimate.
25-Sep	19.4	66.9	6.5	Gr-Brown	100	None	Calm	2.8	6.2	

* There was high variability between the first and second Decchi depths collected; this data point may not be used in data comparisons

Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/21	0.0	16.0	7.4	11.1	41	0.5, 2	0.038	0.320
	0.5	16.5	7.7	11.2	41			
	1.5	16.4	7.8	11.3	42			
	2.5	16.0	7.7	11.3	41			
	3.5	15.3	.	10.7	41			
	4.5	15.3	.	10.5	41			
	5.5	15.2	.	10.3	41			
	6.5	15.1	.	10.1	41			
	7.0	15.0	.	8.7	42			
08/13	0.0	25.4	8.3	10.1	49	1	0.035	0.489
	1.0	23.6	8.6	11.7	51			
	2.0	22.9	8.6	11.1	51			
	3.0	22.5	7.4	10.0	52			
	4.0	22.3	7.1	8.8	53			
	5.0	22.1	6.8	8.3	55			
	6.0	21.9	6.6	4.3	57			

Island Lake -- Mason County

Island Lake is located two miles southwest from Keyport. It is fed primarily by groundwater, and drains via Barker Creek to Dyes Inlet. The lake has a one-acre island. A dense pattern of residential development surrounds the lake.

Size (acres)	108
Maximum Depth (feet)	31
Mean Depth (feet)	21
Lake Volume (acre-feet)	2246
Drainage Area (miles^2)	0.3
Altitude (feet)	230
Shoreline Length (miles)	1.7

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	36
Mean Trophic State Index* (Total Phosphorus):	38

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The 1990 questionnaire on lake and watershed uses was not returned by the volunteer. The following are the volunteer's responses to the 1989 questionnaire. Island Lake is used for fishing, swimming, boating, and jet skiing. Water is withdrawn for irrigation only. There are no current watershed activities, although the watershed has been logged in the past. There are 84 houses on lakeshore; all are on septic systems and about 80 of the houses are occupied year-round. Fish are stocked in the lake. The lake level varies up to five feet during the year. There are wetlands. Lily pads ("about 2-inches in diameter, no flower," possibly *Brasenia*) are found along about 55-60% of the shoreline. Submerged weeds ("oblong leaves, some reach water surface," possibly *Potamogeton* spp.) are found in about 0-15 feet of water on the west side of the lake.

In the opinion of the volunteer, the worst water quality problems in the lake are algae blooms during August and September. In 1989, there was a severe algal bloom around April 1, and a brief bloom around June 1. The volunteer suggested that old drain fields and septic systems may contribute to water quality problems in the lake.

Monitoring Results/Summary of Other Available Information

Secchi disk readings from 1990 were very similar to readings collected in 1989. During both years, water clarity was generally very good with periods of slightly less clarity during June and August. Profile data show that the lake was not stratified on either sampling date. In August, the decrease in dissolved oxygen and pH and the increase in conductivity at seven meters was probably due to the probe resting on lake sediments.

Island Lake -- Mason County

The concentrations of total phosphorus and total nitrogen were low, and confirm that the lake is oligotrophic. Compared with data collected in 1974 (Bortleson *et al.*, 1976), concentrations of total nitrogen were lower in 1990 but concentrations of total phosphorus were about the same.

Compared with nutrient data collected in 1981 (Sumioka and Dion, 1985), concentrations of both total nitrogen and total phosphorus were lower in 1990 than in 1981. In 1971, a gravelly littoral lake bottom supported a sparse growth of macrophytes, although 11-25% of the shoreline was covered by emergent plants (Bortleson *et al.*, 1976).

Island Lake was surveyed in 1970, along with other Mason County lakes, as part of research coordinated by Washington State University. The survey concluded that nutrients were being recycled from the sediments of Island Lake and contributed to the extensive diatom blooms that occurred from January to March 1971 (Funk *et al.*, 1972). Blue-green algae growth was also documented during the fall of 1970 (Funk *et al.*, 1972).

Comments

Compared with other Mason County lakes monitored for the program (Limerick, Mason, Nahwatzel, Phillips, Spencer, and Wooten Lakes), Island Lake had good water clarity and had relatively low concentrations of total phosphorus. Mason Lake had the best overall water clarity and lowest concentrations of total phosphorus. Although Island Lake is about the same size as Phillips Lake and Lake Limerick, the greater maximum and mean depth of Island Lake may contribute to its better lake quality.

Acknowledgement

I thank Bob Kieburtz for volunteering his time to monitor Island Lake during 1989-1990.

Island Lake -- Mason County

Volunteer-Collected Data

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
14-May	14.0	57.2	6.0[1]	Clear	75	Moderate	Calm	15.6	342.0	Lake height 28'6".
29-May	15.0	59.0	6.0[1]	Gr-Brown	90	Moderate	Breezy	19.3		
31-May								15.6		
14-Jun	18.0	64.4	6.0[1]	Clear	0	Trace	Calm	16.3	336.0	Lake height 28 feet.
26-Jun	20.0	68.0	6.0[1]	Clear	10	None	Light	20.4	332.0	Lake height 27'8".
10-Jul	23.5	74.3	6.0[1]	Clear	0	None	Calm	20.8	330.0	Lake height 27'6".
24-Jul	23.0	73.4	6.0[1]	Clear	90	None	Breezy	17.0	324.0	
07-Aug	24.0	75.2	6.0[1]	Clear	0	None	Calm	17.9		
16-Aug								18.3		
23-Aug	22.0	71.6	7.0		90	Trace	Light	15.4	316.0	Water color yellow-light green. I used a different technique. No pH change -- was reading incorrectly.
04-Sep	21.0	69.8	7.0	Lt-Green	0	None	Calm	19.3	316.0	
18-Sep	20.5	68.9	7.0	Lt-Green	0	None	Calm	17.6	314.0	
05-Oct	17.5	63.5	6.5	Lt-Green	0	Moderate	Calm	16.3	312.0	
19-Oct	13.5	56.3	6.5	Lt-Green	0	Moderate	Calm	15.6	313.0	Last reading.

* Secchi data corrected for rope shrinkage

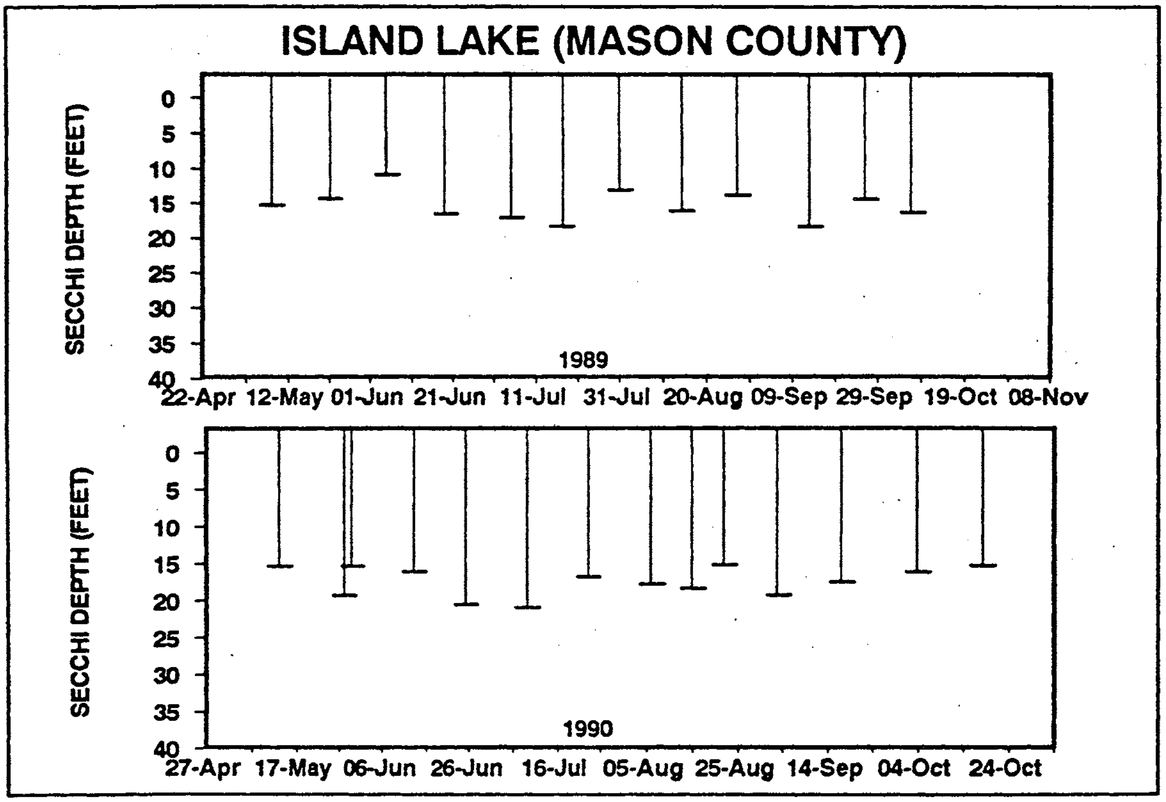
1 pH data may be inaccurate; see comment from 23 August 1991.

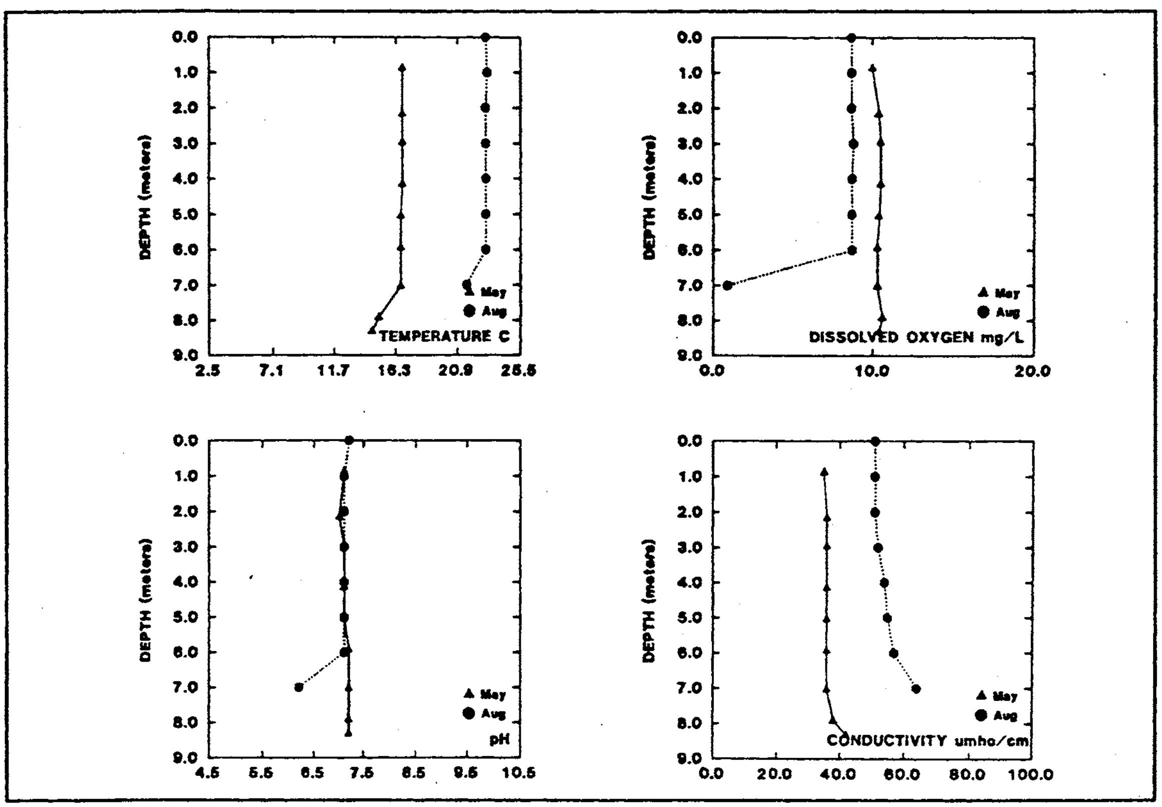
Onsite Visit Data

Date 1990	Depth* (meters)	Temp* (° C)	pH*	Dissolved oxygen* (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/31	0.9	16.8	7.1	10.0	.	1, 3, 4	0.010	0.229
	2.2	16.8	7.0	10.4	.			
	3.0	16.8	7.1	10.5	.			
	4.1	16.8	7.1	10.5	.			
	5.0	16.7	7.1	10.4	.			
	5.9	16.7	7.2	10.3	.			
	7.0	16.7	7.2	10.3	.			
	7.9	15.1	7.2	10.6	.			
	8.3	14.6	7.2	10.4	.			
08/16	0.0	23.0	7.2	8.7	51	1, 3, 5	0.011	0.268
	1.0	23.1	7.1	8.7	51			
	2.0	23.0	7.1	8.7	51			
	3.0	23.0	7.1	8.8	52			
	4.0	23.0	7.1	8.7	54			
	5.0	23.0	7.1	8.7	55			
	6.0	23.0	7.1	8.7	57			
	7.0	21.6	6.2	0.9	64			

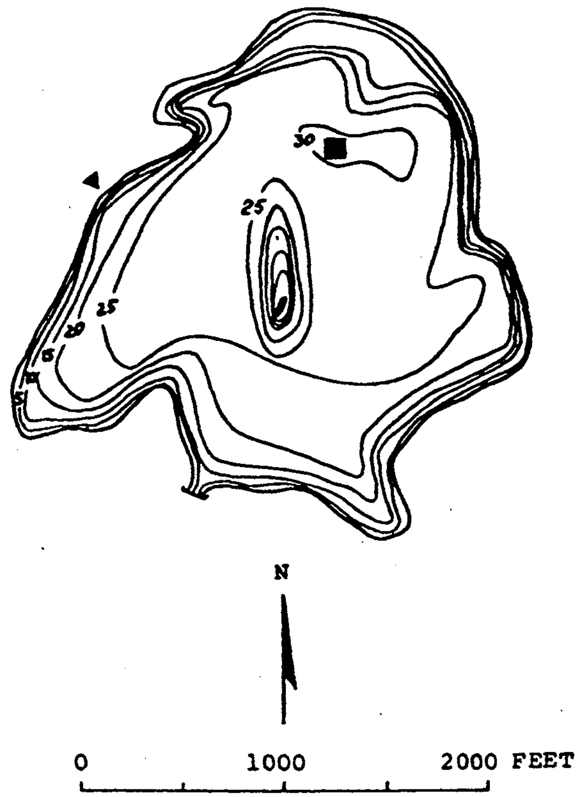
* The 5/31/91 profile data were collected with a Seabird CTD. The 8/16/91 data were collected with a Hydrolab Surveyor II.

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



EXPLANATION

——10——

Line of equal
water depth
Interval 5 feet

Island Lake, Mason County. From Washington
Department of Game, February 15, 1952.

Lake Kahlotus -- Franklin County

Lake Kahlotus is located about 40 miles northeast of Pasco, at the town of Kahlotus. It is about 2.3 miles long. It drains westward before disappearing underground in Washtucna Coulee. The acreage varies with seasons.

Size (acres)	*
Maximum Depth (feet)	*
Mean Depth (feet)	*
Lake Volume (acre-feet)	*
Drainage Area (miles^2)	167
Altitude (feet)	880
Shoreline Length (miles)	5.3

*Present information unknown

Estimated Trophic State:	Eutrophic
Mean Trophic State Index** (Secchi):	***
Trophic State Index (Total Phosphorus):	78

* See Monitoring Results Section
** From Carlson (1977)
*** See Monitoring Results Section

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Kahlotus is used for fishing and waterfowl hunting. There is one boat ramp on the lakeshore and there are no restrictions for motorboat use. Currently the watershed is used for animal grazing and crop agriculture. In the past, the watershed was also used for animal grazing and crop agriculture. There is one house on the lakeshore; it is occupied year-round and uses an onsite wastewater disposal system. There are six culverts that drain into the lake; much of the drainage is agricultural return water and spring meltwater. The worst problems in the lake, in the opinion of the volunteer, are ranked as 1) water level (decreasing year to year), 2) aquatic plants, 3) algae, 4) fish kills, 5) floating debris, and 6) water odors (from decomposition of plants and fish). Overall, the volunteer finds that Lake Kahlotus has poor recreational water quality, and is concerned about possible water quality effects from farm chemicals in runoff and groundwater, and gas powered boats (the volunteer has observed oily film on the water surface). Although the volunteer would like to see motor boats restricted from the lake, the volunteer notes that the number of motor boats using the lake is decreasing because of the lowering water level and increasing amount of plant growth.

The entire lake bottom is covered with submerged plants. In summer months the plants reach the water surface. There are wetlands on the east and west ends of the lake. Because of the lowering water level and the amount of plants in the lake, the volunteer may not be able to continue monitoring.

Lake Kahlotus -- Franklin County

The present size of the lake is considerably smaller than shown on the map; the volunteer reports that the lake hasn't covered 380 acres since the early 1960s. The lowered lake level has exposed an island on the southwest side of the lake and created wetlands at the west and east ends of the lake. During the August 1990 onsite visit, the volunteer mentioned that the lake nearly dried up in 1973.

Monitoring Results/Summary of Other Available Information

Because it was not possible to collect a Secchi reading from Lake Kahlotus (on all sample dates, the Secchi disk either hit bottom or disappeared in weeds), the trophic state index was not calculated from the Secchi disk data. In contrast, secchi visibility in 1974 was 16 feet (Dion *et al.*, 1976); presently the lake is not even that deep.

Profile data collected with the volunteer during August 1990 show that concentrations of dissolved oxygen decreased with depth. This may have resulted from high decomposition within the large aquatic plant population. Conductivity in the water was very high. Conductivity, which is a measure of the ability of the water to conduct an electrical current, is an indicator of the amount of dissolved minerals in water. Conductivity was 2750 μmhos/cm in 1974 (Dion *et al.*, 1976), twice that measured in 1990. Only Sidley Lake in Okanogan County had a higher conductivity than Lake Kahlotus.

Concentrations of total phosphorus and total nitrogen (0.1723 and 3.020 mg/L, respectfully) were very high in the lake during 1990. In 1974, concentrations of total phosphorus and total nitrogen (0.16 and 2.0 mg/L, respectively; Dion *et al.*, 1976) were similar to 1990 concentrations.

During the August onsite visit, quite a few dead fish (possibly bluegill) were observed. Pondweed (*Potamogeton pectinatus*) covered nearly the entire surface of the lake. A milfoil species (*Myriophyllum* spp.; but not the aggressive Eurasian variety) was observed but it was not abundant. A plant sample sent in by the volunteer was identified as coontail (*Ceratophyllum demersum*).

Lake Kahlotus was one of 15 lakes sampled by Ecology in June and September 1990 as part of a statewide lakes survey conducted to supplement the volunteer-collected data. Data collected from this survey showed that concentrations of total phosphorus were high on both sampling dates (Coots, 1991). Also, the concentrations of dissolved oxygen were very high throughout the water column during June, but during September the concentrations of dissolved oxygen were very low (Coots, 1991). The pH on both sampling dates was very high, especially during September. Compared to the other 14 lakes surveyed by Ecology in 1990, and the 25 lakes surveyed in 1989, the September pH of Lake Kahlotus was the highest (9.8). Plant and algae productivity, the composition of the surrounding geology and the concentrating effects of the lower lake level during late summer may contribute to the high conductivity and pH of Lake Kahlotus. During June an algae bloom (consisting of two blue-green algae species, *Anabaena* and *Spirogyra*), and a number of dead bluegill floating on the surface were observed (Coots, 1991). During September, floating mats of sago pondweed (*Potamogeton pectinatus*) were observed. Growth of this plant and an unidentified species of milfoil (*Myriophyllum* sp.) was heavy throughout the lake, particularly along the shoreline. Apparently, even when the lake was deeper, plant growth in the lake was heavy. In 1974, it was reported that the lake bottom was covered completely with submersed aquatic plants and filamentous green algae (Dion *et al.*, 1976).

Sediment and largemouth bass samples were collected from Lake Kahlotus by Ecology in 1989 as part of a statewide toxics survey. Relatively low concentrations of phenol (190 - 280 μg/kg) and 4-methylphenol (59 μg/kg) were detected in the sediment samples (Johnson and Norton, 1990). These are naturally occurring substances that are generally considered to have low toxicity to aquatic organisms. Because concentrations of heavy metals and DDT by-products were also low, the fish and sediment from Lake Kahlotus appeared to be uncontaminated.

Comments

Kahlotus Lake was most definitely eutrophic, and total phosphorus concentrations were in the hypereutrophic range. Eutrophic characteristics of the lake include the high concentrations of total phosphorus, extremely high submerged plant growth, the presence of bloom-forming blue-green algae species, and fish kills. The exact cause of the fish mortalities is unknown. However, it is possible that the heavy plant and algae growth that produced the high concentrations of dissolved oxygen during daytime photosynthesis, may be completely depleting the oxygen supply overnight, when the plants respire and use oxygen from the water.

Compared with other lakes monitored for the program in 1990, the water quality of Lake Kahlotus was very poor. The lake had the highest concentration of total phosphorus of all the volunteer-monitored lakes, although Sunday Lake in Snohomish County had a concentration nearly as high (0.1506 mg/L) during May 1990.

Acknowledgement

I thank Gail Ekenbarger for monitoring Lake Kahlotus during 1989-1990.

Lake Kahlotus -- Franklin County

Volunteer-Collected Data

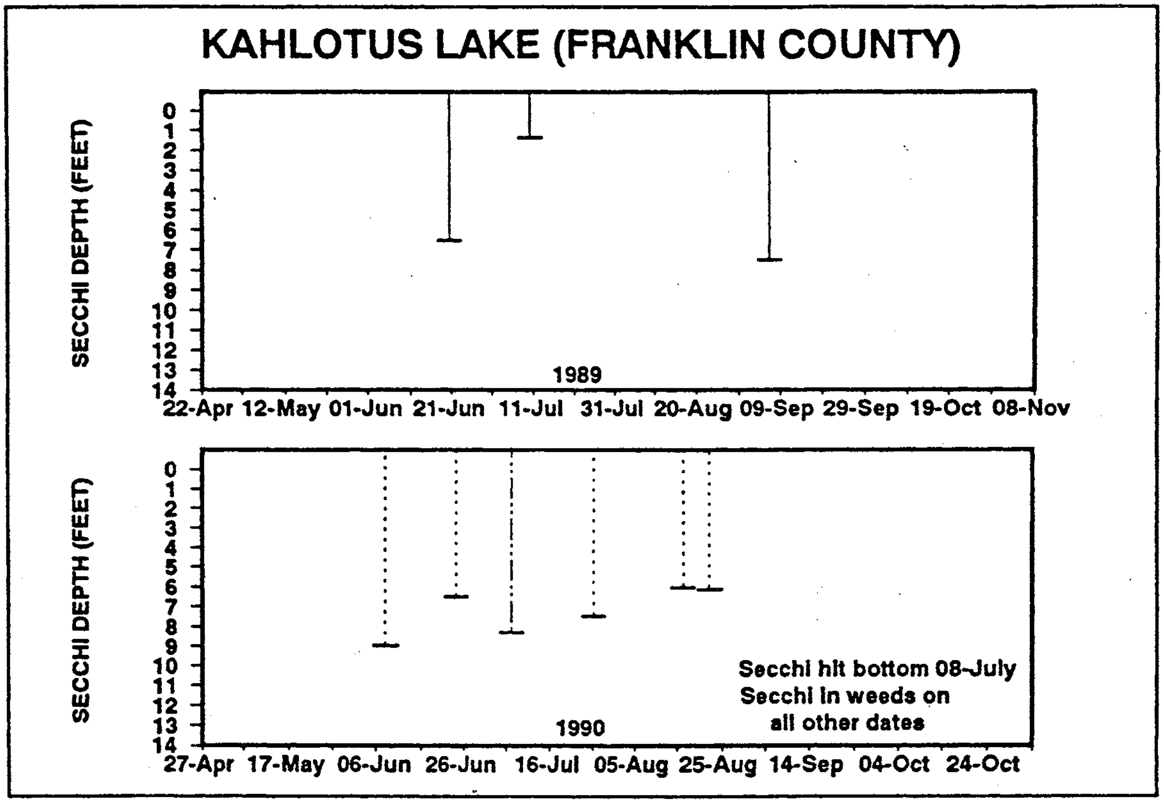
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
09-Jun	20.0	68.0	8.5	Lt-Green	50	Moderate	Light	8.7 w	114.0	Cool weather this spring has retarded algae bloom somewhat.
25-Jun	22.2	72.0	8.0	Lt-Green	0	None	Light	6.4 w	112.0	Heavy plant growth with some algae bloom.
08-Jul	22.8	73.0	9.0	Lt-Green	0	None	Light	8.1 b	106.0	Lake height 8'10". Low fishing activity due to difficult mobility because of heavy plant growth. Lake bottom clearly visible.
27-Jul	21.1	70.0	9.0	Lt-Green	0	Moderate	Light	7.3 w	96.0	Difficult rowing to test area due to plant growth. Algae bloom starting again - very little open water.
17-Aug	20.6	69.1	10.0	Gr-Brown	25	None	Light	6.0 w	96.0	Water color light green/light brown. Plant growth is turning brown for majority of the area - algae bloom scattered.
23-Aug								6.1		

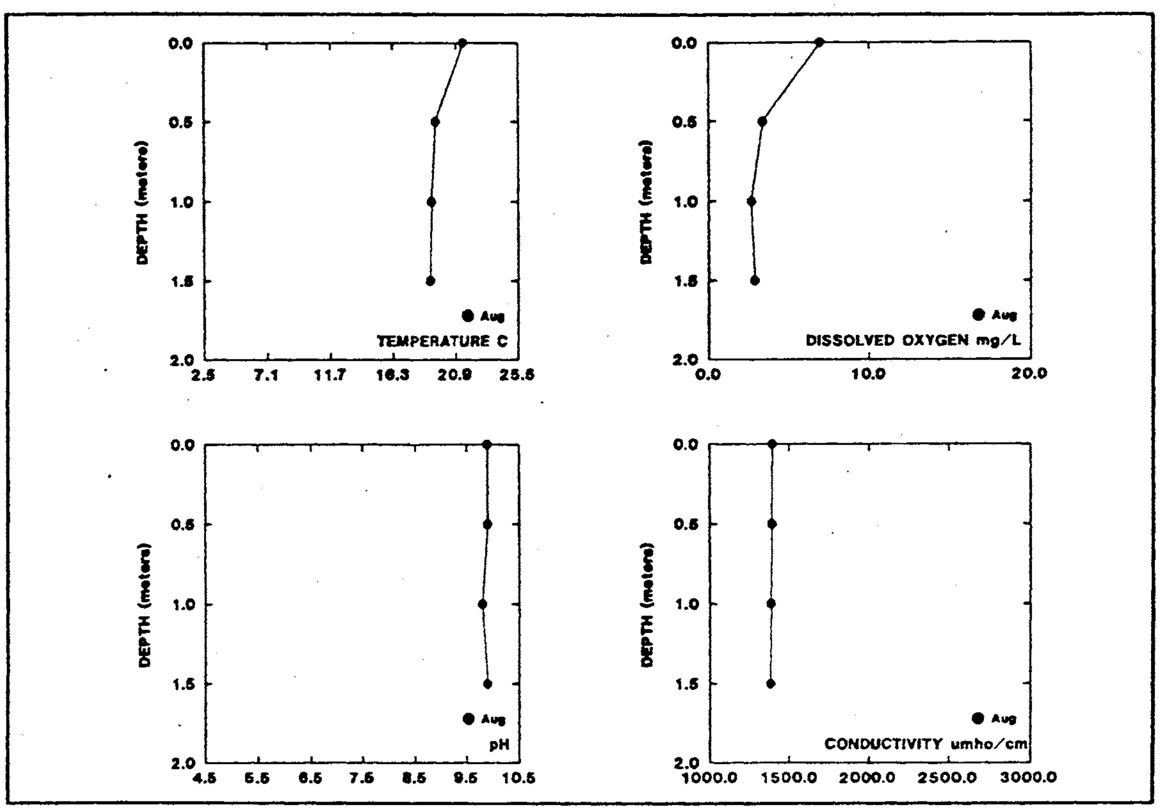
* Secchi data corrected for rope shrinkage
w Secchi disk in weeds
b Secchi disk hit bottom

Onsite Visit Data

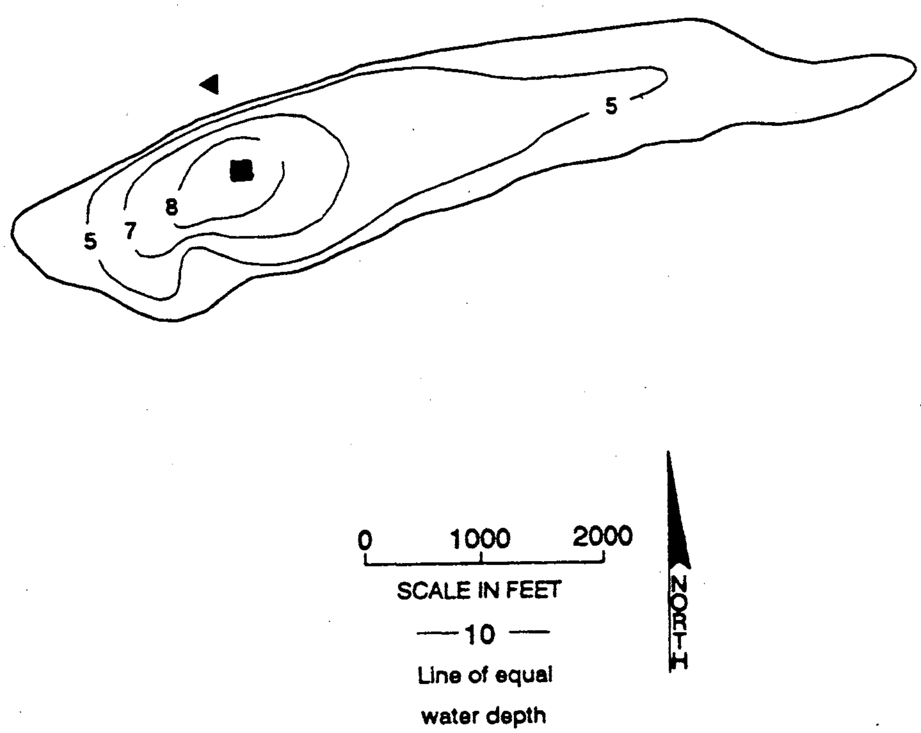
Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
08/23	0.0	21.5	9.9	7.0	1397	0.25	0.172	3.020
	0.5	19.4	9.9	3.4	1392			
	1.0	19.1	9.8	2.7	1387			
	1.5	19.0	9.9	2.9	1385			

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



Lake Kahlotus - Franklin County

Digitized From Washington Department of Game, July, 1954.

Lake Killarney -- King County

Lake Killarney is located 3.5 miles from Auburn. It drains via Hylebos Creek to Commencement Bay. The volunteer sampled the south arm of the lake; physical characteristics listed below are for the south arm only.

Size (acres)	24
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

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	49**
Trophic State Index* (Total Phosphorus):	58

* From Carlson (1977)
** See Comments section

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Killarney is used for fishing, swimming, and rowing. Recreational facilities on the lakeshore include one boat ramp, and there is a speed restriction of 8 mph for motorboats. Lake water is withdrawn for irrigation. Currently the watershed is used for lakeshore development. In the past, the watershed was used for logging and the shoreline was altered. There are 70 houses on the lakeshore. All are occupied year-round, and the lakeshore is about 50% sewered. There are no storm drains that empty into the lake. Trout are stocked in the lake. Presently there is a lake association and an improvement association for the lake. The lake has been chemically treated in the past to control weeds and algae, and the lake will be treated this year to control lilies, pondweed and algae. The worst problems in the lake, in the opinion of the volunteer, are ranked as 1) sediment, 2) aquatic plants, 3) floating debris, 4) floating islands that pop up from lake bottom as lily pads and roots decompose, and 5) water level. Overall, the volunteer finds that Lake Killarney has good recreational water quality, and that plant and algae control contribute to the quality of the water. The volunteer also suggested that Lake Killarney is basically a drainage lake with very little water exchange, and that this adds to the problems in the lake.

There is a lake improvement group, and most residents voluntarily pay $75.00 per year to have the lilypads and weeds controlled with chemicals. Most of the aquatic plants grow in 0-10 feet of water; lily pads are localized in cove areas. Emergent plants grow only on the north side of the north basin.

Lake Killarney -- King County

Monitoring Results/Summary of Other Available Information

Secchi data were very similar during both 1989 and 1990. During both years, water clarity was lowest from late June through July. Profile data show that during June the concentration of dissolved oxygen decreased near the lake bottom. This decrease is most likely from the bacterial decomposition of organic material, such as plants and algae, in the water and sediments. The decrease in pH and the slight increase in conductivity near the lake bottom is most likely related to increased decomposition near the bottom of the lake.

The 1990 concentration of total phosphorus in the water (0.0426 mg/L) was very high, and suggests that the lake may be eutrophic. The concentration of total nitrogen in the water (0.450 mg/L) was moderately high. In comparison, nutrient data collected in 1973 (Bortleson *et al.*, 1976) show that concentrations of total phosphorus and total nitrogen (0.022 and 0.15 mg/L, respectively) were much lower in 1973 (although still in the mesotrophic range) than in 1990. During both 1973 and 1990, the ratio of total nitrogen to total phosphorus was relatively low (11:1 in 1990), and suggest that algae growth in Lake Killarney may possibly be nitrogen-limited.

Eurasian water milfoil (*Myriophyllum spicatum*) was successfully eradicated from Lake Killarney with sonar, an aquatic herbicide (K. Hamel, pers. comm.).

Comments

During both 1989 and 1990 the Secchi data were borderline between mesotrophy and eutrophy. However, the relationship between lake level and water clarity shown with the 1989 data suggest that the water clarity of Lake Killarney may be affected more by suspended sediments than algae growth. As a result, the trophic state estimation is based on the concentration of total phosphorus in the lake, which is clearly in the eutrophic range. Only six of the 74 lakes monitored for the program in 1990 had higher concentrations of total phosphorus than Lake Killarney.

The floating islands that surface from the lake bottom are carried up by gases released during the decomposition of organic material at the bottom of the lake. While these floating islands may be a nuisance, they are not that common in lakes and are interesting to lake ecologists. At Eloika Lake in Spokane County, large floating islands of lake bottom eventually supported wetland vegetation and are now used as waterfowl habitat (Soules, 1990). Floating islands were also noted in 1989 at Big Meadow Lake in Pend Oreille County, but were not noticed by the volunteer in 1990.

Acknowledgement

I thank Paul DesJardin for volunteering his time to monitor Lake Killarney during 1989-1990.

Lake Killarney -- King County

Volunteer-Collected Data

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
02-Jun	18.0	64.4		Dk-Brown	100	Heavy	Light	8.3**	15.3	Lake height measured from top of dock to water.Lake is darker brown this spring (more algae?).
12-Jun	18.0	64.4	6.5	Dk-Brown	75	Heavy	Strong	7.3	12.5	Lake height measured from top of dock. Total lake depth 13 feet to bottom. Lake level rising from heavy rains this spring.
14-Jun								7.3		
28-Jun	23.0	73.4	6.5	Gr-Brown	100	Light	Light	6.4	15.5	Lake height measured from top of dock.
14-Jul	27.0	80.6	6.5	Lt-Green	0	None	Light	5.3	18.5	Lake height 13'. Lake level 18.5" from top of dock.
30-Jul	26.0	78.8	6.5	Lt-Brown	0	None	Calm	5.3	22.5	Several sunny warm days before readings.
16-Aug	25.0	77.0	6.5	Lt-Brown	25	Trace		6.9	26.7	Had a trace of rain on the 17th.
02-Sep	22.0	71.6	6.5	Lt-Brown	0	Light	Calm	7.8	28.5	Lots of rain last two weeks.
15-Sep	20.0	68.0	6.5	Lt-Brown	100	None	Calm	6.9	22.0	
05-Oct	15.5	59.9	6.0	Lt-Brown	10	Heavy	Light	7.3	33.0	Strong winds last few days.
16-Oct	13.0	55.4	6.3	Lt-Brown	10	Moderate	Calm	8.7	32.3	

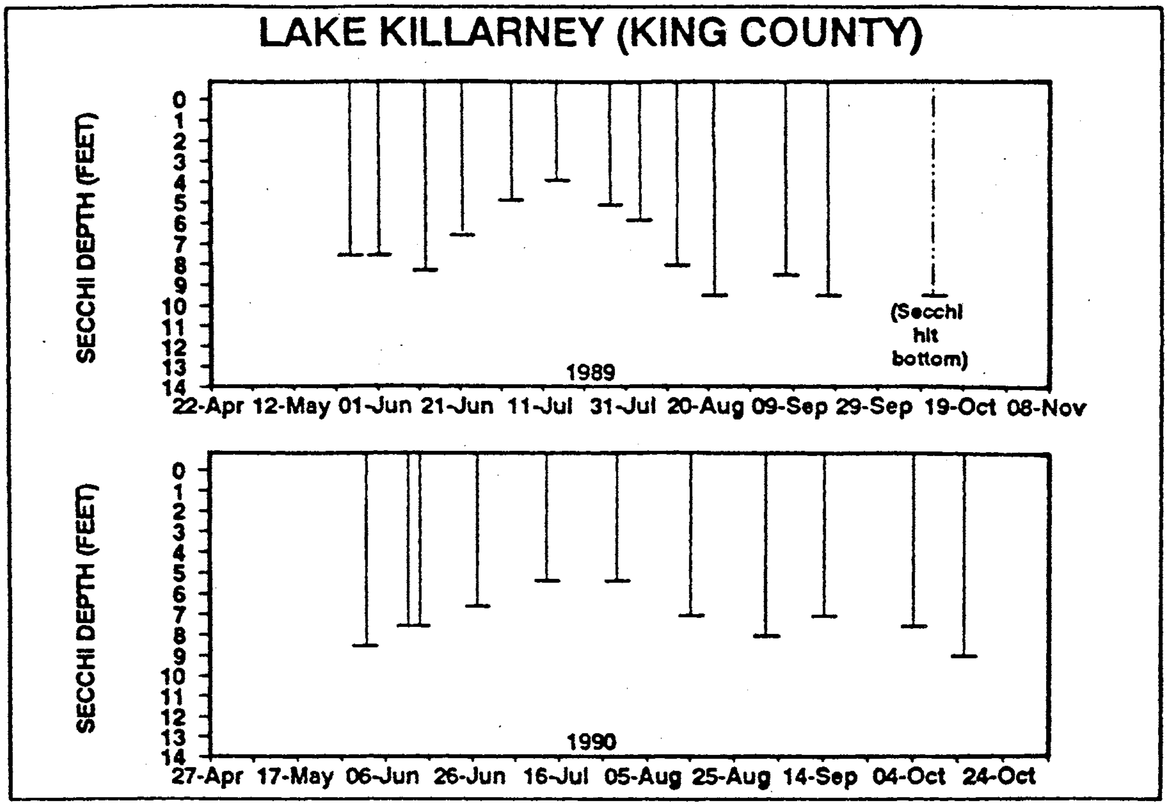
* Secchi data corrected for rope shrinkage

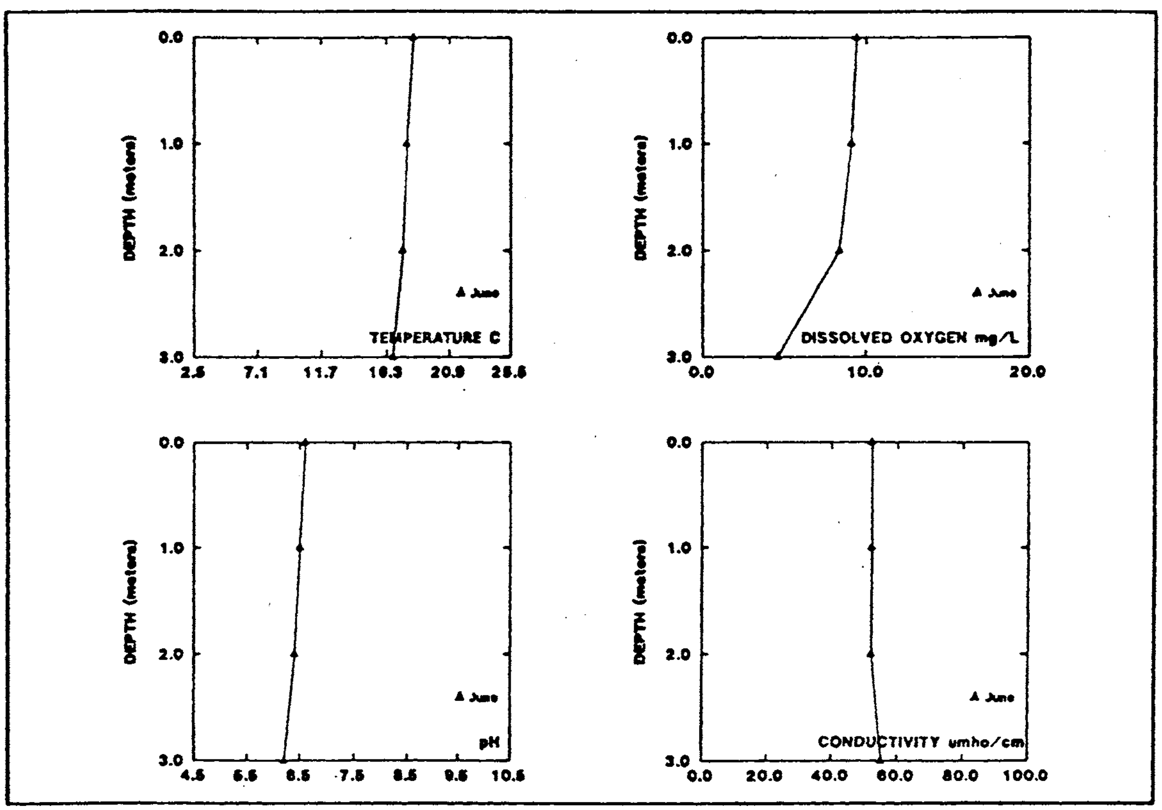
** There was high variability between the first and second Secchi depths; this data pont may not be used in data comparisons

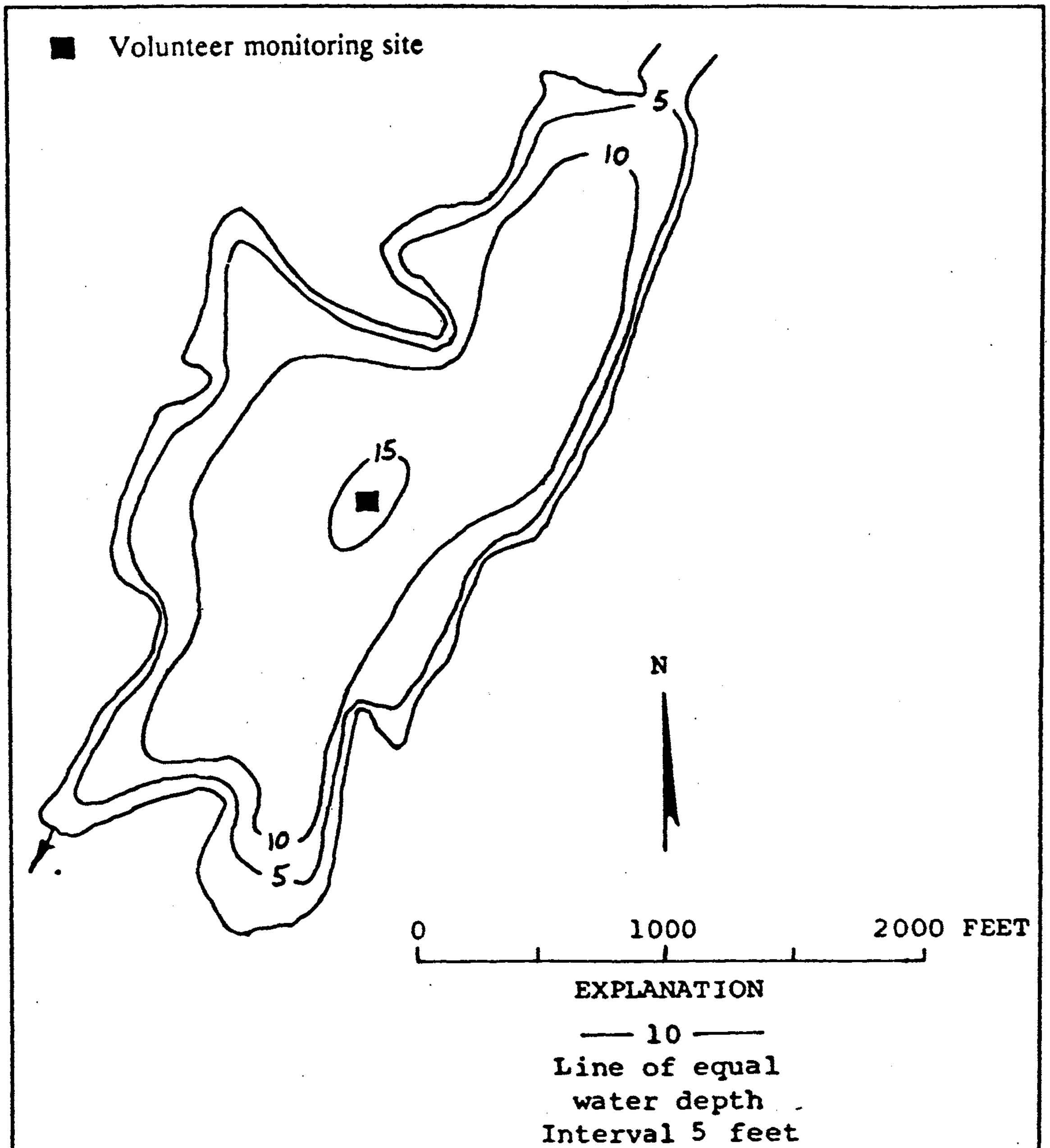
Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/14	0.0	18.3	6.6	9.4	52	1, 2	0.043	0.450
	1.0	17.8	6.5	9.1	52			
	2.0	17.5	6.4	8.4	52			
	3.0	16.8	6.2	4.6	55			

Secchi Depth and Profile Data Graphs







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

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)	4500
Drainage Area (miles^2)	2.7
Altitude (feet)	156
Shoreline Length (miles)	2.7

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Sechhi):	**
Mean Trophic State Index* (Total Phosphorus):	51

* From Carlson (1977)
** See Monitoring Results section

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Kitsap Lake is used for fishing, boating, swimming, rowing, jet skiing, and seaplanes. Recreational facilities on the lakeshore include a park and a picnic area. 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, animal grazing, and lakeshore development. In the past, the watershed was used for logging, crop agriculture, and mining, and the shoreline was altered. There are 109 houses on the lakeshore; all are occupied year-round. The lakeshore is 50% sewered, and there are 15 storm drains that empty into the lake. Rainbow trout are stocked in the lake. Presently there is a neighborhood association and an environmental association for the lake. The lake has been chemically treated in the past to control fish species. The worst problems in the lake, in the opinion of the volunteer, are 1) occasional high fecal coliform bacteria counts, 2) aquatic plants, 3) sediment, 4) algae, and 5) floating debris. Overall, the volunteer finds that Kitsap Lake has good recreational water quality, and suggested that water quality in the lake may be affected by failing septic systems. The 1989 volunteer also suggested that lake quality may be affected by storm drains, septic tanks on the east (unsewered) side of the lake, motor oil and gasoline from power boats, and sediment runoff from gravel pits near the south end of the lake. Submerged plant growth was noted to cover the lake bottom in up to 15 feet of water.

The following are volunteer's comments attached to the 1990 questionnaire:

- The lake is developed completely for residences, except for the south end where there is a city wildlife refuge, and the west end, which houses the Navy's Camp McKean. The east end of the lake was logged about three years ago for residential development. Silt from the clearing was very evident in the lake. There is an extensive wetland at the south end of the lake where there are a lot of lilypads. Weeds grow to the surface of the lake as far as 50 feet from shore in places. Plant growth in the lake has increased dramatically in the last year. Also, there was a large algae bloom in the fall of 1989.

- The volunteer reports a dramatic decrease in the mallard population over the last two years. Wildlife observed in the vicinity include (but are not limited to) osprey, bald eagles, blue heron, muskrat, kingfisher, otter, and pileated woodpeckers. Since improvements to the city park on the lake were made two years ago, use of the lake by boaters has increased tremendously, as has littering.

- Most people (the volunteer has talked to) are concerned about failing septic systems, weed growth, and heavy boat traffic. Public awareness is gradually increasing regarding problems in water quality resulting from the use of pesticides, herbicides and fertilizers. More information needs to be distributed regarding water quality and how residents can help maintain good quality through proper septic tank maintenance, landscaping practices, etc.

Monitoring Results/Summary of Other Available Information

There are not enough Secchi data from 1990 to evaluate trophic status or patterns in algal growth. Profile data collected during May and September 1990 show that on both sampling dates the lake was not stratified with respect to temperature, and concentrations of dissolved oxygen decreased somewhat with depth. At the surface, the pH was unusually high and the conductivity was unusually low. In 1989, Secchi data indicated that the lake was oligotrophic. However, the total phosphorus data collected in 1990, which is usually a more reliable indicator of trophic status, indicates that the lake is more mesotrophic than oligotrophic. The lake may have been mesotrophic for some time, since total phosphorus data collected in 1971 (20 μg/L; Bortleson *et al.*, 1976) and 1981 (30 μg/L; Sumioka and Dion, 1985) showed concentrations characteristic of mesotrophic lakes.

During the September 1990 onsite visit with the volunteer, plants observed in the lake were mostly pondweeds (*Potamogeton* spp.); however, yellow-flowering lily (*Nuphar polysepalum*) and yellow iris (*Iris psuedacorus*) were also observed.

Kitsap Lake was one of 15 lakes sampled by Ecology in 1990 as part of a statewide lakes survey to supplement the volunteer-collected data. Data collected from this survey confirm that Kitsap Lake was mesotrophic (Coots, 1991). Chlorophyll *a*, considered to be the most reliable of the three trophic state parameters, also showed that the lake was more mesotrophic than oligotrophic (Coots, 1991). Other mesotrophic characteristics of the lake were the presence of blue-green algae species during June, when a moderate surface algae bloom was observed, and moderately prolific submerged aquatic plant growth in the lake (Coots, 1991). The low ratio of total nitrogen to total phosphorus indicates that the growth of algae in the lake may be limited by the amount of nitrogen in the water, rather than the amount of phosphorus.

Kitsap Lake -- Kitsap County

There has been a moderate increase in residential development along the lakeshore; a 1971 survey reported that there were 90 nearshore homes (Bortleson *et al.*, 1976).

Comments

In 1989, Kitsap Lake appeared to have unexpectedly good water clarity despite the mean depth of the lake and its location in an urbanized area. The 1990 data, though, suggest that the amount of plant and algae growth in the lake is at expected levels, considering the moderately high concentrations of total phosphorus. Continued lake management to minimize the amount of direct runoff into the lake may help to slow the rate of eutrophication of Kitsap Lake.

Acknowledgement

I thank Randena Schaap for volunteering her time to monitor Kitsap Lake during 1990, and Bruce McCaughan, for monitoring the lake in 1989.

Kitsap Lake -- Kitsap County

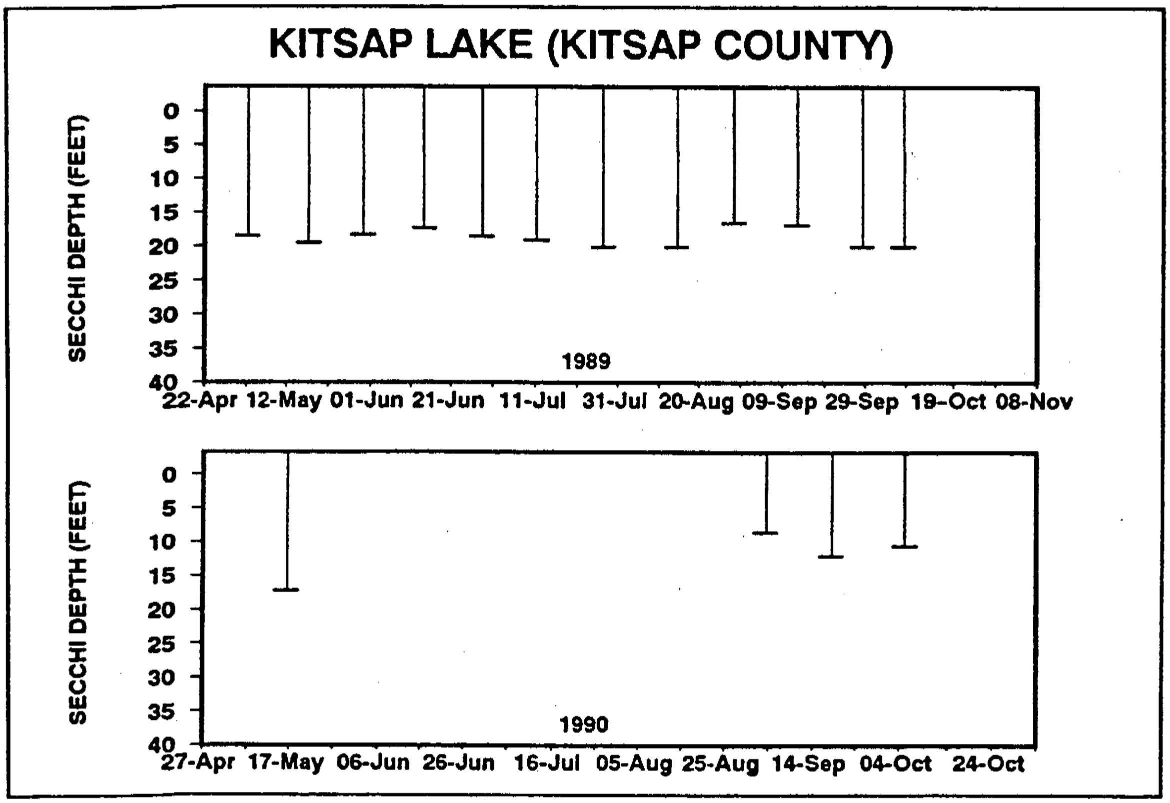
Volunteer-Collected Data

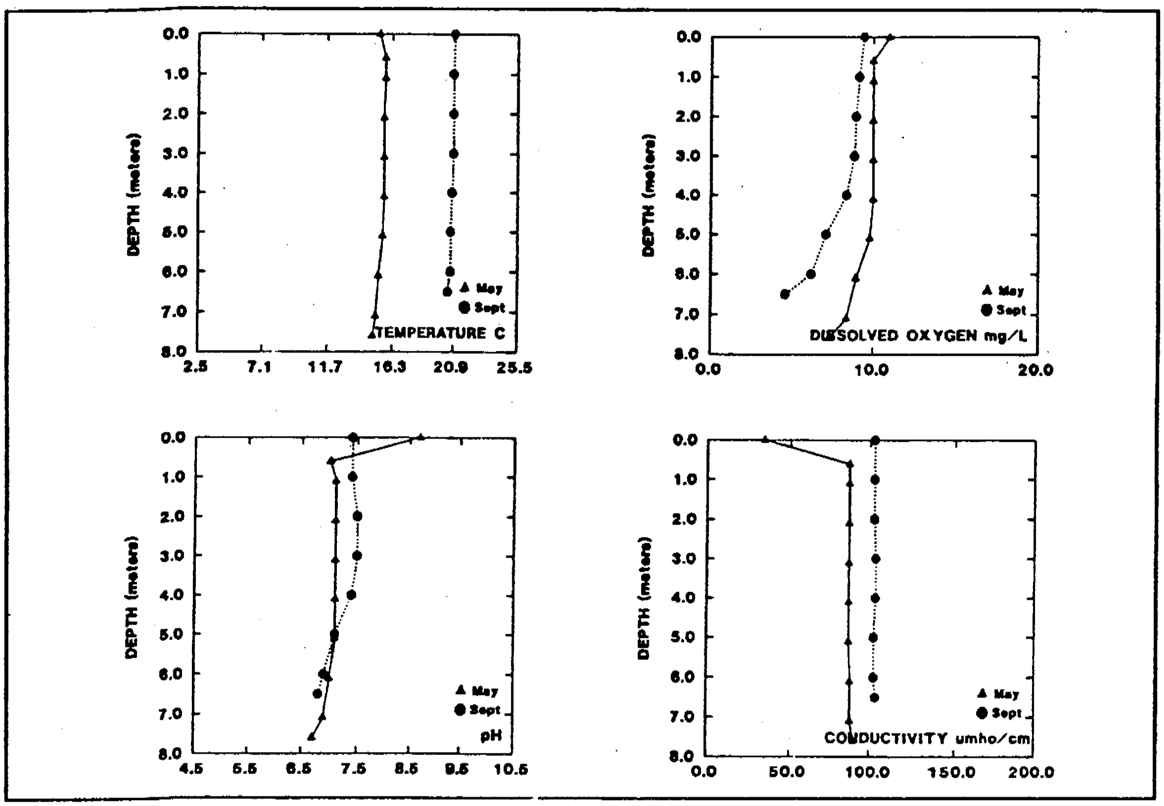
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
17-May	16.5	61.7	6.5	Clear	90	Trace	Strong	17.4	31.0	Average winter high water in lake is 2'4" below dock top. Lake height measurement above is measured below top of dock.
also 04-Sep	21.1	70.0	7.0	Olive-Gr	0	None	Light	9.3		Reading taken with Julie.
19-Sep	21.1	70.0	6.5	Pea-Green	10	Trace	Light	12.7	22.5	
06-Oct	16.7	62.1	6.5	Yellow-Gr	25	Moderate	Calm	11.3	21.5	Lots of suspended algae, free floating and in patches on the surface.

Onsite Visit Data

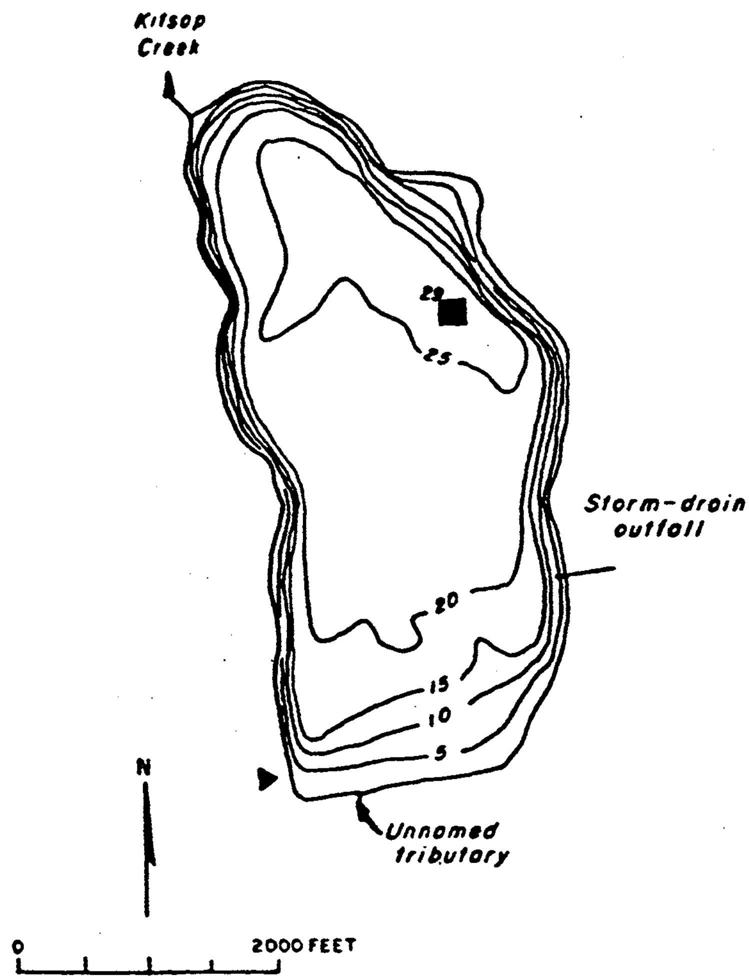
Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/23	0.0	15.4	8.7	11.0	.	0.5, 2, 5	0.018	0.234
	0.6	15.8	7.0	10.0	87			
	1.1	15.8	7.1	10.0	87			
	2.1	15.7	7.1	10.0	87			
	3.1	15.7	7.1	10.0	87			
	4.1	15.7	7.1	10.0	87			
	5.1	15.6	7.1	9.8	87			
	6.1	15.3	7.0	8.9	88			
	7.1	15.1	6.9	8.3	88			
	7.6	14.9	6.7	7.2	90			
09/04	0.0	21.0	7.4	9.4	103	1, 3, 6	0.035	0.439
	1.0	20.9	7.4	9.1	103			
	2.0	20.9	7.5	8.9	103			
	3.0	20.9	7.5	8.8	104			
	4.0	20.8	7.4	8.3	104			
	5.0	20.7	7.1	7.0	103			
	6.0	20.7	6.9	6.1	103			
	6.5	20.5	6.8	4.5	104			

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



EXPLANATION

——10——

Line of equal
water depth
Interval 5 feet

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

Lacamas Lake -- Clark County

Lacamas Lake is located one mile north from Camas. It is formed by two dams in Lacamas Creek at Round Lake. Including Round Lake, it is three miles long. It 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)	7489
Drainage Area (miles^2)	64.3
Altitude (feet)	179
Shoreline Length (miles)	5.3

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	54
Mean Trophic State Index* (Total Phosphorus):	55

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. 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, and there are no restrictions for motorboat use on the lake. Lake water is withdrawn for industrial use. Currently the watershed is used for logging, animal grazing, crop agriculture, and lakeshore development. Grazing animals have direct access to inlet tributaries, and animal wastes from agriculture drain into the inlet tributaries. In the past, the watershed was used for logging, animal grazing, and crop agriculture, and the shoreline was altered. There are approximately 15 houses on the lakeshore, and all are occupied year-round. The lakeshore is 90% sewered, and there are storm drains that empty into the lake. Brown trout are stocked in the lake. Presently there is a lake association. The worst problems in the lake, in the opinion of the volunteer, are ranked as 1) quality of inlet water from livestock operations, 2) algae, 3) water odors, and 4) aquatic plants. Overall, the volunteer finds that Lacamas Lake has poor recreational water quality, and suggested that water quality in the lake may be affected by livestock wastes. The volunteer is also concerned about possible water quality effects from substantial residential development occurring within the watershed.

The shoreline is completely covered with submerged weeds to a depth of ten feet. There are wetland areas on each end of lake; lily pads cover much of the area near the southern wetland. The volunteer noted that there are days when the lake is not suitable for swimming due to poor lake quality.

In 1989, the volunteer reported that a feasibility study determined that 97% of the enrichment of the lake water was due to agricultural practices in the watershed, and it was recommended that phosphorus loading to the lake be reduced by 84% in order to decrease algal growth in the lake. As a result, best management practices to control runoff from animal wastes were being implemented.

Monitoring Results/Summary of Other Available Information

Compared with Secchi data collected in 1989, the average water clarity in Lacamas Lake was somewhat better in 1990. During 1990, algae growth in the lake was not as severe or persistent as in 1989. Water clarity during both years was lowest in late August through early September. Profile data from 1990 show that concentrations of dissolved oxygen decreased sharply with depth; during August, dissolved oxygen was completely depleted in the bottom 13 meters (about 43 feet) of the lake. The low dissolved oxygen concentrations most likely result from bacterial decomposition of organic matter (such as algae and aquatic plants) in the water and sediments.

The 1990 concentrations of total phosphorus were high in both the May and August samples, and clearly show that the lake was eutrophic. However, the 1990 total phosphorus concentrations were lower than concentrations measured in 1981 (0.100 mg/L; Sumioka and Dion, 1985) and 1974 (0.047 mg/L; Bortleson *et al.*, 1976). The concentration of total nitrogen was extremely high in May 1990, and was much higher than concentrations measured in either 1981 or 1974. Because total nitrogen was not high during August, the high May concentration may have resulted from a runoff event.

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

The Intergovernmental Resource Center (IRC) will begin monitoring Lacamas Lake in the near future (J. Lafer, pers. comm.).

Comments

Considering the size and mean depth of Lacamas Lake as compared with other lakes monitored for the program in 1990, the lake quality of Lacamas Lake is poor. The history of animal wastes entering the inlets of the lake has enriched the lake considerably, so that it supports a large amount of plants and algae.

Lacamas Lake -- Clark County

The water clarity of Lacamas Lake is very poor compared with other lakes monitored for the program in 1990; only four lakes (out of 74 monitored lakes) had worse overall water clarity. However, the concentrations of total phosphorus in the lake were not as high as some other lakes; thirteen lakes had higher mean concentrations of total phosphorus than Lacamas Lake.

Acknowledgements

I thank Jan and Judy Baldwin for volunteering their time to monitor Lacamas Lake during 1989-1990.

Lacamas Lake -- Clark County

Volunteer-Collected Data

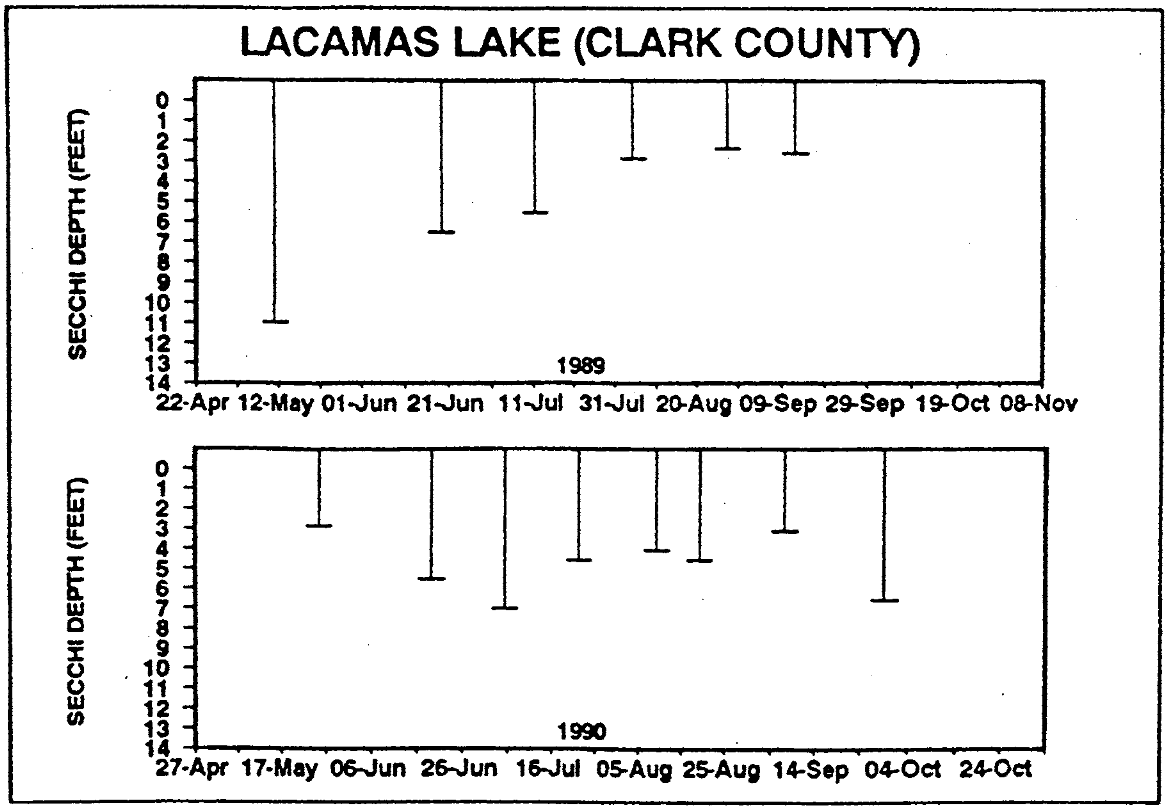
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(ft)	Abbreviated Comments
26-May	17.8	64.0	6.5	Pea-Green	75	Trace		2.98	62.0	
20-Jun	17.2	63.0	6.5	Pea-Green	10	None	Light	5.50		
06-Jul	18.3	65.0	7.0	Green	0	Moderate	Breezy	6.87		Algae starting to be visible, lake is starting to smell. Lake height 6" above average.
23-Jul	20.6	69.0	6.5	Green	25	None	Breezy	4.58		
10-Aug	26.7	80.0	8.0	Green	0	None	Breezy	4.12		Algae starting to bloom.
20-Aug	22.2	72.0	7.0	Pea-Green	10	Light	Calm	4.58		
08-Sep	18.3	65.0	7.5	Pea-Green	75	Light		3.21		Smelly.
30-Sep	17.2	63.0	8.0	Pea-Green	10	None	Light	6.42		

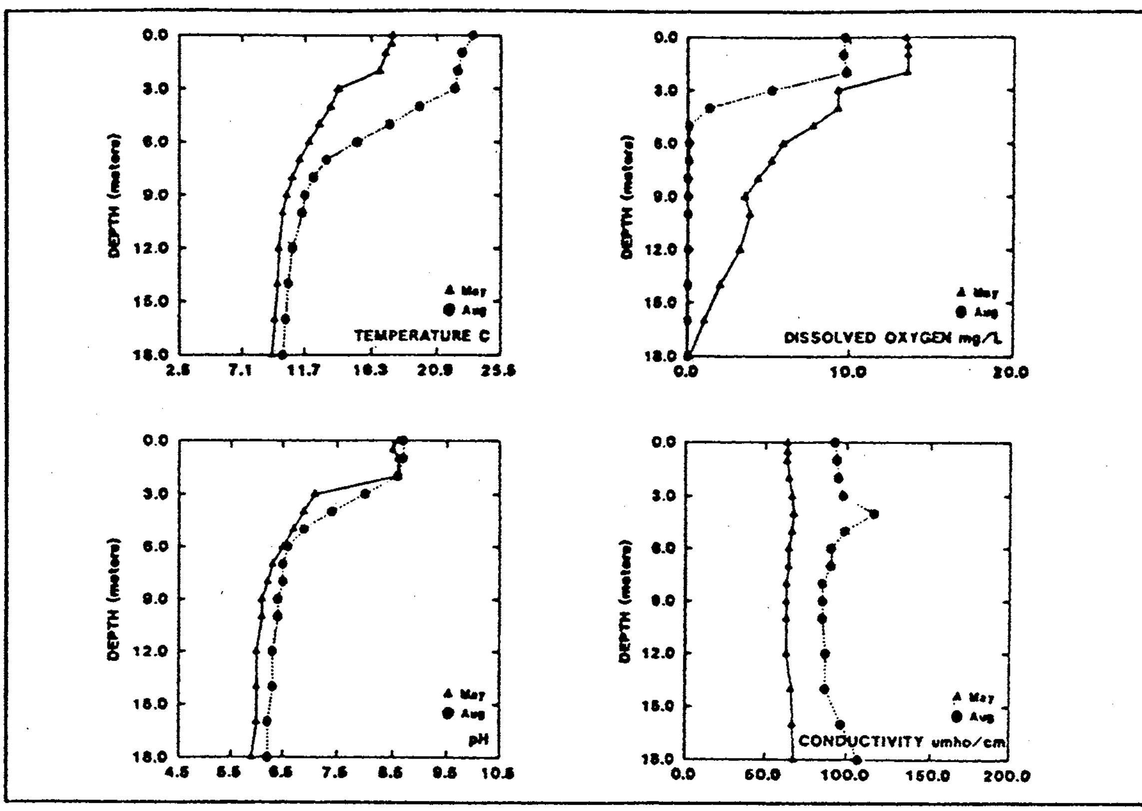
* Secchi data corrected for rope shrinkage

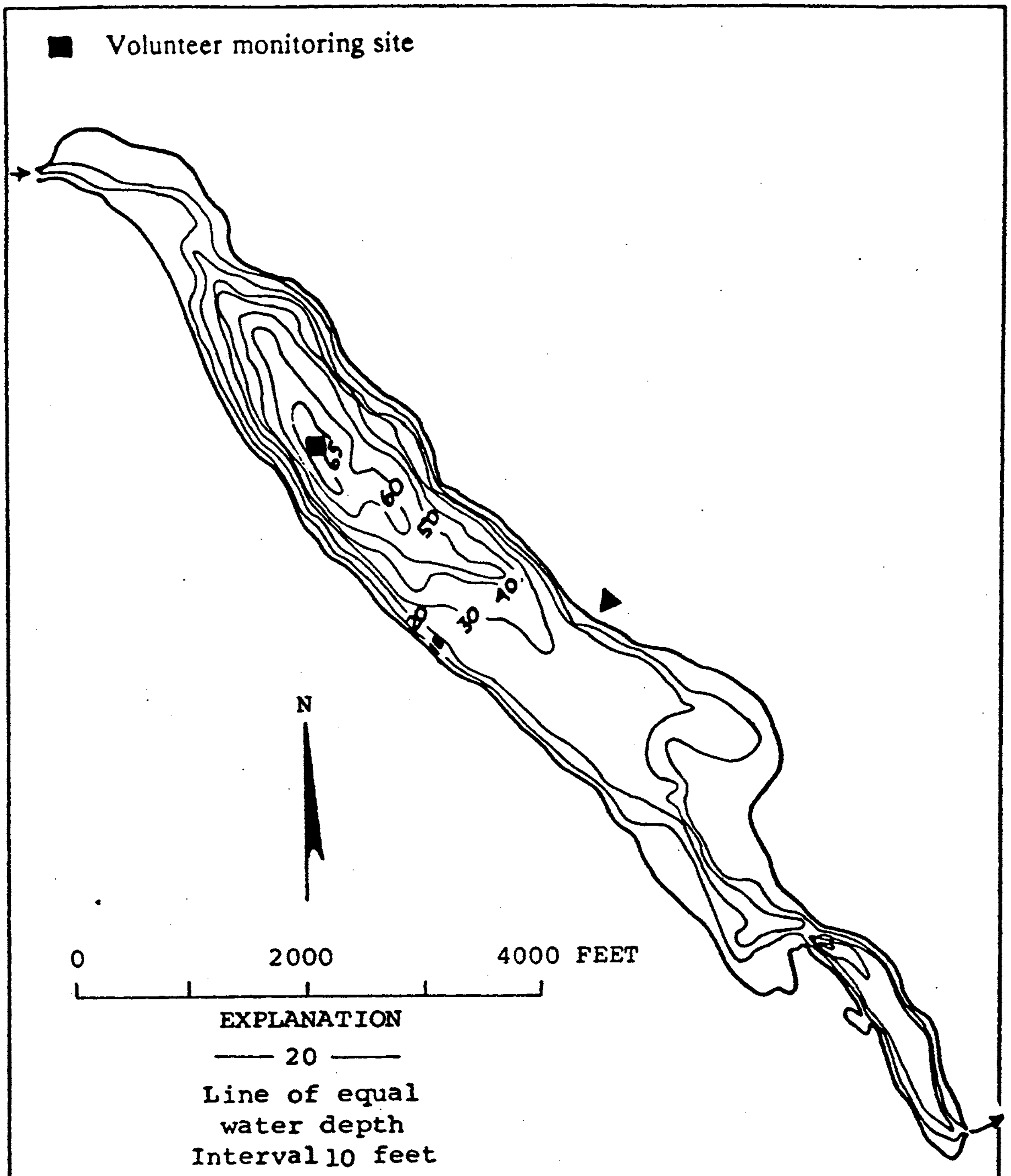
Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/26	0.0	17.8	8.6	13.3	64	0.5, 2	0.037	3.29
	0.5	17.7	8.5	13.4	64			
	1.0	17.3	8.6	13.4	64			
	2.0	16.9	8.6	13.4	65			
	3.0	14.0	7.1	9.3	67			
	4.0	13.5	6.9	9.3	68			
	5.0	12.7	6.7	7.8	67			
	6.0	12.0	6.5	5.9	65			
	7.0	11.3	6.3	5.2	65			
	8.0	10.8	6.2	4.4	64			
	9.0	10.4	6.1	3.6	64			
	10.0	10.1	6.1	3.9	64			
	12.0	9.8	6.0	3.3	64			
	14.0	9.7	6.0	2.1	67			
	16.0	9.5	6.0	1.1	68			
	18.0	9.3	5.9	0.2	69			
08/20	0.0	23.5	8.7	9.7	93	1, 2, 3	0.032	0.780
	1.0	22.7	8.7	9.6	94			
	2.0	22.4	8.6	9.8	95			
	3.0	22.2	8.0	5.2	98			
	4.0	19.7	7.4	1.4	116			
	5.0	17.6	6.9	0.1	99			
	6.0	15.3	6.6	0.1	91			
	7.0	13.2	6.5	0.1	91			
	8.0	12.3	6.5	0.0	86			
	9.0	11.7	6.4	0.0	86			
	10.0	11.5	6.4	0.0	86			
	12.0	10.8	6.3	0.0	88			
	14.0	10.5	6.3	0.0	88			
	16.0	10.3	6.2	0.0	97			
	18.0	10.1	6.2	0.0	107			

Secchi Depth and Profile Data Graphs







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

Leech Lake -- Yakima County

Leech Lake is located on White Pass on the Cascade Crest, adjacent to the north side of State Highway 12. It is fed principally by surface runoff and groundwater, and drains east to the South Fork of Clear Creek and the Tieton River.

Size (acre)	41
Maximum Depth (feet)	15
Mean Depth (feet)	*
Lake Volume (acre-feet)	*
Drainage Area (miles^2)	*
Altitude (feet)	4412
Shoreline Length (miles)	*

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

* Information not available
** From Carlson (1977)
*** See Comments Section

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Leech Lake is used for fly fishing and camping. Recreational facilities on the lakeshore include a picnic area, a camping area, and one boat ramp, and no combustion engines are allowed on the lake. There are no houses on the lakeshore. Fish were not reported as being stocked in the lake. The worst problems in the lake, in the opinion of the volunteer, are 1) aquatic plants, 2) algae, and 3) water level. Overall, the volunteer finds that Leech Lake has fair recreational water quality, and is concerned that there is prolific milfoil growth in the lake which may affect fish populations.

There are 52 condominiums in the watershed; all are connected to a sewer system. The entire lake is ringed with horsetails, and milfoil grows in the southern part of the lake.

Monitoring Results/Summary of Other Available Information

Profile data collected with the volunteer during June and August 1990 show that on both sampling dates the temperature was low and stable throughout the water column. Concentrations of dissolved oxygen were stable during June, but during August the concentrations increased from the surface to the bottom. This increase was probably caused by the prolific submerged plant growth in the lake, which releases oxygen in the water as a byproduct of photosynthesis. The increase in pH with depth during August may also be related to photosynthesis. The concentration of total phosphorus was in the mesotrophic range, although the concentration of total nitrogen was low relative to the concentration of total phosphorus.

Leech Lake -- Yakima County

Leech Lake is one of 15 lakes sampled by Ecology during 1990 as part of a statewide lakes survey that supplemented volunteer-collected data. Survey results show that although the concentrations of nutrients in Leech Lake were moderate, indicating mesotrophy, the concentration of chlorophyll *a* was very low, indicating that there was very little algae growth in the lake (Coots, 1991). Low amounts of algae growth may have occurred because the concentration of nitrogen was low relative to the concentration of total phosphorus; that is, algae growth could have been limited by the low amount of nitrogen in the water. The prolific plant growth in the water could also affect the amount of algae in the water, by out-competing the algae for available nutrients and/or sunlight.

From Washington Department of Game (1951): Leech Lake was shallow, and had thick vegetation over the bottom of the lake. "As vegetation grows it reduces the acreage of the lake and thus reduces the ability of the lake to support many fish." The lake was shown to be up to 15 feet deep at the west end, and reed growth was prolific along the south side.

Bacteriological samples collected from the lake during January-February 1988, and April 1989, showed that of 14 samples collected from the lake, its inlets and outlet, 11 of the samples were considered unsatisfactory for drinking (State of Washington Department of Social and Health Services).

Comments

The trophic state index calculated from Secchi disk and chlorophyll *a* data does not accurately assess the trophic status of Leech Lake. The lake is too shallow to collect Secchi disk readings. Also, growth in the lake is primarily rooted plants, and algae growth is very low; consequently the 1990 concentrations of chlorophyll *a* were low. The concentration of total phosphorus, however, gives a better picture of the trophic state of the lake. Future estimates of trophic status should be based on concentrations of total phosphorus and physical characteristics of the lake.

The volunteer mentioned that the Myriophyllum growing in the lake was identified by the Department of Wildlife as Eurasian water milfoil (*Myriophyllum spicatum*). The samples collected and identified by Ecology did not seem to be *M. spicatum*, but rather the native species of milfoil. This question should be investigated further.

Acknowledgement

I thank Diana Posada for volunteering her time to monitor Leech Lake during 1989-1990.

Leech Lake -- Yakima County

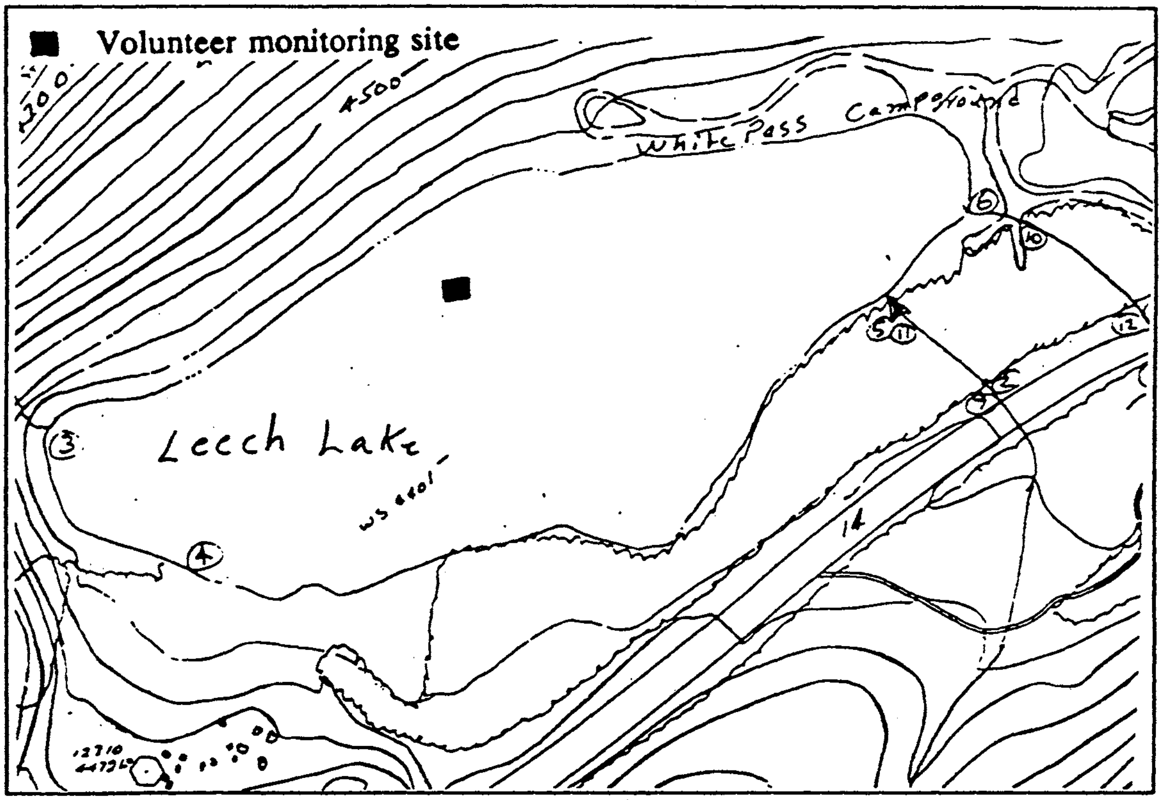
Volunteer-Collected Data

Date	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
07/11/89	17.0	62.6		Clear-Blue				7.0 b		Lake depth dropped 5" from 6/8/89 to now. Weed growth slower because of cold spring.
07/20/89	19.0	66.2		Clear-Blue				6.5 b		Weeds starting to grow on NW side and W side almost completely engulfed. There are more mallards this year.
08/11/89	19.0	66.2		Clear-Blue				5.5		Fish are smaller this year, averaging 9-10" down from 10-12" last year. Weeds are starting to really flourish. The project to clear weeds has begun.
09/07/89	19.0	66.2		Clear-Blue				5.5		Water level seems to have leveled off. The fish are very active. The weed pulling has seemed to help.
06/24/90	16.5	61.7		Clear-Blue				7.5 b		More ducks this year and one heron. Fish size continues on a downswing. Because of the late spring, the weeds have not started to grow.
07/09/90	18.0	64.4		Clear-Blue	25	None	Light	8.5 w		
07/16/90	17.5	63.5		Clear-Blue				7.0 b		Fish population too much for the lake. Fish are torpedo-shaped and continue to decrease in size. Milfoil and horsetails starting to grow.
08/04/90	19.0	66.2		Clear-Blue				5.5		Numerous people on lake - we are hosting a fly fishing fair. Fish averaging 10" with largest 12-13". Milfoil is horrible!

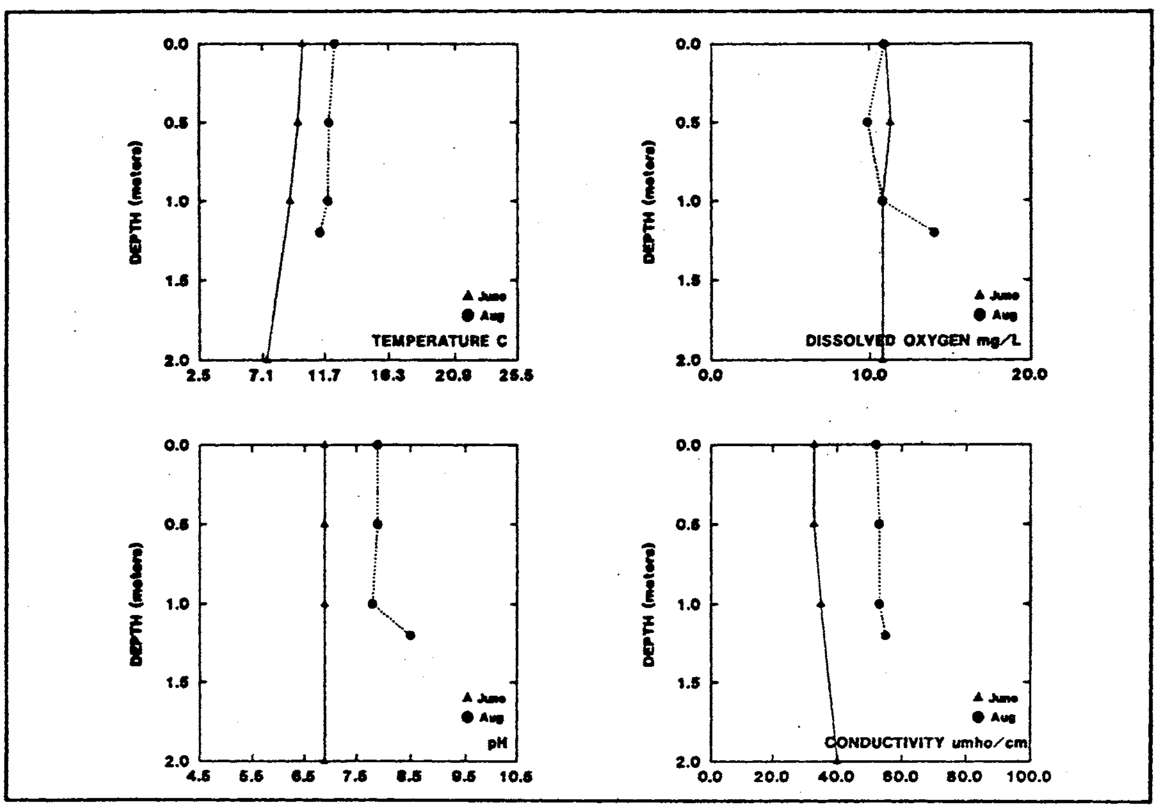
b Secchi disk hit bottom
w Secchi disk in weeds

Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/08	0.5	10.0	6.9	11.0	33	1.0	0.011	0.160
	1.0	9.7	6.9	11.3	33			
	2.0	7.4	6.9	10.8	40			
08/31	0.0	12.4	7.9	10.9	52	1.0	0.019	0.349
	0.5	12.0	7.9	9.9	53			
	1.0	11.9	7.8	10.8	53			
	1.2	11.3	8.5	14.0	55			



Volunteer monitoring site
4500
White Pass Campground
Leech Lake
3
4
5
6
10
11
12
14



DEPTH (meters)
0.0
0.5
1.0
1.5
2.0
▲ June
● Aug
TEMPERATURE C
2.5
7.1
11.7
16.3
20.9
25.5
DISSOLVED OXYGEN mg/L
0.0
10.0
20.0
pH
4.5
5.5
6.5
7.5
8.5
9.5
10.5
CONDUCTIVITY umho/cm
0.0
20.0
40.0
60.0
80.0
100.0

Lake Leo -- Pend Oreille County

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

Size (acre)	43
Maximum Depth (feet)	37
Mean Depth (feet)	17
Lake Volume (acre-feet)	740
Drainage Area (miles^2)	2.9
Altitude (feet)	3290
Shoreline Length (miles)	1.3

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index* (Secchi):	39
Mean Trophic State Index* (Total Phosphorus):	41

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Leo is used for fishing, swimming, and camping. Recreational facilities on the lakeshore include a camping area, a beach, and one boat ramp. There are no restrictions for motorboat use on the lake. Currently the watershed is used for logging and animal grazing. Grazing animals have direct access to the lakeshore or inlet tributaries. In the past, the watershed was used for logging and crop agriculture. There are no houses on the lakeshore. Cutthroat trout are stocked in the lake. The lake has been chemically treated in the past to control fish species. The worst problems in the lake, in the opinion of the volunteer, are 1) aquatic plants, 2) sediment, and 3) floating debris. The volunteer noted that the lake has no "unnatural" water quality problems, and that heavy rains during the spring affected the water clarity.

There are wetland areas near the public access, along the east shore of the lake, and near the island. Yellow-flowering lilypads (*Nuphar*) grow all along the wetland areas. So far, no algae blooms have been observed. Although small amounts of submerged weeds grow along the entire shoreline, the growth is sparse. The volunteer noted that the lake depth appears to have decreased over time; the 1950 map shows the lake is 35-37 feet deep, whereas now the lake is about 30-32 feet deep.

Monitoring Results/Summary of Other Available Information

Secchi data show that water clarity was lowest during May and June, and gradually increased throughout the summer. The Secchi readings, as well as the concentrations of total phosphorus and total nitrogen, indicate that the lake was oligotrophic but approaching mesotrophy. Data collected in 1972 (Dion *et al.*, 1976) show that the concentrations of total phosphorus (0.025 mg/L) and total nitrogen (0.39 mg/L) were higher than in 1990.

The 1990 profile data show that the concentration of dissolved oxygen in the lake decreased considerably from surface to bottom. This condition is more characteristic of mesotrophic and eutrophic lakes than oligotrophic lakes. The increase in conductivity from surface to bottom is most likely related to decomposition in the hypolimnion. Conductivity generally increases near a lake bottom when dissolved oxygen decreases. Iron and other minerals in the sediments are chemically reduced in the absence of oxygen and are released into the water column, resulting in increased conductivity.

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

Comments

Because the lake exhibits both oligotrophic and mesotrophic characteristics, the lake was classified as oligo-mesotrophic. Overall, the water quality of Lake Leo was very good compared to other lakes with similar physical characteristics. Compared with Thomas Lake, located downstream of Lake Leo in the Little Pend Oreille chain of lakes, Lake Leo had a somewhat higher concentration of total phosphorus but slightly better mean summer water clarity. Black Lake in Stevens County had the same mean summer water clarity as Lake Leo, and a slightly higher concentration of total phosphorus.

Acknowledgement

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

Lake Leo -- Pend Oreille County

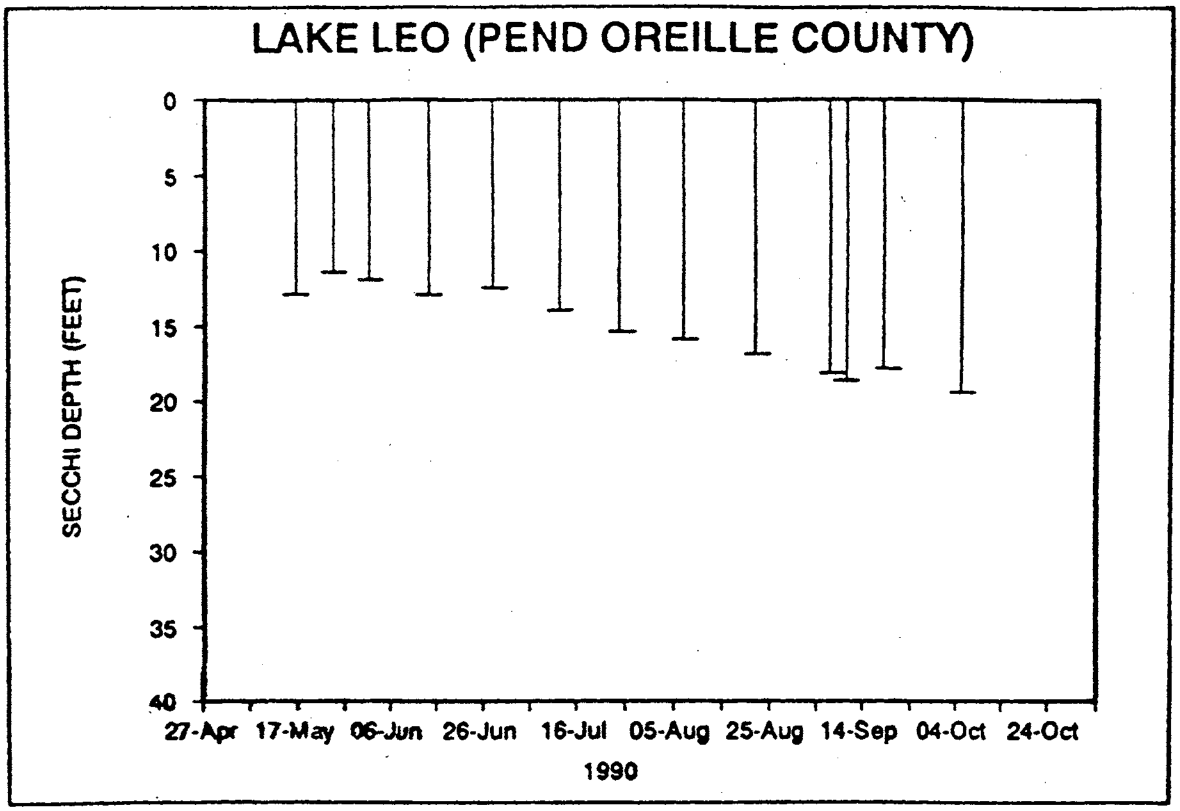
Volunteer-Collected Data

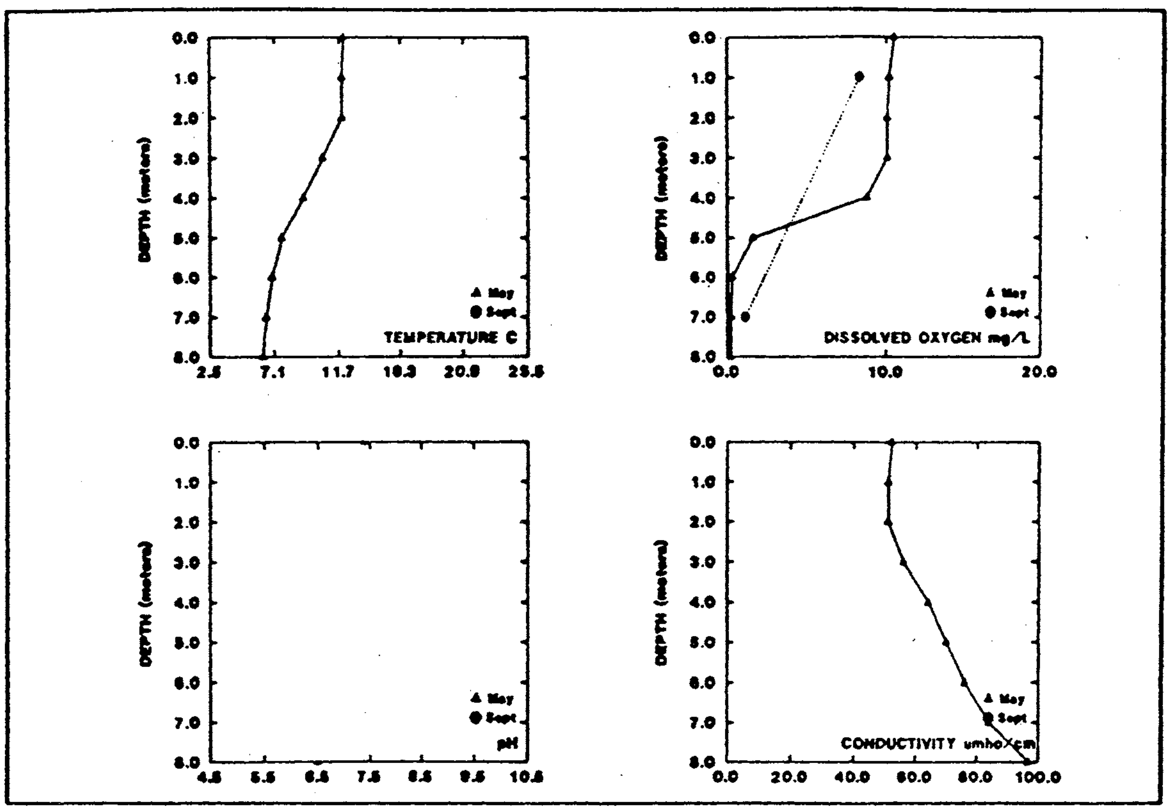
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
17-May	12.2	54.0	6.5	Pea-Green	90	Light	Calm	12.0	0.0	Lake height starting at zero from this date.
25-May								10.5		
02-Jun	11.7	53.0	7.0	Pea-Green	100	Heavy	Light	11.0	6.0	
15-Jun	15.6	60.0	7.0	Pea-Green	0	Light	Breezy	12.0	6.0	Lake height unchanged from last reading.
29-Jun	20.0	68.0	7.0	Pea-Green	0	None	Calm	11.5	3.0	
13-Jul	24.4	76.0	7.0	Lt-Green	0	None	Light	13.0	-3.0	
26-Jul	18.9	66.0	7.0	Lt-Brown	100	Heavy	Calm	14.5	-6.0	Ambient temperature 59 degrees. Record low.
08-Aug	23.3	74.0	7.0	Pea-Green	50	None	Light	15.0	-9.0	
23-Aug	19.4	67.0	7.0	Lt-Green	50	Light	Light	16.0	-9.0	
08-Sep	18.9	66.0	7.0	Lt-Green	10	None	Breezy	17.3	-12.0	
11-Sep								17.8		
20-Sep	16.1	61.0	7.0	Lt-Green	0	None	Light	17.0	-12.0	
06-Oct	11.7	54.0	6.5	Lt-Green	25	None	Breezy	18.5	-12.0	

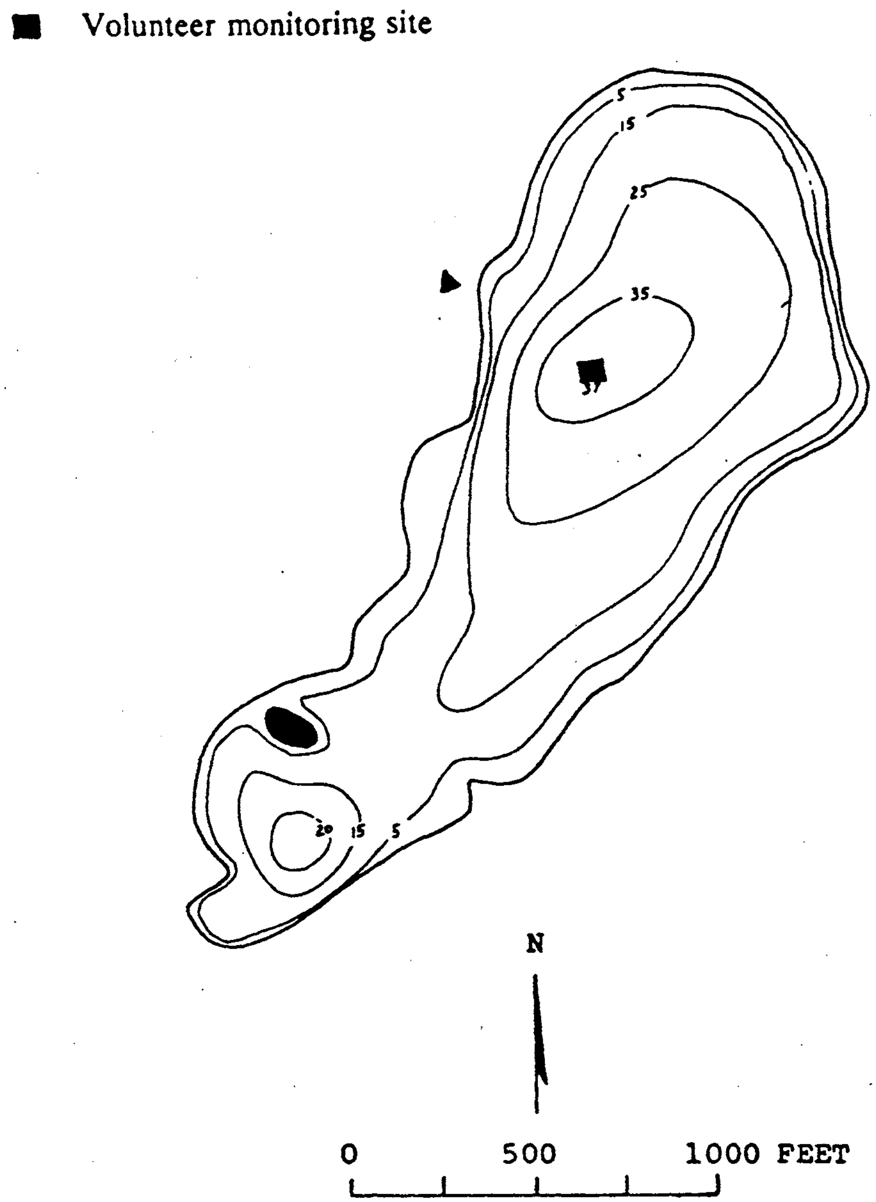
Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/25	0.0	12.0	7.4	10.5	52	0.5, 1, 2	0.012	0.267
	1.0	11.9	7.3	10.2	51			
	2.0	11.9	7.3	10.1	51			
	3.0	10.5	7.2	10.1	56			
	4.0	9.1	7.1	8.8	64			
	5.0	7.6	7.1	1.6	70			
	6.0	6.9	6.8	0.3	76			
	7.0	6.5	6.6	0.2	84			
	8.0	6.3	6.5	0.2	97			
09/11	1.0	.	.	8.3	.	1, 2, 3	0.013	0.288
	7.0	.	.	1.1	.			

Secchi Depth and Profile Data Graphs







EXPLANATION

—— 15 ——

Line of equal water depth Interval 10 feet

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

Liberty Lake -- Spokane County

Liberty Lake is located 15 miles east of Spokane. It is fed by Liberty Creek, and drains northwest to an irrigation canal and the Spokane River.

Size (acres)	710
Maximum Depth (feet)	30
Mean Depth (feet)	23
Lake Volume (acre-feet)	16,000
Drainage Area (miles^2)	13.3
Altitude (feet)	2,053
Shoreline Length (miles)	4.8

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index*:	37

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Liberty Lake is used for fishing, boating, swimming, rowing, jet skiing, and camping. Recreational facilities on the lakeshore include a park, a picnic area, a camping area, a beach, and one boat ramp. There are no restrictions for motorboat use on the lake. Currently the watershed is used for logging, industry, and lakeshore development. In the past, the watershed was used for logging, animal grazing, and crop agriculture. There are approximately 75 houses on the lakeshore; of these, 73 are occupied year-round. The lakeshore is fully sewered, and there are storm drains that empty into the lake. Trout are stocked in the lake. Presently there is a lake association and a sewer district for the lake. The lake has been chemically treated in the past to control algae and fish species. Management activities on the lake this year will include a water quality monitoring program. The worst water quality problem, in the opinion of the volunteer, is floating debris in the lake. Overall, the volunteer finds that Liberty Lake has good recreational water quality, and suggested that stormwater and lawn fertilizing may affect the water quality of the lake.

There is a wetland between the southern inlets (West Fork and East Fork of Liberty Creek). Yellow flowering lily (*Nuphar*) grows in these areas. Submerged plant growth is especially thick near the wetlands and along the west shore. There is residential development around the entire lake except near the marsh area.

The following information was provided by the 1989 volunteer. Alum was used in 1974 and 1980 to precipitate phosphorus from the water. Rotenone hasn't been used since 1974. Sometime in the past, the lake was dredged. There are wetland areas near the outlet. Submerged plants (*Potamogeton*, *Elodea*, and *Ceratophyllum*) cover the entire littoral area up to a depth of six meters. Lily pads (*Nuphar*) and cattails (*Typha* spp.) grow near the marsh at the south outlet. The lakeshore is completely residential except for the county park, a church camp and small areas southeast of Dreamwood Bay where steep slopes limit development. Three inlets receive stormwater runoff. These inlets are on the northwest side of the lake.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 showed that water clarity was better during June and July than during the same months in 1989. No Secchi readings were collected during August and September 1990, which are months when water clarity generally is lowest.

From Michael Kennedy Engineers (1986): Lake restoration included a restoration analysis, prerestoration water quality monitoring, construction of marsh flooding controls in 1979, dredging 21 hectares of lake bottom in 1980-1981, and whole-lake alum treatments in October 1980 and May 1981. The project concluded with two years of lake monitoring. A watershed management study complemented the in-lake work in 1982-85, and further marsh channel repairs in 1985 eliminated the major point where marsh waters entered the lake. New construction projects within the watershed now require a Stormwater Management Plan, which require approval by the Sewer District. The annual phosphorus load has decreased due to decreased inflow from the Liberty Creek Marsh and a decreased amount of phosphorus released from the lake sediments.

Comments

Both Liberty Lake and nearby Newman Lake had mean summer water clarity characteristic of oligotrophic lakes, but have had high total phosphorus concentrations that were characteristic of eutrophic lakes. It is encouraging that the restoration measures have improved the water quality of Liberty Lake; without restoration Liberty Lake would likely have had a considerably higher trophic state index value.

The restoration efforts have resulted in quite a success story for Liberty Lake. Prior to restoration, the lake was eutrophic with mats of blue-green algae, fish kills, and swimming beach closures. From 1983-1985, Carlson's (1977) trophic state index for all three trophic parameters (Secchi disk transparency, total phosphorus and chlorophyll *a*) decreased, indicating an improvement in water quality following restoration. Data from 1990 suggest further improvement in the quality of Liberty Lake.

Acknowledgements

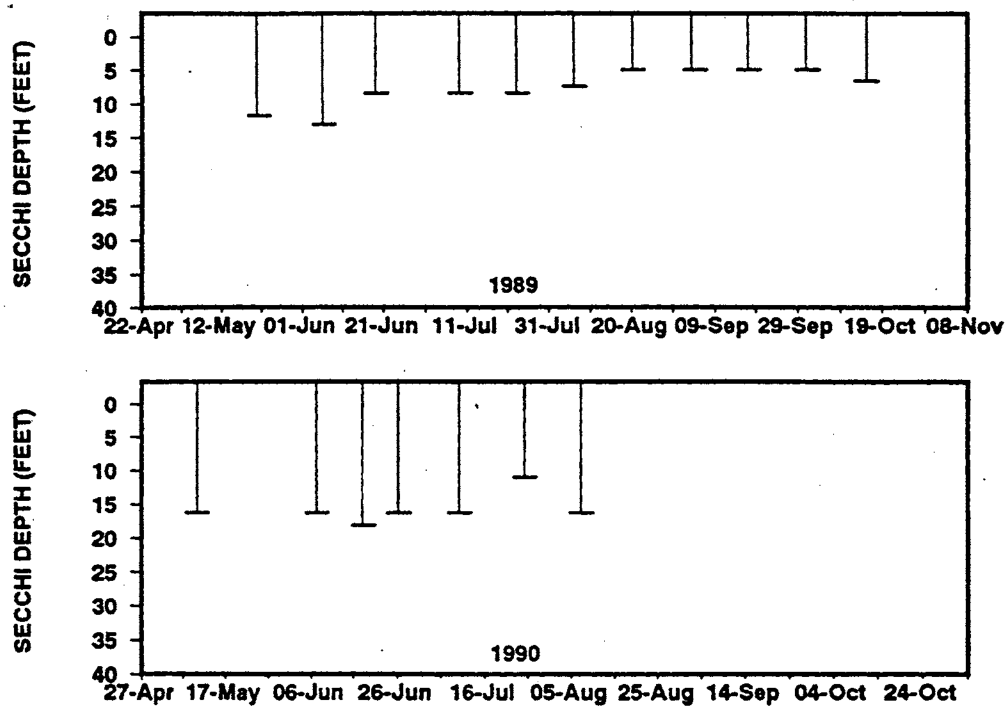
I thank Sue Kaun and Corrinne Mountjoy of Liberty Lake Sewer District #1 for coordinating the monitoring of Liberty Lake during 1989-1990.

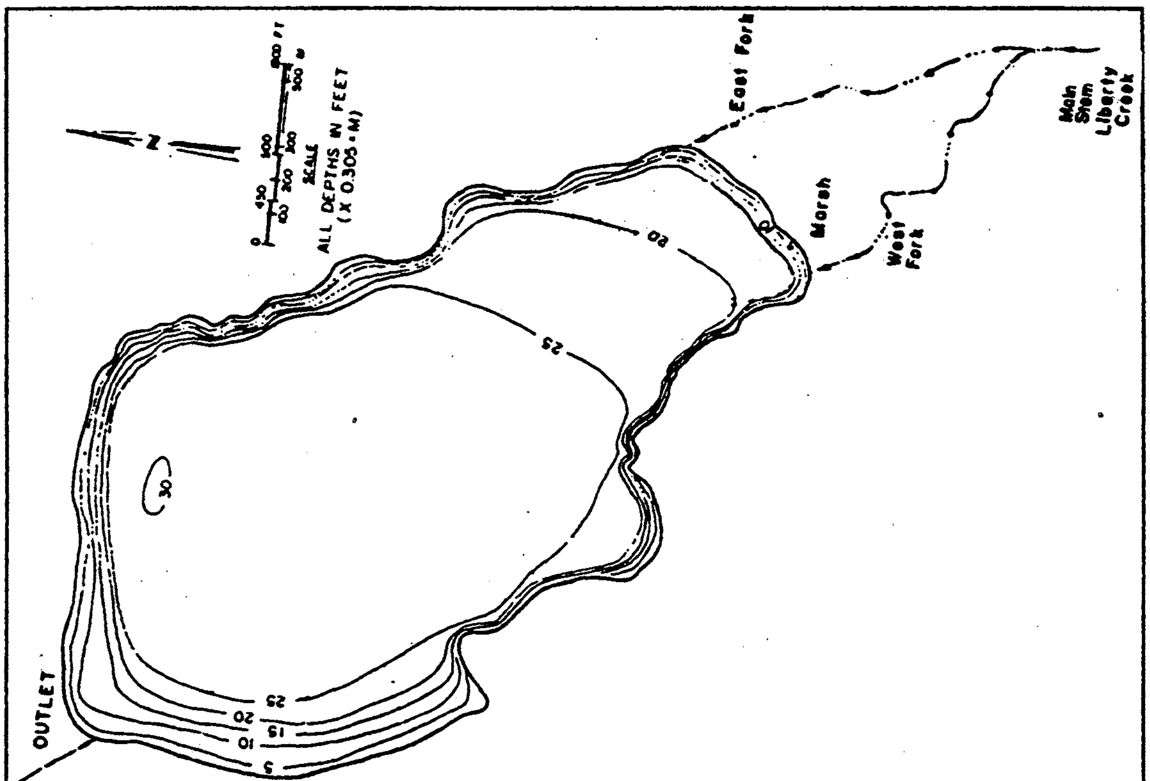
Liberty Lake -- Spokane County

Volunteer-Collected Data

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
11-May	11.0	51.8	7.2	Green	25			16.4		
08-Jun	15.0	59.0		Green	100		Calm	16.4		Raining.
19-Jun	18.0	64.4	7.7	Green	10	None	Light	18.1	49.6	
27-Jun	22.0	71.6	7.6	Green	0	None	Light	16.4	48.4	
11-Jul	23.0	73.4	7.4	Green	0	None	Calm	16.4	49.2	
26-Jul	21.5	70.7	7.0	Pea-Green	100		Light	11.5	48.9	
08-Aug			7.7	Green	10	None	Calm	16.4	48.7	

LIBERTY LAKE (SPOKANE COUNTY)





Lake Limerick -- Mason County

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

Size (acre)	129
Maximum Depth (feet)	24
Mean Depth (feet)	9
Lake Volume (acre-feet)	1210
Drainage Area (miles^2)	13.0
Altitude (feet)	220
Shoreline Length (miles)	4.4

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

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Limerick is used for fishing, boating, swimming and rowing. Recreational facilities on the lakeshore include a picnic area, a beach, and four boat ramps. There is a speed restriction of 30 mph for motorboats. Currently the watershed is used for lakeshore development. In the past, the shoreline was altered. There are approximately 140 houses on the lakeshore; of these, 70 are occupied year-round. The lakeshore is not sewered, and there are six culverts that empty into the lake. Salmon and rainbow trout are stocked in the lake. Presently there is a community association for the lake. The lake has been chemically treated in the past to control algae. The lake will be treated this year to control weeds and algae. Management activities on the lake this year will include mechanical aquatic plant removal, dredging, and lake level drawdown. The worst problems in the lake, in the opinion of the volunteer, are 1) aquatic plants, 2) algae, and 3) water level. Overall, the volunteer finds that Lake Limerick has good recreational water quality.

Weed growth is heavy in about 90% of the lake and a weed harvester is used on the entire lake. Lilies grow in the lake, mostly near the island. There are houses around the entire shoreline.

Monitoring Results/Summary of Other Available Information

Although there were variations in Secchi readings collected during 1990, there was no obvious pattern in water clarity. Overall, Secchi disk readings and concentrations of total phosphorus and total nitrogen indicate that Lake Limerick was mesotrophic. In contrast, data collected in 1974 show that although the concentration of total nitrogen was very similar in August 1974 and August 1990, the concentration of total phosphorus was somewhat lower (0.008 mg/L; Bortleson *et al.*, 1976) in 1974 than in 1990 (0.0151 mg/L). Also in 1974, it was reported that submerged "plants occurred in both thinly scattered and dense patches" (Bortleson *et al.*, 1976).

The profile data collected during May and August 1990 show that on both sampling dates the lake was stratified with respect to temperature. Concentrations of dissolved oxygen decreased with depth, and were completely depleted near the bottom of the lake. In contrast, in August 1974 the concentration of dissolved oxygen was moderately high from the surface (8.2 mg/L) to bottom (7.3 mg/L; Bortleson *et al.*, 1976). Dissolved oxygen is depleted by bacteria which decompose organic material (such as algae and aquatic plants) in the water and sediments.

The pH and conductivity in 1990 were probably affected by decomposition near the bottom of the lake as well; pH generally decreases with decreased concentrations of dissolved oxygen. Conductivity, on the other hand, generally increases near a lake bottom when dissolved oxygen decreases. Iron and other minerals in the sediments are chemically reduced in the absence of oxygen and are released into the water column, resulting in increased conductivity.

Comments

The 25th anniversary of the creation of Lake Limerick is in 1991. Because the lake was oligotrophic in 1974 and was mesotrophic (with some eutrophic characteristics) in 1990, it appears the quality of the lake has degraded considerably in a relatively short time, although additional monitoring is needed to confirm this. The rapid residential development of the lakeshore may have contributed to the rapid decline in lake quality. In 1974, there were only 24 nearshore homes (Bortleson *et al.*, 1976) compared with approximately 140 nearshore homes reported by the volunteer in 1990.

Although several lakes monitored for the program in 1990 were stabilized by dams, only two other lakes (Big Meadow Lake in Pend Oreille County and Horseshoe Lake in Cowlitz County) were artificial. Both of these lakes had higher concentrations of total phosphorus and moderate to poor water clarity. Plant growth is abundant in Big Meadow Lake, whereas algae blooms are more of a problem in Horseshoe Lake.

Trophic state indices calculated from Secchi disk data and total phosphorus data agree well. Secchi disk measurements appear to be a good indicator of Lake Limerick's trophic status.

Acknowledgement

I thank David Best and Bob King for volunteering their time to monitor Lake Limerick during 1990.

Lake Limerick -- Mason County

Volunteer-Collected Data

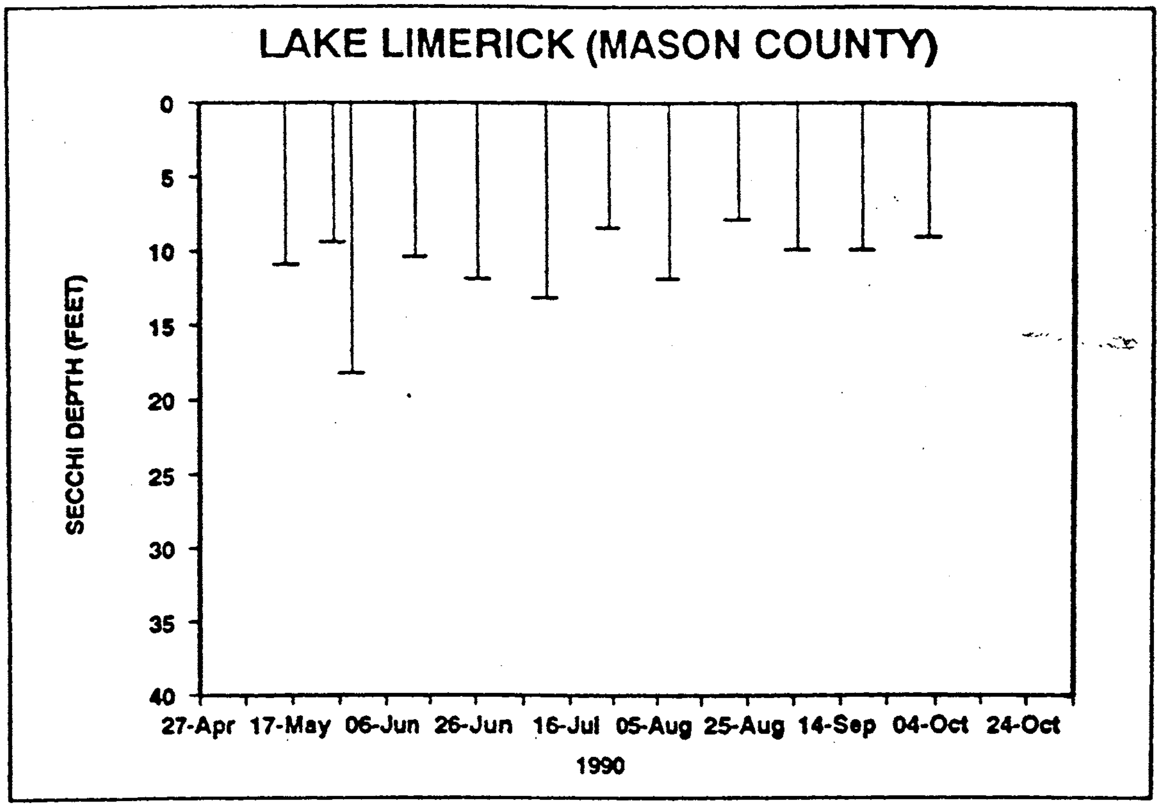
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
16-May	15.6	60.0	6.0	Yellow	90	None	Calm	10.0	7.7	
26-May								8.5		
30-May	17.2	63.0	6.3	Yellow	50	Moderate	Light	17.3	7.5	
13-Jun	17.8	64.0	6.0	Yellow	75	None	Calm	9.5	5.5	
27-Jun	17.8	64.0	6.0	Yellow	90	None	Light	11.0	5.3	
11-Jul	25.6	78.0	6.0	Clear		None		12.3	7.3	
25-Jul	23.3	74.0	6.0	Yellow	90	None	Light	7.5	7.7	
08-Aug	23.9	75.0	6.0	Yellow	50	None		11.0	7.7	
22-Aug								10.5		
23-Aug	21.1	70.0	6.5	Yellow	100	Light	Calm	7.0	6.7	
05-Sep	21.1	70.0	6.0	Yellow	0	None	Breezy	9.0	7.3	
19-Sep	19.4	67.0	6.0	Yellow	100	None	Calm	9.0	6.7	
03-Oct	17.8	64.0	6.0	Yellow	100	Light		8.1	7.1	Last reading for 1990. See you in '91.

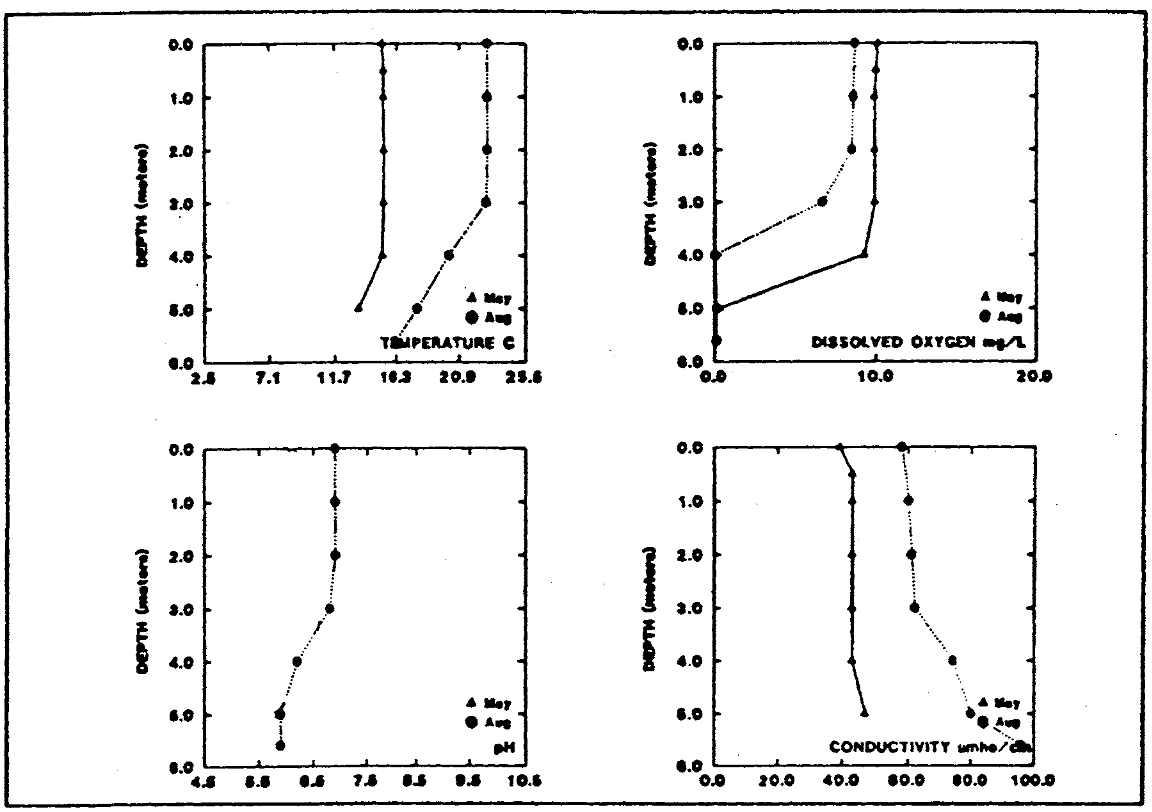
Onsite Visit Data

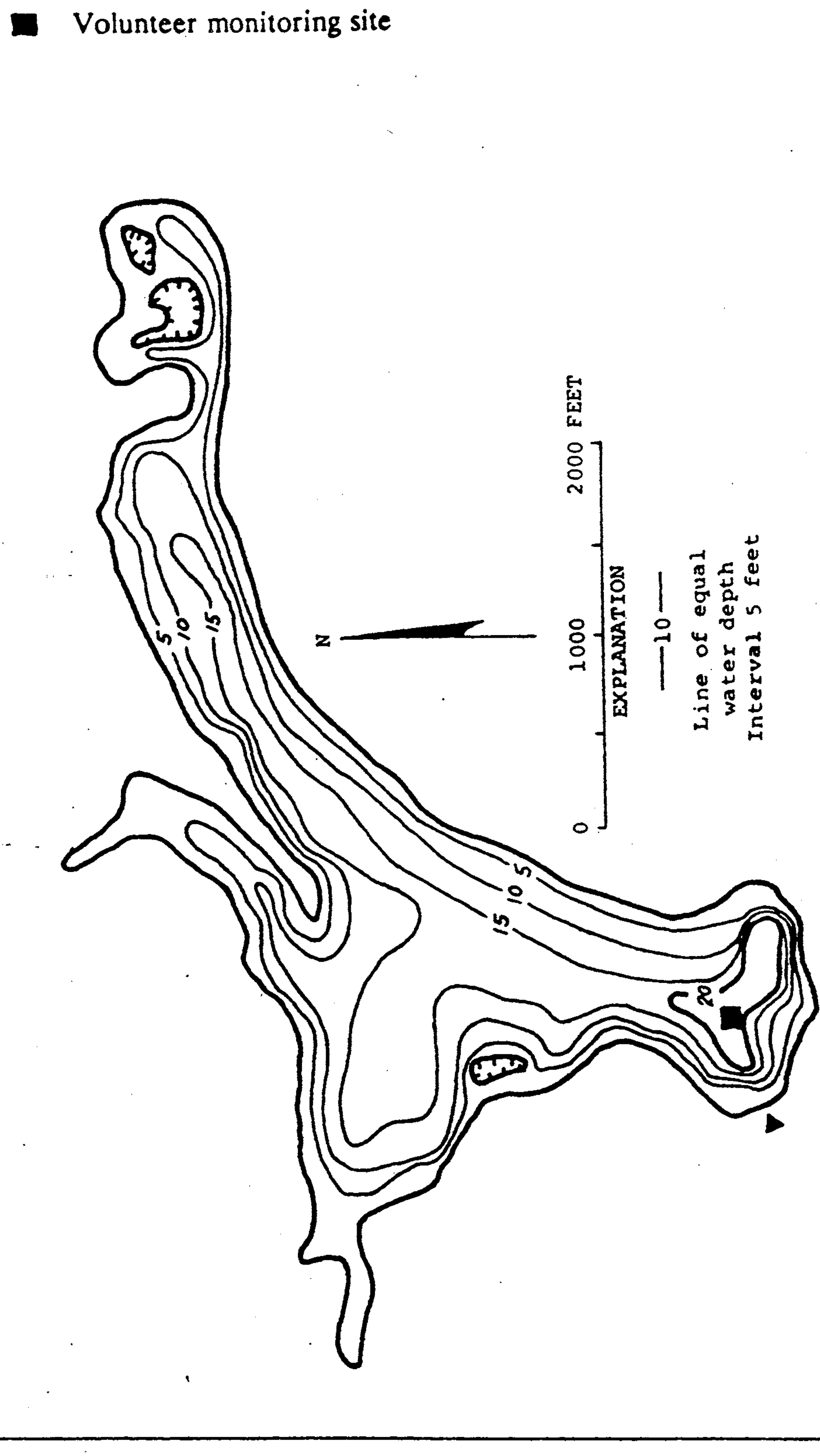
Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/24	0.0	15.2	.*	10.1	39	0, 2, 4	0.017	0.240
	0.5	15.3	.	10.0	43			
	1.0	15.3	.	9.9	43			
	2.0	15.3	.	9.9	43			
	3.0	15.3	.	9.9	43			
	4.0	15.2	.	9.3	43			
	5.0	13.4	.	0.3	47			
08/15	0.0	22.9	6.9	8.7	58	0.5, 1, 2	0.015	0.488
	1.0	22.9	6.9	8.6	60			
	2.0	22.9	6.9	8.5	61			
	3.0	22.8	6.8	6.7	62			
	4.0	20.2	6.2	0.0	74			
	5.0	17.9	5.9	0.1	80			
	5.6	16.3	5.9	0.1	96			

* See Quality Assurance section of this report.

Secchi Depth and Profile Data Graphs







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

Long Lake -- Kitsap County

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

Size (acres)	339
Maximum Depth (feet)	12
Mean Depth (feet)	6
Lake Volume (acre-feet)	2180
Drainage Area (miles^2)	9.4
Altitude (feet)	118
Shoreline Length (miles)	5.1

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	61
Mean Trophic State Index* (Total Phosphorus):	64

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Long Lake is used for fishing, boating, swimming, rowing, jet skiing, and camping. Recreational facilities on the lakeshore include a park, a picnic area, a camping area, a beach, and one boat ramp. There is a speed restriction of 8 mph for motorboats within 300 feet of the shore, docks, and swimming area. Currently the watershed is used for logging, animal grazing, and lakeshore development. Lake water is withdrawn for drinking. Grazing animals have direct access to the lakeshore or inlet tributaries. In the past,the watershed was used for logging and crop agriculture. There are 300 houses on the lakeshore; all are occupied year-round, and the lakeshore is not sewered. Fish were not reported as being stocked in the lake. Presently there is a community association for the lake. Kitsap County and the University of Washington have also been active in Long Lake issues. The lake has been chemically treated in the past to control weeds and algae. Management activities on the lake this year will include mechanical aquatic plant removal. The worst problems in the lake, in the opinion of the volunteer, are 1) aquatic plants, 2) algae, 3) sediment, and 4) water odors during algae blooms. Overall, the volunteer finds that Long Lake has good recreational water quality, and suggested that runoff from land clearing and construction may affect the water quality of the lake.

The volunteer noted that The Bremerton Sun reported there was swimmer's itch this year. However, according to the volunteer, the lake has always had swimmers itch but it must have been worse this year. Growth of submerged weeds, lilies, and algae is especially thick. On the south quarter of the lake (at the south inlet), algae and submerged macrophytes are also thick in the cove near the west inlet. There is a small wetland at the north end near the outlet. Seven inlets drain into the lake (some are really small).

Long Lake -- Kitsap County

In the 1989 questionnaire, the volunteer reported that in the past the shoreline was altered and the lake was dredged. Also, alum was used in 1975, 1976, and 1980. The volunteer is concerned that the lake does not flush completely, and that the county does not have very strict controls on storm and surface runoff and development.

Monitoring Results/Summary of Other Available Information

The Secchi data indicate that the average water clarity in Long Lake was worse in 1990 than in 1989. As in 1989, the volunteer noted in 1990 that algae blooms occurred during June and September. Profile data collected from Long Lake in 1990 show that the lake was not stratified during May and was only weakly stratified during August. In August, the concentration of dissolved oxygen decreased with depth. (Although it appears that there was no dissolved oxygen near the lake bottom, it is likely that the probe was resting on the sediments.) The concentration of dissolved oxygen was probably reduced by bacteria which decompose organic material (such as algae and aquatic plants) in the water and sediments. The decrease in pH and the increase in conductivity with depth is most likely related to decomposition near the lake bottom.

The 1990 concentrations of total phosphorus and total nitrogen were high on both sampling dates (averaging 0.06335 and 0.781 mg/L, respectively). In 1973, the concentration of total phosphorus was in the eutrophic range (0.041 mg/L) and the concentration of total nitrogen was high (0.50 mg/L), and mostly comprised of ammonia nitrogen (Bortleson *et al.*, 1976).

Both the Secchi data and total phosphorus data indicate that Long Lake was eutrophic in 1990. Another eutrophic characteristic of Long Lake was the very prolific growth of plants in the lake.

Researchers at the University of Washington proposed that the dense cover of plants (primarily *Elodea densa*) in Long Lake decrease the release of phosphorus from lake sediments by protecting sediments from wind mixing (Welch and Kelly, 1990). Rooted aquatic plants can be an important source of internal phosphorus loading because plant roots can retrieve phosphorus from lake sediments, and this phosphorus is released into the water column when the plants die and decay. However, by shielding the bottom layers of water from mixing with upper layers of water, the plant beds may trap phosphorus in bottom waters and may have prolonged the effectiveness of previous alum treatments. The lake was also drawn down in 1979 to reduce rooted aquatic plant populations (Welch and Kelly, 1990).

Comments

Long Lake was one of nine lakes monitored for the program in 1990 that had a mean depth of less than ten feet. Of these nine lakes, all except one (Lake Limerick in Mason County) had high concentrations of total phosphorus. As in 1989, there was a relationship between mean depth and trophic state. Shallower lakes generally had higher trophic states than deeper lakes. Long Lake is one of the shallowest lakes in the program, and had one of the highest trophic states of the monitored lakes.

Long Lake -- Kitsap County

Acknowledgement

I thank Wells Solden for volunteering his time to monitor Long Lake during 1989-1990.

Volunteer-Collected Data

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
23-May	16.7	62.0	6.0	Gr-Black	90	Light	Calm	4.7	154.0	Lake depth 12'10". Weed harvest started on May 7th! Some sediment floating and suspended in water; may be from weed harvesting?
12-Jun	16.7	62.0	6.5	Dk-Green		Light	Breezy	3.7	158.0	Lake depth 13'2". Bad weather-winds,rain, couldn't hold anchor late in testing! Weed harvest has worked only a few days due to bad weather.
19-Jun	21.1	70.0	6.5	Greenish	100	None	Calm	4.6	153.0	Lake depth 12'9". Lake color greenish. Lots of algae floating in water and in depth.
09-Jul	25.6	78.0	8.0	Pea-Green	0	None	Light	2.0	150.0	Water color: light pea-soup green. Lake depth 12'6".
03-Aug	25.6	78.0	7.5	Gr-Brown	0	None	Calm	3.1	150.0	Lots of water skiing and fishing. Lots of sediment floating in water. They are still cutting weeds.
01-Sep	20.0	68.0	7.5	Gr-Brown	75	None	Light	2.5	150.0	Lake depth 12.5 feet. Still water skiers, still cutting weeds.
26-Sep	20.0	68.0	6.5	Green	100	None	Light	2.8	148.0	Lake depth 12.33 feet. A greenish-yellow scum on lake (algae bloom) for about 4 days. No wind to blow it away (in some areas). I think the county has stopped harvesting weeds!

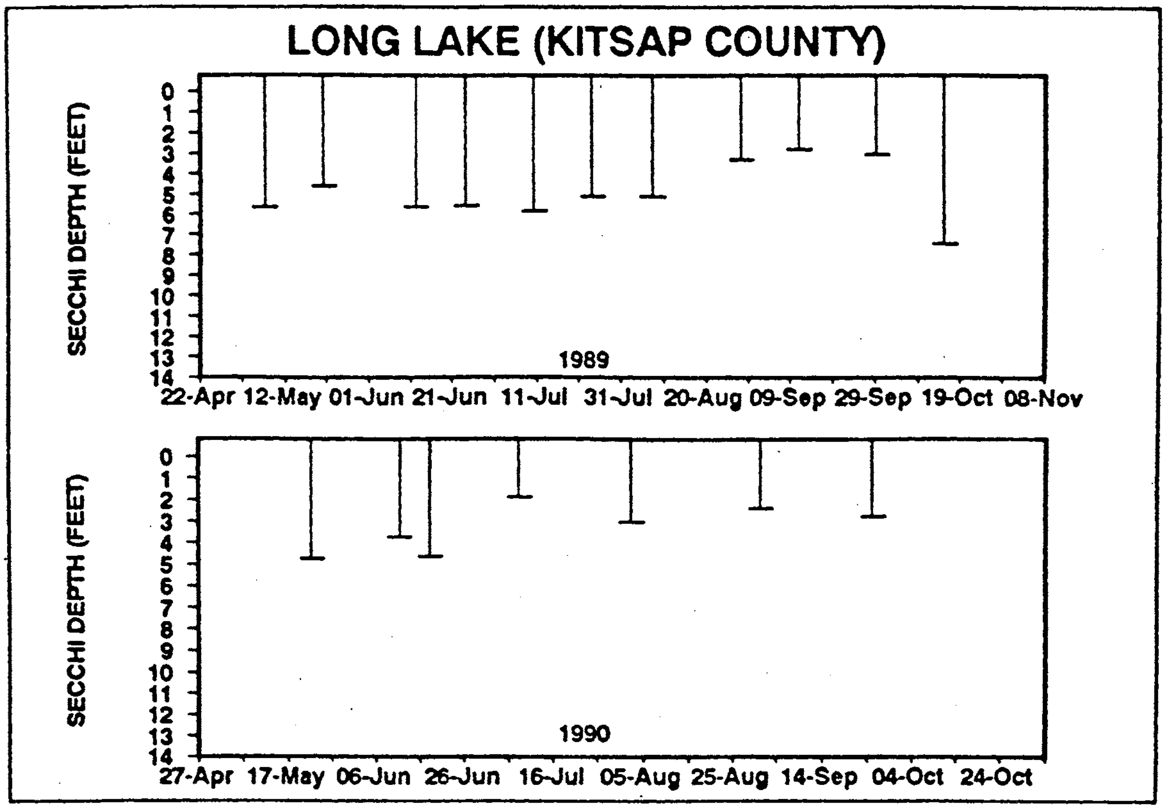
* Secchi data corrected for rope shrinkage

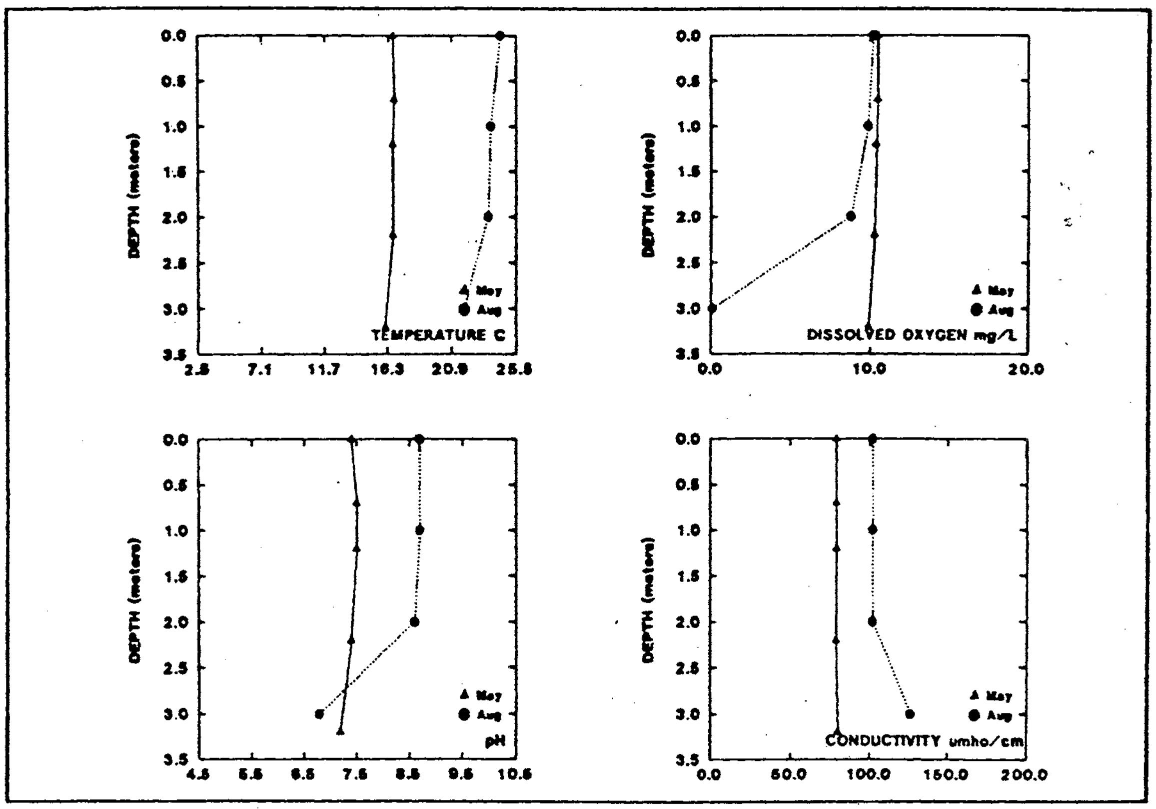
Onsite Visit Data

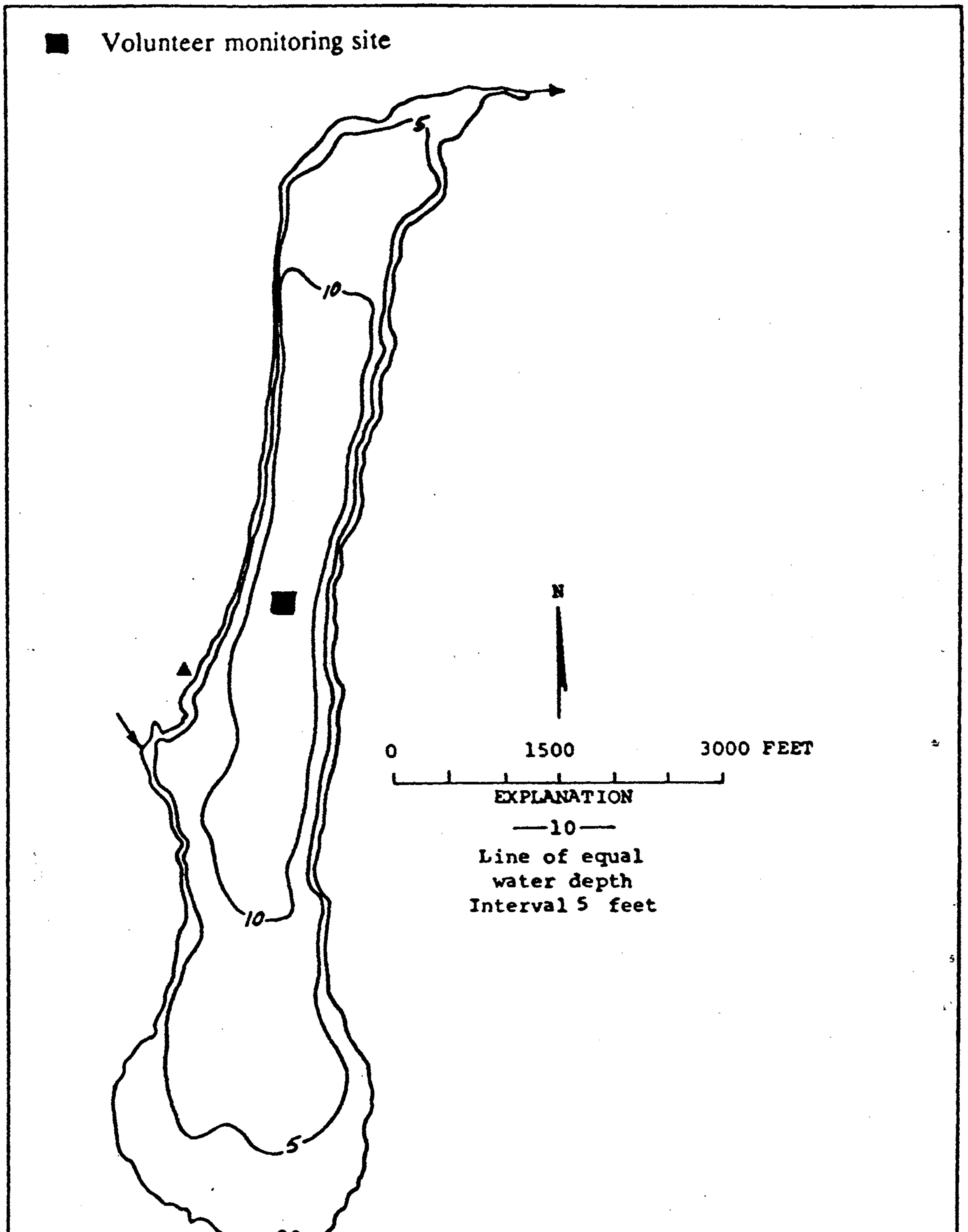
Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/23	0.0	16.7	7.4	10.4	79	0.5, 2	0.057	0.626
	0.7	16.8	7.5	10.5	79			
	1.2	16.7	7.5	10.4	79			
	2.2	16.7	7.4	10.3	79			
	3.2	16.1	7.2	9.9	80			
08/14	0.0	24.4	8.7	10.2	102	*	0.070	0.937
	1.0	23.7	8.7	9.9	102			
	2.0	23.5	8.6	8.8	102			
	3.0	21.8	6.8	0.1	127			

* unknown

Secchi Depth and Profile Data Graphs







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

Long Lake -- Spokane County

Long Lake is an artificial pool of the Spokane River, formed by a dam built in 1913 (and raised in 1950) at river mile 36, about 23 miles northwest of Spokane. It extends upstream about 24 miles. The principal inlet besides the Spokane River is the Little Spokane River. Fifty percent of Long Lake is in Spokane County, 48% is in Stevens County, and 2% is in Lincoln County.

Size (acre)	5149	
Maximum Depth (feet)	180.1	
Mean Depth (feet)	49.9	
Lake Volume (acre-feet)		247,190
Drainage Area (miles^2)	*	
Altitude (feet)	1536	
Shoreline Length (miles)		46.2

* information not available

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index* (Secchi):	46
Mean Trophic State Index* (Total Phosphorus):	54

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The questionnaire on lake and watershed uses was not returned.

In 1990, the volunteer was participating in a monitoring program for Long Lake that included Secchi disk transparency, total phosphorus concentrations, and sediment depth. The Association for the Protection of Lake Spokane is active in comprehensive planning for Long Lake. The volunteer also reported there was less algae during 1990 than in previous years.

Monitoring Results/Summary of Other Available Information

Secchi data were collected at a point about 24 kilometers east from Long Lake Dam. This station corresponds to Station 3 used by investigators at Eastern Washington University (Wagstaff and Soltero, 1982). This report summarizes data for this part of the lake only.

Secchi data collected during 1990 show that water clarity was lowest during May, and was highest during July. Profile data collected during May and August 1990 show that on both sampling dates the concentrations of dissolved oxygen remained high throughout the water column.

From Wagstaff and Soltero (1982): In the past, there has been concern about extensive hypolimnetic anoxia (complete depletion of dissolved oxygen concentrations in the lower strata of water). In 1981, concentrations of dissolved oxygen at Station 3 decreased with depth from July through September, and by August, concentrations fell to 2.7 mg/L at the bottom. At the time of this 1981 survey, lake stations located closer to Long Lake Dam showed lower concentrations of dissolved oxygen. "Prior to 1978, the reservoir was characterized by excessive summer algae growth, limited water clarity and extensive hypolimnetic anoxia....The phytoplankton standing crop in Long Lake does affect oxygen demand both within the water column and at the sediment-water interface, and is a primary factor in the seasonal decline of dissolved oxygen levels in Long Lake".

Lake Class water quality standards for Long Lake (Chapter 173-201-080 (106) WAC) state that the average concentration of total phosphorus in the eutrophic zone shall not exceed 25 μg/L from June 1 to October 31. Long Lake is the only lake in Washington with a phosphorus limitation in the Water Quality Standards. Spokane County banned phosphorus-containing detergents effective approximately June 1990.

During the August 1990 onsite visit with the volunteer, patches of both yellow and white-flowering lilies (*Nuphar polysepalum* and *Nymphaea odorata*, respectively) were common along both shorelines. Also present were waterweed (*Elodea canadensis*) and three species of pondweed (one of which was *Potamogeton filiformis*).

Comments

Although Secchi data collected during 1990 suggest that the lake may have been mesotrophic, the concentration of total phosphorus in the lake is definitely in the eutrophic range. Because the lake exhibits both mesotrophic and eutrophic characteristics, the lake was estimated as meso-eutrophic.

Because Long Lake was the only "run of the river" reservoir monitored for the program in 1990, it is difficult to compare the monitoring results from Long Lake with those from other lakes monitored for program.

Acknowledgement

I thank Rodger Hauge for volunteering his time to monitor Long Lake during 1990.

Long Lake -- Spokane County

Volunteer-Collected Data

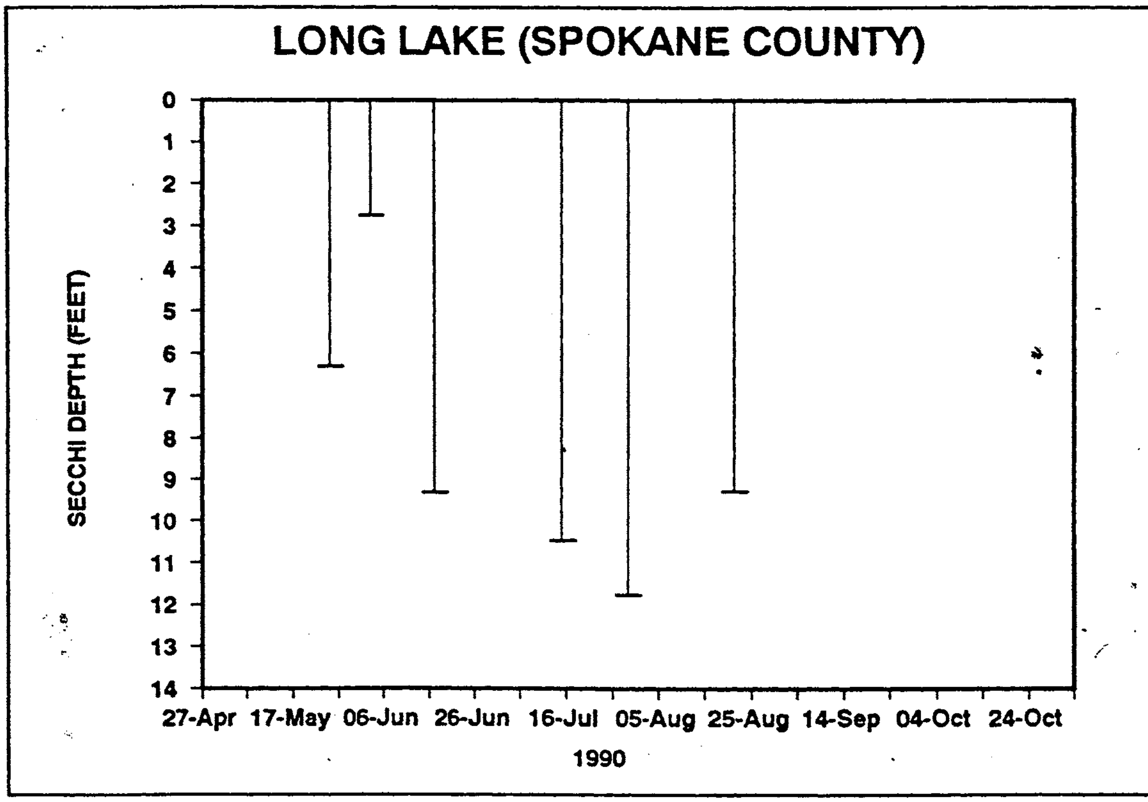
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
26-May								6.0		
04-Jun	8.5	47.3	5.0[1]	Lt-Brown	10	Light	Breezy	2.5		Runoff from recent rains significant. Lake average TP 45 μg/L, Little Spokane TP 94 μg/L
18-Jun	13.5	56.3	5.5[1]	Green	10	None	Calm	9.0		Isothermal in euphotic zone at Suncrest. All stations free of sediment except the Little Spokane.
16-Jul	24.4	76.0	7.5	Green	0	None	Calm	10.2		Earlier pH readings erroneous. Secchi reading in lower two stations 5.0 m and 5.2 m.
30-Jul	24.4	76.0	6.5	Green	0	None	Light	11.5		Color moderate green to blue-green.
22-Aug								9.0		

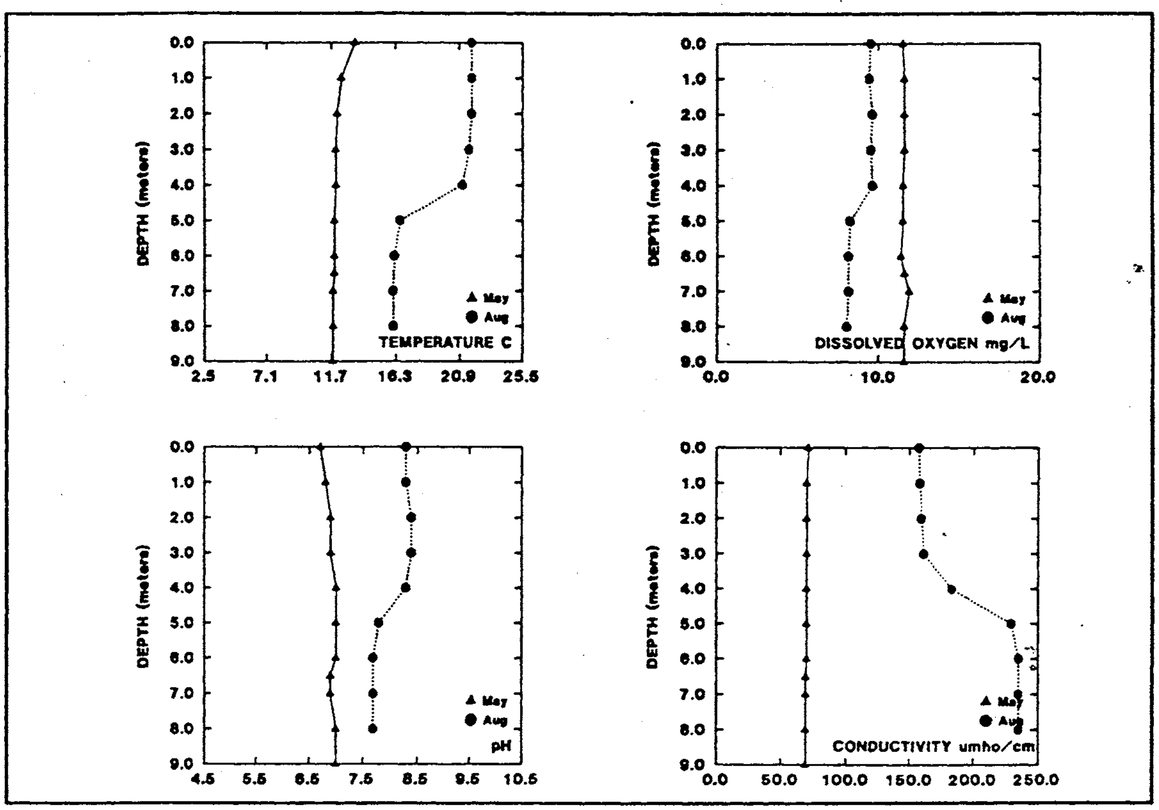
1 pH data inaccurate; see comments from 16 July 1990.

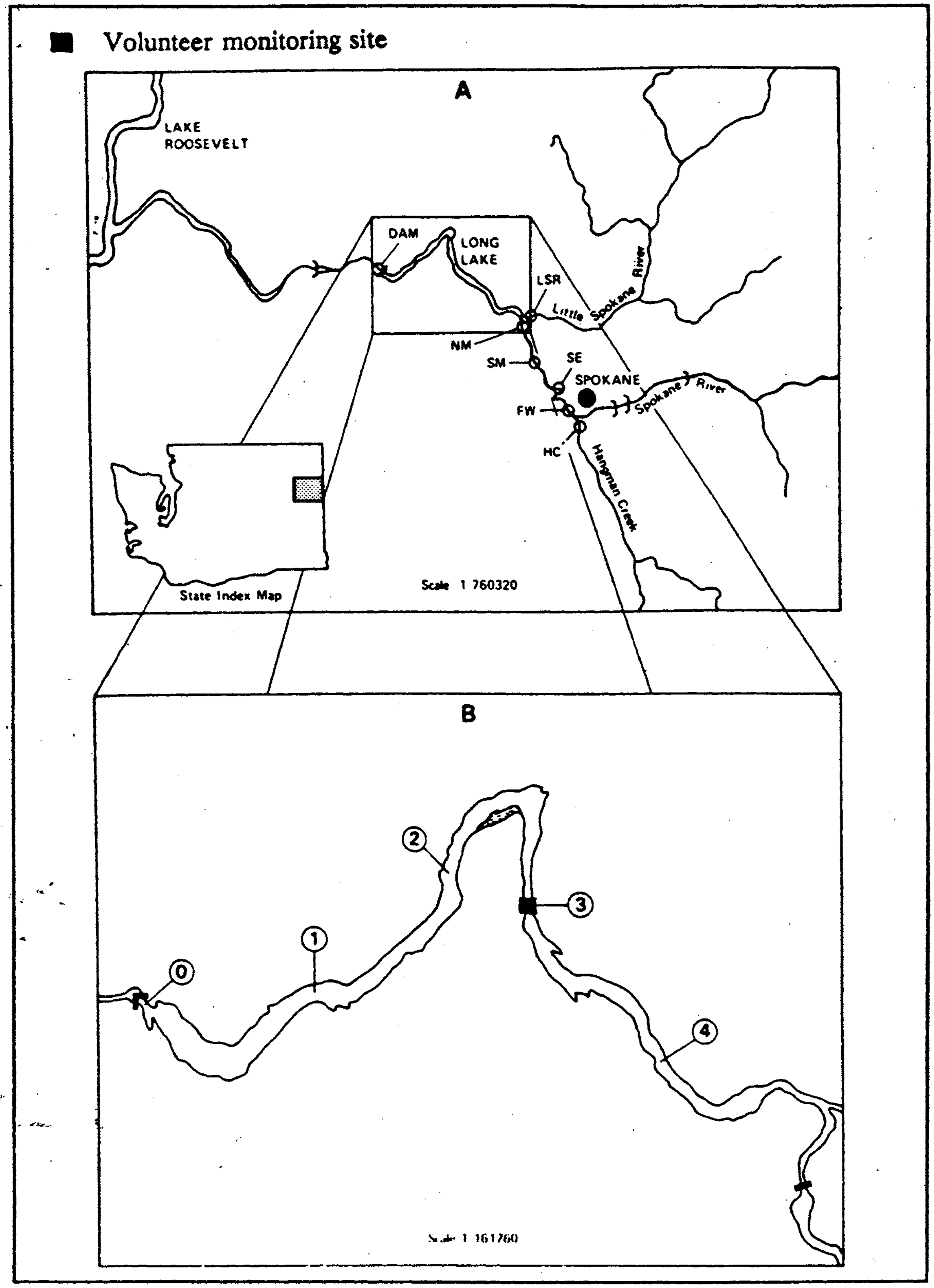
Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/26	0.0	13.4	6.7	11.5	71	1, 3, 6	0.028	0.251
	1.0	12.4	6.8	11.6	70			
	2.0	12.1	6.9	11.6	70			
	3.0	12.0	6.9	11.6	70			
	4.0	12.0	7.0	11.5	70			
	5.0	11.9	7.0	11.5	70			
	6.0	11.9	7.0	11.4	70			
	6.5	11.9	6.9	11.6	69			
	7.0	11.8	6.9	11.9	69			
	8.0	11.8	7.0	11.6	69			
	9.0	11.8	7.0	11.6	69			
08/22	0.0	21.8	8.3	9.5	157	1, 2, 3	0.037	0.293
	1.0	21.8	8.3	9.4	158			
	2.0	21.8	8.4	9.6	159			
	3.0	21.6	8.4	9.5	161			
	4.0	21.1	8.3	9.6	183			
	5.0	16.6	7.8	8.2	229			
	6.0	16.2	7.7	8.1	235			
	7.0	16.1	7.7	8.1	235			
	8.0	16.1	7.7	8.0	235			

Secchi Depth and Profile Data Graphs






Volunteer monitoring site
A
LAKE ROOSEVELT
DAM
LONG LAKE
LSR
Little Spokane River
NM
SM
SE
SPOKANE
Spokane River
FW
HC
Hangman Creek
State Index Map
Scale 1 760320
B
0
1
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3
4

Long Lake -- Thurston County

Long Lake is located 5.5 miles east of Olympia. It consists of two basins 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 Patterson Lake and drains via Himes/Woodland Creek and Lois Lake to Henderson Inlet. The volunteer monitored the north basin of the lake.

Size (acres)	330
Maximum Depth (feet)	21
Mean Depth (feet)	12
Lake Volume (acre-feet)	3900
Drainage Area (miles^2)	8.3
Altitude (feet)	153
Shoreline Length (miles)	7.1

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	49
Mean Trophic State Index* (Total Phosphorus):	50

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. 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, and there is a speed restriction of 45 mph for motorboats. Lake water is withdrawn for irrigation. Currently the watershed is used for industry, animal grazing, crop agriculture, and lakeshore development. In the past, the watershed was used for logging and animal grazing. Also, the lake has been dredged and the shoreline altered. There are approximately 300 houses on the lakeshore; all are occupied year-round. The lakeshore is not sewered, and there are three storm drains that empty into the lake. Brown trout are stocked in the lake. Presently there is a lake association, a lake management district, and a community association for the lake. The lake has been chemically treated in the past to control weeds and algae. Management activities on the lake this year will include mechanical aquatic plant removal and chemical treatment. The worst problems in the lake, in the opinion of the volunteer, are 1) aquatic plants, 2) algae, and 3) fish species. Overall, the volunteer finds that Long Lake has fair recreational water quality. The volunteer suggested that the increasing infestation of Eurasian water milfoil and the increasing number of Canada geese on the lake may affect the water quality of the lake.

Eurasian water milfoil was growing along most of the shoreline, and covered about 167 acres in 1990. Because of problems with the harvesting program in 1990, the shorelines were only harvested twice.

Long Lake -- Thurston County

In 1990, the Thurston County Board of Health made a policy on the use of herbicides in Long Lake, and the lakefront property owners voted on a new lake management district The purpose of the lake management district would be to eradicate Eurasian water milfoil, and to implement an aquatic weed management plan. In 1989, the Lakes Improvement Association sponsored a milfoil-awareness educational program to help protect other Thurston County lakes from Eurasian milfoil introduction.

In 1990, milfoil grew in all water less than ten feet deep. Coontail growth, which was heavy in 1989, was not found in the same areas during 1990, and was found mostly in narrow bands in thirteen feet of water. Emergent vegetation observed include both white and yellow-flowering waterlily (*Nymphaea odorata* and *Nuphar polysepalum*, respectively), cattails (*Typha* spp.), reed canary grass, bulrush (*Scirpus* spp.), and water iris (*Iris pseudacorus*). Submerged vegetation included (in order of abundance) Eurasian water milfoil (*Myriophyllum spicatum*), pondweed (three varieties of *Potamogeton* spp.), waterweed (*Elodea*), northern water milfoil, bladderwort, wild celery (also known as tapegrass; *Vallisneria americana*), and water silk. *Chara* (an alga) and bryozoans (which are really sessile invertebrates) were also found.

In the 1989 questionnaire, the volunteer mentioned that alum was used in the fall of 1983 and Rodeo was used to control lilies prior to 1983.

Monitoring Results/Summary of Other Available Information

Comparisons of the Secchi data graphs from 1989 and 1990, show that water clarity was noticeably poorer during 1990. During both years, water clarity was poorest in September. Profile data collected during May and August 1990 show that on both sampling dates the lake was stratified with respect to temperature and concentrations of dissolved oxygen were depleted near the lake bottom. Dissolved oxygen is usually depleted by bacteria which consume oxygen while decomposing organic material (such as algae and aquatic plants) in the water and sediments. The decrease in pH and increase in conductivity with depth are most likely to be related to increased decomposition. Samples of algae collected by the volunteer during June and July were identified as *Oscillatoria*, a filamentous blue-green alga.

The depleted concentrations of dissolved oxygen near the bottom of the lake may be related to the high volume of Eurasian water milfoil that is cut in the lake each year. Although the majority of the cut plant material is harvested, it is likely that plant remnants remaining in the lake will decompose, and the decomposition process will use available oxygen.

Data collected for the feasibility study of Long Lake showed that during 1983-1985, periods of oxygen depletion was attributed to higher summer temperatures in May and June and the senescence of plants during the fall (Entranco Engineers, 1987). Eurasian water milfoil (*Myriophyllum spicatum*) is thought to age and die (senesce) over the course of summer, ultimately contributing to the internal phosphorus loading of a lake (Welch and Kelly, 1990). It is possible that senescence of Eurasian milfoil and the decay of plants cut by the harvester, combined with fall overturn, contributed to the fall algal bloom. However, Long Lake has a history of heavy algal growth, even before the

Long Lake -- Thurston County

Eurasian water milfoil was introduced into the lake. In 1968, algal blooms and Secchi disk transparency of only four feet were reported by Lee (1969).

The concentrations of total phosphorus in the lake during 1990 were moderately high (0.0200 and 0.0281 mg/L). In contrast, in July 1971 the concentration of total phosphorus was 0.010 mg/L (in the oligotrophic range) and the concentration of total nitrogen was 0.15 mg/L (Bortleson *et al.*, 1976). In 1976-1977, the concentrations of total phosphorus were highest during October and November, exceeding 0.08 mg/L (Entranco Engineers, 1987). Following alum treatment in 1983, concentrations of total phosphorus were much lower, and did not exceed 0.05 mg/L in the north basin (Entranco Engineers, 1987).

From Entranco Engineers (1987): Restoration activities were initiated to address blue-green algal blooms and prolific aquatic plant growth in Long Lake. In 1978, a Phase I Diagnostic/Feasibility study was conducted by Entranco Engineers on Hicks, Pattison (Patterson), Long and Lois Lakes. Conclusions and recommendations from the study included whole-lake alum treatments to precipitate phosphorus from the water column and mechanical harvesting of plants. In 1983, both Long and Pattison Lakes were treated with alum. Aquatic plants have been mechanical harvested in Long Lake since 1983.

Residential development along the lakeshore has increased significantly over time. In 1959, there were 117 nearshore homes (Bortleson *et al.*, 1974), while in 1971 there were 205 nearshore homes (Bortleson *et al.*, 1976).

The Thurston County Health Department collects water quality data from several lakes, including Long Lake (S. Davis, pers. comm.).

Comments

Compared to other Thurston County lakes monitored for the program in 1990 (Clear, Hicks, Patterson, St. Clair, Summit and Ward Lakes), Long Lake and Lake St. Clair had the poorest water clarity, the latter due to its water color. Only Clear Lake and Lake St. Clair had higher concentrations of total phosphorus than Long Lake.

Long Lake and Lake Steilacoom (in Pierce County) are similar in size and shape. Although Lake Steilacoom is urban and receives runoff from a much larger drainage basin than Long Lake, Lake Steilacoom has a long history (about 30 years) of chemical treatment to control weeds and especially algae. Based on 1990 Secchi disk readings and 1989 concentrations of total phosphorus, Lake Steilacoom was eutrophic. The worst water quality problem in Lake Steilacoom is algae growth, whereas in Long Lake the worst water quality problem is the proliferation of aggressive aquatic plants.

Acknowledgements

I thank Kathey Adams for volunteering her time to monitor the north basin of Long Lake during 1989-1990.

Long Lake -- Thurston County

Volunteer-Collected Data

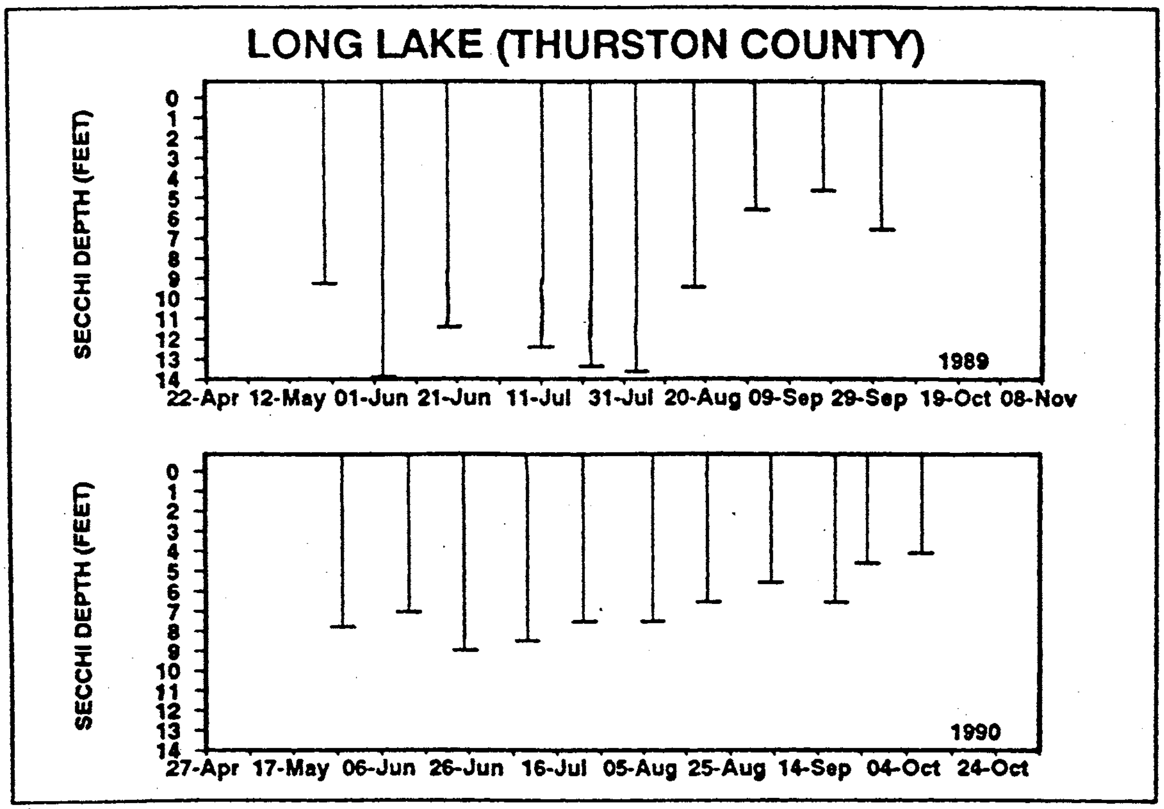
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
29-May	17.6	63.7	7.0	Lt-Brown	100	Light	Breezy	7.6		Little chop on the water.
13-Jun	17.8	64.0	7.0	Lt-Brown	75	Heavy		6.9**		Lake depth 21.5 feet.
26-Jun	22.2	72.0	7.0	Lt-Brown	50	None	Light	8.7	12.3	Lake depth 21.5'. Putting bottom screens down at Lacey City Park.
10-Jul	24.4	76.0	7.0	Gr-Brown	0	None	Light	8.3	13.5	Lake dropped 1.25". Sun makes lake appear more green, previously recorded light brown water color.
23-Jul	23.3	74.0		Gr-Brown	100	Trace	Light	7.3	15.5	Found some form of green algae. Found same glob 6/26/90.
08-Aug	25.6	78.0	7.0	Gr-Brown	90	Trace	Breezy	7.3	17.0	Still seeing the green globs taken 7/23/90.
21-Aug	23.3	74.0	7.0	Gr-Brown	100	Moderate		6.4	17.3	With Julie discovered Secchi rope shrunk 5" in 5'.
04-Sep	21.1	70.0	7.0	Gr-Brown	0	None	Calm	5.5	17.5	
19-Sep	17.8	64.0	7.0	Gr-Brown	10	None	Calm	6.4	18.0	Heavy blue-green algae bloom September 6-12.
26-Sep	16.7	62.0	7.0	Gr-Brown	10	None	Calm	4.6	18.3	Algae bloom - sent sample. Seeing some coontail canopies.
08-Oct	15.6	60.0	7.0	Gr-Brown	10			4.1	18.0	Rained 3 days last week. Still see algae bloom.

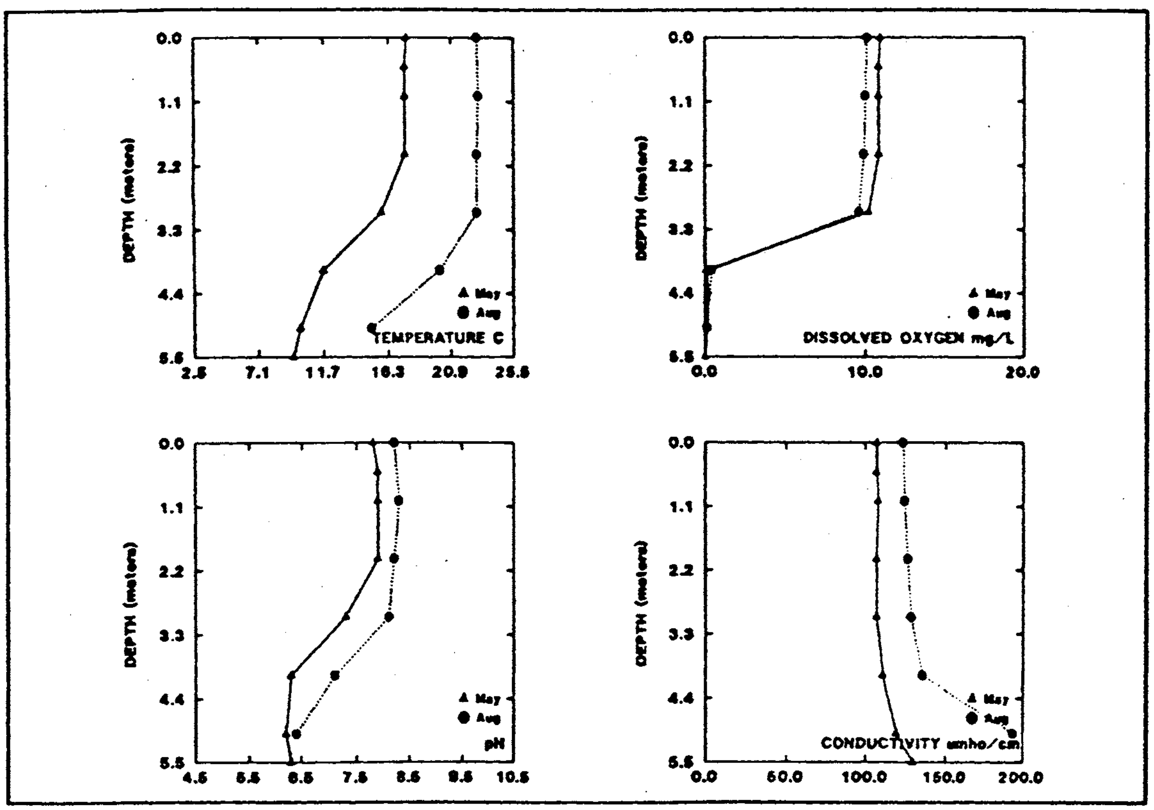
* Secchi data corrected for rope shrinkage
** There was high variability between the first and second Secchi depths; this data pont may not be used in data coomparisons

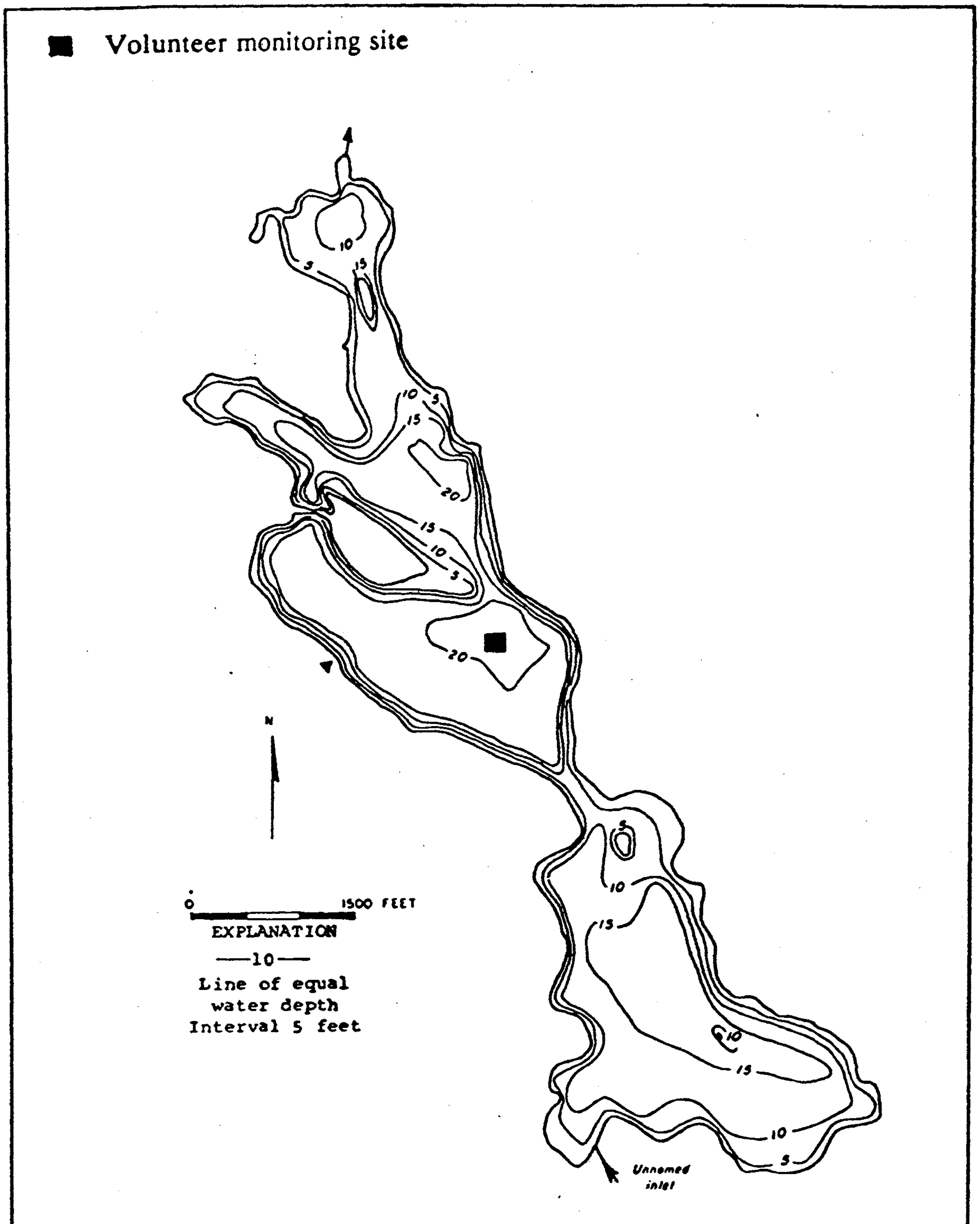
Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/29	0.0	17.6	7.8	10.9	107	0.5, 2	0.020	0.414
	0.5	17.5	7.9	10.8	107			
	1.0	17.5	7.9	10.8	108			
	2.0	17.5	7.9	10.8	107			
	3.0	15.8	7.3	10.2	107			
	4.0	11.7	6.3	0.1	111			
	5.0	10.1	6.2	0.1	119			
	5.5	9.6	6.3	0.0	129			
08/21	0.0	22.8	8.2	10.1	123	1, 2, 3	0.028	0.539
	1.0	22.9	8.3	10.0	124			
	2.0	22.8	8.2	9.9	126			
	3.0	22.8	8.1	9.6	128			
	4.0	20.1	7.1	0.4	135			
	5.0	15.1	6.4	0.1	194			

Secchi Depth and Profile Data Graphs







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

Lake Louise -- Pierce County

Lake Louise is located 1.5 miles southwest of Steilacoom. It has no surface inlets, and is fed principally by runoff and groundwater. Lake Louise has no surface outlets, and it seeps to Puget Sound.

Size (acres)	39
Maximum Depth (feet)	35
Mean Depth (feet)	22
Lake Volume (acre-feet)	860
Drainage Area ($miles^2$)	0.3
Altitude (feet)	230
Shoreline Length (miles)	0.9

Estimated Trophic State:	Mesotrophic*
Mean Trophic State Index** (Secchi):	*
Mean Trophic State Index** (Total Phosphorus):	42

* See Comments section
** From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Louise is used for fishing, boating, swimming, and rowing. Recreational facilities on the lakeshore include one boat ramp. Unless water skiing, there is a speed restriction of 5 mph for motorboats; water skiers must ski in one direction. Currently the watershed is used for lakeshore development. In the past, the watershed was used for crop agriculture. There are approximately 100 houses on the lakeshore; all are occupied year-round. The lakeshore is fully sewered, and there are three storm drains that empty into the lake. Rainbow trout are stocked in the lake. Presently there is no citizen's organization for the lake. The lake has been chemically treated in the past to control weeds, algae, and fish species. The lake will be treated this year to control weeds and algae. Management activities on the lake this year will include chemical treatment. The worst problems in the lake, in the opinion of the volunteer, is occasional swimmer's itch. Overall, the volunteer finds that Lake Louise has good recreational water quality, and is concerned about possible water quality effects from storm and surface runoff.

Monitoring Results/Summary of Other Available Information

There were not enough Secchi readings taken to evaluate patterns in water clarity during 1990. However, average summer water clarity was very similar during 1989 and 1990. Profile data collected from Lake Louise in June and August 1990 show that on both sampling dates, the lake was stratified with respect to temperature and concentrations of dissolved oxygen were depleted near the lake bottom. It is most likely that the dissolved oxygen was depleted by microorganisms which decompose organic material (such as algae and aquatic plants) in the water and sediments. The decrease in pH and increase in conductivity with depth is related to decomposition at the lake bottom. In June 1973, the concentration of dissolved oxygen decreased with depth to 2.0 mg/L (Bortleson *et al.*, 1976), so it appears oxygen depletion near the bottom of the lake has been occurring for some time.

Based on available data from 1973, 1981, and 1990, the concentrations of both total phosphorus and total nitrogen were highest in 1981 and lowest in 1973. In 1973, the concentration of total phosphorus was 0.009 mg/L (which is in the oligotrophic range), and the concentration of total nitrogen was 0.15 mg/L (Bortleson *et al.*, 1976). In 1981, the concentration of total phosphorus was 0.02 mg/L, and the concentration total nitrogen was 0.72 mg/L (Sumioka and Dion, 1985). There are not enough data to evaluate why the total phosphorus concentrations were higher in 1981 than in 1990.

During the August 24, 1990, onsite visit with the volunteer, the volunteer mentioned that the lake was chemically treated the day before for algae.

Comments

Based on the moderately high concentrations of total phosphorus and total nitrogen, as well as the depletion of dissolved oxygen concentrations near the bottom of the lake, Lake Louise was estimated as mesotrophic.

Water quality variance records with Ecology show that Rodeo, Aquathol-K, and copper sulfate have been used for the past ten years to control algae in Lake Louise. Because Lake Louise is treated with chemicals to control algae, the Secchi depth readings do not give an accurate picture of the trophic state of the lake. Therefore, estimates of trophic state should be based on chemical data (total phosphorus and/or chlorophyll *a*). However, a continued record of Secchi disk transparency data can be used to document the severity of algae blooms at Lake Louise.

Compared with other lakes monitored for the program which are chemically treated to control plants and algae, the water clarity of Lake Louise was very good. Lake Steilacoom in Pierce County and Clear Lake in Thurston County also have long histories of chemical treatment to control algae, but water clarity at these lakes was not very good. Even with chemical treatment, Secchi data indicate that Clear Lake was mesotrophic and Lake Steilacoom was eutrophic.

Acknowledgement

I thank Joe Dargan for volunteering his time to monitor Lake Louise during 1989-1990.

Lake Louise -- Pierce County

Volunteer-Collected Data

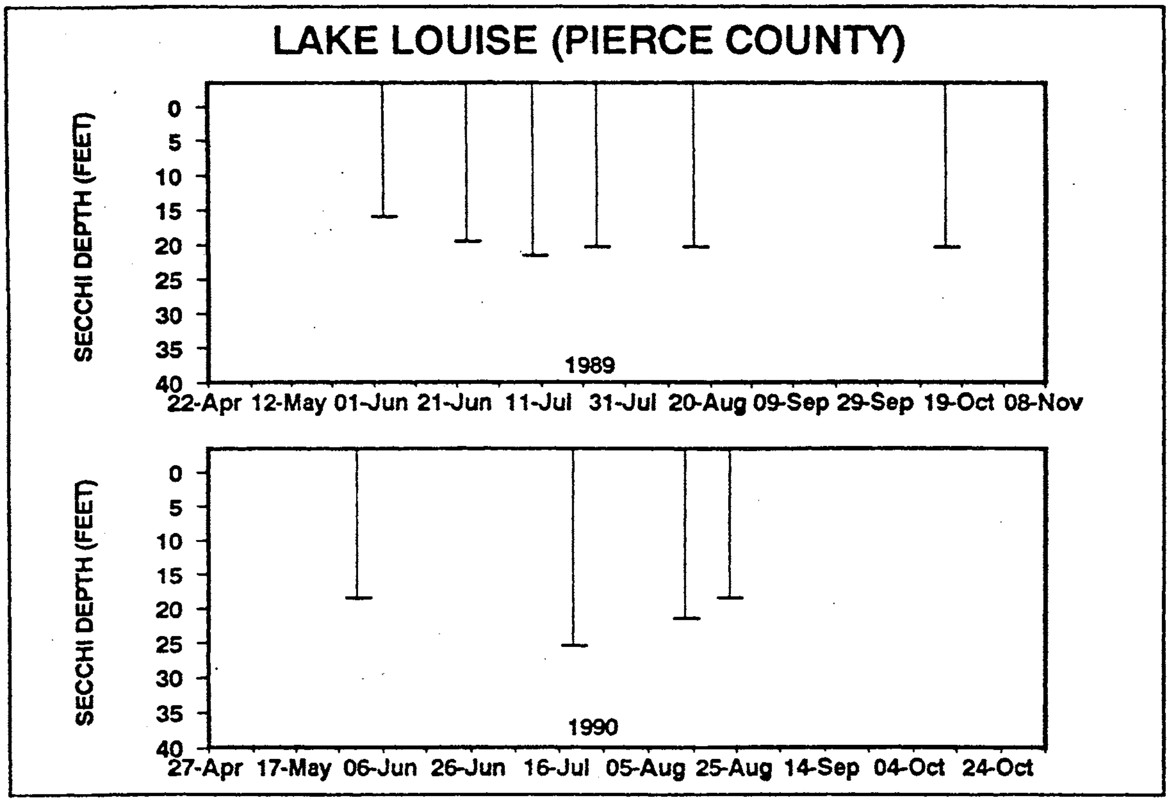
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
01-Jun								18.3		
20-Jul	25.0	77.0	6.5	Green	0	None	Light	24.7		
14-Aug	25.0	77.0		Blue-Gr	0	None	Breezy	21.1		Water color blue-green. Secchi hit bottom at 29.3 feet on second reading.
24-Aug								18.3		

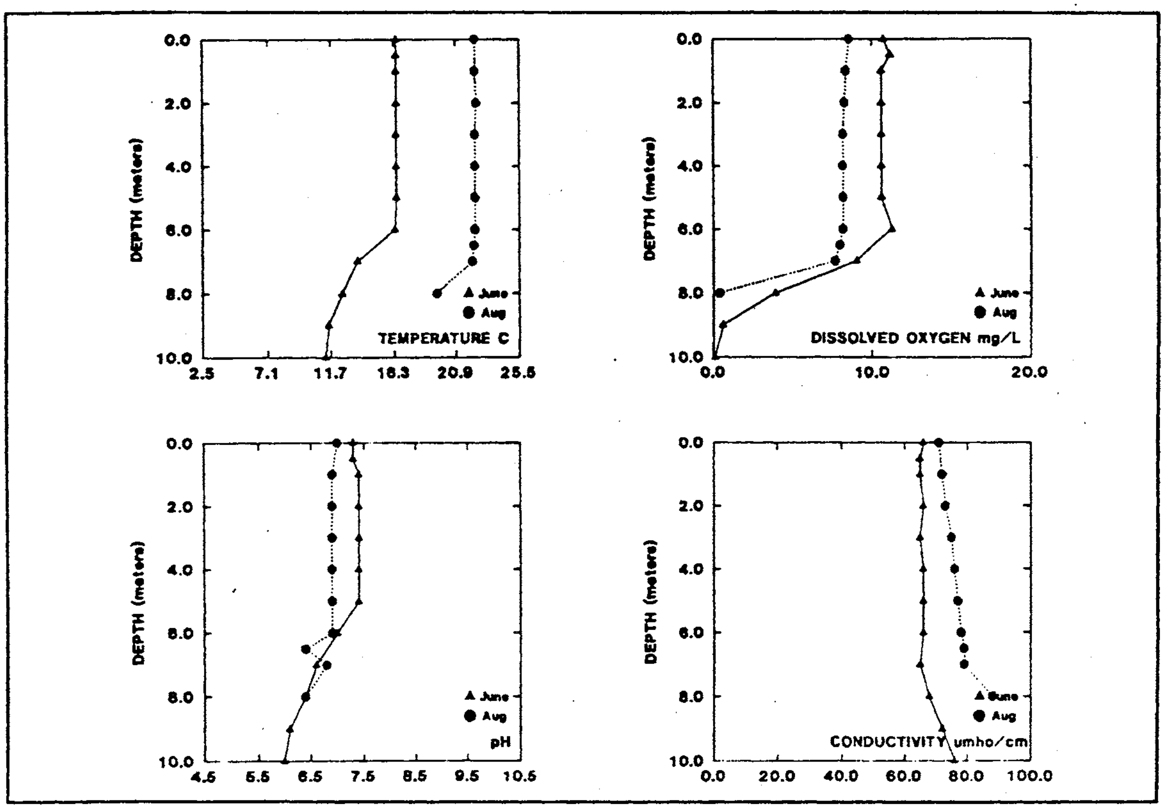
* Secchi data were corrected for rope shrinkage, but there was high variability between the two Secchi depths collected on each sampling date. All Secchi data from this lake were not included in data comparisons.

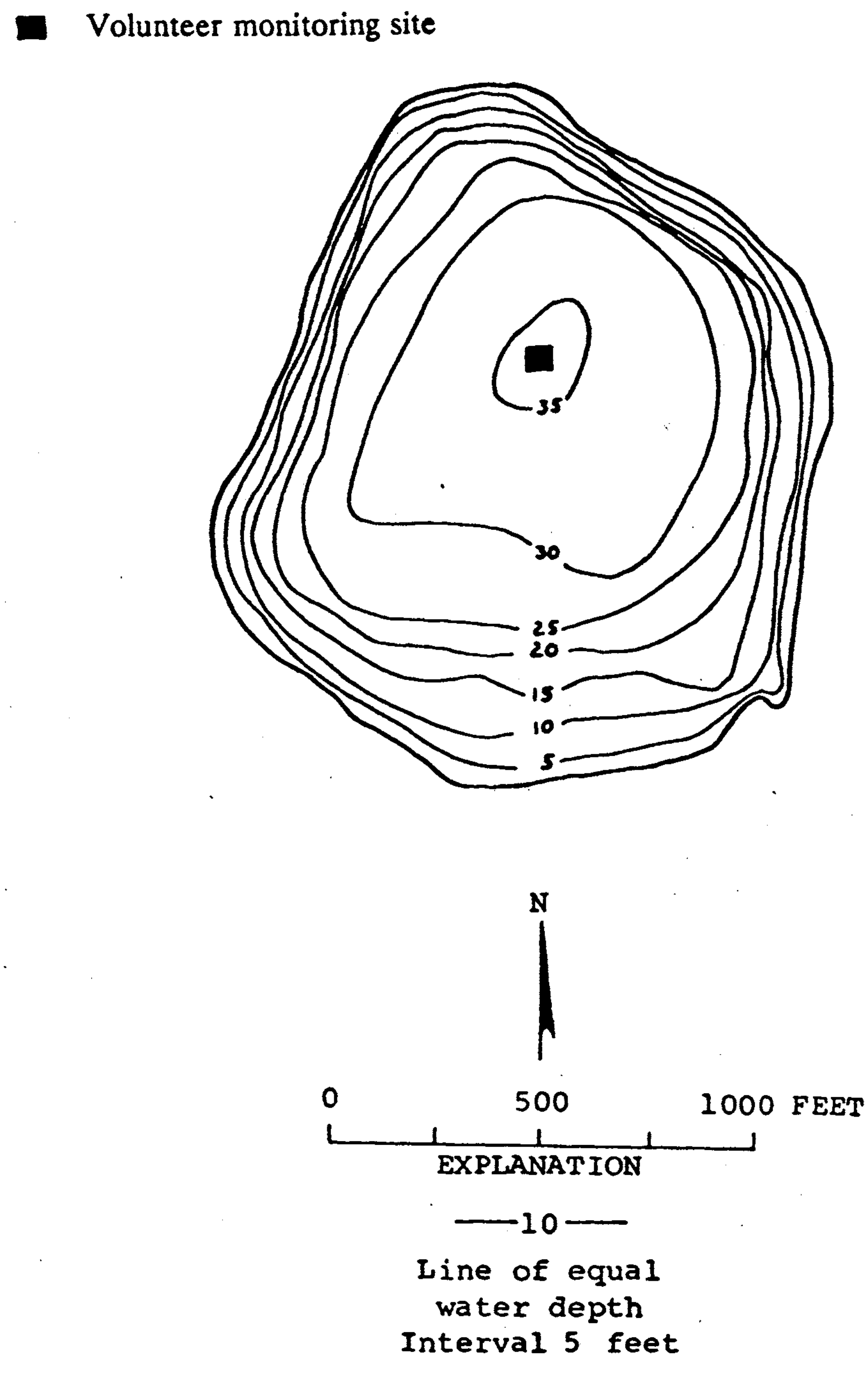
Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/01	0.0	16.5	7.3	11.1	65	1, 3, 5	0.015	0.420
	0.5	16.5	7.3	10.7	66			
	1.0	16.5	7.4	10.6	65			
	2.0	16.5	7.4	10.6	66			
	3.0	16.5	7.4	10.6	65			
	4.0	16.5	7.4	10.6	66			
	5.0	16.5	7.4	10.6	66			
	6.0	16.4	7.0	11.2	66			
	7.0	13.6	6.6	9.0	65			
	8.0	12.5	6.4	3.9	68			
	9.0	11.5	6.1	0.6	72			
	10.0	11.3	6.0	0.1	76			
08/24	0.0	22.3	7.0	8.5	71	2, 5, 7	0.012	0.305
	1.0	22.3	6.9	8.3	72			
	2.0	22.4	6.9	8.2	73			
	3.0	22.3	6.9	8.1	75			
	4.0	22.3	6.9	8.1	76			
	5.0	22.3	6.9	8.1	77			
	6.0	22.3	6.9	8.1	78			
	6.5	22.2	6.4	7.9	79			
	7.0	22.1	6.8	7.6	79			
	8.0	19.5	6.4	0.4	88			

Secchi Depth and Profile Data Graphs







Louise Lake, Pierce County. From Washington Department of Game, June 5, 1950.

Lake Martha -- Snohomish County

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

Size (acres)	62
Maximum Depth (feet)	70
Mean Depth (feet)	33
Lake Volume (acre-feet)	2034
Drainage Area (miles^2)	1.6
Altitude (feet)	186
Shoreline Length (miles)	1.8

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	40
Mean Trophic State Index* (Total Phosphorus):	37

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Martha is used for fishing, boating, swimming, rowing, birding, and trail walking within 50 feet of the lake. Recreational facilities on the lakeshore include one resort and one boat ramp, and there is a speed restriction of 8 mph for motorboats. Currently the watershed is used for logging, animal grazing, crop agriculture, and lakeshore development. In the past, the watershed was used for logging, animal grazing, and crop agriculture. From 1967 though the early 1970s, the lake was dredged and the shoreline was altered on the east end of the lake near the inlet. A U-shaped embayment was created and lots were developed on the artificially-created extension of the shoreline. There are 69 houses on the lakeshore; of these, 51 are occupied year-round. The lakeshore is not sewered, and there is one culvert that empties into the lake. Trout are stocked in the lake. Presently there is a sewer district for the lake. The worst problem in the lake, in the opinion of the volunteer, is aquatic plants. Also, there has been poor fishing this year. Overall, the volunteer finds that Lake Martha has good recreational water quality, and is concerned about possible effects on water quality from septic systems, new construction, and forest logging. The volunteer wants to see an educational program on runoff and uses of garden chemicals. The volunteer also reported that along the south side of the lake the Snohomish County Health Department is applying strict regulations on the resale of properties to increase the distance between septic drainfields and the shore.

In the summer of 1989, waterweed (*Elodea*) in the lake grew thick and tall, especially in the east end of the lake. Only a few mats of *Elodea* were noted in 1990. The lake supports a variety of waterfowl, including green-backed heron and common loon.

Lake Martha -- Snohomish County

Monitoring Results/Summary of Other Available Information

Secchi data show that during 1990, water clarity was lowest during June and July, and gradually increased over summer. Profile data collected during June and August 1990 show that on both sampling dates the lake was stratified with respect to temperature and concentrations of dissolved oxygen decreased with depth, beginning at four meters (about 13 feet). This decrease may be from the decomposition of algae at the bottom of the epilimnion; the extreme temperature differences between the top and bottom layers of water form a density gradient that prevents or slows the sinking of algae to the bottom of the lake. As a result, the algae "sit" on top of the bottom strata of water and decompose, resulting in a loss of oxygen. The decreasing pH with depth during August is most likely a result of decomposition near the lake bottom. In 1974, the concentration of dissolved oxygen was virtually depleted near the bottom of the lake (Bortleson *et al.*, 1976) so it is likely that this decrease in dissolved oxygen with depth has been occurring for many years.

The concentrations of total phosphorus and total nitrogen in 1990 were moderately low (averaging 0.010 and 0.536 mg/L, respectively). In 1974, the concentration of total phosphorus was 0.017 mg/L and total nitrogen was 0.52 mg/L (Bortleson *et al.*, 1976). Total phosphorus concentrations were very similar during 1981 and 1990 (0.010 mg/L and 0.0099 mg/L, respectively), but total nitrogen concentrations were higher in 1981 compared to 1990 (1.0 mg/L and 0.54 mg/L; Sumioka and Dion, 1985). Trophic state indices calculated from data collected in 1981 were very similar to indices calculated from 1990 data.

During the August 1990 onsite visit with the volunteer, *Elodea* spp. and white-flowering lily (*Nymphaea odorata*) were observed. The water color was yellow-green during the visit.

Comments

Based on the moderately deep Secchi disk readings and the relatively low concentrations of total phosphorus, Lake Martha was estimated as oligotrophic.

Lake Martha is one of nine Snohomish County Lakes (Lake Bosworth, Lake Stevens, Sunday Lake, Martha Lake, Lake Martha, Shoecraft Lake, Storm Lake, Panther Lake, Flowing Lake) monitored for the program in 1990. Only Lake Bosworth had lower mean concentrations of total phosphorus than Lake Martha, although both Lake Bosworth and Lake Stevens had better mean summer water clarity than Lake Martha. Except for Sunday Lake, which is eutrophic, all the other monitored Snohomish County lakes were oligotrophic or mesotrophic. Volunteers on both Martha and Sunday Lakes reported shoreline alteration.

Acknowledgement

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

Lake Martha -- Snohomish County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht	Abbreviated Comments
05-Jun								10.5		
21-Jun	18.9	66.0	6.5	Yellow	0	None	Breezy	10.0	59.0	Lake height 4' 11".
04-Jul	18.3	65.0	6.0	Yellow	100	Light	Calm	11.7	56.0	Water color: yellow.
20-Jul	25.6	79.0	7.0	Yellow	0	None	Light	10.2	53.0	pH 7 - 7.5.
10-Aug	23.9	75.0	6.5	Yellow	10	None	Light	13.6	49.5	Thick mats of Elodea that concerned us last year are much less present this year.
28-Aug								14.5		
23-Aug	21.1	70.0	6.5	Yellow	50	Moderate	Light	12.7	47.5	
10-Sep	17.8	64.0	6.5	Yellow	100	Trace	Breezy	15.7	45.9	This month's greater Secchi depth may be due, in part, to reading on shady side of boat; previously sunny with troublesome reflections!
22-Sep	20.0	68.0	6.5	Yellow	0	None	Light	16.9		
02-Oct	16.1	61.0	6.3	Yellow	100	Trace	Breezy	15.0	43.5	Water seemed to appear clouded suddenly at Secchi lowest visible depth, not gradually. Maybe silty - lots of clouding, but not weeds. Algae?
16-Oct	12.2	54.0	6.0	Yellow	25	Heavy	Calm	16.5		Went late in the day - hope tests are still OK.

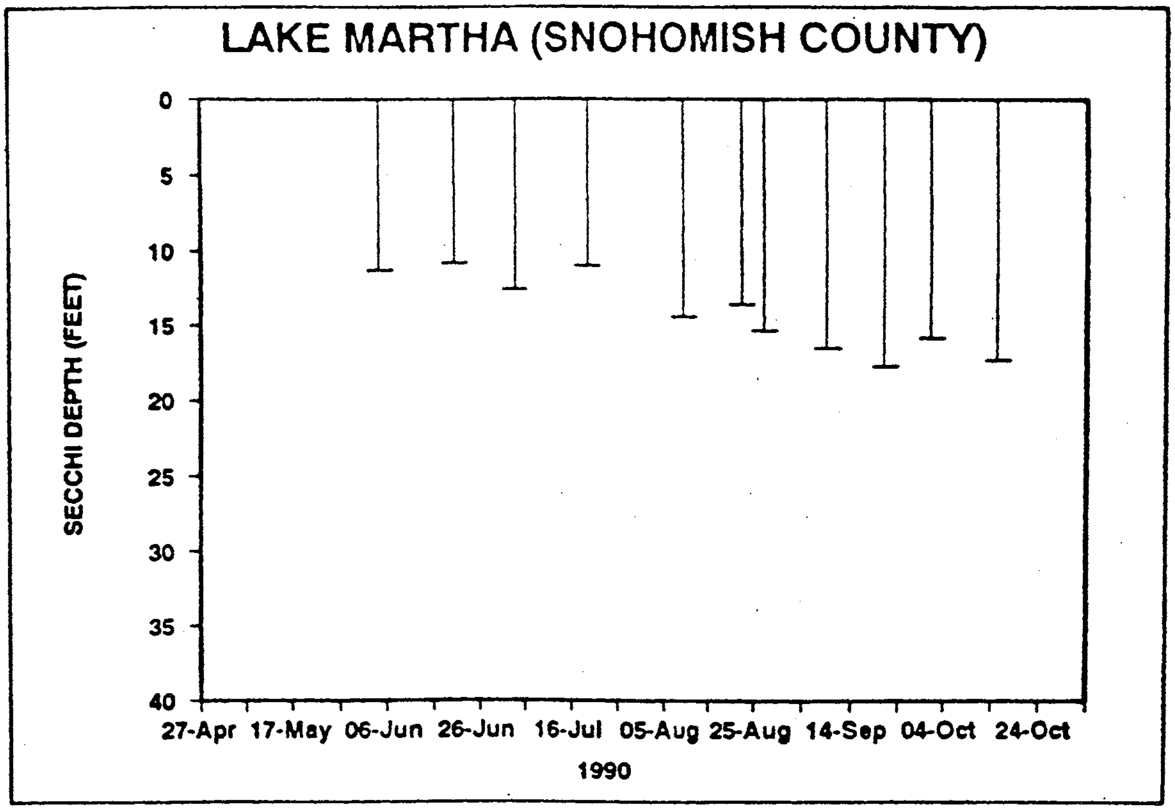
Lake Martha -- Snohomish County

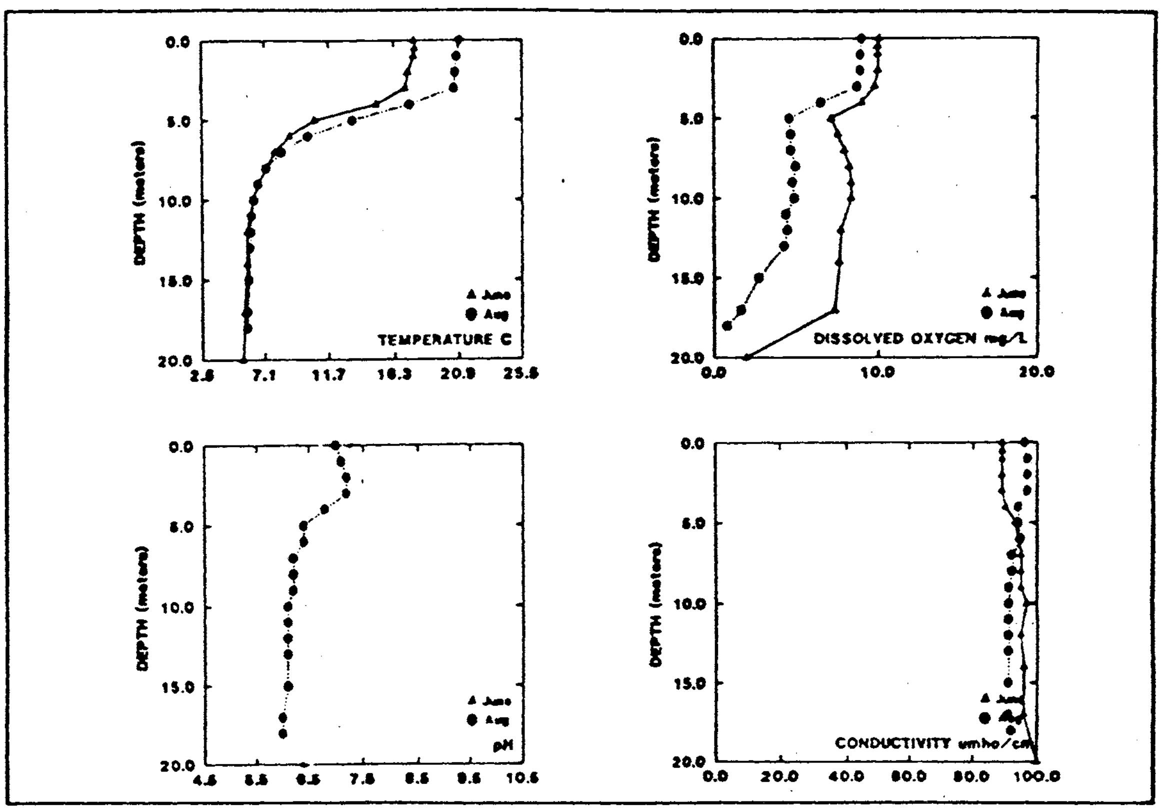
Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/05	0.0	17.7	.*	10.1	89	1, 3	0.008	0.616
	0.5	17.8	.	10.0	89			
	1.0	17.7	.	10.0	89			
	2.0	17.3	.	10.0	89			
	3.0	17.1	.	9.8	89			
	4.0	15.1	.	9.0	90			
	5.0	10.7	.	7.1	93			
	6.0	8.9	.	7.5	94			
	7.0	7.8	.	7.9	95			
	8.0	7.2	.	8.2	95			
	9.0	6.6	.	8.3	95			
	10.0	6.2	.	8.3	97			
	12.0	5.8	.	7.7	95			
	14.0	5.8	.	7.6	96			
	17.0	5.6	.	7.3	96			
	20.0	5.5	.	2.0	100			
08/28	0.0	21.0	7.0	9.0	96	1, 2, 3	0.012	0.456
	1.0	20.8	7.1	8.9	97			
	2.0	20.7	7.2	8.9	97			
	3.0	20.6	7.2	8.7	97			
	4.0	17.4	6.8	6.5	94			
	5.0	13.4	6.4	4.6	94			
	6.0	10.2	6.4	4.7	95			
	7.0	8.3	6.2	4.7	92			
	8.0	7.2	6.2	5.0	92			
	9.0	6.6	6.2	4.8	91			
	10.0	6.3	6.1	4.9	91			
	11.0	6.1	6.1	4.4	91			
	12.0	6.1	6.1	4.5	91			
	13.0	6.0	6.1	4.3	91			
	15.0	5.9	6.1	2.8	91			
	17.0	5.8	6.0	1.7	91			
	18.0	5.8	6.0	0.8	92			

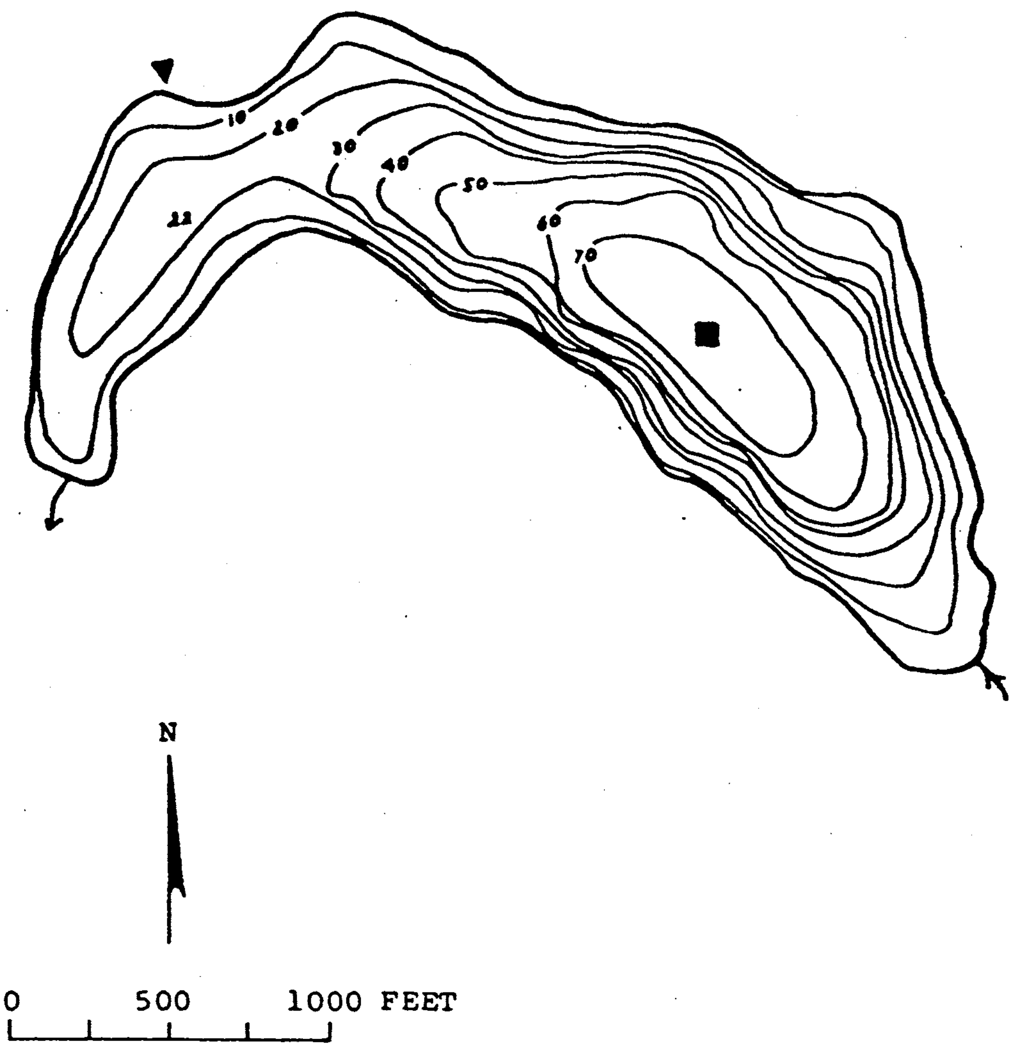
* See Quality Assurance section of this report.

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



EXPLANATION

—— 20 ——
Line of equal
water depth
Interval 10 feet

Martha (31N-4E-18) Lake, Snohomish County. June 2, 1970.

Approx. scale 1:12,000.

Martha Lake -- Snohomish County

Martha Lake is located 2.5 miles northeast of Alderwood Manor. It was originally called Manor Lake. It has no surface inlets, 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)	1346
Drainage Area (miles^2)	0.8
Altitude (feet)	450
Shoreline Length (miles)	1.4

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	37
Trophic State Index* (Total Phosphorus):	43

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Martha Lake is used for fishing, swimming, and rowing. Recreational facilities on the lakeshore include a picnic area, one resort and one boat ramp, and no combustion engines are allowed on the lake. Lake water is withdrawn for irrigation. Currently the watershed is used for lakeshore development. In the past, the watershed was used for crop agriculture. There are 101 houses on the lakeshore; of these, 90 are occupied year-round. Roughly 50% of the homes on the lakeshore (40% of the shoreline) are sewered, and there are two storm drains that empty into the lake. Trout are stocked in the lake. Presently there is a lake association, a community association, and a homeowners association for the lake. The lake has been chemically treated in the past to control fish species. This year there will be a water quality study conducted by the county. The worst problems in the lake, in the opinion of the volunteer, are algae and water lilies. Overall, the volunteer finds that Martha Lake has good recreational water quality, and is concerned about septic tanks and drainage from I-5.

The lake is surrounded by residential homes except for areas near the tavern and the public access. Lily pads grow along the southwest shoreline and along the north tip of the lake. Reeds grow around the north tip and also near the public access.

Monitoring Results/Summary of Other Available Information

Secchi data collected in 1990 show that water clarity in the lake varied throughout the summer, and was lowest during September. Profile data collected during August show that the lake was stratified with respect to temperature, and the concentration of dissolved oxygen decreased with depth and was virtually depleted in the bottom two meters (about 6.5 feet) of the lake. This also occurred in 1973, when concentrations of dissolved oxygen were reported to be 0.2 mg/L near the bottom of the lake and hydrogen sulfide (rotten-egg smell) was detected in the sediments (Bortleson *et al.*, 1976). Hydrogen sulfide can be produced in lakes when oxygen is absent. The decrease in pH with depth in 1990 is likely to be related to decomposition near the lake bottom. There were moderately high concentrations of total phosphorus and total nitrogen in the water samples collected during August 1990.

A water sample collected by the volunteer on May 23, 1991, consisted of pollen, dark-colored cladocerans (a type of microscopic animal) and a lot of algal cells, possibly the blue-green alga *Microcystis*. The sample was collected because the lake suddenly turned a brown-green color. Another sample collected on July 22, 1990, consisted of the blue-green filamentous algae *Oscillatoria*. Detritus clumps were also examined, and contained *Gomphonema*, *Scenedesmus*, *Stephanodiscus*, and a lot of *Aphanocapsa*, and "little green balls" that may have been *Sphaerocystis*. During the August 1990 onsite visit with the volunteer, a heavy growth of *Elodea* spp. was rooted near the volunteer's dock. Some emergent plants, including sedge and cattails, were also observed.

Comments

The trophic state estimation is based on the moderately high concentration of total phosphorus and the low concentration of dissolved oxygen near the bottom of the lake. Because these characteristics are associated with mesotrophic and eutrophic lakes, it is possible that Secchi data may somewhat underestimate the trophic state of Martha Lake. Even so, Secchi readings may be used to document the occurrence and severity of algal growth occurring in the lake.

Acknowledgement

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

Martha Lake -- Snohomish Cuonty

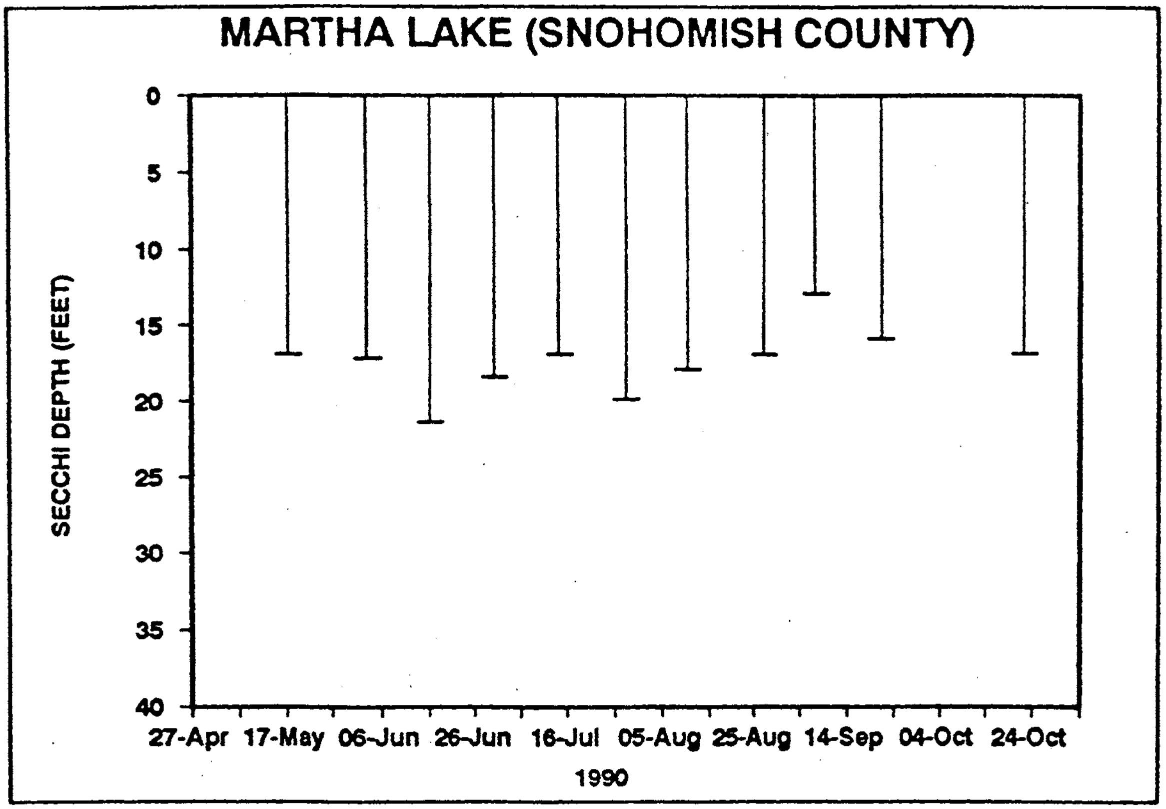
Volunteer-Collected Data

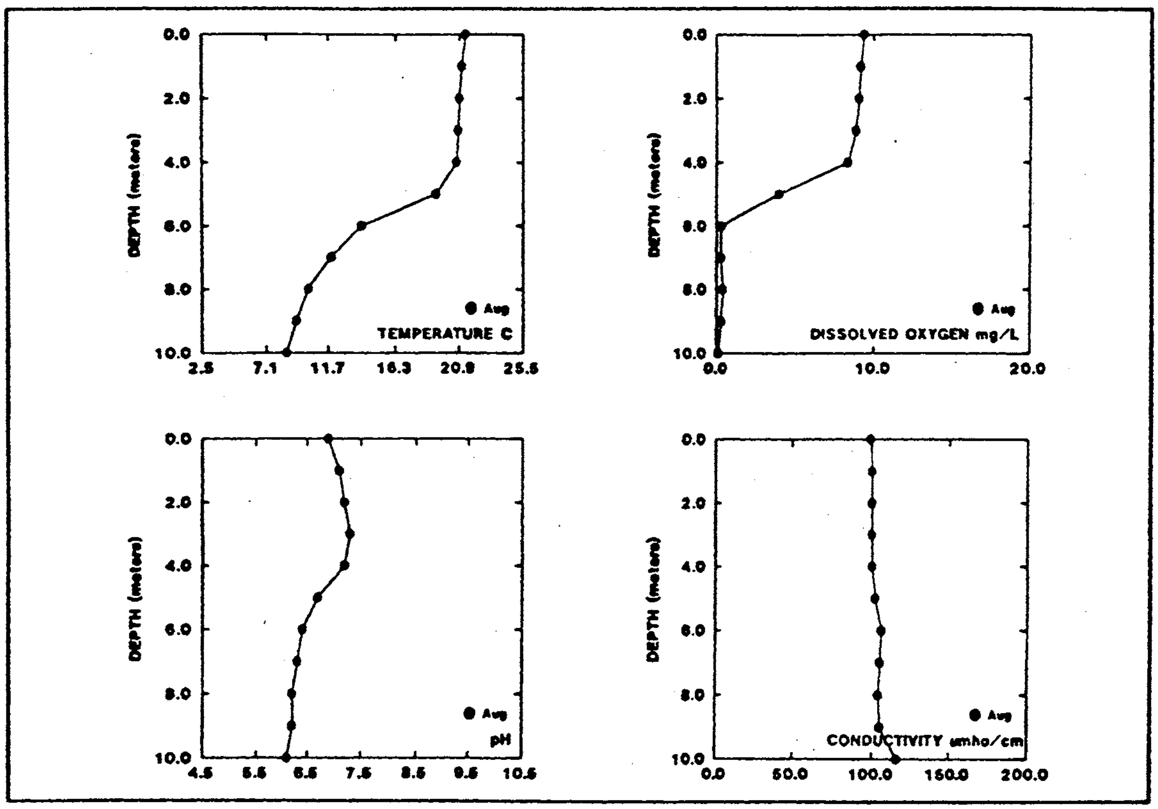
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
18-May	13.3	56.0	6.3	Lt-Green	40	Trace	Light	16.0	-18.3	At 38 feet water depth some algae.
04-Jun	15.0	59.0	6.3	Lt-Green	50	Moderate	Strong	16.3	-16.3	Level of lake higher.
17-Jun	16.1	61.0	6.5	Pea-Green	10	Trace	Light	20.5	-17.3	Water color; light pea-soup green.
01-Jul	20.0	68.0	6.5	Lt-Green	100	Trace	Light	17.5	-19.7	
15-Jul	23.1	73.5	6.7	Lt-Green	0	None	Breezy	16.0	-21.5	
29-Jul	21.1	70.0	6.5	Lt-Green	10	None	Calm	19.0	-24.5	
11-Aug	23.3	74.0	6.5	Lt-Green	0	None	Calm	17.0	-25.5	No rain in over 30 days. Some small algae particles.
28-Aug	20.3	68.5	6.7	Lt-Green	10	Trace	Light	16.0	-28.5	
08-Sep	18.9	66.0	6.7	Lt-Green	100	Trace	Breezy	12.0	-30.3	
22-Sep	20.0	68.0	6.7	Lt-Green	0	None	Calm	15.0		
03-Oct	11.7	53.0	6.5	Lt-Green	5	Trace		16.0	-26.3	

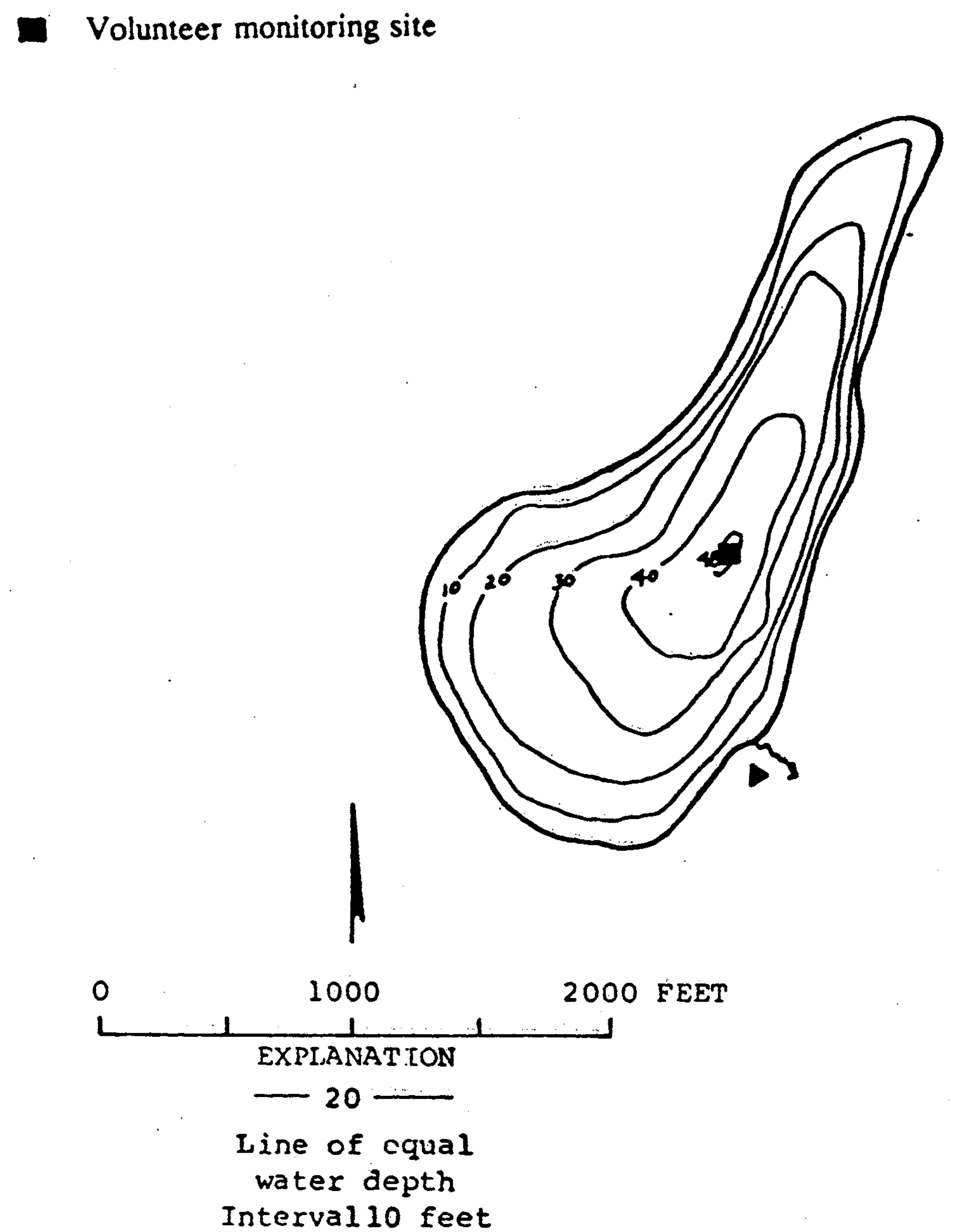
Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
08/28	0.0	21.4	6.9	9.4	99	1, 2, 4	0.015	0.530
	1.0	21.1	7.1	9.2	100			
	2.0	20.9	7.2	9.1	100			
	3.0	20.8	7.3	8.9	100			
	4.0	20.7	7.2	8.4	100			
	5.0	19.2	6.7	4.1	102			
	6.0	14.0	6.4	0.3	106			
	7.0	11.9	6.3	0.3	105			
	8.0	10.2	6.2	0.4	104			
	9.0	9.3	6.2	0.3	105			
	10.0	8.6	6.1	0.1	116			

Secchi Depth and Profile Data Graphs







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

Mason Lake -- Mason County

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

Size (acres)	1000
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

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

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Mason Lake is used for fishing, boating, swimming, rowing, jet skiing, and camping. Recreational facilities on the lakeshore include a park, a picnic area, and three boat ramps. There are some restrictions for motor boating within 100 feet of shore. Lake water is withdrawn for drinking. Currently the watershed is used for logging, animal grazing, crop agriculture, and lakeshore development. In the past, the watershed was used for logging, animal grazing, and crop agriculture. There are approximately 670 houses on the lakeshore; of these, 350 are occupied year-round. The lakeshore is not sewered, and there are 47 culverts that empty into the lake. Fish were not reported as being stocked in the lake. Presently there is a community association for the lake. The worst problems in the lake, in the opinion of the volunteer, are ranked as 1) aquatic plants, 2) algae, 3) water level, and 4) water odors (smells like fresh fish on warm days). Overall, the volunteer finds that Mason Lake has excellent recreational water quality, and is concerned about possible effects on water quality from lawn fertilizing, storm drains, and old septic systems located too close to the lake.

About 90% of the shoreline has been developed for residences. The culverts occur all along the shore, especially at the shallow northeast end and at the southeast end. At the south end of the lake, submerged plants grow in water up to about 20 feet deep.

Mason Lake -- Mason County

Monitoring Results/Summary of Other Available Information

Volunteers monitored five lake stations in Mason Lake (see map). Three deep water stations (Stations 2, 4, and 5) and two stations in water about 60 feet deep on each end of the lake (Stations 1 and 3), were monitored.

At both Stations 1 and 3, the water clarity was lowest during May, July, and October. The variation in Secchi depth was greater at Station 1 than at Station 3. Water clarity at Stations 4 and 5 was similar, and was better than at the other three sites. Variations between readings make it difficult to discern any overall pattern in water clarity. However, all stations had high water clarity during early June, and periods of high water clarity in August and/or September. Water clarity at Station 2 did not correspond to any of the other stations. Station 2 was the only station where water color was reported as milky-green; cloudiness in the water was probably affecting the water clarity. The source of this water color may be worth investigating.

The 1990 concentrations of total phosphorus and total nitrogen in the lake were low (averaging 0.007 mg/L and 0.200 mg/L, respectively) and in the oligotrophic range. In 1981, the concentration of total phosphorus was 0.02 mg/L and the concentration of total nitrogen was 0.99 mg/L (Sumioka and Dion, 1985). In 1972, the concentration of total phosphorus was 0.012 mg/L and the concentration of total nitrogen was 0.19 mg/L (Bortleson *et al.*, 1976).

Although total phosphorus and total nitrogen data collected in 1990 are lower than concentrations reported from 1981 and 1972, the data are very similar to data collected in 1989 (reported in Brower and Kendra, 1990).

Profile data collected during May and August 1990 show that on both sampling dates the lake was thermally stratified, and concentrations of dissolved oxygen decreased with depth. During August, the concentration of dissolved oxygen increased at 8-10 meters at Stations 1, 2, and 4. These increases may be from a combination of decreasing temperatures (cooler water can hold more dissolved oxygen than warmer water) and increased algal growth at these depths. In the lower layer of water, the concentration of dissolved oxygen decreased and was virtually depleted near the bottom of the lake in August. This decrease most likely occurs from the bacterial decomposition of organic material (such as algae and aquatic plants) near the bottom of the lake. Because pH, like oxygen, is also affected by photosynthesis and respiration, the pH profiles are very similar to the dissolved oxygen profiles. Low dissolved oxygen concentrations near the lake bottom appear to have been occurring for many years; data collected in 1968 show that dissolved oxygen concentrations were less than 1 mg/L from 75 feet to the lake bottom (Lee, 1969).

Mason Lake -- Mason County

Secchi data collected in 1970 (Funk *et al.*, 1972), 1972 (Bortleson *et al.*, 1974), 1981 (Sumioka and Dion, 1985), and 1989 (Brower and Kendra, 1990) all show that Mason Lake was oligotrophic. However, the concentrations of total phosphorus varied considerably between the 1972, 1981, and 1989 surveys. The lowest concentrations of total phosphorus were detected during the 1989 survey. Concentrations of chlorophyll *a* were also lower in 1989 compared to data collected in 1972; 1972 data varied from the eutrophic range to the oligotrophic range between March and May.

Residential development along the shore of Mason Lake has increased since 1972, when there were 571 nearshore homes (Bortleson *et al.*, 1976).

In September 1983 Allied Aquatics identified and mapped the following aquatic plants in Mason Lake: *Potamogeton amplifolius, Nymphaea odorata, Brasenia schreberi, Elodea, Vallisneria americana*, and *Potamogeton pusillus*. These plants were located mostly along the north and northwest shores of the lake.

Plant samples collected by the volunteer during November 1990 were identified as large leaved pondweed (*Potamogeton amplifolius*) and Robbins pondweed (*Potamogeton robbinsii*). Both plants grow mostly submerged in water. The large-leaved pondweed has submerged leaves that are 1-2 inches wide and 6-8 inches long that curl downward, and have small oval leaves that float on the water surface.

Comments

Compared to other Mason County lakes monitored for the program in 1990 (Island, Limerick, Nahwatzel, Phillips, Spencer and Wooten Lakes), Mason Lake had the best water clarity and lowest concentration of total phosphorus.

Acknowledgements

I thank Tom Black, who coordinated the five volunteers during 1989, and Tom Brokaw and Jerry Nelson, who coordinated the volunteers during 1990. The volunteers participating during 1989-1990 were: Tom Black, Dick Bowers, Bob Groves, Ray Hussey, Clay Johnson, Don Lamberto, Roy Magnussen, Jerry Nelson, and John Smith.

Mason Lake -- Mason County

Volunteer-Collected Data -- Station 1

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
15-May	12.2	54.0	8.5	Clear	100			22.0 w	24.3	Lake height measured from top of dock.
30-May	17.8	64.0	6.5	Clear	10	Light	Light	23.8 w	24.3	Lake height measured from top of dock.
14-Jun	17.8	64.0	6.5	Clear	0	None		30.3	23.0	
28-Jun	18.3	65.0	6.0	Clear	90			28.4	25.3	
12-Jul	22.2	72.0	6.0	Clear	10			22.0	26.5	Water color light green/clear.
26-Jul	21.1	70.0	6.0	Lt-Green	100	None	Light	23.8	28.3	Air temperature 60 degrees.
09-Aug	23.3	74.0	6.0	Lt-Green	0			25.7	29.0	
22-Aug	21.1	70.0	6.0	Lt-Green	0			25.7	29.5	
06-Sep	21.1	70.0	6.0	Lt-Green	10	None		27.5	29.7	
21-Sep	21.1	70.0	6.0	Lt-Green	0	None	Calm	33.9	28.6	
03-Oct	17.8	64.0	6.0	Lt-Green	100	Moderate	Breezy	21.1	28.0	Dark day. Wind breezy to gusty.

* Secchi data corrected for rope shrinkage, but there was high variability between the first and second Secchi depths collected on each sampling date. All Secchi data from this station were not used in comparisons with data collected by others.
w Secchi disk in weeds

Volunteer-Collected Data -- Station 2

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
18-May	15.6	61.0	.	Lt-Green	50	None	Breezy	17.4		
04-Jun	13.3	56.0	.	Milky-Gr	75	Moderate	Light	25.7**		No anchor.
18-Jun	16.7	62.1	.	Lt-Green	50	Trace	Light	21.1**		No anchor.
29-Jun	19.4	67.0	.	Clear	0	Light	Light	24.7**		Some boat traffic.
13-Jul	22.8	73.0	.	Milky-Gr		None	Calm	25.7**		
30-Jul	22.8	73.0	.	Lt-Green	0	None	Breezy	25.7		
27-Aug	21.1	70.0	.	Milky-Gr	90	Trace	Light	19.3		
10-Sep	21.1	70.0	.	Lt-Green	10	None	Calm	22.9		
24-Sep	20.0	68.0	.	Milky-Gr	100	None	Calm	22.0		Full cloud cover.
06-Oct	18.9	66.0	.	Lt-Green	50	Light	Calm	19.3		

* Secchi data corrected for rope shrinkage.
** There was high variability between the first and second Secchi depths collected; this data point may not be included in data comparisons

Volunteer-Collected Data -- Station 3

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
29-May	15.6	60.0	6.0	Lt-Green	50	Moderate	Calm	29.3	24.0	
12-Jun	16.7	62.0	6.0	Lt-Green	50	None	Light	27.5	23.0	
26-Jun	16.7	62.0	6.0	Lt-Green	75	None		24.7	26.0	
11-Jul	23.3	74.0	6.0	Lt-Green	10	None	Light	22.9	26.5	Busy water, lots of boats, hot day.
22-Jul	25.6	78.0	6.0	Lt-Green	25	None	Breezy	24.7	28.0	Choppy water.
09-Aug	23.9	75.0	6.0	Lt-Green	0	None	Calm	27.5	28.5	
20-Aug	23.9	75.0	6.0	Lt-Green	10	Light	Calm	27.5	29.0	
03-Sep	21.1	70.0	6.0	Lt-Green	0	None	Breezy	29.3	27.5	
20-Sep	21.1	70.0	6.0	Lt-Green	25	None	Calm	27.5	28.5	Some type of bloom in lake, everywhere.
30-Sep	20.0	68.0	6.0	Lt-Green	0		Light	30.3**		
15-Oct	15.0	59.0	6.0	Lt-Green	25	Heavy	Light	22.9	25.0	

* Secchi data corrected for rope shrinkage
** There was high variability between the first and second Secchi depths collected; this data point may not be included in data comparisons

Mason Lake -- Mason County

Volunteer-Collected Data -- Station 4

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
21-May	14.4	58.0	6.5	Lt-Green	90	Moderate	Light	24.3	29.5	Water depth 83'.
25-May								22.9		
05-Jun	15.6	60.0	6.5	Lt-Green	50	Light		34.8	28.3	Lake depth 83'.
20-Jun	15.6	60.0	6.0	Lt-Green	10	None	Light	24.7**	30.0	
03-Jul	18.3	65.0	6.0	Clear	25	Trace	Calm	28.9	31.5	
17-Jul	24.4	76.0	6.0	Lt-Green	0	None	Calm	25.2	32.5	
02-Aug	22.2	72.0	6.0	Lt-Green	0	None	Light	28.4	34.3	
14-Aug	23.3	74.0	6.0	Lt-Green	0	None	Light	33.9	34.5	
16-Aug								23.8		
31-Aug	20.8	69.5	7.0	Lt-Green	75	Heavy	Breezy	22.5	33.0	
12-Sep	19.4	67.0	7.0	Lt-Green	100	Trace	Light	33.9	33.5	
25-Sep	19.2	66.5	7.0	Lt-Green	100	None	Calm	27.5	34.0	
06-Oct	17.8	64.0	7.0	Lt-Green	75	Moderate	Calm	25.7**	33.7	

* Secchi data corrected for rope shrinkage.

** There was high variability between the first and second Secchi depths collected; these two data points may not be included in data comparisons

Volunteer-Collected Data -- Station 5

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
25-May	15.6	60.0	.	Lt-Green	25	None	Calm	25.7		
13-Jun	15.6	60.0	.	Lt-Green	50	Trace	Calm	33.9		
20-Jun	17.2	63.0	.	Lt-Green	10	None	Breezy	29.3		
05-Jul	20.6	69.0	.	Green	10	Trace	Light	24.7	7.5	Heavy boat traffic during the 4th of July.
19-Jul	20.3	68.5	.	Clear	0	None	Calm	28.4		
04-Aug	23.3	68.5	.	Lt-Green	0	None	Light	27.5		
19-Aug	22.2	72.0	.	Lt-Green	10	None		31.2		
31-Aug	20.8	69.5	.	Lt-Green	75	Moderate		24.7		Windy.
14-Sep	20.6	69.0	.	Lt-Green	0	None	Breezy	22.9		
27-Sep	20.0	68.0	.	Lt-Green	0	None	Calm	28.4		Sunny and calm. Good fishing.
06-Oct	17.8	64.0	.	Lt-Green	50	Moderate	Calm	22.9		

* Secchi data corrected for rope shrinkage; but there was high variability between the two Secchi depths collected on each sampling date. All Secchi data from this station will not be included in comparisons with data collected by others.

Mason Lake -- Mason County

Onsite Visit Data -- Station 4

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/25	0.0	14.2	6.5	10.8	46	1, 4, 8	0.007	0.230
	0.5	14.2	6.7	10.7	46			
	1.0	14.2	6.8	10.7	46			
	2.0	14.2	6.9	10.6	47			
	3.0	14.0	6.9	10.7	46			
	4.0	14.0	6.9	10.7	47			
	5.0	14.0	6.9	10.7	46			
	6.0	13.9	6.9	10.7	46			
	7.0	13.9	6.9	10.6	46			
	8.0	13.7	6.9	10.6	46			
	9.0	13.3	6.8	10.4	47			
	10.0	12.6	6.7	10.3	47			
	12.0	10.5	6.5	9.5	50			
	14.0	9.6	6.4	9.1	51			
	17.0	8.8	6.3	8.7	51			
	20.0	8.4	6.2	8.3	51			
	25.0	8.1	6.2	7.6	51			
08/16	0.0	22.6	7.3	9.1	53	3, 5, 7	0.008	0.163
	1.0	22.6	.	.	.			
	2.0	22.6	.	.	.			
	3.0	22.6	.	.	.			
	4.0	22.6	.	.	.			
	5.0	22.6	7.2	9.0	53			
	6.0	22.4	7.2	9.1	58			
	7.0	22.3	7.2	9.2	58			
	8.0	19.7	7.5	10.7	58			
	9.0	18.0	7.4	10.7	59			
	10.0	15.7	7.0	10.4	59			
	11.0	15.0	6.8	8.5	58			
	16.0	10.5	6.5	4.5	59			
	20.0	9.6	6.3	2.9	60			
	25.0	9.2	6.1	0.8	60			

Onsite Visit Data -- Station 1

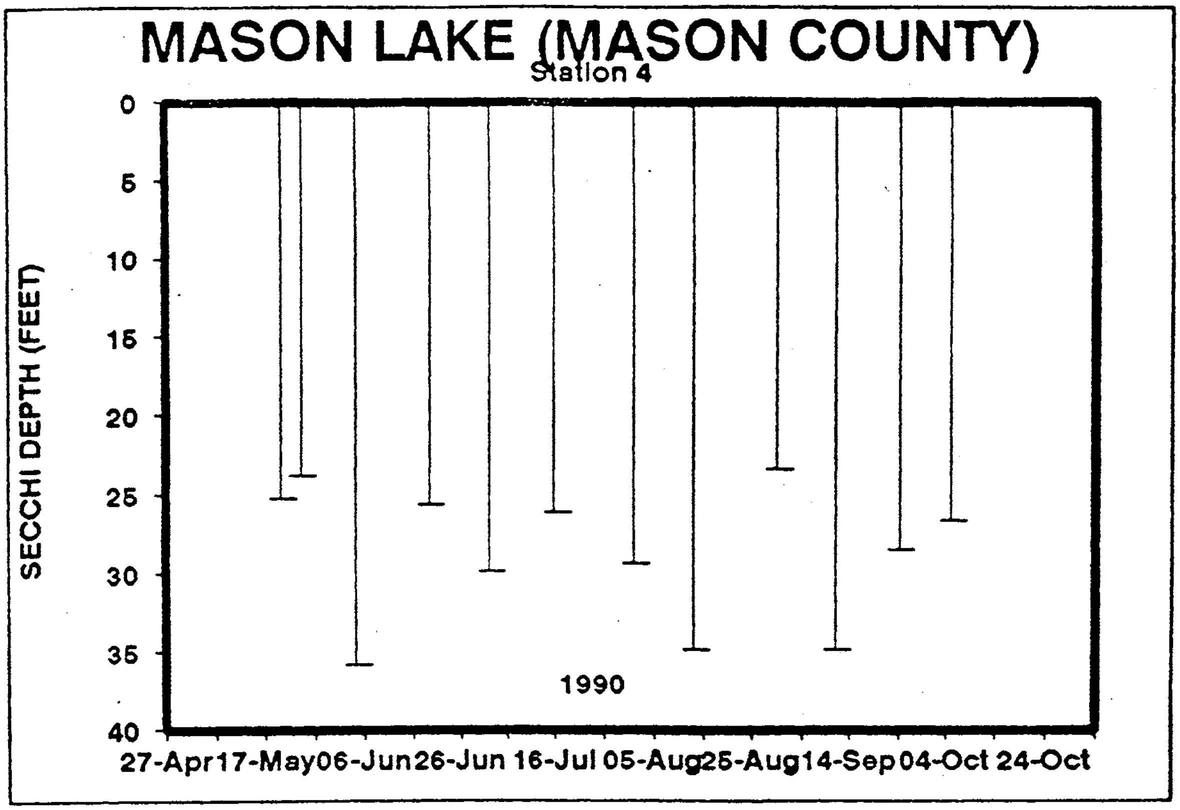
Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)
08/16	0.0	22.1	7.4	9.3	50
	1.0	22.1	.	.	.
	2.0	22.1	.	.	.
	3.0	22.1	.	.	.
	4.0	22.1	.	.	.
	5.0	22.0	7.3	9.3	53
	6.0	22.0	7.3	9.3	56
	7.0	21.9	7.3	9.3	56
	8.0	21.1	7.4	10.0	57
	9.0	16.3	7.1	10.2	57

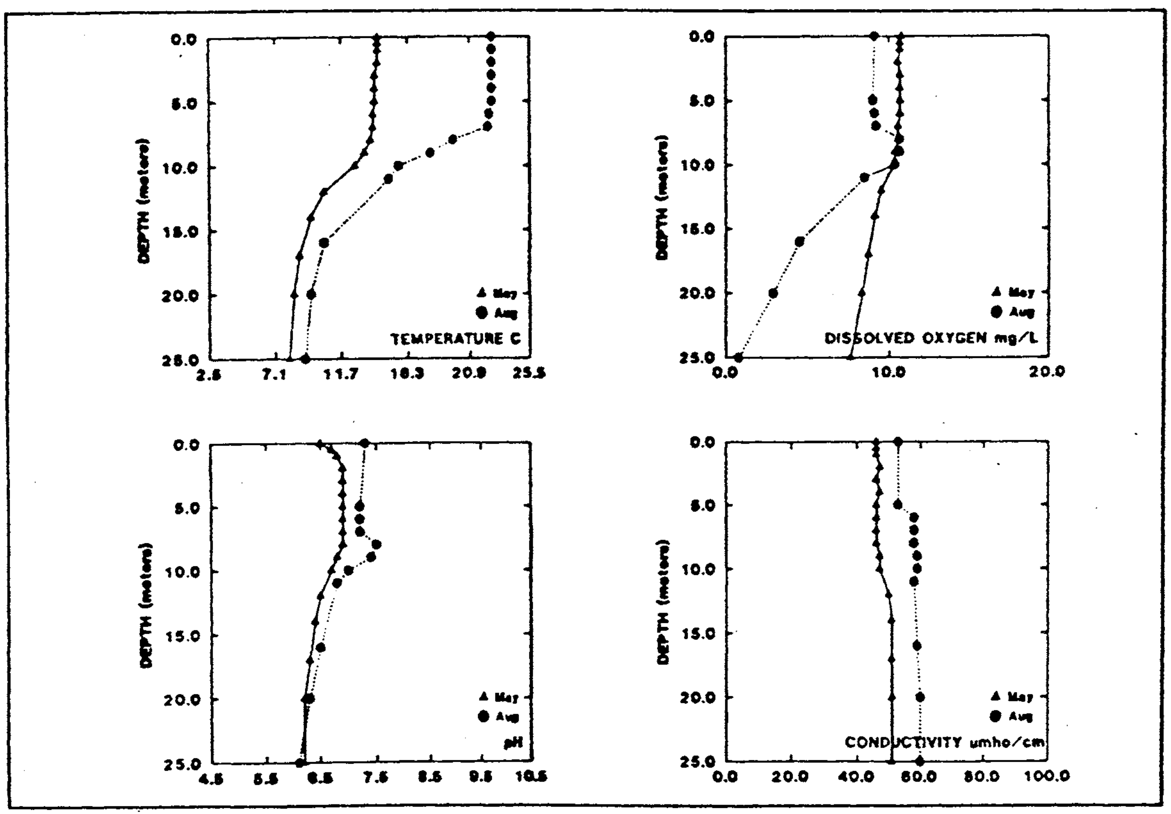
Mason Lake -- Mason County

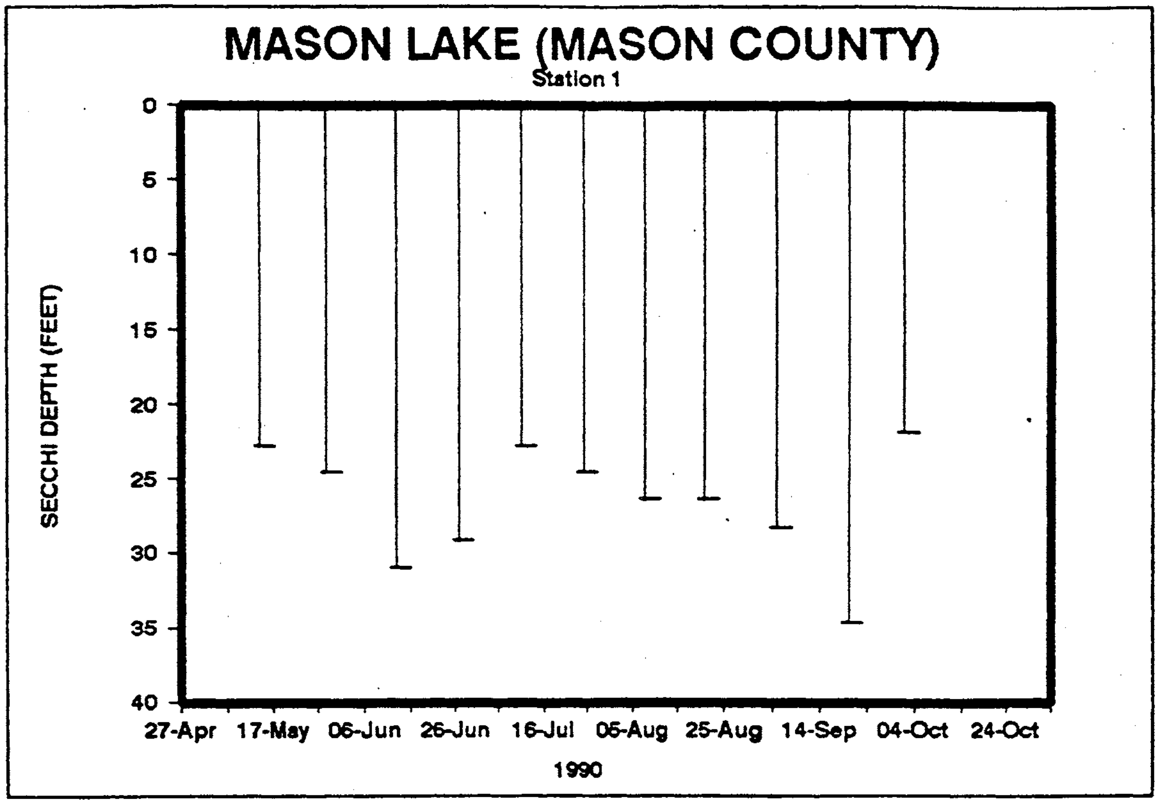
Onsite Visit Data -- Station 2

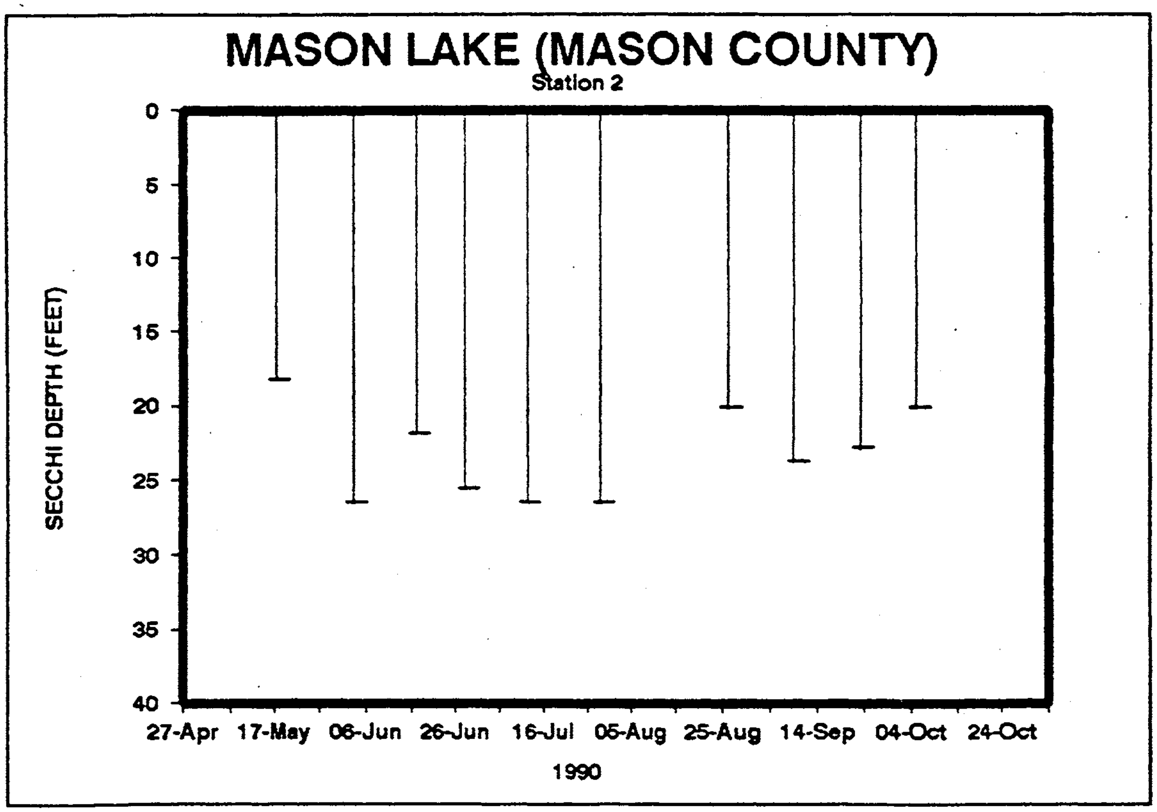
Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)
08/16	0.0	22.5	7.3	9.4	50
	1.0	22.5	.	.	.
	2.0	22.5	.	.	.
	3.0	22.5	.	.	.
	4.0	22.5			
	5.0	22.3	7.3	9.2	53
	6.0	22.3	7.3	9.2	57
	7.0	21.9	7.4	9.5	57
	8.0	20.5	7.4	10.1	57
	9.0	18.2	7.4	10.4	57

Secchi Depth and Profile Data Graphs






MASON LAKE (MASON COUNTY)
Station 1
SECCHI DEPTH (FEET)
0
5
10
15
20
25
30
35
40
27-Apr
17-May
06-Jun
26-Jun
16-Jul
05-Aug
25-Aug
14-Sep
04-Oct
24-Oct
1990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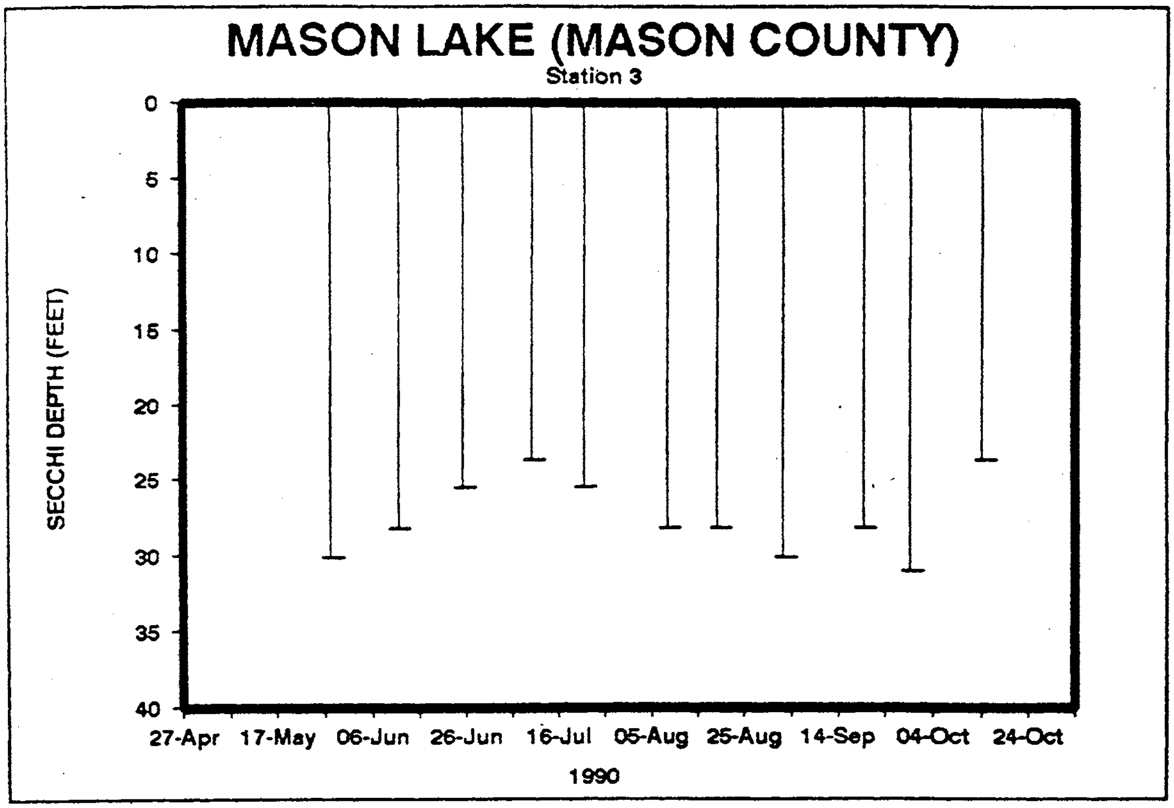
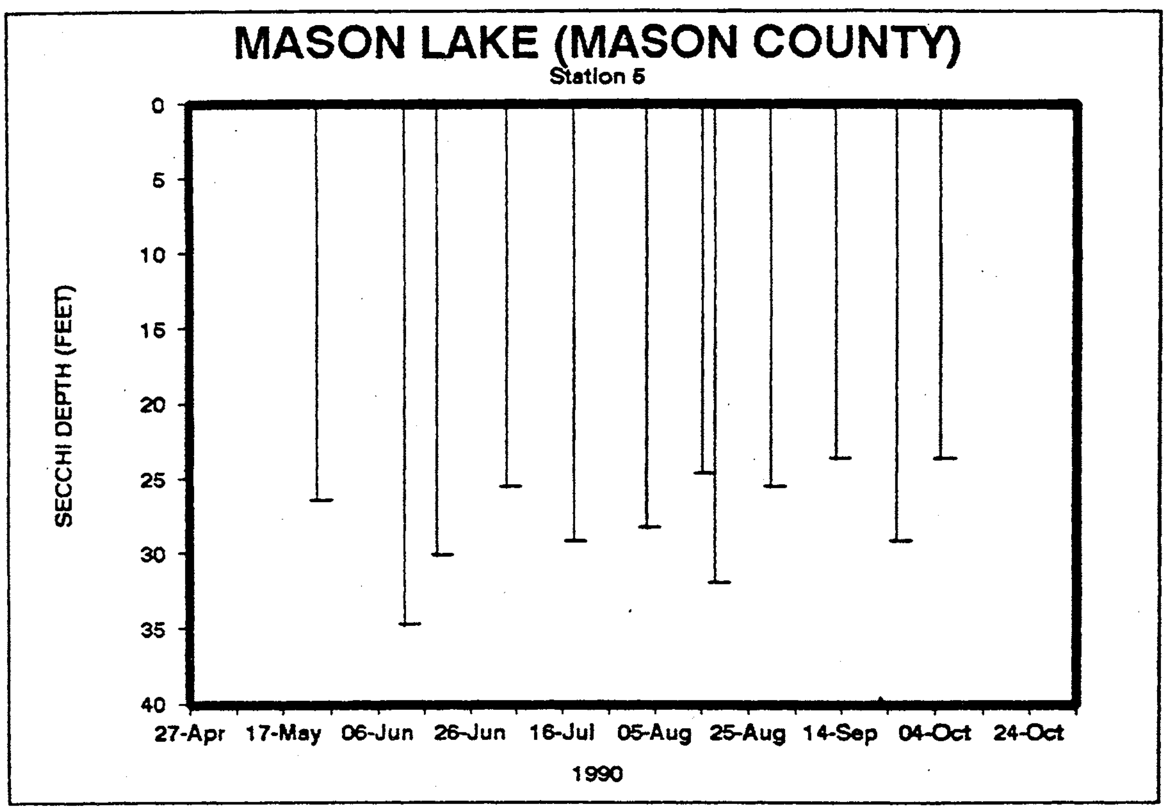
Station 2
SECCHI DEPTH (FEET)
0
5
10
15
20
25
30
35
40
27-Apr
17-May
06-Jun
26-Jun
16-Jul
05-Aug
25-Aug
14-Sep
04-Oct
24-Oct
1990


MASON LAKE (MASON COUNTY)
Station 3
SECCHI DEPTH (FEET)
0
5
10
15
20
25
30
35
40
27-Apr
17-May
06-Jun
26-Jun
16-Jul
05-Aug
25-Aug
14-Sep
04-Oct
24-Oct
1990


MASON LAKE (MASON COUNTY)
Station 5
SECCHI DEPTH (FEET)
0
5
10
15
20
25
30
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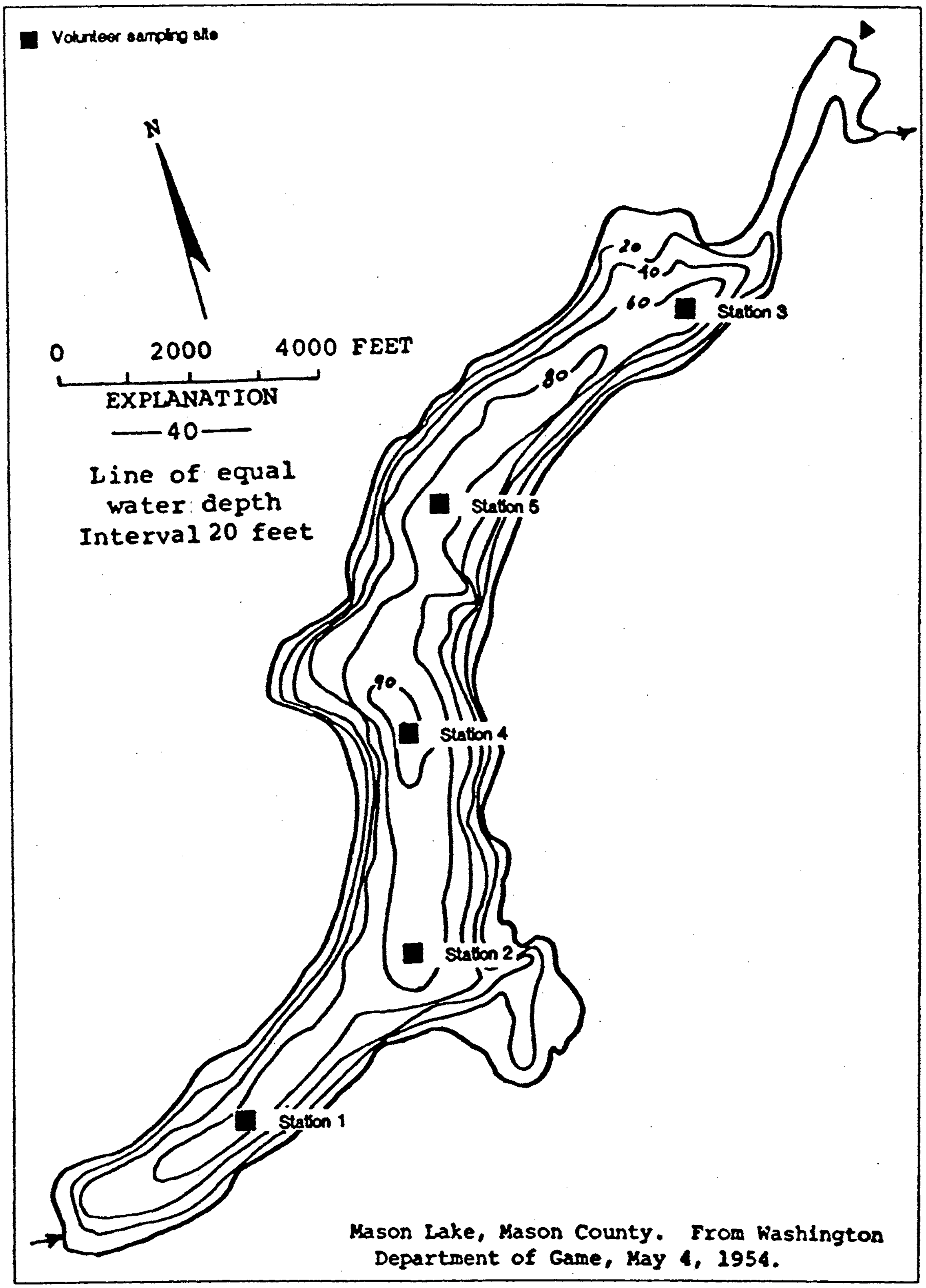
27-Apr
17-May
06-Jun
26-Jun
16-Jul
05-Aug
25-Aug
14-Sep
04-Oct
24-Oct
1990



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

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
Maximum Depth (feet)	25
Mean Depth (feet)	12
Lake Volume (acre-feet)	1000
Drainage Area (miles^2)	1.8
Altitude (feet)	516
Shoreline Length (miles)	1.9

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

* From Carlson (1977)
** See Comments Section

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Mission Lake is used for fishing, swimming, and rowing. There is a speed restriction of 7 mph for motorboats on the lake. Lake water is withdrawn for drinking. Currently the watershed is used for logging, crop agriculture, and lakeshore development. In the past, the watershed was used for logging, animal grazing, and mining, and the shoreline was altered. There are 71 houses on the lakeshore. The lakeshore is not sewered, and there are at least three culverts that empty into the lake. Rainbow and cutthroat trout are stocked in the lake. The lake has been chemically treated in the past to control fish species (the volunteer reports that rotenone has been used five times since 1950). The worst problems in the lake, in the opinion of the volunteer, are ranked as 1) aquatic plants, 2) algae, 3) fecal deposits from seagulls, 4) fish kill, 5) floating debris, 6) water level, 7) sediment, and 8) fish species. Overall, the volunteer finds that Mission Lake has fair recreational water quality, and is concerned about the reduction in lake depth over the years.

The volunteer also noted that seagulls introduced a parasite that caused a trout fluke disease. She mentioned that the parasite was identified by a representative from the Department of Wildlife.

Submerged plants grow throughout the lake; these and lilies are especially thick on the east side of the lake. The lilies include a pink and white variety (*Nymphaea*), of which there is "prolific" growth in the lake, as well as the yellow-flowering variety (*Nuphar*). There is a clearcut on the southwest side of the lake.

Monitoring Results/Summary of Other Available Information

Profile data collected during 1990 show that the lake was not stratified during May, and was only weakly stratified during August. Dissolved oxygen decreased with depth and was virtually depleted near the lake bottom during August. Dissolved oxygen is usually depleted by bacteria which use oxygen to decompose organic material (such as algae, aquatic plants and woody debris) near the lake bottom. The decrease in pH and increase in conductivity with depth during August are most likely related to increased decomposition near the lake bottom. In February and June 1970, the concentrations of dissolved oxygen also decreased with depth and were depleted near the lake bottom (Collings, 1973), so it is likely that deep-water oxygen depletion is not uncommon.

In 1990, the concentrations of total phosphorus and total nitrogen were moderately high (averaging 0.0143 and 0.228 mg/L, respectively). In 1970, total nitrogen ranged from 0.09-0.49 mg/L (Collings, 1973), and the concentration of total phosphorus was 0.006 mg/L (Bortleson *et al.*, 1976).

In 1970, the following plants were observed growing in Mission Lake: pondweed, watershield (*Brasenia*), waterweed (*Elodea*), waterlily (*Nuphar*), bulrush (*Scirpus*), sedge (*Cyperus*), and cattail (*Typha*; Collings, 1973).

Residential development around the lakeshore has increased over time. There were 20 nearshore homes in 1953, 48 in 1971 (Collings, 1973), and 71 in 1990.

The water sample collected by the volunteer on August 7, 1990, was of a brown scum floating on the water. The sample contained general detritus and insect exoskeletons, as well as adult insects (midge and thrip). Foam and scum were also reported from Lake Nahwatzel and Phillips Lake in Mason County. A sample of the foam from Lake Nahwatzel also contained of organic material.

Comments

On each Secchi reading date, the Secchi disk hit the lake bottom and was still visible. As a result, the Secchi data could not be used to estimate the trophic status of the lake. The mesotrophic estimate is based on the moderately high concentrations of total phosphorus, and the moderately high aquatic plant productivity in the lake.

Acknowledgement

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

Mission Lake -- Kitsap Lake

Volunteer-Collected Data

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
17-May	15.6	60.0	6.5	Lt-Green		None	Light	16.0 w	0.0	Lake height marker in place as of today.
23-May								18.0 b		
31-May	16.7	62.0	6.5	Lt-Green		Heavy	Breezy	18.5 b	2.0	
15-Jun	20.0	68.0	7.0	Green	10	Trace	Breezy	12.7 b	4.0	Two secchi readings confirmed figure.
04-Jul	22.8	73.0	6.5	Pea-Green	25	Light	Light	11.5 b	5.0	Lake height up 5" on marker in lake. Influx of speed boats daily at public access, starting to cause beach damage.
18-Jul	25.6	78.0	6.5	Green	0	None	Calm	12.7 b	4.7	lake depth 20.25 feet (not 25' as on map).
07-Aug	23.9	75.0	6.5	Pea-Green	0	None	Calm	14.0 b	3.0	Water color: "plain yuk". Sample in mail taken today of brown scum and bubbles over whole lake.
14-Aug								13.5 b		
28-Aug	17.8	64.0	6.5	Gr-Brown	10	Trace	Light	13.0 b	0.0	Note on lake height: Normal (5 in.) in yardstick measure in lake.
15-Sep	18.9	66.0	6.5	Gr-Brown	50	None	Light	13.0 b	-0.5	
27-Sep	16.7	62.0	6.5	Gr-Brown	10	None	Gusty	13.0 b	-1.3	
17-Oct	15.6	60.0	6.5	Gr-Brown	10	Moderate		13.0 b	1.3	The change of weather conditions at this time limits accuracy in future monitor conditions.

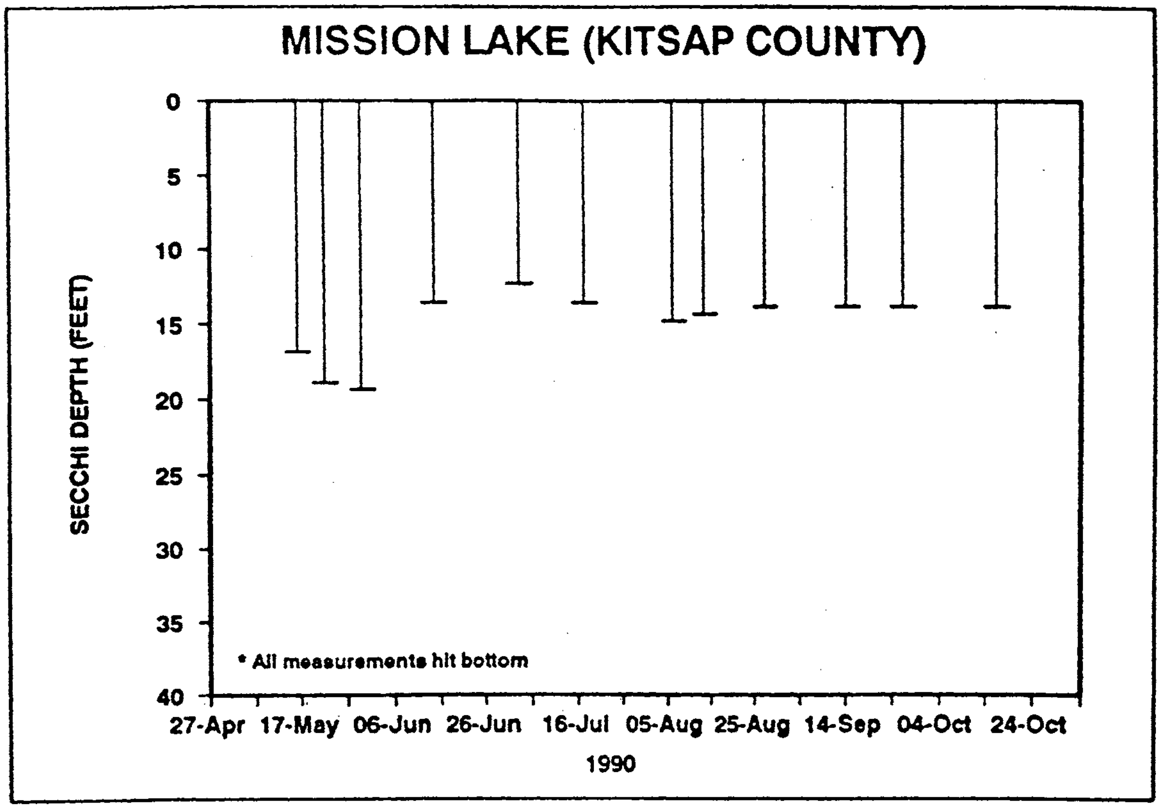
b Secchi disk hit bottom
w Secchi disk in weeds

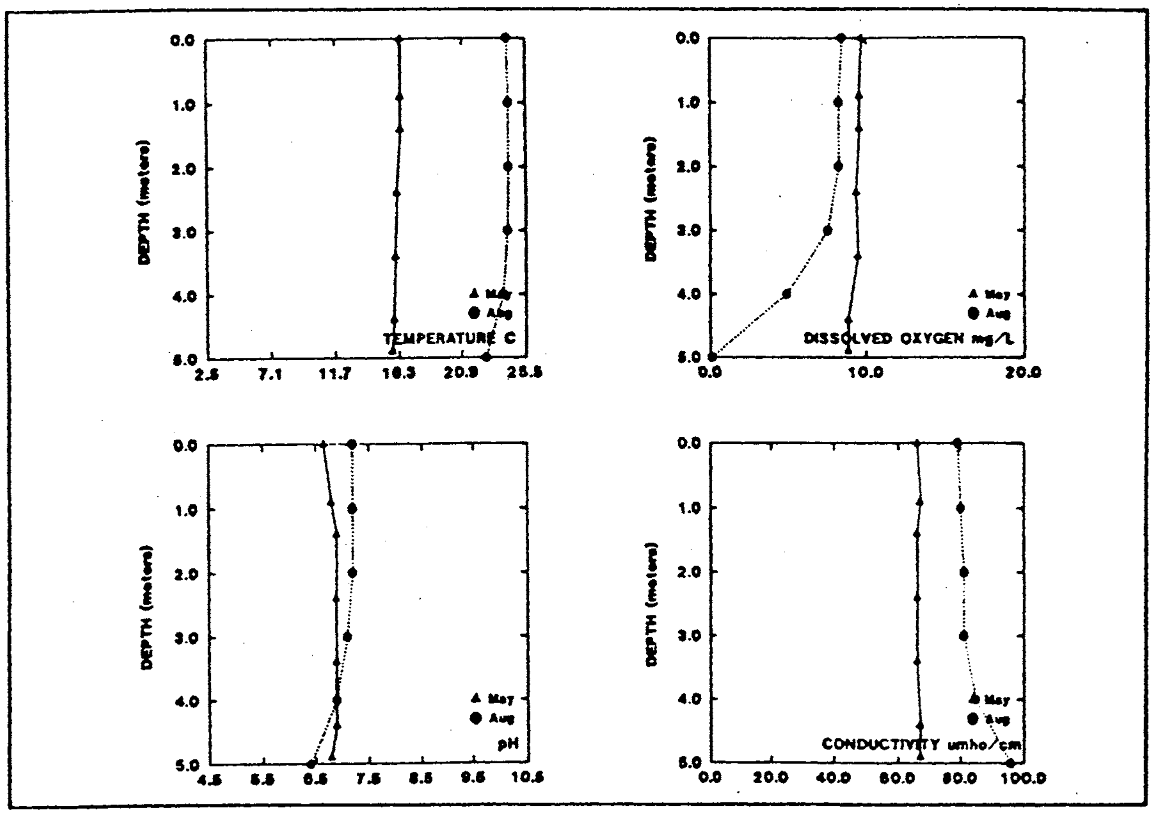
Onsite Visit Data

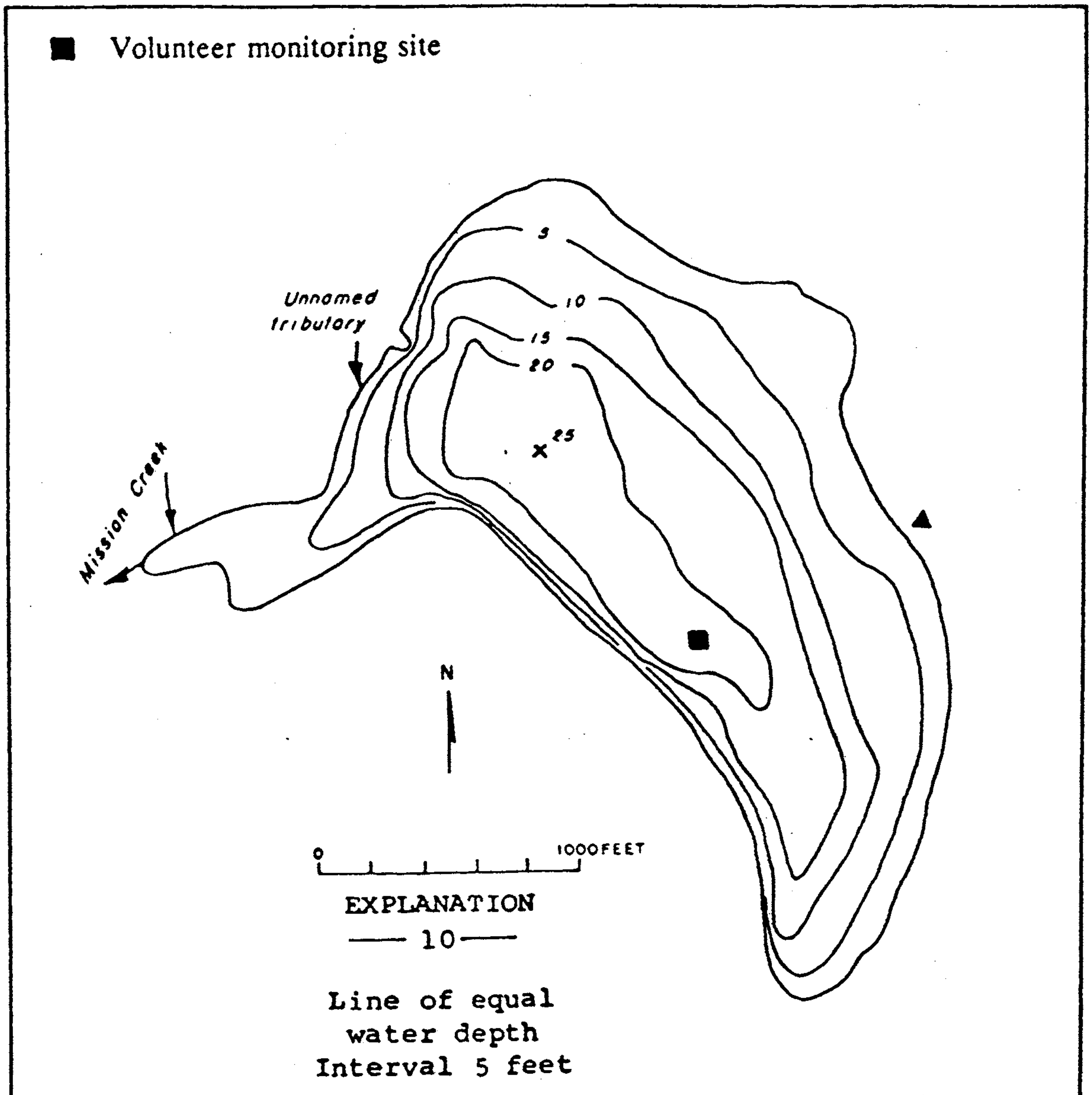
Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/23	0.0	16.4	6.7	9.7	66	0.5, 2.5	0.014	0.224
	0.9	16.4	6.8	9.6	67			
	1.4	16.4	6.9	9.6	66			
	2.4	16.1	6.9	9.4	66			
	3.4	16.0	6.9	9.5	66			
	4.4	15.9	6.9	8.9	67			
	4.9	15.8	6.8	8.9	67			
08/14	0.0	24.2	7.2	8.5	79	*	0.014	0.232
	1.0	24.3	7.2	8.3	80			
	2.0	24.3	7.2	8.3	81			
	3.0	24.2	7.1	7.6	81			
	4.0	23.9	6.9	5.0	85			
	5.0	22.7	6.4	0.1	96			

* unknown

Secchi Depth and Profile Data Graphs







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

Lake Nahwatzel -- Mason County

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

Size (acres)	269
Maximum Depth (feet)	25
Mean Depth (feet)	17
Lake Volume (acre-feet)	4642
Drainage Area (miles^2)	6.2
Altitude (feet)	440
Shoreline Length (miles)	2.9

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	38
Mean Trophic State Index* (Total Phosphorus):	40

* From Carlson (1977)

Summary of Questionnaire Results and Other Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Nahwatzel is used for fishing, boating, swimming, rowing, jet skiing, and camping. Recreational facilities on the lakeshore include one resort and one boat ramp, and there are no restrictions for motorboat use on the lake. Lake water is withdrawn for drinking. Currently the watershed is used for logging and residential development is occurring on the lakeshore. In the past, the watershed was used for logging. There are 111 houses on the lakeshore, 27 of which are occupied year-round. The lakeshore is not sewered. Trout and bass are stocked in the lake. The lake has been chemically treated in the past to control fish species. Overall, the volunteer finds that Lake Nahwatzel has good recreational water quality, and is concerned that some septic systems may not be working properly.

The volunteer believes there may be osprey nests in the wooded area north of the lake; the volunteer is concerned that the osprey population does not seem to be increasing. There is a wetland near the outlet. The southwest shore is also marshy. Foam sometimes appears on the lakeshores. There are pilings from a railroad bridge at the north end of the lake, near the marshy wetland area.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity in Lake Nahwatzel was lowest during May and June, and gradually increased over the course of the summer. Profile data collected during May and August 1990 show that the lake was not thermally stratified, indicating that the lake was mixing. As would be expected from a lake that was mixing, dissolved oxygen, pH, and conductivity were stable from surface to the bottom. Lake Nahwatzel was one of 15 lakes surveyed by Ecology in 1990 as part of a statewide lakes survey to supplement volunteer-collected data. Temperature and dissolved oxygen profile data collected by Ecology during 1990 also show that the lake was mixing during June and September (Coots, 1991). Compared to other lakes sampled by Ecology in 1990, Lake Nahwatzel had low concentrations of nutrients and low specific conductance. Sedge (*Scirpus*) grows along about 40% of the shoreline. *Chara*, an algae that looks like a macrophyte, was also found to be growing in deeper areas of the lake in 1974 (Bortleson *et al.*, 1976).

The concentrations of total phosphorus collected during the May and August 1990 onsite visit with the volunteer were slightly higher than concentrations measured during June and September. However, all samples collected in 1990 had generally low concentrations of total phosphorus, indicating that the lake was oligotrophic. In August 1974, the concentration of total phosphorus in the lake was 0.007 mg/L and the concentration of total nitrogen was 0.29 mg/L (Bortleson *et al.*, 1976).

Residential development along the lakeshore has increased somewhat since 1974, when there were 86 nearshore homes (Bortleson *et al.*, 1976).

The volunteer took pictures of foam piling up as much as one foot thick on the lakeshore. The volunteer reported that the foam is found periodically. This foam is likely from organic material on the lake which is whipped up by winds into a brownish foam. The foam sample collected by the volunteer on April 21, 1990, contained chironomid exoskeltons. Another sample collected by the volunteer during August contained a lot of detritus, zooplankton (microscopic animal) parts, bryozoan spores, exuvia (skins or coverings shed off by larvae, animals or insects), some filamentous algae and a few live insects. The plant sample collected during the onsite visit is in the *Campanulaceae* family, possibly *Lobelia dortmanna*. Plant flowers are needed for a positive identification. The plant grows submerged in water and appears grassy, although the leaves are round and tough.

The relatively shallow depth of the lake probably makes the lake more susceptible to mixing from winds.

Comments

Volunteers at Mission Lake in Kitsap County, and Phillips Lake in Mason County, also reported foam at the shoreline during 1990. A sample collected from Mission Lake also contained detritus, insect exoskeletons and adult insects.

Compared with other Mason County lakes monitored for the program in 1990 (Island, Limerick, Mason, Phillips, Spencer and Wooten Lakes), Lake Nahwatzel had moderately good water clarity and low concentrations of total phosphorus.

Nahwatzel Lake -- Mason County

Acknowledgement

I thank Dave Fowble for volunteering his time to monitor Lake Nahwatzel during 1990.

Volunteer-Collected Data

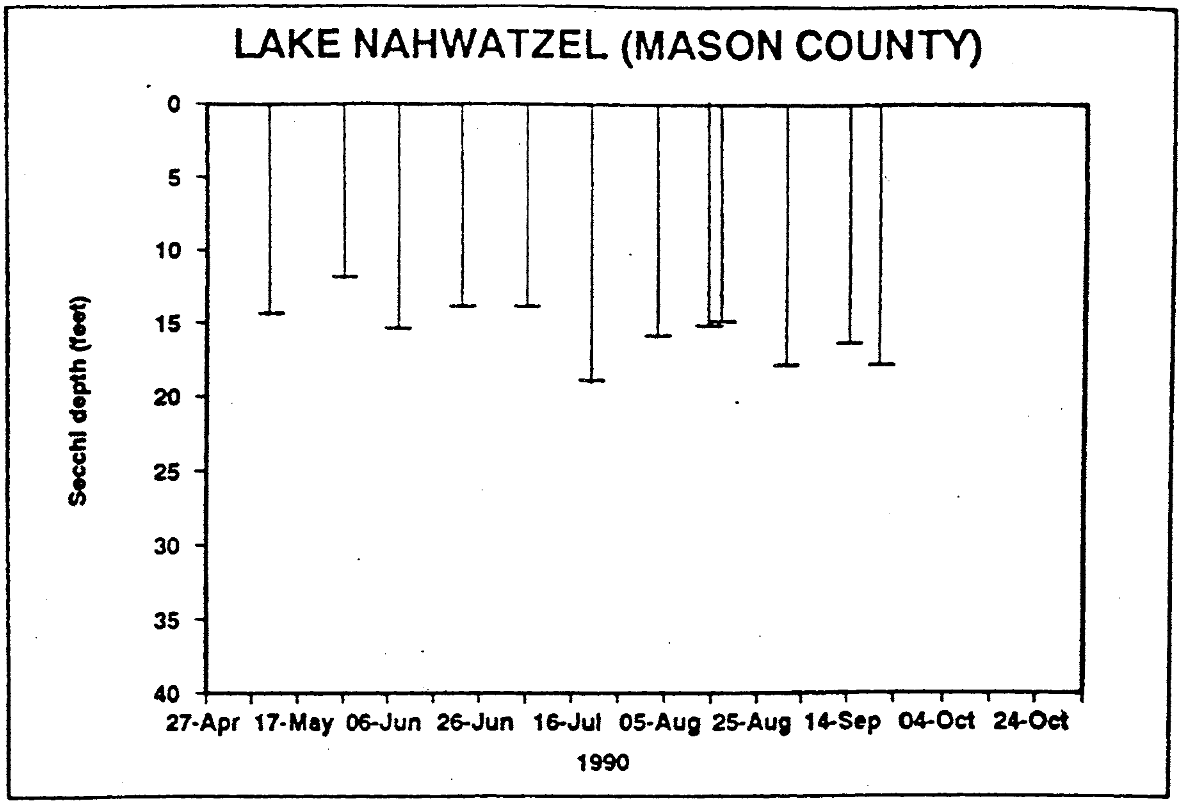
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht	Abbreviated Comments
12-May	15.6	60.0	6.0	Lt-Green	100	Trace	Breezy	13.5		Have sample of suds to examine.
28-May	15.6	60.0	6.0	Lt-Green	10	Light	Breezy	11.0		Lake up 1 inch since last time.
09-Jun	16.7	62.0	6.0	Green	100	Moderate	Calm	14.5	4.5	Lake height up 4.5" since 5/12.
23-Jun	17.8	64.0	6.0	Green	2	None	Light	13.0	3.5	Bright sun. Lake was 24.5' deep 5/12/90.
07-Jul	21.1	70.0	6.0	Green	0	Heavy	Light	13.0		Lake depth 23'11.5". Bright sun 76 degree temp.
21-Jul	26.7	80.0	6.0	Green	0	None	Calm	18.0		Bright sun, 90 degrees. Lake depth 22'5.5"
04-Aug	24.4	76.0	6.0	Green	1	None	Light	15.0		74 degrees outside. Lake depth 23.5'. Possible error with lake height last time?
15-Aug								14.3		Taken during onsite visit
18-Aug	22.2	72.0	6.0	Pea-Green	100	Heavy	Light	14.0		
01-Sep	21.1	70.0	6.0	Lt-Green	100	Heavy	Calm	17.0		Lake depth 23'3".
15-Sep	18.9	66.0	6.0	Lt-Green	100		Calm	15.5		Lake depth 32.5.
22-Sep	20.0	68.0	6.0	Lt-Green	0	None	Calm	17.0		Last reply card. Lake depth 22'11".
06-Oct	17.2	63.0	6.0	Lt-Green	40	Light	Calm			No boat available - info taken from dock. Lake depth 23'.

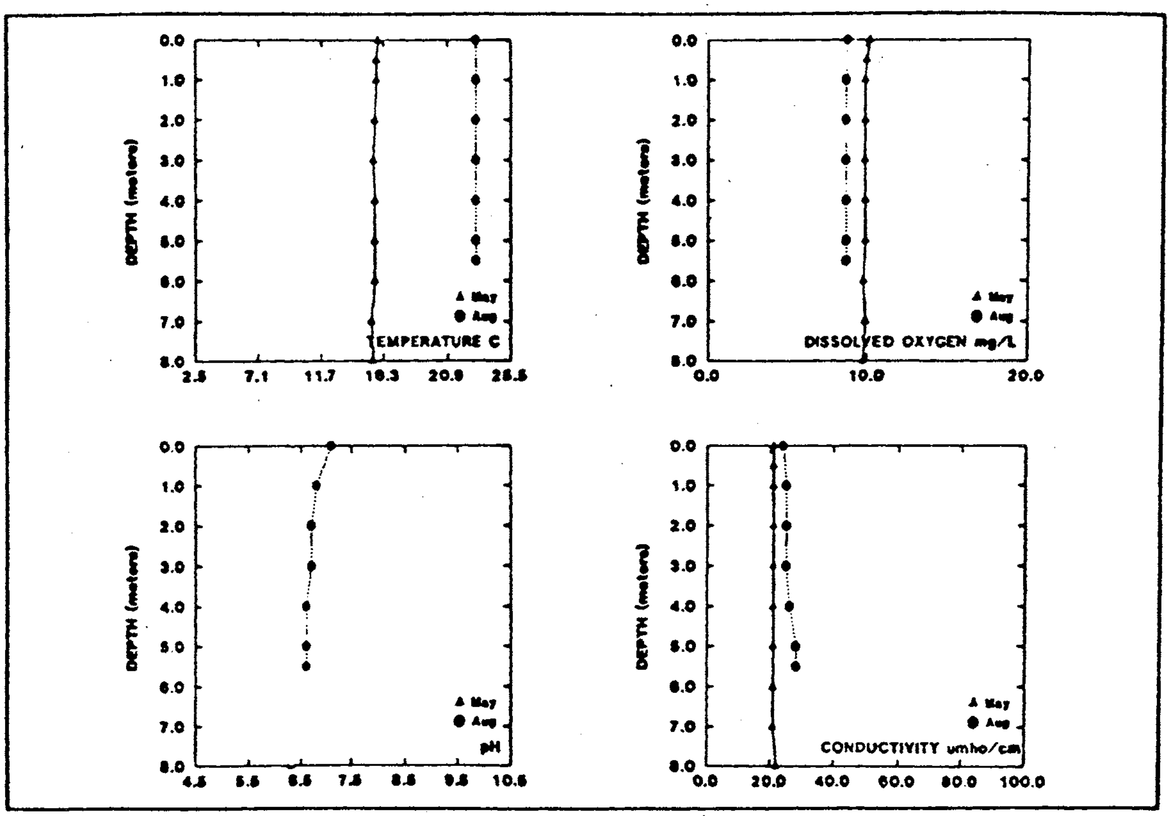
Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/24	0.0	15.9	.*	10.2	21	0.5, 2, 4	0.012	0.268
	0.5	15.8	.	10.0	21			
	1.0	15.8	.	9.9	21			
	2.0	15.7	.	9.9	21			
	3.0	15.6	.	9.9	21			
	4.0	15.7	.	9.9	21			
	5.0	15.7	.	9.9	21			
	6.0	15.7	.	9.8	21			
	7.0	15.5	.	9.9	21			
	8.0	15.6	.	9.8	22			
08/15	0.0	23.0	7.1	8.8	24	1, 3, 5	0.012	0.236
	1.0	23.0	6.8	8.7	25			
	2.0	23.0	6.7	8.7	25			
	3.0	23.0	6.7	8.7	25			
	4.0	23.0	6.6	8.7	26			
	5.0	23.0	6.6	8.7	28			
	5.5	23.0	6.6	8.7	28			

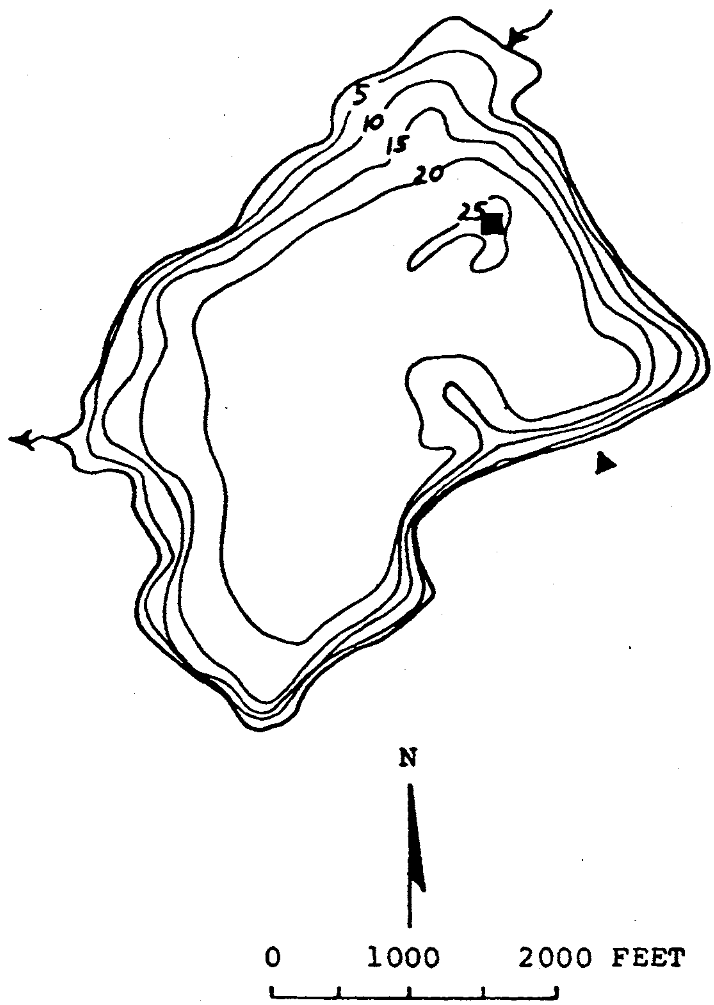
* See Quality Assurance section of this report.

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



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

Newman Lake -- Spokane County

Newman Lake is located about 16 miles east of Spokane. Thompson Creek is the principal inlet at the north end of the lake. Newman Lake drains via the Spokane Valley Irrigation Canal, which controls the lake elevation. The canal drains southeast into the Spokane River Valley.

Size (acres)	1200
Maximum Depth (feet)	30
Mean Depth (feet)	19
Lake Volume (acre-feet)	23,000
Drainage Area (miles^2)	28.6
Altitude (feet)	2124
Shoreline Length (miles)	9.7

Estimated Trophic State:	Mesotrophic*
Mean Trophic State Index** (Secchi):	36
Mean Trophic State Index** (Total Phosphorus):	50

* See Comments Section
** From Carlson (1977)

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

The 1990 questionnaire on lake and watershed uses was not returned. The following are from the volunteer's responses to the 1989 questionnaire. Newman Lake is used for fishing, swimming, boating, jet skiing, hiking, and waterfowl hunting. There is a picnic area, a privately-owned camping area, and two resorts on the lakeshore. Speed limits are established for motor boats used at night and inside buoys. Lake water is withdrawn for drinking and other domestic uses, and for irrigation. The watershed is used primarily for logging, but also for agriculture (both crops and animal grazing). In the past, the watershed was logged, mined, and the shoreline was altered some. There are 420 houses on the lakeshore; of these, 85 are occupied year-round, and all are on septic systems. The lake was treated with alum in August 1989, to control algal growth and phosphorus recycling from the sediments. Individual homeowners rake weeds from their lakeshore areas. Fish are stocked in the lake, and the lake has wetland areas. The worst problems in the lake, in the opinion of the volunteer, are 1) algal blooms, 2) weeds, 3) surface water runoff, and 4) garbage, debris and leaves. The volunteer also noted that oxygen depletion in the lower strata of the lake was a problem. Lily pads cover about 25% of the lake shoreline and the entire lake bottom is covered by submerged plants and algae. The volunteer suggested that nutrients in lake sediments, and surface and subsurface runoff may affect lake water quality.

Newman Lake -- Spokane County

The volunteer noted that Washington State University completed a two-year lake restoration feasibility (Phase I) study. Lake restoration (Phase II) is now in progress. Restoration plans include alum treatment and installation of an aerator. A watershed plan has been prepared and implemented, and a septic system survey will be conducted by the Spokane County Health Department.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that the average summer water clarity in the lake was better than during 1989. During both years, the water clarity was low early in summer, and improved through late summer.

Profile data collected during May and August 1990 show that the lake was thermally stratified, and that concentrations of dissolved oxygen decreased with depth and were virtually depleted near the lake bottom. Dissolved oxygen concentrations are usually depleted by bacteria which decompose organic material (such as algae and aquatic plants) in the water and sediments. In 1974, the concentration of dissolved oxygen decreased to 0.3 mg/L near the lake bottom (Dion *et al.*, 1976), so it is likely that dissolved oxygen depletion in deep water is common. The decrease in pH with depth is related to increased decomposition near the lake bottom.

The concentrations of total phosphorus and total nitrogen in 1990 were moderately high (averaging 0.0233 and .0335 mg/L, respectively) and indicate that the lake was mesotrophic, but approaching eutrophy. In 1974, the concentration of total phosphorus was 0.035 mg/L, the concentration of total nitrogen was 0.84 mg/L, and hydrogen sulfide (rotten-egg smell) was detected in bottom water samples (Dion *et al.*, 1976). These data all suggest that in 1974, the lake was more eutrophic.

During the August 1990 onsite visit with the volunteer, Robbins pondweed (*Potamogeton robbinsii*) was observed.

Several surveys have shown that Newman Lake was having water quality problems. A survey conducted in 1968 reported that a moderate algal bloom was occurring during October, and as a result the Secchi disk transparency was only four feet (Lee, 1969). In June 1974, algal density was moderately high, concentrations of total phosphorus and orthophosphorus were high, Secchi disk transparency was only five feet, hydrogen sulfide (rotten-egg smell) was present in hypolimnion samples, and concentrations of dissolved oxygen were depleted near the bottom of the lake (Dion *et al.*, 1976).

From Washington Water Research Center (WWRC; 1978): In 1978, Newman Lake was meso-eutrophic. Algal blooms mainly of *Aphanizomenon flos-aquae* and *Anabaena flos-aquae* (both are types of blue-green algae and are associated with high phosphorus concentrations) persisted from July through December 1978. By the end of July, the hypolimnion was anoxic, probably from the decay of sinking algae. This anoxia contributed to the decline in fishing success at Newman, as well as the odor problem (WWRC, 1978).

From WWRC (1988): The soils around Newman Lake are not adequate for septic systems and septic systems are contributing significantly to the nutrient loading of the lake. Newman Lake has been experiencing episodes of extensive blooms of undesirable algae since the late 1960s.

Residential development of the lakeshore has increased since 1974, when there were 316 nearshore homes (Dion *et al.*, 1976).

Comments

Although the concentration of total phosphorus was borderline between mesotrophy and eutrophy, the water clarity was within the oligotrophic range. Because total phosphorus is generally a better indicator of trophic status than Secchi depth, and because Newman Lake exhibited characteristics associated higher trophic states, the lake was estimated as mesotrophic. Newman Lake was the only lake monitored for the program in 1990 that was recently treated with alum. As a result, it is difficult to compare the water quality of Newman Lake with the other monitored lakes.

Acknowledgement

I thank Robert C. Jones for volunteering his time to monitor Newman Lake during 1989-1990.

Newman Lake -- Spokane County

Volunteer-Collected Data

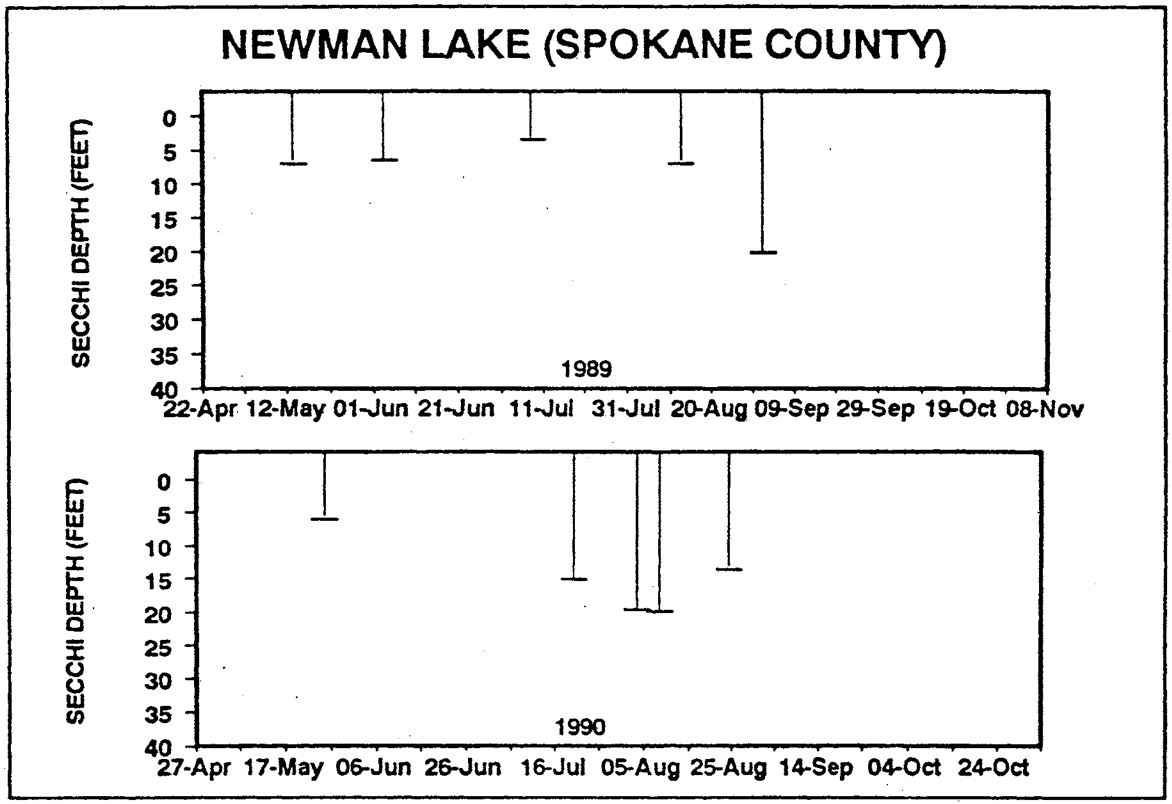
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
26-May	14.0	57.2		Green	0	Heavy	Light	7.3		
21-Jul	26.0	78.8		Clear	0	None	Calm	15.6		Alum treatment of 1989 still in good shape. Pollen in water earlier in spring now gone.
04-Aug	25.0	77.0		Clear	0	None	Calm	19.7		Alum still holding on bottom.
09-Aug								20.0		
25-Aug	20.0	68.0		Gr-Brown	25	None	Calm	14.2		Water color light green-light brown. Alum still holding pretty well to bottom - no aerator yet.

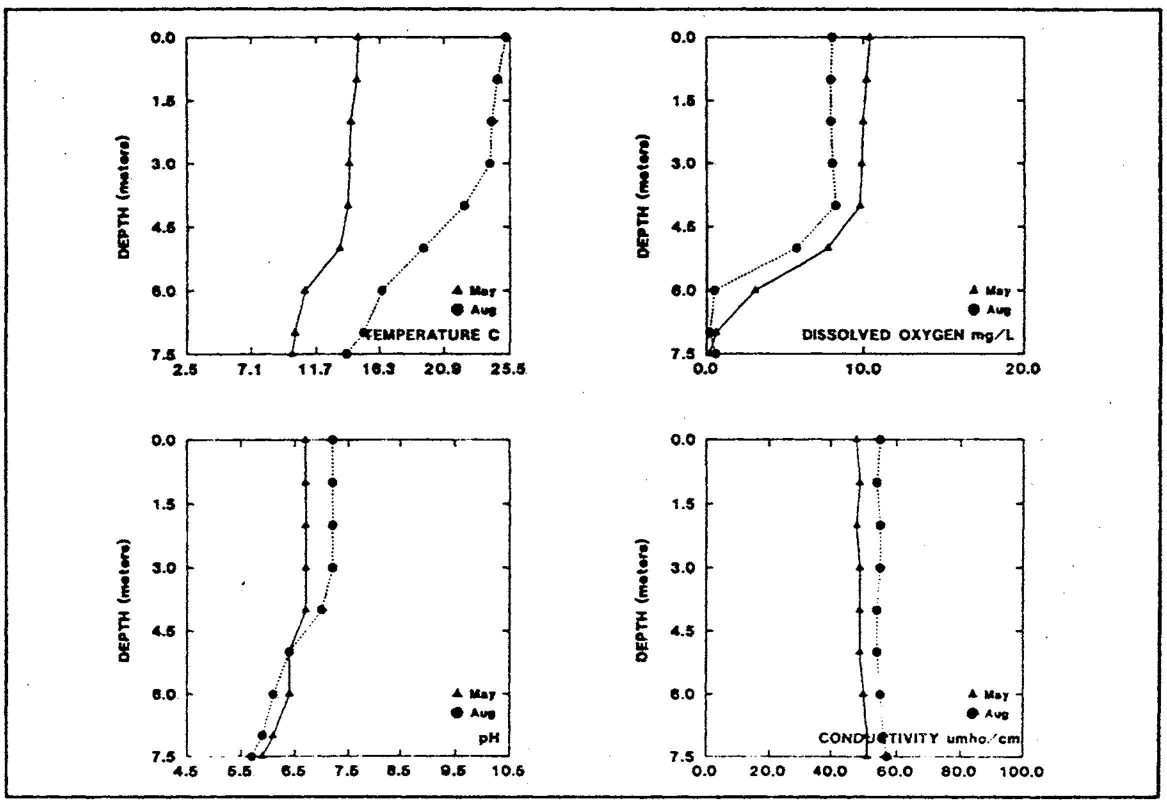
* Secchi data corrected for rope shrinkage

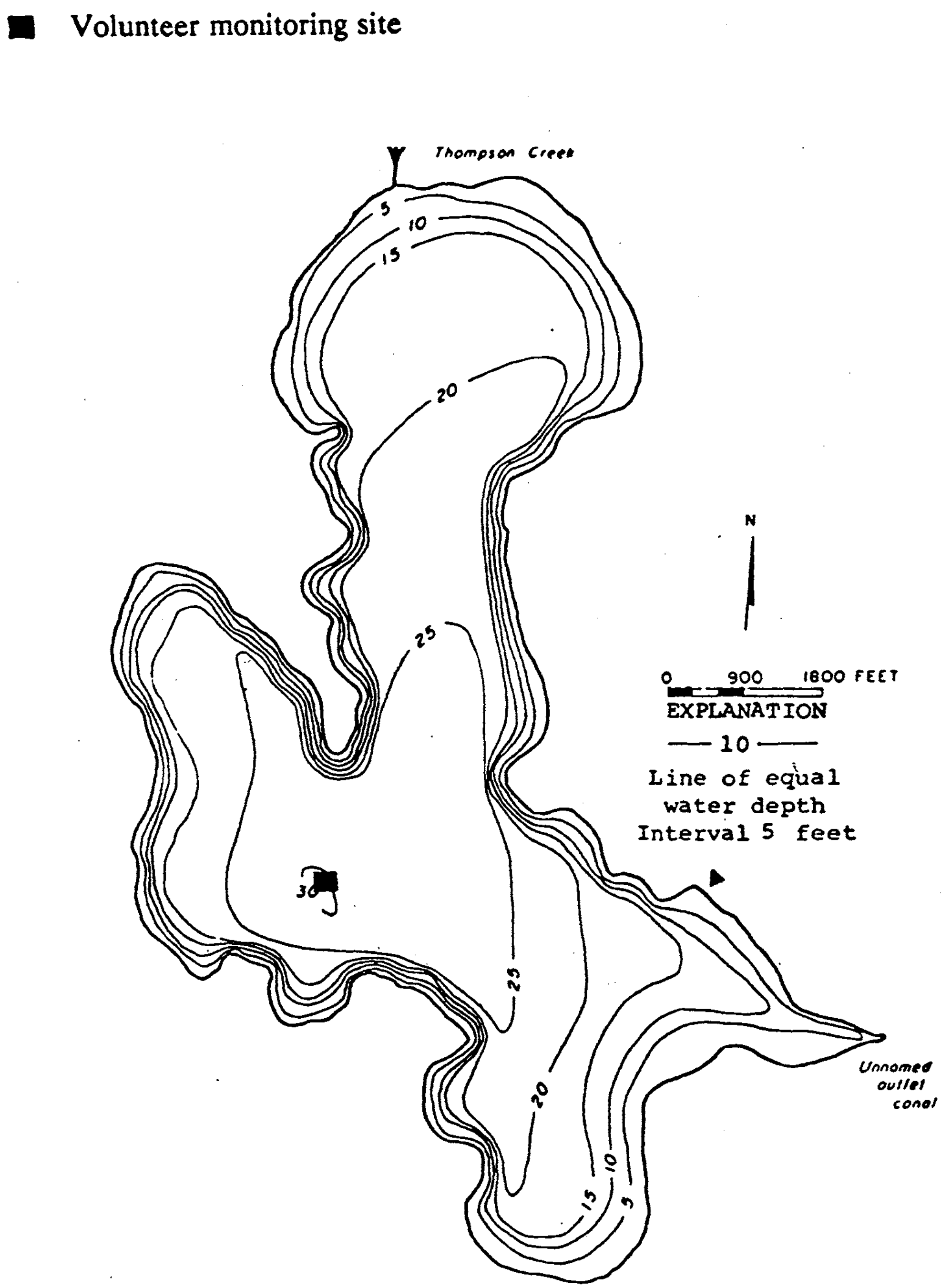
Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/26	0.0	14.7	6.7	10.4	48	1, 2, 4	0.023	0.311
	1.0	14.6	6.7	10.2	49			
	2.0	14.2	6.7	10.0	48			
	3.0	14.1	6.7	9.9	49			
	4.0	14.0	6.7	9.8	49			
	5.0	13.4	6.4	7.8	49			
	6.0	10.9	6.4	3.1	50			
	7.0	10.2	6.1	0.6	51			
	7.5	10.0	5.9	0.2	51			
08/09	0.0	25.2	7.2	8.1	55	1, 2, 3	0.024	0.358
	1.0	24.6	7.2	8.0	54			
	2.0	24.2	7.2	8.0	55			
	3.0	24.1	7.2	8.1	55			
	4.0	22.3	7.0	8.3	54			
	5.0	19.5	6.4	5.7	54			
	6.0	16.5	6.1	0.5	55			
	7.0	15.1	5.9	0.2	56			
	7.5	13.9	5.7	0.6	57			

Secchi Depth and Profile Data Graphs







Newman Lake, Spokane County. From Washington
Department of Game, February 18, 1951.

Ohop Lake -- Pierce County

Ohop Lake is located 1.5 miles north of Eatonville. It is 2.2 miles long. It is fed by Ohop Creek and drains via Ohop Creek to the Nisqually River.

Size (acres)	230
Maximum Depth (feet)	25
Mean Depth (feet)	17
Lake Volume (acre-feet)	3800
Drainage Area ($miles^2$)	17.3
Altitude (feet)	524
Shoreline Length (miles)	4.6

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	49
Mean Trophic State Index* (Total Phosphorus):	57

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Ohop Lake is used for fishing, boating, swimming, rowing, and jet skiing. Recreational facilities on the lakeshore include one boat ramp. There is a speed restriction of 7 mph for motorboats that does not apply to water skiing; there is also a time restriction for waterskiing. Lake water is withdrawn for drinking and irrigation. Currently the watershed is used for industry and animal grazing, and residential development is continuing on the lakeshore. In the past, the watershed was used for logging and crop agriculture. There are approximately 100 houses on the lakeshore; of these, one third are occupied year-round. The lakeshore is not sewered, and there are about six storm drains that empty into the lake. Trout are stocked in the lake. Presently there is a lake association and a community association for the lake. The lake has been chemically treated in the past to control weeds, and management activities on the lake this year will include chemical treatment to control weeds. The worst problems in the lake, in the opinion of the volunteer, are 1) aquatic plants, 2) algae, and 3) water level. Overall, the volunteer finds that Ohop Lake has excellent recreational water quality, and is concerned about lawn fertilizing in the watershed.

According to the volunteer, there are only one to two accessible lots left to develop on the lakeshore. Presently residential development occurs along about 40-45% of the shoreline; the rest is wetlands or inaccessible. There are wetlands near both the inlet and outlet. Submerged weeds and lily pads grow along most of the shore except near residential areas. The lake is closed to swimming on days following chemical treatment.

Ohop Lake -- Pierce County

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity did not vary much from May through August, although water clarity was lowest during May. In 1990, the profile data show that the lake was thermally stratified and concentrations of dissolved oxygen were virtually depleted near the bottom of the lake. During August, dissolved oxygen was generally absent from the bottom 2.6 meters (about 8.5 feet) of the lake. The decrease in pH, and the increase in conductivity with depth, is related to the decreased oxygen. In 1971, the concentration of dissolved oxygen decreased to 1.1 mg/L near the lake bottom (Bortleson *et al.*, 1976), so it is likely that low dissolved oxygen concentrations have been occurring in Ohop Lake for many years.

The concentrations of both total phosphorus and total nitrogen were high (averaging 0.043 and 0.390 mg/L, respectively). In 1971, the concentration of total phosphorus (0.030 mg/L; Bortleson *et al.*, 1976) was similar to the concentration found in 1990.

Water quality variance records with Ecology show that Ohop Lake was chemically treated on July 7, July 31, August 9, August 17, and September 17, 1990. Aquathol K, Komeen, Sonar and copper sulfate were used to control lily pads and algae. Bristly sedge (*Carex comosa*), a rare native plant species, was identified growing at Ohop Lake. To protect the rare sedge, there are restrictions for controlling other nearshore aquatic plants at Ohop Lake.

Comments

Of the six Pierce County lakes monitored for the program in 1990 (Lakes Louise, Ohop, Spanaway, Steilacoom, Tanwax and Whitman), Ohop Lake had the highest mean concentration of total phosphorus. However, Ohop Lake and Lake Tanwax had very similar mean summer Secchi and total phosphorus trophic state indices.

Acknowledgement

I thank Kerry Kleiber for volunteering his time to monitor Ohop Lake during 1990.

Ohop Lake -- Pierce County

Volunteer-Collected Data

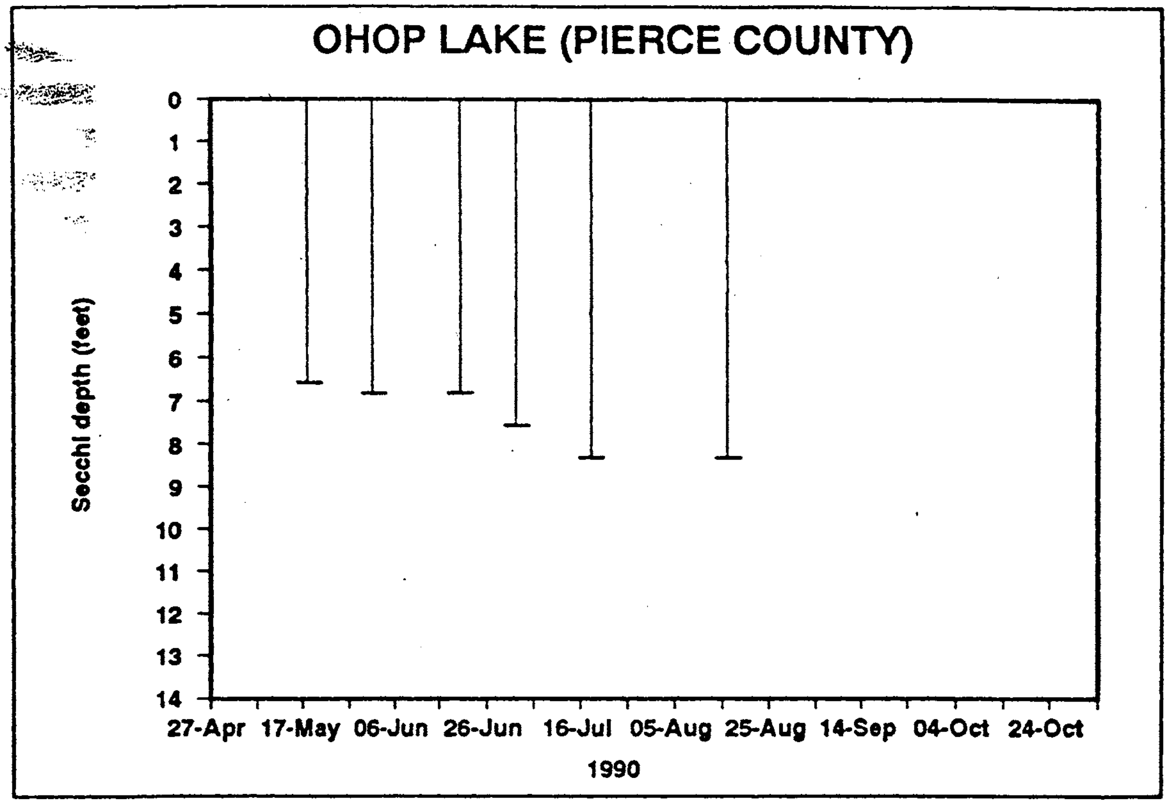
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
19-May	16.0	60.8	6.5	Gr-Brown	90	Light	Calm	6.3	276.0	Slight algae bloom.
02-Jun								6.5		
21-Jun	22.0	71.6	6.5	Gr-Brown	25	None	Calm	6.5	264.0	Lot of algae particles in water.
03-Jul	24.0	75.2	6.5	Lt-Green	10	None	Light	7.3	252.0	
19-Jul	27.0	80.6	6.5	Clear	0	None	Calm	8.0	252.0	
17-Aug								8.0		

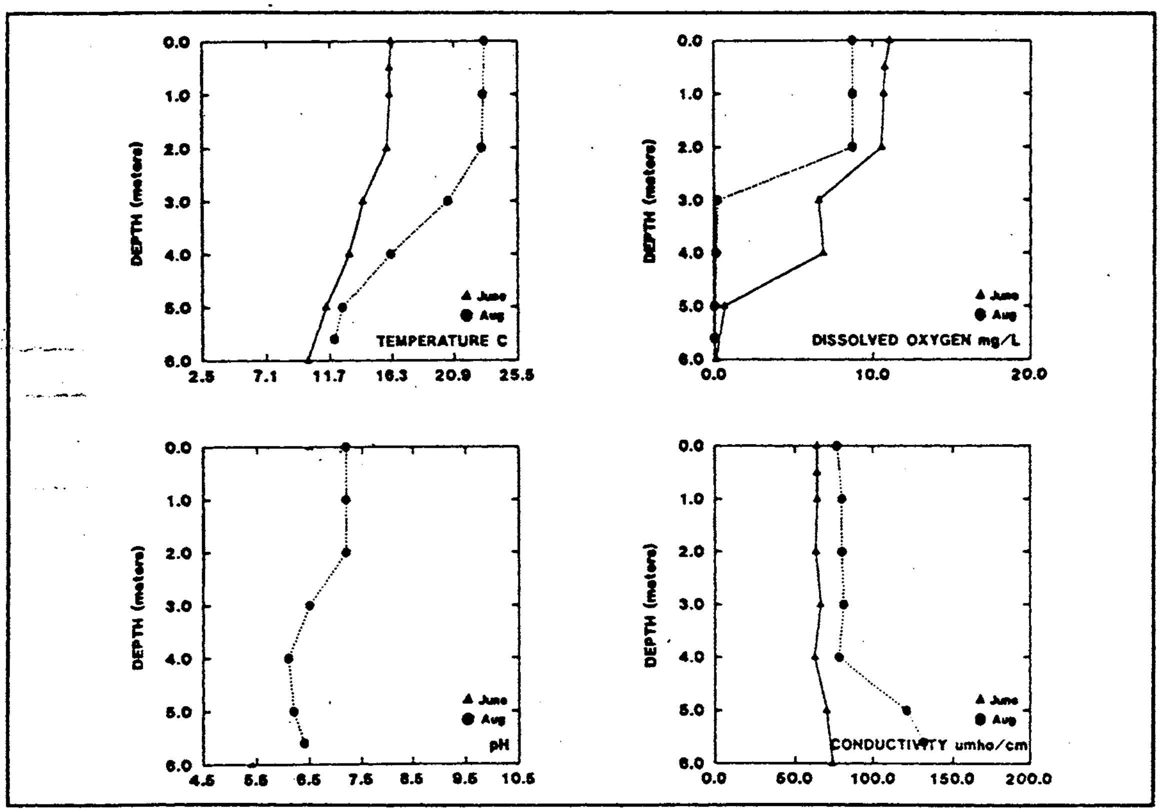
Onsite Visit Data

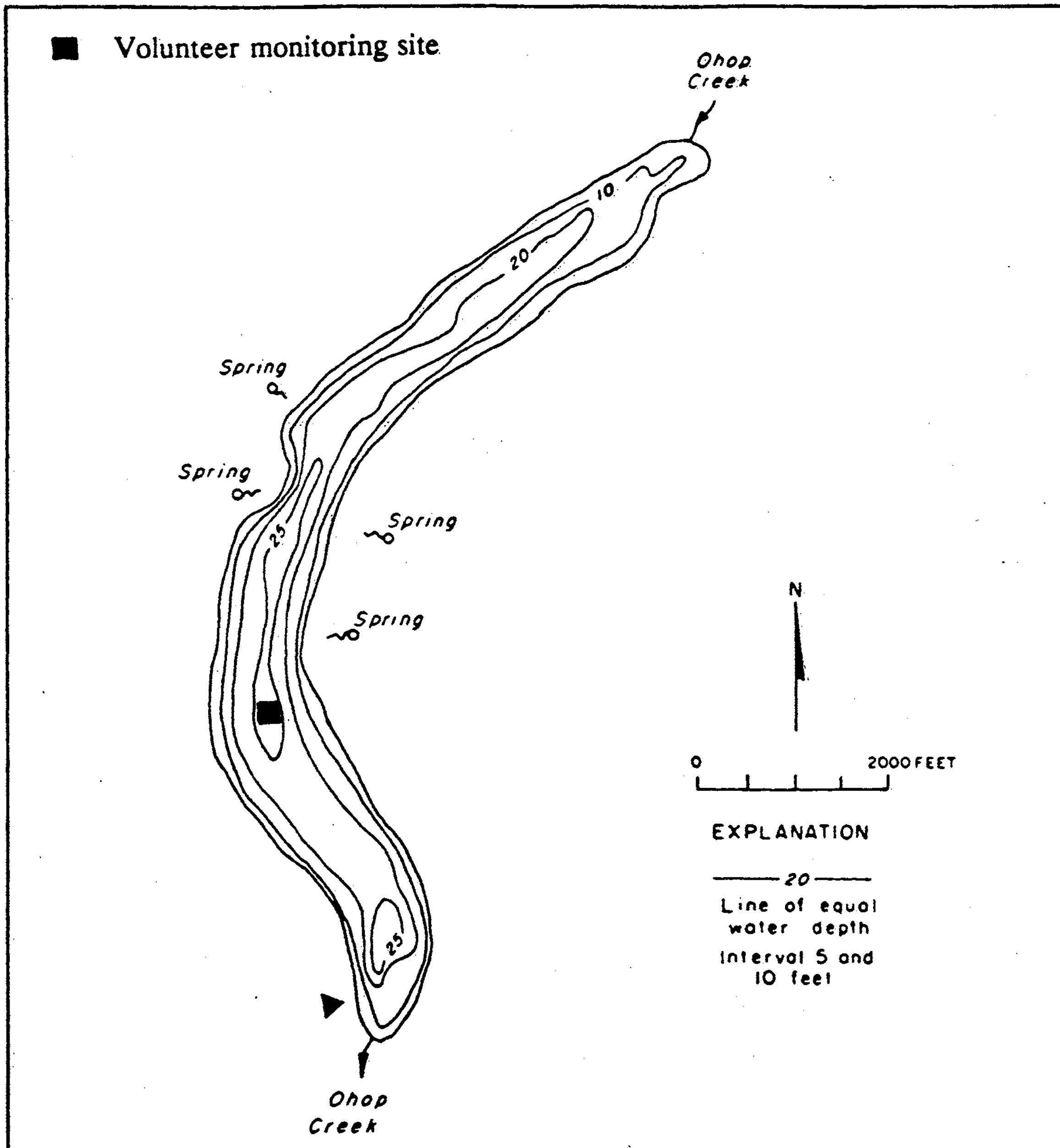
Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/02	0.0	16.2	.*	11.1	64	0.5, 2	0.031	ND
	0.5	16.1	.	10.8	64			
	1.0	16.1	.	10.7	64			
	2.0	15.9	.	10.6	63			
	3.0	14.1	.	6.5	66			
	4.0	13.1	.	6.8	62			
	5.0	11.4	.	0.6	70			
	6.0	10.1	.	0.1	74			
08/17	0.0	23.1	7.2	8.7	77	1, 2	0.037	0.390
	1.0	23.0	7.2	8.7	80			
	2.0	22.9	7.2	8.7	80			
	3.0	20.5	6.5	0.2	81			
	4.0	16.2	6.1	0.1	78			
	5.0	12.6	6.2	0.0	121			
	5.6	12.0	6.4	0.0	132			

* See Quality Assurance section of this report
ND No data; sample not analyzed by laboratory

Secchi Depth and Profile Data Graphs







Ohop Lake, Pierce County. From Washington Department of Game, June 14, 1954.

Lake Osoyoos -- Okanogan County

Lake Osoyoos is located one mile north of Oroville. It is ten miles long and extends north into Canada. The total size of the lake is 5729 acres; 3693 acres lie in British Columbia, Canada, and 2036 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)	5729
Maximum Depth (feet)	208
Mean Depth (feet)	46
Lake Volume (acre-feet)	266,000
Drainage Area (miles^2)	3150
Altitude (feet)	911
Shoreline Length (miles)	29.7

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	48

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. 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. Lake water is withdrawn for municipal, industrial, and agricultural uses. Currently the watershed is used mainly for crop agriculture, although lakeshore development is also occurring. In the past, the watershed was used for animal grazing and crop agriculture. There are approximately 300 houses on the lakeshore; most are occupied year-round. The lakeshore is not sewered on the U.S. side, although most homes on the Canadian side are sewered. Fish were not reported as being stocked in the lake, and fishing was reported as not being very good during summer. Presently there is a lake association for the lake. The lake has been chemically treated in the past to control weeds. Management activities on the lake this year will include mechanical aquatic plant removal, although harvesting will occur in Canada only. In the opinion of the volunteer, the worst problem in the lake is aquatic plants. Overall, the volunteer finds that Lake Osoyoos has good recreational water quality, and is concerned that there is no sewer system on the U.S. side.

The volunteer reports that Eurasian milfoil in Lake Osoyoos was growing more this year than in any past year, and floating fragments were observed on both the U.S. and Canadian sides of the lake. On the U.S. side, milfoil grows especially thick just south of the International Boundary, on the east side of the lake near Dairy Point and Smith Point, and along the south end of the lake. There is also a heavy growth of reeds along Boundary Point and near Lake Osoyoos State Park.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity was lowest during July. Average summer water clarity in Lake Osoyoos was very similar during 1989 and 1990.

From Brower and Kendra (1990): In 1989, Ecology sampled Lake Osoyoos just south of the International Boundary and Boundary Point at a site about 50 feet deep. The survey results showed that Lake Osoyoos was mesotrophic, based on moderate Secchi disk transparency and epilimnetic concentrations of total phosphorus and chlorophyll *a*. The lake was stratified during June, but had turned over and was mixing when sampled during September. Because the lake was mixing, the temperature, dissolved oxygen, and pH were relatively stable from surface to bottom. The very low readings at the deepest part of the lake are probably in error; most likely, the instrument was resting on the lake bottom. The pH was much higher during June than September; the higher overall pH and higher concentrations of dissolved oxygen from 2 to 6.5 meters during June probably resulted from algae growth. During June, the water color was green and a mild algae bloom was observed in the water.

Lake Osoyoos was also shown to be mesotrophic in 1974 (Dion *et al.*, 1976) and 1981 (Sumioka and Dion, 1985), based on Secchi disk transparency, concentrations of total phosphorus, and very low concentrations of dissolved oxygen near the bottom of the lake.

From Johnson and Norton (1990): As part of the Toxics Monitoring portion of the 1989 Lake Monitoring Program, sediment and largemouth bass samples were collected from Lake Osoyoos. No unusual concentrations of metals or organics were detected from bottom sediments. Compared to other lakes sampled, fish tissues in Lake Osoyoos contained elevated concentrations of selenium (0.95 mg/Kg) and total DDT compounds, primarily in the form of degradation by-products (210 μg/kg). The elevated concentrations of DDT compounds suggest that there was significant historical use of DDT in the drainage basin. Although concentrations of DDT and selenium were within levels considered acceptable for human consumption, it was recommended that Lake Osoyoos fish be included in Ecology's annual Biological Monitoring Program.

Eurasian water milfoil (*Myriophyllum spicatum*) was first reported in Lake Osoyoos in 1975 (Gibbons *et al.*, 1984). Mechanical harvesting of the milfoil was proposed but did not occur because the hydraulic permit was denied 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 large-scale chemical controls of water milfoil. Efforts to control milfoil are now at a standstill, although natural populations of chironomids and caddisfly larvae appear to eat the milfoil in noticeable quantities (K. Hamel, Ecology, pers. comm.).

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 pumped for domestic water use, had the potential to exhibit water quality problems observed in Skaha Lake. Lake Osoyoos receives water from Skaha Lake via the Okanogan River, and secondary sewage effluent from the town of Oliver is pumped into the Okanogan River, about three miles north from Lake Osoyoos. The south Lake Osoyoos stations did not exhibit the extent of blue-green algal growth as did Lake Skaha and the northern Lake Osoyoos stations. Point source discharges in British Columbia from primary and secondary wastewater treatment facilities, and cannery and packing house wastes, as well as runoff from agricultural lands, were cited as nutrient sources to be studied further.

Comments

Although Lake Osoyoos did not have very good water clarity, 15 of the other 73 lakes monitored for the program in 1990 had worse overall water clarity than Lake Osoyoos. Long Lake in Thurston County was the only other monitored lake that was harvested to control Eurasian milfoil.

Acknowledgements

I thank Kathy Jones for volunteering her time to monitor Lake Osoyoos during 1989, and Walter Ullrich for monitoring the lake during 1990.

Lake Osoyoos -- Okanogan County

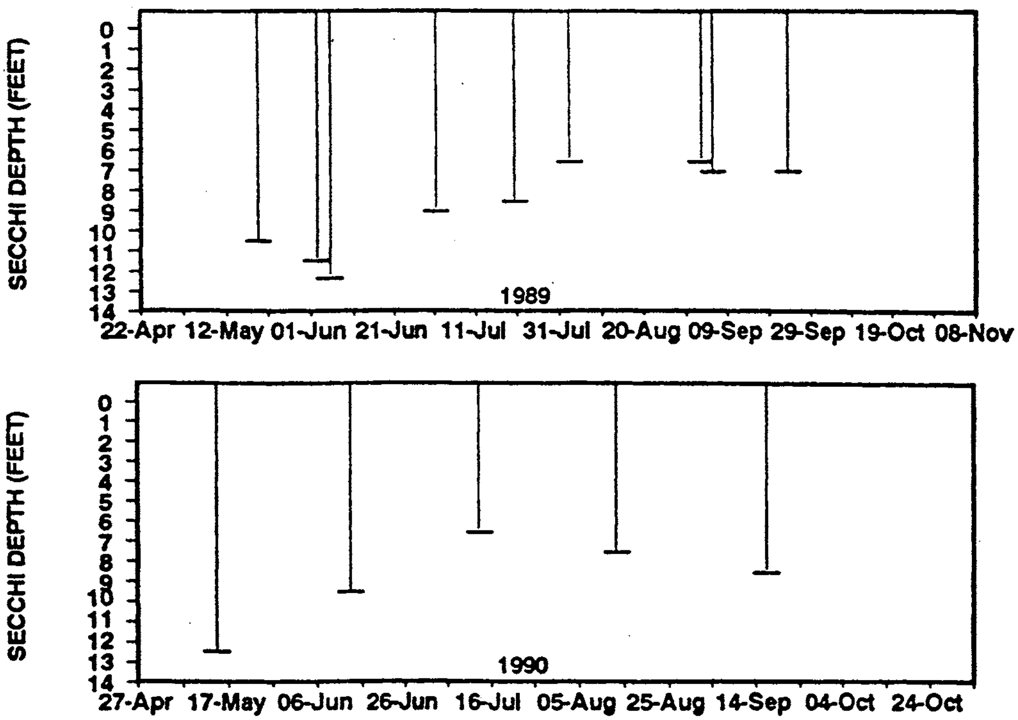
Volunteer-Collected Data

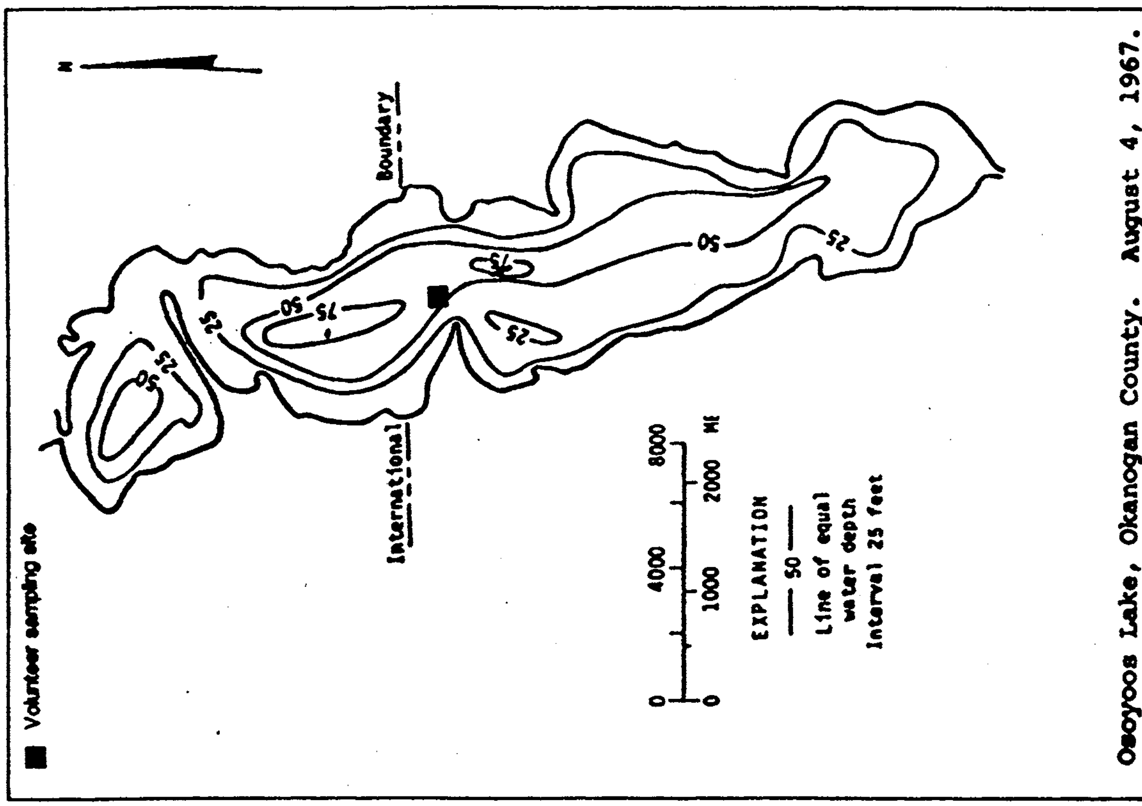
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
15-May	15.6	60.0	6.5	Lt-Green	50	Moderate	Calm	11.9**		Lake height normal. Accumulations kept at Zosel Dam. Bottom stirred up from first secchi reading.
14-Jun	17.8	64.0	7.0	Lt-Brown	10	Light	Light	9.2	914.0	Flood stage heavy sediment.
14-Jul	23.9	75.0	7.5	Lt-Brown	0	None	Calm	6.4	912.2	Lake full of loose milfoil fragments and long stems. Raked 40 lbs. of milfoil off 100 ft lake front each day this past week, all from Canada.
14-Aug	26.7	80.0	7.0	Green	0	None	Breezy	7.3	911.5	Heavy floating milfoil since July.
17-Sep	24.4	76.0	7.5	Lt-Green	0	None	Calm	8.3	911.5	Indian summer. Lake down 0.5 feet over Labor Day.

* Secchi data corrected for rope shrinkage

** There was high variability between the first and second Secchi depths collected; this data point may not be included in data comparisons.

LAKE OSOYOOS (OKANOGAN COUNTY)





Panther Lake -- Snohomish County

Panther Lake is located 4.5 miles northeast of Snohomish. It is fed by Flowing Lake and an unnamed stream at the south end. It drains via Panther Creek to the Pilchuk River. It is the northernmost of the "Three Lakes" group -- Storm Lake, Flowing Lake, and Panther Lake.

Size (acres)	48
Maximum Depth (feet)	36
Mean Depth (feet)	23
Lake Volume (acre-feet)	1101
Drainage Area (miles^2)	0.8
Altitude (feet)	455
Shoreline Length (miles)	1.3

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

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The questionnaire on lake and watershed uses was not returned.

Monitoring Results/Summary of Other Available Information

Secchi data show that water clarity varied only three feet during summer, but was lowest during June and August 1990. Profile data collected during June and August show that the lake was thermally stratified, and concentrations of dissolved oxygen decreased with depth. During August, concentrations of dissolved oxygen were depleted from the bottom five meters (almost 16.5 feet) of the lake, likely by bacteria which use oxygen when decomposing organic material (such as algae, aquatic plants and woody debris) in the water and sediments. In 1973, concentrations of dissolved oxygen were 0.3 mg/L near the lake bottom (Bortleson *et al.*, 1976), so it is likely that low dissolved oxygen at depth is common. Submerged logs and related woody debris covering the bottom of the lake from the lake's past use as a log storage pond (Bortleson *et al.*, 1976) may contribute to decomposition at the lake bottom. In 1973, hydrogen sulfide (rotten-egg smell) was detected in the bottom layer of water (Bortleson *et al.*, 1976); hydrogen sulfide can form in lake water that is depleted of dissolved oxygen. The decrease in pH, and increase in conductivity with depth during 1990, are probably related to the decreased concentrations of dissolved oxygen with depth.

Panther Lake -- Snohomish County

The 1990 concentrations of total phosphorus and total nitrogen were moderately high in general. In August 1973, the concentration of total phosphorus was 0.013 mg/L and total nitrogen was 0.39 mg/L (Bortleson *et al.*, 1976). Except for the June 1990 concentration of total nitrogen, which was nearly twice the August concentration, total phosphorus and total nitrogen in 1990 were similar to 1973 concentrations.

The water sample collected on June 2, 1990, by the volunteer consisted of *Coelosphaerium*, pollen, and large quantities of blue-green algae which were either *Anacystis* or *Microcystis*. During the August onsite visit with the volunteer, white-flowering lily pads (*Nymphaea odorata*) and cattails (*Typha* spp.) were observed.

Comments

Of the Three Lakes group, Storm Lake had the lowest mean concentration of total phosphorus and Panther had the highest. All three lakes had similar mean summer water clarity and all were mesotrophic.

The Secchi disk trophic state indices (TSI) were higher than the total phosphorus TSIs for only 10 of the 73 lakes monitored for the program in 1990. Storm, Flowing, and Panther Lakes were among these 10 lakes. It is difficult to know for sure why Secchi data indicate greater eutrophication than total phosphorus data in these three lakes.

Acknowledgement

I thank Kurt Gibbons for volunteering his time to monitor Panther Lake during 1990.

Panther Lake -- Snohomish County

Volunteer-Collected Data

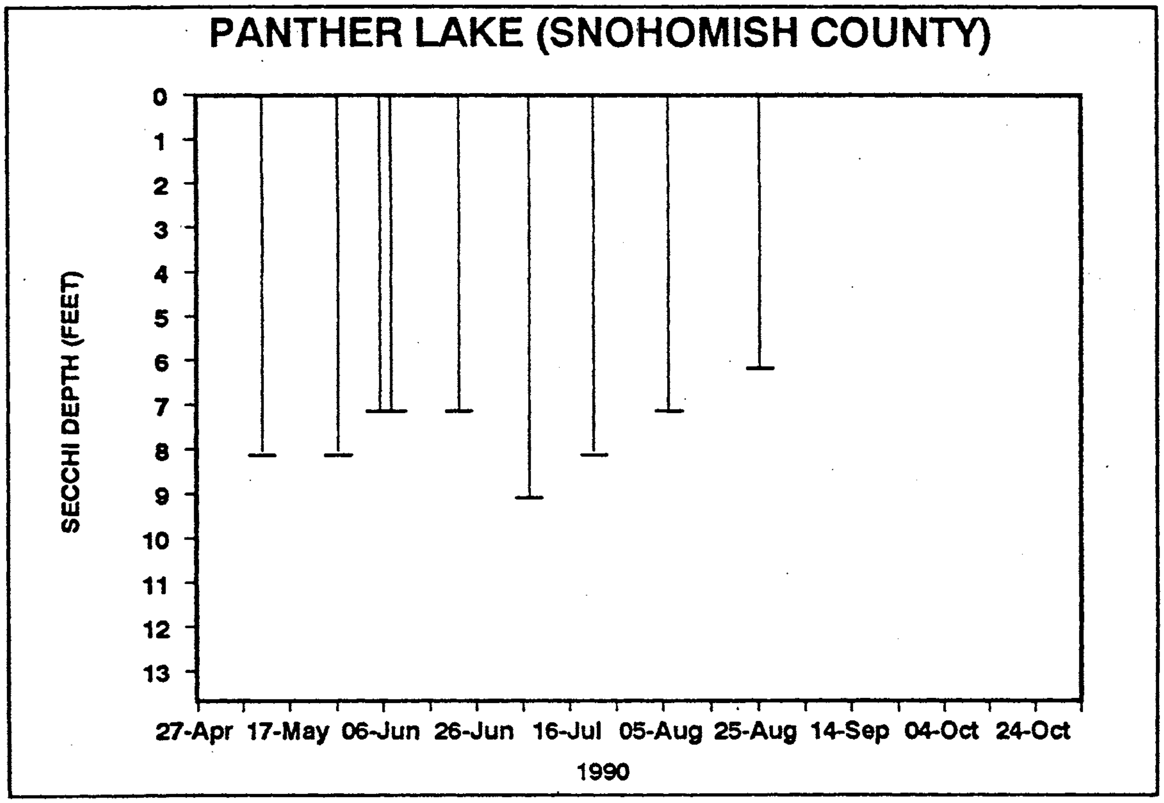
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
12-May	16.7	62.0	6.0	Gr-Brown	50		Calm	8.0	0.0	Lake height high.
28-May	16.7	62.0	6.0	Gr-Brown	100	Moderate	Calm	8.0	2.0	
06-Jun								7.0		
09-Jun	16.7	62.0	6.0	Gr-Brown	100	Light	Light	7.0	1.0	
23-Jun	22.2	72.0	6.0	Gr-Brown	50	Trace	Light	7.0	2.0	Please refer to lake height from 5/12/90 reading of high level.
08-Jul	22.8	73.0	6.0	Gr-Brown	10	None	Calm	9.0	-2.0	Lake height -2" from high level.
22-Jul	27.8	82.0	6.0	Gr-Brown	50	None	Light	8.0	-4.0	
07-Aug	20.0	68.0	6.0	Gr-Brown	0	None	Calm	7.0	-8.0	
26-Aug	22.2	72.0	6.0	Gr-Brown	10	Trace	Calm	6.0	-8.0	

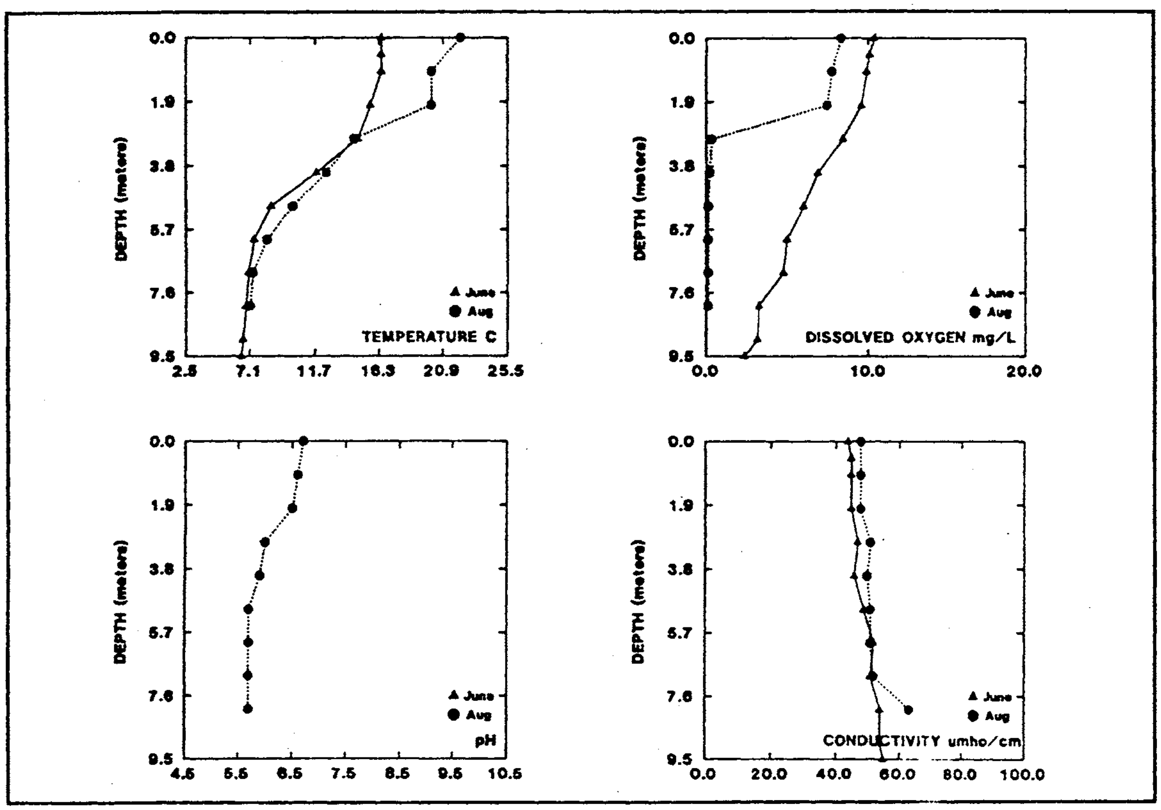
Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/06	0.0	16.5	.*	10.4	44	1	0.013	0.665
	0.5	16.5	.	10.1	45			
	1.0	16.5	.	9.9	45			
	2.0	15.7	.	9.6	45			
	3.0	14.8	.	8.4	47			
	4.0	11.8	.	6.8	46			
	5.0	8.6	.	5.9	49			
	6.0	7.4	.	4.9	52			
	7.0	7.0	.	4.7	51			
	8.0	6.8	.	3.2	54			
	9.0	6.6	.	3.1	54			
	9.5	6.5	.	2.3	55			
08/30	0.0	22.2	6.7	8.3	48	1, 2	0.017	0.371
	1.0	20.1	6.6	7.7	48			
	2.0	20.1	6.5	7.4	48			
	3.0	14.5	6.0	0.3	51			
	4.0	12.5	5.9	0.2	50			
	5.0	10.1	5.7	0.1	51			
	6.0	8.3	5.7	0.1	51			
	7.0	7.3	5.7	0.1	52			
	8.0	7.1	5.7	0.1	63			

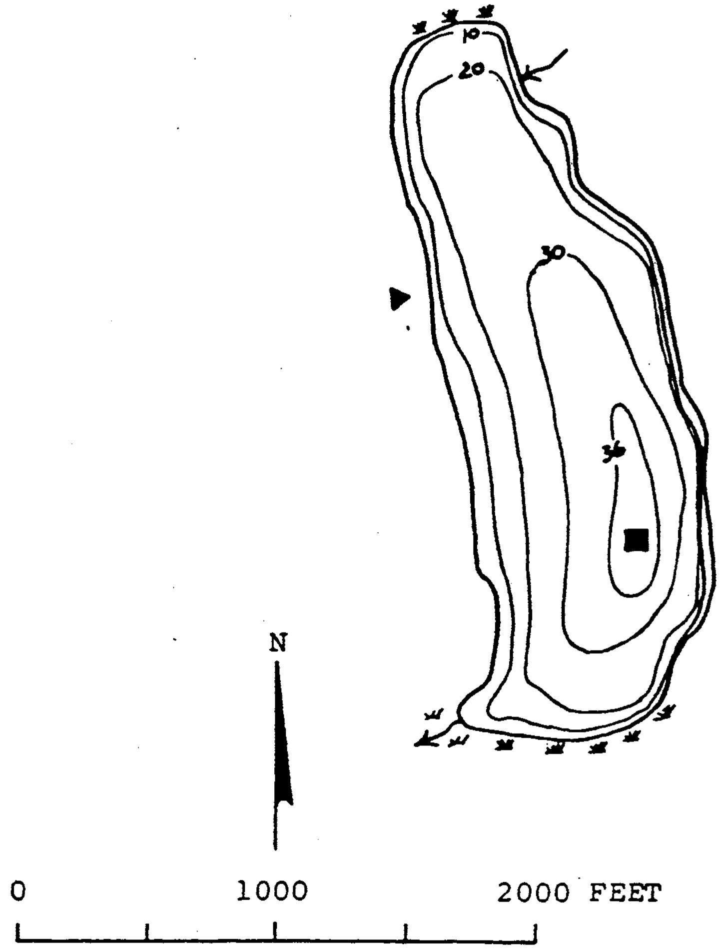
* See Quality Assurance section of this report.

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



EXPLANATION

—— 20 ——

Line of equal
water depth
Interval 10 feet

Panther Lake, Snohomish County. From Washington
Department of Game, January 24, 1949.

Patterson Lake -- Thurston County

Patterson Lake is located six miles southeast of Olympia. It consists of two basins connected by a narrow neck. There is a railroad bridge over this neck. The north basin covers 75 acres and the south basin covers 182 acres. The lake is fed by Hicks Lake and drains to Long Lake and ultimately to Henderson Inlet, via Himes/Woodland Creek. Patterson Lake is also known locally as Pattison Lake.

Size (acres)	257
Maximum Depth (feet)	19
Mean Depth (feet)	13
Lake Volume (acre-feet)	2500
Drainage Area (miles^2)	3.8
Altitude (feet)	154
Shoreline Length (miles)	4.6

North Basin

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	39
Mean Trophic State Index* (Total Phosphorus):	45

* From Carlson (1977)

South Basin

Estimated Trophic State:	*See Results Section

Summary of Questionnaire Results and Information From the Volunteer

The north and south basins were monitored by two different volunteers. Each basin is discussed separately below.

The following volunteer remarks and 1990 questionnaire responses apply to the north basin of Patterson Lake. Patterson Lake is used for fishing, swimming, and rowing. Recreational facilities on the lakeshore include one boat ramp, and there is a speed restriction of 5 mph for motorboats. Lake water is not withdrawn for any uses. Currently the watershed is used for crop agriculture and the lakeshore is being developed further for residences. In the past, the watershed was used for animal grazing and the shoreline was altered. There are approximately 70 houses on the lakeshore; all are occupied year-round. The lakeshore is not sewered, and no storm drains empty into the lake. Trout are stocked in the lake. Presently there is a lake association and a lake management district for the lake. Management activities on the lake this year will include plant harvesting. In the opinion of the volunteer, algae growth was the worst problem in the lake, although "the lake as a whole was clear this year". Thick algae growth during August was raked in daily by lakefront property owners. Algae growth in the lake was mainly in areas on the west side of the basin. There are conservancy areas on each side of the bridge, and thick surface weeds extend out beyond these conservancy areas. Overall, the volunteer finds that North Patterson has good recreational water quality, and is concerned about possible water quality effects from lakeshore septic tanks.

The following volunteer remarks and 1989 questionnaire responses apply to the south basin of Patterson Lake. South Patterson Lake is used for fishing, swimming (although the volunteer reports that "often the water quality is too poor"), canoeing/rowing, and sailing. There is a speed limit of 5 mph for motor boats, and public access is limited to the fishing season (April 23 through October 31, 1989). Currently the watershed is used for agriculture (both crops and animal raising) and the lakeshore is being developed further for residences. The shoreline was altered in the past along the passage between the two basins; presently there are train tracks over this passage. There are 100 houses on the shore of the south basin; all are on septic systems, and 95% of these houses are occupied year-round. In 1989, the south basin was chemically treated around June 28, August 1, and September 1, to control weeds growing near the public access. Fish are stocked in the lake. The lake has wetland areas. In the opinion of the volunteer, The worst problem in the lakes in the lake are 1) algal blooms, and 2) weeds. These problems are bad during most of the summer, but especially during mid-September 1989, when there was a severe bloom of the blue-green algae species *Anabaena*. The volunteer suggested that septic systems may affect the water quality. According to the volunteer, the water quality of the north basin was better than the south basin in 1989.

The volunteer identified water lilies and cattails in wetland areas and along the shores of both basins near the passage between the basins. *Ceratophyllum* and *Potamogeton praelongus* cover most of the south basin. The volunteer also noted that floating mats of *Ceratophyllum* are common during summer in the south basin, whereas there are only a few small mats in the north basin. Algae blooms occur throughout the south basin. Two eagles, an adult and a juvenile, hunt in the south basin in spring-summer.

Monitoring Results/Summary Of Other Available Information

The north and south basins were monitored by two different volunteers. Each basin is discussed separately below.

In the north basin, Secchi data show that water clarity did not vary during summer. Profile data collected during May and August 1990 show that the lake was thermally stratified, and that dissolved oxygen decreased with depth. The decrease in pH and increase in conductivity with depth is likely related to increased decomposition near the lake bottom.

The concentrations of total phosphorus and total nitrogen in the north basin were medium-high in 1990. The concentrations of these nutrients were lower in 1990 than in 1981, but

higher than concentrations measured during 1974. In 1981, the concentration of total phosphorus was 0.030 mg/L and the concentration of total nitrogen was 1.4 mg/L (Sumioka and Dion, 1985). In 1974, the concentration of total phosphorus was 0.014 mg/L and the concentration of total nitrogen was 0.39 mg/L (Bortleson *et al.*, 1976).
In 1974, it was reported that emersed plants were scattered in dense beds and submerged plants covered approximately 25% of the lake bottom (Bortleson *et al.*, 1976).

There does not appear to be an increase in the number of residences in the north basin since 1974 when there were 74 nearshore homes (Bortleson *et al.*, 1976).

In the south basin, only three of nine Secchi readings did not disappear in weeds. Because of this, there were not enough readings to estimate the trophic state of the basin. Compared with 1989 conditions, aquatic plant growth started earlier and algae growth was not as severe in 1990. Also, aquatic plants did not come as close to the surface in 1990 as in August and September 1989. No profile data were collected from the South basin in 1990.

From Entranco Engineers (1987): A Phase I Diagnostic/Feasibility Study of Patterson Lake was conducted in response to increasing blue-green algal blooms and prolific aquatic plant growth in Patterson Lake. Data collected during 1984-1985 as part of the restoration plan indicated that concentrations of total phosphorus in both the north and the south basins varied considerably, although highest concentrations were found during late fall and winter. Following an alum treatment of 382 tons during September 1983, the concentration of total phosphorus was lower during the fall and winter of 1984, than prior to treatment. Mechanical harvesting in the north basin occurred from 1983-1984. Harvesting was stopped because of pressure from lakeshore residents. A survey of aquatic plant growth in North Patterson during August 1985 showed that plant growth was mainly concentrated at the south end near the channel leading to the south basin. Nearest to the channel were populations of yellow and white-flowering lilies (*Nuphar* and *Nymphaea odorata*, respectively). Extending towards the mid-basin and along the shoreline were the submerged species coontail (*Ceratophyllum demersum*) and waterweed (*Elodea canadensis*). In deeper water near the center of the lake was pondweed (*Potamogeton crispus*). Along the north shore were two species of pondweed: *P. crispus* and *P. amplifolius*. Compared to the south basin, the north basin had less of the bottom surface covered with submerged species of plants and less of the shoreline was supporting plants (except for an area surrounding the public access area, the entire shoreline of the south basin is ringed with aquatic plants). The water of the north basin was dark and humic-colored; however, following alum treatment, the color changed to aquamarine (Entranco Engineers, 1987).

Severe algal growth and other water quality problems in Patterson Lake have been documented during several surveys. A 1968 survey found Secchi disk transparency in Patterson 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). Moderate to heavy blooms of algae, low Secchi disk transparency, and very low concentrations of dissolved oxygen near the bottom of the lake were reported in 1971 (Bortleson *et al.*, 1974). In 1974, the lake was likely eutrophic because there were high concentrations of total phosphorus and chlorophyll *a*, and low Secchi disk transparency; blue-green algae (*Aphanizomenon*) dominated the algal populations during June, and dissolved oxygen concentrations were depleted near the bottom of the lake (Bortleson *et al.*, 1976). In 1981, concentrations of total phosphorus and nitrogen were very high (Sumioka and Dion, 1985).

Residential development of the south basin of Patterson Lake has increased since 1981, when there were 85 nearshore homes (Sumioka and Dion, 1985).

Water quality variance records with Ecology indicate that Patterson Lake was treated with Rodeo on June 28, August 1, and September 11, 1989, to control lily pads growing near the boat ramp of the southern basin. Because Thurston County discourages the use of aquatic herbicides in lakes, an application to treat Patterson Lake in 1990 was denied.

A filamentous green algae sample collected from a dock post in the south basin of Patterson Lake on May 29, 1990, was identified as *Cladophora*, and it was noted by the volunteer to be thicker in 1990 than in 1989. Lots of epiphytic diatoms were also associated with the sample. During the August onsite visit with the north basin volunteer, a filamentous green algae was present, and tapegrass (*Vallisneria americana*) was observed. The south basin volunteer also noted an abundance of tapegrass.

Comments

The lake quality of North Patterson is noticeably better than the quality of the southern basin. Although the 1983 alum treatment may have improved lake quality, the benefits from alum treatments do not last indefinitely. Continued Secchi disk and phosphorus monitoring will indicate if lake quality declines.

Compared to other lakes monitored for the program, the water quality of South Patterson Lake is not very good. The basin is very shallow, which allows rooted submerged plants to flourish. All of the lakes monitored for the program in 1990 that have a mean depth of less than 15 feet are either mesotrophic or eutrophic. South Patterson Lake is an not exception. Nearby Long Lake, which has similar depth and prolific plant growth, had better water clarity than South Patterson Lake in 1990.

Acknowledgements

I thank Peg Eisenmann for monitoring the north basin during 1990, and Dave and Molly Hallock for volunteering their time to monitor the south basin during 1989-1990.

Patterson Lake -- Thurston County

Volunteer-Collected Data -- North Basin

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
30-May	15.6	60.0	6.5		95	Light	Calm	14.7	78.0	Lake color: light grey green to clear. Lake height measured at dock.
14-Jun	17.2	63.0	6.5	Lt-Green	0	None	Light	14.2	78.5	
25-Jun	17.8	64.0	6.5		10	None	Light	14.7	78.0	Water color: clear/green.
11-Jul	21.1	70.0	7.0	Lt-Green	10	None	Light	14.7	74.0	Dock height measure was accidently moved.
07-Aug	23.3	74.0	7.0	Green	0	None	Calm	13.7 w	66.0	Lots of floating algae observed.
22-Aug	21.1	70.0		Lt-Green	90	Light	Breezy	14.7	63.0	Samples taken with J. Rector.
05-Sep	21.1	70.0	7.0	Green	0	None	Calm	14.7	62.0	
22-Sep	20.6	69.0	7.0	Lt-Green	0	None	Calm	13.7	61.0	Filamentous algae along northwest shore.
19-Oct	18.3	65.0	7.0	Green	10	Light	Light	13.7	61.0	Green scum on surface, northwest area.

w Secchi disk entered weeds

Volunteer-Collected Data -- South Basin

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
25-May	17.5	63.5	7.0	Green	25	Light	Calm	16.0 w	17.1	Clumps of blue-green algae (Aphanizonmenon?) present. Potamageton fruits are above surface. clumps of Ceratophyllum are beginning to reach the surface.
08-Jun	19.0	66.2	7.0	Green	50	Light	Breezy	14.7 w	16.0	Second secchi reading taken at different location and disk entered weeds at 15 feet.
17-Jun			7.5	Green	90	Trace	Light	12.8 w	16.9	Elodea in flower. Ceratophyllum mats present.
01-Jul	22.0	71.6.	7.5	Green	100	None	Calm	13.7	12.6	pH using real color chart pH=7.0.
08-Jul	22.0	71.6	7.0	Green	10	Moderate	Light	13.7	20.4	
15-Jul	26.5	79.7	7.0	Green	0	None	Calm	13.3 w	21.7	Hot last week.
30-Jul	23.5	74.3	8.5	Green	100	None	Light	11.9 w	24.5	Done with Julie and Ken - Hydrolab demo. pH strip read 8.5+ using copied chart and 8.5 with real chart.
19-Aug	24.0	75.2	7.7	Green	50	Moderate	Calm	7.3 w	26.7	Large mats of Spirogyra(?) on top and Ceratophyllum/Elodea along shore. Ceratophyllum nearly to surface at deep spot.
16-Sep	21.0	69.8	7.5	Green	50	Trace	Light	9.2	27.3	Small clumps of algae are visible. Spirogyra (?) mats cover nearly the entire shoreline.

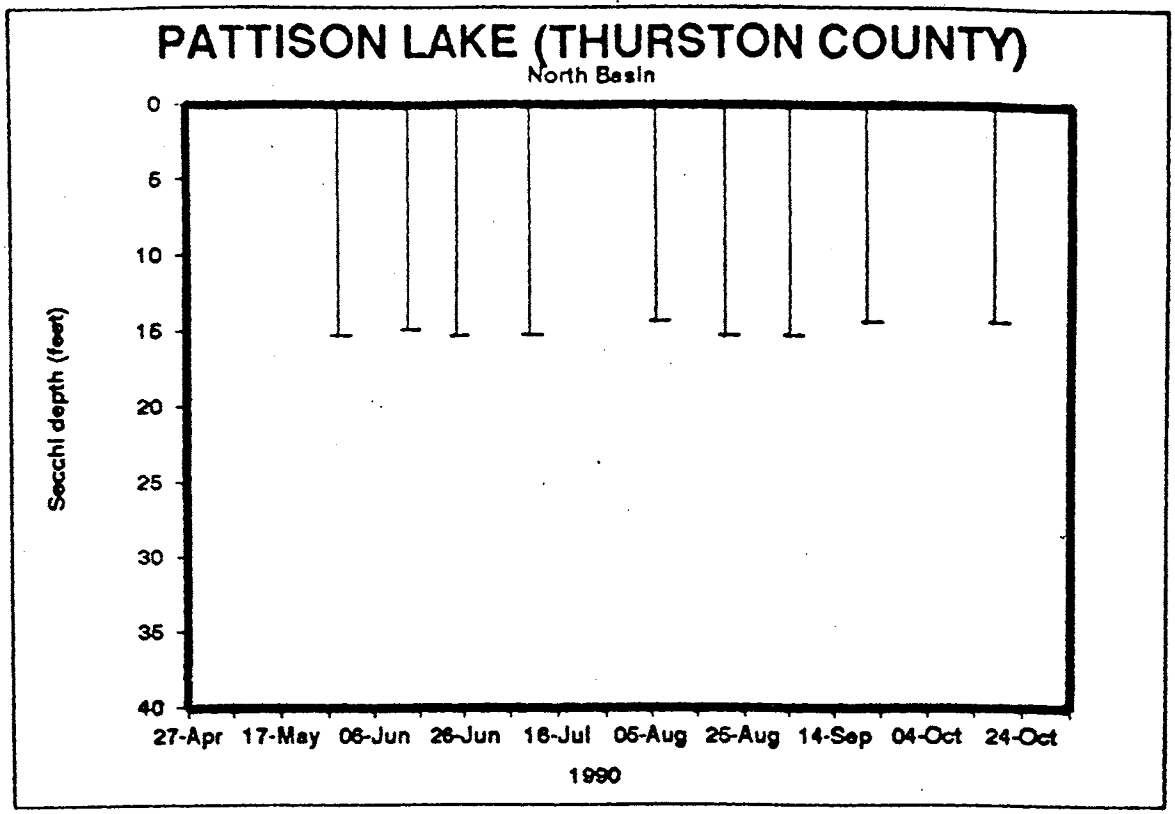
* Secchi data corrected for rope shrinkage
w Secchi disk entered weeds

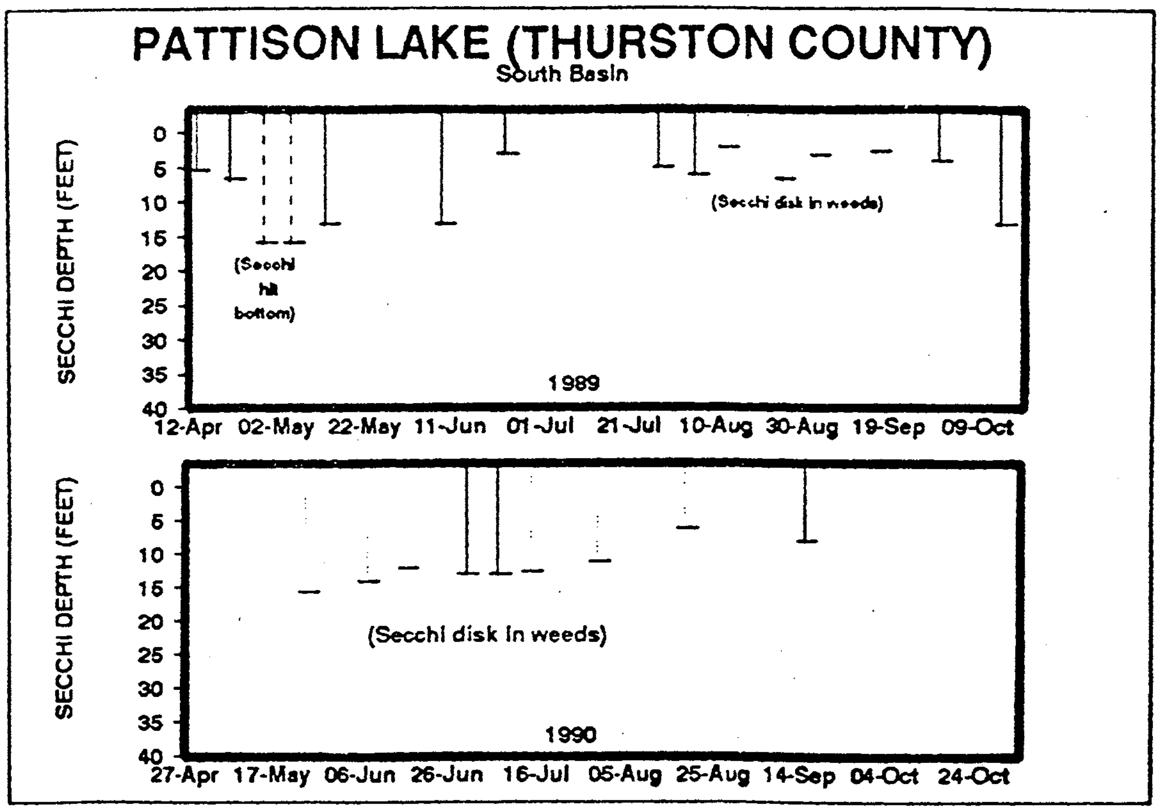
Patterson Lake -- Thurston County

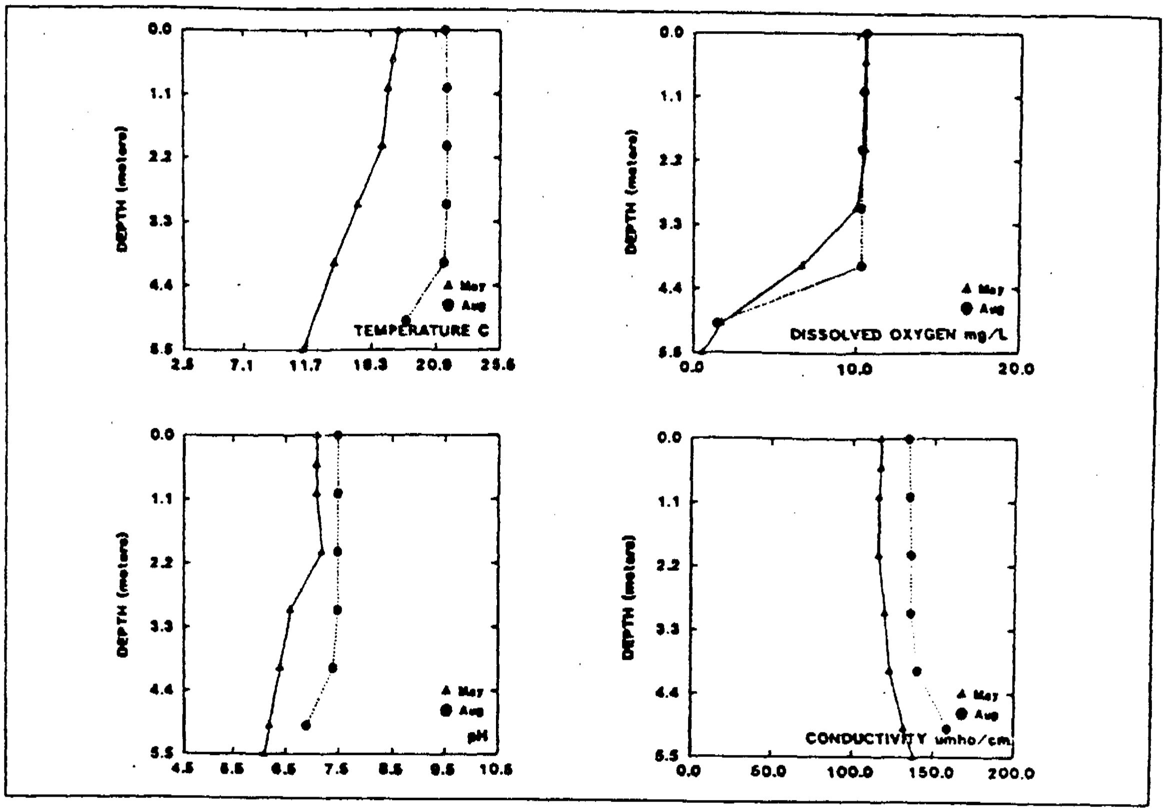
Onsite Visit Data -- North Basin

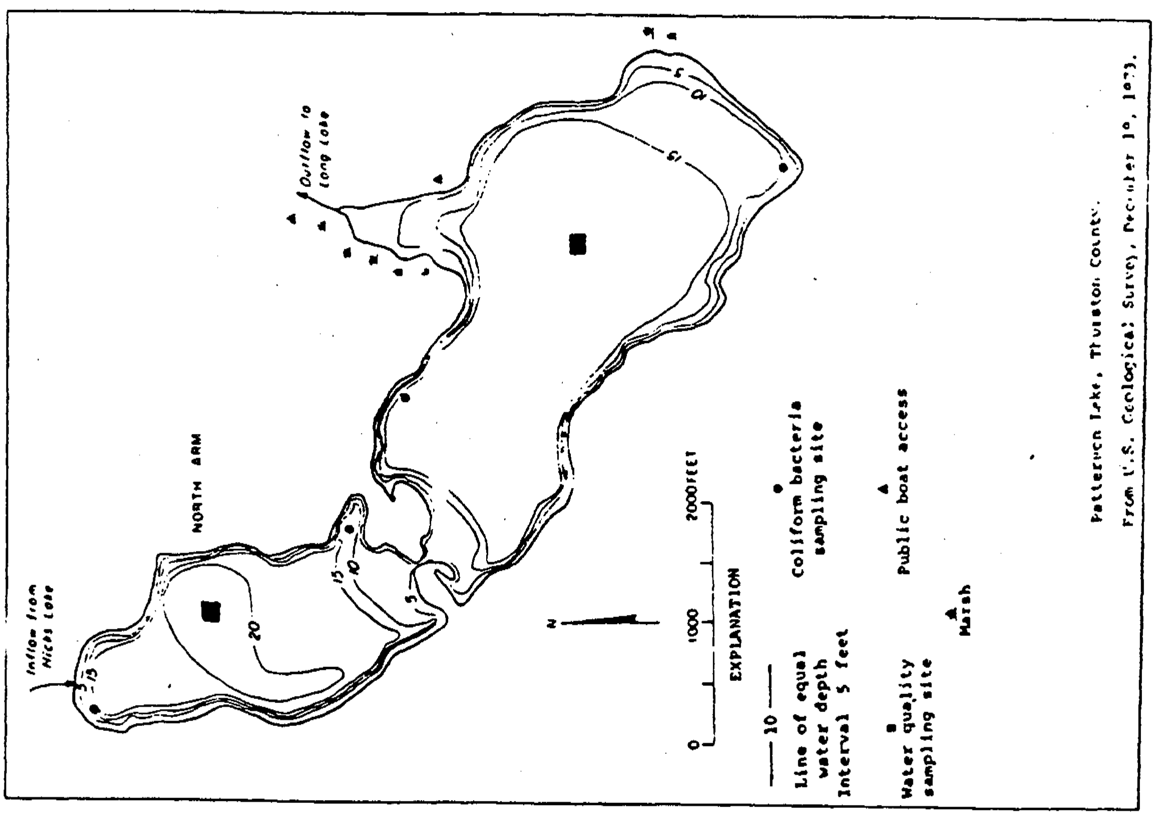
Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/30	0.0	18.3	7.1	10.4	117	0.5, 2	0.020	0.650
	0.5	17.9	7.1	10.5	117			
	1.0	17.5	7.1	10.5	116			
	2.0	17.1	7.2	10.5	116			
	3.0	15.4	6.6	10.0	120			
	4.0	13.7	6.4	6.7	123			
	5.0	.	6.2	1.8	132			
	5.5	11.4	6.1	0.6	138			
08/22	0.0	21.6	7.5	10.6	134	1, 2, 4	0.015	0.950
	1.0	21.7	7.5	10.4	135			
	2.0	21.7	7.5	10.3	136			
	3.0	21.7	7.5	10.3	136			
	4.0	21.5	7.4	10.3	140			
	5.0	18.8	6.9	1.5	159			

Secchi Depth and Profile Data Graphs






DEPTH (meters)
TEMPERATURE C
▲ May
● Aug
DISSOLVED OXYGEN mg/L
pH
CONDUCTIVITY umho/cm


Inflow from Hicks Lake
NORTH ARM
Outflow to Long Lake
EXPLANATION
Line of equal water depth Interval 5 feet
Water quality sampling site
Coliform bacteria sampling site
Public boat access
Marsh
0 1000 2000 FEET
Patterson Lake, Thurston County.
From U.S. Geological Survey

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)	1800
Drainage Area (miles^2)	0.5
Altitude (feet)	188
Shoreline Length (miles)	2.6

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index* (Secchi):	38
Mean Trophic State Index* (Total Phosphorus):	41

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Phillips Lake is used for fishing, swimming, boating, jet skiing, and rowing. Recreational facilities on the lakeshore include a picnic area, a beach and a boat ramp. There are no restrictions on motor boat use on the lake. Lake water is withdrawn for drinking and other domestic uses. Currently, the watershed is used for logging and the lakeshore is being developed further for residences. In the past, the watershed was used for logging, and the shoreline was altered during bulkhead construction. There are approximately 150 houses on the lakeshore; of these, about 35 are occupied year-round. The lakeshore is not sewered, and there are five culverts that drain into the lake. There is a lake association for the lake. The lake has been chemically treated in the past to control fish species. Rainbow trout are stocked in the lake. The worst problem in the lake, in the opinion of the volunteer, is weeds. Overall, the volunteer finds that Phillips Lake has good recreational water quality. The volunteer is concerned about water quality effects from boating, and the increasing number of people who use the lake.

Aquatic plant growth in Phillips Lake was not as bad in 1990 as in 1989. Submerged plant growth covered about 50% of the lake bottom in 1990, compared with most of the lake bottom in 1989. No lily pads, cattails, or algae blooms were noted in 1990.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that lowest water clarity occurred during early summer and early fall. Although the average summer water clarity was better during 1990 than in 1989, there were more readings taken during 1990 from which to evaluate the trophic state of the lake. Profile data collected during May and August 1990 show that the lake was not thermally stratified during August. As would be expected from a lake that is mixing, the temperature, conductivity and dissolved oxygen were stable from surface to bottom on both sampling dates. The concentrations of total phosphorus and total nitrogen were moderately high compared to the other lakes monitored for the program. The concentrations of these nutrients, as well as Secchi depth and dissolved oxygen concentrations, were similar to data collected in 1972 (Bortleson *et al.*, 1976). However, in 1972 there were very few rooted aquatic plants growing on the lake bottom.

A 1970 survey of Phillips Lake showed Secchi disk transparency ranging from 10 to 20 feet, with lowest transparency occurring during May, June, and November 1970 (Funk *et al.*, 1972). A blue-green algal bloom was observed during October 1970.

In 1972, Phillips Lake was most likely oligo-mesotrophic because Secchi disk transparency ranged from 12 to 16 feet and concentrations of total phosphorus and chlorophyll *a* ranged between the oligotrophic and mesotrophic ranges (Bortleson *et al.*, 1976a).

Residential development along the shore of Phillips Lake has increased since 1972, when 125 nearshore homes were reported (Bortleson *et al.*, 1976b).

A sample of foam collected by the volunteer on May 22, 1990, was found to contain decomposing debris and quite a few chironomid exoskeletons (outer coverings from microscopic animals). The identification notes state that the lake was very productive, unless the sample was collected from an area of high concentration. Lake Nahwatzel and Mission Lake also have occasional reports of foam on the shorelines. Samples of foam from both lakes contained organic debris.

Comments

Phillips Lake exhibits both oligotrophic and mesotrophic characteristics. Oligotrophic characteristics are the relatively high water clarity and the high concentrations of dissolved oxygen throughout the water column. The concentrations of total phosphorus were barely within the mesotrophic range. Although the data suggest that the lake may be more oligotrophic than mesotrophic, the volunteer reports that half of the lake bottom is covered with aquatic plants, which is more a mesotrophic characteristic. The lake was therefore classified as oligo-mesotrophic.

Acknowledgement

I thank James Keeley for volunteering his time to monitor Phillips Lake during 1989-1990.

Phillips Lake -- Mason County

Volunteer-Collected Data

Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
15-May	13.3	56.0		Lt-Green	75	Light	Light	20.0	23.0	
29-May	15.0	59.0	7.0	Lt-Green	50	Trace	Light	21.0	23.0	
14-Jun	16.7	62.0	7.5	Lt-Green	0	Trace	Light	21.3 w	22.0	
29-Jun	18.3	65.0	7.5	Lt-Green	25	Light	Light	15.0	11.5	Lake height 11.5" down from high water.
17-Jul			7.5	Lt-Green	10	None	Light	15.0	13.5	
31-Jul	22.2	72.0	7.5	Green	75	None	Light	14.5		
15-Aug			6.8	Lt-Green	25	Trace	Light	19.0	18.0	
01-Sep	20.0	68.0	6.8	Lt-Green	10	Light	Calm	19.0	20.0	Test early because of ski boats.
18-Sep	18.3	65.0	6.5	Lt-Green	10	Light		16.0	22.0	
01-Oct	15.6	60.0	6.5	Lt-Green	50	Breezy		15.0	24.0	
16-Oct	12.2	54.0		Lt-Green	10	Moderate	Breezy	15.0	23.0	

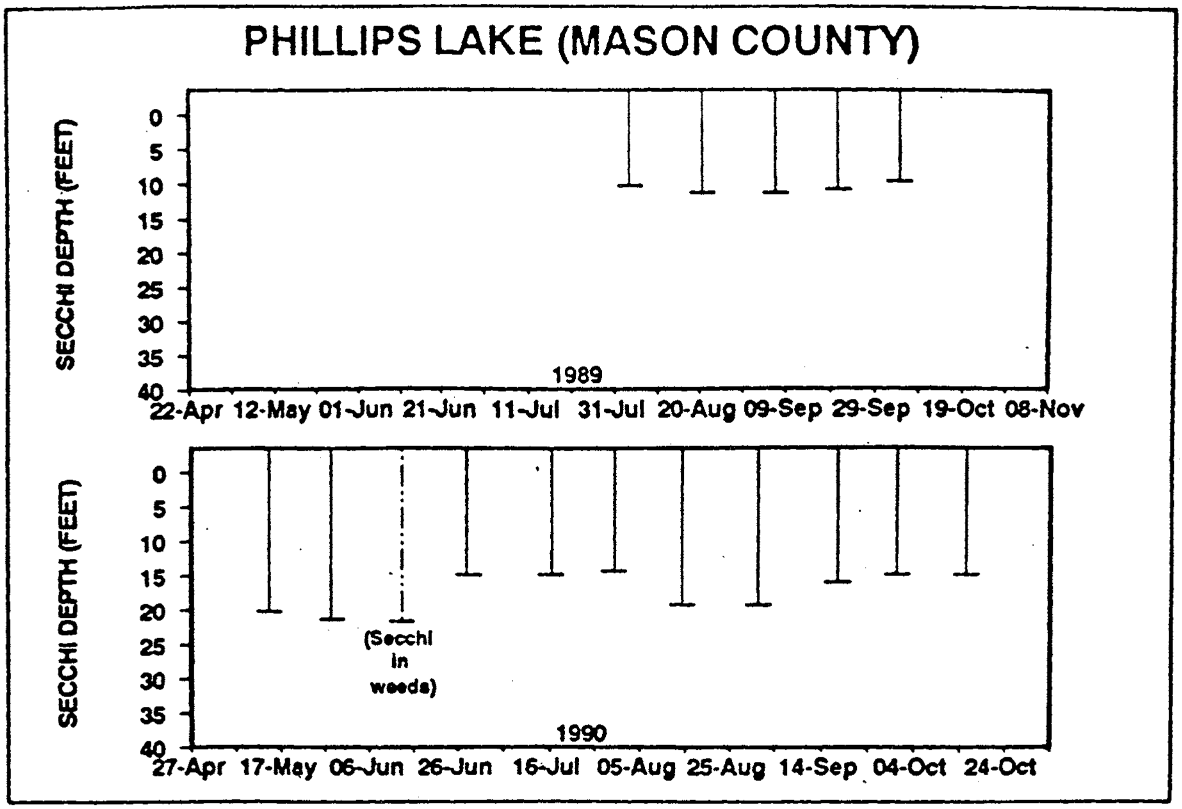
w Secchi disk entered weeds

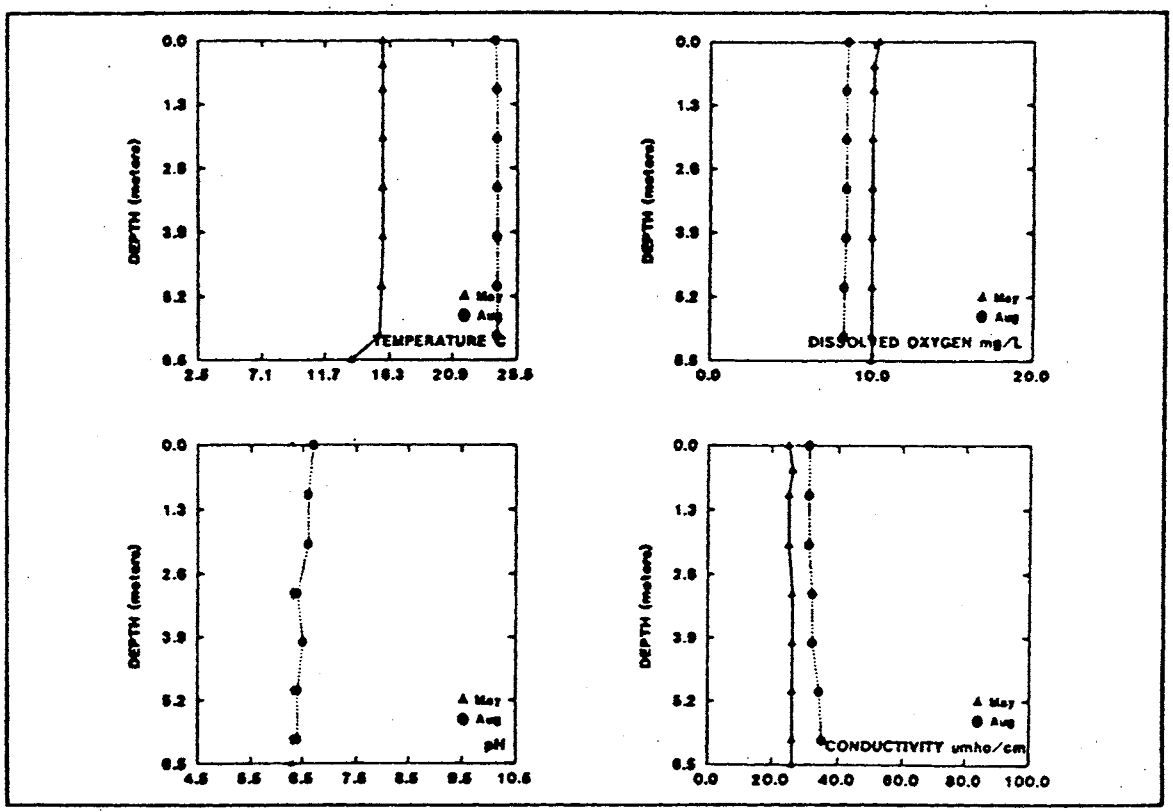
Onsite Visit Data

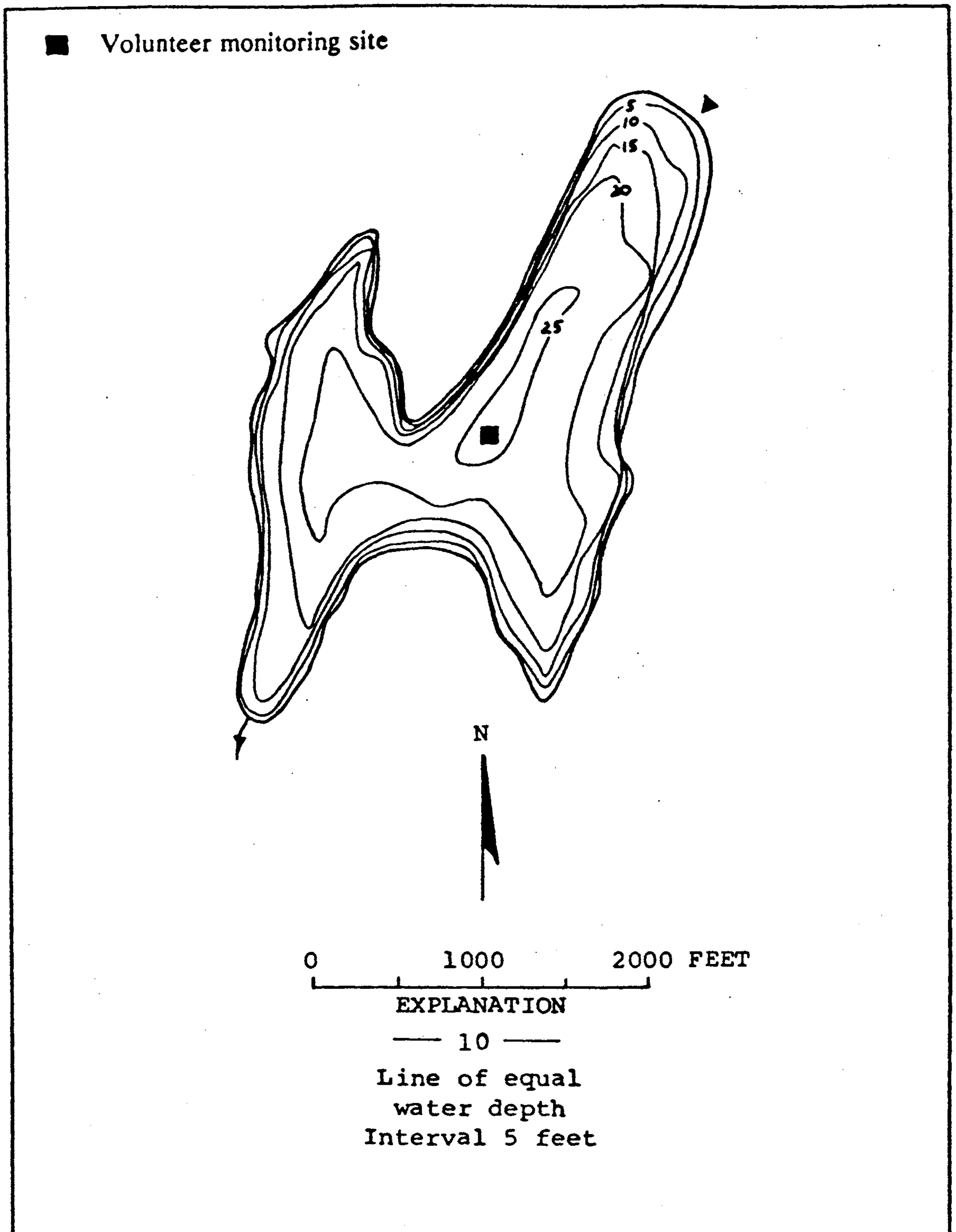
Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/24	0.0	15.8	.*	10.3	25	0.5, 3, 5	0.013	0.304
	0.5	15.8	.	10.0	26			
	1.0	15.8	.	10.0	25			
	2.0	15.8	.	9.9	25			
	3.0	15.8	.	9.9	26			
	4.0	15.8	.	9.9	26			
	5.0	15.7	.	9.9	26			
	6.0	15.6	.	9.9	26			
	6.5	13.6	.	9.9	26			
08/15	0.0	24.0	6.7	8.4	31	1, 3, 5	0.013	0.493
	1.0	24.1	6.6	8.3	31			
	2.0	24.1	6.6	8.3	31			
	3.0	24.1	6.4	8.3	32			
	4.0	24.1	6.5	8.3	32			
	5.0	24.1	6.4	8.2	34			
	6.0	24.1	6.4	8.2	35			

* See Quality Assurance section of this report.

Secchi Depth and Profile Data Graphs







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

Round Lake -- Clark County

Round Lake is located eight miles northwest of Vancouver, on the west side of Lake River. It is fed by Lacamas Lake via a narrow channel crossed by a highway bridge.

Size (acres)	30
Maximum Depth (feet)	55
Mean Depth (feet)	26
Lake Volume (acre-feet)	786
Drainage Area (miles^2)	64.7
Altitude (feet)	179
Shoreline Length (miles)	1.1

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	48
Mean Trophic State Index* (Total Phosphorus):	56

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Round Lake is used for fishing, swimming, and hiking. Recreational facilities on the lakeshore include a park and a picnic area. There is a speed restriction of 5 mph for motorboats. Lake water is withdrawn for industrial use. Currently the watershed is used for animal grazing, crop agriculture, and lakeshore development. Animal wastes from agriculture drain into the inlet tributaries. In the past, the watershed was used for animal grazing and crop agriculture. There is one house on the lakeshore, and it is occupied year-round. The lakeshore is not sewered. Fish (species not specified) are stocked in the lake. Presently there is a lake association for the lake. The worst problems in the lake, in the opinion of the volunteer, are 1) sediment, 2) algae, 3) aquatic plants, 4) floating debris, 5) fish species, and 6) water odors.

Round Lake is separated from Lacamas Lake by a bridge. There is a water filtration plant near the north end of Round Lake. The submerged plant beds were growing at an alarming rate, and the volunteer thought the beds would soon grow entirely across one section of the lake. There is a log boom, wier, and dam at the south end of the lake. There are wetland areas on the east and north ends of the lake. Thick weed beds grow in shallow water, just south of the swimming access area.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity was lowest during May and August, likely from spring and summer algae growth. Profile data collected during those months show that the lake was thermally stratified and that of dissolved oxygen decreased with depth. Dissolved oxygen profiles from mesotrophic and eutrophic lakes usually look similar to the temperature profiles. The erratic-looking dissolved oxygen profiles from Round Lake shows that dissolved oxygen was depleted in the metalimnion, which is a layer of water that is characterized by large changes of temperature with depth. This oxygen depletion may have been caused by respiration of bacteria decomposing large amounts of algae that were trapped by strong density gradients in the metalimnion. Dissolved oxygen concentrations approached zero near the bottom of the lake. In 1974, the concentration of dissolved oxygen below ten feet was nearly depleted and hydrogen sulfide (rotten-egg smell) was detected in the lower layer of water (Bortleson *et al.*, 1976); it is likely that low dissolved oxygen concentrations near the lake bottom are common from year to year.

The concentrations of total phosphorus and total nitrogen were high compared to other lakes monitored for the program. Only seven of 74 other monitored lakes had equal or higher average total phosphorus concentrations during 1990. In September 1974, the concentration of total phosphorus was 0.029 mg/L and the concentration of total nitrogen was 0.69 mg/L (Bortleson *et al.*, 1976), which were very similar to those measured in August 1990.

In 1974, submerged waterweed (*Elodea*) grew in dense beds (Bortleson *et al.*, 1976). High nutrient concentrations in Lacamas Lake have resulted in severe algae blooms and an increasing amount of aquatic plant growth. As a result, best management practices in the Lacamas Lake watershed are being implemented to control the amount of animal waste runoff that enters the lake.

Comments

Compared with Lacamas Lake, Round Lake had a slightly higher mean concentration of total phosphorus and considerably better mean summer water clarity in 1990.

Acknowledgement

I thank Jeri Millard for volunteering her time to monitor Round Lake during 1990.

Round Lake -- Clark County

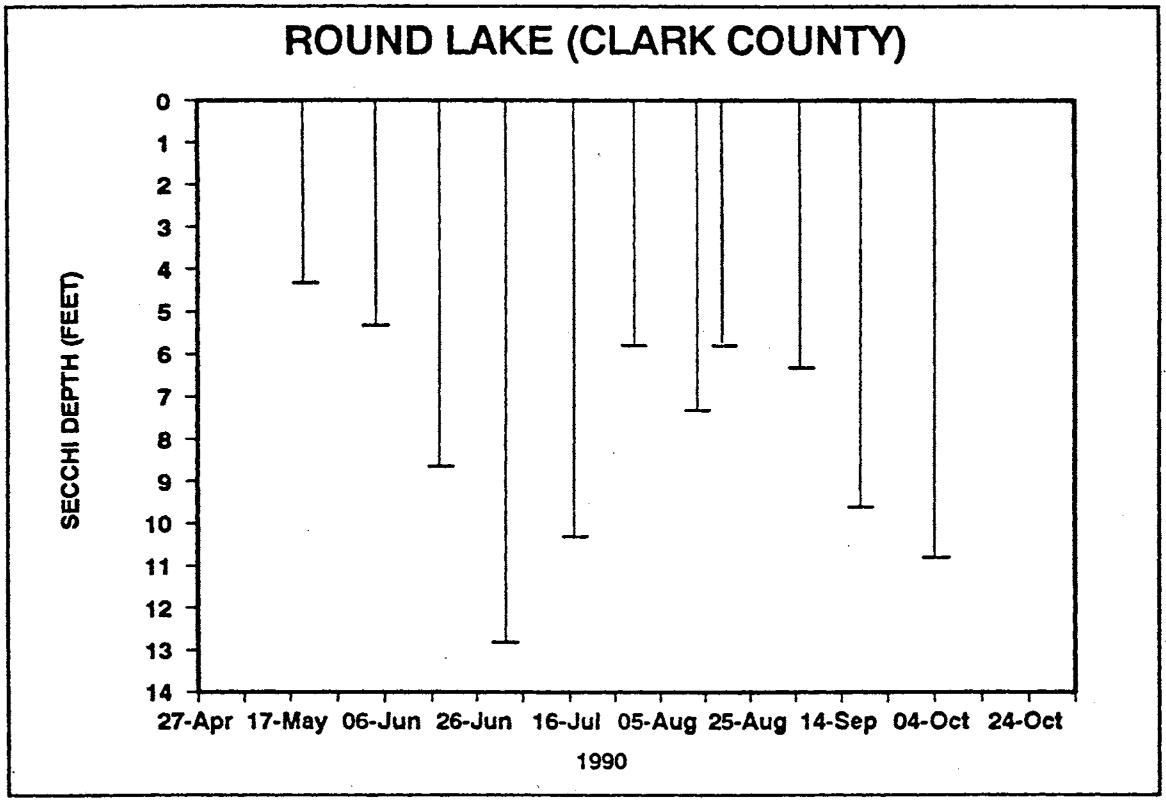
Volunteer-Collected Data

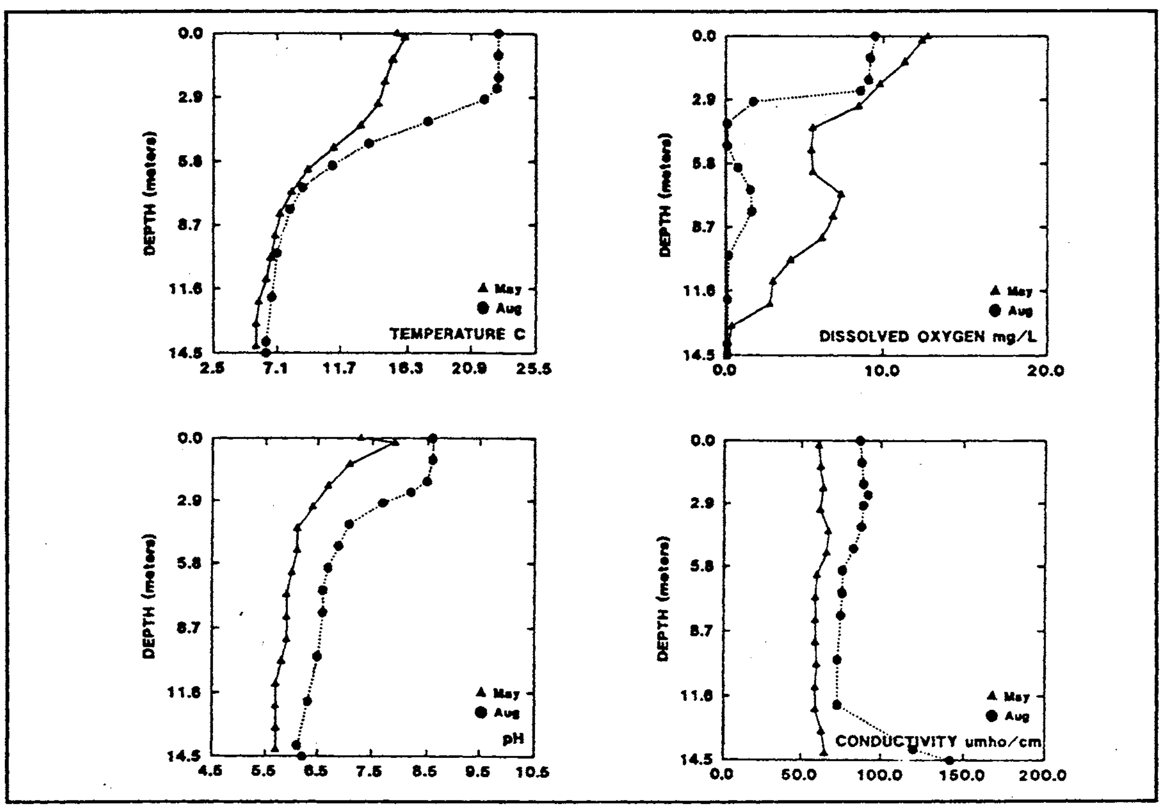
Date 1990	Temperature (° C)	(° F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
21-May	15.6	60.0	6.5	Gr-Brown	50	Heavy	Breezy	4.0	13.1	
05-Jun	17.2	63.0	6.5	Gr-Brown	90	Moderate	Calm	5.0	13.3	
19-Jun	17.8	64.0	5.5	Gr-Brown	0	None	Calm	8.3	13.6	
03-Jul	17.8	64.0	6.5	Green	10	Light	Calm	12.5	13.2	Algae starting to bloom.
18-Jul	19.4	67.0	7.0	Green	10	None	Calm	10.0	13.8	More algae bloom.
31-Jul	21.7	71.0	7.0	Green	100	Trace	Light	5.5	14.0	Weed growth accelerating; weeds flowering. - algae same as before.
14-Aug	25.0	77.0	8.0	Pea-Green	0	Trace	Calm	7.0	14.0	Weed bloom almost over - beds increasing in size.
20-Aug	21.7	71.0	7.5	Pea-Green	90	Light	Calm	5.5	12.0	
06-Sep	22.2	72.0	6.5	Pea-Green	0	None	Calm	6.0	12.0	
19-Sep	17.8	64.0	6.5	Green	100	None	Calm	9.3	12.0	
05-Oct	15.6	60.0	6.5	Green	0	Heavy	Light	10.5	11.0	

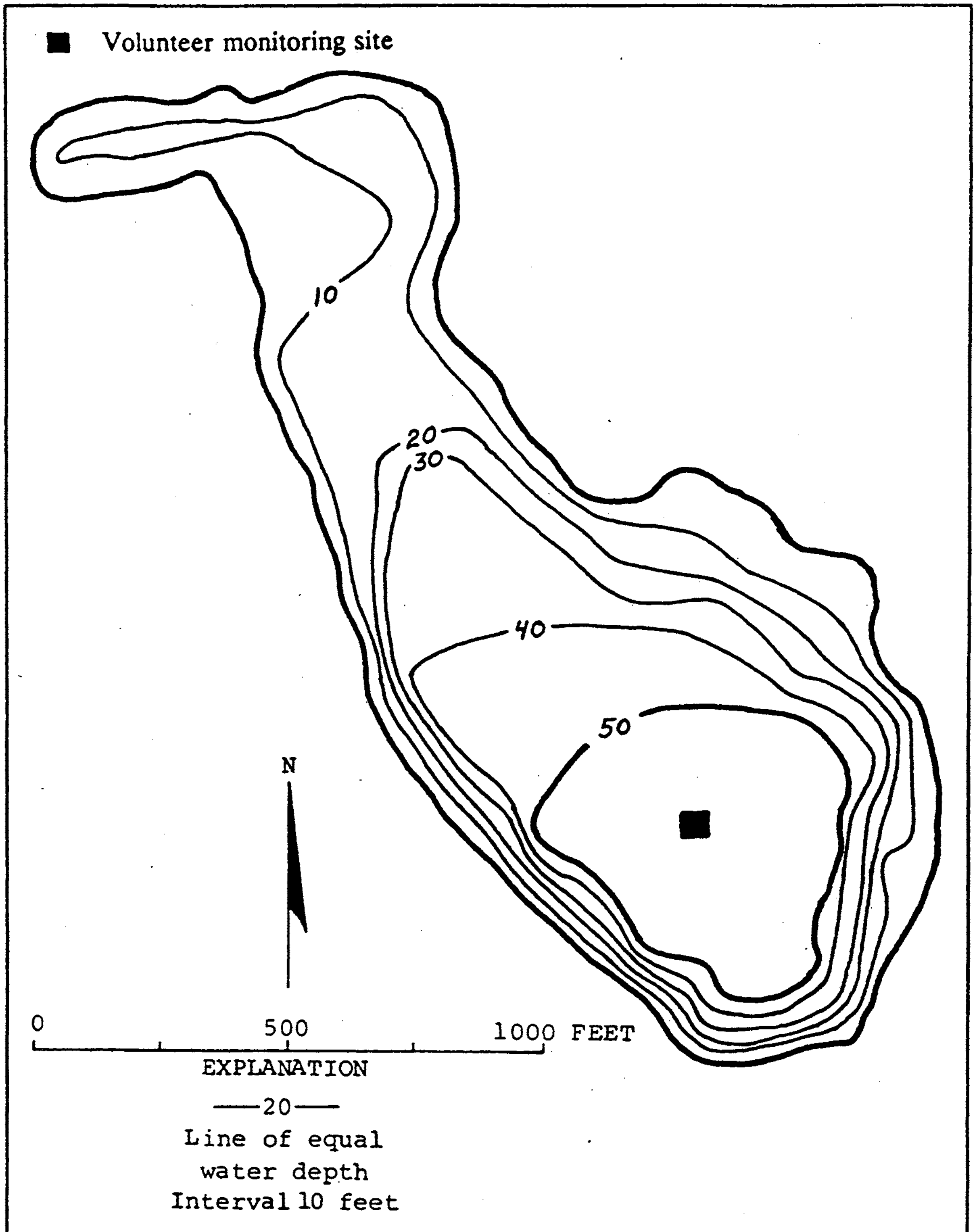
Onsite Visit Data

Date 1990	Depth (meters)	Temp (° C)	pH	Dissolved oxygen (mg/L)	Conductivity (umhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/21	0.0	15.6	7.3	12.7	.	0.5, 2, 4	0.042	0.822
	0.2	16.1	7.9	12.3	61			
	1.2	15.3	7.1	11.3	62			
	2.2	14.8	6.7	9.8	64			
	3.2	14.3	6.4	8.5	62			
	4.2	13.1	6.1	5.6	67			
	5.2	11.2	6.1	5.5	66			
	6.2	9.3	6.0	5.6	60			
	7.2	8.1	5.9	7.4	59			
	8.2	7.3	5.9	6.9	59			
	9.2	7.0	5.9	6.2	59			
	10.2	6.6	5.8	4.2	60			
	11.2	6.3	5.7	3.1	59			
	12.2	5.8	5.7	2.9	59			
	13.2	5.6	5.7	0.4	63			
	14.2	5.6	5.7	0.1	65			
08/20	0.0	22.9	8.6	9.5	87	1, 2	0.030	0.685
	1.0	22.9	8.6	9.2	88			
	2.0	22.9	8.5	9.1	89			
	2.5	22.8	8.2	8.6	92			
	3.0	21.9	7.7	1.8	89			
	4.0	17.8	7.1	0.1	88			
	5.0	13.7	6.9	0.1	83			
	6.0	6.6	6.7	0.8	76			
	7.0	8.9	6.6	1.6	76			
	8.0	8.0	6.6	1.7	75			
	10.0	7.1	6.5	0.2	73			
	12.0	6.7	6.3	0.1	73			
	14.0	6.3	6.1	0.1	120			
	14.5	6.3	6.2	0.1	142			

Secchi Depth and Profile Data Graphs







Round Lake, Clark County. From
U.S. Geological Survey, February 27, 1974.

Sacheen Lake -- Pend Oreille County

Sacheen Lake is located about 34 miles north of Spokane, and 12 miles west of Newport. It is two miles long. Principal inlets include Moon and Cedar Creeks. It drains via the West Branch of the Little Spokane River. There is a low dam at the outlet, built in 1922.

Size (acres)	317
Maximum Depth (feet)	40
Mean Depth (feet)	24
Lake Volume (acre-feet)	7615
Drainage Area (miles^2)	42.8
Altitude (feet)	2234
Shoreline Length (miles)	6.3

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	40
Mean Trophic State Index* (Total Phosphorus):	49

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Sacheen is used for fishing, boating, swimming, rowing, jet skiing, camping, and diving. There is one resort and one boat ramp on the lakeshore, and there is a speed restriction of 35 mph for motorboats. Lake water is withdrawn for drinking, industrial use, and irrigation. Currently the watershed is used for logging, animal grazing, crop agriculture, and the lakeshore is being developed further for residences. In the past, the watershed was used for logging, animal grazing, and crop agriculture. The lake has been dredged and the shoreline has been altered. There are approximately 200 houses on the lakeshore; of these, 20 are occupied year-round. The lakeshore is not sewered. Rainbow and western brook trout are stocked in the lake. Presently there is a lake association and a sewer district for the lake. The lake has been chemically treated in the past to control fish species. Management activities on the lake this year will include a Phase I Diagnostic/Feasibility study which is funded in part by a Centennial Clean Water Fund grant. The worst problem in the lake, in the opinion of the volunteer, is suspended sediments in the water. Overall, the volunteer finds that Lake Sacheen has good recreational water quality, and is concerned about possible water quality effects from livestock, speed boats, and automobile waste. The volunteer is also concerned that plant growth in the lake is presently uncontrolled.

There are cattails south of the public access area near the wetland. The volunteer reported that pondweed (*Potamogeton crispus*), milfoil (*Myriophyllum*) with lily pads are located along most of the shore, and lily and milfoil growth particularly heavy near the north inlet. There is heavy residential development along about 70% of the shoreline.

Sacheen Lake -- Pend Oreille County

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that although water clarity did not vary much, water clarity was lowest during July and August. Profile data collected during May and August 1990 show that on both sampling dates the lake was thermally stratified and concentrations of dissolved oxygen were depleted below the thermocline. During August, the increase in dissolved oxygen at 4 meters was likely from algae growing at this depth and releasing oxygen as a product of photosynthesis. The oxygen depletion near the lake bottom most likely resulted from the bacterial decomposition of organic material (such as algae, aquatic plants and woody debris) in the water and sediments. Concentrations of dissolved oxygen were also depleted near the lake bottom in 1981 (Sumioka and Dion, 1985) and 1974 (Dion *et al.*, 1976). The decrease in pH and increase in conductivity with depth are most likely related to decomposition in the water and sediments.

The 1990 concentrations of total phosphorus and total nitrogen were moderate to high. In 1974, (Bortleson *et al.*, 1976) and 1981 (Sumioka and Dion, 1985), similar concentrations of total phosphorus were found. Total nitrogen data from 1974 were also similar to 1990 concentrations. Trophic state indices calculated from 1981 data show that based on total phosphorus and Secchi data, the lake was mesotrophic (Sumioka and Dion, 1985).

In 1981 there were 232 nearshore homes (Sumioka and Dion, 1985) and in 1974 there were 204 nearshore homes (Dion *et al.*, 1976).

During the August 1990 onsite visit with the volunteer, American elodea (*Elodea canadensis*), large-leaved pondweed (*Potamogeton amplifolius*), coontail (*Ceratophyllum demersum*), and duckweed (*Lemna minor*) were observed. Also, a milfoil (*Myriophyllum* spp.) sample was collected for identification. Unfortunately, we were unable to determine whether the plant was the aggressive Eurasian milfoil or the native milfoil.

Comments

The Secchi data show that the water clarity of Sacheen Lake is very good, considering the moderately high concentrations of total phosphorus in the water. Based on total phosphorus concentrations, the lake was estimated as mesotrophic.

Compared with other Pend Oreille County lakes monitored for the program in 1990 (Big Meadow, Davis and Sullivan Lakes), Sacheen Lake had better water clarity and lower concentrations of total phosphorus than Big Meadow Lake, but both Davis Lake and Sullivan Lake have better water quality than Sacheen Lake.

Acknowledgement

I thank David Hebb for volunteering his time to monitor Lake Sacheen during 1990.

Sacheen Lake -- Pend Oreille County

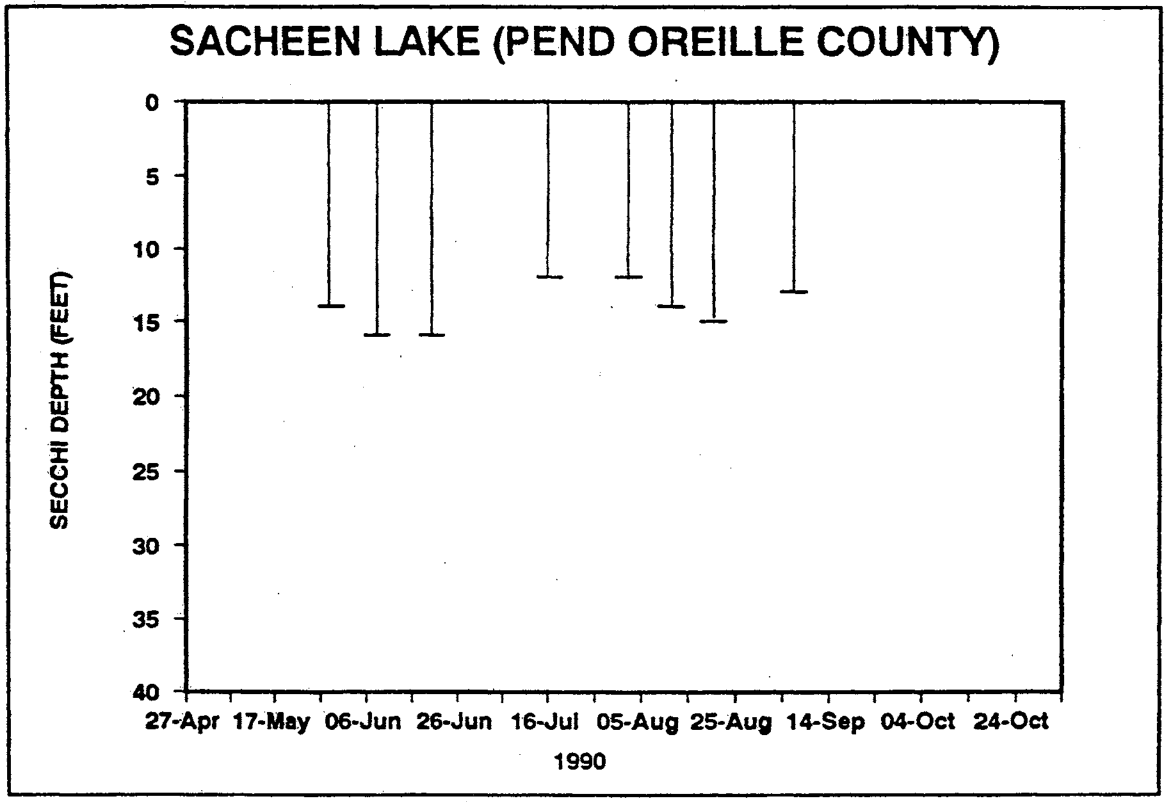
Volunteer-Collected Data

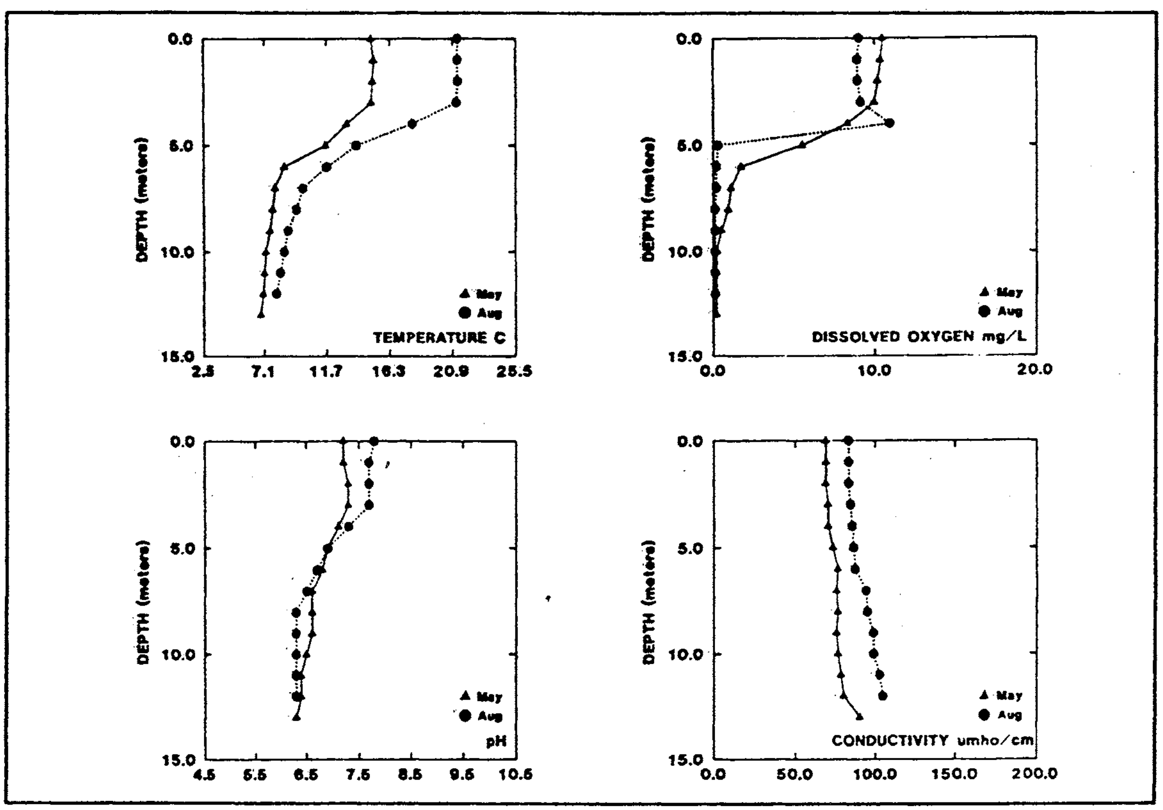
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht	Abbreviated Comments
30-May								13.0		
09-Jun	15.8	60.4	6.5	Brown	30	Moderate	Light	15.0	-3.0	Water color: light - dark brown. Significant surface activity (skiing etc.), much coarse sediment.
21-Jun	17.8	64.0	6.0	Lt-Brown	10	None	Light	15.0	-3.0	Calm, clear, weeds growing. The pH was definitely 6.0, down 0.5.
17-Jul	25.6	78.1	6.0	Gr-Brown	10		Breezy	11.0		
03-Aug	24.4	75.9	6.5	Gr-Brown	0	None	Light	11.0		Always stirred up by boats.
12-Aug	23.3	73.9	6.5	Gr-Brown	10	Trace	Light	13.0		Water color light green-brown. Weed growth along the shore at many places.
21-Aug	21.7	71.1	6.5	Gr-Brown	90	Heavy	Calm	14.0		Lots of rain and wind previous day. Reading taken with Dave.
07-Sep	20.0	68.0	6.5	Yellow-Br	0	Nohe	Breezy	12.0		Water color yellow-brown.

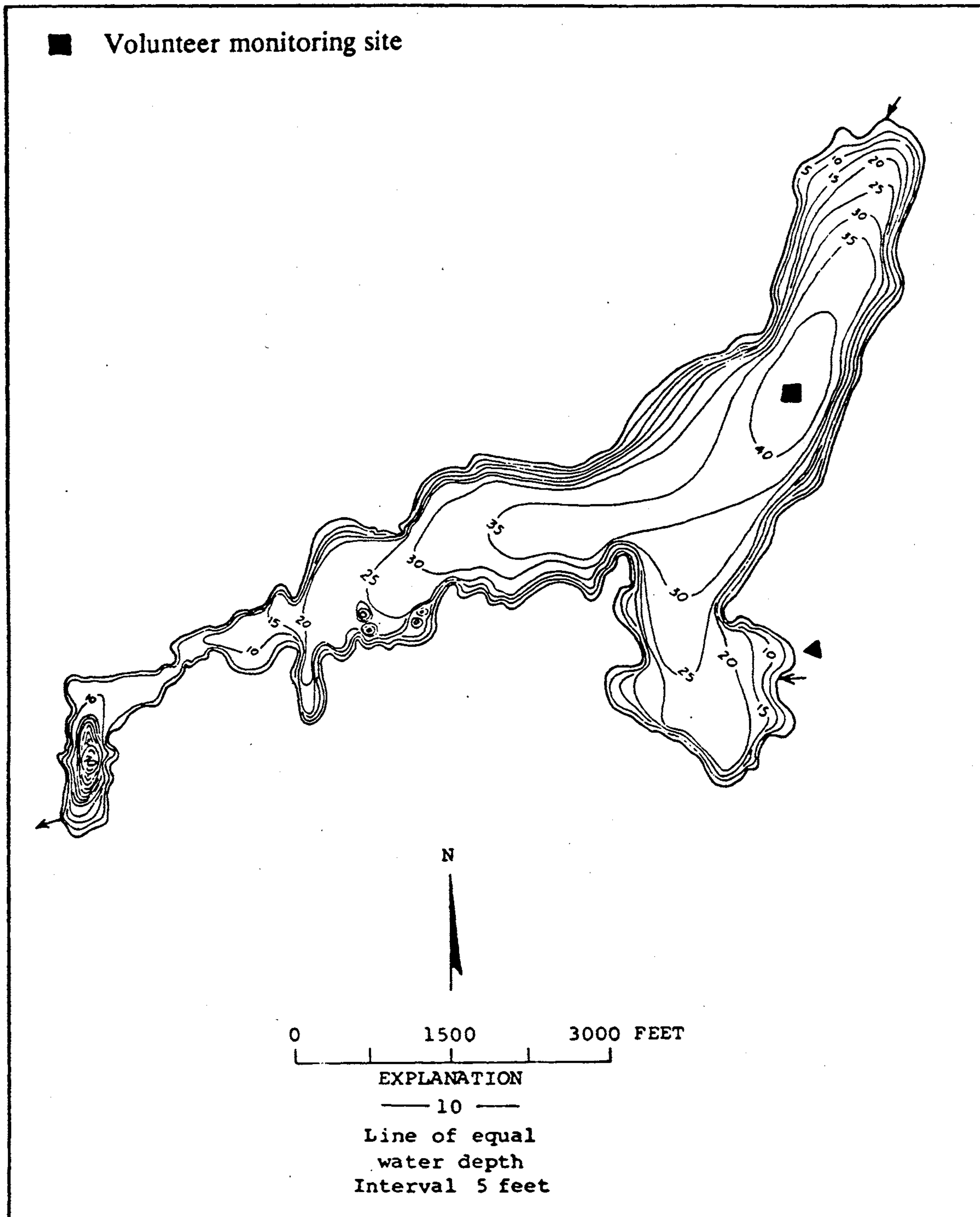
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/30	0.0	15.0	7.2	10.5	69	1, 2, 3	0.018	0.365
	1.0	15.2	7.2	10.4	69			
	2.0	15.1	7.3	10.2	69			
	3.0	15.0	7.3	10.0	70			
	4.0	13.2	7.1	8.3	70			
	5.0	11.6	6.9	5.5	73			
	6.0	8.6	6.8	1.7	76			
	7.0	7.9	6.6	1.1	75			
	8.0	7.7	6.6	0.9	76			
	9.0	7.5	6.6	0.5	75			
	10.0	7.2	6.5	0.2	76			
	11.0	7.1	6.4	0.2	78			
	12.0	7.0	6.4	0.2	80			
	13.0	6.8	6.3	0.2	90			
08/21	0.0	21.3	7.8	9.0	83	1, 2, 3	0.026	0.435
	1.0	21.3	7.7	8.9	83			
	2.0	21.3	7.7	8.9	83			
	3.0	21.2	7.7	9.1	84			
	4.0	18.0	7.3	11.0	85			
	5.0	13.9	6.9	0.3	86			
	6.0	11.7	6.7	0.2	87			
	7.0	10.0	6.5	0.2	94			
	8.0	9.5	6.3	0.1	95			
	9.0	8.9	6.3	0.1	99			
	10.0	8.6	6.3	0.1	99			
	11.0	8.3	6.3	0.1	103			
	12.0	8.0	6.3	0.1	105			

Secchi Depth and Profile Data Graphs







Sacheen Lake, Pend Oreille County. From
Washington Department of Game, March 4, 1957.

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.

Size (acres)	814
Maximum Depth (feet)	140
Mean Depth (feet)	71
Lake Volume (acre-feet)	33,100
Drainage Area (miles^2)	3.7
Altitude (feet)	273
Shoreline Length (miles)	1.8

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index* (Secchi) East Arm:	39
Mean Trophic State Index* (Total Phosphorus) East Arm:	39

* From Carlson (1977)

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

The following are from the volunteers' remarks and questionnaire responses. Lake Samish is used for fishing, boating, water skiing, swimming, rowing, and jet skiing. There is a park, a picnic area, a beach and one public boat ramp on the lakeshore for public recreation. Lake water is withdrawn for drinking and other domestic uses. Currently the watershed is used for logging and lakeshore development. In the past, the watershed was used for logging and animal grazing, and the lake was dredged. There are 505 houses within the Lake Samish basin; of these, 288 are on the lakeshore. All houses are occupied year-round, and the lakeshore is fully sewered. There are about 60 storm drains and culverts that empty into the lake. Presently there is a water district (#12) for sewage collection for the lake. The worst problems in the lake, in the opinion of the volunteers, are 1) aquatic plants, and 2) water level. The water level problems have involved Ecology and have affected some lake residents. The beaver dam at the outlet, which affects the lake level, was torn down three times during 1990. Overall, the volunteers find that Lake Samish has excellent recreational water quality, but they are concerned about aquatic weeds and stormwater runoff from I-5, as well as the limited water resource allocations at the lake. The volunteers also noted that the cove at the mouth of Lake Creek is almost totally filled up, despite dredging after the construction of I-5.

The volunteers noted four predominant aquatic plants growing in the lake. Three of the plants, wild celery (*Vallisneria americana*, also known as tapegrass), a water lily (*Nymphaea* spp.) and northern watermilfoil (Myriophyllum exalbescens) were identified by the Whatcom County Cooperative Extension Office. Wild celery grows along the shoreline of the east basin, with the exception of two areas that have a steep shoreline. Wild celery grows along about 60% of the shore of the west basin. Lilies and northern watermilfoil grow predominantly in an area about 1500 feet east of the bridge on the south shore of the east basin. Cattails and "grass" grow along an area just east of the Lake Creek inlet. There is a wetland at the south end of the east basin, at the lake's outlet. Please see the Comments section regarding identification of aquatic plant species in Lake Samish.

In the 1989 questionnaire, the volunteers noted that cattails (*Typha* spp.), small oval-pad lilies (possibly *Brasenia schreberi*) and large round pad lilies (possibly *Nymphaea odorata*) were mapped in shallower areas near Lake Creek, Wefer Creek, and Friday Creek. The volunteers reported that growth of a variety of weeds was rapidly spreading along the shoreline in water up to ten feet deep.

The volunteers were interviewed for an article printed in the Bellingham Herald on July 12, 1989. The article reported that the Lake Samish shoreline was sewered in 1976-77, and the volunteers commented that the lake water was clearer after the sewers were installed. Local residents are concerned about how water quality may be affected by roadside spraying, potential spills along Interstate 5, and motor oil from boats.

<u>Monitoring Results/Summary of Other Available Information</u>

Secchi data collected during 1990 show that the lowest water clarity occurred from August through September, in both basins of the lake. Lower water clarity during September was particularly evident in the West Arm of the lake. Compared with data collected during 1989, there were more distinct variations in water clarity during 1990, and mean summer water clarity was slightly better in 1990 than in 1989.

Profile data were collected from the East Arm during June and August 1990. The profile data show that on both sampling dates, the lake was thermally stratified and concentrations of dissolved oxygen decreased with depth below the thermocline. The decrease in dissolved oxygen concentrations probably resulted from bacteria consuming oxygen while decomposing organic material (such as algae, aquatic plants and woody debris) in the water and sediments. The decrease in pH with depth is most likely related to increased decomposition near the lake bottom. The profile data were very similar to profile data collected by Ecology in 1989 (Brower and Kendra, 1990). Data from October 1968 showed that concentrations of dissolved oxygen decreased to 1.5 mg/L near the bottom of the lake (Lee, 1969). A phenomenon known as metalimnetic maxima (higher concentrations in the metalimnion of the lake, caused by either lower temperatures or by algae which grow faster than they sink) was apparent in dissolved oxygen profiles in this study as well as during June 1989 (Brower and Kendra, 1990) and October 1968 (Lee, 1969). The lake was described as oligotrophic in 1969 (Lee, 1969). Dissolved oxygen concentrations were also found to be depleted near the bottom of the lake in 1971 (Bortleson *et al.*, 1974).

In 1990, the concentrations of total phosphorus and total nitrogen were low to moderate compared to other lakes monitored for the program. Concentrations of these nutrients were similar to concentrations in 1989 (Brower and Kendra, 1990) and in 1971 (Bortleson *et al.* 1976).

In 1971, 26-50% of the shoreline was covered by submerged plants, including *Vallisneria* (Bortleson *et al.*, 1974). In 1989, *Vallisneria americana* was growing along approximately 90% of the shoreline of the east basin (Brower and Kendra, 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 (Johnson and Norton, 1990). Sediments contained arsenic (21.0 μg/Kg), 4-methylphenol (1500 ug/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 (Johnson and Norton, 1990).

The Water Resources Program of Ecology has been monitoring the lake stage because of an ongoing controversy over water withdrawal permits.

Residential development of the lakeshore has increased since 1954. The volunteer reported there were 288 nearshore homes in 1990; in 1954 there were 142 nearshore homes (Bortleson *et al.*, 1974).

During the August 1990 visit with the volunteers, both tapegrass (*Vallisneria americana*) and waterweed (*Elodea* spp.) were observed near the public boat launch.

Comments

Although each basin of the lake varies considerably with respect to size and depth, both basins had the same mean summer trophic state index (Secchi) value.

Identification of the water lilies may need to be verified, because there are some discrepancies in the identifications of the small-leaved versus the large-leaved varieties. Both *Nymphaea odorata* (a white-flowering water lily with large, round leaves) and *Brasenia schreberi* (a small, round-leaved "lily pad" that has small, inconspicuous flowers; also known as water shield) were found in Lake Samish in 1989 (Brower and Kendra, 1990).

Lake Samish -- Whatcom County

Identification of the small-leaved lily was not consistent with the identification conducted at the County Extension Office.

Acknowledgement

I thank A. B. Davis and J. David Jenkins for volunteering their time to monitor the east and west arms of Lake Samish, respectively, during 1989 - 1990.

Lake Samish -- Whatcom County

Volunteer-Collected Data -- East Arm

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht	Abbreviated Comments
04-Jun	15.0	59.0	7.2	Lt-Green	50	Heavy	Gusty	13.7**		
22-Jun	20.0	68.0		Lt-Green	100	None	Gusty	15.6		
07-Jul	20.0	68.0	6.3	Lt-Green	100	Light	Light	17.9		
21-Jul	24.5	76.1	6.0	Lt-Green	0	None	Calm	22.0	267.4	
04-Aug	24.0	75.2	6.0	Lt-Green	0	None	Light	19.3	267.3	
15-Aug	24.0	75.2	6.0	Lt-Green	90	None	Strong	9.6	265.8	
30-Aug	21.0	69.8	7.3	Green	100	Moderate	Light	8.7		
13-Sep	20.0	68.0		Green	0	None	Calm	10.1	267.2	
26-Sep	19.5	67.1	6.5	Lt-Green	100	None	Calm	10.1	267.2	
09-Oct	16.0	60.8	6.5	Lt-Green	100	None	Calm	9.2**	267.5	

* Secchi data corrected for rope shrinkage

** There was high variability between the first and second Secchi depths collected; these two data points may not be included in data comparisons

Volunteer-Collected Data -- West Arm

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht	Abbreviated Comments
22-Jun	20.0	68.0	6.0	Lt-Green	100	None	Gusty	16.4		
07-Jul	20.0	68.0	6.0	Lt-Green	0	Trace	Light	19.3	268.0	
22-Jul	24.0	75.2	6.3	Lt-Green	0	None	Light	22.2	267.5	
04-Aug	22.0	71.6	6.0	Lt-Green	0	None	Calm	18.3	267.3	
15-Aug	24.0	75.2	6.0	Lt-Green	0	None	Light	11.0	267.2	Sea level elevation is a DOE lake gage compared to a gage set by water district engineers.
30-Aug	20.5	68.9	7.3	Lt-Green	100	Moderate	Light	10.1	267.20	
13-Sep	20.0	68.0		Lt-Green	0	None	Breezy	6.0	267.18	
26-Sep	18.0	64.4	6.5	Lt-Green	100	None	Calm	10.1	267.2	Height above sea level is calculated by adding 266.63 to DOE gage reading. Differential calculated from sea level gage established by engineers.
09-Oct	15.5	59.9	6.5	Lt-Green	100	None	Calm	11.0	267.5	

* Secchi data corrected for rope shrinkage

Lake Samish -- Whatcom County

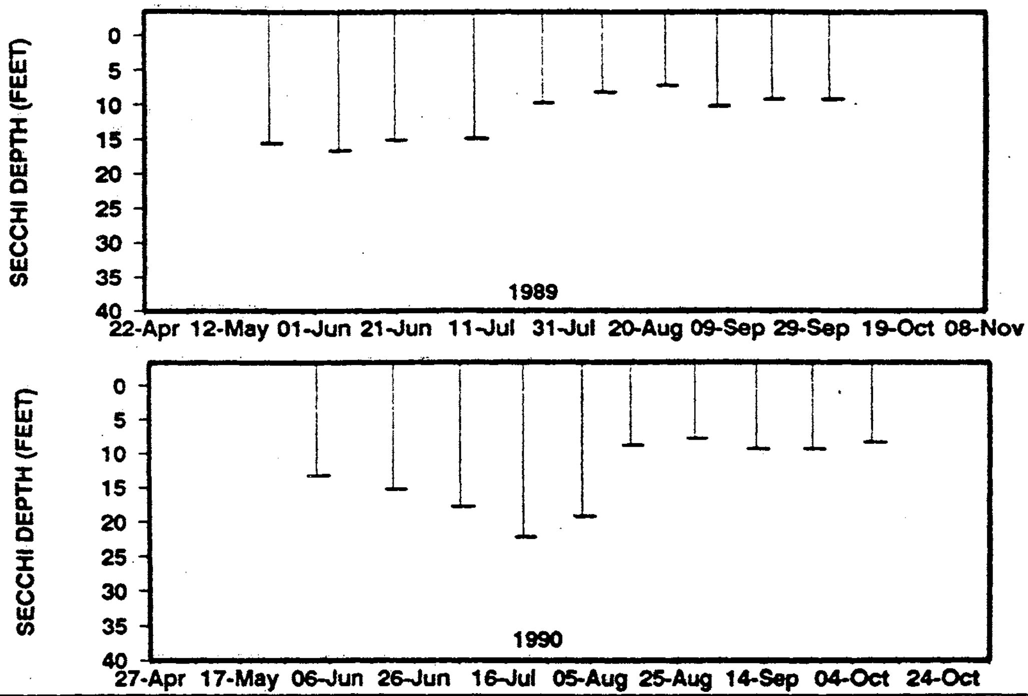
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/04	0.0	15.6	7.2	10.6	62	1, 4, 7	0.013	NA
	0.5	15.6	7.3	10.6	62			
	1.0	15.6	7.3	10.6	62			
	2.0	15.6	7.3	10.6	62			
	3.0	15.6	7.3	10.6	63			
	4.0	15.6	7.3	10.6	63			
	5.0	15.5	7.3	10.6	63			
	6.0	15.5	7.3	10.6	65			
	7.0	13.5	7.3	10.6	65			
	8.0	13.7	7.1	10.8	67			
	9.0	11.8	7.0	11.1	68			
	10.0	10.1	6.9	11.4	89			
	11.0	9.1	6.8	10.8	70			
	13.0	8.1	6.7	8.9	71			
	15.0	7.5	6.4	8.0	71			
	17.0	6.9	6.7	8.1	70			
	20.0	6.6	6.3	4.7	72			
08/15	0.0	23.4	8.5	9.8	71	1, 3, 6	0.010	0.362
	1.0	23.5	8.6	9.8	71			
	2.0	23.5	8.6	9.8	71			
	4.0	23.4	8.7	9.8	70			
	6.0	22.6	8.6	9.8	69			
	8.0	4.3	7.7	10.8	68			
	10.0	12.6	7.0	8.5	68			
	12.0	8.9	6.7	3.2	70			
	14.0	8.1	6.5	2.1	70			
	16.0	7.6	6.4	1.7	68			
	18.0	7.3	6.3	0.5	69			
	19.0	7.2	6.1	0.2	73			

NA data not available -- sample not analyzed by laboratory

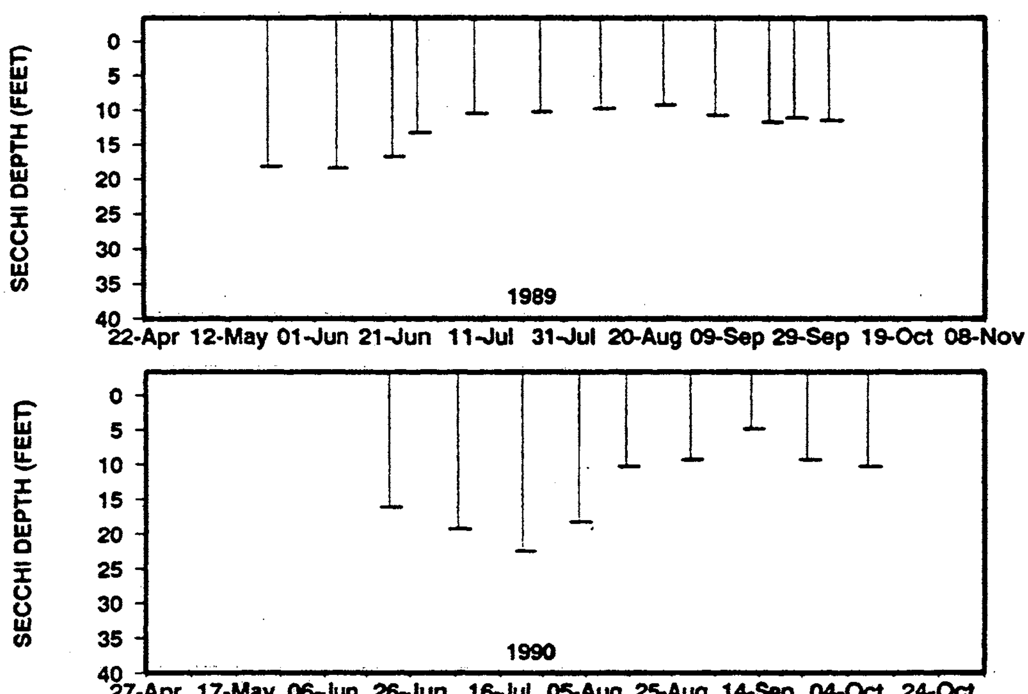
LAKE SAMISH (WHATCOM COUNTY)

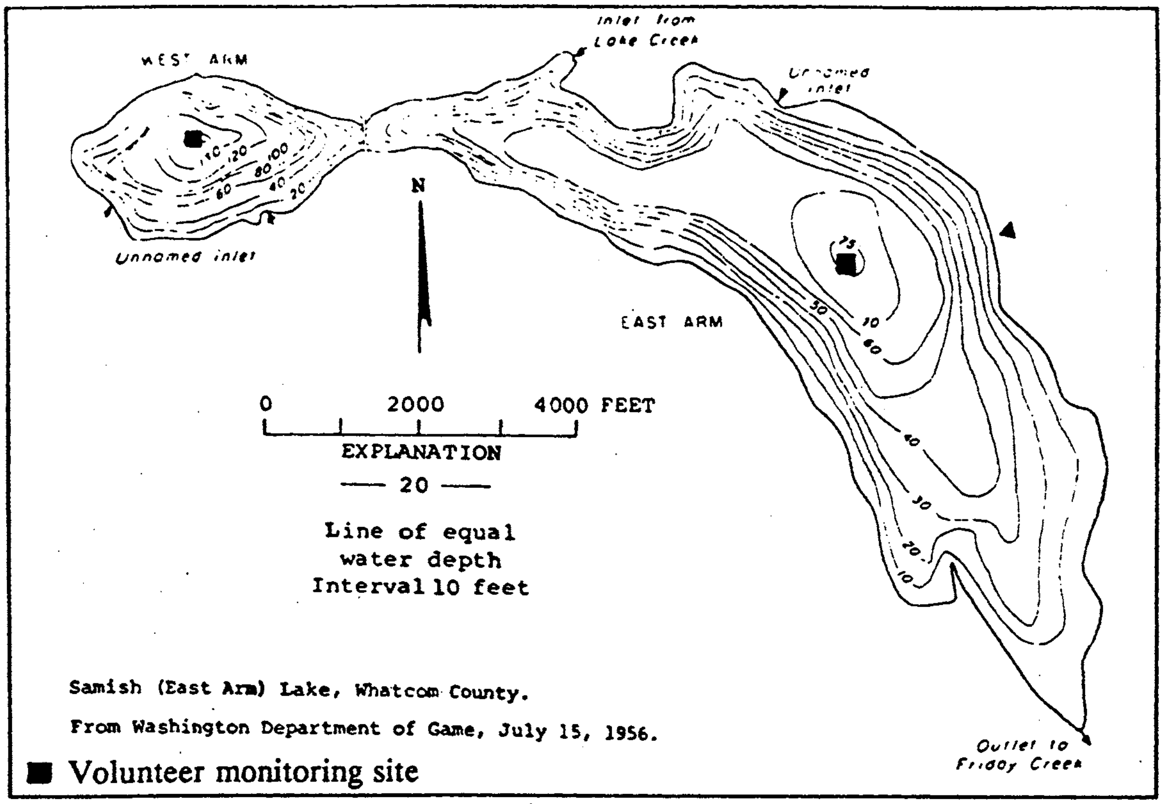
East Arm



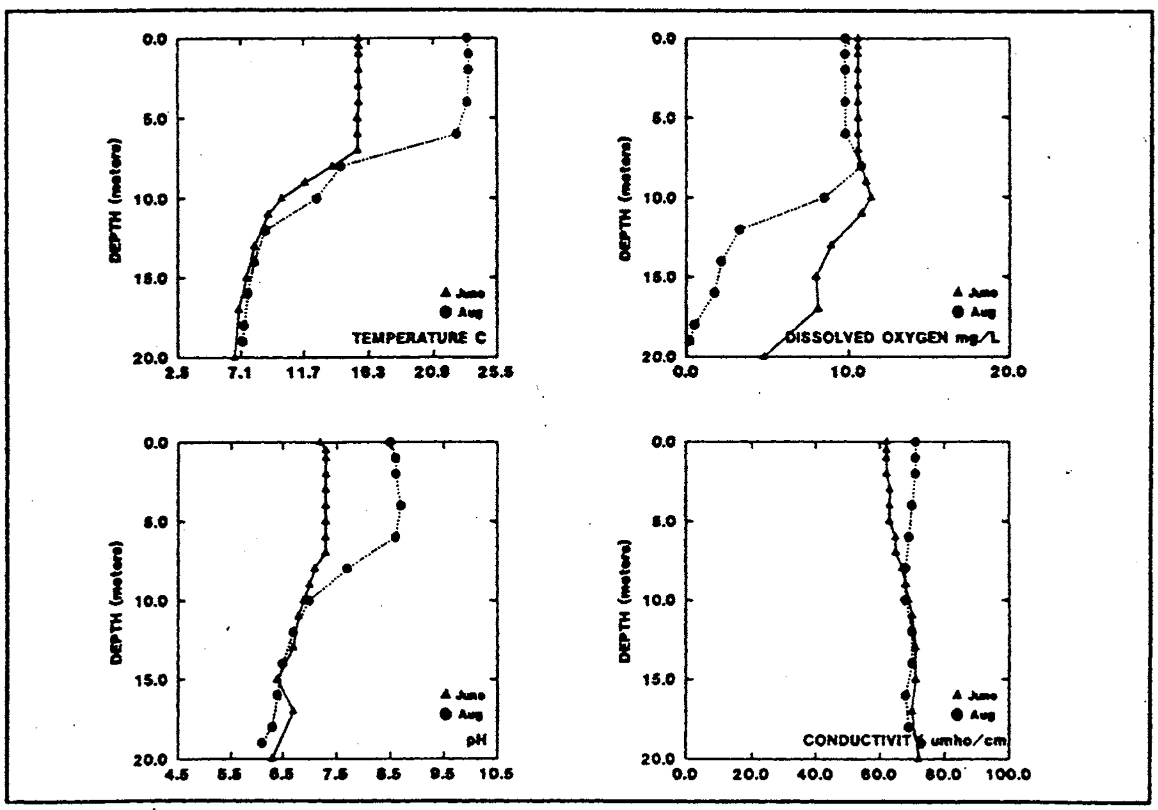
LAKE SAMISH (WHATCOM COUNTY)

West Arm





WEST ARM
Inlet from Lake Creek
Unnamed inlet
Unnamed inlet
N
EAST ARM
0 2000 4000 FEET
EXPLANATION
20
Line of equal water depth Interval 10 feet
Samish (East Arm) Lake, Whatcom County.
From Washington Department of Game, July 15, 1956.
Volunteer monitoring site
Outlet to Friday Creek



DEPTH (meters)
TEMPERATURE C
DISSOLVED OXYGEN mg/L
pH
CONDUCTIVITY umho/cm
June
Aug

Lake Shoecraft -- Snohomish County

Lake Shoecraft is located 600 feet southwest of Lake Goodwin. It is fed via a canal from Lake Goodwin, and drains to Weallup Lake and Tulalip Creek, and ultimately to Tulalip Bay.

Size (acres)	130
Maximum Depth (feet)	35
Mean Depth (feet)	18
Lake Volume (acre-feet)	2400
Drainage Area (miles^2)	6.0
Altitude (feet)	324
Shoreline Length (miles)	2.4

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

* From Carlson (1977)

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

The following are from the volunteer's remarks and questionnaire responses. Lake Shoecraft is used for fishing, boating, swimming, rowing, and jet skiing. Recreational facilities on the lakeshore include one boat ramp, and there is a speed restriction of 8 mph for motorboats. In the past, the watershed was logged. There are approximately 200 houses on the lakeshore; of these, 180 are occupied year-round. About 90% of the shoreline is developed for residences. The lakeshore is not sewered, and no storm drains empty into the lake. Trout are stocked in the lake. Presently there is a waterskiing association for the lake. The lake has been chemically treated in the past to control fish species. The worst problems in the lake, in the opinion of the volunteer, are ranked as 1) runoff, 2) aquatic plants, 3) algae, and 4) water level. Overall, the volunteer finds that Lake Shoecraft has fair recreational water quality, and is concerned about possible water quality effects from septic systems and road runoff.

The volunteer noted that there is a large merganser population at the lake, and there are still some otters but they were rarely seen in the last two years. Water and jet skiing have been increasing each year.

There are reeds on the lakeshore along the canal that enters Lake Shoecraft from Lake Goodwin. Submerged plants grow especially thick just north of this canal, at a wetland at the north end of the lake, at a cove on the west side of the lake and all around the island at the south end. Lily pads grow in water up to ten feet deep just north of the public boat launch area. The volunteer also noted that the land surrounding the lake is moderate to steep in places, and that most road runoff runs towards the lakeshore.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity in Lake Shoecraft did not vary much during the summer, but was greatest during late August and October. Profile data collected during June and August 1990 show that on both sampling dates, the lake was thermally stratified and concentrations of dissolved oxygen decreased below the thermocline. In August, the decrease in pH and the increase in conductivity with depth is probably related to increased decomposition in the water and sediments. In 1973, concentrations of dissolved oxygen decreased to 0.8 mg/L near the lake bottom (Bortleson *et al.*, 1976), so it is likely that low dissolved oxygen concentrations near the lake bottom have been occurring for many years.

The 1990 concentrations of total phosphorus and total nitrogen were borderline between low and medium (averaging 0.0119 and 0.398 mg/L, respectively). In June 1974, the concentration of total phosphorus was 0.014 mg/L and total nitrogen was 0.15 mg/L (Bortleson *et al.*, 1976). Those concentrations are in the range associated with mesotrophic lakes.

In 1974, there were 100 nearshore homes compared with approximately 200 reported by the volunteer in 1990. The cobble, gravel and sand littoral bottom was reported to support a sparse growth of rooted aquatic plants in 1974 (Bortleson *et al.*, 1976).

From Edwards *et al.*, 1987: Lake Shoecraft is part of the Seven Lakes Sewer District. These lakes were studied during 1983-1984 to establish existing water quality, to identify existing and potential future sources of significant bacterial contamination and nutrient loading to the lakes (especially from shoreline septic tank drainfield systems), and to recommend appropriate restoration and management measures to maintain lake quality at desirable levels. Two septic system surveys were conducted in 1983-1984 to determine the percentage of failing shoreline septic systems and phosphorus loading from failing systems. Although shoreline water near seven of the 109 shoreline residences at Lake Shoecraft indicated potentially failing systems, none of the homes had confirmed wastewater system failures. Phosphorus loading to the lake from all potential sources showed that 139 kg P/yr entered Lake Shoecraft, with the majority of the phosphorus coming from groundwater (85 kg/L). Wastewater loading into groundwater contributed 6 kg P/yr (4% of total), streamflow contributed 15 kg P/yr (11% of total), and surface runoff, precipitation and internal loading from the sediments contributed 11 kg P/yr each (8% each of total).

During the August 1990 onsite visit with the volunteer, a large-leaved pondweed (*Potamogeton amplifolius*) was identified. The underwater leaves of this plant are large and somewhat curled, and the floating leaves are small, flat and oval-shaped. An algae sample collected in August was identified as the blue-green alga *Gloeotrichia*. This alga is visible to the unaided eye and appears as small green "fuzzy" balls. Also, a large brownish lumpy mass was observed in the lake during the onsite visit. This mass was most likely a colony of bryozoans, which are a type of immobile animals (called sessile invertebrates). Freshwater bryozoans have been reported to be generally associated with unpolluted and unsilted waters (Pennak, 1989). In lakes, bryozoans are found in shaded areas of the shallows, and the outer layer can be covered with detritus or algae (Pennak, 1989). Bryozoans are eaten by invertebrates which in turn are eaten by fish.

Comments

Lake Goodwin, another lake in the Seven Lakes Sewer District, was monitored for the program in 1989. Compared with the water clarity in Lake Shoecraft in 1990, the water clarity of Lake Goodwin in 1989 was very similar.

Acknowledgement

I thank Bob Moore for volunteering his time to monitor Lake Shoecraft in 1990.

Lake Shoecraft -- Snohomish County

Volunteer-Collected Data

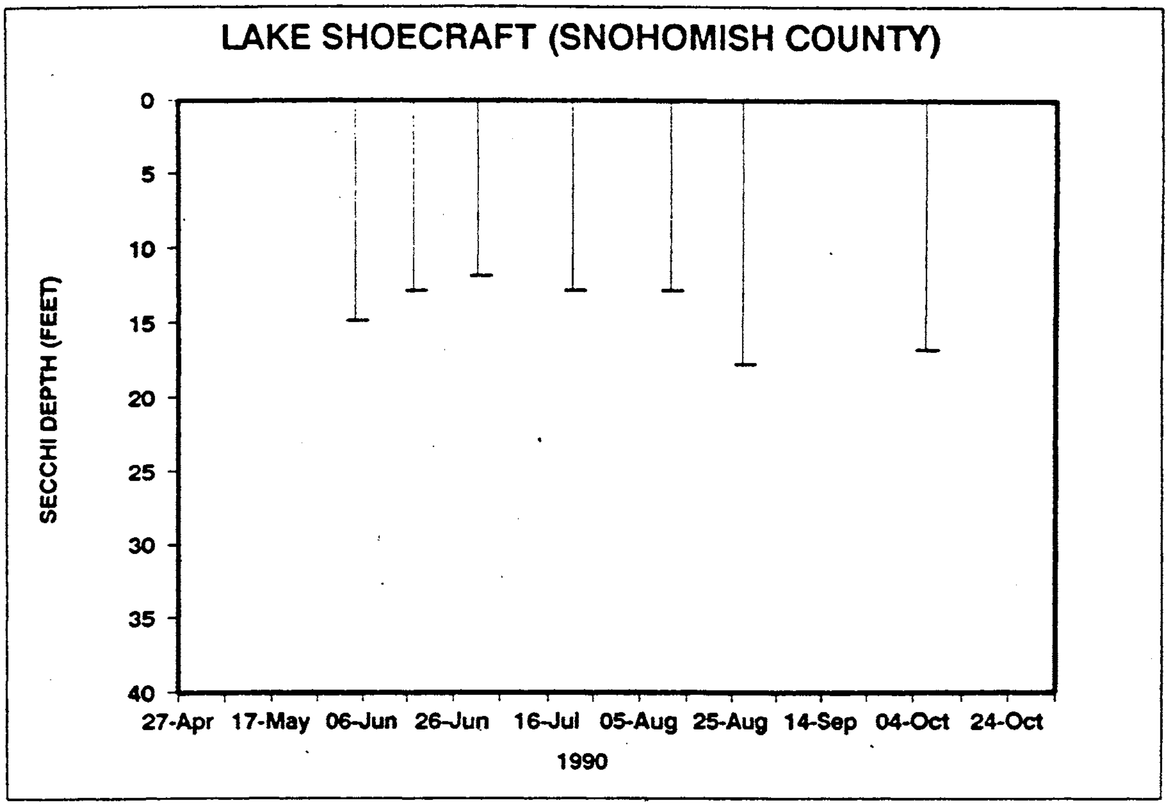
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
05-Jun								14.0		
18-Jun	18.9	66.0	6.5	Gr-Brown	0	Trace	Light	12.0	-2.0	Lake height 2" low at dock.
02-Jul	17.8	64.0	6.5	Lt-Green	90	Light	Light	11.0	-5.0	Cloudy-light rain in a.m. Moderate boat traffic over weekend 6/30-7/1.
22-Jul	23.9	75.0	6.5	Lt-Green	50	None	Light	12.0	-10.0	Heavy boat traffic, hot over weekend - 90 degrees.
08-Aug								17.0		
12-Aug	25.6	78.0	6.5	Lt-Green	10	None	Light	12.0	-12.0	Lake blooming. Heavy boat traffic over weekend. Hot weather 85 - 90 degrees.
07-Oct	17.8	64.0	6.5	Lt-Green	10	Breezy	Calm	16.0	-12.0	Lake level rose approximately 2" - possibly from heavy rains last week.

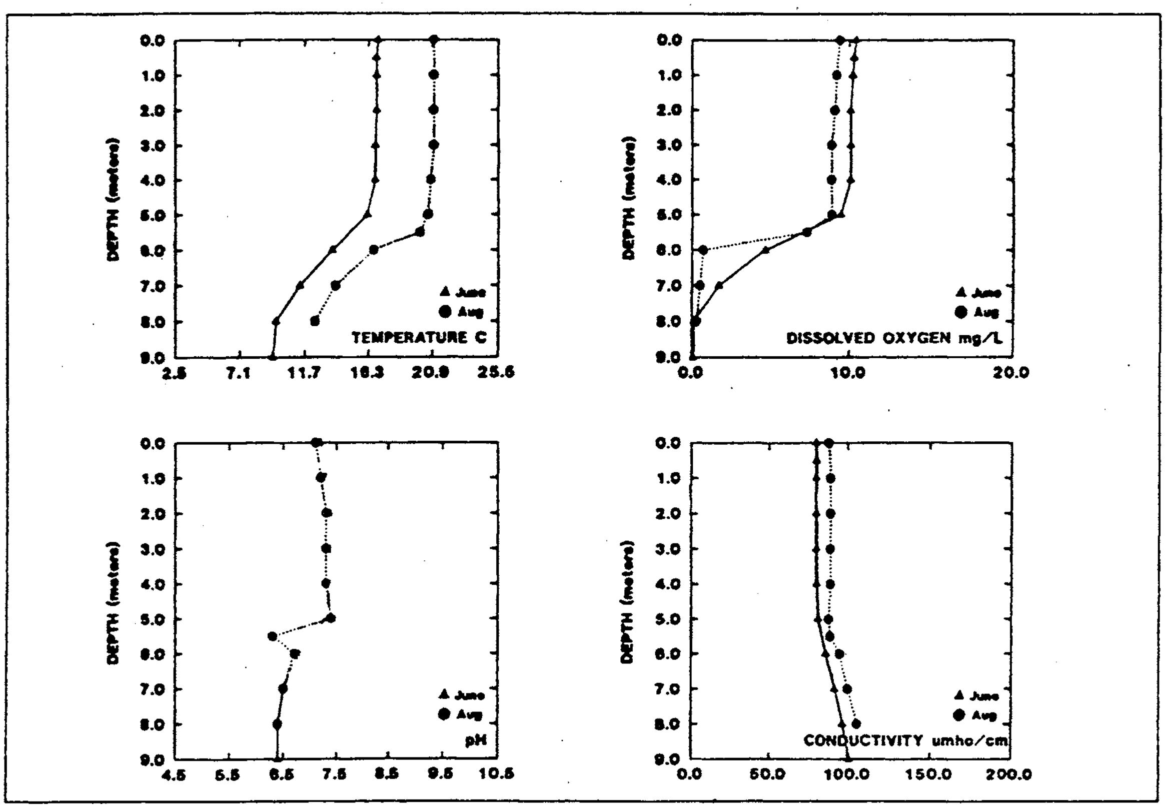
Onsite Visit Data

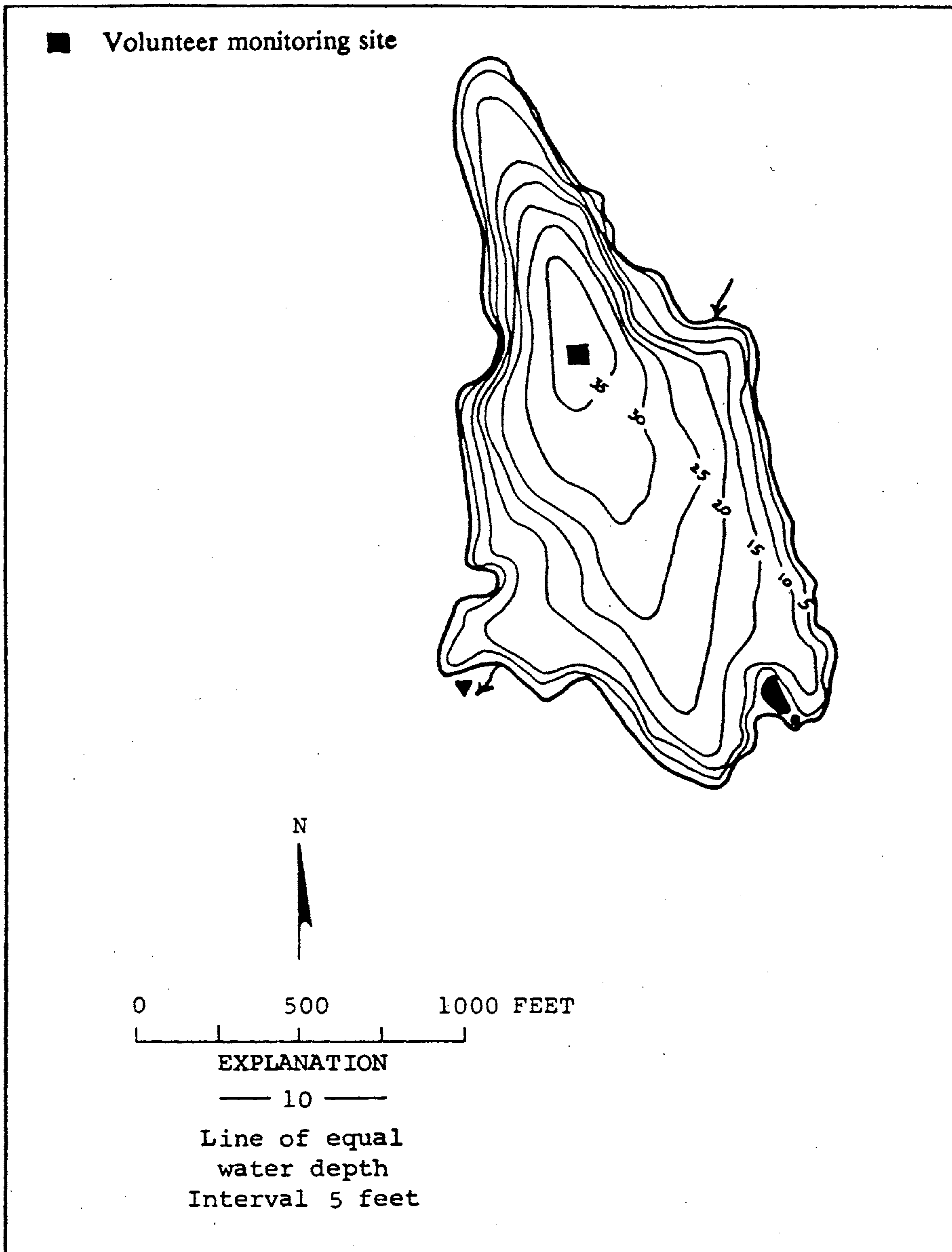
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/05	0.0	17.0	.*	10.4	80	1, 3, 5	0.012	NA
	0.5	16.9	.	10.3	80			
	1.0	16.9	.	10.2	80			
	2.0	16.9	.	10.1	80			
	3.0	16.8	.	10.1	80			
	4.0	16.8	.	10.1	80			
	5.0	16.2	.	9.5	81			
	6.0	13.7	.	4.7	86			
	7.0	11.3	.	1.7	92			
	8.0	9.6	.	0.1	97			
	9.0	9.4	.	0.1	101			
08/28	0.0	21.0	7.1	9.4	88	1, 3, 5	0.012	0.398
	1.0	21.0	7.2	9.2	89			
	2.0	21.0	7.3	9.1	89			
	3.0	21.0	7.3	8.9	89			
	4.0	20.8	7.3	8.9	89			
	5.0	20.6	7.4	8.9	88			
	5.5	20.1	6.3	7.3	89			
	6.0	16.7	6.7	0.7	95			
	7.0	13.9	6.5	0.5	100			
	8.0	12.4	6.4	0.3	106			

* See Quality Assurance section of this report
NA data not available; sample not analyzed by laboratory

Secchi Depth and Profile Data Graphs







Shoecraft Lake, Snohomish County. From Washington Department of Game, May 22, 1952.

Sidley Lake -- Okanogan County

Sidley Lake is located 0.7 miles northwest of Molson. It is the westernmost lake of the Sidley Lakes (Molson Lakes) group. The lake historically has had an outlet, but the lake had no surface ouflow for several years. The lake has no inlet.

Size (acres)	116
Maximum Depth (feet)	22
Mean Depth (feet)	15
Lake Volume (acre-feet)	1725
Drainage Area (miles^2)	2.5
Altitude (feet)	3675
Shoreline Length (miles)	2.5

Estimated Trophic State:	Meso-eutrophic**
Mean Trophic State Index* (Secchi):	45
Trophic State Index* (Total Phosphorus):	55

* See Comments Section
** From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Sidley Lake is used for fishing and camping. There is one boat ramp on the lakeshore, and there are no restrictions for motorboat use on the lake. Lake water is not withdrawn for any uses. Currently the watershed is used for animal grazing and lakeshore development. Grazing animals have direct access to the lakeshore or inlet tributaries. In the past, the watershed was used for logging, animal grazing, and crop agriculture. There is one house on the lakeshore which is occupied year-round and has an onsite wastewater disposal system. Rainbow trout are stocked in the lake. The worst problems in the lake, in the opinion of the volunteer, are water level and fish kills. Overall, the volunteer finds that Sidley Lake has good recreational water quality, and suggests that minerals and low water level may affect water quality.

According to the volunteer, outlets were located at the east and west ends of the lake. Water has not flowed from these outflows since 1984. Reeds and weeds are thick on the west and east shores, in up to 15 feet of water.

During the onsite visit with the volunteer, an aerator line was visible on the west end of the lake. The volunteer reported it was installed by the Department of Wildlife and was run during the winter of 1989 to prevent winterkill. The volunteer noted that in 1989 fish mortalities occurred all over the lake. In February 1990, he observed dead fish near the aerator (the aerator was running at the time).

Sidley Lake -- Okanogan County

Because of high alkalinity in the lake, the Department of Wildlife reportedly stocked the lake with Lahontan cutthroat trout in 1990. The volunteer noted that the planted trout did not grow very much.

The volunteer mentioned during the onsite visit that the lake is a "soap lake" and that during high winds a white foam forms on the surface.

<u>Monitoring Results/Summary of Other Available Information</u>

Secchi data collected during 1990 show that water clarity decreased from May to June, and although there was little variation in the clarity after the end of June, the water clarity was lowest during October. Profile data collected during August 1990 show that the lake was not thermally stratified, but concentrations of dissolved oxygen decreased considerably from the surface to the bottom of the lake. During July 1974, concentrations of dissolved oxygen were high throughout the water column (Dion *et al.*,1976). The 1990 conductivity was extremely high. High conductivity in the lake was also measured in 1974 (2700 μmhos/cm; Dion *et al.*, 1976). Because land uses in the watershed are very limited, it is likely the conductivity results from the surrounding geology.

The 1990 concentrations of both total phosphorus and total nitrogen were both high and very similar to concentrations found in 1974. In 1974, the concentration of total phosphorus was 0.035 mg/L and the concentration of total nitrogen was 1.76 mg/L (Dion *et al.*, 1976). Sidley Lake was sampled by Ecology during June and September 1990 as part of a statewide lakes survey to supplement the volunteer-collected data (Coots, 1991). The dissolved oxygen profiles from this survey were considerably different from the profile collected during the August 1990 onsite visit. Reasons for the differences are unknown; however, it is possible that different sites were sampled during each survey. During August, the dissolved oxygen was very low near the lake bottom (1.5 mg/L). The June and September profiles show that while the concentrations of dissolved oxygen decreased with depth, the concentrations never fell below 6.1 mg/L, and during June concentrations increased somewhat at about 3 - 4.5 meters (Coots, 1991). This increase could have occurred from increased photosynthesis of plants near the lake bottom and/or decreased water temperatures which allow for a higher solubility of oxygen in solution (Coots, 1991). The decreased concentrations near the bottom during June do suggest, though, that bacterial decomposition at the bottom of the lake may be consuming oxygen concentrations. The very stable pH from surface to bottom suggests that the lake may have a high alkalinity (which refers to a lake's capability to "buffer" itself from pH changes). This would support the Department of Wildlife's decision to plant Lahontan cutthroat, a species which may tolerate high alkalinity, in the lake.

In 1974, it was reported that the south shore of Sidley Lake was littered with stumps and wood debris (Dion *et al.*, 1976)). Also, the lake bottom was a "reddish brown silty muck" and was covered in areas with sphagnum moss. During the 1990 survey, it was reported that the lake bottom was covered with an unidentified aquatic moss (Coots, 1991). The water contained a large population of zooplankton during both the 1974 and 1990 surveys. It is possible that heavy grazing of phytoplankton by zooplankton can decrease algal abundance, which would increase water clarity. This could explain why the water clarity was better than expected given the high concentration of total phosphorus in the water (i.e., Secchi readings may be inversely correlated to zooplankton grazing).

Plants collected from the dock at Sidley Lake during the onsite visit with the volunteer were identified as *Chara*, and pondweed (*Potamogeton pectinatus*). *Chara* is a filamentous alga that grows well in hard water. It appears "fluffy" in water but loses its shape when removed. It has a gritty feel to it, owing to calcium carbonate deposits on the plant. The pondweed grows submerged in the water and appears grass-like. *Nitella*, another alga that looks like a macrophyte, was also identified during the 1990 survey (Coots, 1991).

During September 1990, algae were visible in the water, but not in bloom proportions. The anchor smelled very septic when raised after sampling.

Comments

Sidley Lake exhibits both mesotrophic and eutrophic characteristics. The trophic state estimation reported here is a compromise between the moderately low (mesotrophic) Secchi depths and the high (eutrophic) concentrations of total phosphorus.

Sidley Lake had the highest specific conductance of any of the lakes monitored for the program in 1990. Kahlotus Lake in Franklin County also had high specific conductance, ranging from 1385-1397 μmhos/cm. Most other lakes monitored for the program had specific conductance from 100-300 μmhos/cm.

As mentioned in the Results section above, it is possible that zooplankton grazing may be significantly decreasing algae abundance, resulting in increased water clarity. Although we have no data to support this, it is clear that Secchi depth data underestimate the trophic state of Sidley Lake. Future estimates of trophic state should be based on chemical as well as transparency data, although Secchi data may still be useful to document the occurrence and severity of algae growth in the lake.

Acknowledgement

I thank John Myrick for volunteering his time to monitor Sidley Lake during 1990.

Sidley Lake -- Okanogan County

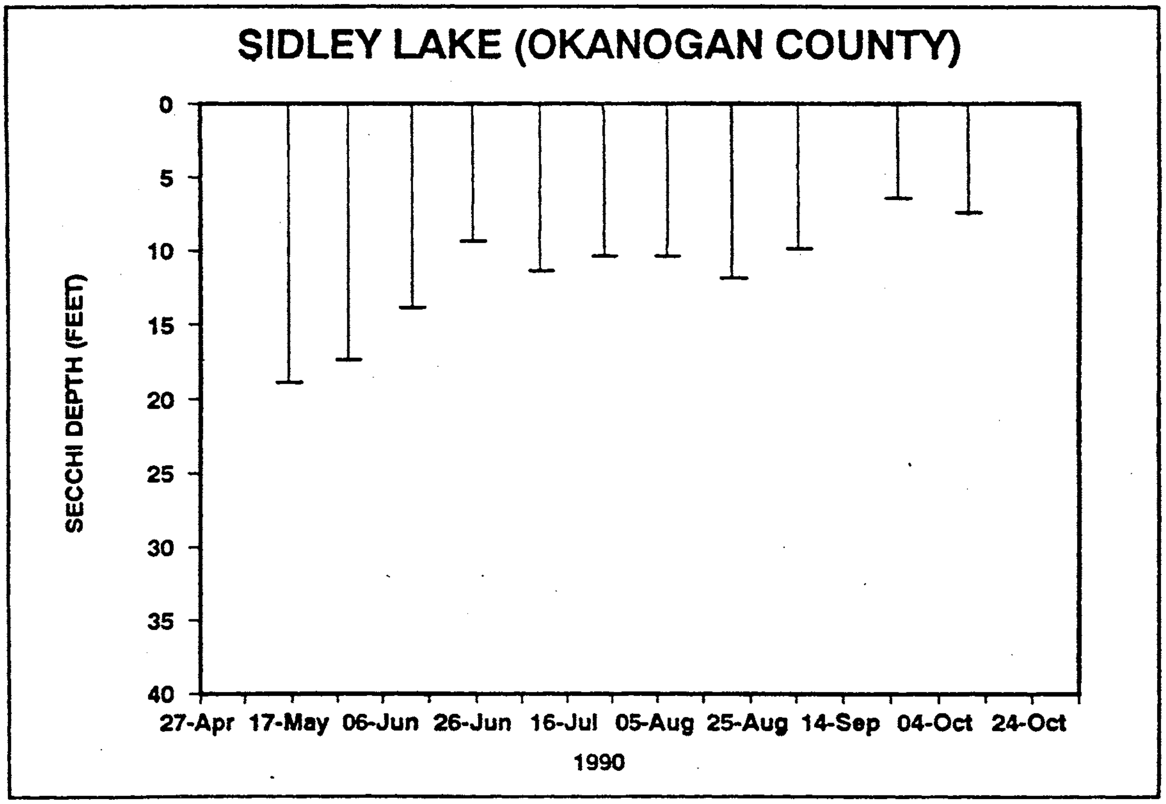
Volunteer-Collected Data

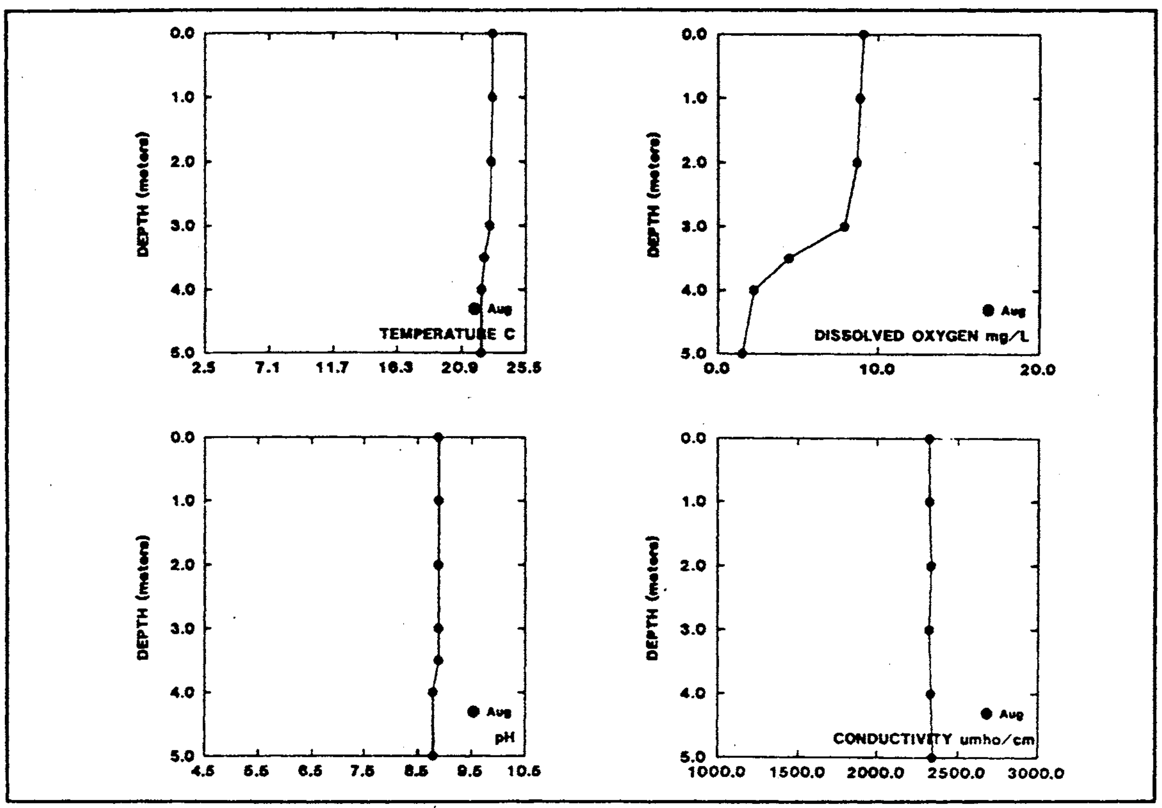
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
17-May	12.2	54.0	8.5	Clear	100	Trace	Light	18.0	28.0	
30-May	12.8	55.0	8.5	Clear	50	Light	Light	16.5	31.0	
13-Jun	12.2	54.0	8.4	Clear	100	Trace	Breezy	13.0	33.0	
26-Jun	17.8	64.0	8.4	Lt-Green	50	None	Breezy	8.5	32.0	
11-Jul	22.8	73.0	8.5	Lt-Green	0	None	Light	10.5	31.0	
25-Jul	22.2	72.0	8.7	Lt-Green	100	Moderate	Light	9.5	31.0	
08-Aug	23.3	74.0	8.8	Green	75	None	Light	9.5	29.0	
22-Aug	21.1	70.0	8.7	Lt-Green	25	Heavy	Breezy	11.0	29.0	
05-Sep	18.3	65.0	8.9	Lt-Green	0	None	Breezy	9.0	27.5	Water color pale light green. Suspended particles unusual this time of year.
26-Sep	17.2	63.0	8.7	Lt-Green	10	None	Light	5.5	25.0	Suspended particles.
11-Oct	10.0	50.0	8.7	Clear	50	None	Breezy	6.5	20.0	Suspended particles. Water normally clear to approx. 12 feet this time of year.

Onsite Visit Data

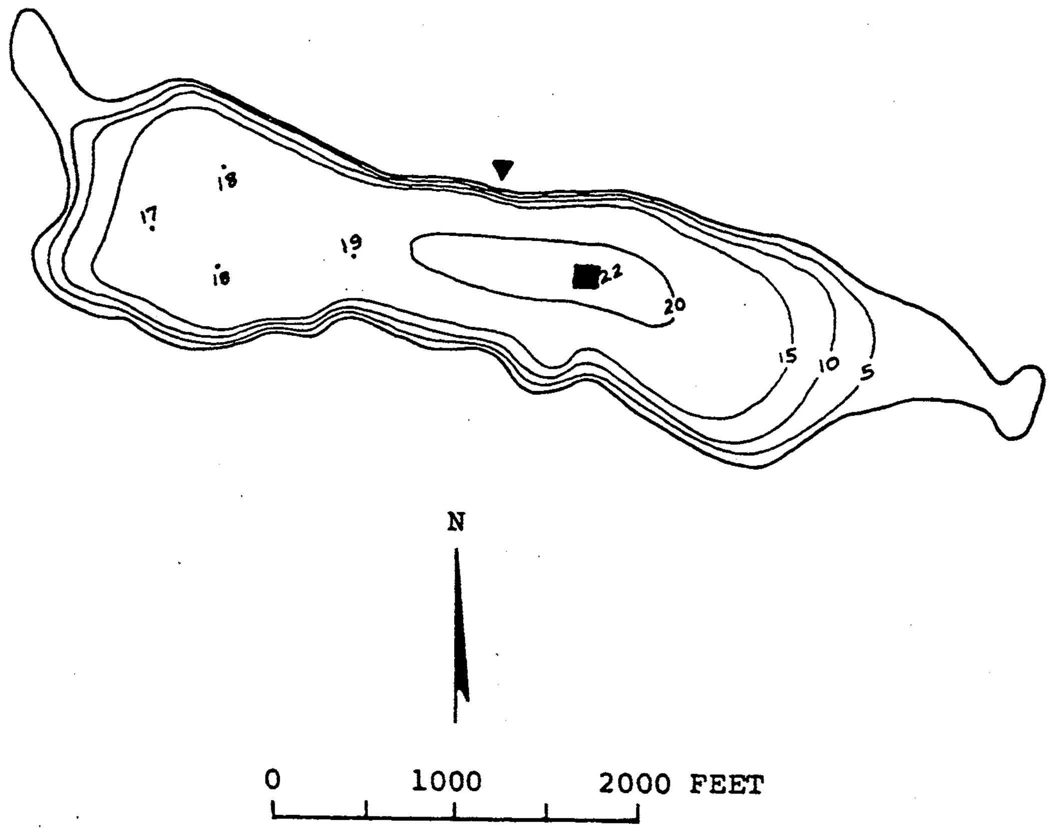
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
08/13	0.0	23.1	8.9	9.1	2320	1, 2, 4	0.034	1.650
	1.0	23.1	8.9	8.9	2320			
	2.0	23.0	8.9	8.7	2330			
	3.0	22.9	8.9	7.9	2320			
	3.5	22.5	8.9	4.4				
	4.0	22.3	8.8	2.2	2330			
	5.0	22.3	8.8	1.5	2340			

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



EXPLANATION

—— 10 ——

Line of equal water depth Interval 5 feet

Sidley Lake, Okanogan County. From Washington Department of Game, December 16, 1951.

Lake Spanaway -- Pierce County

Lake Spanaway is located ten miles south of Tacoma, and 0.5 mile west of Spanaway. It is fed by Copper Creek, and drains via Spanaway Creek to Clover Creek and Lake Steilacoom. Daron Island lies in the northern portion of the lake.

Size (acres)	280
Maximum Depth (feet)	28
Mean Depth (feet)	16
Lake Volume (acre-feet)	4600
Drainage Area (miles^2)	17.0
Altitude (feet)	320
Shoreline Length (miles)	4.4

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

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Spanaway is used for fishing, boating, swimming, rowing, jet skiing, and hydroplane races (twice each summer). Recreational facilities on the lakeshore include a park, a picnic area, a beach, and two boat ramps. There are no restrictions for motorboat use on the lake. Lake water is withdrawn for irrigation only. Currently the watershed is used for logging and the lakeshore is being developed further for residences. In the past, the watershed was used for logging, crop agriculture, lake or wetlands dredging, and the shoreline was altered. There are approximately 177 houses on the lakeshore; all are occupied year-round. The lakeshore is not sewered, and there is one storm drain that empties into the lake. Rainbow trout are stocked in the lake. The lake has been chemically treated in the past to control weeds, algae, and fish species. The lake will be treated this year to control weeds and algae. The worst problems in the lake, in the opinion of the volunteer, are ranked as 1) algae, 2) aquatic plants, 3) sediment, 4) recreational overcrowding, 5) floating debris, 6) water level, 7) water odors, and 8) fish species. Overall, the volunteer finds that Lake Spanaway has fair recreational water quality. The volunteer suggested that septic systems, road runoff, watershed runoff to Copper Creek, heavy recreational use and the overall shallow nature of the lake may affect water quality.

The entire lakeshore is developed for residences, including the island. Submerged weeds are especially visible in the southern half of the lake; the volunteer reports that the plants reach the surface at times. Algae blooms are generalized but appear thicker at the south end. The wind also blows the algae to the south end. 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 (some with white flowers, most likely *Nymphaea odorata*) grow in cove areas at the south, west, and north areas of the lake. The southeast portion of the lake was chemically treated this year. A lot of ducks and geese live at the lake year-round.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity decreased steadily from May through early July, and highest water clarity occurred during August. Profile data collected during June and August 1990 show that on both sampling dates, the lake was thermally stratified and concentrations of dissolved oxygen were depleted from the bottom three meters (about 9.5 feet) of the lake. The dissolved oxygen was most likely consumed by bacteria which decompose organic material (such as algae, aquatic plants and woody debris) in the water and sediments. The decrease in pH and increase in conductivity with depth is most likely related to increased decomposition in the water sediments. In June 1973, the concentration of dissolved oxygen was high throughout the water column, and the lake was stratified (Bortleson *et al.*, 1976).

The 1990 concentrations of total phosphorus and total nitrogen were medium compared to other lakes monitored for the program. The concentration of total nitrogen was particularly high during June 1990. The concentration of total nitrogen was higher in 1990 (averaging 0.847 mg/L) than in 1973 (0.19 mg/L; Bortleson *et al.*, 1976), but lower than in 1981 (1.2 mg/L; Sumioka and Dion, 1985). The concentration of total phosphorus in 1990 (averaging 0.0183 mg/L) was lower than in 1973 (0.028 mg/L), but was similar to 1981 (0.010 mg/L).

In 1973, there were 220 nearshore homes (Bortleson *et al.*, 1976). There were 161 nearshore homes in 1981 (Sumioka and Dion, 1985). Approximately 18% of the shoreline is county park. In 1973, emergent plants grew along 26-50% of the shoreline (Bortleson *et al.*, 1976).

During the August 1990 onsite visit with the volunteer, the lake was observed to have heavy recreational use and bulkheads surrounded the majority of the shoreline.

Water variance records with Ecology reveal that Spanaway Lake was chemically treated on June 19 and 20, July 27, August 1 and September 12, 1990. Copper sulfate was used to control algal growth. Rodeo, Komeen and Aquathol K were used to control pondweeds, lily pads, and elodea.

Lake Spanaway -- Pierce County

Comments

Trophic state indices calculated from 1981 data show that the lake was oligotrophic, although the concentration of dissolved oxygen was 0.2 near the lake bottom (Sumioka and Dion, 1985). In 1990, the trophic state of Spanaway Lake was mesotrophic, based on the moderately deep Secchi readings and the moderately high concentrations of total phosphorus. Compared with other Pierce County lakes monitored for the program in 1990 (Lakes Louise, Ohop, Steilacoom, Tanwax and Whitman), Lake Spanaway had good water clarity and lower concentrations of total phosphorus. Lake Louise, which is regularly treated with chemicals to control algae, has the best water clarity of the lakes but the chemical treatment undoubtedly contributes to improved water clarity. Total phosphorus concentrations in Lake Louise and Lake Steilacoom were slightly lower than in Lake Spanaway. Tanwax Lake had the worst water clarity and Ohop Lake had the highest concentration of total phosphorus.

Acknowledgement

I thank Sue Thompson for volunteering her time to monitor Lake Spanaway during 1990.

Lake Spanaway -- Pierce County

Volunteer-Collected Data

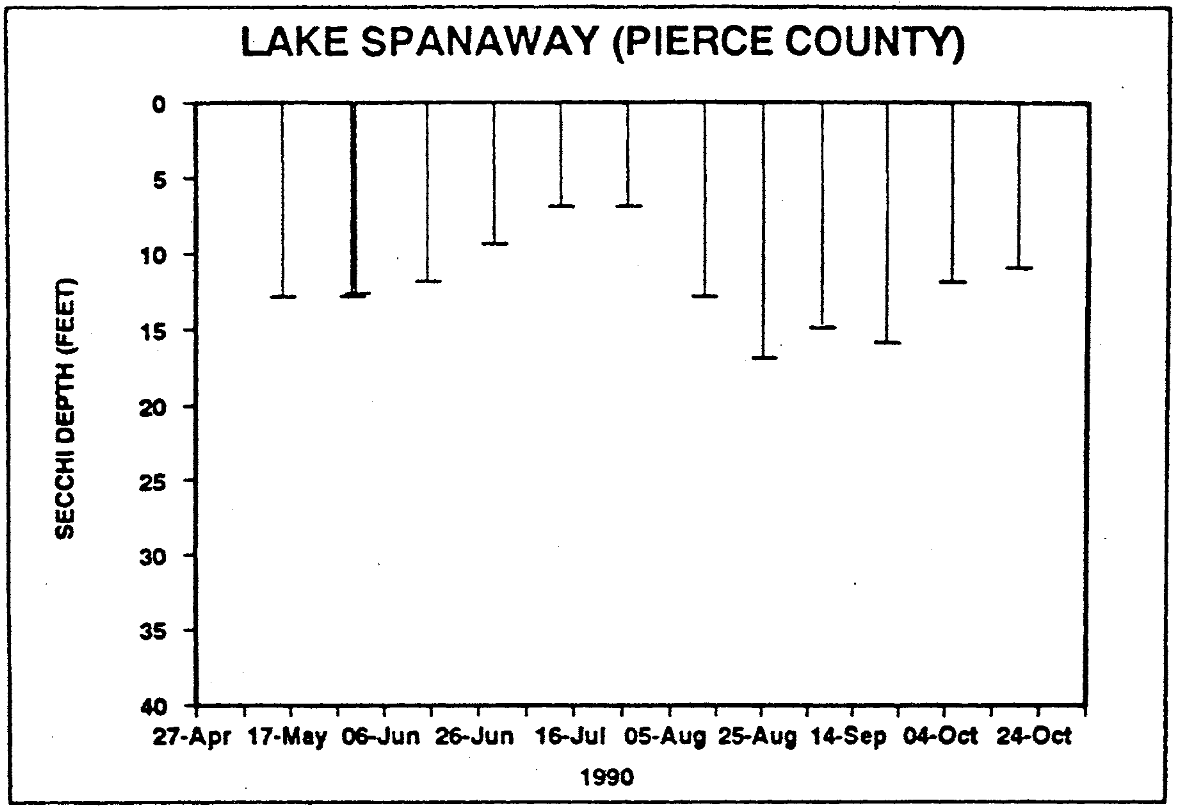
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
16-May	15.6	60.0	7.0	Lt-Green	0	Light	Light	12.0		Lake height of 0 will be starting point.
31-May	15.0	59.0	7.0	Green	100	Heavy	Breezy	12.0	0.7	
01-Jun								11.8		
16-Jun	19.4	67.0	7.0	Gr-Brown	75	None	Light	11.0	0.7	
30-Jun	22.2	72.0	7.5	Gr-Brown	75	Light	Light	8.5*	-0.5	Lake height down .5" from original mark.
14-Jul	24.4	76.0	7.5	Gr-Brown	0	None	Breezy	6.0	-1.7	
28-Jul	22.2	72.0	7.0	Green	0	None	Light	6.0	-2.5	
13-Aug	25.6	78.0	7.5	Green	75	None	Calm	12.0	-3.5	Water is clearer than usual but there seems to be a lot more algae and green weeds and slime growing on the bottom.
26-Aug	24.4	76.0	7.0	Green	50	Trace	Calm	16.0	-3.7	Water is still fairly clear but you can see a lot of algae floating in the water.
08-Sep	21.1	70.0	7.0	Green	75	Trace	Calm	14.0	-3.5	Still a lot of algae in the water.
22-Sep	19.4	67.0	7.0	Green	0	None	Calm	15.0	-4.5	A lot more weeds and algae growing on bottom.
06-Oct	15.6	60.0	7.0	Gr-Brown	75	Moderate	Calm	11.0	-4.3	More weed growth on bottom; algae still visibly floating.
20-Oct	12.8	55.0	7.0	Gr-Brown	75	None	Calm	10.0	-4.0	Green floating algae: a lot of new hatches of something swimming around (tiny).

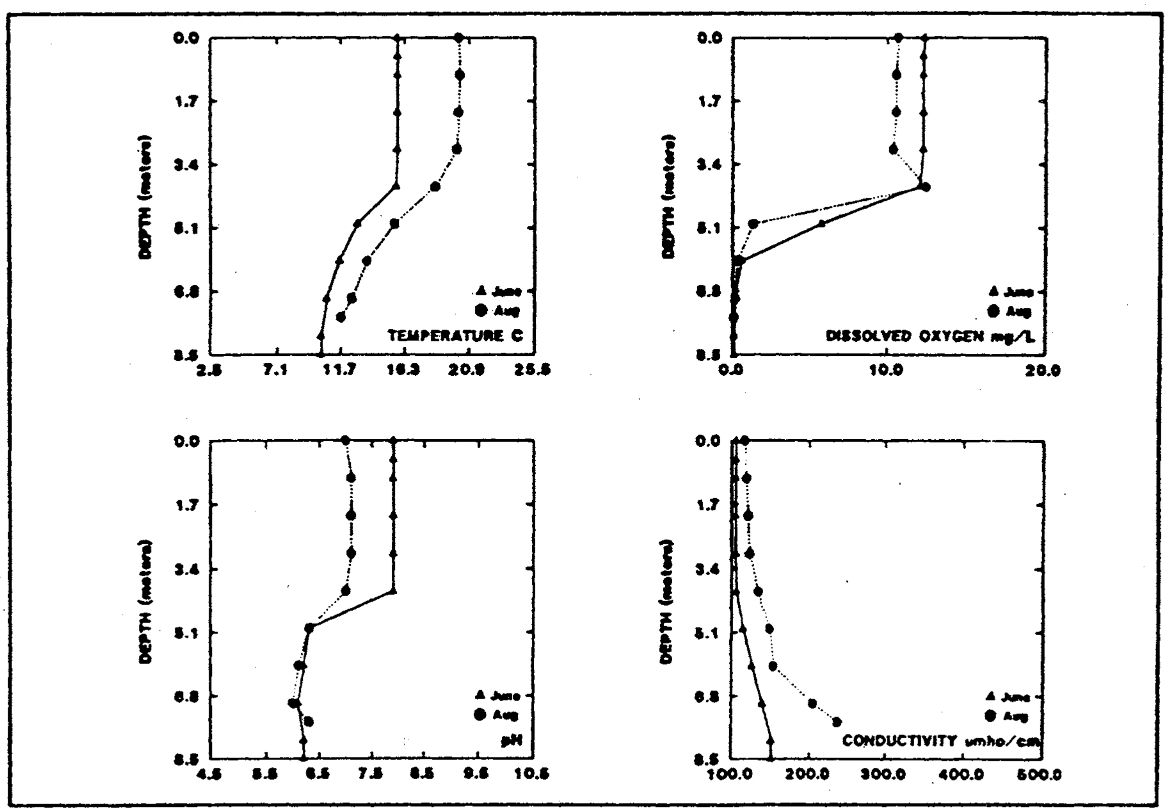
* There was high variability between the first ad second Secchi depths collected; this data point may not be included in data comparisons.

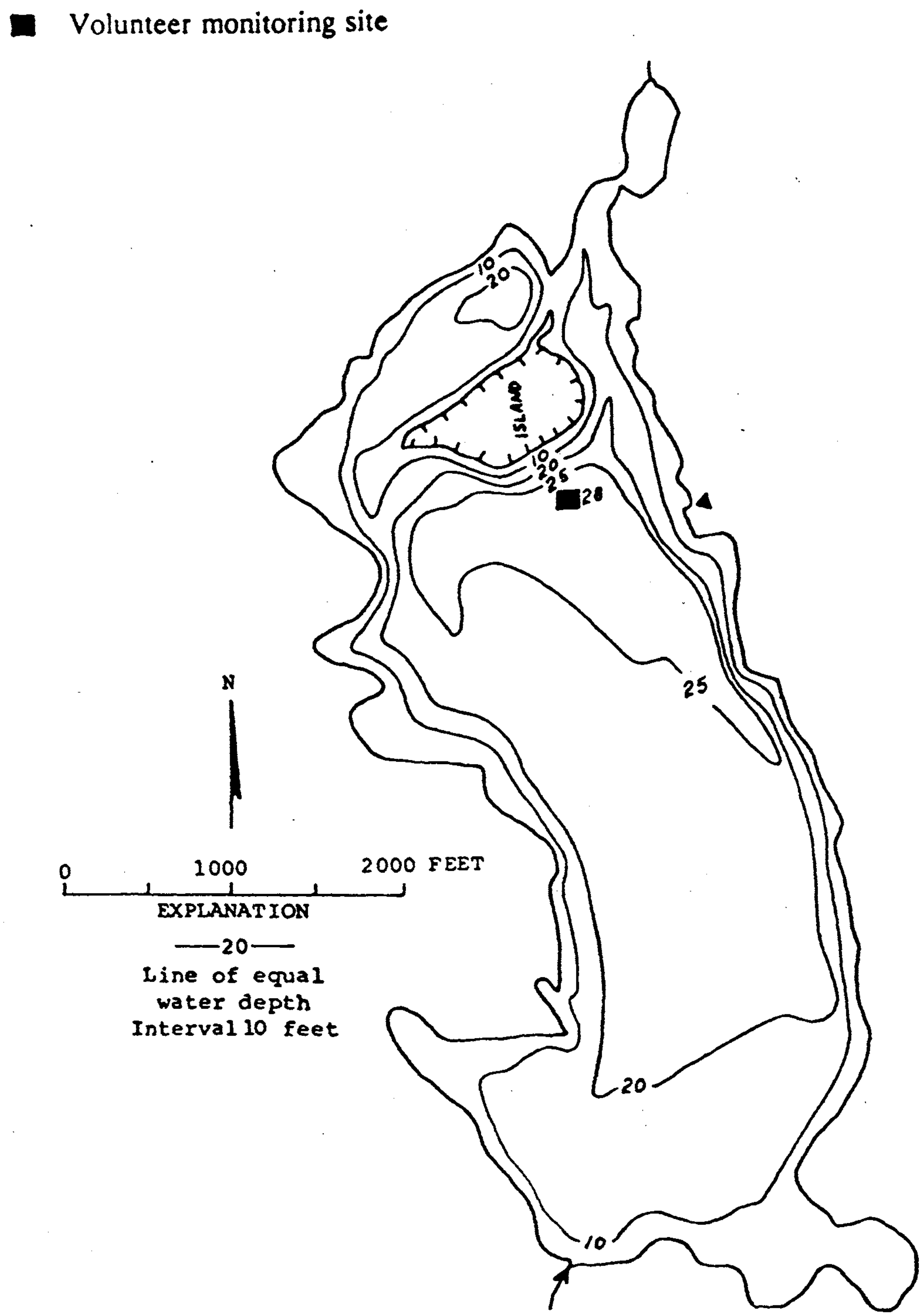
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/01	0.0	15.8	7.9	12.4	106	1, 3.5	0.022	1.010
	0.5	15.8	7.9	12.3	106			
	1.0	15.8	7.9	12.3	106			
	2.0	15.8	7.9	12.3	106			
	3.0	15.8	7.9	12.3	106			
	4.0	15.7	7.9	12.1	107			
	5.0	12.9	6.3	5.7	116			
	6.0	11.6	6.2	0.6	126			
	7.0	10.7	6.1	0.1	139			
	8.0	10.3	6.2	0.1	150			
	8.5	10.3	6.2	0.1	150			
08/24	0.0	20.2	7.0	10.7	117	1, 2, 3	0.015	0.683
	1.0	20.3	7.1	10.6	119			
	2.0	20.2	7.1	10.6	121			
	3.0	20.1	7.1	10.4	123			
	4.0	18.6	7.0	12.5	134			
	5.0	15.6	6.3	1.3	149			
	6.0	13.6	3.1	0.3	153			
	7.0	12.5	6.0	0.2	205			
	7.5	11.7	6.3	0.1	238			

Secchi Depth and Profile Data Graphs







Spanaway Lake, Pierce County. From Washington Department of Game, February 2, 1950.

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)	5152
Drainage Area (miles^2)	1.7
Altitude (feet)	170
Shoreline Length (miles)	4.3

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	40
Mean Trophic State Index* (Total Phosphorus):	39

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Spencer Lake is used for fishing, boating, swimming, rowing, jet skiing, camping, and waterfowl hunting. Recreational facilities on the lakeshore include one resort, and two boat ramps. Motor boat restrictions on the lake are limited to general county regulations. Lake water is withdrawn for drinking and other domestic uses. Currently the watershed is used for animal grazing and the lakeshore is being developed further for residences. In the past, the watershed was used for logging and the shoreline was altered. There are approximately 88 houses on the lakeshore; of these, 58 are occupied year-round. The lakeshore is not sewered, and there is one storm drain that empties into the lake. Rainbow trout are stocked in the lake. The lake has been chemically treated in the past to control weeds and fish species. The worst problem in the lake, in the opinion of the volunteer, is from aquatic plants. Overall, the volunteer finds that Spencer Lake has good recreational water quality, and suggests that septic tanks may affect water quality of the lake.

Submerged plant growth is particularly heavy in the northernmost cove and the south basin near the outlet. Lily pads, mostly pink and white-flowering (most likely *Nymphaea odorata*) and some yellow-flowering (*Nuphar polysepalum*) grow in the south basin. Reeds grow along isolated areas of the north and south shores. There is "swamp land" around the outlet area. The volunteer noted that there was a weir at the outlet until about 1950, when the state built a dike. The shoreline is mostly residential.

Spencer Lake -- Mason County

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity was lowest during May and October. The best water clarity occurred during mid-summer. Profile data collected during May and August 1990 show that on both sampling dates, the lake was stratified and concentrations of dissolved oxygen decreased considerably below the thermocline. In August, the decrease in pH and the increase in conductivity with depth is most likely related to decomposition in the water and sediments. The 1990 concentrations of total phosphorus and total nitrogen were low to moderate (averaging 0.011 and 0.307 mg/L, respectively). Compared with data collected in 1974, the concentrations of total phosphorus were similar, but the concentration of total nitrogen was considerably higher in 1974 (0.83 mg/L; Bortleson *et al.*, 1976). In 1974, dense beds of emergent plants were observed in the shallow north bay and southwest bay near the outlet, and there were 89 nearshore homes (Bortleson *et al.*, 1976). Concentrations of dissolved oxygen decreased to 0.5 mg/L at 26 feet in August 1974 (Bortleson *et al.*, 1976).

The plant sample collected during the August 1990 onsite visit with the volunteer was identified as large-leaved pondweed (*Potamogeton amplifolius*). This plant grows almost entirely below the water surface but may have some small flat oval-shaped leaves floating on the water surface. The submerged leaves are large (1-2 inches wide and 6-8 inches long) and curl downward.

Comments

Spencer Lake was one of seven Mason County lakes (Island, Limerick, Mason, Nahwatzel, Phillips, and Wooten Lakes) monitored for the program in 1990. Water clarity and total phosphorus concentrations at Spencer Lake were very similar to those at Lake Nahwatzel and Phillips Lake. Island Lake, Lake Wooten and Mason Lake had better clarity and lower phosphorus concentrations than Lake Spencer. Lake Limerick had the lowest overall water clarity and highest concentrations of total phosphorus of the monitored Mason County lakes.

Acknowledgement

I thank Larry Charrier for volunteering his time to monitor Spencer Lake during 1990.

Spencer Lake -- Mason County

Volunteer-Collected Data

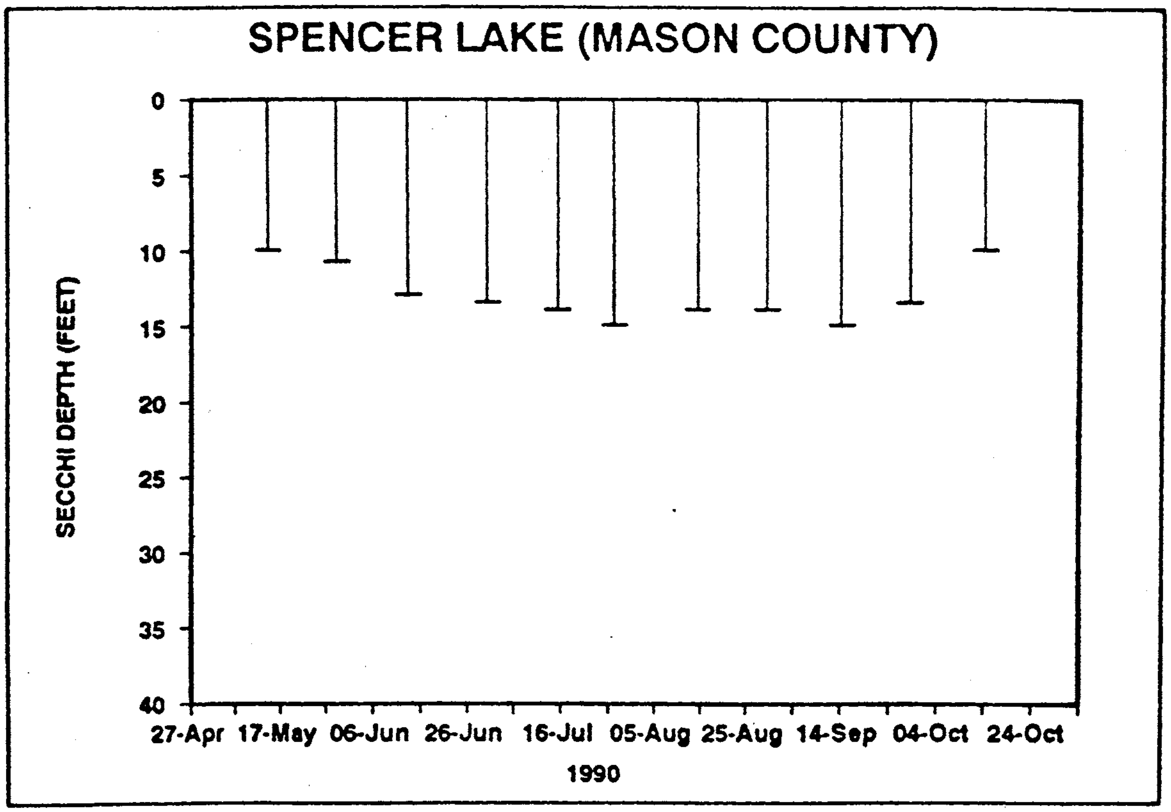
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
15-May	14.4	58.0	5.5	Gr-Brown	75	Moderate	Light	9.0	12.0	Lake height 12" below winter high.
30-May	15.6	60.0	6.5	Green	50	Moderate	Light	9.7	11.5	Lake height 11.5" below winter high. Secchi hit bottom at 30'.
14-Jun	17.8	64.0	6.5	Lt-Green	0	None	Calm	12.0	10.5	Lake height 10.5" below winter high.
01-Jul	17.8	64.0	6.5	Lt-Green	75	Trace	Light	12.5	12.5	Lake height = distance measured below winter high.
16-Jul	23.3	74.0	7.0	Lt-Green	10	None	Breezy	13.0	14.5	Lake height is measured below winter high.
28-Jul	23.3	74.0	6.0	Lt-Green	0	None	Light	14.0	17.5	Lake height read as 17.5" below winter high.
15-Aug	23.3	74.0	6.5	Lt-Green	75	None	Light	13.0	20.0	
30-Aug	21.1	70.0	6.0	Lt-Green	75	Moderate	Breezy	13.0	22.0	
15-Sep	20.0	68.0	6.5	Lt-Green	90	None	Breezy	14.0	21.5	
29-Sep	19.4	67.0	6.5	Lt-Green	75	None	Light	12.5	23.0	
15-Oct	14.4	58.0		Green	90	Heavy	Light	9.0	22.0	

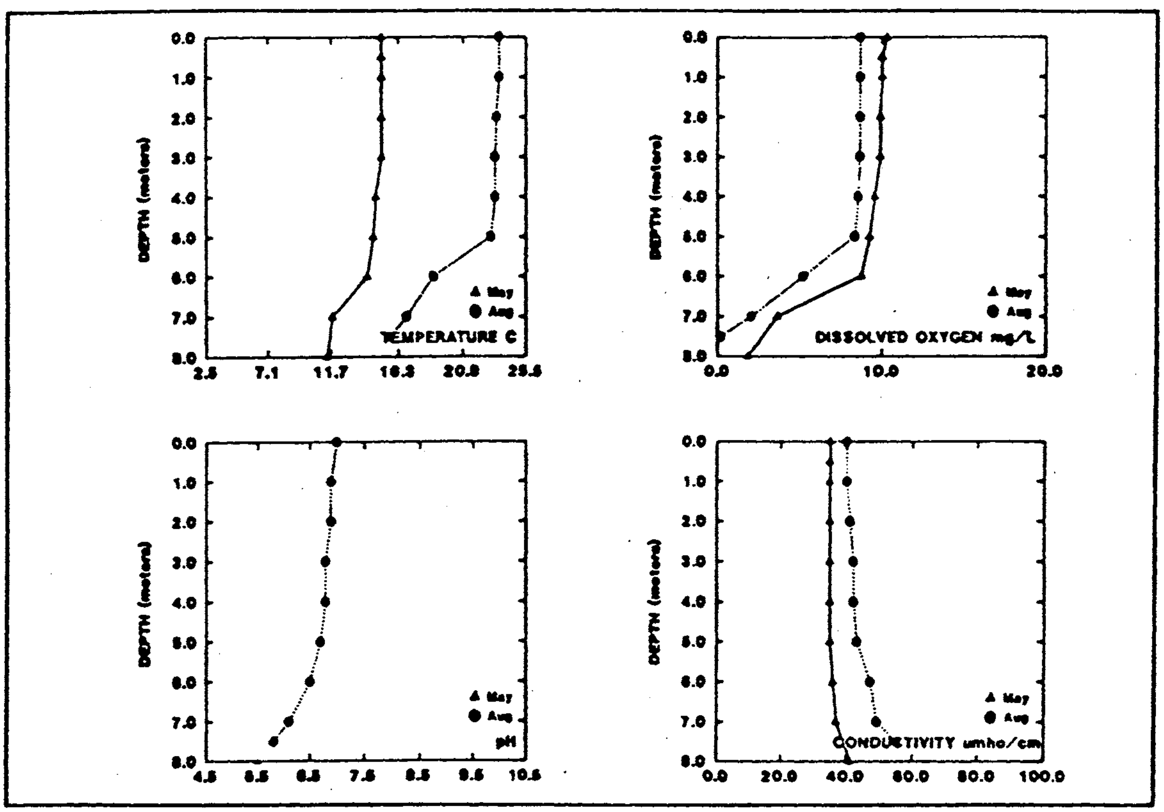
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/24	0.0	15.2	.*	10.3	35	0.5, 2.5	0.009	0.267
	0.5	15.2	.	10.0	35			
	1.0	15.2	.	10.0	35			
	2.0	15.2	.	9.9	35			
	3.0	15.2	.	9.9	35			
	4.0	14.8	.	9.6	35			
	5.0	14.6	.	9.3	35			
	6.0	14.2	.	8.8	36			
	7.0	11.8	.	3.7	37			
	8.0	11.4	.	1.9	41			
08/15	0.0	23.5	7.0	8.7	40	1, 2.5, 4	0.013	0.346
	1.0	23.5	6.9	8.7	40			
	2.0	23.3	6.9	8.7	41			
	3.0	23.2	6.8	8.7	42			
	4.0	23.2	6.8	8.6	42			
	5.0	22.9	6.7	8.4	43			
	6.0	18.8	6.5	5.3	47			
	7.0	16.9	6.1	2.1	49			
	7.5	15.8	5.8	0.2	55			

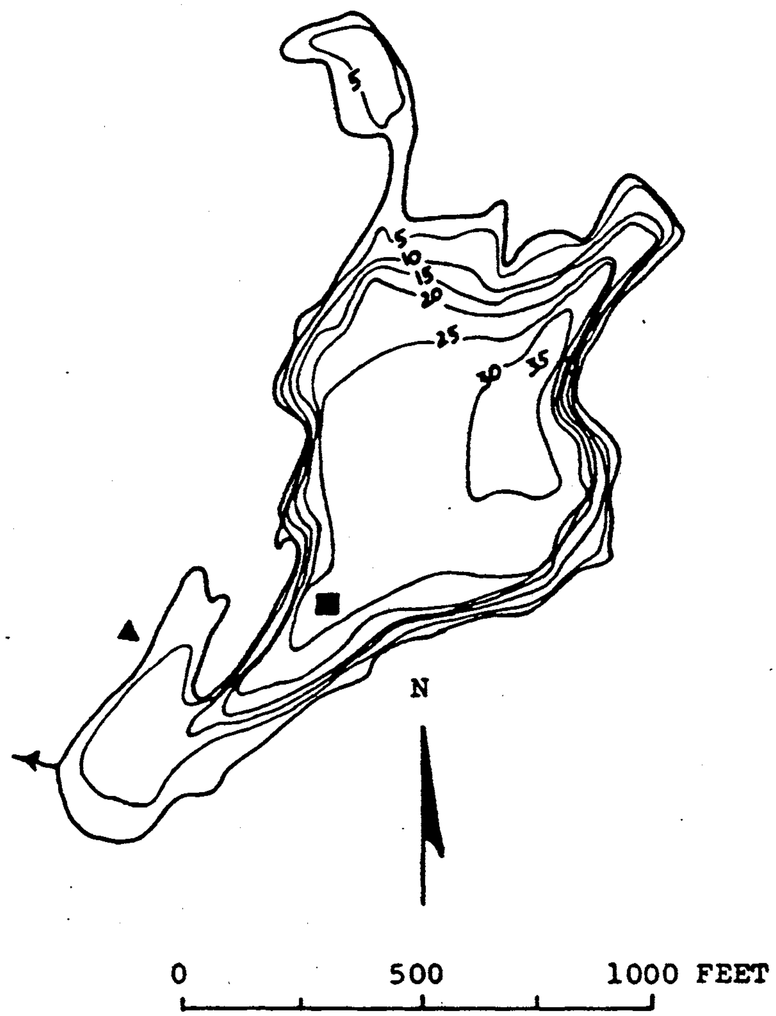
* See Quality Assurance section of this report.

Secchi Depth and Profile Data Graphs





Volunteer monitoring site



EXPLANATION

— 10 —

Line of equal
water depth
Interval 5 feet

Spencer Lake, Mason County. From Washington
Department of Game, July 30, 1947.

Starvation Lake -- Stevens County

Starvation Lake is located 10 miles southeast of Colville, and 14 miles north of Chewelah. It has no inlets, and an outlet stream drains to the southeast and seeps into the ground. Approximately one-third of the lake is located in the Little Pend Oreille National Wildlife Refuge.

Size (acres)	30
Maximum Depth (feet)	14
Mean Depth (feet)	8
Lake Volume (acre-feet)	233
Drainage Area (miles^2)	3
Altitude (feet)	2375
Shoreline Length (miles)	0.9

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	**
Mean Trophic State Index* (Total Phosphorus):	56

* From Carlson (1977)
** See Monitoring Results Section

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Starvation Lake is used for fishing, boating, swimming, rowing, and camping. Recreational facilities on the lakeshore include a picnic area, a camping area and one boat ramp, and there are no restrictions for motorboat use on the lake. Lake water is not withdrawn for any uses. Currently the watershed is used for logging and animal grazing. Grazing animals have direct access to the lakeshore or inlet tributaries, and animal wastes enter the lake. In the past, the watershed was used for logging, animal grazing and crop agriculture, and the lake was dredged. There are five houses on the lakeshore; of these, four are occupied year-round. The lakeshore is not sewered. Rainbow trout are stocked in the lake. The lake has been chemically treated in the past to control weeds and fish species. The worst problems in the lake, in the opinion of the volunteer, are ranked as 1) aquatic plants, 2) algae, 3) floating debris, 4) water level, 5) sediment, and 6) water odors (described as pungent "fish tank" odor). Overall, the volunteer finds that Starvation Lake has poor recreational water quality.

The entire lake bottom is covered with weeds which grow to the surface. Lily pads ring the shoreline, and sometimes grow as far as 50 feet from shore. There is a large wetland area around the outflow area. There is a heavy growth of reeds along the southeast shore at, and adjacent to, the wetland. During the September 1990 onsite visit with the volunteer, the volunteer noted that the growth of lilies has approximately doubled in the last four years. In the 1989 questionnaire, the volunteer noted that in the past, the lake had been dredged and the shoreline was altered. Also, the lake was treated in 1985 to control fish species. The volunteer was concerned about oil in the lake from motor boats and that cattle have direct access to the lakeshore.

Monitoring Results/Summary of Other Available Information

Because only one Secchi reading did not enter weeds, Secchi data could not be used to estimate the 1990 trophic status. Profile data collected during May and September 1990 show that the concentration of dissolved oxygen increased somewhat from surface to bottom. This increase may have resulted from the dense plant growth in the lake, which would release oxygen into the water during photosynthesis. In contrast, in 1974 the concentration of dissolved oxygen was stable throughout the water column, and the lake was periodically aerated to raise dissolved oxygen concentrations (Dion *et al.*, 1976).

Concentrations of total phosphorus and total nitrogen in 1990 were high on both sampling dates (averaging 0.0359 and 0.895 mg/L, respectively). In comparison, in 1974 the concentration of total phosphorus (0.058 mg/L; Dion *et al.*, 1976) was higher than in 1990, and the concentration of total nitrogen (0.72 mg/L; Dion *et al.*, 1976) was lower. In 1974, the lake bottom was completely covered with submersed aquatic plants (*Chara*), and the entire shoreline was covered with dense beds of emergent aquatic plants (yellow lily, sedge, and cattail; Dion *et al.*, 1976).
In 1989, it appeared that areas of the shoreline were damaged and denuded of vegetation, probably due to cattle.

During the September 1990 onsite visit with the volunteer, clumps of algae about one foot in diameter were observed. These clumps primarily consisted of the blue-green alga *Oscillatoria*, but also contained *Lyngbia*. Mats of coontail (*Ceratophyllum* spp.) reached the surface. Algae clumps consisting of *Chara* and *Nitella* were also floating on the surface. Pondweed (*Potamogeton pectinatus*) was present as well.

Comments

Starvation Lake is one of six lakes in Stevens County monitored for the program in 1990. Compared with the other Stevens County lakes monitored (Black, Deep, Deer, Thomas, and Waitts Lakes), Starvation Lake had the highest concentrations of total phosphorus. Starvation Lake is also smaller and shallower than the other monitored Stevens County lakes. Of the 74 lakes monitored statewide in 1990, 32 lakes had worse overall water clarity, although only seven had higher mean concentrations of total phosphorus.

Acknowledgement

I thank Tom Fierce for volunteering his time to monitor Starvation Lake during 1989-1990.

Starvation Lake -- Stevens County

Volunteer-Collected Data

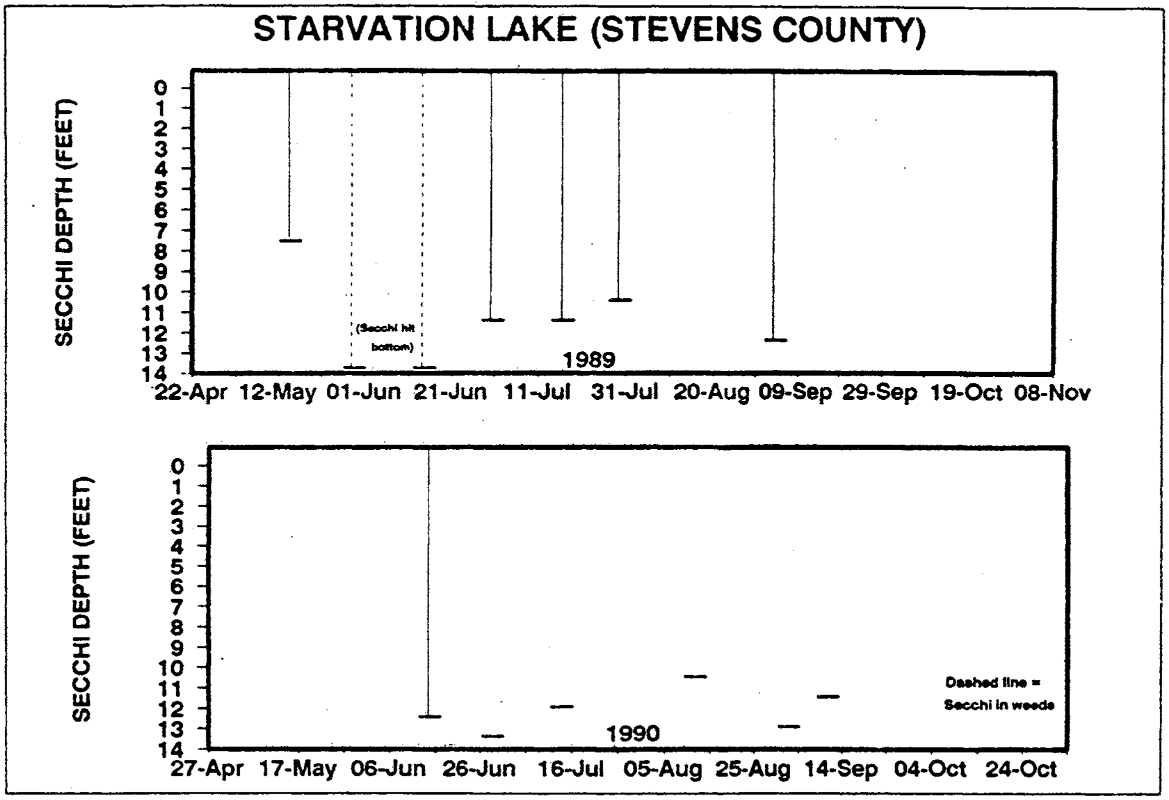
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
15-Jun	17.8	64.0	6.0	Green	50	Light	Breezy	11.9		Lake height: very high.
29-Jun	25.6	78.0	6.5			None	Calm	12.8 w		Lake height near normal. Water color dirty green. Large blooms of algae floating loose, aquatic growth in center of lake has reached the surface and growing rapidly in places where it was never observed before.
14-Jul	24.4	76.0	6.0	Green	0	None	Light	11.5 w		Lake height near normal. Algae blooms growing at an alarming rate.
12-Aug	25.6	78.0	6.5		0	None	Calm	10.1 w		Water color green/moderately clear. Lake depth 16.5' at reading site.
02-Sep	21.1	70.0	6.0		10	None	Light	12.4 w		Water color dark green but clear. Weed and algae blooms are abundant.
11-Sep	19.4	67.0	6.0	Gr-Brown	0	None	Calm	11.0 w		

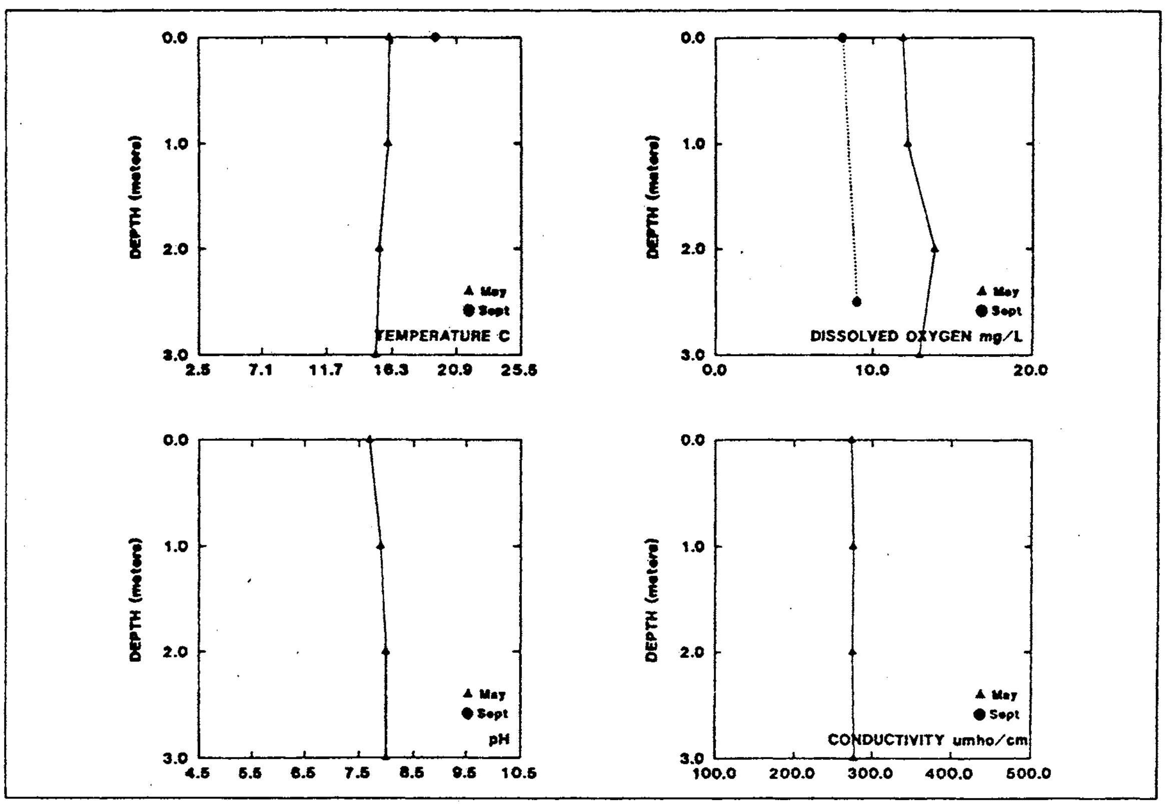
* Secchi data corrected for rope shrinkage
w Secchi disk entered weeds

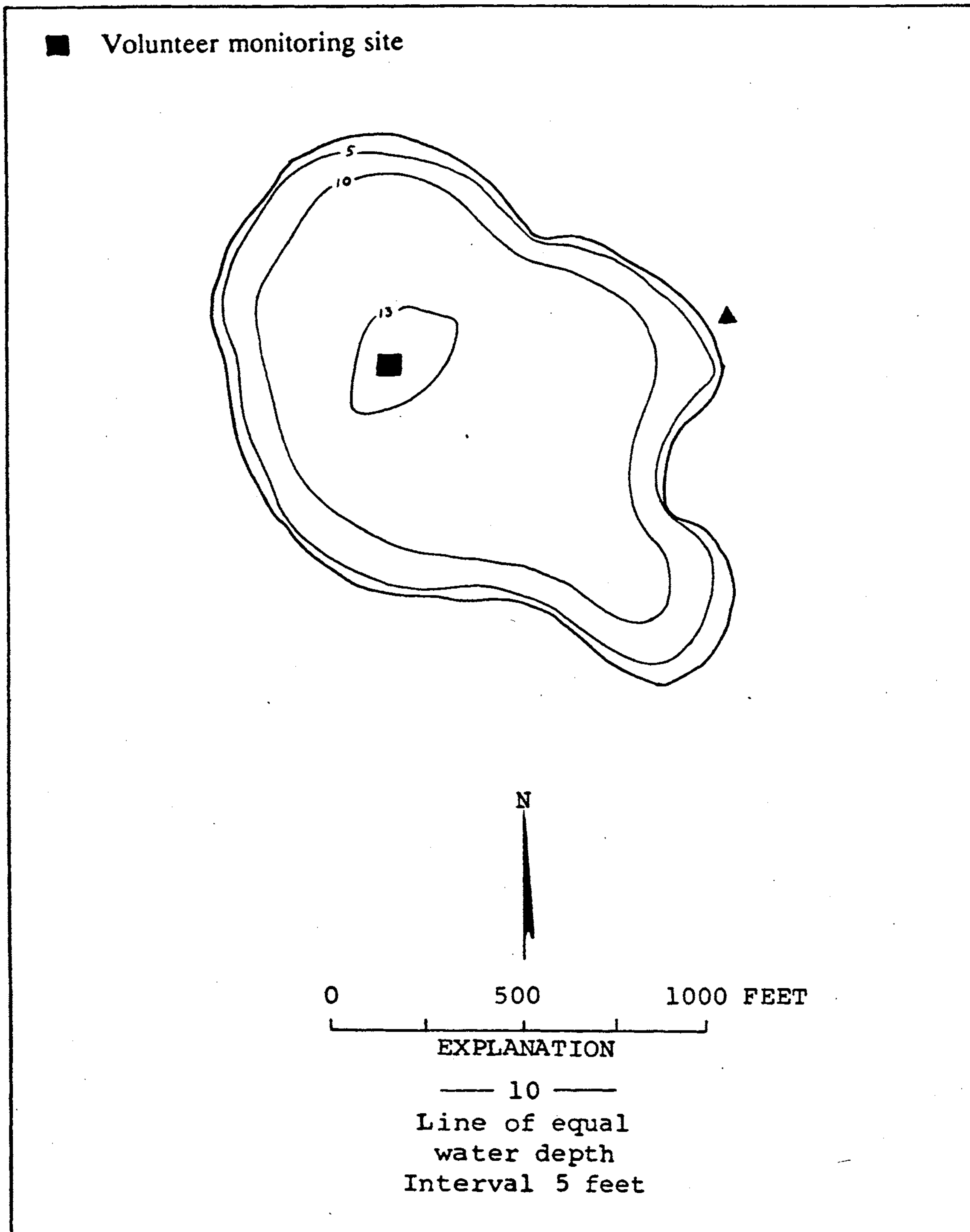
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/29	0.0	16.1	7.7	11.9	274	0.5, 1	0.033	0.906
	1.0	16.0	7.9	12.2	276			
	2.0	15.4	8.0	13.9	275			
	3.0	15.2	8.0	13.0	277			
09/11	0.0	19.4	.	8.1	.	1, 2, 2.5	0.038	0.885
	2.5	.	.	9.0	.			

Secchi Depth and Profile Data Graphs







Starvation Lake, Stevens County. From Washington Department of Game, January 28, 1947.

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 and drains to the Nisqually River. The south arm of Lake St. Clair is a deep conical-shaped depression.

Size (acres)	180
Maximum Depth (feet)	70
Mean Depth (feet)	28
Lake Volume (acre-feet)	5100
Drainage Area (miles^2)	6.4
Altitude (feet)	73
Shoreline Length (miles)	7.5

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	49
Mean Trophic State Index* (Total Phosphorus):	53

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake St. Clair is used for fishing, boating, swimming, rowing, and jet skiing. There are two boat ramps on the lakeshore, and on parts of the lake there is a speed restriction of 5 mph for motorboats. Lake water is withdrawn for drinking and other domestic uses. Currently the watershed is used for logging, animal grazing, crop agriculture, and lakeshore development. Grazing animals have direct access to the lakeshore or inlet tributaries. In the past, the watershed was used for logging, animal grazing, and crop agriculture, the lake was dredged, and the shoreline was altered. There are approximately 300 houses on the lakeshore; of these, 250 are occupied year-round. The lakeshore is not sewered, and two storm drains empty into the lake. Trout are stocked in the lake. The lake has been chemically treated in the past to control fish species. The channel under the bridge will be dredged in 1990. The worst problems in the lake, in the opinion of the volunteer, are ranked as 1) algae, 2) aquatic plants, 3) water level, and 4) suspended sediments. Overall, the volunteer finds that Lake St. Clair has good recreational water quality, and suggested that older septic systems, runoff from new construction and roads, farm runoff in the watershed, and crop and lawn fertilizing may affect water quality. The volunteer is also concerned about the decreasing water level of the lake.

Lilies, mostly white and pink-flowering (most likely *Nymphaea odorata*) and very few yellow-flowering (*Nuphar polysepalum*), and reeds (mostly wild iris - *Iris pseudacarus*, but some reeds) grow in the coves and near the islands. There is a wetland in the south arm of the lake near the creek. Several varieties of "grass" also grow in some cove areas. The east side of the north arm is wooded. During the May 1990 onsite visit with the volunteer, the volunteer mentioned that in the past two years the lake level has dropped considerably without rising again.

In the 1989 questionnaire, the volunteer noted that the passage under the bridge was too shallow for some boats to navigate through.

Monitoring Results/Summary of Other Available Information

The volunteer's monitoring site is located in the north arm of the lake. Secchi data collected during 1990 show that water clarity was lowest during June and August. Profile data collected during June and August 1990 show that on both sampling dates the lake was thermally stratified and concentrations of dissolved oxygen decreased near the bottom of the lake and at the base of the epilimnion. The dissolved oxygen was most likely to have been depleted by bacterial decomposition of organic material (such as algae, aquatic plants or woody debris) in the water and sediments. Because of the strong thermocline, it is likely that a density gradient trapped sinking algae at the bottom of the epilimnion, where the algae decomposed, resulting in depletion of the dissolved oxygen. In contrast, in June 1972 the concentration of dissolved oxygen was not depleted near the lake bottom, and in the north basin the dissolved oxygen concentration was 7.3 mg/L at 62 feet (Bortleson *et al.*, 1976).

The 1990 concentrations of total phosphorus and total nitrogen were high (averaging 0.0291 and 0.529 mg/L, respectively). The concentrations of total phosphorus (0.020 mg/L) and total nitrogen (0.51 mg/L) were lower in 1972 than in 1990 (Bortleson *et al.*, 1976). In 1981, the concentration of total phosphorus was 0.080 mg/l and the concentration of total nitrogen was 2.0 mg/L (Sumioka and Dion, 1985). These latter concentrations were extremely high, and along with the reported Secchi depth (3.5 feet), indicate that in 1981 the lake was eutrophic (Sumioka and Dion, 1985).

Lake St. Clair was one of 15 lakes sampled in June and September 1990 by Ecology staff as part of a statewide survey to supplement data collected by the volunteers (Coots, 1991). The profile and nutrient data collected from this survey were very similar to data collected during the 1990 onsite visit with the volunteer. The aquatic plants noted by the volunteer and those reported from the other Ecology survey (Coots, 1991) probably differ because different basins of the lake were sampled for each survey. The Coots (1991) survey data were collected from the south basin.

Lake St. Clair has been reported to be "highly colored from natural sources" (Bortleson *et al.*, 1976); the volunteer reported a reddish-brown color during the monitoring season.

Lake St. Clair -- Thurston County

During the May 1990 onsite visit with the volunteer, white-flowering lily (*Nymphaea odorata*) was abundant.

Comments

Because of the unusual morphometry of Lake St. Clair, it is difficult to compare the water quality of the lake with other lakes monitored for the program. Other Thurston County lakes monitored for the program in 1990 were Clear, Hicks, Long, Patterson, Summit, and Ward Lakes. Although Lake St. Clair had the poorest overall water clarity of these lakes, Clear Lake had the highest concentration of total phosphorus.

In 1990 we reported that the trophic state of Lake St. Clair should probably be based on chemical as well as water clarity data. The 1990 Secchi data were fairly comparable to the total phosphorus data, and only slightly underestimated the trophic state of the lake based on phosphorus (that is, Secchi data indicate better water quality than the total phosphorus data). Most lakes monitored for the program in 1990 had Secchi data which indicated a slightly higher trophic state (indicating worse water quality) than the total phosphorus data.

Acknowledgement

I thank M. E. Christopherson for volunteering hos time to monitor Lake St. Clair from 1989 - 1990.

Lake St. Clair -- Thurston County

Volunteer-Collected Data

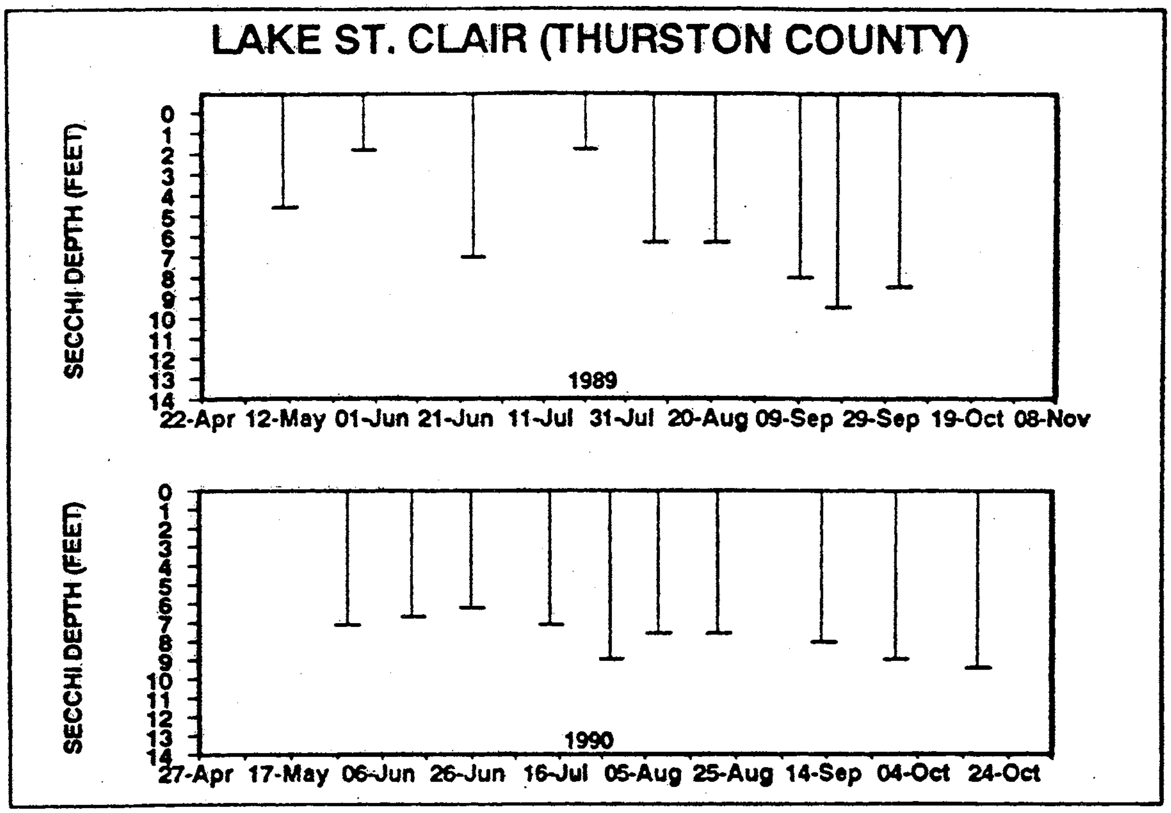
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
30-May	15.0	59.0	7.0	Lt, Rusty	25	Light	Light	6.4	12.0	Lake much lower than usual for this time of year.
14-Jun	16.7	62.0	7.0	Red-Brown	0	Trace	Light	6.0	17.0	Lake height up 4". Depth at check point approx. 50'.
27-Jun	18.3	65.0	7.0	Lt, Red-Br	50	Trace	Breezy	5.5	12.0	Water color reddish brown. pH reading didn't really match any specific color, 7 was the closest.
15-Jul	23.9	75.0	6.5	Red-Brown	0	None	Light	6.4	8.0	Fast drop in lake level (from 17" high to current 8")
29-Jul	25.6	78.0	6.5	Red-Brown	0	None	Light	8.3	4.0	Can't get a match on the pH (recorded 6.5 - 7). Lake level dropping fast with the warm weather.
09-Aug	26.1	79.0	6.5	Red-Brown	10	None	Calm	6.9**	0.0	Water level dropped to the zero point on yardstick. Will start over on minus figure.
22-Aug	21.1	70.0	6.5	Red-Brown	90	Light	Breezy	6.9	-1.0	Lake height started with 18" on the marker, currently -1 or 19" drop in water level since May.
14-Sep	18.3	65.0		Red-Brown	75	None	Light	7.3**	-2.0	Total drop in lake height 20".
30-Sep	18.3	65.0	6.5	Red-Brown	0	None		8.3	-3.0	The lake has probably reached its lowest level of the season. Cooler weather and rain should start to bring it up.
18-Oct	11.1	52.0	6.5	Gr-Brown	0	Moderate		8.7	0.0	A lot of little grey greenish particles in water (no sign of algae on surface).

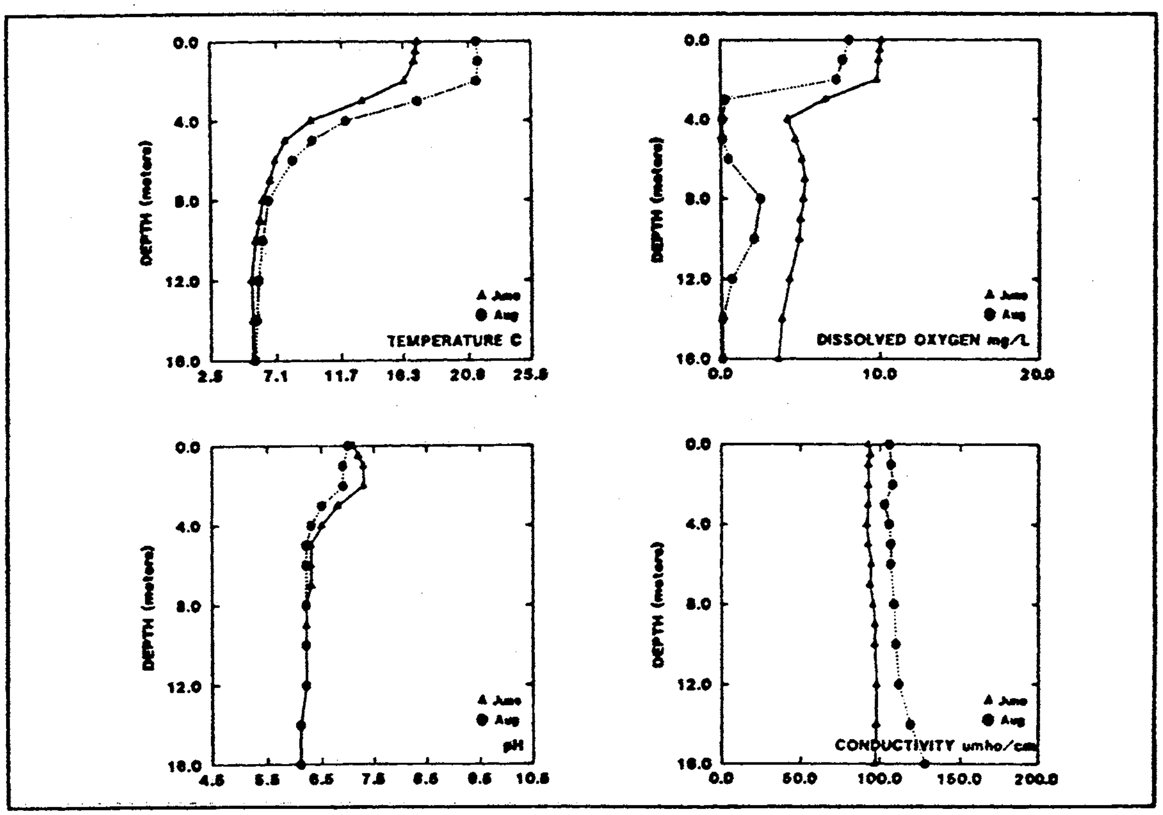
* Secchi data corrected for rope shrinkage
** High variability between the first and second Secchi depths collected; these two data points may not be used in data comparisons

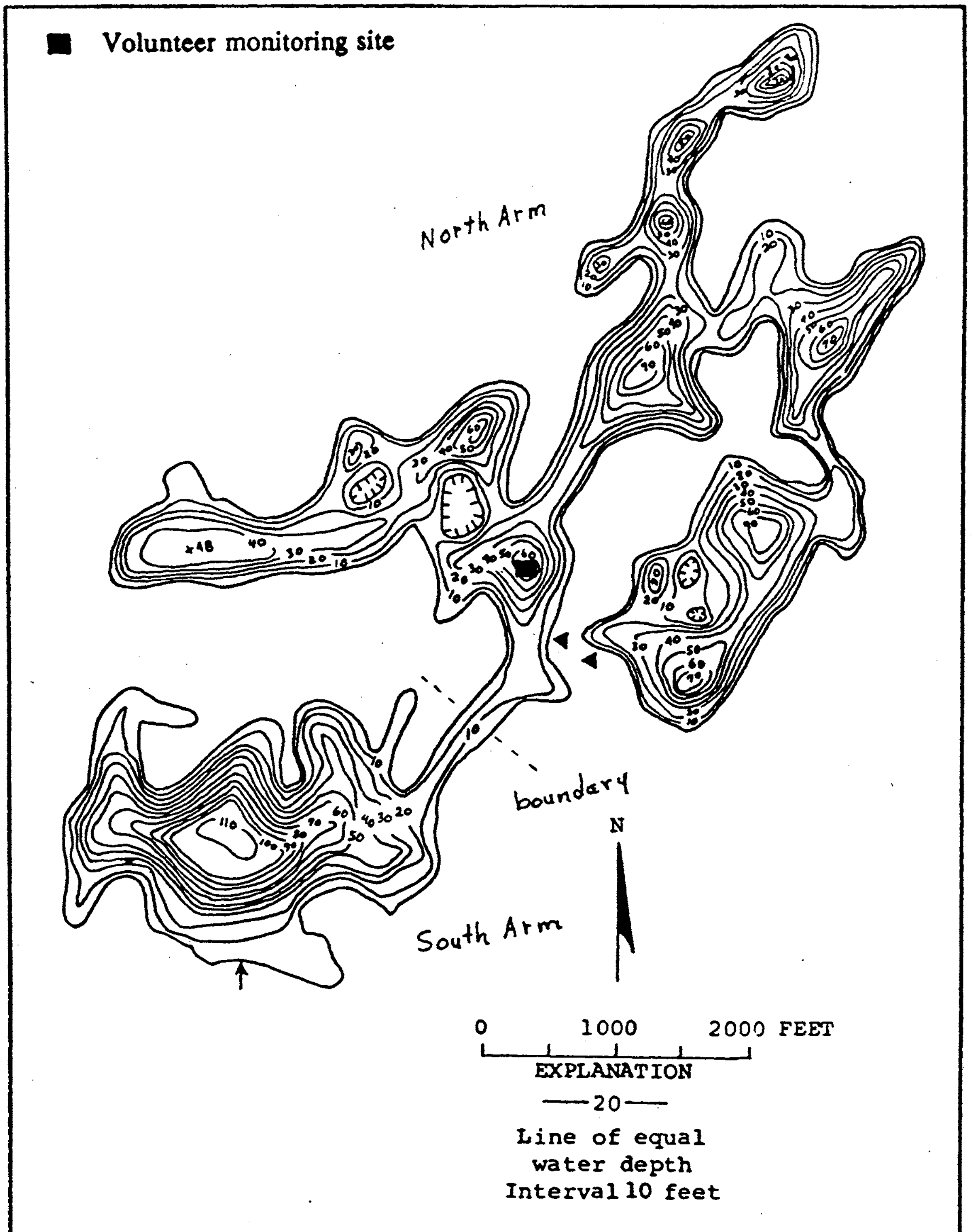
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/30	0.0	17.3	7.1	10.1	93	0.5, 2	0.035	0.526
	0.5	17.2	7.2	10.0	94			
	1.0	17.1	7.3	9.9	93			
	2.0	16.4	7.3	9.8	93			
	3.0	13.2	6.8	6.6	93			
	4.0	9.5	6.5	4.2	92			
	5.0	7.8	6.3	4.7	93			
	6.0	7.0	6.3	5.1	95			
	7.0	6.6	6.3	5.3	94			
	8.0	6.1	6.2	5.2	96			
	9.0	5.9	6.2	5.0	97			
	10.0	5.6	6.2	4.9	97			
	12.0	5.3	6.2	4.3	98			
	14.0	5.4	6.1	3.8	98			
	16.0	5.4	6.1	3.6	97			
08/22	0.0	21.5	7.0	8.1	106	1, 2	0.024	0.532
	1.0	21.6	6.9	7.7	107			
	2.0	21.5	6.9	7.3	108			
	3.0	17.3	6.5	0.3	103			
	4.0	12.0	6.3	0.1	106			
	5.0	9.6	6.2	0.1	107			
	6.0	8.2	6.2	0.5	107			
	8.0	6.5	6.2	2.5	109			
	10.0	6.1	6.2	2.1	110			
	12.0	5.8	6.2	0.7	112			
	14.0	5.7	6.1	0.1	119			
	16.0	5.6	6.1	0.1	128			

Secchi Depth and Profile Data Graphs







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

Lake Steilacoom -- Pierce County

Lake Steilacoom is located three miles east of Steilacoom. It is an urban lake fed by Clover Creek and Ponce de Leon Creek, and drains via Chambers Creek to Puget Sound.

Size (acres)	320
Maximum Depth (feet)	20
Mean Depth (feet)	11
Lake Volume (acre-feet)	3500
Drainage Area ($miles^2$)	89.4
Altitude (feet)	210
Shoreline Length (miles)	5.7

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	51
Trophic State Index* (Total Phosphorus):	45

* From Carlson (1977)

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

The 1990 questionnaire was not returned by the volunteer. The following are from the 1989 questionnaire responses. Lake Steilacoom is used for fishing, swimming, boating, and jet skiing. There is a length restriction for motor boats, and jet boats are not allowed on the lake. The lake water is used by a salmon hatchery downstream from the lake. Currently the watershed includes industrial development which includes the McChord Airforce Base. The lakeshore is being developed further for residences. The lake has been dredged in the past. There are about 330 houses on the lakeshore; all are occupied year-round, and the lakeshore is fully sewered. The lake is chemically treated almost every year (to control weeds, algae and snails which carry the swimmer's itch parasite), predominately with copper sulfate. Fish are stocked in the lake. The worst problems in the lake, in the opinion of the volunteer, are 1) algal blooms (mainly during June and July), 2) weeds (mainly during August), and 3) continual suspension of sediments in the water. The volunteer also suggested that motor boat use and runoff from McChord Airforce base may affect lake quality.

<u>Monitoring Results/Summary of Other Available Information</u>

Secchi data show that in both 1989 and 1990, the water clarity was lowest during early summer (late May-early June) and August. In 1989, high water clarity corresponded to copper sulfate treatments for controlling algae. Profile data collected during 1990 show that concentrations of dissolved oxygen were very high at the surface, and decreased with depth.

Lake Steilacoom -- Pierce County

The 1990 concentration of total phosphorus was medium-high, and the concentration of total nitrogen was high (0.0167 and 0.870 mg/L, respectively). The concentrations of both nutrients were considerably lower in June 1990 than in June 1989 (Brower and Kendra, 1990). However, the volunteer sampling site was located at the deep site of the north basin (north of the bridge), whereas the 1989 survey was conducted in the south basin. Based on these data, the south basin appears more eutrophic than the north basin.

From Johnson and Norton (1990): Ecology collected one sediment sample in 1989 from the north basin to determine the copper concentration in lake sediments. The copper concentration was extremely high (1010 μg/Kg) when compared to concentrations of 20 - 50 μg/Kg found in most of the other nine lakes sampled in 1989. The high concentration of copper in the single sediment sample and the history of copper sulfate treatments in Lake Steilacoom warranted additional study to evaluate potential adverse biological effects on benthic invertebrate populations. Ecology conducted further study of the sediments in 1990; a report of the results is in preparation.

A report to the residents and members of the Lake Steilacoom Lake Improvement Club stated that the lake had been chemically treated since 1955, but has been treated with the "present treatment" (presumably, copper sulfate) for the past 15 years (Report of the Steilacoom Lake Improvement Club, Inc., June 1989).

Residential development of the lakeshore has increased since 1971, when there were 285 nearshore homes (Bortleson, *et al.*, 1976).

<u>Comments</u>

Despite chemical treatment to control algae, water clarity is low. Compared with other lakes monitored for the program, the water quality of Lake Steilacoom is poor.

Although copper sulfate treatment has been the method of choice for controlling algae in Lake Steilacoom, long-term use of this chemical has many disadvantages. Research has shown that five lakes in Minnesota treated with copper sulfate for 58 years sustained many undesirable side effects as a result of the treatments (Hanson and Stefan, 1984). Dissolved oxygen depletion, copper accumulation in the sediments, shifts in algal species to those more tolerant of higher copper sulfate concentrations (and shifts from green algal species to less desirable blue-green species) and reductions in benthic macroinvertebrates were among the documented effects. These effects may have already occurred in Lake Steilacoom; alternative lake management options should be explored. Management options may include nutrient source controls (to reduce stormwater and other runoff) and controlling internal recycling of phosphorus from sediments. Application for a grant from Ecology's Centennial Clean Water Fund is strongly recommended to partially fund the development of a lake management plan and lake restoration.

Lake Steilacoom -- Pierce County

Acknowledgement

I thank Fred Weir for volunteering his time to monitor Lake Steilacoom during 1989-1990.

Volunteer-Collected Data

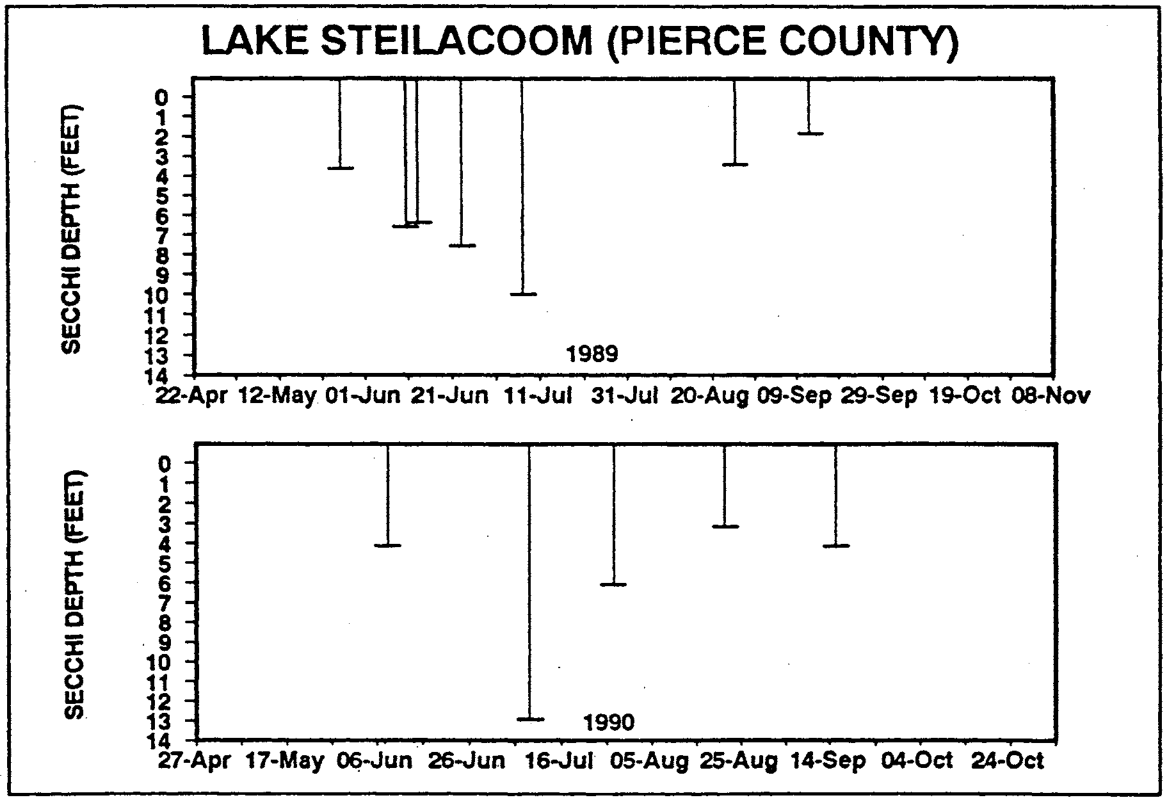
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
09-Jun	21.0	70.0	7.5	Green	100	Light	Calm	4.1		
10-Jul	23.9	75.0	6.5	Green	0	None	Light	12.4		
28-Jul	21.7	71.0	7.5	Green	0	None	Breezy	6.0		
22-Aug	21.1	70.0	6.5	Green	10	Moderate	Light	3.2		
16-Sep	20.6	69.0	7.5	Green	50	None	Light	4.1		

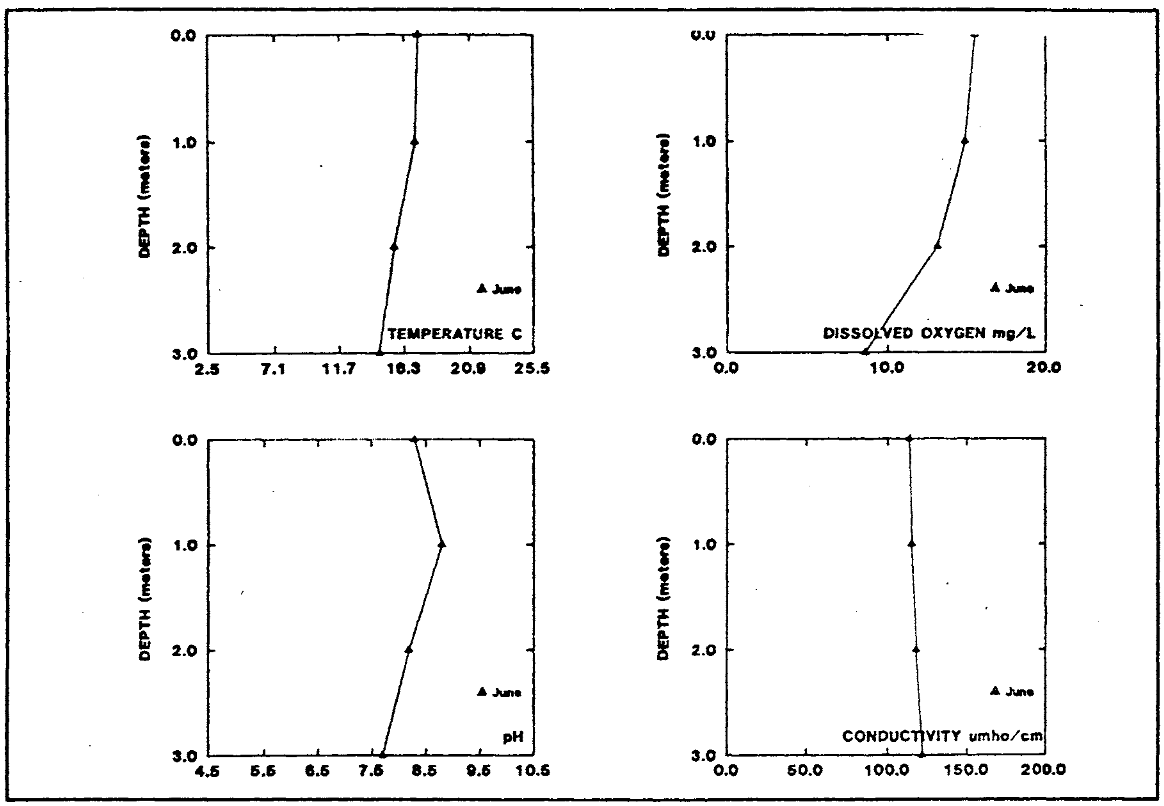
* Secchi data corrected for rope shrinkage

Onsite Visit Data

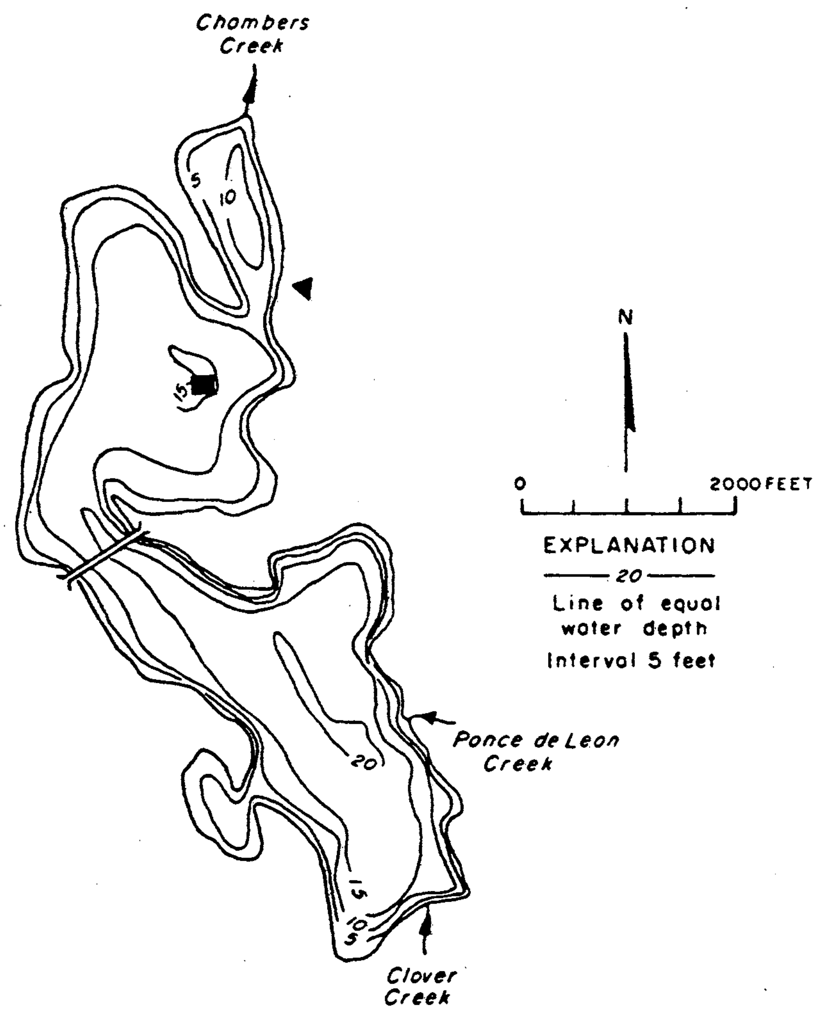
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/09	0.0	17.3	8.3	15.5	114	0.5, 1	0.017	0.870
	1.0	17.1	8.8	14.9	115			
	2.0	15.6	8.2	13.1	118			
	3.0	14.5	7.7	8.6	122			

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



Steilacoom Lake, Pierce County. From Washington Department of Game, June 2, 1950.

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

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	34
Mean Trophic State Index* (Total Phosphorus):	38

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Stevens is used for fishing, boating, swimming, rowing, jet skiing, and float planes. Recreational facilities on the lakeshore include a park, a picnic area, a beach, and two boat ramps, and there is a speed restriction of 35 mph for motorboats. Currently the watershed is used for logging, industry, animal grazing, crop agriculture, and lakeshore development. In the past, the watershed was used for logging, animal grazing, and crop agriculture. Also, the lake was dredged and the shoreline was altered. There are 281 houses on the lakeshore, and the lakeshore is about 90% sewered. There are about seven storm drains that empty into the lake. Trout, bass, perch, and catfish are stocked in the lake. Presently there is a sewer district and a community association for the lake. The worst problems in the lake, in the opinion of the volunteer, are 1) algae, 2) aquatic plants, and 3) water level. Overall, the volunteer finds that Lake Stevens has good recreational water quality, and suggested that septic systems and runoff from agriculture, crops and residential areas may affect water quality.

There are wetlands located at the north end of the lake, near the city boat launch, near a small cove on the east side, and also at the south end. Submerged weeds are thick near these wetland areas. There are lily pads at the south end of the lake near the bridge, and thick weeds and brush grow on the bank. Algae blooms are common in the south end of the lake during the summer. Except for the wetland areas, the entire lakeshore is developed.

Lake Stevens -- Snohomish County

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity in Lake Stevens was lowest during late June. Profile data collected during June and August 1990 show that on both sampling dates, the lake was thermally stratified. Because the profiling instrument malfunctioned during the June sampling, it was not possible to postcalibrate the instrument (and thus check the quality of the field data). Because the quality of the data could not be assured, the June profile data are not reported here.

The August 1990 concentrations of dissolved oxygen increased slightly above the thermocline, indicating possible increased algae growth at this depth. Although the concentrations of dissolved oxygen decreased below the thermocline, concentrations were not exhausted. In July and August 1972, the concentration of dissolved oxygen decreased to 3.5 mg/L and 0.0 mg/L near the lake bottom, respectively (Bortleson *et al.*, 1976a and 1976b).

Concentrations of total phosphorus and total nitrogen were moderately low on both sampling dates (averaging 0.011 and 0.354 mg/L, respectively). In comparison, data collected in 1972 (Bortleson *et al.*, 1976a) show that the concentration of total phosphorus (0.005 mg/L) was lower and the concentration of total nitrogen (0.43 mg/L) was higher.

From Snohomish County Public Works (1991): Lake Stevens currently has high nutrient concentrations, low water clarity, high growth of algae, and low concentrations of dissolved oxygen in its deeper waters. The primary problem identified was the high concentrations of phosphorus in the water. The primary source of the phosphorus was internal loading from the sediments, and the major outside sources were runoff and groundwater. 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; proposed for September, 1992); and hypolimnetic aeration (to increase oxygen concentrations in deep water and help keep phosphorus in the sediments).

Comments

Lake Stevens is one of nine lakes in Snohomish County monitored for the program in 1990. Compared with other lakes (Bosworth, Flowing, Lake Martha, Martha Lake, Panther, Shoecraft, Storm, and Sunday), Lake Stevens had the best overall water clarity and had low concentrations of total phosphorus. Lake Stevens is considerably larger and deeper than the other lakes.

Lake Stevens -- Snohomish County

Although the 1990 data collected for this project do not indicate a problem with dissolved oxygen, the 1972 data do indicate that Lake Stevens has had problems with low dissolved oxygen concentrations during the fall. Our method of using spring total phosphorus and mean summer water clarity to assess trophic status apparently does not reflect problems in the lake that occur during late summer and fall.

Acknowledgement

I thank Mark McCullough for volunteering his time to monitor Lake Stevens during 1990.

Lake Stevens -- Snohomish County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
02-Jun	16.0	60.8	7.5	Gr-Brown	75	Moderate	Breezy	23.5	0.0	Lake height of 0 is reference point as of today. South end of lake was more brown than rest of lake.
06-Jun								23.5		
14-Jun	17.5	63.5	7.5	Green	0	Trace	Breezy	17.5	2.0	South end of lake had much more algae - brown water color.
26-Jun	21.0	69.8	7.2	Gr-Brown	0	None	Breezy	13.5	0.0	South end warmer than north end-water clarity less in cove and south end.
11-Jul	24.5	76.1	7.0	Gr-Brown	50	None	Breezy	17.5	-5.0	Lots of little algae, greenish brown in color-south end of lake more brown than rest of lake.
01-Aug	24.0	75.2	7.0	Green	0	None	Breezy	22.5	-11.0	Large quantity of algae in south end of lake.
20-Aug	21.5	70.7	7.0	Green	25	Light	Light	20.5	-13.0	Free floating algae not as bad as before - even concentration over all of lake. Boat activity tapering off.
30-Aug								21.0		
10-Sep	21.0	69.8	7.0	Green	0	None	Breezy	19.5	-16.0	Algae bloom in south end of lake.
22-Sep	21.0	69.8	7.5	Green	0	None	Calm	19.0	-17.0	Plant growth seems to be dying down. Free floating algae are increased in south end of lake.

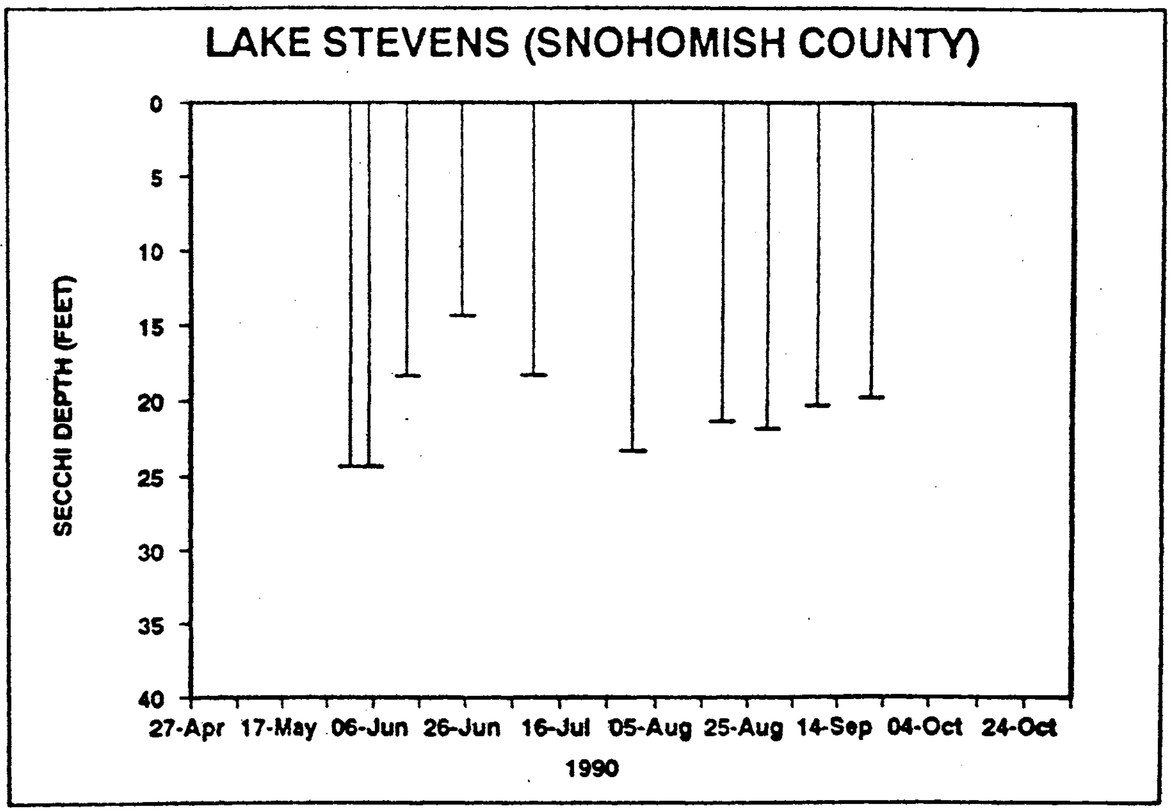
Lake Stevens -- Snohomish County

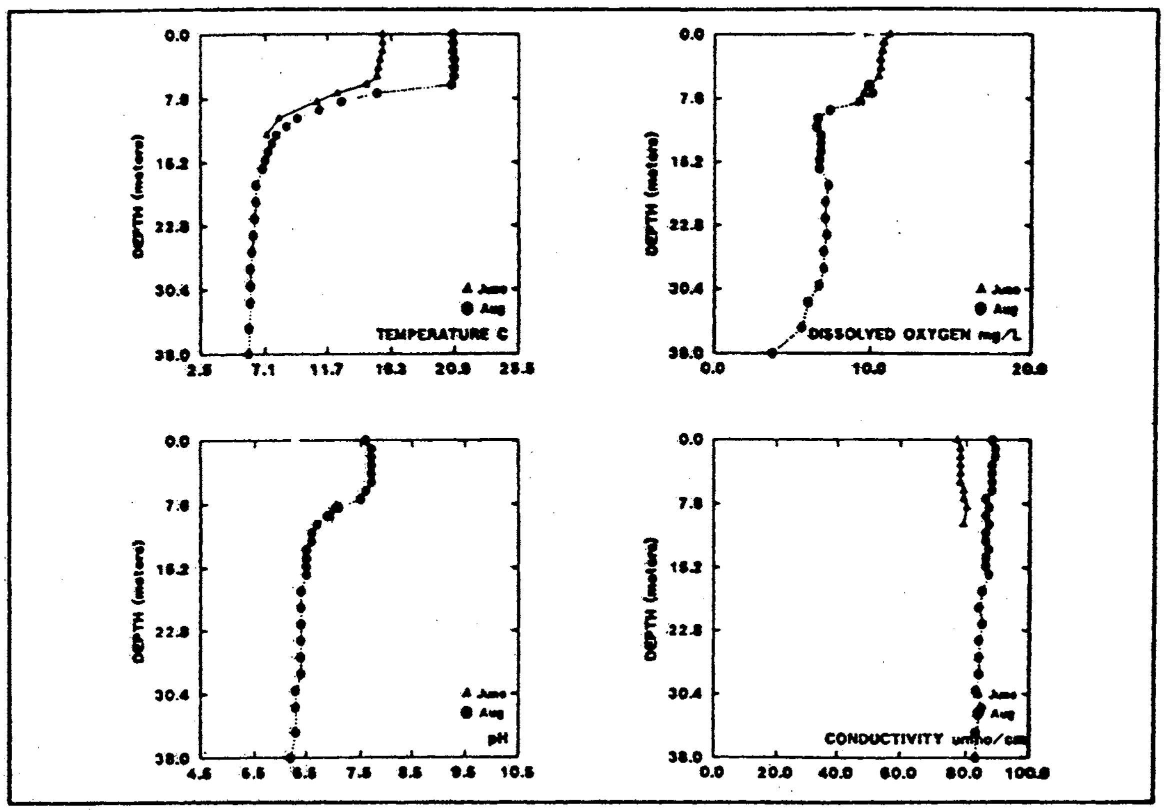
Onsite Visit Data

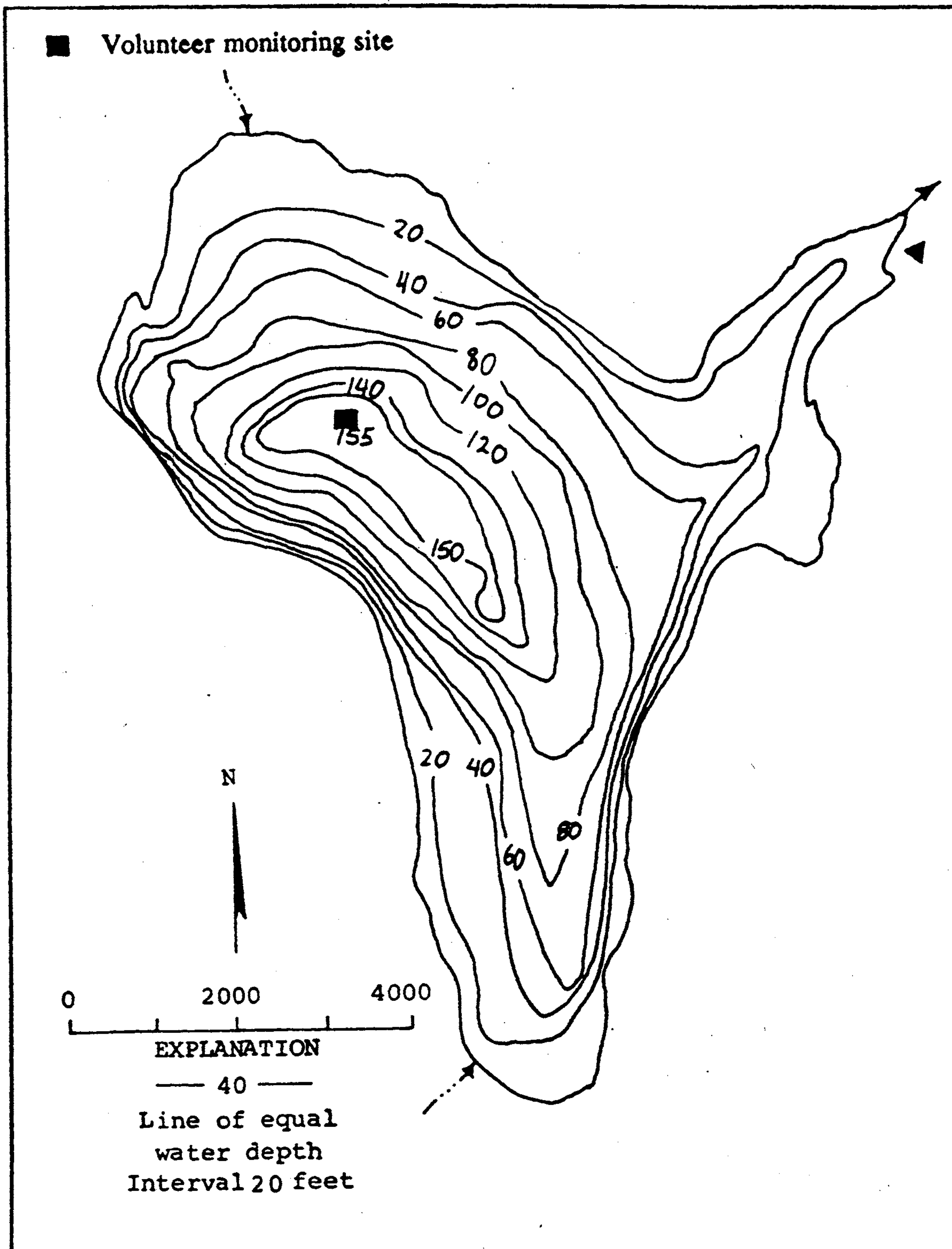
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/06	0.0	.*	.*	.*	.*	2, 3, 5	0.009	0.356
	1.0	.	.	.	.			
	2.0	.	.	.	.			
	3.0	.	.	.	.			
	4.0	.	.	.	.			
	5.0	.	.	.	.			
	6.0	.	.	.	.			
	7.0	.	.	.	.			
	8.0	.	.	.	.			
	10.0	.	.	.	.			
	12.0	.	.	.	.			
8/30	0.0	20.8	7.6	9.6	88	1, 3, 6	0.012	0.352
	1.0	20.8	7.7	9.3	89			
	2.0	20.8	7.7	9.3	89			
	3.0	20.9	7.7	9.3	88			
	4.0	20.9	7.7	9.3	88			
	5.0	20.9	7.7	9.3	88			
	6.0	20.7	7.6	9.8	88			
	7.0	15.2	7.5	10.1	83			
	8.0	12.7	7.1	9.3	87			
	9.0	11.1	6.9	7.4	86			
	10.0	9.5	6.7	6.6	87			
	11.0	8.7	6.6	6.5	86			
	12.0	7.9	6.6	6.8	86			
	13.0	7.6	6.5	6.8	87			
	14.0	7.3	6.5	6.8	86			
	15.0	7.1	6.5	6.7	86			
	16.0	6.9	6.5	6.7	87			
	18.0	6.4	6.4	7.3	85			
	20.0	6.4	6.4	7.1	84			
	22.0	6.3	6.4	7.1	85			
	24.0	6.2	6.4	7.2	84			
	26.0	6.1	6.4	7.0	84			
	28.0	6.0	6.4	7.0	84			
	30.0	6.0	6.3	6.7	83			
	32.0	6.0	6.3	6.0	85			
	35.0	5.9	6.3	5.6	83			
	38.0	5.9	6.2	3.7	83			

* Hydrolab shorted out below 12 m and could not be post-calibrated. Quality assurance for these data cannot be guaranteed, so they are not reported here

Secchi Depth and Profile Data Graphs







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

Storm Lake -- Snohomish County

Storm Lake is located 5.5 miles north of Monroe. It has no inlets, and drains to Flowing Lake and the Pilchuk River.

Size (acres)	79
Maximum Depth (feet)	46
Mean Depth (feet)	22
Lake Volume (acre-feet)	1777
Drainage Area (miles^2)	0.4
Altitude (feet)	528
Shoreline Length (miles)	1.7

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	47
Mean Trophic State Index* (Total Phosphorus):	40

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Storm Lake is used for fishing, boating, swimming, and rowing. Recreational facilities on the lakeshore include one boat ramp, and there is a speed restriction of 5 mph for motorboats. Currently the watershed is used for logging, animal grazing, crop agriculture, and lakeshore development. Grazing animals have direct access to the lakeshore or inlet tributaries. In the past, the watershed was used for logging and crop agriculture, the lake was dredged, and the shoreline was altered. There are 33 houses on the lakeshore, and the lakeshore is not sewered. Trout are stocked in the lake. The lake has been chemically treated in the past to control fish species. The worst problems in the lake, in the opinion of the volunteer, are 1) algae, and 2) water odors (septic smell). Overall, the volunteer finds that Storm Lake has good recreational water quality, and suggested that water quality may be affected by older septic systems, new construction, land clearing, logs in the lake, fill along the lakeshore, gas outboard motors, and fishermen using the lake as a bathroom.

According to the volunteer, there are areas of the shoreline that have logs and marsh with no development, and the majority of the shoreline near the residences has been altered. Most of the undeveloped area is at the southeast end of the lake.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity did not vary much over summer, although the clarity was lowest during May. Profile data collected during June and August

1990 show that on both sampling dates, the lake was thermally stratified and dissolved oxygen decreased from the surface to the bottom of the lake. During August, the concentrations of dissolved oxygen were depleted at the bottom two meters (about 6.5 feet) of the lake.

The 1990 concentrations of total phosphorus and total nitrogen (averaging 0.012 and 0.455 mg/L, respectively) were borderline between low and medium. Data collected in 1973 show that the concentration of total phosphorus was 0.013 mg/L and the concentration of total nitrogen was 0.41 mg/L (Bortleson *et al.*, 1976); these concentrations are very similar to the concentrations found in 1990. In 1973, the lake was described as having trees and shrubs growing over the water, and that logs and debris covered the shoreline (Bortleson *et al.*, 1976).

Comments

Storm Lake was one of the few lakes at which Secchi data overestimated trophic state compared to trophic state predicted by the concentrations of total phosphorus. The Secchi data from Panther Lake, Flowing Lake, Bosworth Lake (Snohomosh County), and Sunday Lake (Skagit County) also indicated higher trophic states (that is, lower water quality) than the trophic states suggested by the total phosphorus data. The darker water color of Storm, Flowing, and Panther Lakes, possibly from the high amounts of woody debris at the bottom of these lakes, may have affected water clarity. Although Secchi data may overestimate the trophic state of these lakes somewhat, Secchi data are very useful for documenting the occurrence and severity of algae growth in these lakes.

A comparison of profile and nutrient data from Storm, Panther and Flowing Lakes show that the temperature, pH and conductivity profiles were all very similar. Although the dissolved oxygen profiles for all three lakes show that the concentrations of dissolved oxygen decrease from surface to bottom, during August the concentrations of dissolved oxygen in Storm Lake, unlike Panther Lake, were only depleted near the lake bottom and not throughout the hypolimnion.

Acknowledgement

I thank Ann Marie James for volunteering her time to monitor Storm Lake during 1990. I also thank Kurt Gibbons for his assistance with collecting the profile data from Panther, Storm, and Flowing Lakes during June and August 1990.

Storm Lake -- Snohomish County

Volunteer-Collected Data

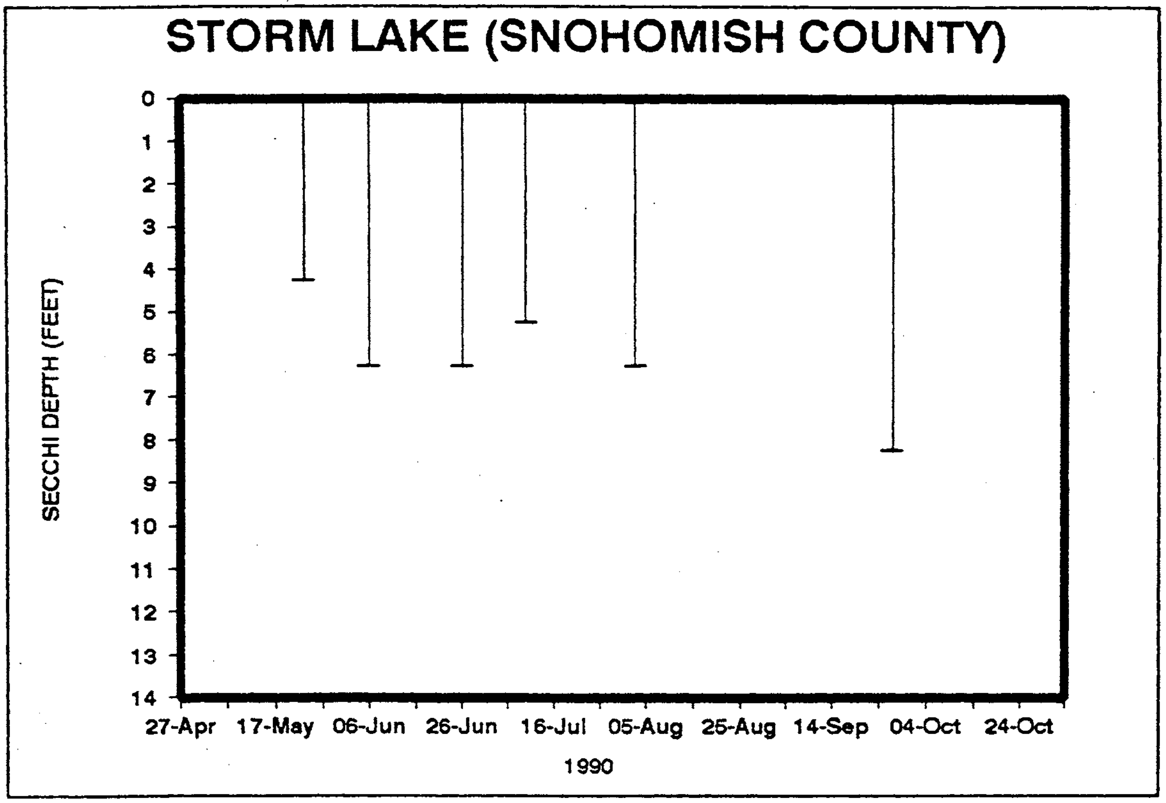
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
23-May	14.4	58.0	6.5	Lt-Brown	90	Light	Calm	6.0		
06-Jun	16.4	61.5	6.0	Gr-Brown	100	Moderate	Light	8.0		
26-Jun	20.0	68.0	6.5	Gr-Brown	0	None	Light	8.0		
10-Jul	23.3	74.0	6.5	Gr-Brown	0	None	Calm	7.0		
03-Aug	23.3	74.0	6.5	Gr-Brown	0	None	Light	8.0		
27-Sep	17.8	64.0	6.5	Gr-Brown	0	None	Calm	10.0		

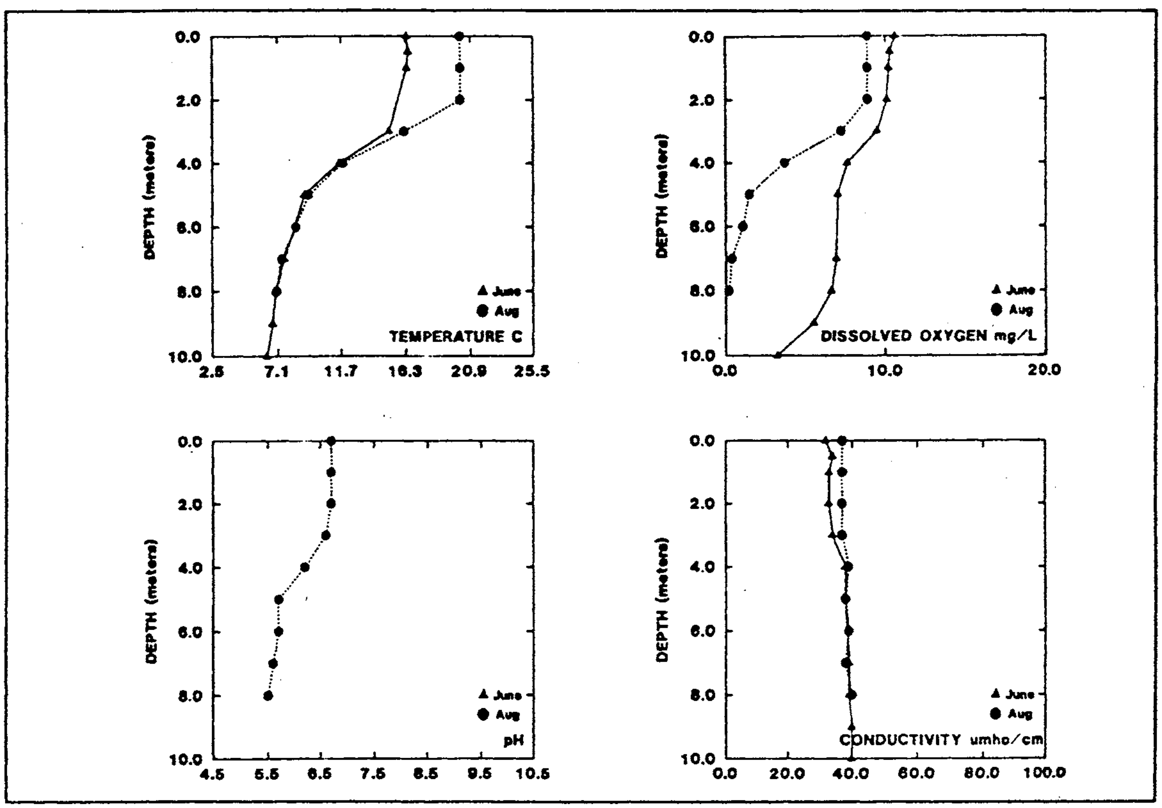
Onsite Visit Data

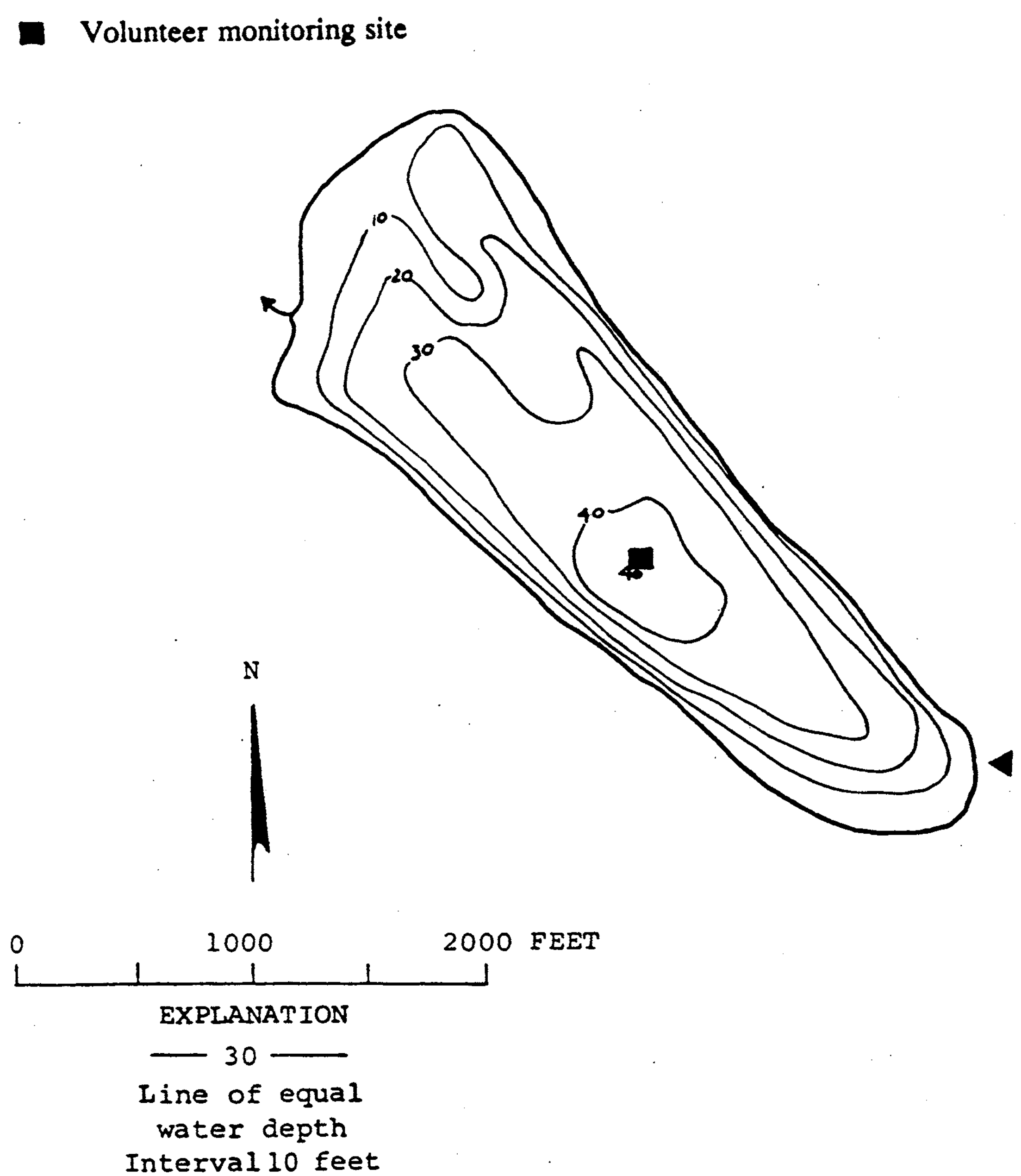
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/06	0.0	16.4	.*	10.6	32	0.5, 3	0.014	0.564
	0.5	16.5	.	10.3	34			
	1.0	16.4	.	10.2	33			
	2.0	1.6	.	10.1	33			
	3.0	15.1	.	9.5	34			
	4.0	11.5	.	7.7	38			
	5.0	9.0	.	7.1	38			
	7.0	7.6	.	7.0	39			
	8.0	6.9	.	6.7	39			
	9.0	6.7	.	5.6	40			
	10.0	6.3	.	3.3	40			
08/30	0.0	20.2	6.7	8.9	37	1, 2	0.010	0.347
	1.0	20.2	6.7	8.9	37			
	2.0	20.2	6.7	8.9	37			
	3.0	16.2	6.6	7.3	37			
	4.0	11.8	6.2	3.8	39			
	5.0	9.3	5.7	1.5	38			
	6.0	8.4	5.7	1.1	39			
	7.0	7.4	5.6	0.4	38			
	8.0	7.0	5.5	0.2	40			

* See Quality Assurance section of this report.

Secchi Depth and Profile Data Graphs







Storm Lake, Snohomish County. From Washington
Department of Game, March 18, 1948.

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)	1380
Maximum Depth (feet)	332
Mean Depth (feet)	193
Lake Volume (acre-feet)	267,000
Drainage Area (miles^2)	51.2
Altitude (feet)	2583
Shoreline Length (miles)	8.9

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	30

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Sullivan Lake is used for fishing, boating, swimming, rowing, jet skiing, camping, scuba diving, and bird watching. Recreational facilities on the lakeshore include a picnic area, a camping area, a beach, and two boat ramps. There is a speed restriction of 35 mph for motorboats (a new county ordinance effective this year). Currently the watershed is used for logging, animal grazing, and lakeshore development. Grazing animals have direct access to the lakeshore or inlet tributaries. In the past, the watershed was used for logging and mining, and the shoreline was altered (when the lake was dammed in 1931). There are 17 houses on the lakeshore; of these, two are occupied year-round. The lakeshore is not sewered. Rainbow trout are stocked in the lake. Presently there is a public utility district for the lake. Every year the lake level is drawn down for hydroelectric use from October 1 through April 15. The worst problems in the lake, in the opinion of the volunteer, are 1) occasional high water level, and 2) floating debris. Overall, the volunteer finds that Sullivan Lake has excellent recreational water quality, and suggested that logging, boating, and wastewater disposal methods may affect water quality.

There are campgrounds located at the north and south ends of the lake. There is a wetland at the south end that contains floating loon nest platforms; pondweed (*Potamogeton richardsonii*) grows in deeper water off the wetland area. A mountain sheep feeding station is also located near the wetland. Most residences are located at the north end of the lake.

Sullivan Lake -- Pend Oreille County

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1989 and 1990 show that average summer water clarity and the overall pattern of water clarity was the same during both years. As with many other lakes monitored for the program, lowest water clarity occurred in early summer.

Water samples were not collected from Sullivan Lake in 1990. However, judging from the low productivity of the lake as indicated by the high water clarity of the water, it is likely that the nutrient concentrations in the lake are low. In 1974, the concentration of total phosphorus was 0.007 mg/L and the concentration of total nitrogen was 0.13 mg/L (Dion *et al.*, 1976).

Comments

Of the lakes monitored for the project in 1990, only Lake Chelan had better mean summer water clarity than Sullivan Lake. Mean water clarity at Lake Chelan was 48 feet, compared to 26 feet at Sullivan Lake.

Acknowledgement

I thank Dick Vogel for volunteering his time to monitor Sullivan Lake during 1990, and Terry Williams for monitoring the lake during 1989.

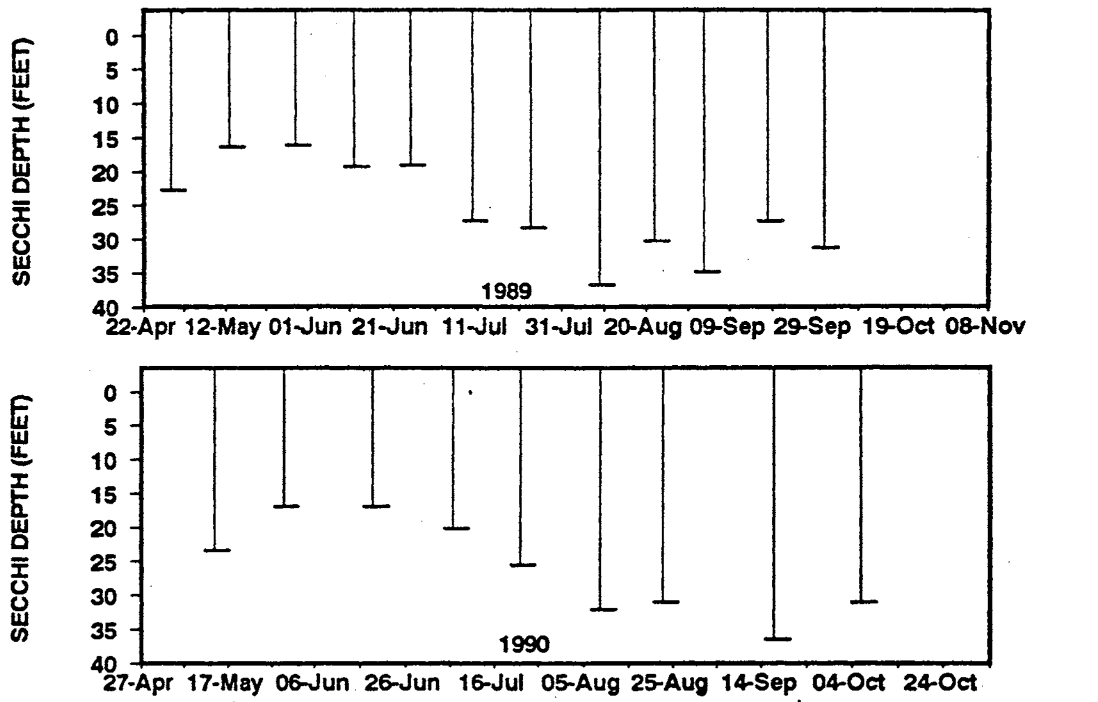
Sullivan Lake -- Pend Oreille County

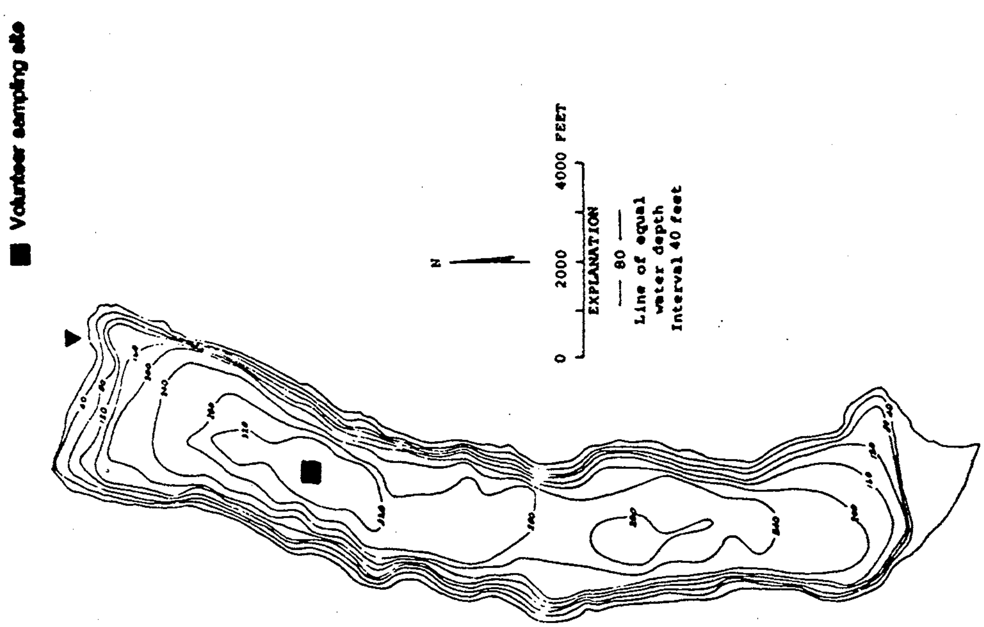
Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
15-May	10.0	50.0	6.0	Lt-Green	100	Light	Breezy	23.0	296.0	Lake height: 296', 15' below normal.
31-May	12.2	54.0	6.5	Green	10	Heavy	Calm	17.0	310.0	Lake height: 310', 1-2' below maximum height. 6"+ rainfall for May. Yellow lodgepole pollen on water.
20-Jun	15.6	60.0	6.5	Green	50	Light	Breezy	17.0	305.0	Lake height: 305', 7' below maximum.
08-Jul	21.1	70.0	6.0	Green	10	Light	Calm	20.0	312.0	
23-Jul	23.3	74.0	6.5	Green	90	Trace	Calm	25.0	310.0	Pine pollen is now gone.
10-Aug	22.2	72.0	6.5	Lt-Green	100	None	Breezy	31.0	310.0	
24-Aug	20.0	68.0	6.5	Lt-Green	10	None	Light	30.0*	305.0	
18-Sep	18.9	66.0	6.5	Lt-Green	10			35.0		
07-Oct	12.8	55.0	6.5	Black	10	Trace	Light	30.0		Lake dam headgate was opened Oct 3 and has dropped the lake level 5 to 7 feet.

* There was high variability between the first and second Secchi depths collected; this data point may not be used in data comparisons.

SULLIVAN LAKE (PEND OREILLE COUNTY)





Sullivan Lake, Pend Oreille County. From U.S. Geological Survey, July 24, 1974.

Summit Lake -- Thurston County

Summit Lake is located in a steep forested valley nine miles west of Olympia. It is two miles long. It 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

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	34
Mean Trophic State Index* (Total Phosphorus):	38

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The 1990 questionnaire was not returned by the volunteer. The following are the volunteer's responses to the 1989 questionnaire. Summit Lake is used for fishing, boating, swimming, jet skiing, picnicking, camping, and hiking. There are two boat ramps on the lakeshore, and there are speed restrictions and time restrictions for motor boating. Lake water is withdrawn for drinking and other domestic uses, and for irrigation. Currently the watershed is logged and is used for animal grazing. In the past, the watershed was logged and the shoreline was altered. There are about 400 houses on the lakeshore; all are on septic systems and about 200 of the houses are occupied year-round. The lake has been chemically treated in the past with rotenone to remove rough fish, and fish are stocked in the lake. Homeowners remove aquatic plants from their lakeshore areas. There are wetlands associated with the lake. The worst problems in the lake, in the opinion of the volunteer, are 1) fecal coliform bacteria levels, and 2) lake level, especially during the winter months. The volunteer suggested that failing septic systems and storm runoff may affect water quality. A Lake Management District has been formed.

Monitoring Results/Summary of Other Available Information

Although there are not enough Secchi data from 1990 to evaluate patterns in algae growth, 1990 Secchi data were in the same range as the 1989 data. The profile data were collected during June and August 1990; during June a Seabird profiling instrument was used, and during August a Hydrolab Surveyor II was used. The conductivity data from the Seabird were questionable so they are not reported here.

Summit Lake -- Thurston County

On both sampling dates, the lake was thermally stratified and concentrations of dissolved oxygen decreased from surface to bottom. This decrease was particularly evident during August. The dissolved oxygen was most likely consumed by bacteria which decompose organic material (such as algae, aquatic plants and woody debris) in the water and sediments. The profile data were very similar to data collected by Ecology in 1989 (Brower and Kendra, 1990). Low dissolved oxygen concentration (less than 1 mg/L) were also detected near the bottom of the lake in 1968 (Lee, 1969) and 1971 (Bortleson *et al.*, 1974).

The June 1990 concentrations of total phosphorus and total nitrogen (averaging 0.0103 and 0.191 mg/L, respectively) were low compared to other lakes sampled in 1990, and were very similar to nutrient data collected in 1989 (Brower and Kendra, 1990).

The Thurston County Health Department has been collecting water samples from the lake since 1990. Samples are collected from the inlet, outlet, and in-lake from the deep site, to determine nutrient loading to the lake (S. Davis, pers. comm.).

Residential development of the lakeshore has increased since 1971, when there were 290 nearshore homes (Bortleson *et al.*, 1976).

<u>Comments</u>

Summit Lake was one of seven Thurston County lakes monitored for the project in 1990. Compared with Clear, Hicks, Long, Patterson, St. Clair, and Ward Lakes, Summit Lake had good water clarity and low concentrations of total phosphorus.

<u>Acknowledgement</u>

I thank Larry Davis for volunteering his time to monitor Summit Lake during 1989-1990.

Summit Lake -- Thurston County

Volunteer-Collected Data

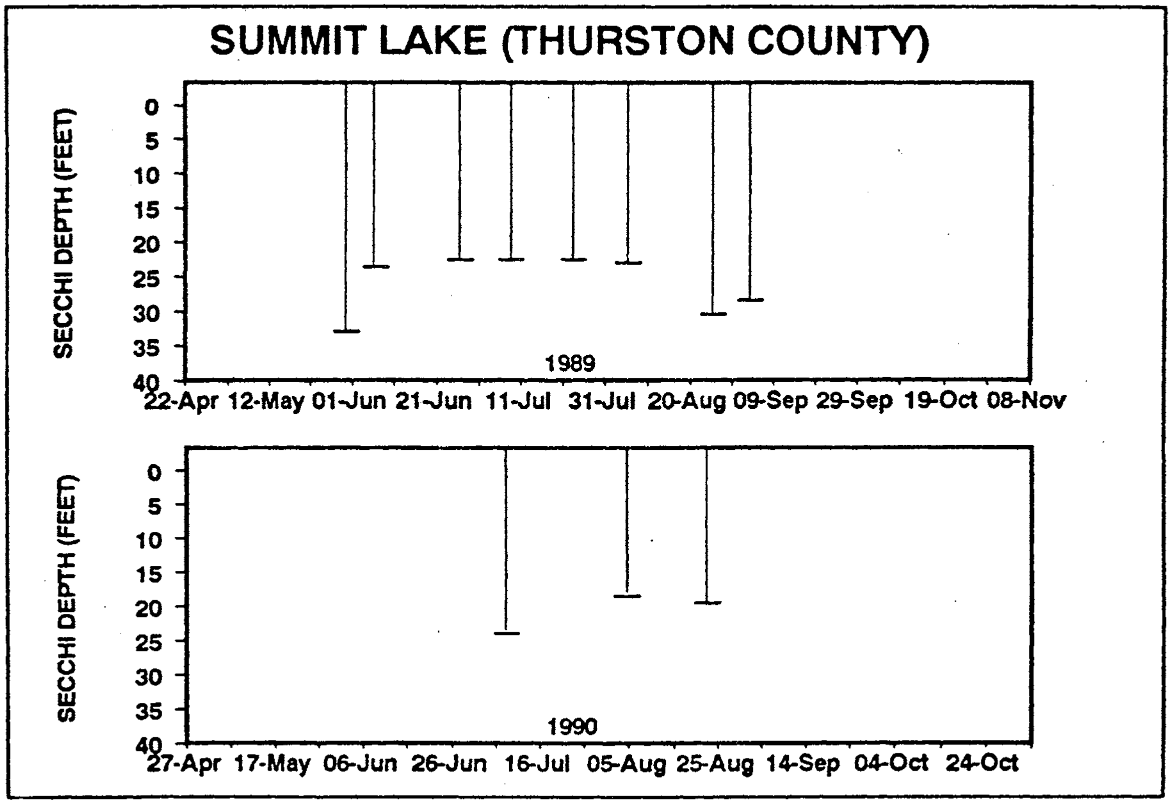
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
09-Jul	18.3	65.0	5.5	Lt-Green	0	None	Light	23.4		Lake height: April height.
05-Aug	12.2	54.0	5.5	Lt-Green	0	None	Breezy	18.3		Lake height is high for August.
23-Aug	20.5	69.0	5.5	Green	75	Light	Light	19.3		Did reading with Julie Rector; pH meter read 7.0.

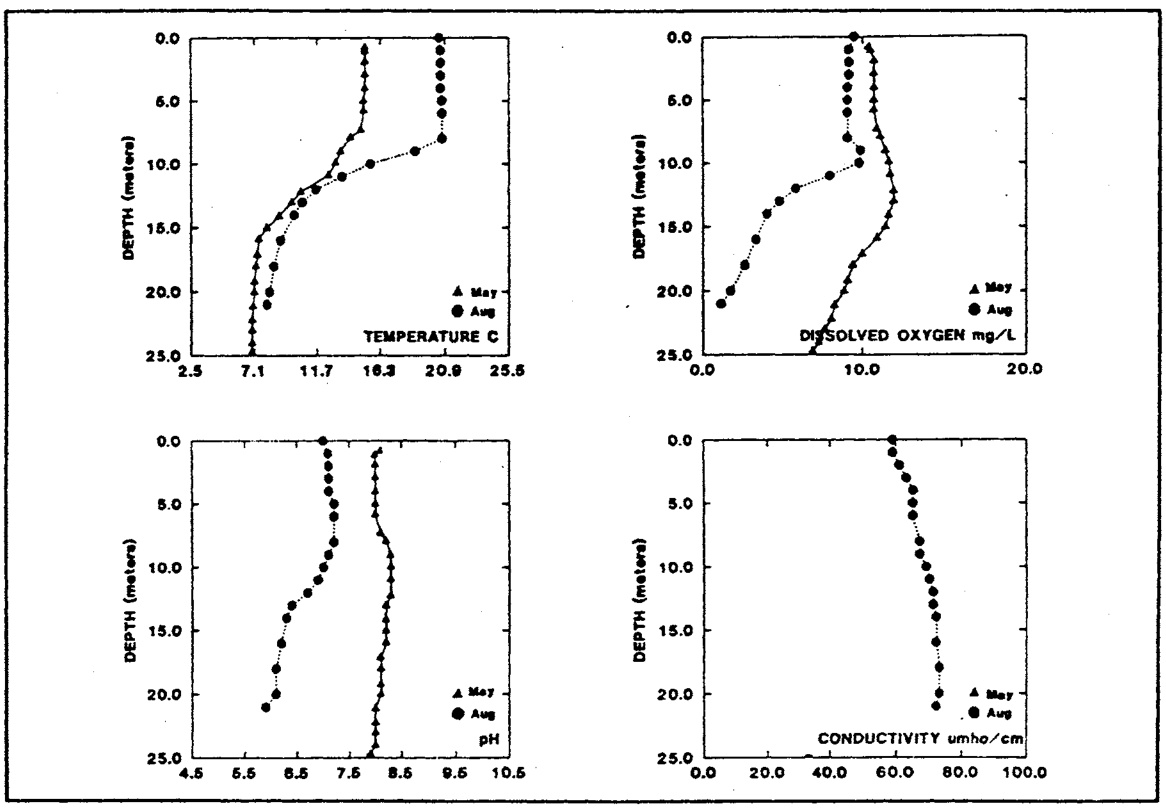
* Secchi data corrected for rope shrinkage

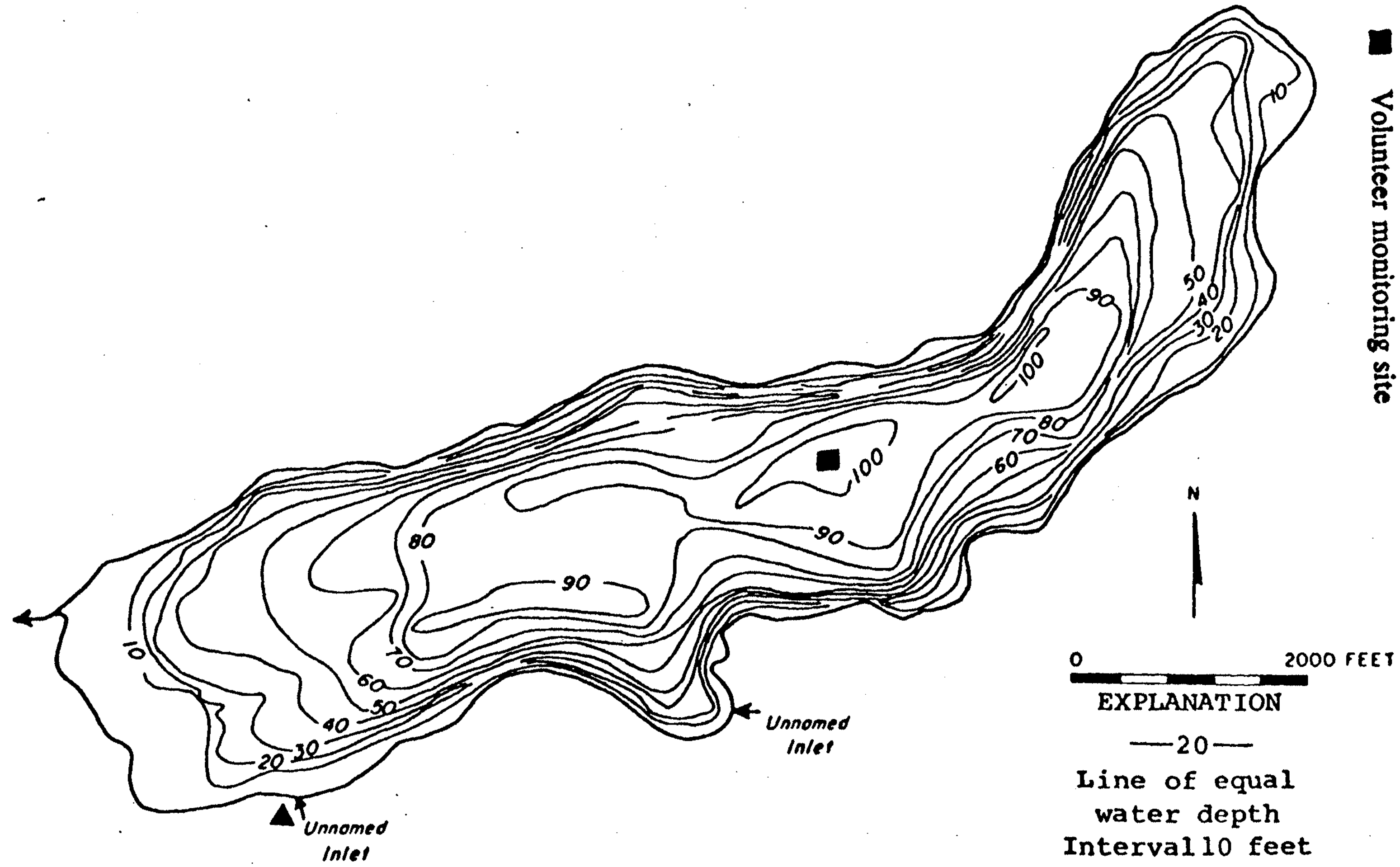
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/31	0.8	15.2	8.1	10.4		1, 3, 5	0.005	0.170
	1.7	15.2	8.0	10.5				
	1.9	15.2	8.0	10.7				
	2.9	15.2	8.0	10.7				
	3.9	15.2	8.0	10.7				
	5.0	15.1	8.0	10.7				
	5.8	15.1	8.1	10.7				
	7.3	14.9	8.2	10.9				
	7.9	14.1	8.3	11.1				
	9.0	13.4	8.3	11.4				
	9.9	13.0	8.3	11.6				
	10.9	12.5	8.3	11.7				
	12.2	10.5	8.2	11.9				
	13.0	9.9	8.2	11.9				
	14.2	8.9	8.2	11.6				
	15.0	8.0	8.2	11.4				
	15.9	7.4	8.1	10.9				
	17.1	7.3	8.1	10.0				
	17.9	7.2	8.1	9.4				
	19.2	7.1	8.1	9.1				
	20.0	7.1	8.0	8.9				
	21.1	7.0	8.0	8.3				
	22.2	6.9	8.0	8.1				
	23.0	6.9	8.0	7.7				
	24.0	6.9	8.0	7.3				
	24.7	6.9	7.9	6.9				
08/23	0.0	20.5	7.0	9.5	59	1, 4, 8	0.015	0.213
	1.0	20.6	7.1	9.2	59			
	2.0	20.6	7.1	9.2	61			
	3.0	20.6	7.1	9.2	63			
	4.0	20.6	7.1	9.1	65			
	5.0	20.7	7.2	9.1	65			
	6.0	20.7	7.2	9.1	65			
	8.0	20.7	7.2	9.1	67			
	9.0	18.8	7.1	9.9	67			
	10.0	15.6	7.0	9.8	69			
	11.0	13.5	6.9	8.0	70			
	12.0	11.6	6.7	5.8	71			
	13.0	10.6	6.4	4.8	71			
	14.0	10.0	6.3	4.0	72			
	16.0	9.0	6.2	3.3	72			
	18.0	8.5	6.1	2.6	73			
	20.0	8.2	6.1	1.7	73			
	21.0	8.0	5.9	1.1	72			

Secchi Depth and Profile Data Graphs







Summit Lake, Thurston County. From Washington Department of Game, June 23, 1952.

Sunday Lake -- Skagit 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

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	48**
Mean Trophic State Index* (Total Phosphorus):	72

* From Carlson (1977)
** See Comments Section

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Sunday Lake is used for fishing, boating, swimming, and rowing. Recreational facilities on the lakeshore include one boat ramp, and only electric motors are allowed on the lake. Currently the watershed is used for logging, crop agriculture, and lakeshore development. In the past, the watershed was used for logging and animal grazing, and the lake was dredged. There are 19 houses on the lakeshore, and all are occupied year-round. The lakeshore is not sewered, and there is one storm drain that empties into the lake. Fish were not reported as being stocked in the lake. Presently there is a community association for the lake. The lake has been chemically treated in the past to control weeds. The worst problems in the lake, in the opinion of the volunteer, are ranked as 1) algae, 2) sediment, 3) aquatic plants, 4) water odors (during heavy algae blooms), 5) fish kill, 6) fish species, 7) water level, and 8) floating debris. Overall, the volunteer finds that Sunday Lake has poor recreational water quality, and suggested that lawn fertilizing practices and septic systems may affect water quality. The volunteer is concerned about possible long-term water quality effects from past development practices.

The volunteer noted that the lake was clean and clear 30 years ago and fish were abundant. Presently, there are definite water quality problems. There are lots of lilies on the north shore in up to ten feet of water. There are wetlands on the east side of the lake near the outlet. Weed growth is heavy over the entire lake. The volunteer reported that the lake did not have algae blooms until the late 1970s.

Sunday Lake -- Skagit County

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity varied considerably and was lowest during July. Profile data collected during June and August 1990 show that on both sampling dates, the lake was thermally stratified and concentrations of dissolved oxygen were depleted from the bottom 2-3 meters of the lake. Dissolved oxygen is usually consumed by bacteria which decompose organic material (such as algae, aquatic plants, and woody debris) in the water and sediments. In August, the decrease in pH and the increase in conductivity with depth is most likely related to increased decomposition near the lake bottom. Concentrations of dissolved oxygen decreased to 2.2 mg/L near the lake bottom in July 1973 (Bortleson *et al.*, 1976) so it is likely that low dissolved oxygen concentrations have been occurring near the lake bottom for many years.

The 1990 concentrations of total phosphorus were very high, especially during June. Nutrient data collected in 1973 were much lower than in 1990; in July 1973, the concentration of total phosphorus was 0.018 mg/L and the concentration of total nitrogen was 0.53 mg/L (Bortleson *et al.*, 1976). Based on these data, in 1973 the lake was mesotrophic, whereas now the lake is most definitely eutrophic.

In 1973, Bortleson *et al.* (1976) reported that the lake had a heavy cover of emergent plants (watershield, lilies, and sedge) and submerged plants (*Chara* and *Elodea*). Fecal coliform bacteria were present in the lake water in 1973 (Bortleson *et al.*, 1976).

Comments

The trophic state indices for the Secchi and total phosphorus data were very different. Because the average water clarity was lower than would be expected given the high concentrations of total phosphorus, it is likely that some factor other than phosphorus is limiting algal growth in Sunday Lake.

Compared to the other nearby lakes monitored for the project in 1990 (Lakes Bosworth, Flowing, Lake Martha, Martha Lake, Panther, Shoecraft, Stevens and Storm), Sunday Lake had the highest concentrations of total phosphorus. Panther Lake and Storm Lake had similar mean summer water clarity as Sunday Lake.

Fifteen lakes monitored for the project in 1990 had worse overall water clarity than Sunday Lake. Only one other lake, though, had a higher concentration of total phosphorus. Lake Kahlotus, in Franklin County, had a total phosphorus trophic state index of 78. Lake Kahlotus is eutrophic from agricultural runoff.

Acknowledgement

I thank Darryl Johnson for volunteering his time to monitor Sunday Lake during 1990.

Sunday Lake -- Skagit County

Volunteer-Collected Data

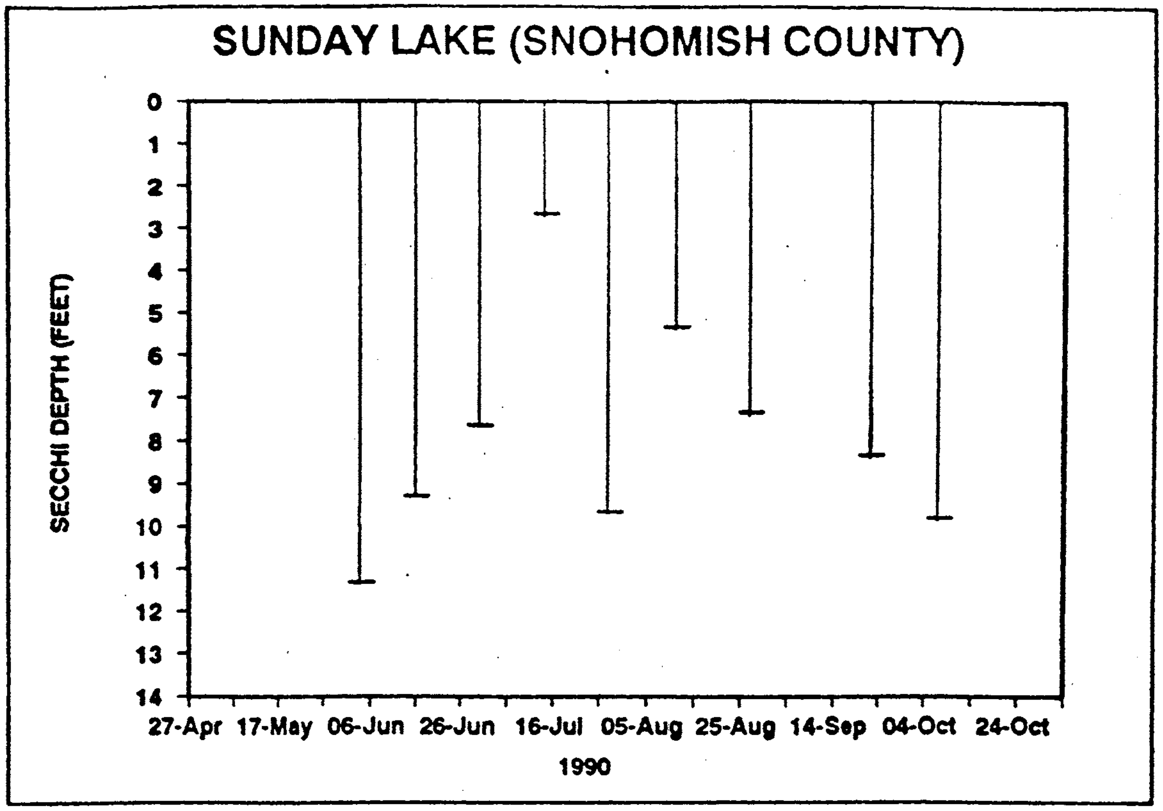
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
05-Jun								11.0		
17-Jun	17.2	63.0	7.0	Lt-Brown	25	Trace		9.0	36.3	Anchored 22'.
01-Jul	21.1	70.0	7.0	Lt-Brown	90	None	Light	7.3	26.0	Anchored at 19'6". Approximately 5 acres cleared of timber above lake.
15-Jul	27.2	81.1	9.0	Gr-Brown	0	None	Light	2.3		Anchored at 19 ft.
29-Jul	23.9	75.0	6.5	Lt-Brown	10	None	Calm	9.3	20.0	
12-Aug	27.2	81.1	7.5	Gr-Brown	0	None	Calm	5.0	16.5	
28-Aug								7.0		
23-Sep	23.9	75.0	7.0	Lt-Brown	100	None	Calm	8.0	12.0	
08-Oct	10.0	50.0	6.5	Lt-Brown		Moderate		9.5	14.0	

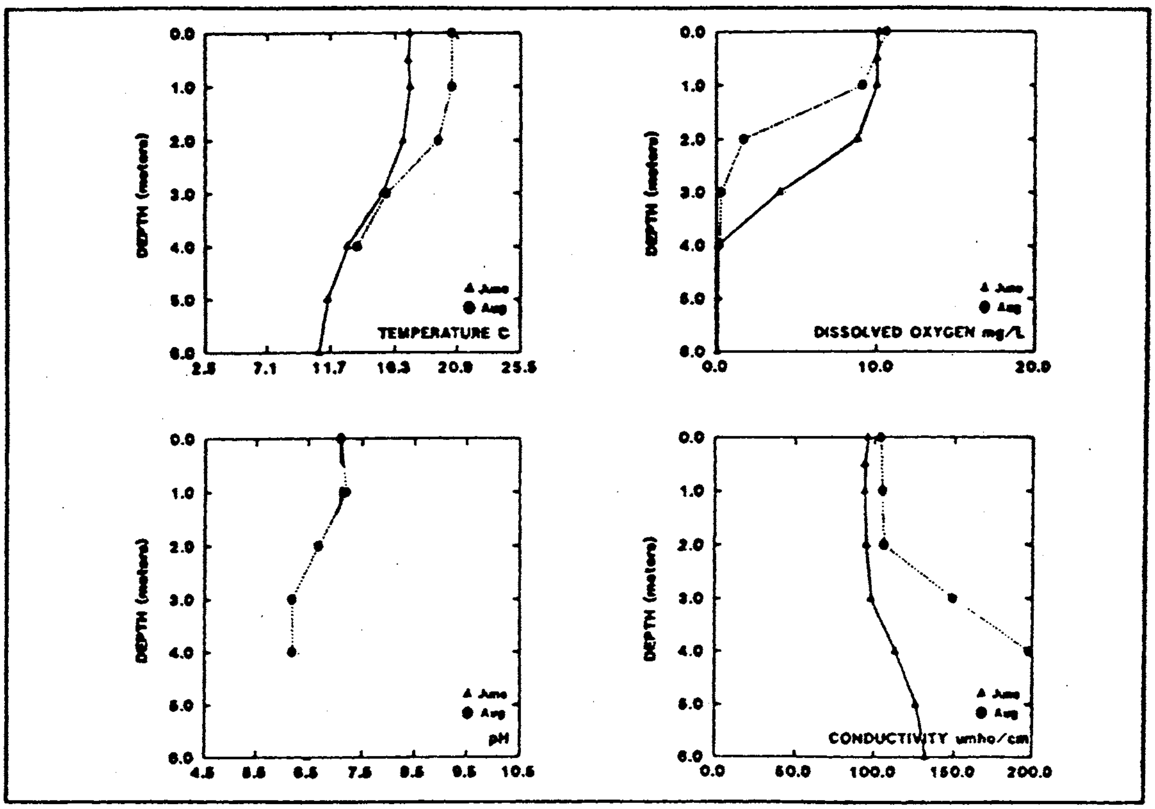
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/05	0.0	17.4	.*	10.1	96	1, 2	0.151	NA
	0.5	17.3	.	10.0	94			
	1.0	17.4	.	10.0	94			
	2.0	16.9	.	8.8	95			
	3.0	15.4	.	3.9	98			
	4.0	12.9	.	0.1	113			
	5.0	11.5	.	0.1	126			
	6.0	10.9	.	0.1	132			
08/28	0.0	20.5	7.1	10.6	104	1, 2	0.071	0.933
	1.0	20.5	7.2	9.1	105			
	2.0	19.5	6.7	1.7	106			
	3.0	15.7	6.2	0.3	149			
	4.0	13.6	6.2	0.2	198			

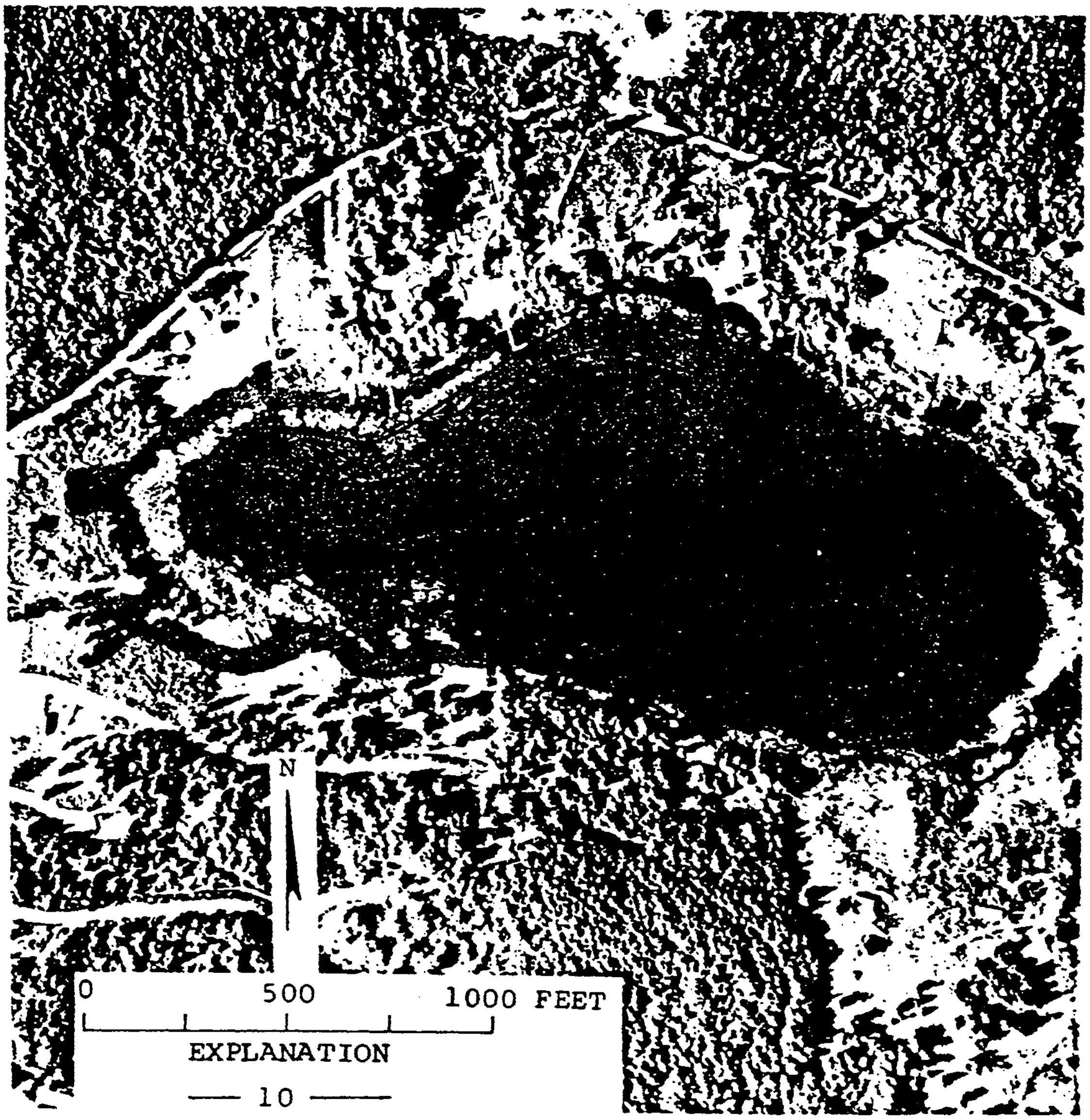
* See Quality Assurance section of this report
NA Data not available; sample not analyzed by laboratory.

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



Line of equal
water depth
Interval 5 feet

Sunday Lake, Snohomish County. Bathymetric map from U.S. Geological Survey, July 27, 1973. Aerial photo, July 14, 1973.

Tanwax Lake -- Pierce County

Tanwax Lake is located 5.5 miles north of Eatonville. It is fed by the Benbow Lakes group and Stidham Lake, and drains via Tanwax Creek to the Nisqually River.

Size (acres)	170
Maximum Depth (feet)	30
Mean Depth (feet)	20
Lake Volume (acre-feet)	3300
Drainage Area (miles^2)	4.1
Altitude (feet)	600
Shoreline Length (miles)	2.8

Estimated Trophic State:	Eutrophic
Mean Trophic State Index* (Secchi):	51
Mean Trophic State Index* (Total Phosphorus):	55

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Tanwax is used for fishing, boating, swimming, rowing, jet skiing, camping, and waterfowl hunting. Recreational facilities on the lakeshore include a picnic area, a camping area, three resorts, and two boat ramps. There is a speed restriction of 8 mph for motorboats within 200 feet of shore. Currently the watershed is used for animal grazing and lakeshore development. Grazing animals have direct access to the lakeshore or inlet tributaries, and animal wastes from agriculture drain into the lake or inlet tributaries. In the past, the watershed was used for logging and crop agriculture, and the shoreline was altered. There are 72 houses on the lakeshore; of these, 33 are occupied year-round. The lakeshore is not sewered, and there are storm drains that empty into the lake. Fish are stocked in the lake. A lake association is presently being formed. The lake has been chemically treated in the past to control fish species. The worst problems in the lake, in the opinion of the volunteer, are 1) water level, and 2) aquatic plants. There are weeds at the outlet. Overall, the volunteer finds that Lake Tanwax has excellent recreational water quality, and suggested that septic systems, development, animals grazing in the watershed, burning of the hillside to clear land, fertilizers, and too many waterfowl may affect water quality.

Resorts on the lake raise german brown trout and rainbow trout in pens. The lake receives heavy recreational use by water skiers and anglers. Stidham Creek drains from Stidham Lake into the northwest side of Lake Tanwax. There are wetlands near the main inlet and the outlet. Among the aquatic plants in the lake are cattails, lilies (white, yellow, and pink-flowering), and irises. Submerged plants are especially thick near the outlet.

Tanwax Lake -- Pierce County

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that the water clarity fluctuated somewhat throughout summer, but was lowest during late August and September. Profile data collected during June and August 1990 show that on both sampling dates, the lake was thermally stratified and concentrations of dissolved oxygen were virtually zero in the bottom 2.5 meters (about 8 feet) of the lake. Dissolved oxygen is usually consumed by bacteria which use oxygen while decomposing organic material (such as algae, aquatic plants and woody debris) in the water and sediments. In August, the decrease in pH and the increase in conductivity with depth is most likely related to increased decomposition near the lake bottom. In 1971, the concentrations of dissolved oxygen decreased to 0.3 mg/L near the bottom of the lake (Bortleson *et al.*, 1976); it is likely that low dissolved oxygen concentrations have been occurring near the bottom of Lake Tanwax for many years.

Tanwax Lake was one of 15 lakes sampled by Ecology in 1990 as part of a statewide lakes survey to supplement volunteer-collected data. The lake was sampled on June 11 and September 10, 1990. Although the lake was thermally stratified on both sampling dates, the concentrations of dissolved oxygen were fairly stable throughout the water column on June 11, whereas the data collected on September 10 and during the onsite visits with the volunteer (June 2 and August 17) indicate that the concentrations of dissolved oxygen decreased considerably from surface to bottom.

The 1990 concentrations of total phosphorus and total nitrogen were high. The June and September data (Coots, 1991) were similar to data collected with the volunteer during August. Nutrient concentrations in 1990 were highest in the samples collected with the volunteer during June. In 1981, the concentration of total phosphorus was 0.030 mg/L and the concentration of total nitrogen was 1.08 mg/L; trophic state parameters (Secchi disk transparency, total phosphorus and chlorophyll *a*) indicated that the lake was eutrophic in 1981 (Sumioka and Dion, 1985). Data collected in 1971 showed that the concentration of total phosphorus was 0.020 mg/L and the concentration of total nitrogen was 0.09 mg/L (Bortleson *et al.*, 1976). The 1971 total phosphorus concentration was in the mesotrophic range.

Comments

Tanwax Lake was one of six Pierce County lakes monitored for the program in 1990. Compared with Lakes Louise, Ohop, Spanaway, Steilacoom, and Whitman, Lake Tanwax had the highest mean concentration of total phosphorus. Lake Steilacoom and Lake Tanwax had the lowest mean summer Secchi depth.

Each of the Tanwax Lake water samples analyzed for nutrients in 1990 were within the range associated with eutrophic lakes. Other eutrophic characteristics of the lake include the anoxic hypolimnion (depleted dissolved oxygen concentrations in the bottom layer of water), and the presence of blue-green algae species. The lake also has a moderately large population of aquatic plants, especially near the outlet.

Acknowledgement

I thank Marsha Erickson for volunteering her time to monitor Lake Tanwax during 1990.

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
19-May	17.0	62.6	7.0	Gr-Brown	50	Moderate	Breezy	5.7 b	0.0	Level of lake-first measurement 18" from the bottom.
02-Jun								5.5		
10-Jun	17.0	62.6	6.5	Gr-Brown	100	Heavy	Gusty	5.5 b	3.0	
30-Jun	23.0	73.4	7.0	Gr-Brown	25	Moderate	Breezy	6.0	-9.5	
28-Jul	24.0	75.2	6.5	Gr-Brown	0	Light	Light	6.0		Heavy Water Skiing.
14-Jul	27.0	80.6	7.0	Gr-Brown	0	None	Calm	7.3		
17-Aug								7.0		
25-Aug	23.0	73.4	7.0	Gr-Brown	50	Light	Calm	5.0	-14.0	Green algae is floating on the surface near shore.
01-Sep	21.0	69.8	7.0	Gr-Brown	90	Trace	Light	4.7	-12.0	
23-Sep	20.0	68.0	6.5	Gr-Brown	100	None	Calm	7.7		Skiers buzzing around.

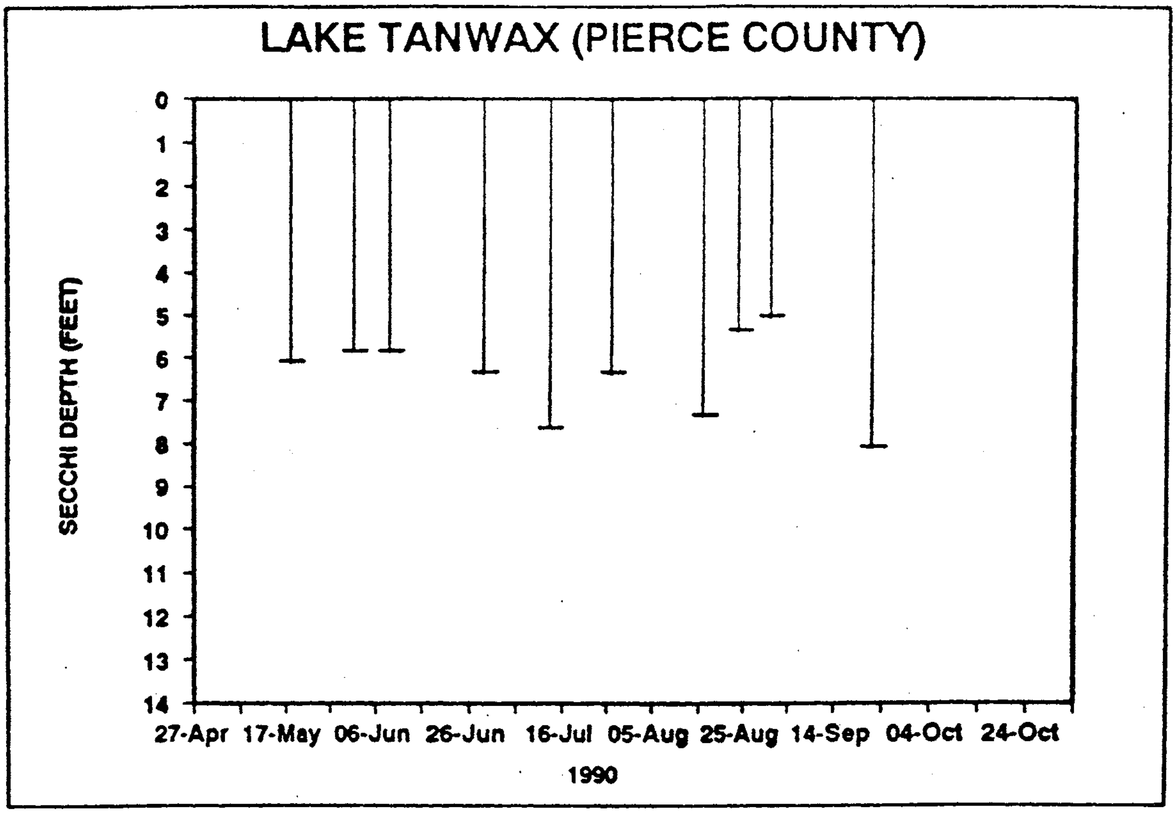
b Secchi disk hit bottom

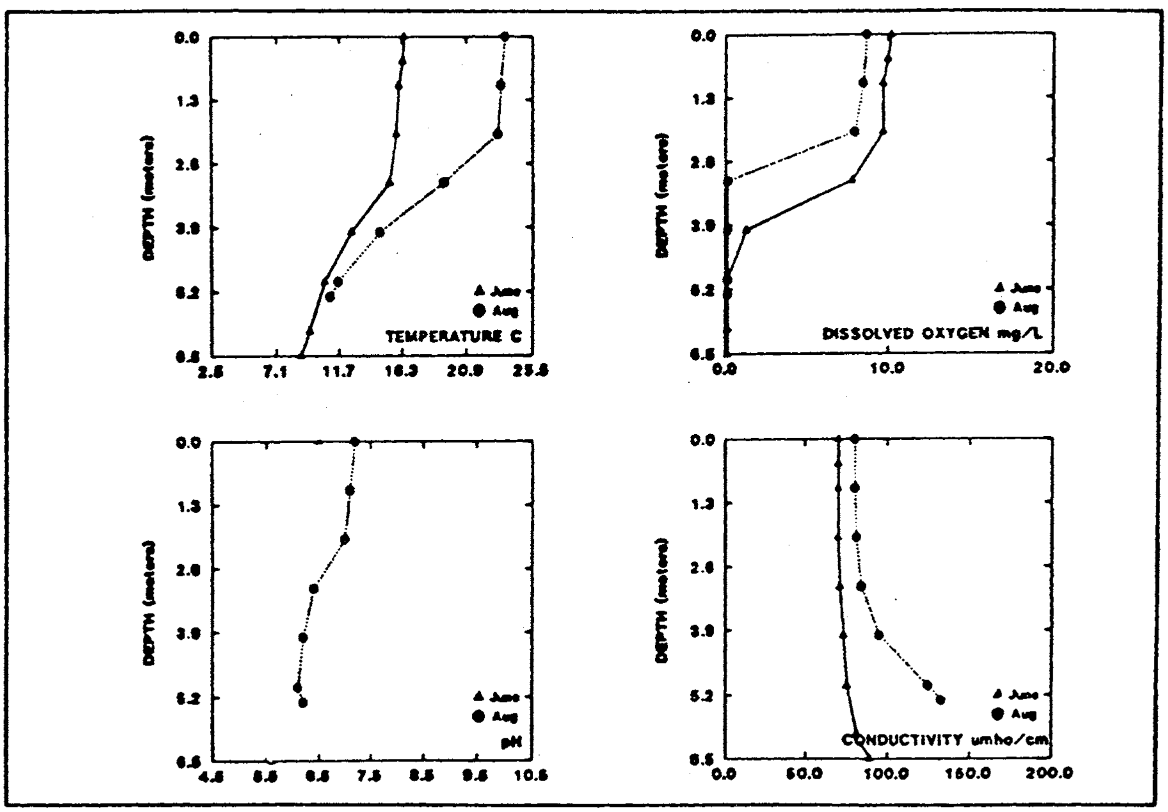
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/02	0.0	16.5	.*	10.2	70	0.5, 2.5	0.038	0.607
	0.5	16.4	.	10.0	70			
	1.0	16.1	.	9.7	70			
	2.0	15.9	.	9.7	70			
	3.0	15.4	.	7.8	71			
	4.0	12.6	.	1.3	73			
	5.0	10.6	.	0.1	75			
	6.0	9.5	.	0.1	81			
	6.5	8.9	.	0.1	89			
08/17	0.0	23.6	7.2	8.7	80	0.5, 1, 2	0.030	0.638
	1.0	23.3	7.1	8.5	80			
	2.0	23.1	7.0	8.0	81			
	3.0	19.3	6.4	0.1	84			
	4.0	14.7	6.2	0.1	95			
	5.0	11.6	6.1	0.1	125			
	5.3	11.0	6.2	0.1	133			

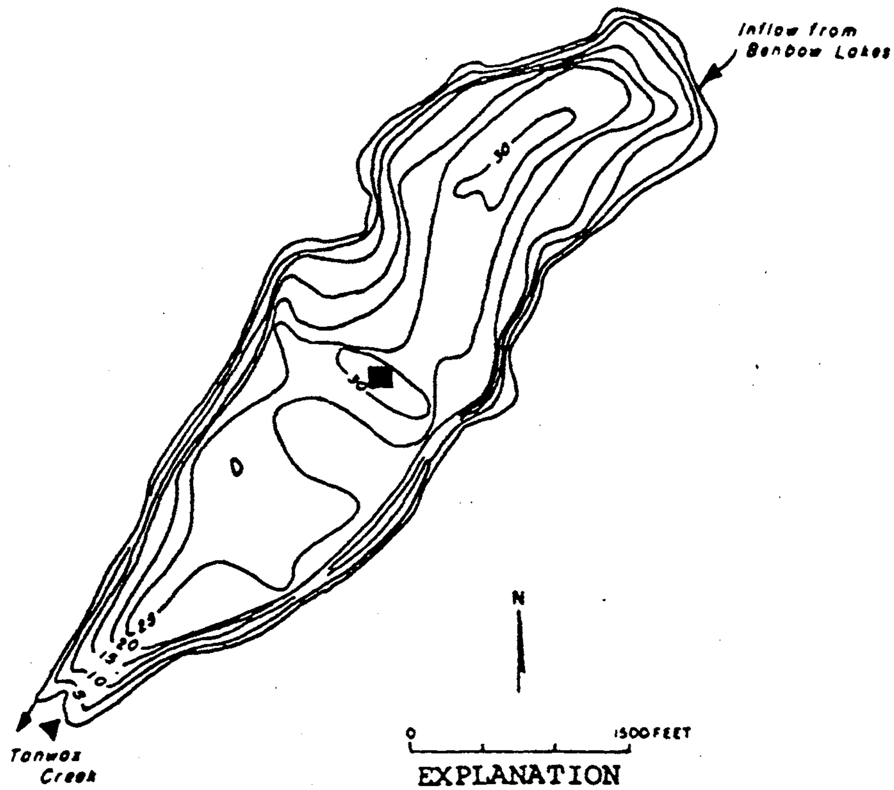
* See Quality Assurance section of this report

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



EXPLANATION

—10—

Line of equal
water depth
Interval 5 feet

Tanwax Lake, Pierce County. From Washington
Department of Game, June 26, 1952.

Lake Thomas -- Stevens County

Lake Thomas is located 17 miles northeast of Colville. Lake Thomas is in the Little Pend Oreille chain of lakes. It is fed by Heritage Lake via a narrow channel, and drains south to Gillette Lake and ultimately to the Little Pend Oreille River. There is no boat ramp on the lake, but it is accessible from the other lakes in the Little Pend Oreille chain.

Size (acres)	170
Maximum Depth (feet)	55
Mean Depth (feet)	23
Lake Volume (acre-feet)	4000
Drainage Area (miles^2)	12.7
Altitude (feet)	3147
Shoreline Length (miles)	3.3

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index* (Secchi):	40
Mean Trophic State Index* (Total Phosphorus):	36

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Thomas is used for fishing, boating, swimming, rowing, jet skiing, and camping. Recreational facilities on the lakeshore include a state park and a camping area, and there are no restrictions for motorboat use on the lake. Currently the watershed is used for logging and lakeshore development. In the past, the watershed was used for logging and mining, and the shoreline was altered. There are 72 houses on the lakeshore; of these, four are occupied year-round. The lakeshore is not sewered. Cutthroat trout and rainbow trout are stocked in the lake. The lake has been chemically treated in the past to control fish species. The worst problems in the lake, in the opinion of the volunteer are 1) aquatic plants, 2) sediment, and 3) floating debris. Overall, the volunteer finds that Lake Thomas has good recreational water quality, and suggested that septic systems, power boats, and litter from boats (cans, cigarette butts, styrofoam cups) may affect water quality.

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.

Lake Thomas -- Stevens County

Monitoring Results/Summary of Other Available Information

Secchi data collected in 1989 and 1990 show that water clarity had the same general pattern during both years (although there was not as much variation between Secchi readings in 1990. Mean water clarity was the same during both years.

Profile data collected during May 1990 show that the lake was thermally stratified and concentrations of dissolved oxygen decreased considerably below the thermocline. The increase in conductivity with depth is most likely related to increased decomposition near the lake bottom. During both 1972 (Dion *et al.*, 1976) and 1981 (Sumioka and Dion, 1985) the concentration of dissolved oxygen was virtually zero near the lake bottom, so it is likely that low dissolved oxygen concentrations near the bottom have been occurring for many years.

The 1990 concentrations of total phosphorus and total nitrogen were low, especially during September. In 1981, the concentration of total phosphorus was 0.020 mg/L and the concentration of total nitrogen was 0.69 mg/L. In 1972, the concentration of total phosphorus was 0.027 mg/L and the concentration of total nitrogen was 1.0 mg/L (Dion *et al.*, 1976). Trophic state indices calculated from 1981 data indicate that the lake was mesotrophic. Data collected during 1990 show that the lake had both oligotrophic and mesotrophic characteristics. Oligotrophic characteristics of the lake were the low concentrations of total phosphorus and the high water clarity, although the clarity was borderline between oligotrophy and mesotrophy. Mesotrophic characteristics of the lake were the very low concentrations of dissolved oxygen near the bottom of the lake and the moderately high amount of aquatic plant growth around the lake.

Water quality variance records with Ecology show that in 1989 about two acres of the lake were treated with Rodeo to control water lily and water shield. An application for a water quality variance permit to apply aquatic herbicides in Lake Thomas was denied in 1990.

During the September 1990 onsite visit with the volunteer, a slight odor of hydrogen sulfide (rotten-egg smell) was detected in the water. Pondweed (*Potamogeton praelongus*), Eurasian milfoil (*Myriophyllum spicatum*), and white-flowering lily (*Nymphaea* spp.) were identified during the visit. Also, the alga *Nitella* was identified. Freshwater jellyfish, which are relatively rare, were observed in the water.

Comments

Of the 74 lakes monitored for the program in 1990, only four lakes (Chelan, Bosworth, Mason and Whatcom) had lower concentrations of total phosphorus than Lake Thomas.

Lake Thomas is one of seven Stevens County lakes monitored for the program in 1990. Compared to Black, Deep, Deer, Leo, Starvation, and Waitts Lakes, Lake Thomas had moderate water clarity but had the lowest mean concentration of total phosphorus. Lake Leo, which is upstream in the Little Pend Oreille chain of lakes, had similar water clarity but slightly higher concentrations of total phosphorus. It is possible that phosphorus is trapped in Lake Leo, due to the morphology of the watershed. This may result in reduced phosphorus loading to Lake Thomas. Dissolved oxygen concentrations at Lake Leo also decreased considerably below the thermocline.

Acknowledgements

I thank Ray Hawk, Robert Strauss and Carolyn Lerman for volunteering their time to monitor Lake Thomas during 1989-1990.

Lake Thomas -- Stevens County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
16-May	8.3	47.0	7.5	Yellow-Gr	100	Heavy	Light	10.1	0.0	Water color: yellow green. Lake height of 0 reference point as of today.
30-May	14.4	58.0	7.0	Green-ochre		75	HeaBreezy		11.0	3.0
13-Jun	12.2	54.0	7.0	Lt-Olive	100	Heavy	Light	11.0	3.0	
28-Jun	20.0	68.0	7.0	YellowGold	90	None		11.9	-1.0	
12-Jul	23.3	74.0	7.0	YellowGold	10	None	Light	13.7	-2.7	
27-Jul	21.1	70.0		YellowGold	50	Heavy		11.9**	-2.6	Past 3 days very stormy, heavy rain and wind. Lots of waves.
07-Aug	23.3	74.0	6.5	Lt-Olive	0	None	Light	12.1	-6.3	
23-Aug	20.8	69.5	6.5	Yellow-Gr	25	None	Light	10.5		Do not use sunglasses.
05-Sep	20.0	68.0	6.5	Yellow-Gr	0	None	Breezy	13.3		Do not wear dark glasses during observations on Secchi/pH/or water color.
10-Sep	20.6	69.0	6.5	Lt-Green	0	None	Light	13.7		Readings coincided with Dave Hallock's visit.
25-Sep	17.8	64.0	6.5	Lt-Sand	0	None	Light	16.5	-6.0	
10-Oct	11.1	52.0	7.0	Lt-Olive	25	Moderate	Light	11.9	-6.5	
24-Oct	*8.3	47.0	7.0	YellowGold	0	Moderate	Light	11.9**	-5.3	2.25" snow on 10/21. This has melted and with rain on 10/22 lake height rose 1.5" . Lake appears turbid, more than usual.

* Secchi data corrected for rope shrinkage

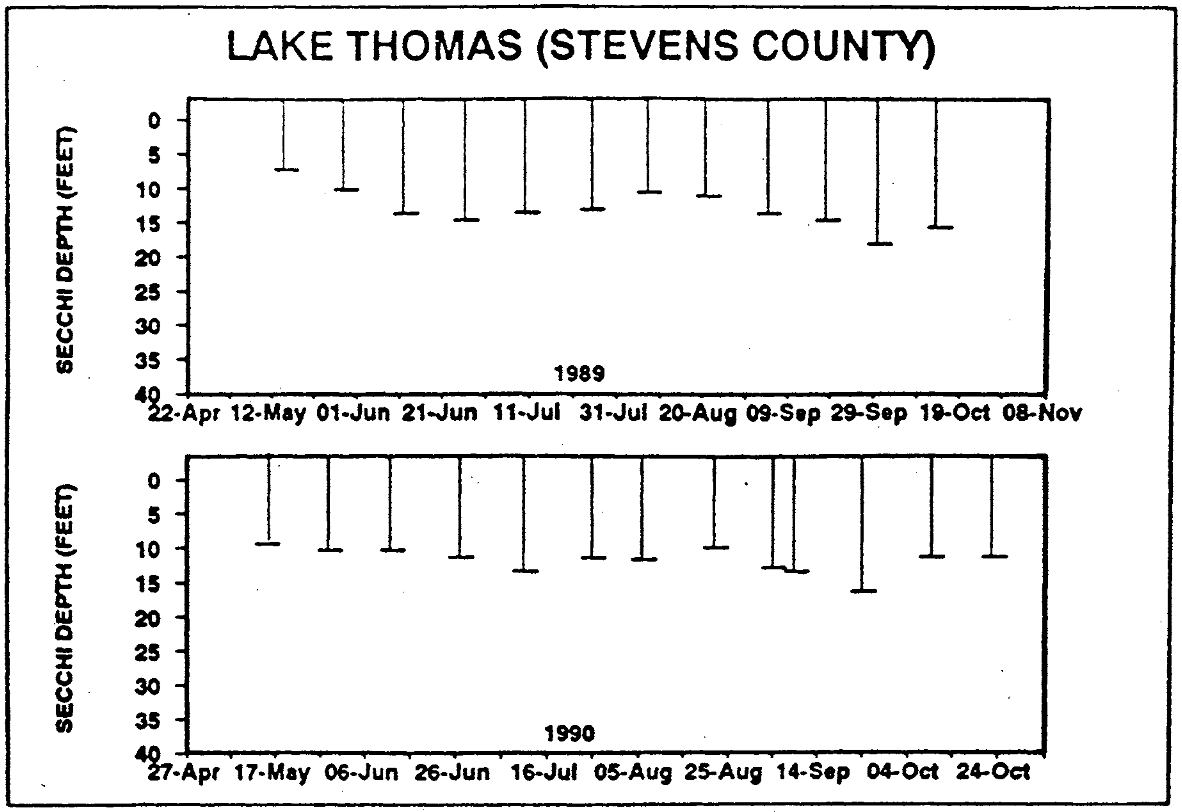
** There was high variability between the first and second Secchi depths collected; these data points may not be used in data comparisons.

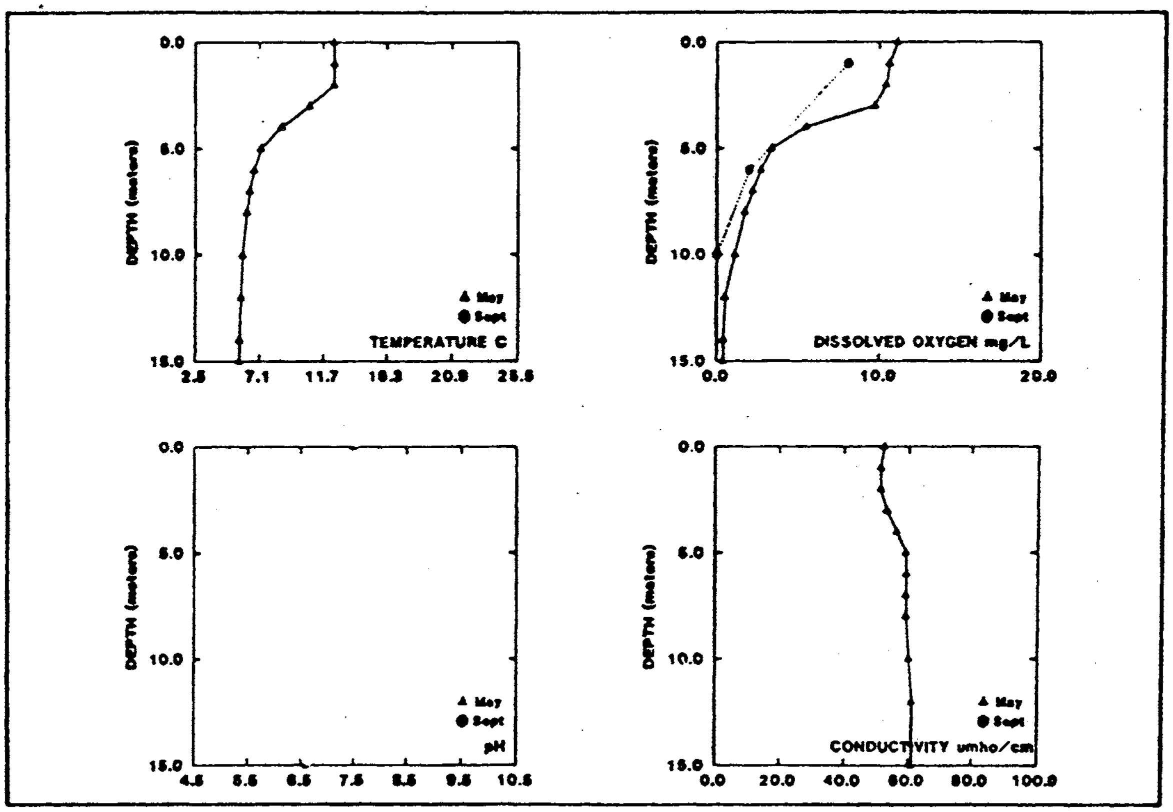
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/25	0.0	12.5	.*	11.1	52	0.5, 1, 2	0.011	0.285
	1.0	12.5	.	10.6	51			
	2.0	12.5	.	10.4	51			
	3.0	10.7	.	9.7	53			
	4.0	8.7	.	5.5	56			
	5.0	7.2	.	3.4	59			
	6.0	6.7	.	2.7	59			
	7.0	6.4	.	2.2	59			
	8.0	6.2	.	1.7	59			
	10.0	5.9	.	1.1	60			
	12.0	5.8	.	0.5	61			
	14.0	5.7	.	0.4	61			
	15.0	5.7	.	0.4	61			
09/10	1.0	.	.	8.1	.	1, 2, 3	0.007	0.273
	6.0	.	.	2.0	.			
	10.0	.	.	0.0				

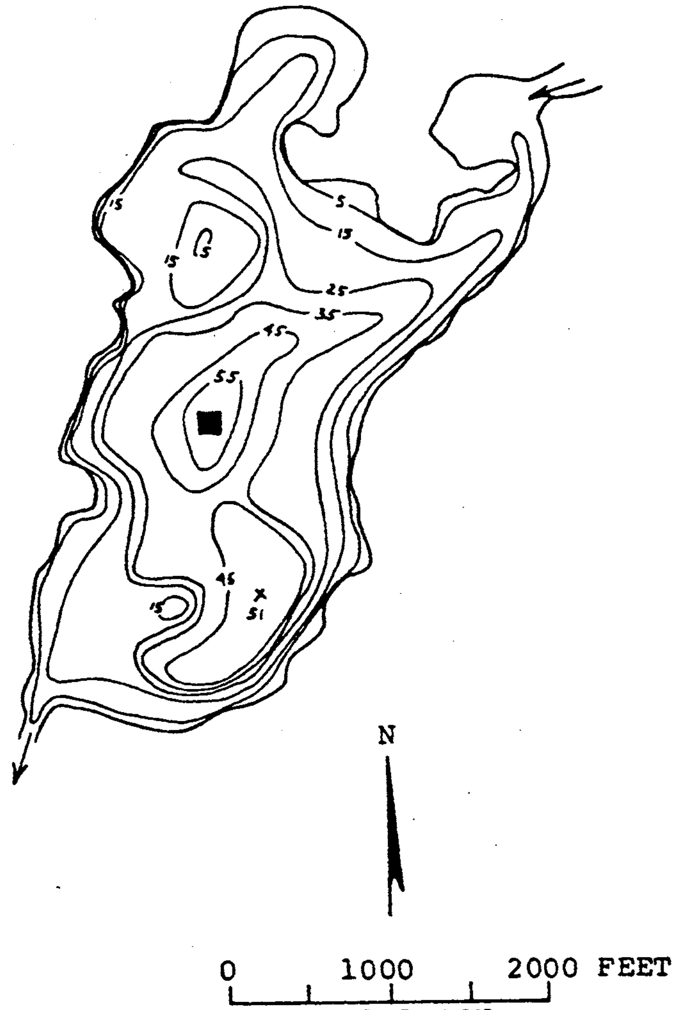
* See Quality Assurance Section of this report.

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



EXPLANATION

—— 15 ——

Line of equal
water depth
Interval 10 feet

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

North Twin Lake -- Ferry County

North Twin Lake is located about eight miles north of Inchelium. A dam built in 1963 raised the original lake level about ten feet and connected North and South Twin Lakes. North Twin Lake is fed principally by Granite Creek, and drains via Stranger Creek to Lake Roosevelt. The following information apply to North Twin Lake only.

Size (acres)	744
Maximum Depth (feet)	57
Mean Depth (feet)	*
Lake Volume (acre-feet)	*
Drainage Area (miles^2)	*
Altitude (feet)	2572
Shoreline Length (miles)	*

* information not available

Estimated Trophic State:	Mesotrophic**
Mean Trophic State Index*** (Secchi):	31
Mean Trophic State Index*** (Total Phosphorus):	41

** See Comments Section
*** From Carlson

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Twin Lake is used for fishing, boating, swimming, rowing, jet skiing, camping, and waterfowl hunting. Recreational facilities on the lakeshore include a picnic area, a camping area, a beach, three resorts, and three boat ramps. There are no restrictions for motorboat use on the lake. Lake water is withdrawn for irrigation. Currently the watershed is used for logging, animal grazing, and lakeshore development. Grazing animals have direct access to the lakeshore or inlet tributaries. In the past, the watershed was used for logging, animal grazing, and crop agriculture, the lake was dredged and the shoreline was altered. There are approximately 15 houses on the lakeshore; of these, five are occupied year-round. The lakeshore is not sewered. Brook trout and rainbow trout are stocked in the lake. The lake will be drawn down during the winter to freeze the roots of lakeshore weeds. The worst problems in the lake, in the opinion of the volunteer, are 1) fish parasites, 2) water level, and 3) aquatic plants. Overall, the volunteer finds that North Twin Lake has excellent recreational water quality, and suggested that logging and destruction of the upper watershed may affect water quality.

Cattails grow along the north side of the lake near Boss Creek. Submerged plants ("tooleys") grow along the majority of the shore in shallow water. There were two beaver lodges, one on the west side and the other in the southeast cove. In shallow water at the south end of the lake near the outlet, there are levy piles and aquatic plants.

In the fall of 1989, lake management activities conducted by the Washington Water Research Center (WWRC) included drawing down the lake level and dredging near the passage between the north and south basins of the lake.

<u>Monitoring Results/Summary of Other Available Information</u>

There were not enough Secchi data collected to evaluate patterns in water clarity. Profile data collected during May and September 1990 show that on both sampling dates the lake was thermally stratified. The decrease in pH and increase in conductivity with depth is most likely related to increased decomposition near the lake bottom. Data collected in 1968 indicate that Secchi transparency was about 16.5 feet, and dissolved oxygen was depleted near the bottom of the lake (Lee, 1969).

The 1990 concentrations of total phosphorus and total nitrogen were moderately high during May, but low during September.

From WWRC (1988): Both North and South Twin Lakes were studied by WSU in 1985 to determine the current water quality of the lakes and their inlets, outlets, and potable water wells and to propose remedial actions to maintain or improve water quality. Prolific growth of aquatic plants and the presence of blue-green algae indicated declining water quality in the lakes. The WWRC identified internal recycling of nutrients as the primary source of nutrient loading into the lakes. Other sources identified include septic tank drainfields, soil erosion from logging operations, and cattle grazing within the watersheds. Drawing down the lake level during winter was proposed to economically control rooted plants by exposing and freezing roots during winter.

During the September 1990 onsite visit with the volunteer, there was a mild bloom of the blue-green alga *Gloeotrichia*. The volunteer reported at the time that the lake was cleaner and had less weeds than 15 years ago. Aquatic plants identified in the lake during the onsite visit include: American elodea (*Elodea canadensis*), tapegrass (*Vallisneria americana*), pondweeds (*Potamogeton robbinsii* and *P. amplifolius*), watershield (*Brasenia schreberi*), *Najas*, milfoil (*Myriophyllum* spp.), and yellow-flowering lily (*Nuphar polysepalum*). Clumps of a filamentous green alga (*Spirogyra*) about one to two feet in diameter were observed on the bottom of the lake near the channel area.

Except for the resort, the lakeshore was undeveloped in 1968 (Lee, 1968).

North Twin Lake -- Ferry County

Comments

As in 1989, the Secchi data suggest that Twin Lake was oligotrophic. Although blue-green algae species and prolific aquatic plant growth in the lake prompted restoration work, the few Secchi readings collected by the volunteer indicate that the lake has relatively good water clarity. It is apparent, then, that either water clarity is not a good indicator of trophic status in North Twin Lake, or more Secchi depth readings are needed to adequately represent the mean summer water clarity.

The total phosphorus trophic state index was calculated from the mean (average) of the May and September total phosphorus concentrations. Although this mean value is borderline between oligotrophy and mesotrophy, the May value was clearly in the mesotrophic range. Also, the low dissolved oxygen concentrations below the thermocline are not characteristic of oligotrophic lakes. Based on the total phosphorus concentrations and the moderately high amount of aquatic plant growth in North Twin Lake, the lake was estimated as mesotrophic.

Acknowledgement

I thank Scott Charbonneau for volunteering his time to monitor Twin Lake during 1989-1990.

North Twin Lake -- Ferry County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
31-May	14.0	57.2	6.5	Green	100	Heavy	Light	29.9		Pine pollen on /in surface.
18-Jul	23.0	73.4	6.5	Green	0	None	Light	19.3		
13-Sep	17.2	63.0	6.5	Green		None	Calm	28.4		Small floating bubbles on surface. Some below surface particles in water.

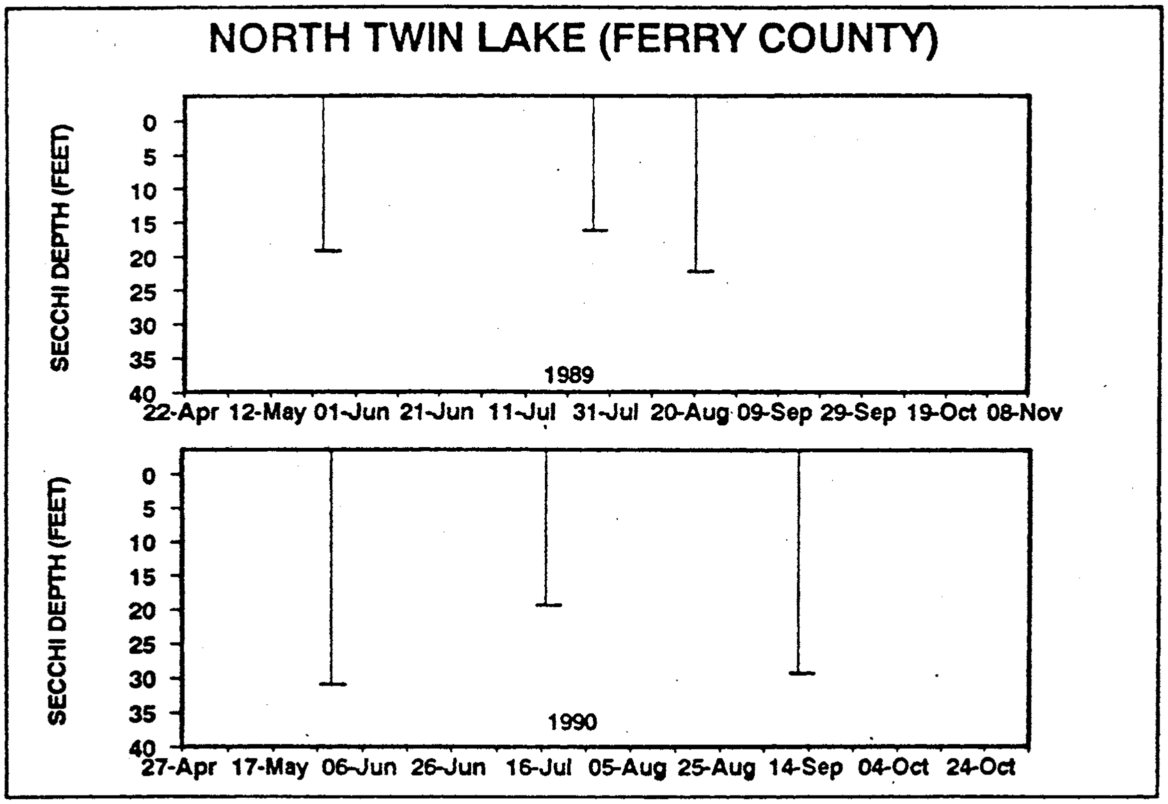
* Secchi data corrected for rope shrinkage

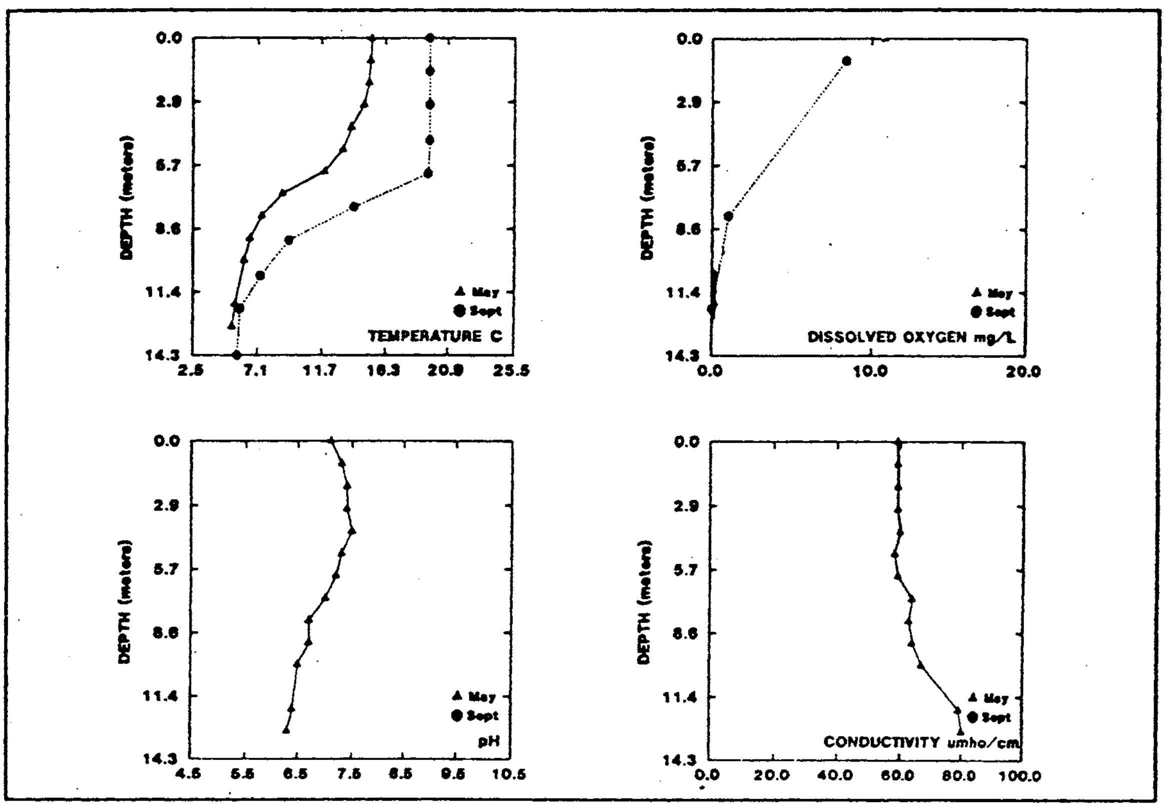
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/31	0.0	15.3	7.1	.*	59	1, 2, 3	0.019	0.361
	1.0	15.2	7.3	.	59			
	2.0	15.1	7.4	.	59			
	3.0	14.7	7.4	.	59			
	4.0	13.8	7.5	.	60			
	5.0	13.2	7.3	.	58			
	6.0	11.9	7.2	.	59			
	7.0	8.9	7.0	.	64			
	8.0	7.4	6.7	.	63			
	9.0	6.5	6.7	.	64			
	10.0	6.1	6.5	.	67			
	12.0	5.4	6.4	.	79			
	13.0	5.2	6.3	.	80			
09/13	0.0	19.6	.	.	.	1, 3, 5	0.007	0.319
	1.0	.	.	8.4	.			
	1.5	19.6	.	.	.			
	3.0	19.6	.	.	.			
	4.6	19.6	.	.	.			
	6.1	19.5	.	.	.			
	7.6	14.0	.	.	.			
	8.0	.	.	1.0	.			
	9.1	9.4	.	.	.			
	10.7	7.3	.	.	.			
	12.2	5.8	.	0.0	.			
	14.3	5.6	.	.	.			

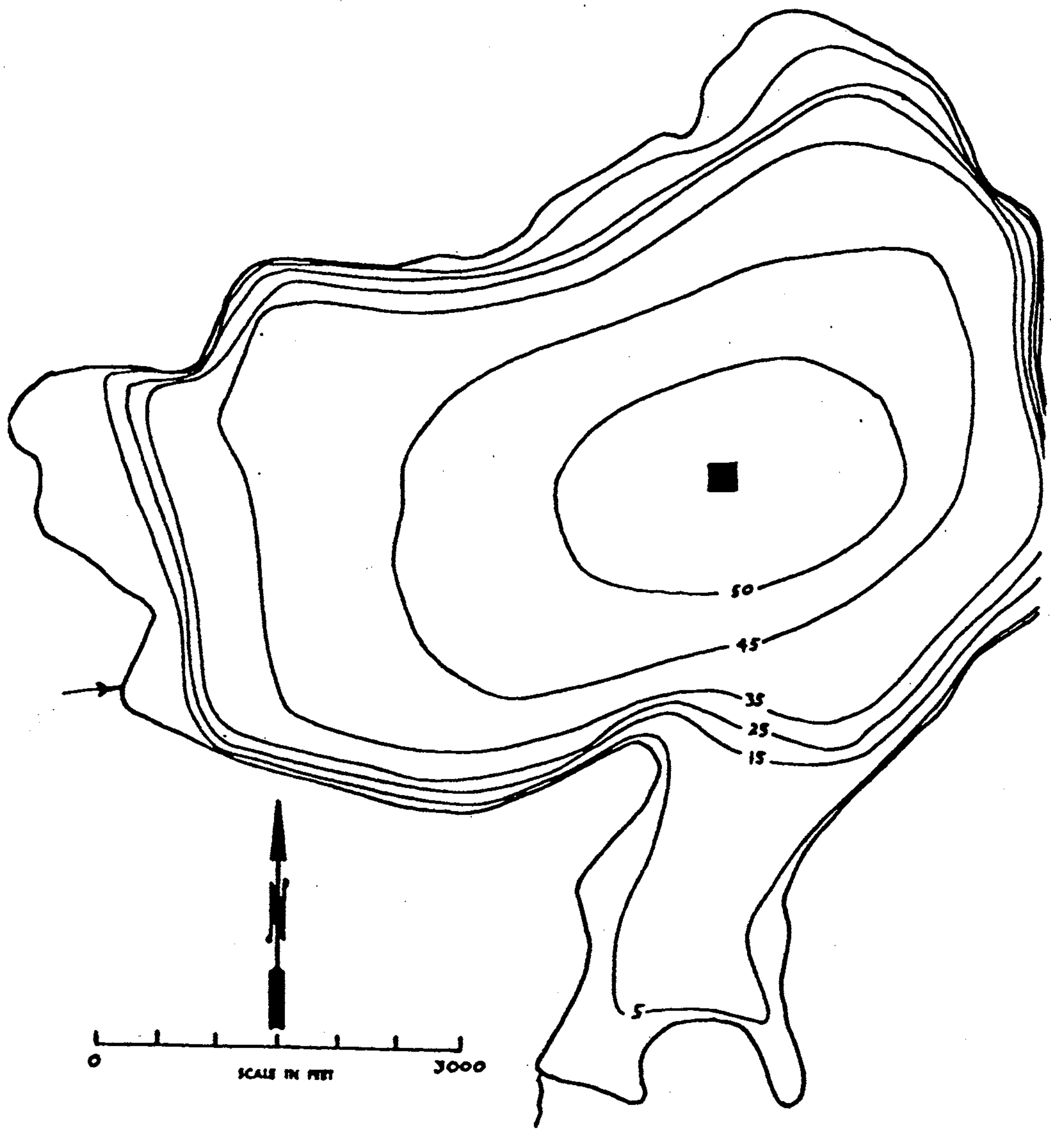
* See Quality Assurance section of this report.

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



NORTH TWIN LAKE — FERRY COUNTY
T 32 N — R 35 E — Secs 9-10-11-15
884.0 Surface Acres
Surv. 13 Feb. 1954—State Dept of Game
Volume—28,284 Acre Feet

Vancouver Lake -- Clark County

Vancouver Lake is located three miles northwest of Vancouver. It is about three miles long and two miles wide, and is on a flood plain of the Columbia River. It is fed by Burnt Bridge Creek and drains via Lake River to the Columbia River. During periods of tidal inflow, the direction of flow in Lake River is reversed, and water flows into Vancouver Lake.

Size (acres)	2858
Maximum Depth (feet)	*
Mean Depth (feet)	*
Lake Volume (acre-feet)	*
Drainage Area (miles^2)	*
Altitude (feet)	9
Shoreline Length (miles)	*

* information not available

Estimated Trophic State:	Eutrophic
Mean Trophic State Index** (Secchi):	73
Trophic State Index** (Total Phosphorus):	65

** From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The questionnaire on lake and watershed uses was not returned.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity was lowest during July and August. Profile data collected during June 1990 show that the lake was weakly stratified with respect to temperature, and that pH, dissolved oxygen and conductivity were fairly stable from surface to bottom. The concentration of total phosphorus (0.0664 mg/L) was high.

From Port of Vancouver, 1976: Past studies showed that Vancouver Lake had high levels of bacteriological pollution, excessive organic and inorganic nutrients, blue-green algae, weeds, sediment and other water quality problems attributed largely to pollutant loads carried by the lake's major tributaries. Data collected in 1967-1968 showed that the blue-green algae *Aphanizomenon flos-aquae* was the dominant form of algae, and blue-green algae counts were as high as 8500/mL during August. Phosphorus concentrations averaged 0.230 mg/L. Although the lake is very shallow (from 1-4 feet deep), which makes it susceptible to wind mixing, concentrations of dissolved oxygen were very low, even at the surface (5.7 mg/L was measured at the surface). In 1967, data collected by Bhagat and

Vancouver Lake -- Clark County

Funk showed orthophosphorus concentrations as high as 1.6 mg/L and total Kjeldahl nitrogen as high as 8.68 mg/L.

Comments

Vancouver Lake was the shallowest lake that was monitored for the program in 1990. Of the 73 lakes monitored during 1990, Vancouver Lake also had the lowest mean summer water clarity, although Lake Kahlotus in Franklin County and Sunday Lake in Snohomish County had higher mean concentrations of total phosphorus than Vancouver Lake.

Acknowledgement

I thank Ray Lavasseur for volunteering his time to monitor Vancouver Lake during 1990.

Vancouver Lake -- Clark County

Volunteer-Collected Data

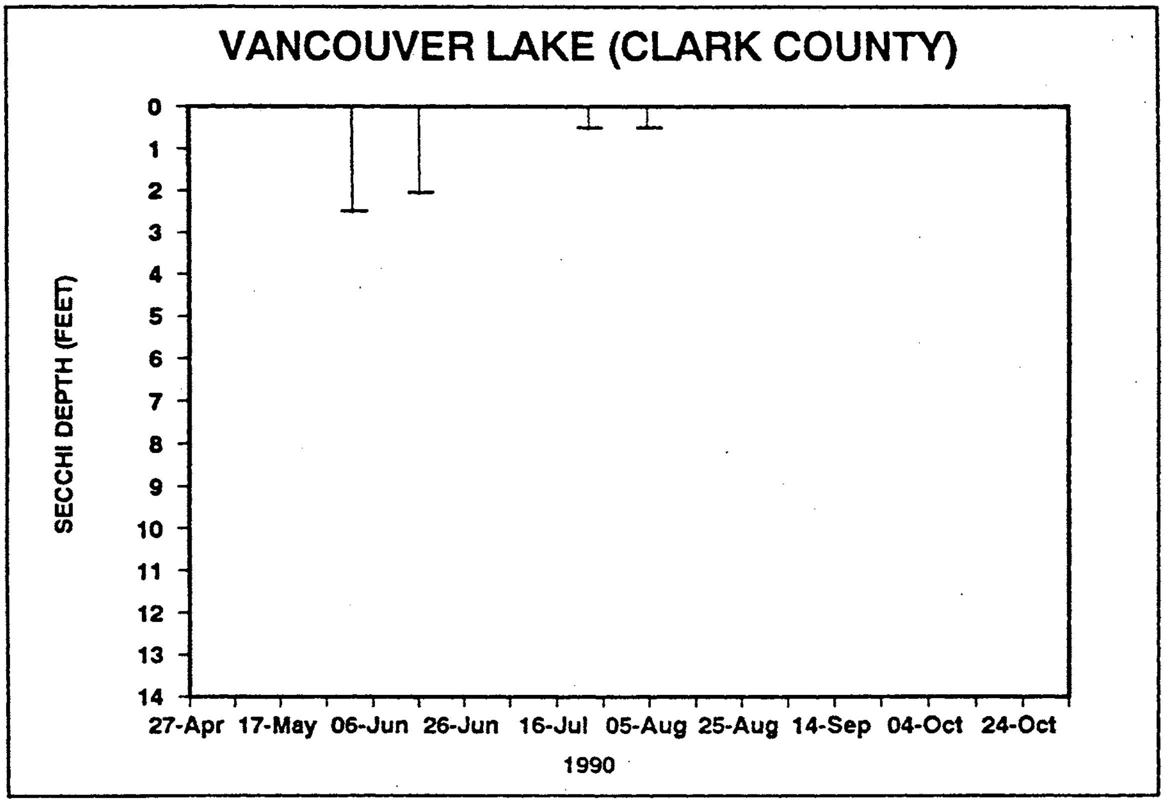
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
03-Jun	15.0	59.0	6.5	Green	90			2.5		
17-Jun	17.2	63.0	6.0	Green	0	Trace	Calm	2.0	17.0	
24-Jul	24.0	75.2	6.5	Gr-Brown	100	None	Light	0.5	12.0	
06-Aug	24.0	75.2	6.5	Green	0	None	Breezy	0.5	10.0	

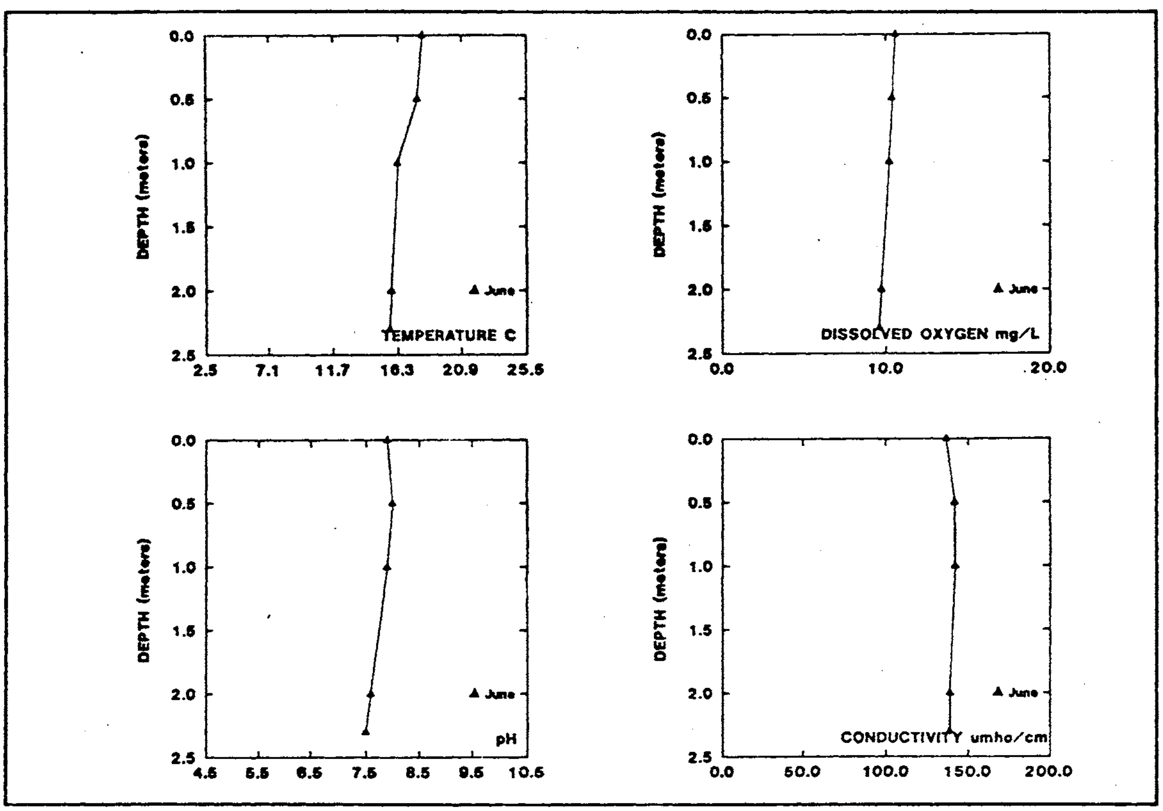
Onsite Visit Data

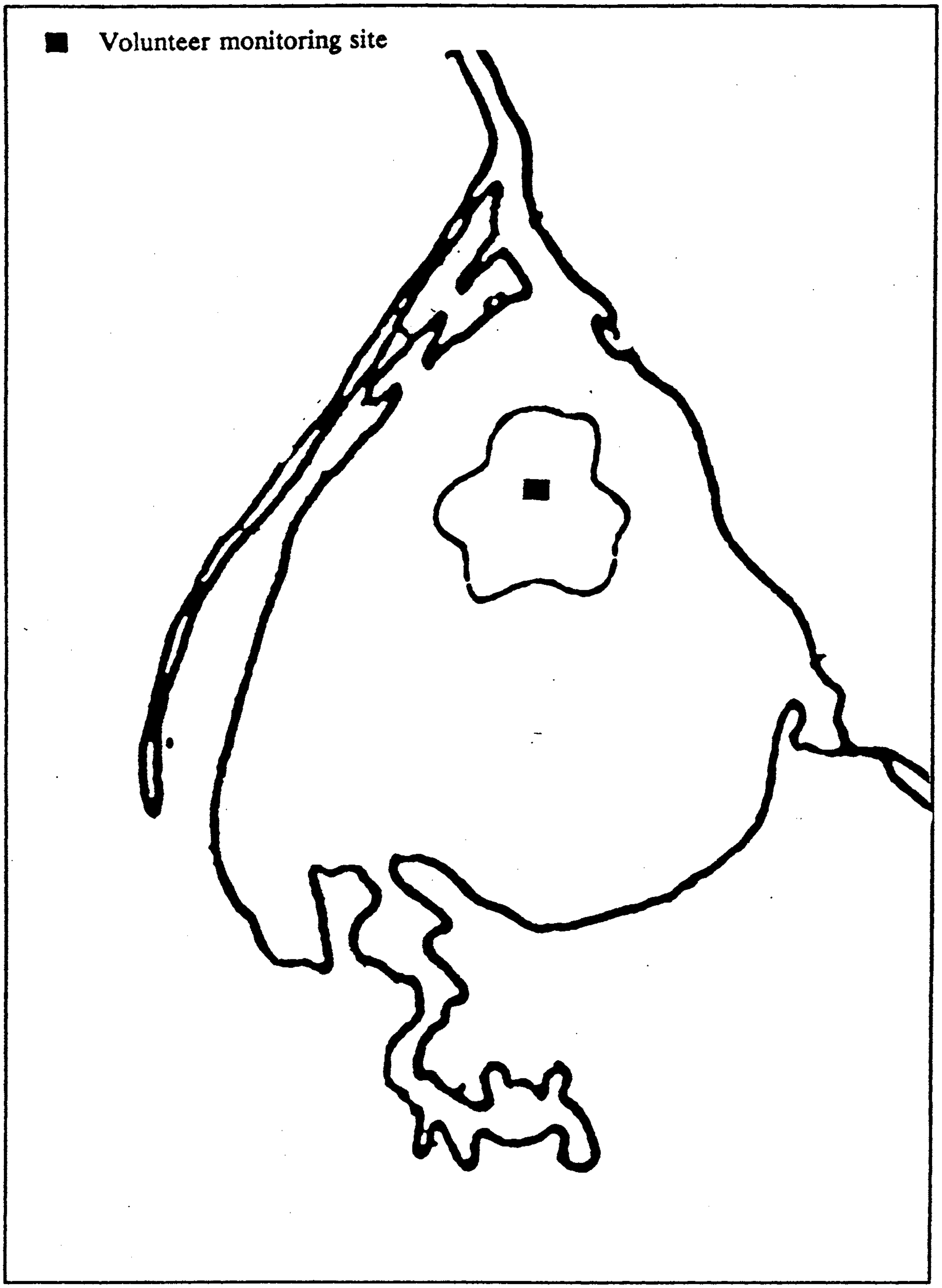
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/26	0.0	18.1	7.9	10.6	137	*	0.066	0.307
	0.5	17.7	8.0	10.4	142			
	1.0	16.3	7.9	10.2	142			
	2.0	15.8	7.6	9.7	139			
	2.3	15.7	7.5	9.6	139			

* unknown

Secchi Depth and Profile Data Graphs






Volunteer monitoring site

Waitts Lake -- Stevens County

Waitts Lake is located seven miles south of Chewelah, and 2.5 miles west of Valley. It is a reservoir stabilized by a low dam built in 1927. It is fed by two creeks and drains east via an unnamed creek about two miles to the Colville River.

Size (acres)	472
Maximum Depth (feet)	68
Mean Depth (feet)	40
Lake Volume (acre-feet)	18,784.
Drainage Area (miles^2)	11.7
Altitude (feet)	1946
Shoreline Length (miles)	3.3

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index* (Secchi):	36
Trophic State Index* (Total Phosphorus):	44

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Waitts Lake is used for fishing, boating, swimming, rowing, jet skiing, camping, and waterfowl hunting. Recreational facilities on the lakeshore include three resorts and one boat ramp, and there are no restrictions for motorboat use on the lake. Currently the watershed is used for logging, animal grazing, and crop agriculture. Grazing animals have direct access to the lakeshore or inlet tributaries. In the past, the watershed was used for logging, animal grazing, and crop agriculture, and the shoreline was altered. Lakeshore residences are not sewered. Brown trout are stocked in the lake. Presently there is a community association for the lake. The lake has been chemically treated in the past to control fish species. The worst problem in the lake, in the opinion of the volunteer, was aquatic plants. Overall, the volunteer finds that Waitts Lake has good recreational water quality, and suggested that septic tanks may affect water quality.

There are wetlands on the northwest end, and particularly on the south end 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.

According to the volunteer, many grebes have nested near the lake for the past two years, although the duck population has diminished drastically in the past two years. There is a large mud hen population, and a large variety of migratory waterfowl.

Waitts Lake -- Stevens County

Presently, no additional development is allowed because of restrictions on installing septic systems. Sewering the lakeshore has been proposed.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity was lowest during May and June, and gradually increased over summer. Profile data collected during August 1990 show that the lake was thermally stratified, and concentrations of dissolved oxygen were virtually depleted in the bottom four meters (about 13 feet) of the lake. The increase in dissolved oxygen from 5-7 meters may be from increased algae growth at this depth, but may also be due to cooler water temperatures, since oxygen is more soluble in cooler water. Low oxygen usually results from decomposition of organic material (such as algae and aquatic plants) in the water and sediments. The increase in conductivity and the decrease in pH with depth is most likely related to decomposition near the lake bottom. In both 1981 and 1974, concentrations of dissolved oxygen were also depleted near the lake bottom (Sumioka and Dion, 1985; Dion *et al.*, 1976), so it is likely that low dissolved oxygen concentrations have been occurring in Waitts Lake for many years.

The 1990 concentrations of total phosphorus and total nitrogen (0.0155 and 0.469 mg/L, respectively) were moderately high. The concentrations found in 1990 were similar to concentrations found in 1981 (0.020 mg/L; Sumioka and Dion, 1985) and 1974 (0.017 mg/L; Dion *et al.*, 1976). Total nitrogen was 0.69 mg/L in 1981 and 0.35 mg/L in 1974.

Waitts Lake was one of 15 lakes sampled by Ecology during June and September 1990 as part of a statewide lakes survey to supplement volunteer-collected data (Coots, 1991). Profile data collected were very similar to profile data collected with the volunteer during August 1990. Total phosphorus concentrations from both June and September, though, were considerably lower than the concentration in the sample collected with the volunteer during August. The total nitrogen concentration in the sample collected with the volunteer was also higher than the concentrations in the statewide survey. It is likely that the higher nutrient concentrations in the onsite visit samples resulted from having the composite sample include a depth from the metalimnion (4.5 meters). In a stratified lake, nutrient concentrations are usually higher in the metalimnion (middle layer of water) than in the epilimnion (upper layer).

In 1974, algal density was moderately high, hydrogen sulfide (rotten-egg smell) was detected in the hypolimnion, and very few submersed aquatic plants were observed (Dion *et al.*, 1976).

During the August 1990 onsite visit with the volunteer, pondweed (*Potamogeton illinoensis*) was identified. This plant has both submerged and floating leaves. The floating leaves are long, and the flowers appear on cylindrical spikes that emerge from the water. There was extensive growth of the alga *Nitella* near the volunteer's house. Coots, turtles, mallards, and grebes were also observed.

Comments

Waitts Lake exhibited both oligotrophic and eutrophic characteristics. Oligotrophic characteristics include the relatively good water clarity, and relatively low concentrations of total phosphorus and chlorophyll *a* found during June and September. Eutrophic characteristics of Waitts Lake are the extremely low concentrations of dissolved oxygen near the lake bottom and the presence of blue-green algae species noted during September. Because Waitts Lake exhibited both oligotrophic and mesotrophic characteristics, the lake was estimated as oligo-mesotrophic.

Waitts Lake was one of seven Stevens County lakes monitored for the program in 1990. Compared with Black, Deep, Deer, Leo, Starvation, and Thomas Lakes, Waitts Lake had the greatest water clarity.

Acknowledgement

I thank Beth and Jack Pulliam for volunteering their time to monitor Waitts Lake during 1990.

Waitts Lake -- Stevens County

Volunteer-Collected Data

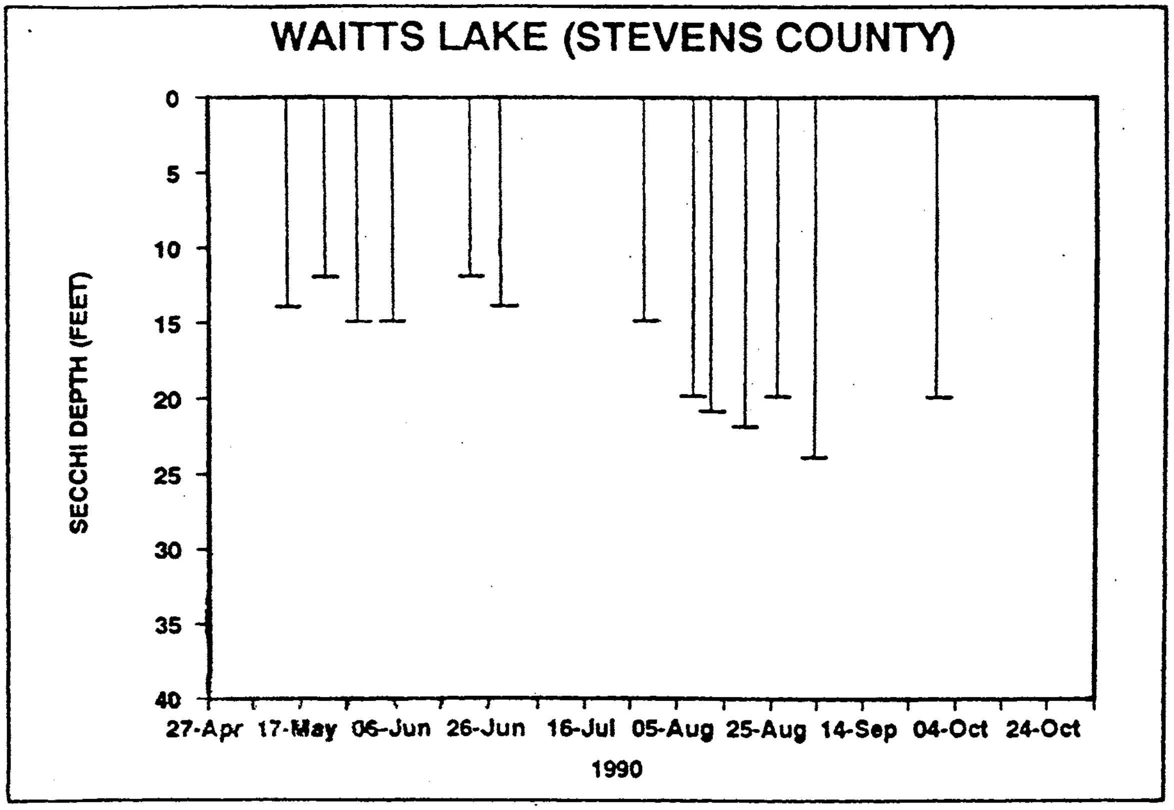
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
15-May	10.6	51.0	6.0	Black	0	Heavy	Calm	13.0		First clear day (eve) in past 2 weeks. Mostly rain and wind.
23-May	11.7	53.0	6.0	Dk-Green	50	Heavy	Light	11.0		
30-May	12.2	54.0	6.5	Dk-Green	25	Light	Calm	14.0		
06-Jun	11.7	53.0		Black	100	Moderate	Calm	14.0		Second reading may be inaccurate due to rain.
23-Jun	16.1	61.0	6.5	Black	100	Trace	Calm	11.0*		
30-Jun	21.1	70.0	8.0	Teal	0	None	Calm	13.0		
30-Jul	23.3	74.0	6.5	Black	10	None	Calm	14.0		pH recorded as 6.5 - 7.
09-Aug	20.6	69.0	6.5	Black	50	None	Calm	19.0	16.5	
13-Aug	22.2	72.0	7.5	Gr-Black	0	None	Breezy	20.0	16.0	
20-Aug	20.0	68.0	6.5	Black	100	Heavy	Calm	21.0	11.0	
27-Aug	17.2	63.0	6.5	Green	0	None	Calm	19.0	18.0	
04-Sep	16.7	62.0	6.5	Gr-Black	0	None	Breezy	23.0	19.3	
01-Oct	15.0	59.0	6.5	Black		Light	Breezy	19.0*	22.0	Secchi reading not accurate due to wind. More algae present in water.

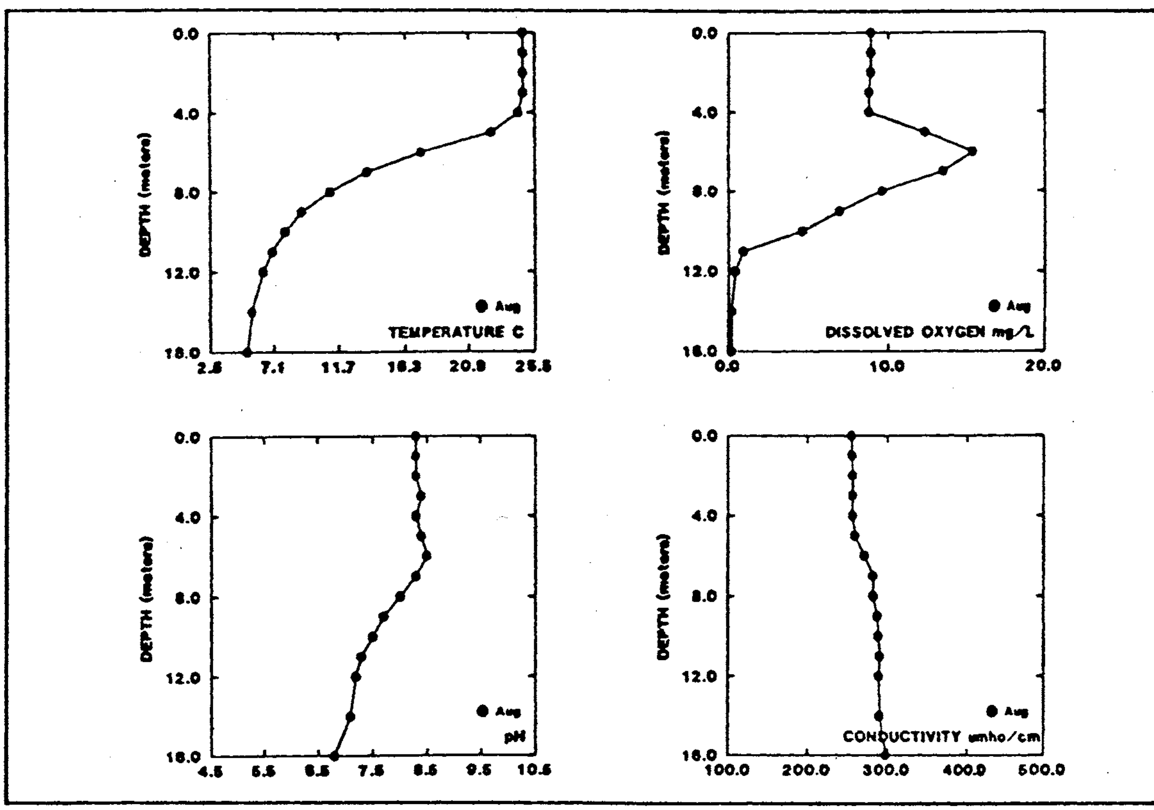
* There was high variability between the first and second Secchi depths collected; these two data points may not be included in data comparisons

Onsite Visit Data

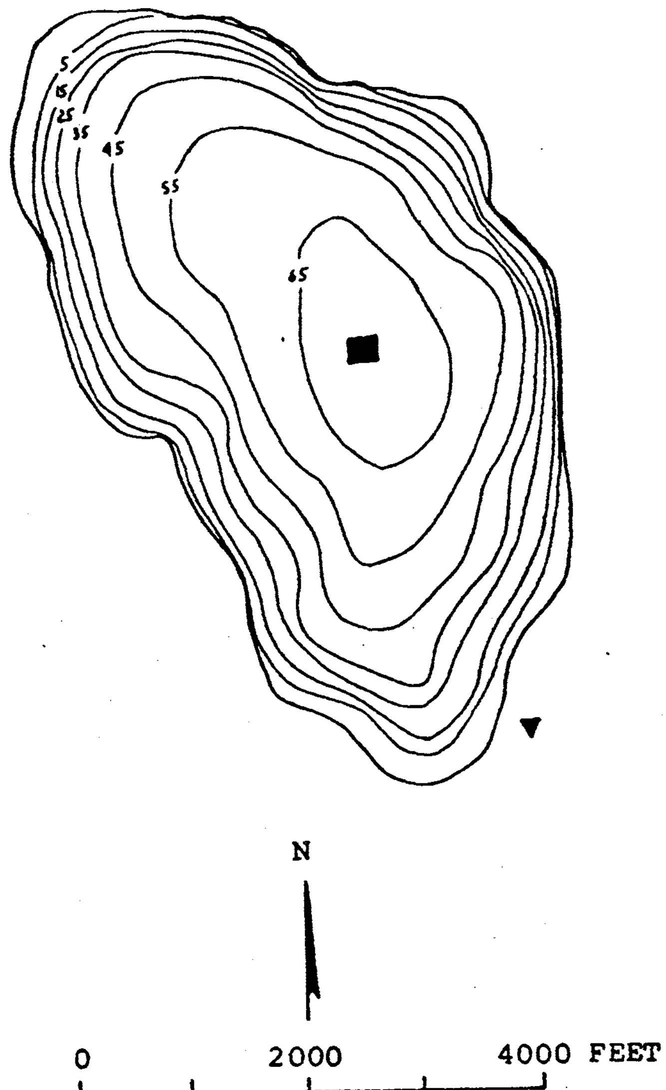
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
08/09	0.0	24.7	8.3	8.9	255	1, 2.5, 4.5	0.016	0.469
	1.0	24.7	8.3	8.9	255			
	2.0	24.7	8.3	8.9	256			
	3.0	24.7	8.4	8.8	256			
	4.0	24.4	8.3	8.8	256			
	5.0	22.5	8.4	12.3	259			
	6.0	17.5	8.5	15.3	271			
	7.0	13.7	8.3	13.4	282			
	8.0	11.1	8.0	9.6	282			
	9.0	9.1	7.7	6.9	287			
	10.0	7.9	7.5	4.6	288			
	11.0	7.0	7.3	0.9	290			
	12.0	6.3	7.2	0.4	289			
	14.0	5.5	7.1	0.2	290			
	16.0	5.1	6.8	0.2	298			

Secchi Depth and Profile Data Graphs





■ Volunteer monitoring site



EXPLANATION

— 15 —

Line of equal
water depth
Interval 10 feet

Waitts Lake, Stevens County. From Washington
Department of Game, February 9, 1954.

Wannacut Lake -- Okanogan County

Wannacut Lake is located 4.6 miles southwest of Oroville. It is two miles long. It has several small inlets, and no outlet. It is within the Okanogan River watershed.

Size (acres)	410
Maximum Depth (feet)	158
Mean Depth (feet)	55
Lake Volume (acre-feet)	22,500
Drainage Area (miles^2)	20.0
Altitude (feet)	1850
Shoreline Length (miles)	5.4

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	42

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Wannacut is used primarily for fishing. Recreational facilities on the lakeshore include one resort and one boat ramp, and there are no restrictions for motorboat use. Currently the watershed is used for animal grazing and the lakeshore is being developed further for residences. Grazing animals have direct access to the lakeshore or inlet tributaries. In the past, the watershed was used for logging. The lakeshore is not sewered. Rainbow trout and Lahontan cutthroat trout are stocked in the lake. The lake has been chemically treated in the past to control fish species. The worst problem in the lake, in the opinion of the volunteer, was fish species. Overall, the volunteer finds that Lake Wannacut has good recreational water quality.

There were no visible aquatic plants growing at the surface. There is a wetland with occasional cattle grazing at the north end of the lake. Most homes and cabins are on the east shore.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity in Wannacut Lake was greatest during June, and did not fluctuate much after July. Data collected in July 1974 showed that there was high Secchi visibility, and the concentration of total phosphorus was low (0.008 mg/L; Dion *et al.*, 1980). Other data collected in 1974 showed that on all sampling dates the concentration of dissolved oxygen was completely depleted near the lake bottom, and hydrogen sulfide (rotten-egg smell) was detected in the bottom layer of water. About 39% of the lake bottom was covered with muskgrass in 1974 (Dion *et al.*, 1980).

Wannacut Lake -- Okanogan County

The lake is reported to be slightly saline, principally due to magnesium sulfate (Wolcott, 1973). This is reported to create a dense layer of water at depth which prevents complete circulation of the lake (Dion *et al.*, 1980).

Comments

Past data show that Wannacut Lake exhibited both mesotrophic and eutrophic characteristics. Mesotrophic characteristics include moderately good water clarity and moderate plant growth. Eutrophic characteristics include the depletion of dissolved oxygen and the presence of hydrogen sulfide near the lake bottom. Because water clarity was considerably lower in 1990 than previously reported in 1975, additional study is recommended to evaluate present total phosphorus, chlorophyll *a* and dissolved oxygen concentrations in the lake.

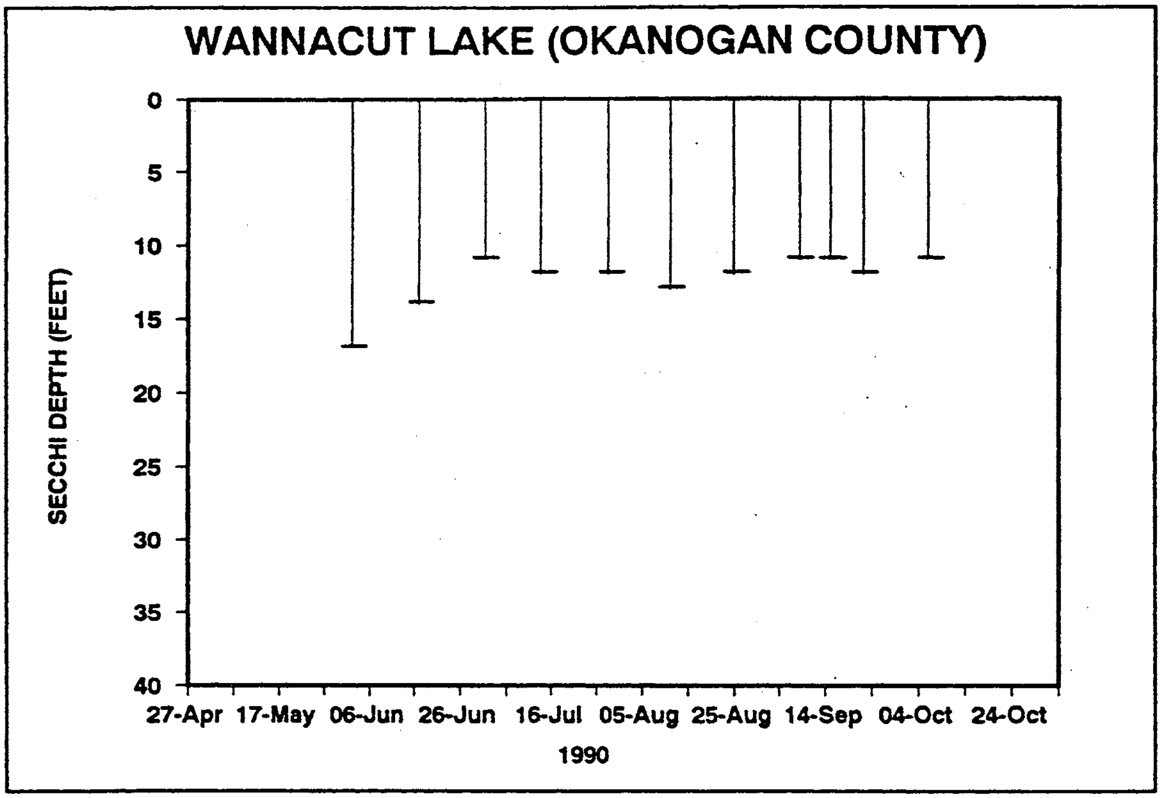
Acknowledgement

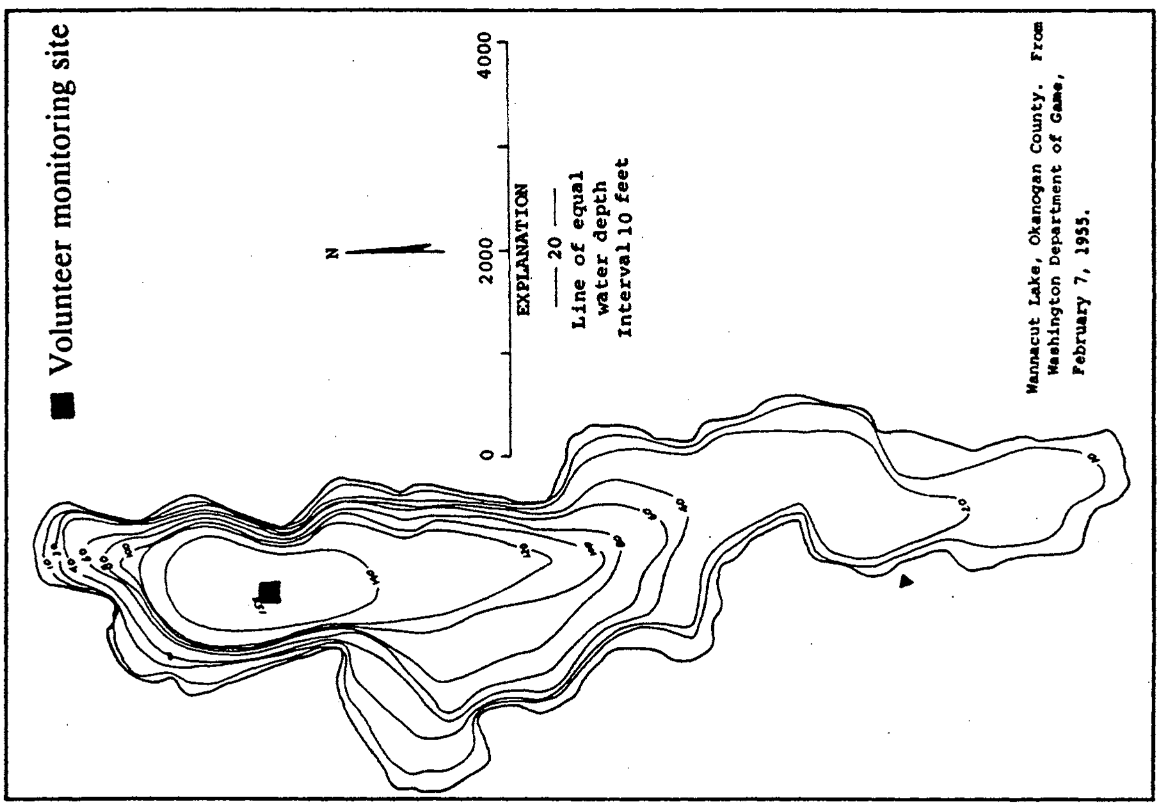
I want to thank Randall Hamsher for volunteering his time to monitor Lake Wannacut during 1990.

Wannacut Lake -- Okanogan County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
03-Jun	15.0	59.0	7.5	Green	90	Heavy	Breezy	16.0		
18-Jun	20.0	68.0	7.5	Green	75	Trace	Light	13.0		
02-Jul	21.1	70.0	7.5	Green	10	Trace	Light	10.0	-1.0	
15-Jul	24.4	76.0	7.5	Green	0	None	Light	11.0	-1.0	No change in lake height.
30-Jul	26.7	80.0	7.5	Green	0	None	Light	11.0	-1.0	Saw a bald eagle.
12-Aug	26.9	80.5	7.5	Green	0	Light	Light	12.0	-2.0	
26-Aug	20.6	69.0	7.5	Lt-Green	0	Light	Light	11.0	-1.0	
09-Sep	22.2	72.0	7.5	Milky-Gr	0	None	Calm	10.0	-2.0	
16-Sep	20.0	68.0	7.5	Milky-Gr	75	Trace	Light	10.0		
23-Sep	18.9	66.0	7.5	Milky-Gr	0	None	Calm	11.0	-6.0	
07-Oct	17.2	63.0	7.5	Milky-Gr	0	None	Calm	10.0	-2.0	


WANNACUT LAKE (OKANOGAN COUNTY)
SECCHI DEPTH (FEET)
0
5
10
15
20
25
30
35
40
27-Apr 17-May 06-Jun 26-Jun 16-Jul 05-Aug 25-Aug 14-Sep 04-Oct 24-Oct
1990


Volunteer monitoring site
N
0
2000
4000
EXPLANATION
— 20 —
Line of equal
water depth
Interval 10 feet
Wannacut Lake, Okanogan County. From
Washington Department of Game,
February 7, 1955.

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 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

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi) Volunteer #1:	31
Mean Trophic State Index* (Secchi) Volunteer #2:	34
Mean Trophic State Index* (Total Phosphorus):	39

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The questionnaire on lake and watershed uses was not returned.

Monitoring Results/Summary of Other Available Information

Secchi data were collected at the same deep-water site by two different volunteers. Ward Lake was one of five lakes in the program set up with more than one volunteer, as a quality-control check for the whole program. Comparisons between readings collected by the two volunteers show that overall the readings were very similar. Also, the mean summer average Secchi values from both volunteers indicated that the lake was oligotrophic. Although the fluctuations of readings from the two volunteers show somewhat different patterns of water clarity, both data sets show that the highest water clarity occurred during August.

Profile data collected during May and August 1990 show that on both sampling dates, the lake was thermally stratified and the concentrations of dissolved oxygen decreased considerably below the thermocline. The increase in dissolved oxygen concentrations from 5-7 meters probably resulted from decreased water temperatures at these depths, because oxygen is more soluble in cooler water than in water. Dissolved oxygen near the bottom of the lake was likely consumed by bacteria which use oxygen when decomposing organic material (such as algae, aquatic plants and woody debris) in the water and sediments. The decrease in pH and the increase in conductivity with depth is most likely related to decomposition near the lake bottom. In June 1972, the concentrations of dissolved oxygen decreased to 1.8 mg/L near the lake bottom (Bortleson *et al.*, 1976), so it is likely that low dissolved oxygen concentrations have been occurring near the bottom of Ward Lake for many years.

The 1990 concentrations of total phosphorus and total nitrogen (averaging 0.0111 and 0.263 mg/L, respectively) were low to moderate compared to other lakes monitored for the program in 1990. Compared to data collected in 1972, the 1990 total phosphorus concentrations were very similar and the total nitrogen concentrations were somewhat lower. In July 1972, the concentration of total phosphorus was 0.010 mg/L and the concentration of total nitrogen was 0.31 mg/L (Bortleson *et al.*, 1976).

In 1972, there were 30 nearshore homes and the shoreline in some areas was covered with submersed logs (Bortleson *et al.*, 1976).

A surface scum collected by one of the volunteers on May 22, 1990, contained mostly pollen. Weeds from a narrow band about three feet deep were identified as water-starwort (*Callitriche* spp.). The volunteer noted that this plant recently appeared in the lake. During the August 1990 onsite visit with the volunteer, white-flowering lily (*Nymphaea odorata*) was observed in front of some lakeshore homes.

Comments

Both the Secchi and total phosphorus data suggest that the lake was oligotrophic. Although the very low dissolved oxygen concentrations found near the bottom of the lake are not characteristic of an oligotrophic lake, it is possible that springwater (which is often low in dissolved oxygen) that feeds the lake affects the dissolved oxygen content of the lower layer of water.

Ward Lake was one of seven lakes in Thurston County that was monitored for the program in 1990. Compared to Clear, Hicks, Long, Patterson, St. Clair and Summit Lakes, only Summit lake had lower concentrations of total phosphorus than Ward Lake. Ward Lake and Summit Lake tied in having the best overall water clarity of the monitored Thurston County lakes.

Acknowledgements

I thank Lou Anne Houck and Kit Weaver for volunteering their time to monitor Ward Lake during 1990.

Ward Lake -- Thurston County

Volunteer-Collected Data

Volunteer #1

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
29-May	16.1	61.0	6.0	Clear	100	Trace	Calm	22.0		Water color: clear-light green.
11-Jun	16.1	61.0	6.0	Clear	75	Moderate	Calm	18.0		Secchi depth reading may be due to inadequate light.
26-Jun	21.1	70.0	6.5	Clear	25	None	Calm	22.0		
29-Jul	25.6	78.0	6.5	Clear	0	None	Light	22.0		
21-Aug								25.5		
03-Sep	21.7	71.0	6.0	Clear	0		Breezy	20.0		

Volunteer #2

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
23-May	15.6	60.0	6.5	Clear	100	Moderate	Calm	17.0*	43.5	Lake height was down approximately 2' from 4/80 to 4/90. Fixed stake down 6" from 4/22/90. Station 2 at deep hole.
07-Jun	16.7	62.0	6.0	Lt-Br	25	Moderate	Breezy	17.0	43.0	Water color light grey/green. 2" to 4" waves. Color coming from Blvd. and Log Cabin Rd. earth moving.
20-Jun	17.2	63.0	7.0	Lt-Gr	0	None	Light	18.0	42.0	
03-Jul	17.8	64.0	7.0	Gray-Gr	0	Trace	Light	20.0	40.5	
18-Jul	23.3	74.0	7.5	Gray-Gr	0	None	Breezy	20.0	38.5	
01-Aug	23.3	74.0		Gray-Gr	0	None	Breezy	20.0	33.0	
14-Aug	24.4	76.0	7.5	Lt-Gr	0	None	Light	22.0	32.0	I'm guessing my pH strips don't change color.
29-Aug	21.1	70.0	7.5	Lt-Gr	100	Moderate	Light	20.0	29.0	
12-Sep	20.6	69.0	7.5	Lt-Gr	100		Breezy	19.5	28.5	
25-Sep	20.0	68.0	7.5	Lt-Gr	100	None	Calm	19.0	26.0	
12-Oct	15.6	60.0	7.5	Lt-Gr	100	Moderate	Breezy	18.0	25.0	Light rain steady wind.
24-Oct	14.4	58.0	7.5	Lt-Gr	100		Breezy	18.0	28.5	Lake is about 12" higher than this time in '89.

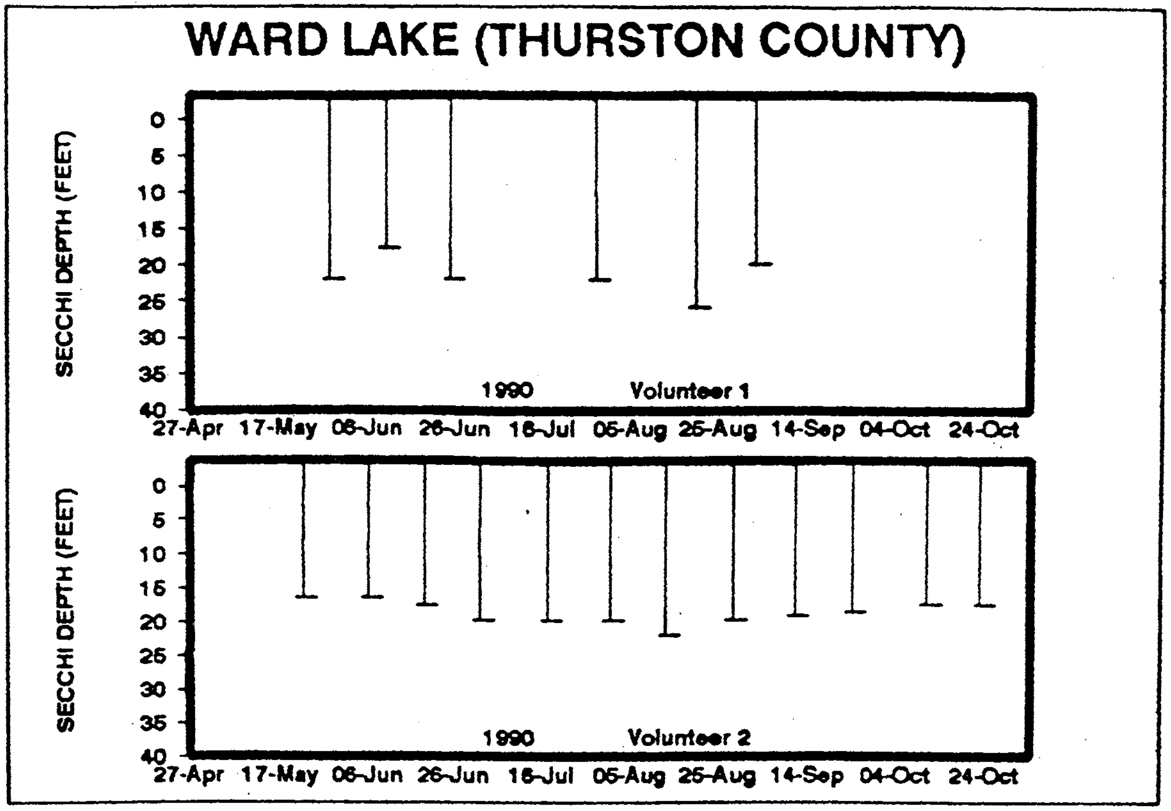
* reading not taken from deep site.

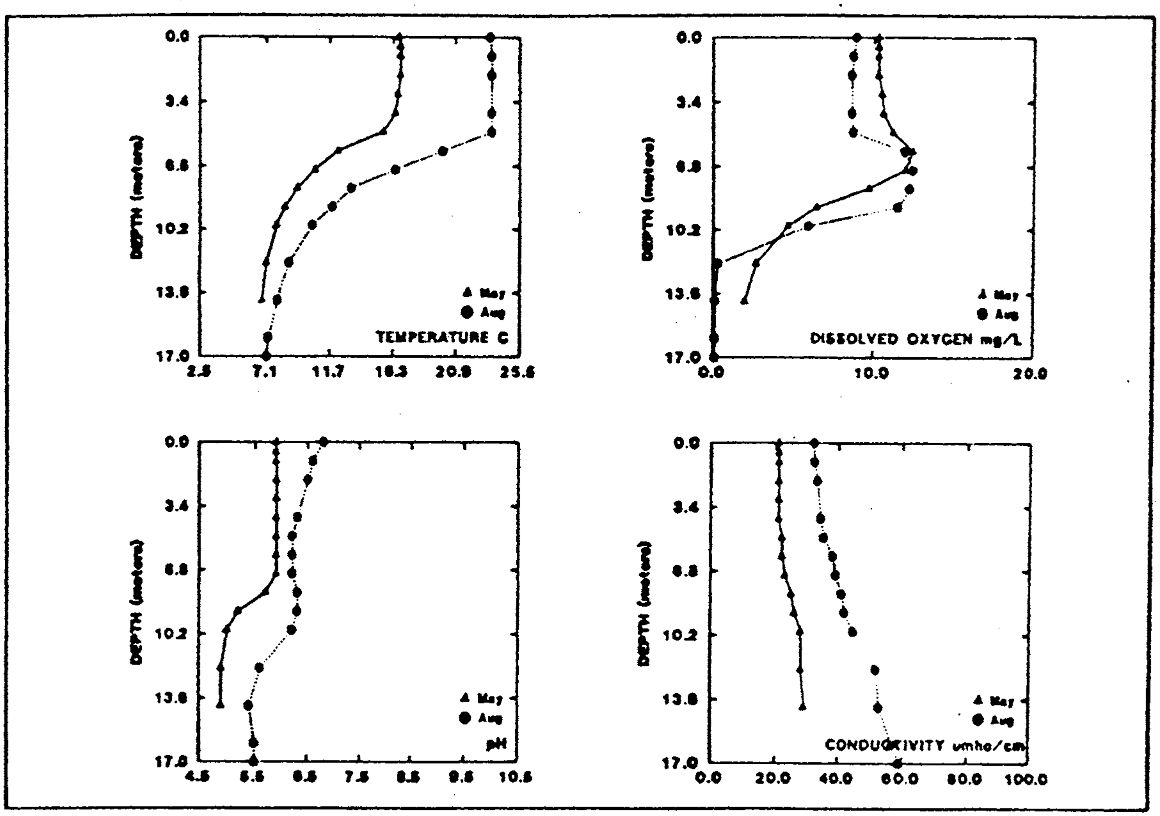
Ward Lake -- Thurston County

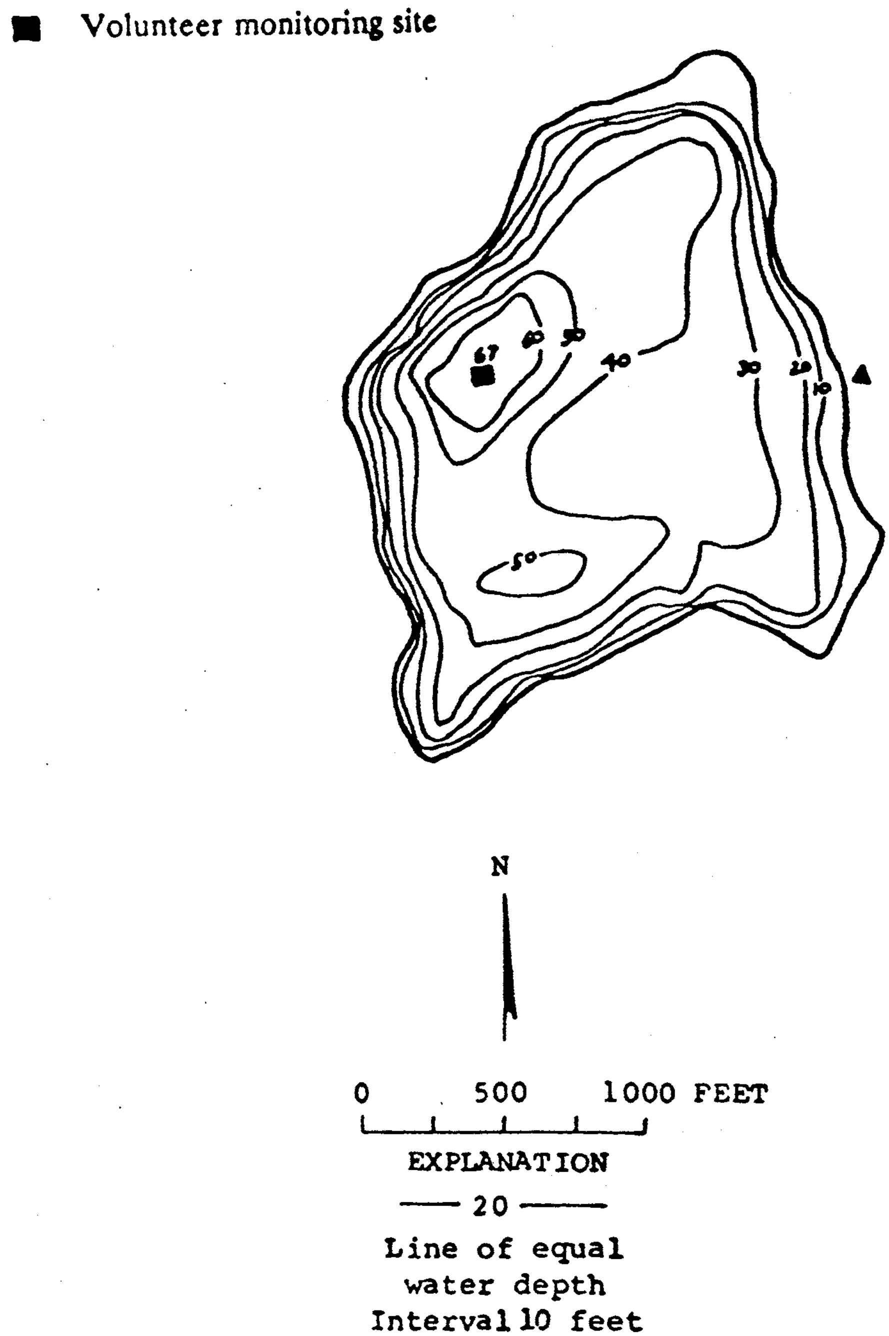
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/29	0.0	16.8	5.9	10.3	21	1, 3	0.010	0.262
	0.5	16.9	5.9	10.3	21			
	1.0	16.9	5.9	10.3	21			
	2.0	16.9	5.9	10.3	21			
	3.0	16.7	5.9	10.5	21			
	4.0	16.5	5.9	10.6	21			
	5.0	15.6	5.9	11.2	22			
	6.0	12.3	5.9	12.4	22			
	7.0	10.6	5.9	11.9	23			
	8.0	9.3	5.7	9.7	25			
	9.0	8.4	5.2	6.4	26			
	10.0	7.8	5.0	4.6	28			
	12.0	7.1	4.9	2.6	28			
	14.0	6.8	4.9	1.9	29			
08/21	0.0	23.4	6.8	8.9	32	1, 3, 5	0.012	0.265
	1.0	23.5	6.6	8.7	32			
	2.0	23.5	6.5	8.6	33			
	4.0	23.5	6.3	8.6	34			
	5.0	23.5	6.2	8.7	35			
	6.0	20.0	6.2	11.9	38			
	7.0	16.5	6.2	12.4	39			
	8.0	13.3	6.3	12.2	41			
	9.0	11.9	6.3	11.5	42			
	10.0	10.4	6.2	5.9	45			
	12.0	8.7	5.6	0.3	52			
	14.0	7.9	5.4	0.1	53			
	16.0	7.2	5.5	0.1	57			
	17.0	7.1	5.5	0.1	59			

Secchi Depth and Profile Data Graphs







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

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

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi):	36
Mean Trophic State Index* (Total Phosphorus):	38

* From Carlson (1977)

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

The following are from the volunteer's remarks and questionnaire responses. 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, one resort, and two boat ramps. There are no restrictions for motorboat use on the lake. Lake water is withdrawn for drinking and other domestic uses. Currently the watershed is used for logging, animal grazing, and lakeshore development. In the past, the watershed was used for logging and crop agriculture. There are approximately 150 houses on the lakeshore; of these, 10 are occupied year-round. The lakeshore is not sewered, although there is some private wastewater collection and treatment in the watershed. Kokanee salmon are stocked in the lake. Presently there is a sewer district being formed for the lake. The worst problems in the lake, in the opinion of the volunteer, are pollution from septic systems, and fish species. Overall, the volunteer finds that Lake Wenatchee has excellent recreational water quality, and suggested that septic systems may affect the water quality.

Reeds and lilies grow in the cove just south of the Wenatchee River. Algae blooms also occur in this area. Minor algae growth occurs in areas of the north shore. There are fish pens just north of the White River inlet.

Lake Wenatchee -- Chelan County

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1989 and 1990 show that although fluctuations in water clarity differed somewhat between the two years, the mean summer water clarity was very similar. Overall, water clarity in Lake Wenatchee was lower during June and July and increased in August. Profile data collected during June and August show that the lake was not thermally stratified during June. Because the lake was mixing, conductivity and pH did not vary much from surface to bottom. During August, the lake was thermally stratified, yet pH, conductivity and dissolved oxygen were stable from the surface to the bottom. These profiles were very similar to profile data collected during 1989 (Brower and Kendra, 1990), 1974 (Dion *et al.*, 1976) and 1968 (Lee, 1969).

The 1990 concentrations of total phosphorus and total nitrogen were low during June, and were approaching medium-high during August. The June 1990 nutrient concentrations were similar to data collected during 1989 (Brower and Kendra, 1990). However, concentrations of both total phosphorus and total nitrogen were much higher in August 1990 than in September 1989.

Analyses of fish and sediment samples collected in 1989 for toxics indicated no significant levels of the chemicals analyzed (Johnson and Norton, 1990). 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. These fish samples were well within levels considered acceptable for human consumption (Johnson and Norton, 1990).

An article from the Wenatchee World (January 9, 1989) reported that sockeye net pens were to be placed in the west end of the lake. The pens will be used to hold adult sockeye salmon until they spawn.

During August 1990, aquatic plants identified in the west end of the lake include: milfoil (*Myriophyllum* sp.), water buttercup (*Ranunculus aquatilus*), and waterweed (*Elodea nuttalli*).

Comments

It is difficult to take Secchi disk readings from Lake Wenatchee because the area receives strong and frequent winds. As a result, the clarity readings are somewhat erratic and tend to overestimate the trophic state (that is, underestimate the water quality) of the lake. Although changes in water clarity as determined using a Secchi disk can still be used to predict changes in the water quality of the lake, future estimates of trophic state should be confirmed using chemical data.

Lake Wenatchee -- Chelan County

Acknowledgement

I thank Gary Craig for volunteering his time to monitor Lake Wenatchee during 1989-1990.

Lake Wenatchee -- Chelan County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
04-Jun								17.0		
26-Jun	12.0	53.6	6.0	Green	25	Trace	Breezy	16.5		Heavy snow melt.
16-Jul	12.0	53.6	6.0	Green	0	None	Gusty	12.8		High Snowmelt, glacier melt. Been windy for days.
30-Jul	20.0	68.0	6.0	Green	0	None	Calm	15.6		No wind in past 3 days.
10-Aug	19.0	66.2	6.0	Lt-Green	0	None	Calm	18.3		Calm clear weather. Light wind past week.
14-Sep	19.0	66.2	6.0	Lt-Green	0	None	Calm	22.0		No wind 1.5 days. Glacial melt slightly less.

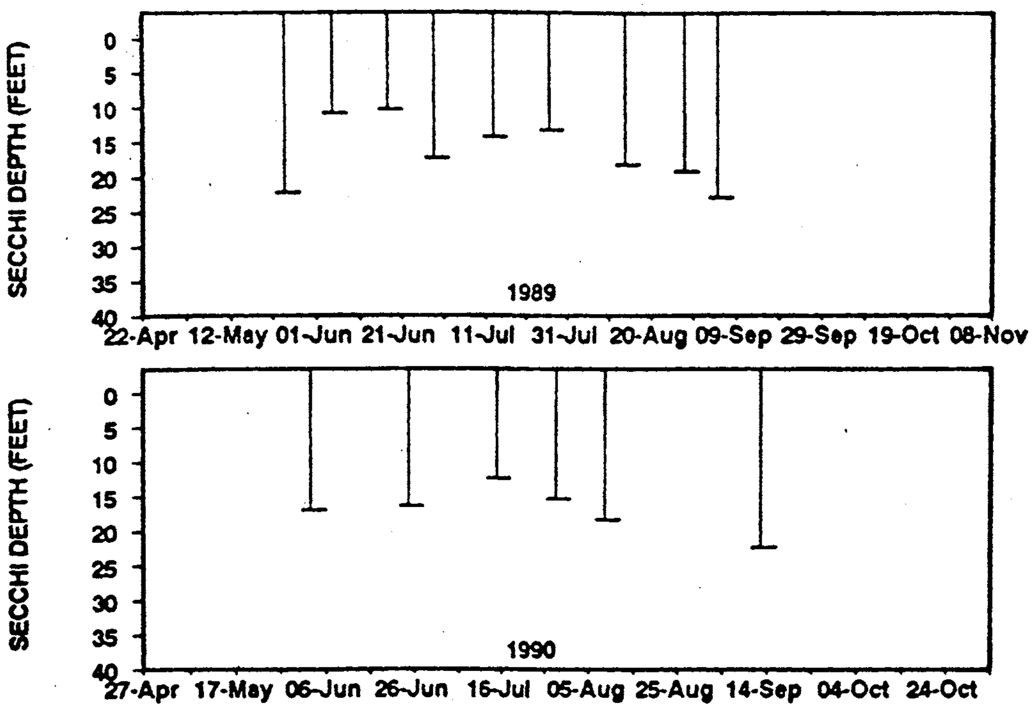
* Secchi data corrected for rope shrinkage

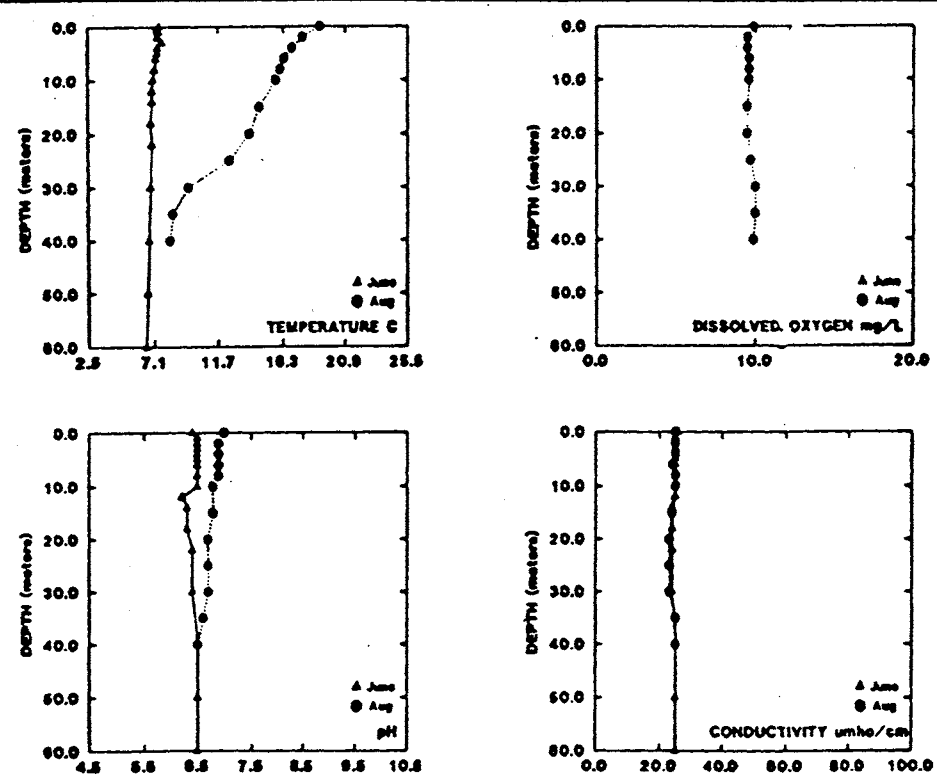
Onsite Visit Data

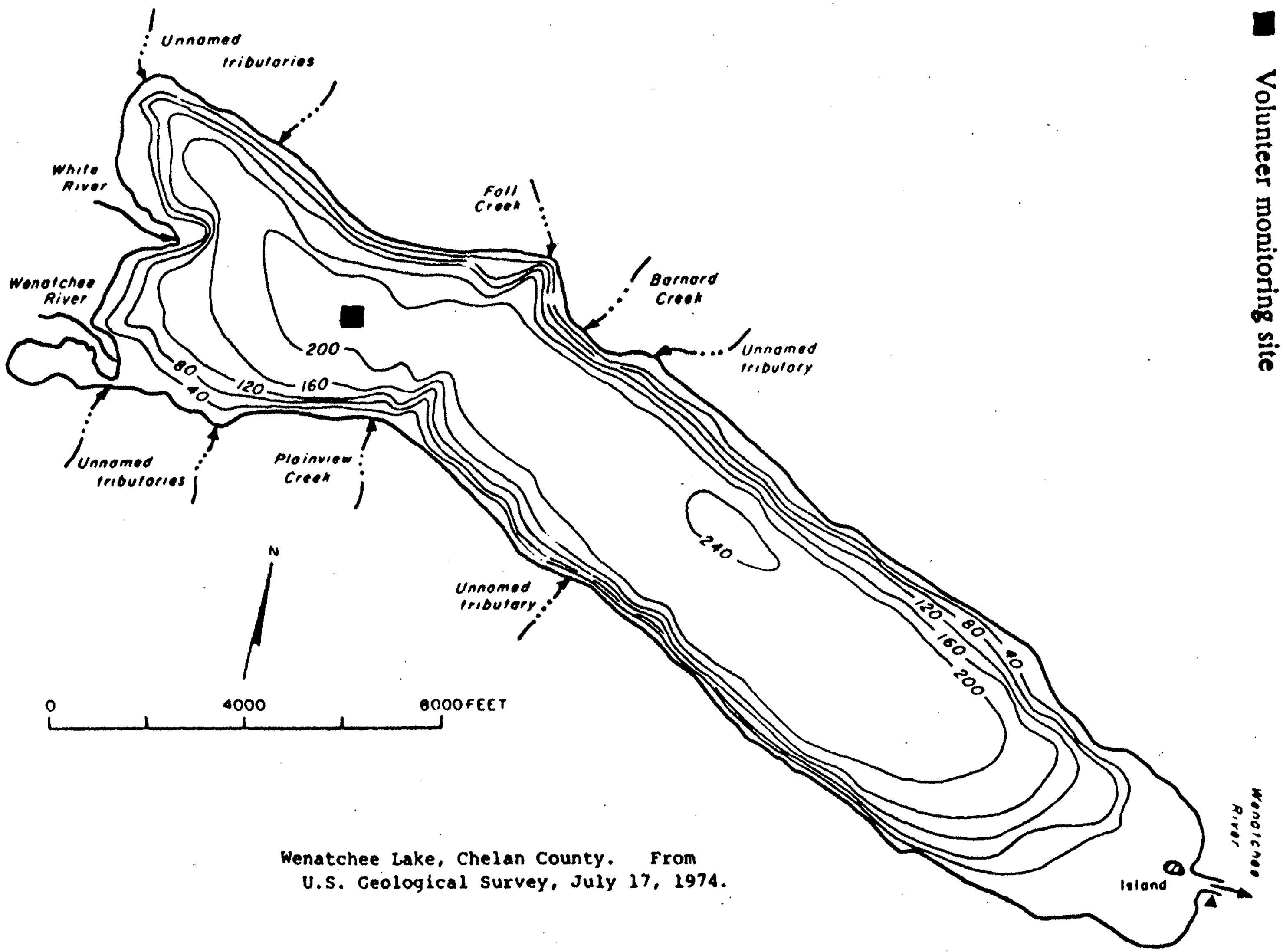
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/04	0.0	7.4	6.4	.*	26	2, 10, 22	0.008	0.106
	1.0	7.4	6.5	.	25			
	2.0	7.3	6.5	.	25			
	3.0	7.6	6.5	.	25			
	4.0	7.3	6.5	.	25			
	5.0	7.3	6.5	.	25			
	6.0	7.2	6.5	.	25			
	8.0	7.1	6.5	.	25			
	10.0	7.0	6.5	.	25			
	12.0	6.9	6.2	.	25			
	14.0	6.9	6.3	.	24			
	18.0	6.8	6.3	.	24			
	22.0	6.9	6.4	.	24			
	30.0	6.8	6.4	.	24			
	40.0	6.7	6.5	.	25			
	50.0	6.6	6.5	.	25			
	60.0	6.5	6.5	.	25			
08/20	0.0	19.1	7.0	9.9	25	2, 4, 6	0.012	0.168
	2.0	17.8	6.9	9.5	25			
	4.0	17.0	6.9	9.5	25			
	6.0	16.4	6.9	9.6	24			
	8.0	16.1	6.9	9.6	25			
	10.0	15.8	6.8	9.6	25			
	15.0	14.6	6.8	9.5	24			
	20.0	13.9	6.7	9.5	23			
	25.0	12.5	6.7	9.7	23			
	30.0	9.5	6.7	10.0	23			
	35.0	8.4	6.6	10.0	25			
	40.0	8.2	6.5	9.9	25			

* See Quality Assurance section of this report.

LAKE WENATCHEE (CHELAN COUNTY)







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

Lake Whatcom -- Whatcom County

Lake Whatcom is located three miles east of Bellingham. It is a natural lake stabilized by a dam. It is 12 miles long. Inlets include Carpenter, Olson, Smith, Fir, Brannian and Austin Creeks. It drains via Whatcom Creek to Bellingham Bay. The lake surface acreage below does not include Reveille Island (12 acres). Lake Whatcom is the water supply for the City of Bellingham.

Size (acres)	5,000
Maximum Depth (feet)	330
Mean Depth (feet)	154
Lake Volume (acre-feet)	767,700
Drainage Area (miles^2)	55.9
Altitude (feet)	315
Shoreline Length (miles)	26.5

Estimated Trophic State:	Oligotrophic
Mean Trophic State Index* (Secchi) Station #1:	35
Mean Trophic State Index* (Secchi) Station #2:	32
Mean Trophic State Index* (Total Phosphorus):	31

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Whatcom is used for fishing, boating, swimming, rowing, jet skiing, camping, and waterfowl hunting. Recreational facilities on the lakeshore include a park, a picnic area, a camping area, a beach, three resorts, and five boat ramps. Lake water is withdrawn for municipal use, industrial use, irrigation, a Washington Department of Wildlife fish hatchery, and for drinking and other domestic uses. Currently the watershed is used for logging, industry, animal grazing, and crop agriculture, and the lakeshore is being developed further for residences. In the past, the watershed was used for logging, animal grazing, crop agriculture, and mining, and the shoreline was altered. The lakeshore is partially sewered, and there are storm drains that empty into the lake. Fish were not reported as being stocked in the lake. Presently there are two grassroots organizations that support protection of the lake. The worst problems in the lake, in the opinion of the volunteer, are 1) sediments suspended in the water column, and 2) debris torrents. The volunteer is concerned about water quality effects from urban runoff, sediment, nonpoint pollution, *giardia* (protozoan) and coliform (bacteria).

Lake Whatcom -- Whatcom County

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that at both stations, water clarity was lowest during July. Profile data collected during May and August 1990 at Station #1 show that on both sampling dates the lake was thermally stratified. Because of inclement weather on June 4, profile data were collected only from the first 13 meters. Concentrations of dissolved oxygen were fairly constant above and below the thermocline during June.

The 1990 concentrations of total phosphorus were very low (averaging 0.0064 mg/L), although concentrations of total nitrogen were moderately high. In 1974, total phosphorus ranged from 0.003 - 0.006 mg/L, and total nitrogen ranged from 0.16 - 0.29 mg/L (Bortleson *et al.*, 1976). In 1981, the concentration of total phosphorus was 0.010 mg/L and the concentration of total nitrogen was 0.57 mg/L (Sumioka and Dion, 1985). Trophic state indices calculated from 1981 data showed that based on Secchi disk and total phosphorus data, the lake was oligotrophic (Sumioka and Dion, 1985); however, chlorophyll *a* data were borderline between oligotrophy and mesotrophy.

The lake has been studied since the 1960s by Western Washington University. Data collected by University researchers confirm that concentrations of total phosphorus in the lake were low (0.005 - 0.015 mg/L in 1985; Creahan *et al.*, 1986) and concentrations of nitrogen (especially nitrate/nitrite-nitrogen) were moderately high (0.0042 - 0.513 mg/L in 1986; Rector and Matthews, 1987). The concentrations of nitrogen in the lake water are high relative to the concentration of phosphorus; researchers have concluded that the productivity of algae in the lake is likely limited by the amount of phosphorus in the water (Creahan *et al.*, 1986).

Water quality in the lake has varied with location. The lake is divided into three subbasins: a deep, clean basin flows to two shallow, mesotrophic basins. The smallest and shallowest basin is heavily developed in some areas, and has the heaviest recreational use (Creahan *et al.*, 1986). Dissolved oxygen concentrations in this basin are depleted near the bottom, and algal productivity is greater than in the other two basins (Rector and Matthews, 1987). The volunteer's monitoring stations in 1990 were located in the large, deep, clean basin. This larger basin contains large quantities of woody debris in some areas, from past use of the lake as a log storage pond for sawmills and from past debris torrents (Rector and Matthews, 1987).

Several debris torrents have occurred in the tributaries of Lake Whatcom, carrying logs, sediments and assorted debris into the lake (Weden and Associates, 1983). Debris torrents, which are "short duration, high intensity, high volume surges of debris-laden water" that occur in stream channels, have been reported in Lake Whatcom as far back as 1917 (Syverson, 1984). The most severe debris torrent occurred in the Smith Creek drainage on January 10, 1983 (Syverson, 1984). The actual volume of debris washed into the lake from these debris torrents is unknown.

Lake Whatcom -- Whatcom County

Comments

The trophic state estimation applies only to the large basin monitored by the volunteers. Compared with the other lakes monitored for the program in 1990, only Lake Chelan had lower concentrations of total phosphorus than Lake Whatcom.

Acknowledgements

I thank Robin Bigelow, Wendy Hand and Lisa Saben for volunteering their time to monitor Lake Whatcom during 1990.

Volunteer-Collected Data

Station 1

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
12-Jun	13.3	56.0	6.5	Clear	90	Heavy	Breezy	20.0*		
26-Jun	16.7	62.0	6.5	Lt-Green	75	Trace	Light	17.0	.0	
10-Jul	20.0	68.0	6.5	Clear	0	None	Breezy	17.0		
24-Jul	17.8	64.0	6.5	Green	100	Trace	Light	15.0	-2.0	
09-Aug	20.0	68.0	6.5	Clear	10	None	Breezy	18.0	6.0	
23-Aug	18.3	65.0	6.5	Lt-Green	75	Light	Breezy	19.0	-8.0	
09-Sep	17.8	64.0	6.5	Lt-Green	100	Trace	Breezy	20.0	-12.0	

* There was high variability between the first and second Secchi depths collected; this data point may not be inlucded in data comparisons.

Station 2

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
14-Jun	15.0	59.0				Trace	Calm	22.5*		
19-Jul	20.0	68.0	7.0	Lt-Green	0	None	Calm	15.0		
04-Aug	21.7	71.0	6.5	Lt-Green	0	None	Calm	23.0		
26-Aug	20.0	68.0	6.5	Lt-Green	0	None	Calm	24.0		
10-Sep	20.0	68.0	6.5	Lt-Green	0	None	Light	24.0		
30-Sep	17.8	64.0	6.5	Lt-Green	50	None	Light	26.0		

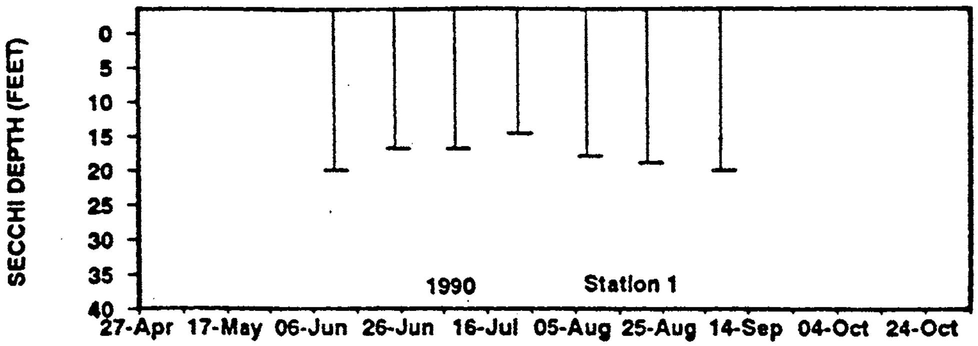
* There was high variability between the first and second Secchi depths collected; this data point may not be inlucded in data comparisons.

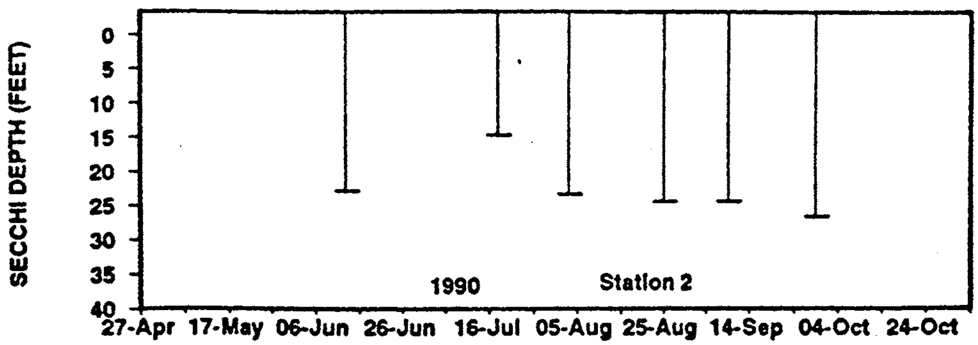
Lake Whatcom -- Whatcom County

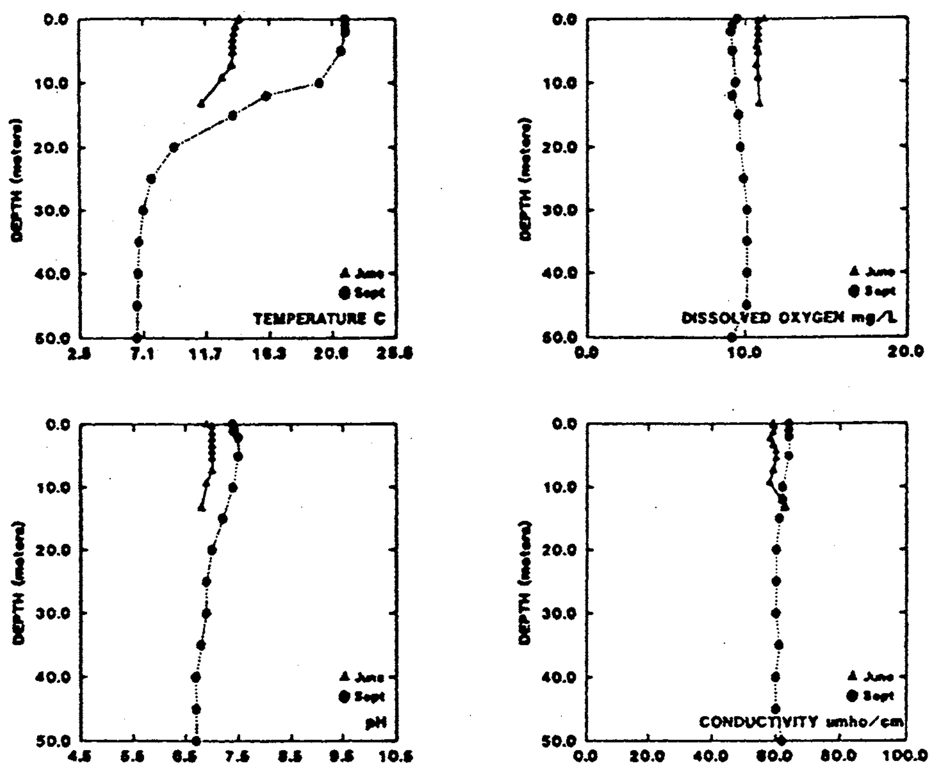
Onsite Visit Data -- Station 1

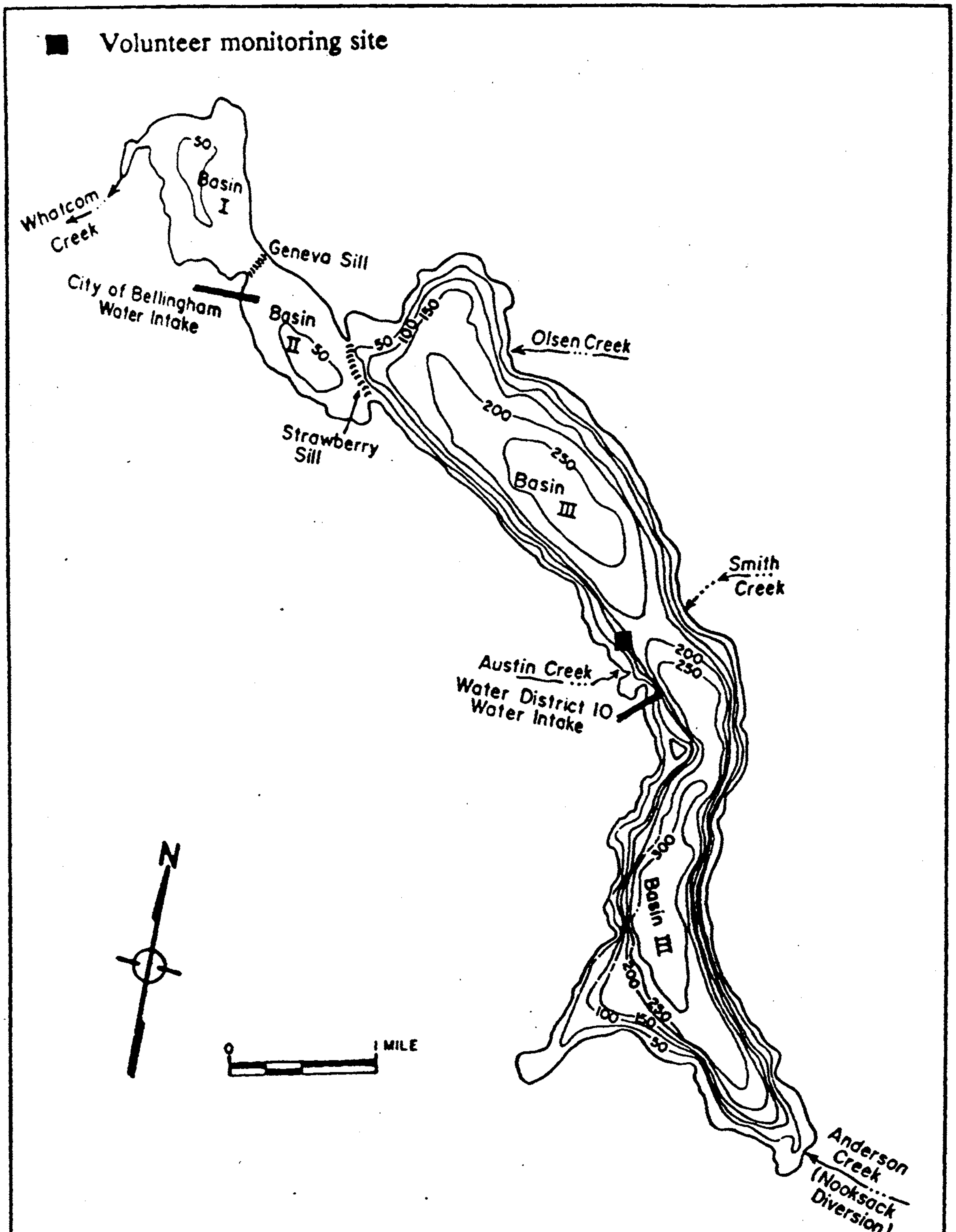
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
06/04	0.0	14.2	6.9	11.2	59	1, 5, 8	0.006	0.502
	0.3	14.1	7.0	10.8	59			
	1.3	13.9	7.0	10.8	59			
	2.3	13.8	7.0	10.8	58			
	3.3	13.7	7.0	10.8	59			
	4.3	13.7	7.0	10.7	60			
	5.3	13.7	7.0	10.8	60			
	7.3	13.6	7.0	10.7	59			
	9.3	12.9	6.9	10.8	58			
	13.3	11.4	6.8	10.9	63			
08/15	0.0	21.9	7.4	9.5	64	1, 5, 10	0.007	0.415
	1.0	21.9	7.4	9.2	64			
	2.0	21.9	7.5	9.1	64			
	5.0	21.6	7.5	9.2	64			
	10.0	20.0	7.4	9.4	62			
	12.0	16.1	6.8	9.2	62			
	15.0	13.7	7.2	9.6	61			
	20.0	9.4	7.0	9.7	60			
	25.0	7.7	6.9	9.9	60			
	30.0	7.1	6.9	10.1	60			
	35.0	6.8	6.8	10.1	61			
	40.0	6.7	6.7	10.1	60			
	45.0	6.6	6.7	10.1	60			
	50.0	6.6	6.7	9.2	62			

LAKE WHATCOM (WHATCOM COUNTY)









LAKE WHATCOM BATHYMETRY & BASINS

Lake Whitman -- 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 via Tanwax Creek to the Nisqually River.

Size (acres)	30
Maximum Depth (feet)	20
Mean Depth (feet)	12
Lake Volume (acre-feet)	346
Drainage Area (miles^2)	1.0
Altitude (feet)	601
Shoreline Length (miles)	1.0

Estimated Trophic State:	Meso-eutrophic
Mean Trophic State Index* (Secchi):	45
Mean Trophic State Index* (Total Phosphorus):	53

* From Carlson (1977)

Summary of Questionnaire Results and Information from the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Whitman Lake is used for fishing, boating, swimming, rowing, jet skiing, and camping. Recreational facilities on the lakeshore include one boat ramp, and there are no restrictions for motorboat use on the lake. Currently the watershed is used for logging and animal grazing. In the past, the watershed was used for logging and crop agriculture, and the shoreline was altered. There are 54 houses on the lakeshore; of these, 25 are occupied year-round. The lakeshore is not sewered, and there is one storm drain that empties into the lake. Trout are stocked in the lake. There is a lake association (the Lake Whitman Improvement Club) for the lake. The lake has been chemically treated in the past to control both weeds and algae. The worst problems in the lake, in the opinion of the volunteer, are 1) algae, and 2) aquatic plants. Overall, the volunteer finds that Lake Whitman has fair recreational water quality.

There are wetlands near the inlets. There is a lot of algae growth in shallow water (5 feet or less), although it is not localized in any one area. Lily pads, cattails and irises growing along beaches have also been a problem. Plants are particularly thick in the south end of the lake and around the island. The majority of the shoreline is developed for residences.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1990 show that water clarity was greatest during June, and gradually decreased over summer. Profile data collected during May and August 1990 show that on both sampling dates, the lake was thermally stratified and concentrations of dissolved oxygen were virtually depleted from the entire hypolimnion (bottom layer of water). Dissolved oxygen is consumed by bacteria which decompose organic material (such as algae, aquatic plants and woody debris) in the water and sediments. The decrease in pH and the increase in conductivity with depth is most likely related to increased decomposition near the lake bottom. In 1973, the concentration of dissolved oxygen decreased to 0.4 mg/L near the lake bottom (Bortleson *et al.*, 1976) so it is likely that low concentrations of dissolved oxygen have been occurring in Whitman Lake for many years.

The 1990 concentrations of total phosphorus and total nitrogen were high on both sampling dates (averaging 0.0297 and 0.460 mg/L, respectively). However, in 1981 the concentration of both nutrients was higher (0.040 mg/L total phosphorus and 1.1 mg/L total nitrogen; Sumioka and Dion, 1985). Trophic state indices calculated from 1981 Secchi depth and chlorophyll *a* data show that the lake was mesotrophic, whereas the total phosphorus data suggested the lake was eutrophic. In 1973, the concentration of total phosphorus was 0.013 mg/L (Bortleson *et al.*, 1976).

In 1973, emergent plants covered approximately 80% of the shoreline with some large patches at the south end of the lake; there was also a heavy cover of submerged plants (*Elodea* and pondweed) in the lake (Bortleson *et al.*, 1976).

During the August 1990 onsite visit with the volunteer, a large brownish mass was observed in shallow water. It is possible that this was a colony of bryozoans, which are sessile invertebrates (immobile, spineless animals). Bryozoans are associated with calm and relatively nonturbid water. Bryzoans are eaten by larger invertebrates, which in turn are eaten by fish. Also observed during the onsite visit was a discharge line leading from a lakeshore residence. The volunteer mentioned that this line circulates lake water into a large fish tank in the resident's home.

Comments

Whitman Lake was one of six Pierce County lakes monitored for the program in 1990. Compared to Lakes Louise, Ohop, Spanaway, Steilacoom, and Tanwax Lakes, Whitman Lake had moderate water clarity and high concentrations of total phosphorus. Both Lake Ohop and Lake Tanwax had somewhat higher concentrations of total phosphorus. Overall, compared to the other 74 lakes monitored for the program, 18 lakes had higher concentrations of total phosphorus than Lake Whitman.

Acknowledgement

I thank Marsha Swanson for volunteering her time to monitor Lake Whitman during 1990.

Lake Whitman -- Pierce County

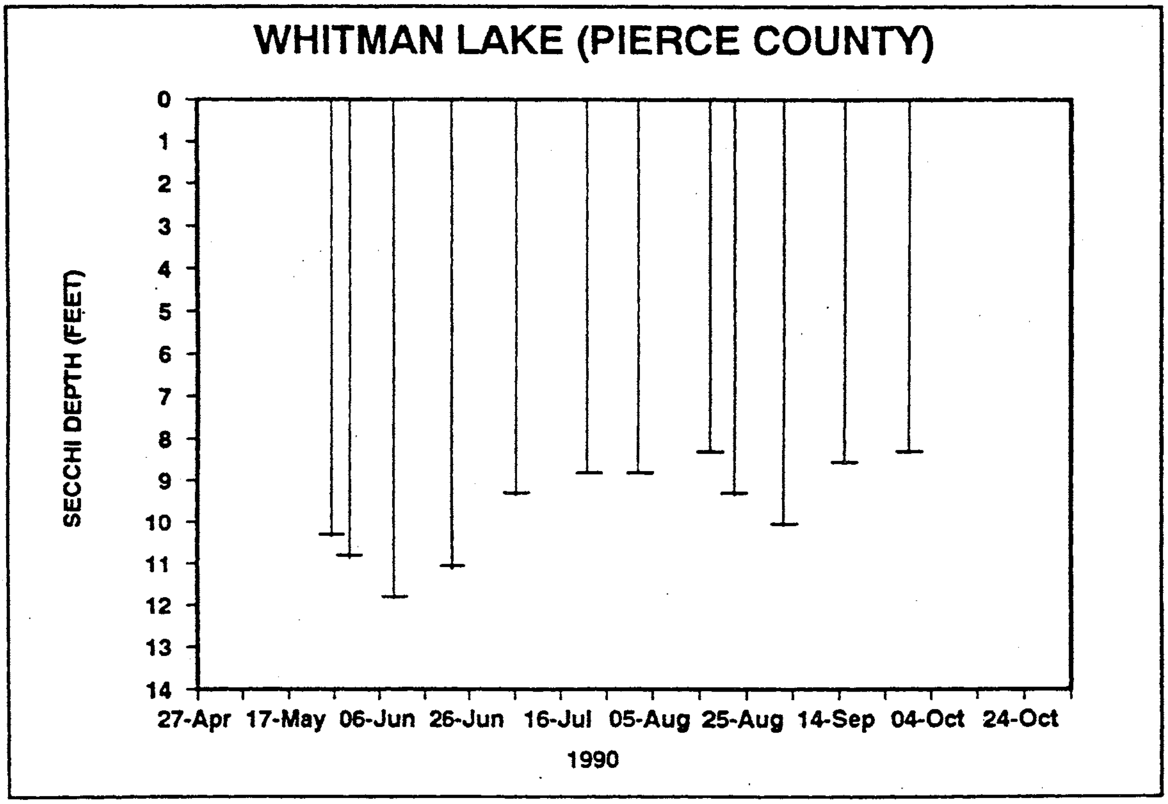
Volunteer-Collected Data

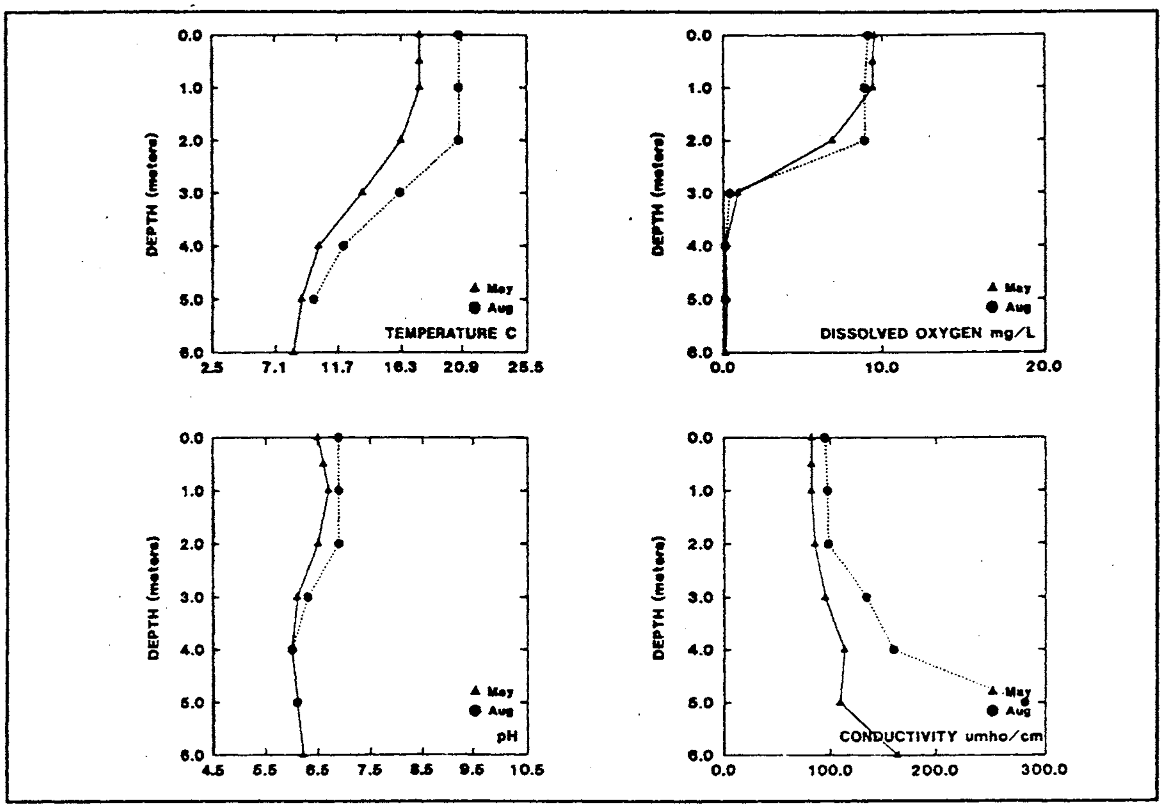
Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft)	Lake Ht(in)	Abbreviated Comments
27-May	18.0	64.4	6.5		75	Moderate	Calm	10.0	0.00	Water color golden brown/yellowish.
31-May									10.5	
10-Jun	18.5	65.3	6.5	Yellow-Br	100	Heavy	Strong	11.5		We saw a bald eagle over the lake!
23-Jun	25.0	77.0	6.5	Yellow-Br	5	Moderate	Light	10.7	0.7	Submerged balls of green slimy algae in the lake!
07-Jul	24.0	75.2	6.5	Gold-Br	25	Heavy	Light	9.0	-0.3	Lots of ski boats in last 4 days.
23-Jul	24.0	75.2	6.5	Yellow-Br	100	None	Breezy	8.5	-5.0	Lots of ski boats yesterday, all day.
03-Aug	25.0	77.0	6.5	Yellow-Br	0	None	Light	8.5	-5.0	
18-Aug	24.0	75.2	6.5	Gold-Brown		100	Moderate	Calm	8.0	
23-Aug								9.0		
03-Sep	21.0	69.8	6.5	Yellow-Br	10	None	Calm	9.7	-4.4	Water full of 1/4" green filaments of algae.
16-Sep	21.0	69.8	6.5	Yellow-Br	90	None	Light	8.3	-5.0	
30-Sep	21.0	69.8	6.5	Yellow-Br	0	None	Breezy	8.0	-5.5	Lots of 1/8" - 1/4" green filaments.

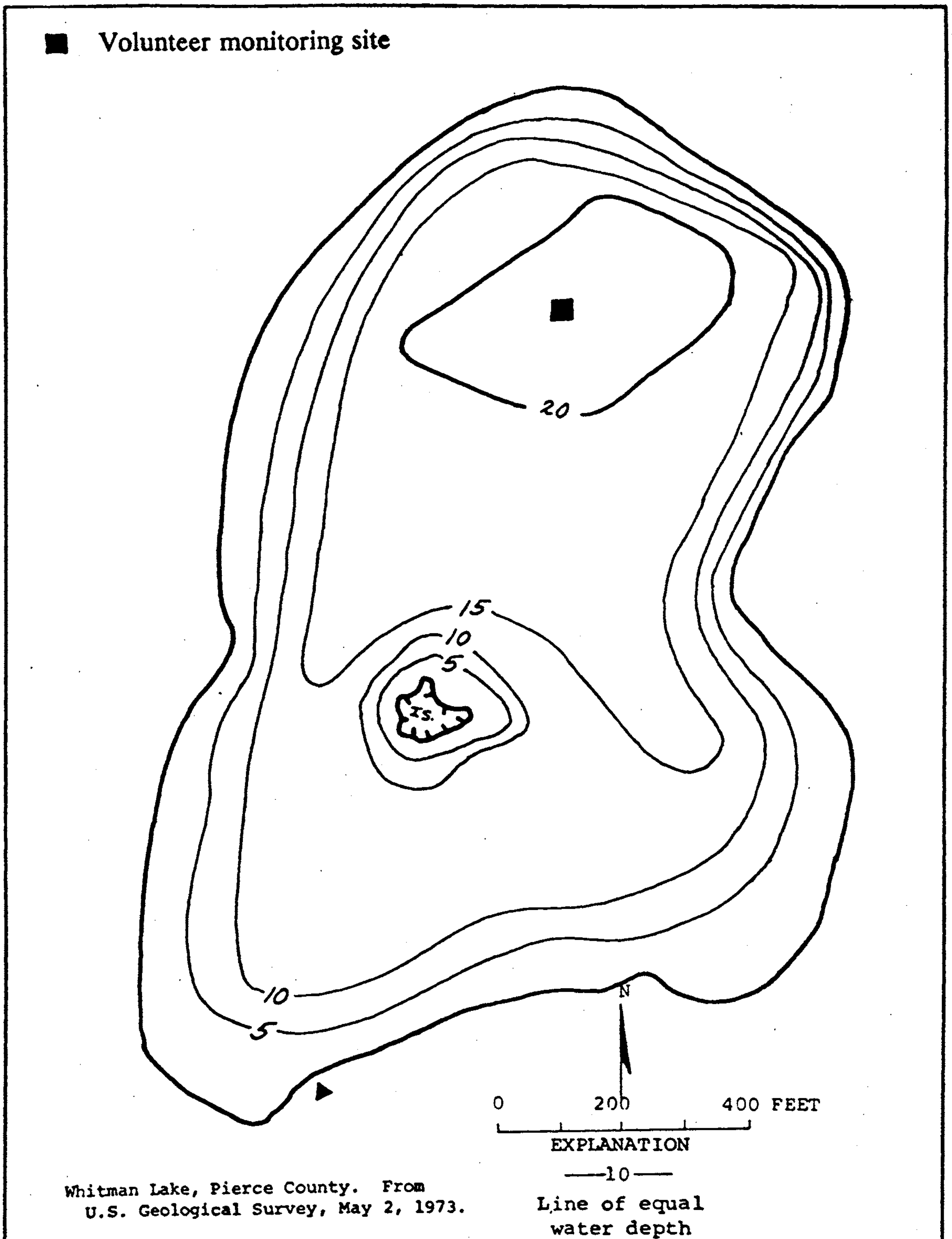
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/31	0.0	17.7	6.5	9.5	82	1	0.026	0.417
	0.5	17.7	6.6	9.4	82			
	1.0	17.7	6.7	9.4	82			
	2.0	16.3	6.5	6.8	85			
	3.0	13.5	6.1	0.9	95			
	4.0	10.3	6.0	0.1	113			
	5.0	9.0	6.1	0.2	109			
	6.0	8.4	6.2	0.1	165			
08/23	0.0	20.7	6.9	9.1	95	1, 2	0.034	0.504
	1.0	20.7	6.9	8.9	97			
	2.0	20.7	6.9	8.9	98			
	3.0	16.2	6.3	0.4	135			
	4.0	12.1	6.0	0.1	161			
	5.0	9.9	6.1	0.1	281			

Secchi Depth and Profile Data Graphs







Whitman Lake, Pierce County. From U.S. Geological Survey, May 2, 1973.

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)	2052
Shoreline Length (miles)	5.3

Estimated Trophic State:	Mesotrophic
Mean Trophic State Index* (Secchi):	44
Mean Trophic State Index* (Total Phosphorus):	46

* From Carlson (1977)

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Williams Lake is used for fishing, boating, swimming, rowing, jet skiing, camping, and waterfowl hunting. Recreational facilities on the lakeshore include two resorts and one boat ramp, and there is a speed restriction set by Spokane County of 50 mph for motorboats. Lake water is withdrawn for drinking and irrigation. Currently the watershed is used primarily for animal grazing, crop agriculture, and the lakeshore is being developed further for residences. In the past, the watershed was used for animal grazing and crop agriculture. There are 28 houses on the lakeshore; of these, 11 are occupied year-round. The lakeshore is partially sewered, and there are two culverts that empty into the lake. Trout are stocked in the lake. Presently there is a sewer district and a community association for the lake. The lake has been chemically treated in the past to control fish species. The worst problems in the lake, in the opinion of the volunteer, are 1) algae, 2) aquatic plants, and 3) water level. Overall, the volunteer finds that Williams Lake has good recreational water quality, and is concerned that the lakeshore is not sewered.

There are wetland areas on the west end of the lake. Weeds come to the surface of the water in these shallow areas and in an area greater than 25 feet deep on the east end (just off the public dock).

In the 1989 questionnaire, the volunteer noted the following information: 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. The lake has been treated with rotenone several times to eliminate rough fish; the last treatment was in 1988.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1989 and 1990 show that mean summer water clarity was somewhat better in 1989 than in 1990, although the low water clarity during April and May 1989 did not occur during 1990. Profile data collected during May and August 1990 show that on both sampling dates, the lake was thermally stratified and concentrations of dissolved oxygen decreased considerably below the thermocline. During August, concentrations of dissolved oxygen were virtually depleted in the bottom 12 meters (about 39 feet) of the lake. Dissolved oxygen is usually depleted by bacterial decomposition of organic material (such as plants and algae) in the water and sediments. During August, the decrease in pH and increase in conductivity with depth is most likely related to increased decomposition near the lake bottom. The profile data were similar to data collected by Ecology during 1989 (Brower and Kendra, 1990). Dissolved oxygen concentrations were also depleted in the lower layer of Williams Lake in surveys conducted in 1968 (Lee, 1969) and 1973 (McConnell *et al.*, 1976), so it is likely that low dissolved oxygen concentrations near the bottom of Williams Lake have been occurring for many years.

The 1990 concentrations of total phosphorus and total nitrogen were moderately high (averaging 0.018 and 0.504 mg/L, respectively). These concentrations were very similar to concentrations measured during Ecology's 1989 survey. In 1973, the concentration of total phosphorus was 0.027 mg/L and the concentration of total nitrogen was 0.12 mg/L (Dion *et al.*, 1976).

In 1973, a bloom of diatoms, flagellates, and blue-green algae occurred during the spring and summer (McConnell *et al.*, 1976). Although plant growth was generally light, there were areas of dense plant growth, consisting of cattails (*Typha* sp.), sedge (*Cyperaceae*), coontail (*Ceratophyllum* sp.), waterweed (*Elodea* sp.), pondweed (*Potamogeton* sp.), and water milfoil (*Myriophyllum* sp.; McConnell *et al.*, 1976). During the August 1990 onsite visit with the volunteer, aquatic plants identified in the lake included American elodea (*Elodea canadensis*), coontail (*Ceratophyllum demersum*) and watermeal (*Wolffia* spp.).

Hydrogen sulfide (rotten-egg smell) was detected in bottom water samples collected in 1973 (Dion *et al.*, 1976) and 1989 (Brower and Kendra, 1990). Hydrogen sulfide can be produced when bacteria decompose organic material such as algae, aquatic plants or woody debris in the absence of oxygen.

Williams Lake -- Spokane County

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.

Water quality variance records with Ecology state that an application for a permit to apply aquatic herbicides in Williams Lake was denied in 1990.

Comments

Williams Lake was one of five Spokane County lakes monitored for the program in 1990. Compared to Eloika, Liberty, Long, and Newman Lakes, Williams Lake had the lowest concentration of total phosphorus (Liberty Lake did not have total phosphorus samples analyzed for the program in 1990). Only Newman Lake had better overall water clarity than Williams Lake.

Acknowledgement

I thank Brad McHenry for volunteering his time to monitor Williams Lake during 1989-1990.

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
21-May	14.0	57.2	7.5	Green	0	Moderate	Calm	12.4	1.5	Lake height of 0 will be reference point as of today.
23-May								13.3		
05-Jun	14.0	57.2	8.0	Green	0	Heavy	Light	11.9	1.7	Lake height 0 reading at 1.50 feet now at 1.68 feet. Have had heavy rains and winds last 2 weeks.
20-Jun	19.0	66.2	8.0	Green	0	None	Light	10.1	1.6	Pine pollen and algae starting.
09-Jul	23.0	73.4	8.0	Dark-Gr	0	None	Calm	9.2	1.4	Can see water quality deteriorating.
21-Jul	24.0	75.2	7.5	Green	0	None	Breezy	9.2	1.2	Water seems to be of relatively good quality.
06-Aug	24.0	75.2	8.0	Green	0	None	Strong	9.2	1.0	Looks like different kinds of algae in lake.
10-Aug								9.6		
20-Aug	24.0	75.2	8.0	Green	10	Trace	Calm	9.2	0.8	
05-Sep	24.0	75.2	8.0	Green	0	None	Calm	11.9	0.6	Lake looks good. Most algae scum gone.

* Secchi data corrected for rope shrinkage

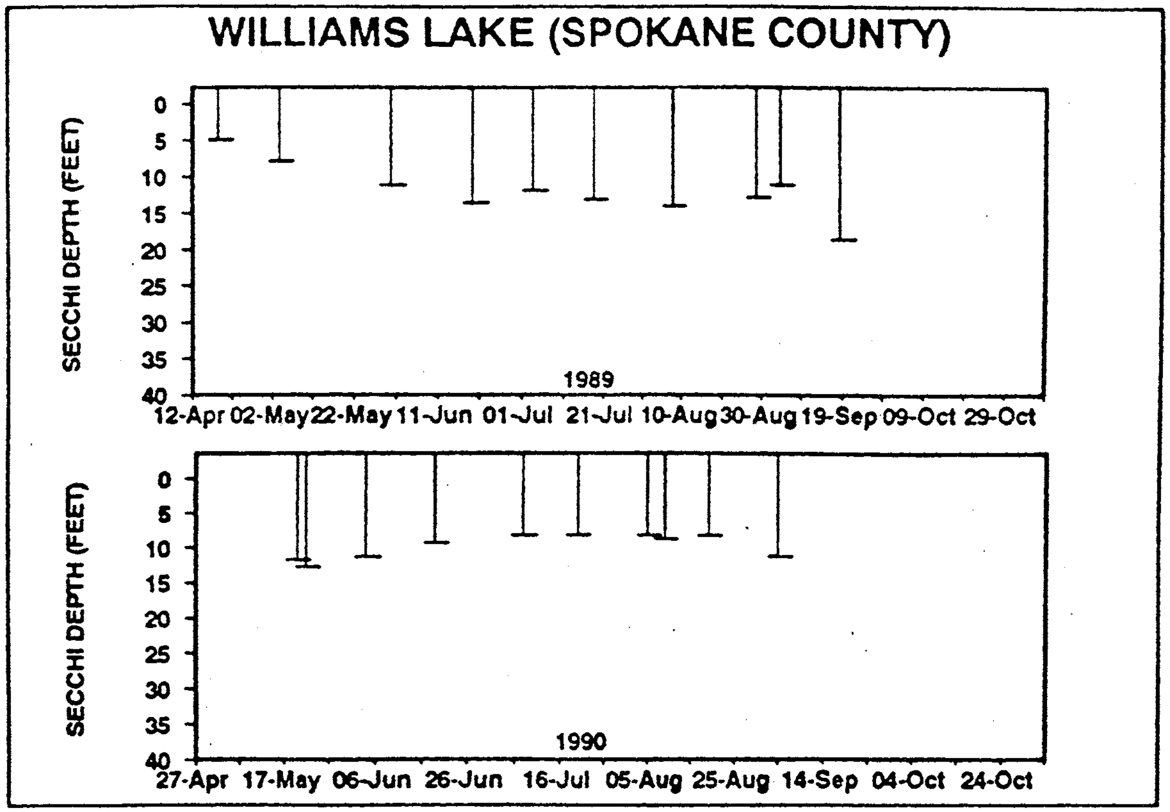
Williams Lake -- Spokane County

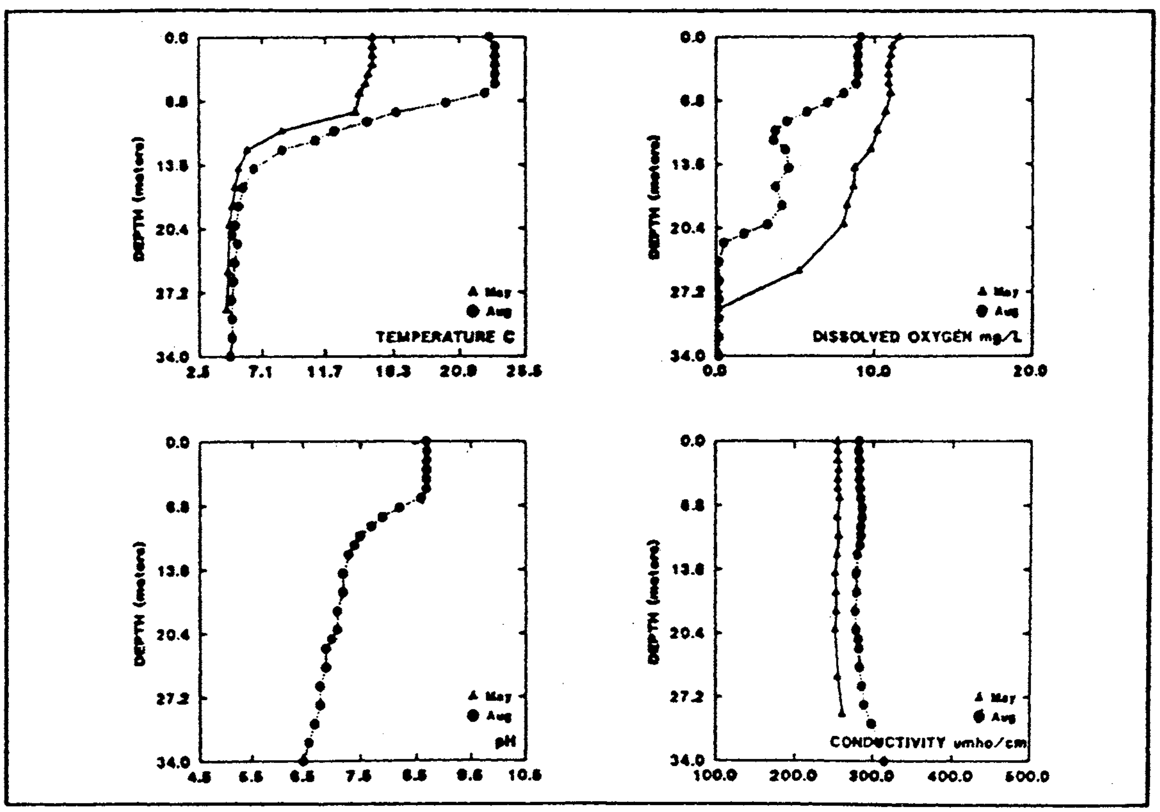
Onsite Visit Data

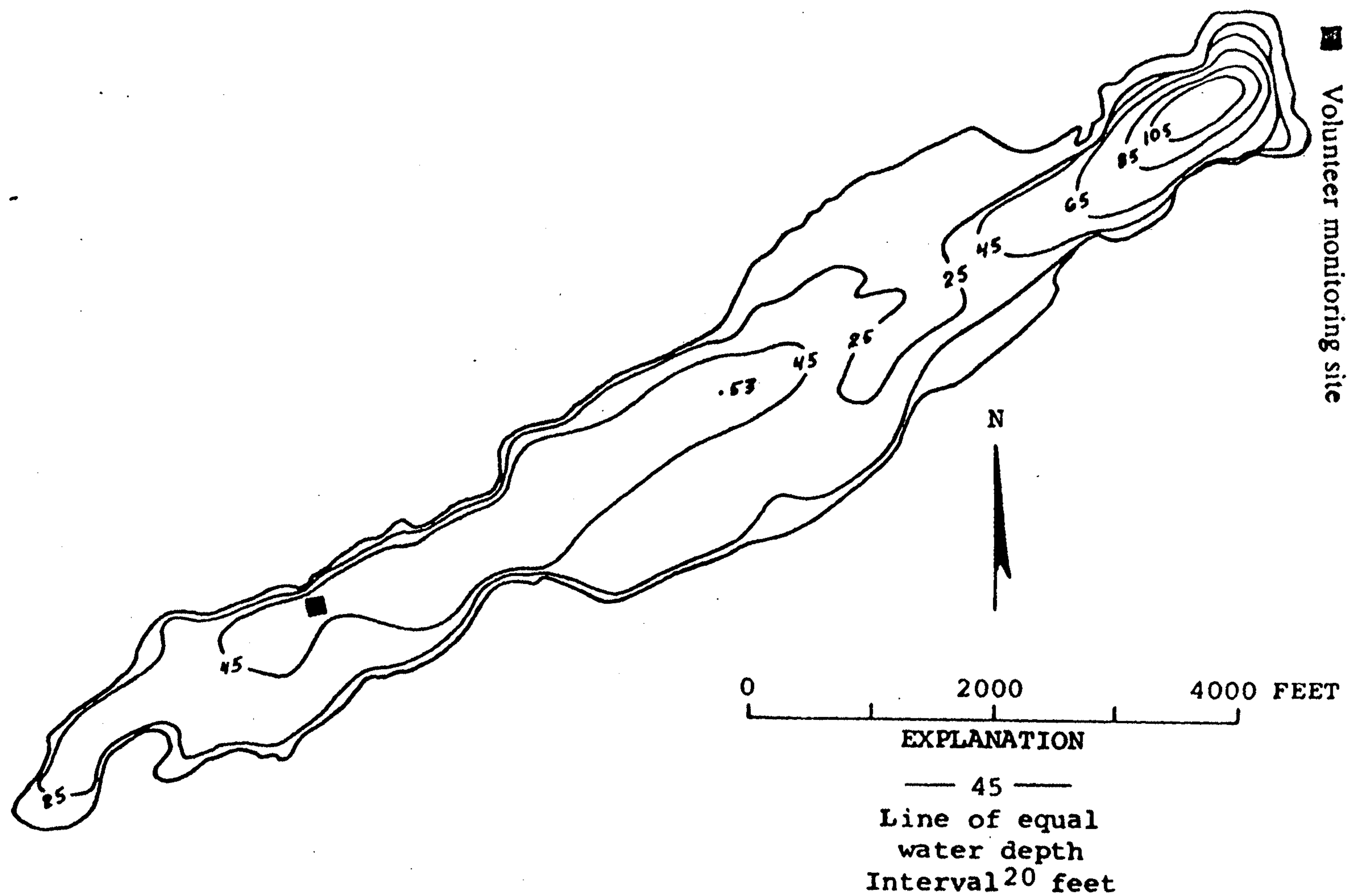
Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (μmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
05/23	0.0	14.9	.*	11.5	253	1, 3, 6	0.019	0.488
	1.0	14.9	.	11.1	254			
	2.0	14.9	.	11.0	254			
	3.0	14.9	.	10.9	255			
	4.0	14.6	.	10.9	254			
	5.0	14.4	.	10.9	254			
	6.0	14.0	.	11.0	256			
	8.0	13.7	.	10.7	254			
	10.0	8.6	.	10.2	255			
	12.0	6.0	.	9.8	253			
	14.0	5.4	.	8.7	251			
	16.0	5.1	.	8.6	252			
	18.0	4.9	.	8.2	252			
	20.0	4.7	.	8.0	251			
	25.0	4.6	.	5.2	254			
	29.0	4.5	.	0.2	260			
08/10	0.0	23.0	8.7	9.1	282	1, 3, 5	0.017	0.520
	1.0	23.4	8.7	8.9	281			
	2.0	23.4	8.7	8.9	282			
	3.0	23.4	8.7	8.9	282			
	4.0	23.4	8.7	8.9	282			
	5.0	23.4	8.7	8.8	283			
	6.0	22.7	8.6	8.0	284			
	7.0	20.0	8.2	7.0	286			
	8.0	16.5	7.9	5.7	286			
	9.0	14.5	7.7	4.5	284			
	10.0	12.3	7.5	3.8	284			
	11.0	11.0	7.6	3.7	283			
	12.0	8.6	7.3	4.4	280			
	14.0	6.5	7.2	4.6	278			
	16.0	5.7	7.2	3.8	279			
	18.0	5.4	7.1	4.2	277			
	20.0	5.2	7.1	3.3	278			
	21.0	4.9	7.0	1.8	281			
	22.0	5.3	6.9	0.5	282			
	24.0	5.1	6.9	0.2	283			
	26.0	5.0	6.8	0.2	286			
	28.0	4.9	6.8	0.2	289			
	30.0	4.9	6.7	0.2	299			
	32.0	4.9	6.6	0.2	308			
	34.0	4.8	6.5	0.2	315			

* See Quality Assurance section of this report.

Secchi Depth and Profile Data Graphs







Williams Lake, Spokane County. From
Washington Department of Game, January 1948.

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

Estimated Trophic State:	Oligo-mesotrophic
Mean Trophic State Index* (Secchi):	32
Trophic State Index* (Total Phosphorus):	43

* From Carlson

Summary of Questionnaire Results and Information From the Volunteer

The following are from the volunteer's remarks and questionnaire responses. Lake Wooten is used for fishing, boating, swimming, rowing, and jet skiing. Recreational facilities on the lakeshore include one boat ramp, and there are no restrictions for motorboat use on the lake. Lake water is withdrawn for drinking and irrigation. Currently the watershed receives primarily residential use. In the past, the watershed was used for logging, and the shoreline was altered. There are 67 houses on the lakeshore; of these, 8 are occupied year-round. The lakeshore is not sewered, and there are four culverts that empty into the lake. Rainbow and cutthroat trout are stocked in the lake. Presently there is no citizen's organization for the lake. The lake has been chemically treated in the past to control fish species. In the opinion of the volunteer, the worst problem in the lake is algal growth. Overall, the volunteer finds that Lake Wooten has good recreational water quality, and suggested that poor or inadequate septic systems and lawn fertilizing may affect water quality.

There is very little aquatic plant growth in the lake. 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.

Monitoring Results/Summary of Other Available Information

Secchi data collected during 1989 and 1990 show that during both years water clarity was lowest during September. Overall, mean summer water clarity was better during 1990. Profile data collected August 1990 show that the lake was very warm and thermally stratified.

Lake Wooten -- Mason County

Concentrations of dissolved oxygen increased somewhat near the bottom of the lake. This probably occurred because of the decreased water temperature (dissolved oxygen is more soluble in cooler water than in warmer water). During 1989, profile data collected by Ecology showed dissolved oxygen concentrations increased near the bottom during June, but were virtually depleted near the bottom of the lake during September (Brower and Kendra, 1990).

The 1990 concentrations of total phosphorus and total nitrogen were moderately high (0.0146 and 0.638, respectively). Compared with nutrient data collected by Ecology in 1989, the concentrations of both total phosphorus, and particularly, total nitrogen were higher during 1990.

A severe bloom of the blue-green alga *Gloeotrichia* occurred during September 1989 (Brower and Kendra, 1990).

Residential development of the lakeshore has increased since 1974; there were 47 nearshore homes in 1974 (Bortleson *et al.*, 1976), compared with 67 nearshore homes reported by the volunteer in 1990.

Comments

In 1990, we reported that the water clarity in Lake Wooten gradually decreased over the entire summer, which we felt was unusual. This same pattern was generally repeated in 1990.

Lake Wooten was one of seven Mason County lakes monitored for the program in 1990. Compared to Island, Limerick, Mason, Nahwatzel, Phillips, and Spencer Lakes, Lake Wooten had moderately high total phosphorus concentrations and moderately good water clarity. Nevertheless, Mason Lake had the best water clarity and the lowest nutrient concentrations of the monitored Mason County lakes.

Acknowledgement

I thank Rusty Kidrick for volunteering her time to monitor Lake Wooten during 1989-1990.

Lake Wooten -- Mason County

Volunteer-Collected Data

Date 1990	Temperature (°C)	(°F)	pH	Water Color	%Cloud Cover	Recent Rain	Wind	Secchi (ft) *	Lake Ht(in)	Abbreviated Comments
16-May	15.0	59.0		Green				24.1		Data sheet last years style. Lake depth 32'. Secchi rope readings corrected for a 7 foot shrinkage.
12-Jun	17.0	62.6	6.5	Lt-Green	50	Moderate	Light	25.4**	32.0	
06-Jul	20.0	68.0	6.5	Green	50	Heavy	Breezy	22.5	32.0	Start of algae bloom.
19-Jul	23.0	73.4	6.5	Lt-Green	0	None	Light	23.4	32.0	Not as much algae bloom as last year at this time.
07-Aug	24.0	75.2	6.5	Green	0	None	Light	25.0	21.0	Algae growth still less than last two years.
14-Aug								25.4		Reading taken with Ken Pensula.
31-Aug	22.0	71.6	6.5	Green	0	Heavy	Breezy	18.3	20.0	
14-Sep	20.0	68.0	6.5	Lt-Green	0	None	Light	20.9	17.0	Almost no algae bloom.
27-Sep	19.0	66.2	6.5	Lt-Green	0	None	Calm	19.9	15.5	Algae bloom is gone.
11-Oct	16.0	60.8	6.5	Lt-Green	100	None	Breezy	19.0	15.0	

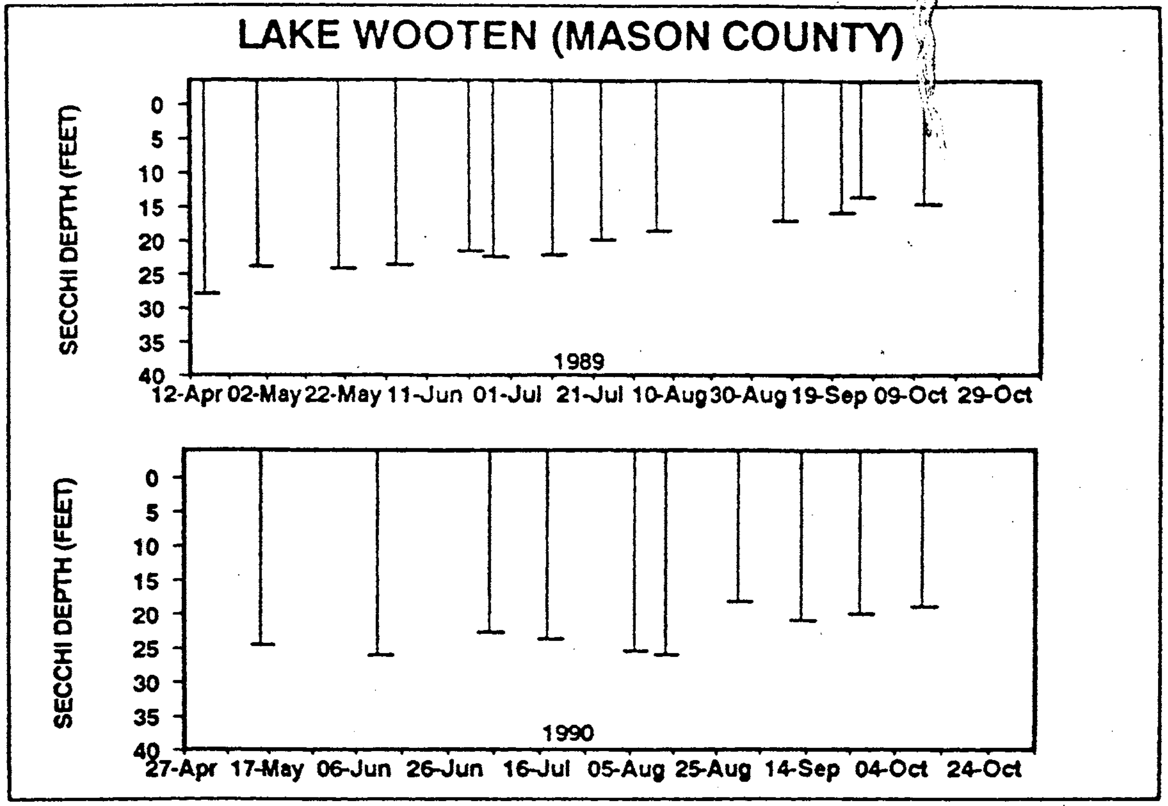
* Secchi data corrected for rope shrinkage

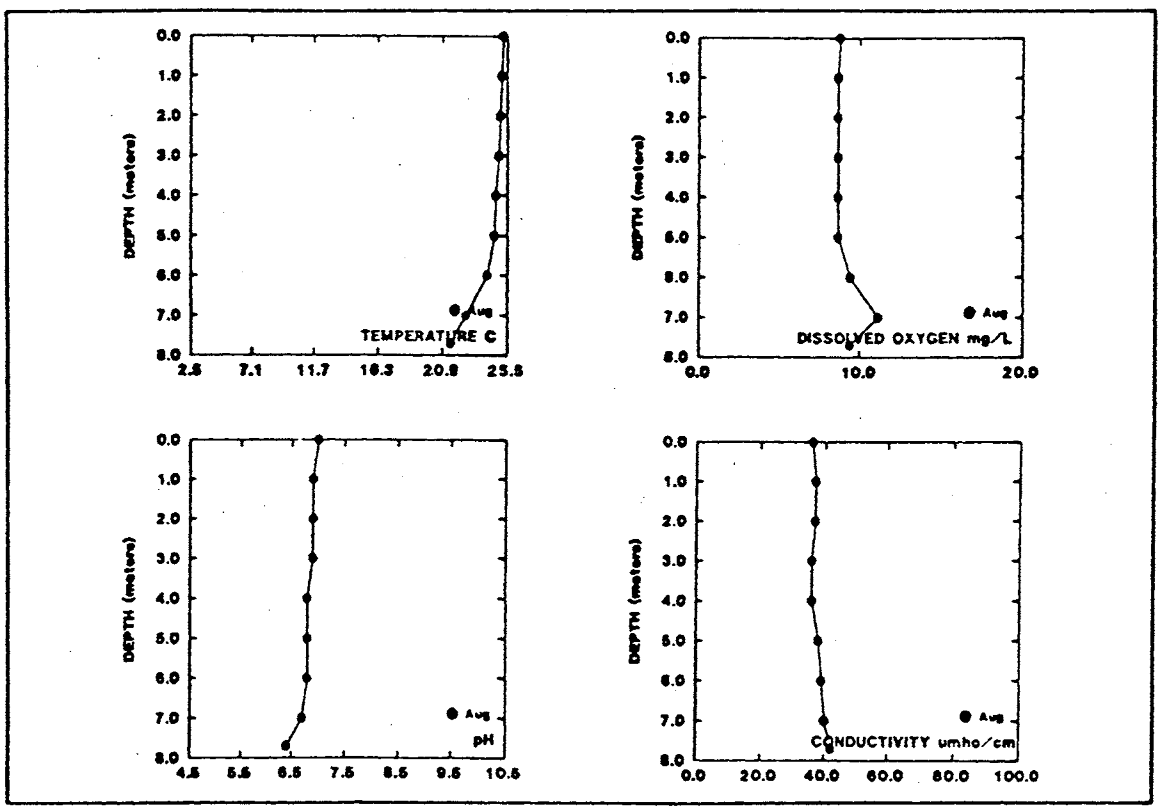
** There was high variability between the first and second Secchi depths collected; this data point may not be included in data comparisons.

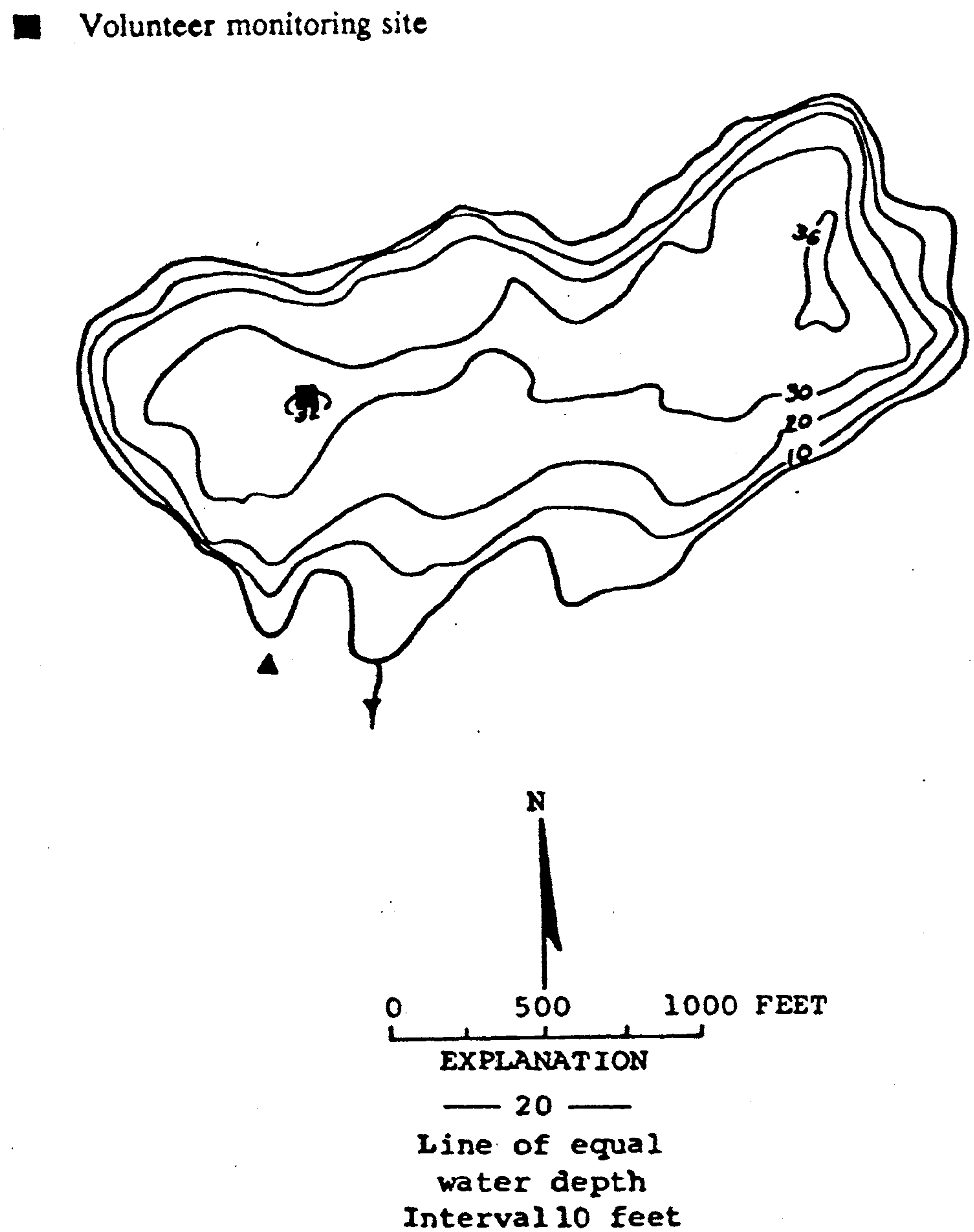
Onsite Visit Data

Date 1990	Depth (meters)	Temp (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µmhos/cm)	Composite sample depths (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
08/14	0.0	25.2	7.0	8.7	36	2, 3, 4	0.015	0.638
	1.0	25.1	6.9	8.6	37			
	2.0	25.0	6.9	8.6	37			
	3.0	24.9	6.9	8.6	36			
	4.0	24.7	6.8	8.6	36			
	5.0	24.6	6.8	8.6	38			
	6.0	24.1	6.8	9.4	39			
	7.0	22.6	6.7	11.2	40			
	7.7	21.5	6.4	9.4	42			

Secchi Depth and Profile Data Graph







Wooten Lake, Mason County. From Washington
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Appendix A

Questionnaire on Lake and Watershed Uses

Appendix A. WASHINGTON'S CITIZEN LAKE MONITORING PROJECT

QUESTIONNAIRE

Your Name ______________________ Date ______________
Lake Name ______________________
County ______________________

Please complete this questionnaire as best you can and return it to Julie Rector by September 15, 1990. This is a very important part of the project; your answers will help us to update our files about your lake, and will help us to interpret your monitoring data. You may still collect Secchi disk data through mid-October.

Some of the questions (#7, #9, and #14) can only be answered by boating around your lake. Please do not try to answer these questions from memory because we need thorough and accurate information. If it is helpful, use binoculars or walk along the lakeshore. Note that questions #17 and #18 ask you to evaluate fishing and swimming in your lake over the entire summer.

Contact Julie if you aren't sure how to answer some of the questions. Thanks for your time spent on this!

Watershed and Lake Uses

1. What are the recreational uses of the lake?
   - ☐ Fishing
   - ☐ Motor Boating (including water skiing)
   - ☐ Swimming
   - ☐ Canoeing/Rowing/Sailing/Wind Surfing
   - ☐ Jet Skiing
   - ☐ Camping
   - ☐ Waterfowl Hunting
   - ☐ Other ______________________

2. What public recreational facilities are there on the lakeshore?
   - ☐ Picnic Area
   - ☐ State Park
   - ☐ Camping
   - ☐ Resorts (How many? ______)
   - ☐ Pit Toilet
   - ☐ Flush Toilet
   - ☐ Shower
   - ☐ Boat Ramps (How many? ______)
   - ☐ Parks
   - ☐ Beach
   - ☐ Other ______________________

3. Are there restrictions for motor boat use on the lake?
   - ☐ No motor boating allowed
   - ☐ Speed limits for motor boats: ______ mph
   - ☐ Other restrictions: (please list ______________)
   - ☐ No, there are no restrictions 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? (Note if one activity is especially dominant.) (A watershed is all land that drains eventually into a lake, and includes land that drains into streams that flow into the lake.)
   - ☐ Logging
   - ☐ Agriculture--crops, orchards, tree farms . . .
   - ☐ Agriculture--animal grazing and animal feeding operations
     Do livestock have direct access to the lakeshore or to inlet tributaries? ☐ Yes ☐ No
     Is manure drainage entering the lake? ☐ 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 ____________________

7. How many houses are there on the lakeshore? (The exact number is best; estimate the number if you live on a very large lake.)
   - ☐ Exactly ____________
   - ☐ Estimated ____________

   How many of these houses are occupied year-round? (Estimate) ________

8. Is the lakeshore area sewered?
   - ☐ Yes--Fully
   - ☐ Yes--Partially (_____% of the shoreline, or ______% of the homes are 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

10. Has the lake been treated with any chemicals in the past?
    - ☐ Yes, for weed control
    - ☐ Yes, for algae control
    - ☐ Yes, for eliminating rough fish
    - ☐ No
    - ☐ Don't know

11. Will the lake be treated with any chemicals this year?
    - ☐ Yes, for weed control
    - ☐ Yes, for algae control
    - ☐ Yes, for eliminating rough fish
    - ☐ No
    - ☐ Don't know

12. Are any lake management activities occurring on your lake this year?
   - ☐ Yes, mechanical harvester is being used
   - ☐ Yes, the lake will be/has been chemically treated (Algae ☐, Weeds ☐)
   - ☐ Yes, the lake will be/has been dredged
   - ☐ Yes, the lake will be drawn down next winter
   - ☐ Yes, ________________________________
   - ☐ No management activities will be pursued this year

13. Are fish stocked in the lake?
   - ☐ Yes (What species? ______________________)
   - ☐ No
   - ☐ Don't know

14. On the attached map, mark where algae blooms occur and where weed grow in your lake. Try to show both the types of plants (for example, submerged weeds, reeds, cattails, lily pads, or algae) and the amount of lake they inhabit. Also mark wetlands on the attached map. (Wetlands are land areas that are saturated with water during some parts of the year. Wetlands include marshes, swamps and bogs.) Feel free to add any other information you feel might be useful. See the example map for how to do this. **Please complete the map carefully; this map will tell us a <u>lot</u> about your lake!**

<u>Lake Water Quality</u>

15. Overall, how would you evaluate the recreational water quality on your lake?
   - ☐ Excellent
   - ☐ Good--no uses are restricted because of poor water quality
   - ☐ Fair--some uses are restricted because of water quality
   - ☐ Poor--would not swim in this lake most days out of the year

16. What have been the biggest water quality problems on your lake in 1990?
   <u>Please rank problems in the order of their importance</u> with No. 1 being the worst problem and No. 2 being the next worse problem, etc.
   - ___ Weeds
   - ___ Algal blooms
   - ___ Lake level
   - ___ Rough fish
   - ___ Fish kill
   - ___ Sediments suspended in the water
   - ___ Garbage, debris, leaves
   - ___ Odor (describe)________________________________
   - ___ Other ________________________________

17. 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 to swimming? (☐ Yes, ☐ No)
   - ☐ No

18. Were there days when fishing was difficult in your lake because of poor water quality, for example--excessive plants of algae.
   - ☐ Yes, about how many days out of the year? ________
     Was the lake officially closed to fishing? (☐ Yes, ☐ No)
   - ☐ No

19. What do you see to be the predominant source(s) of contamination into your lake? (Use another piece of paper if you need more room.)

____

____

20. Is there any other information that you would like to pass on about your lake?

____

____

____

Lake Organizations

21. Are there any lake groups for your lake?

- ☐ Lake Association
- ☐ Lake Management District
- ☐ Sewer District
- ☐ Community Association
- ☐ Other(s) ______________________________

Monitoring/Training

22. Do you feel you were adequately trained to use the Secchi disk and that your questions on lake monitoring were answered? ☐ Yes ☐ No
If no, how could the training be improved? ______________________________

____

23. How many times did you take a Secchi disk reading? ____________
(This is to make sure we've received as many sheets as you've mailed.)

24. What is the condition of your Secchi disk?
- ☐ Fine
- ☐ Chipped paint, but usable
- ☐ Rope needs to be remarked
- ☐ Disk needs replacing

25. Did you enjoy participating in the project? (Please comment)

____

____

____

____

26. Would you volunteer again for next summer?
- ☐ Yes
- ☐ No, I'll return the disk and thermometer at the end of this 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 ______________________________

27. Suggestions for improving the program for the 1991 sampling season:

____

____

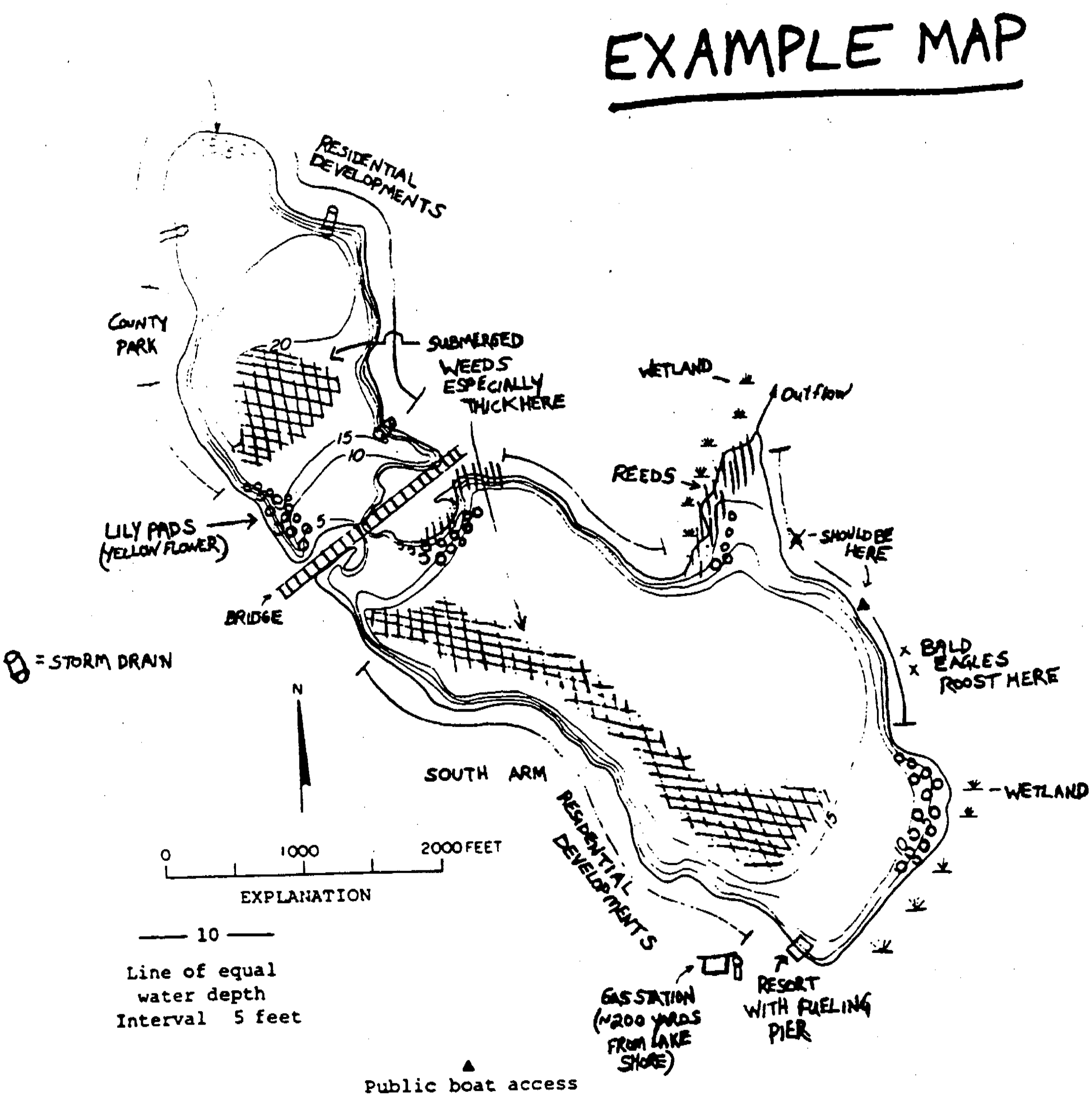
____

____

____

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE!

Appendix A. Continued



NOTE: Entire bottom of both basins is covered with submerged weeds that extend to surface in clumps, especially in later spring. Algae blooms are not localized in any one area.

Appendix B

Questionnaire Results

Appendix B. **Questionnaire Results.**

Although six lakes had more than one volunteer, questionnaires were mailed to only one volunteer per lake. Of active volunteers on 73 lakes, 53 volunteers (73%) completed and returned questionnaires. Lakes which are represented in the following summary of questionnaire results are listed in Table B1. Results of the questionnaire are summarized in Table B2.

Overall, the completed questionnaires indicated that the majority of lakes in the program have lakeshore residences and are used for public recreation. Logging and agriculture are common uses of the lakes watersheds. Although most of the volunteers perceived some kind of water quality problem in their lake (mostly aquatic plant and algal growth), only 11 volunteers reported that the recreational quality of their lakes were "fair" or "poor," and only nine volunteers would not swim in their lakes for some duration of the year because of poor water quality. Most of the volunteers were concerned about possible water quality effects from septic systems. Yard-care fertilizers and nearshore construction were also cited as possible sources of water quality problems. Five volunteers reported that their lakes were chemically treated in 1990 to control aquatic plants and/or algae, and all five lakes had short-term water quality variance permits filed with Ecology. As a result of questionnaire responses, in the future the program will increase education efforts on aquatic plants and algae, and on water quality effects from septic systems.

The following sections summarize questionnaire results in more detail, with results presented for major topics represented in the questionnaire. Please note that this summary pertains only to those lakes for which we received completed questionnaires, and many questionnaires had incomplete answers for some questions. The questionnaire mailed to the volunteers in 1990 differed somewhat from the questionnaire used in 1989; the 1990 questionnaire had fewer questions (some questions were consolidated, others deleted) and the volunteers were not asked to map macrophytes. A sample of the 1990 questionnaire is in Appendix A.

Public Recreation. Fishing, swimming, and boating are the most prevalent uses of the lakes. All 53 lakes are used for fishing. Of 17 lakes with public parks, 5 have state parks. Of 27 lakes which are used for camping, only 17 were reported to have public camping facilities. Of 50 lakes used for swimming, 21 have public beaches.

Boating. More lakes are used for rowing (47) than motorboating (36). Seventeen lakes have no restrictions for motorboat use, but 5 do not allow motorboats. Twenty-four lakes have speed restrictions for boating, and 15 of these lakes have speed restrictions of $<=$ 8 mph (for several of these, this low speed limit applies only within 200 feet of shore). Forty-eight lakes have public boat ramps; 31 have 1 ramp, 10 have two ramps, and seven lakes have three or more ramps. Three lakes (Cortez, Round, and Thomas) do not have a boat ramp.

Water Withdrawal. Drinking water was the most common reason for water withdrawal (20 lakes). Water is also withdrawn for municipalities (3 lakes), industries (5 lakes) and for irrigation (18 lakes). Nine lakes have no water withdrawn.

Table B1. Lakes Represented in Questionnaire Results: Fifty-three Volunteers Completed and Returned Questionnaires from 53 Lakes.

Lake (County)	
Aeneas (Okanogan)	Mission (Kitsap)
Big (Skagit)	Nahwatzel (Mason)
Black (Stevens)	Ohop (Pierce)
Blue (Grant)	Osoyoos (Okanogan)
Bosworth (Snohomish)	Patterson (Thurston)
Chelan (Chelan)	Round (Clark)
Cortez (Grant)	Sacheen (Pend Oreille)
Cranberry (Island)	Samish (Whatcom)
Crawfish (Okanogan)	Shoecraft (Snohomish)
Curlew (Ferry)	Sidley (Okanogan)
Davis (Pend Oreille)	Spanaway (Pierce)
Eloika (Spokane)	Spencer (Mason)
Flowing (Snohomish)	St. Clair (Thurston)
Goss (Island)	Starvation (Stevens)
Horseshoe (Cowlitz)	Stevens (Snohomish)
Killarney (King)	Storm (Snohomish)
Kitsap (Kitsap)	Sullivan (Pend Oreille)
Lacamas (Clark)	Sunday (Snohomish)
Leo (Pend Oreille)	Tanwax (Pierce)
Liberty (Spokane)	Thomas (Stevens)
Limerick (Mason)	Waitts (Stevens)
Long (Kitsap)	Wannacut (Okanogan)
Long (Thurston)	Wenatchee (Chelan)
Louise (Pierce)	Whatcom (Whatcom)
Lake Martha (Snohomish	Whitman (Pierce)
Martha Lake (Snohomish)	Williams (Spokane)
Mason (Mason)	Wooten (Mason)

Table B2. Summary of Questionnaire Responses: Number and Percentage of Lakes Which Support Various Uses and Facilities, According to Volunteer Responses from 53 Completed and Returned Questionnaires.

	Number of Lakes with Uses/Facilities	% of Returned Surveys
Recreational Uses		
Fishing	53	100
Swimming	50	94
Rowing	47	89
Motorboating	36	68
Jet Skiing	29	55
Camping	27	51
Waterfowl Hunting	9	17
Public Facilities		
State Parks	8	15
Other Parks	17	32
Camping Areas	17	32
Resorts	17	32
Beaches	21	40
Boat Ramp(s)	48	91
Boating Restrictions		
No Motor Boats Allowed	5	9
No Restrictions at All	17	32
Speed Restrictions	24	45
Lake Water Uses		
Drinking/Domestic	20	38
Municipal	3	6
Industrial	5	9
Irrigation	18	34
No Withdrawal	9	17
Current Watershed Uses		
Logging	31	58
Agriculture - Crops	22	41
Agriculture - Animal Grazing	32	60
Industry	6	11
Lakeshore Residential Development	46	87

Appendix B. Continued.

Watershed Uses. The questionnaire asked about both present and past uses of each lake's watershed. Animal grazing and logging are the most prevalent current uses (32 and 31 lake watersheds, respectively). In the past, 35 watersheds were used for crop agriculture, and 24 were used for animal grazing. Forty-three watersheds were logged in the past.

Sixteen of the 32 lakes that currently have animal grazing within their watersheds have animals with direct access either to the lakeshore or inlet tributaries. Twenty-two watersheds are used for crop agriculture. Six watersheds (Kitsap, Liberty, Long [Thurston County], Osoyoos, Stevens, and Whatcom Lakes) are used for industry.

The questionnaire also asked whether the lake (or wetlands) was dredged in the past, and whether the shoreline was altered. Shoreline alteration refers to the dredging or filling of shoreline; usually done in conjunction with development. Fifteen volunteers reported their lake was dredged, and 28 reported that the shoreline was altered in some way.

Lakeshore Residential Development. Residences are being built on 87% (46) of the lakeshores. Thirty-one lakes had exact counts for the number of lakeshore homes, 18 were estimates and four lakes did not give any numbers for nearshore homes.

The number of nearshore homes ranged from 0-670 at lakes where data were provided. The mean number of homes was 121, and the median was 72. Twenty-two percent of the lakes (11) had fewer than 25 nearshore homes. Two of these have no homes (Cranberry and Leo), and two lakes have only one home (Round and Sidley). Williams Lake has only 28 houses, but also has about 125 permanent trailers and 55 lots for RVs that are used during the summer. These trailers and lots are located in a small area of the northeast shore, near the public access.

Although several lakes have lakeshore residences that are occupied only seasonally (15 lakes have fewer than 50% of the homes occupied year-round), 22 lakes have 75-100% of the residences occupied year-round. Only one volunteer noted that none of the residences were occupied year-round (Crawfish Lake -- this is a high elevation lake that gets snowed in every winter and can only be accessed by snowmobile).

Lakeshore Sewering. The majority of the lakeshores are not sewered (37), and rely on onsite wastewater disposal (mostly septic systems). Four lakes have 50% of the homes sewered, and six lakes have 90-100% of the homes sewered. These six lakes with 90-100% of the lakeshore sewered are Big, Lacamas, Liberty, Louise, Samish, and Stevens.

Fishing. As noted above, all 53 lakes are used for fishing. Forty-three of these lakes were reported to be stocked with fish, and seven were reported to not be stocked. Trout (especially rainbow trout) were reported to be stocked in most of the lakes. Please note that lakes and species reported to be stocked were not verified with the Department of Wildlife.

Appendix B. Continued.

Lake Management. The questionnaire asked if the lakes were treated in 1990, or sometime in the past, with chemicals to control weeds, algae, or undesirable fish species. Because chemical treatment is a sensitive issue with many people and agencies, please note that the information reported here for past treatments was not verified, and is the conjecture of the volunteers who completed the questionnaires. Lakes reported to be treated with chemicals in the 1990 questionnaires were verified against applicator reports filed with Ecology's Water Quality Program. All lakes with reported chemical treatment in 1990 to control weeds or algae had short-term water quality variance permits filed with Ecology, as well as applicator reports indicating the dates the lakes were treated and the chemicals used.

Thirteen volunteers reported that their lakes were treated in the past to control weeds, and five lakes were treated in 1990. Nine lakes were treated in the past to control algae, whereas four were treated in 1990. Twenty-four volunteers reported that their lakes were treated in the past to control fish species, whereas only one lake was reported to be treated in 1990 (after some inquiry, we found that the lake in question was not treated in 1990 after all).

Other management techniques used in 1990 include mechanical harvesting (5 lakes), dredging (Lake St. Clair and Lake Limerick), and lake drawdown (Lake Cortez and Lake Eloika; the former is for water resources management, not aquatic plant control). One lake (Sacheen Lake) was being studied for a Phase 1 project, and another was in the midst of Phase II (Lake Eloika).

Perceived Problems in Lakes. Overall, the majority of lakes (26) were perceived by the volunteers to have "good" recreational water quality. Twelve volunteers reported their lakes have "excellent" recreational water quality, eight were "fair" and three lakes (Lacamas, Sunday and Starvation) were "poor". Four volunteers did not reply to this question.

The volunteers were asked to rank the problems in order of severity, with #1 being the worst problem. Aquatic plants were reported as being the most prevalent problem. They were reported as being a problem in the most lakes (34), and ranked #1 or #2 in most lakes (20 and 11, respectively). Algae was the next most prevalent problem; 27 lakes were reported to have algae problems; it was the #1 problem in 12 lakes, and #2 in another 12. Although lake level was reported to be a problem in 19 lakes, only four volunteers reported it to be the #1 problem. Seventeen volunteers listed suspended sediments as a problem, and 7 of these reported that it was the #1 problem. The other problems listed in the questionnaire (undesirable fish species, garbage and debris, odor and fish kill) were reported by a minority of the volunteers, with five or fewer volunteers listing each as being the #1 problem. Fish kill was the least reported problem. Three volunteers indicated that there were no problems to report.

The volunteers had the option of filling in other problems found in their lakes. Other problems included waterfowl, occasional high fecal coliform bacteria counts, swimmers itch, poor fishing, recreational overcrowding, and poorly maintained or poorly located septic systems. The latter was the most frequently listed of the other problems.

Appendix B. Continued.

For the lakes assessments, the volunteers were asked if poor water quality.affected the number of days/year that they could swim or fish. Of nine volunteers indicating that there were days they would not swim, six reported that they would not swim for 14 - 31 days. Sixty days/year, 120 days/year and 350 days/year were also reported. Only one volunteer indicated that swimming was officially closed, and noted that the closure was required following chemical treatment of the lake. Of seven volunteers indicating that fishing was limited due to water quality, one indicated that fishing was limited 120 days/year.

Perceived Sources of Water Quality Problems. This was an open question, with plenty of space provided for the volunteers to list and elaborate on any possible sources. Although not all volunteers listed any sources, the majority (23) listed septic systems as possible sources of water quality problems. In addition, 11 listed runoff, seven listed yard-care fertilizers, six listed new development and construction, and four listed motorboats.

Lake Organizations. Not all volunteers answered this question. Of those who did, 15 said their lakes have lake associations, two have lake management districts, seven have sewer districts, 12 have community associations and nine have no organization at all.

Volunteers. Forty-two volunteers of the 53 who returned the questionnaire (79%) indicated that they wanted to continue monitoring in 1991. However, six volunteers indicated that they did not want to volunteer again. Three of these people indicated that they were too busy, one did not live on the lake and did not give a reason for not wanting to continue (but inconvenience may have been a factor), and two were not satisfied with the program.

Appendix C

Quality Assurance Data for Volunteer-Collected Secchi Depths

LAKE	SECCHI1 (FEET)	SECCHI2 (FEET)	CV %	ROOT MEAN SQUARE %
AENEAS	11.50	12.00	3	3
AENEAS	12.50	14.00	8	
AENEAS	13.00	13.00	0	
AENEAS	14.00	14.00	0	
AENEAS	18.00	18.00	0	
AENEAS	16.00	16.00	0	
AENEAS	17.00	17.00	0	
AENEAS	17.00	17.00	0	
AENEAS	18.00	18.00	0	
AMERICAN	27.00	28.00	3	
BIG	6.00	6.00	0	2
BIG	5.87	5.87	0	
BIG	5.00	5.00	0	
BIG	5.00	5.00	0	
BIG	5.00	5.00	0	
BIG	7.00	7.00	0	
BIG	2.00	2.00	0	
BIG	3.00	3.00	0	
BIG	6.00	5.50	6	
BIG MEADOW	8.25	8.25	0	1
BIG MEADOW	8.50	8.50	0	
BIG MEADOW	11.25	11.25	0	
BIG MEADOW	8.00	7.75	2	
BIG MEADOW	6.75	6.75	0	
BIG MEADOW	6.25	6.25	0	
BIG MEADOW	7.00	7.00	0	
BIG MEADOW	7.50	7.50	0	
BIG MEADOW	9.50	9.60	1	
BIG MEADOW	11.20	11.30	1	
BIG MEADOW	14.50	14.20	1	
BLACK	19.00	19.50	2	1
BLACK	13.25	13.50	1	
BLACK	13.00	13.00	0	
BLACK	12.00	12.00	0	
BLACK	16.00	16.50	2	
BLACK	15.00	15.00	0	
BLACK	18.00	18.00	0	
BLACK	17.00	17.50	2	
BLACK	17.00	17.00	0	
BLUE	12.33	12.33		0
BLUE	10.00	10.50	3	
BLUE	9.17	9.17		
BOSWORTH	12.00	15.00	16	8
BOSWORTH	13.00	11.50	9	
BOSWORTH	13.00	13.00	0	
BOSWORTH	11.50	10.00	10	
BOSWORTH	12.00	11.50	3	
BOSWORTH	12.00	12.00	0	
BOSWORTH	12.00			
BOSWORTH	12.00	13.00	6	
BOSWORTH	10.50	12.50	12	
BOSWORTH	14.00	15.00	5	
CHELAN	43.00	43.00	0	2
CHELAN	50.00	51.00	1	
CHELAN	53.00	55.00	3	
CHELAN	47.00	48.00	1	
CLEAR	11.00	11.00		0
CLEAR	22.00	22.00	0	
CLEAR	13.00	13.00	0	
CLEAR	20.00	20.00	0	
CLEAR	26.00	26.00	0	
CLEAR	25.00	25.00		
CLEAR	25.00	25.00		
CLEAR	24.00			
CLEAR	25.00			
CORTEZ	10.00	10.00		3
CORTEZ	8.17	8.00	1	
CORTEZ	6.00	6.00	0	
CORTEZ	7.50	8.00	5	
CORTEZ	10.00	9.50	4	
CORTEZ	3.50	3.50		

LAKE	SECCHI1 (FEET)	SECCHI2 (FEET)	CV %	ROOT MEAN SQUARE %
CORTEZ	3.00	3.00		
CORTEZ	2.50			
CORTEZ	2.33	2.50	5	
CRANBERRY	9.00	9.75	6	4
CRANBERRY	9.25	9.75	4	
CRANBERRY	11.00	11.25	2	
CRANBERRY	9.75	10.00	2	
CRAWFISH	11.00	11.00	0	6
CRAWFISH	17.00	17.00	0	
CRAWFISH	20.00	18.00	7	
CRAWFISH	21.00	19.00	7	
CRAWFISH	18.00	18.50	2	
CRAWFISH	17.00	15.00	9	
CURLEW	23.00	22.00	3	3
CURLEW	20.00	19.00	4	
CURLEW	15.00	16.00	5	
CURLEW	17.00	17.50	2	
DAVIS	15.00	16.00	5	3
DAVIS	13.00	13.00	0	
DAVIS	15.00	14.00	5	
DAVIS	15.00	15.00	0	
DAVIS	18.00	19.00	4	
DAVIS	15.00	16.00	5	
DAVIS	16.00	16.00	0	
DAVIS	19.00	20.00	4	
DEEP	9.00			
DEEP	12.00			
DEEP	13.00			
DEEP	13.00			
DEEP	15.00			
DEEP	20.00			
DEER	18.00	18.50	2	2
DEER	17.00	17.50	2	
DEER	16.67	17.00	1	
DEER	17.00	16.50	2	
DEER	20.00	20.00	0	
DUCK	1.50	1.50	0	0
DUCK	2.00	2.00	0	
DUCK	4.00	4.00	0	
ELOIKA	8.00	8.00	0	1
ELOIKA	7.50	7.50	0	
ELOIKA	7.50	7.40	1	
ELOIKA	6.00	5.90	1	
ELOIKA	8.90	8.60	2	
ELOIKA	10.00	9.80	1	
ELOIKA	8.10	8.10	0	
ELOIKA	5.10	5.10	0	
ELOIKA	2.50	2.50	0	
ELOIKA	2.80	2.80		
ELOIKA	5.00	5.00	0	
ELOIKA	7.20	7.10	1	
FLOWING	13.50	13.50	0	0
FLOWING	13.50	13.50	0	
FLOWING	11.50	11.50	0	
FLOWING	10.75	10.75	0	
FLOWING	10.00	10.00	0	
FLOWING	12.00	12.00	0	
FLOWING	9.00	9.00	0	
FLOWING	6.50	6.50	0	
FLOWING	9.00	9.00	0	
FLOWING	11.00	11.00	0	
FLOWING	9.00	9.00	0	
GOSS	22.83	22.83	0	2
GOSS	24.50	24.67	0	
GOSS	18.67	18.83	1	
GOSS	12.50	13.00	3	
GOSS	20.33	20.83	2	
GOSS	19.50	20.00	2	
HICKS	13.00			
HICKS	14.00			
HICKS	17.50			

LAKE	SECCHI1 (FEET)	SECCHI2 (FEET)	CV %	ROOT MEAN SQUARE %
HICKS	12.00	12.00	0	
HORSESHOE	2.25	2.00	8	2
HORSESHOE	3.25	2.50	18	
HORSESHOE	3.75	3.50	5	
HORSESHOE	5.00	5.00	0	
HORSESHOE	4.00	4.00	0	
HORSESHOE	2.50	2.50	0	
HORSESHOE	4.25	4.25	0	
HORSESHOE	5.00	5.00	0	
HORSESHOE	4.75	4.75	0	
HORSESHOE	4.00	4.00	0	
HORSESHOE	3.00	3.00	0	
HORSESHOE	2.80	3.00	5	
ISLAND	17.00	17.50	2	2
ISLAND	21.00	19.50	5	
ISLAND	17.75	17.83	0	
ISLAND	22.25	21.67	2	
ISLAND	22.67	22.83	0	
ISLAND	18.50	18.50	0	
ISLAND	19.50	19.67	1	
ISLAND	16.83	17.00	1	
ISLAND	21.00	21.25	1	
ISLAND	19.25	19.50	1	
ISLAND	17.83	18.00	1	
ISLAND	17.00	17.17	1	
KAHLOTUS	9.50	9.50		4
KAHLOTUS	7.00	7.50	5	
KAHLOTUS	8.83	8.83		
KAHLOTUS	8.00	8.00		
KAHLOTUS	6.50	6.75	3	
KILLARNEY	9.00	8.00	8	5
KILLARNEY	8.00	8.00	0	
KILLARNEY	7.00	7.75	7	
KILLARNEY	5.75	6.00	3	
KILLARNEY	5.75	6.00	3	
KILLARNEY	7.50	7.75	2	
KILLARNEY	8.50	9.00	4	
KILLARNEY	7.50	8.00	5	
KILLARNEY	8.00	7.25	7	
KILLARNEY	9.50	9.25	2	
KITSAP	19.00	19.50	2	2
KITSAP	9.33	9.00	3	
KITSAP	12.66	13.00	2	
KITSAP	11.33	11.66	2	
LACAMAS	3.25	3.25	0	2
LACAMAS	6.00	6.25	3	
LACAMAS	7.50	7.50	0	
LACAMAS	5.00	5.00	0	
LACAMAS	4.50	4.50	0	
LACAMAS	5.00	5.00	0	
LACAMAS	3.50	3.75	5	
LACAMAS	7.00	7.00	0	
LEO	12.00	12.00	0	1
LEO	11.00	11.33	2	
LEO	12.00	12.00	0	
LEO	11.50	11.50	0	
LEO	13.00			
LEO	14.50			
LEO	15.00			
LEO	16.00			
LEO	17.33	17.00	1	
LEO	17.00	17.33	1	
LEO	18.50			
LIBERTY	16.41	0.00		0
LIBERTY	16.41	0.00		
LIBERTY	18.05	0.00		
LIBERTY	16.41	0.00		
LIBERTY	16.41	0.00		
LIBERTY	11.48	0.00		
LIBERTY	16.41	0.00		
LIMERICK	10.00	9.50	4	3

LAKE	SECCHI1 (FEET)	SECCHI2 (FEET)	CV %	ROOT MEAN SQUARE %
LIMERICK	17.25	17.50	1	
LIMERICK	9.50	9.75	2	
LIMERICK	11.00	10.50	3	
LIMERICK	12.25	11.75	3	
LIMERICK	7.50	7.00	5	
LIMERICK	11.00	10.83	1	
LIMERICK	7.00	7.50	5	
LIMERICK	9.00	8.50	4	
LIMERICK	9.00	9.17	1	
LIMERICK	8.08	8.00	1	
LONG(KITSAP)	5.13	5.13	0	0
LONG(KITSAP)	4.08	4.08		
LONG(KITSAP)	5.00	5.00	0	
LONG(KITSAP)	2.17	2.17	0	
LONG(KITSAP)	3.33	3.33	0	
LONG(KITSAP)	2.67	2.67	0	
LONG(KITSAP)	3.08	3.08		
LONG(SPOKANE	2.46	2.46		0
LONG(SPOKANE	9.02			
LONG(SPOKANE	10.17	10.17		
LONG(SPOKANE	11.48			
LONG(THURSTO	8.25	9.00	6	6
LONG(THURSTO	7.50	9.00	13	
LONG(THURSTO	9.50	9.00	4	
LONG(THURSTO	9.00	9.50	4	
LONG(THURSTO	8.00			
LONG(THURSTO	8.00			
LONG(THURSTO	7.00	6.50	5	
LONG(THURSTO	6.00	6.50	6	
LONG(THURSTO	7.00	6.50	5	
LONG(THURSTO	5.00	5.50	7	
LONG(THURSTO	4.50	4.50	0	
LOUISE	27.00	32.00	12	
LOUISE	23.00			
LAKE MARTHA	10.00	10.00	0	1
LAKE MARTHA	11.75	11.80	0	
LAKE MARTHA	10.17	9.92	2	
LAKE MARTHA	13.58	13.92	2	
LAKE MARTHA	12.75	12.83	0	
LAKE MARTHA	15.67	16.08	2	
LAKE MARTHA	16.92	16.50	2	
LAKE MARTHA	15.00	15.08	0	
LAKE MARTHA	16.50	17.00	2	
MARTHA LAKE	16.00	17.00	4	4
MARTHA LAKE	16.25	17.25	4	
MARTHA LAKE	20.50	21.50	3	
MARTHA LAKE	17.50	18.00	2	
MARTHA LAKE	16.00	17.00	4	
MARTHA LAKE	19.00	18.00	4	
MARTHA LAKE	17.00	17.00	0	
MARTHA LAKE	16.00	16.00	0	
MARTHA LAKE	12.00	13.00	6	
MARTHA LAKE	15.00	16.00	5	
MARTHA LAKE	16.00	16.00	0	
MASON 1	24.00	26.00	6	6
MASON 1	26.00	29.50	9	
MASON 1	33.00	32.00	2	
MASON 1	31.00	32.00	2	
MASON 1	24.00	27.00	8	
MASON 1	26.00	26.00	0	
MASON 1	28.00	31.00	7	
MASON 1	28.00	26.00	5	
MASON 1	30.00	34.00	9	
MASON 1	37.00	32.00	10	
MASON 1	23.00	22.00	3	
MASON 2	19.00	18.00	4	4
MASON 2	28.00	26.00	5	
MASON 2	23.00	21.00	6	
MASON 2	27.00	25.00	5	
MASON 2	28.00	26.00	5	
MASON 2	28.00	27.00	3	

LAKE	SECCHI1 (FEET)	SECCHI2 (FEET)	CV %	ROOT MEAN SQUARE %
MASON 2	21.00	20.00	3	-
MASON 2	25.00	26.00	3	
MASON 2	24.00	24.00	0	
MASON 2	21.00	21.00	0	
MASON 3	32.00	32.00	0	2
MASON 3	30.00	30.00	0	
MASON 3	27.00	27.00	0	
MASON 3	25.00	25.00	0	
MASON 3	27.00	27.00	0	
MASON 3	30.00	30.00	0	
MASON 3	30.00	30.00	0	
MASON 3	32.00	32.00	0	
MASON 3	30.00	30.00	0	
MASON 3	33.00	30.00	7	
MASON 3	25.00	25.50	1	
MASON 4	26.50	26.50	0	3
MASON 4	38.00	38.50	1	
MASON 4	27.00	29.00	5	
MASON 4	31.50	31.50	0	
MASON 4	27.50	27.50	0	
MASON 4	31.00	32.00	2	
MASON 4	37.00	36.00	2	
MASON 4	24.50	25.00	1	
MASON 4	37.00	37.00	0	
MASON 4	30.00	31.00	2	
MASON 4	28.00	26.00	5	
MASON 5	28.00	32.00	9	5
MASON 5	37.00	37.00	0	
MASON 5	32.00	34.00	4	
MASON 5	27.00	27.00	0	
MASON 5	31.00	35.00	9	
MASON 5	30.00	29.00	2	
MASON 5	34.00	32.00	4	
MASON 5	27.00	26.00	3	
MASON 5	25.00	27.00	5	
MASON 5	31.00	33.00	4	
MASON 5	25.00	25.00	0	
MISSION	16.00	16.25	1	1
MISSION	18.50	-2.00		
MISSION	12.75	0.00		
MISSION	11.50	0.00		
MISSION	12.75	0.00		
MISSION	14.00	0.00		
MISSION	13.00	13.25	1	
MISSION	13.00	13.00	0	
MISSION	13.00	12.75	1	
MISSION	13.00	13.00	0	
NAHWATZEL	13.50	12.75	4	2
NAHWATZEL	11.00	10.75	2	
NAHWATZEL	14.50	14.00	2	
NAHWATZEL	13.00	13.00	0	
NAHWATZEL	13.00	13.50	3	
NAHWATZEL	18.00	18.00	0	
NAHWATZEL	15.00	15.25	1	
NAHWATZEL	14.00	13.75	1	
NAHWATZEL	17.00	16.25	3	
NAHWATZEL	15.50	15.25	1	
NAHWATZEL	17.00	17.25	1	
NEWMAN	8.00	8.00	0	2
NEWMAN	17.00	18.00	4	
NEWMAN	21.50	22.00	2	
NEWMAN	15.50	15.00	2	
OHOP	6.25	6.50	3	0
OHOP	6.50	6.50	0	
OHOP	7.25	7.25	0	
OHOP	8.00	8.00	0	
OSOYOOS	13.00	7.00	42	3
OSOYOOS	10.00	10.00	0	
OSOYOOS	7.00			
OSOYOOS	8.00	8.00	0	
OSOYOOS	9.00	8.00	8	

LAKE	SECCHI1 (FEET)	SECCHI2 (FEET)	CV %	ROOT MEAN SQUARE %
PANTHER	8.00	9.00	8	3
PANTHER	8.00	8.00	0	
PANTHER	7.00	7.00	0	
PANTHER	7.00	7.00	0	
PANTHER	9.00	9.00	0	
PANTHER	8.00	8.00	0	
PANTHER	7.00	7.00	0	
PANTHER	6.00	6.00	0	
PATTISON 2	16.00	16.00	0	1
PATTISON 2	15.50	15.50	0	
PATTISON 2	16.00	16.00	0	
PATTISON 2	16.00	16.00	0	
PATTISON 2	15.00	15.00	0	
PATTISON 2	16.00	16.00	0	
PATTISON 2	16.00	15.50	2	
PATTISON 2	15.00	15.00	0	
PATTISON 2	15.00	15.00	0	
PATTERSON 1	17.50	17.50	0	2
PATTERSON 1	16.00	0.00		
PATTERSON 1	14.00	13.50	3	
PATTERSON 1	15.00	15.00	0	
PATTERSON 1	15.00			
PATTERSON 1	14.50	13.50	5	
PATTERSON 1	13.00			
PATTERSON 1	8.00			
PATTERSON 1	10.00	9.50	4	
PHILLIPS	14.50	14.50	0	1
PHILLIPS	20.00	21.00	3	
PHILLIPS	21.00	21.00	0	
PHILLIPS	21.25	21.25	0	
PHILLIPS	15.00	15.50	2	
PHILLIPS	15.00	15.00	0	
PHILLIPS	19.00	19.00	0	
PHILLIPS	19.00	19.00	0	
PHILLIPS	16.00	16.00	0	
PHILLIPS	15.00	15.00	0	
PHILLIPS	15.00	14.50	2	
ROUND	4.00	4.00	0	2
ROUND	5.00	5.00	0	
ROUND	8.33	8.00	3	
ROUND	12.50	12.50	0	
ROUND	10.00	10.50	3	
ROUND	5.50	5.50	0	
ROUND	7.00	6.50	5	
ROUND	5.50	5.50	0	
ROUND	6.00	6.00	0	
ROUND	9.30	9.00	2	
ROUND	10.50	10.50	0	
SACHEEN	15.00	14.00	5	4
SACHEEN	15.00	15.00	0	
SACHEEN	11.00	12.00	6	
SACHEEN	11.00	11.00	0	
SACHEEN	13.00	14.00	5	
SACHEEN	14.00	14.00	0	
SACHEEN	12.00	12.00	0	
SAMISH 1	15.00	17.00	9	4
SAMISH 1	17.00	16.50	2	
SAMISH 1	19.50	20.00	2	
SAMISH 1	24.00	23.00	3	
SAMISH 1	21.00	21.00	0	
SAMISH 1	10.50	11.00	3	
SAMISH 1	9.50	10.00	4	
SAMISH 1	11.00	11.00	0	
SAMISH 1	11.00	11.00	0	
SAMISH 1	10.00	11.50	10	
SAMISH 2	19.50	20.00	2	3
SAMISH 2	21.00	21.00	0	
SAMISH 2	24.25	25.00	2	
SAMISH 2	20.00	19.50	2	
SAMISH 2	12.00	11.50	3	
SAMISH 2	11.00	11.00	0	

LAKE	SECCHI1 (FEET)	SECCHI2 (FEET)	CV %	ROOT MEAN SQUARE %
SAMISH 2	6.50	7.00	5	
SAMISH 2	11.00	10.75	2	
SAMISH 2	12.00	12.50	3	
SHOECRAFT	12.00	12.00	0	2
SHOECRAFT	11.00	11.50	3	
SHOECRAFT	12.00	12.00	0	
SHOECRAFT	12.00	11.50	3	
SHOECRAFT	16.00	16.50	2	
SIDLEY	18.00	18.00	0	3
SIDLEY	16.50	16.25	1	
SIDLEY	13.00	12.00	6	
SIDLEY	8.50	9.00	4	
SIDLEY	10.50	11.00	3	
SIDLEY	9.50	9.00	4	
SIDLEY	9.50	9.50	0	
SIDLEY	11.00	11.50	3	
SIDLEY	9.00	9.00	0	
SIDLEY	5.50	5.00	7	
SIDLEY	6.50	6.50	0	
SPANAWAY	12.00	12.00	0	5
SPANAWAY	12.00	12.25	1	
SPANAWAY	11.00	11.00	0	
SPANAWAY	8.50	8.50	0	
SPANAWAY	6.00	7.50	16	
SPANAWAY	6.00	6.00	0	
SPANAWAY	12.00	12.00	0	
SPANAWAY	16.00	16.00	0	
SPANAWAY	14.00	14.00	0	
SPANAWAY	15.00	15.00	0	
SPANAWAY	11.00	11.00	0	
SPANAWAY	10.00	10.00	0	
SPENCER	9.00	9.00	0	
SPENCER	9.75	9.75	0	0
SPENCER	12.00	12.00	0	
SPENCER	12.50	12.50	0	
SPENCER	13.00	13.00	0	
SPENCER	14.00	14.00	0	
SPENCER	13.00	13.00	0	
SPENCER	13.00	13.00	0	
SPENCER	14.00	14.00	0	
SPENCER	12.50	12.50	0	
SPENCER	9.00	9.00	0	
ST. CLAIR	7.00	7.50	5	7
ST. CLAIR	6.50	7.00	5	
ST. CLAIR	6.00	6.50	6	
ST. CLAIR	7.00	7.50	5	
ST. CLAIR	9.00	8.50	4	
ST. CLAIR	7.50	8.50	9	
ST. CLAIR	7.50	8.00	5	
ST. CLAIR	8.00	9.50	12	
ST. CLAIR	9.00	10.00	7	
ST. CLAIR	9.50	9.50	0	
STARVATION	13.00	14.00	5	5
STARVATION	14.00	13.00	5	
STARVATION	12.50	11.00	9	
STARVATION	11.00	11.00	0	
STARVATION	13.50			
STARVATION	12.00	11.00	6	
STEILACOOM	4.50	4.50	0	
STEILACOOM	13.50			
STEILACOOM	6.50			
STEILACOOM	3.50			
STEILACOOM	4.50			
STEVENS	23.50	23.60	0	1
STEVENS	17.50	17.50	0	
STEVENS	13.50	13.60	1	
STEVENS	17.50	17.60	0	
STEVENS	22.50	22.50	0	
STEVENS	20.50	20.50	0	
STEVENS	19.50	19.50	0	
STEVENS	19.00	19.50	2	

LAKE	SECCHI1 (FEET)	SECCHI2 (FEET)	CV %	ROOT MEAN SQUARE %
STORM	6.00	6.50	6	4
STORM	8.00	8.00	0	
STORM	8.00	8.50	4	
STORM	7.00	7.50	5	
STORM	8.00	8.00	0	
STORM	10.00	10.50	3	
SULLIVAN	23.00	24.00	3	4
SULLIVAN	17.00	17.00	0	
SULLIVAN	17.00	18.00	4	
SULLIVAN	20.00	21.00	3	
SULLIVAN	25.00	27.00	5	
SULLIVAN	31.00	33.00	4	
SULLIVAN	30.00	33.00	7	
SULLIVAN	35.00	35.00	0	
SULLIVAN	30.00	32.00	5	
SUMMIT	25.50	25.50	0	1
SUMMIT	20.00	20.00	0	
SUMMIT	21.00	21.50	2	
SUNDAY	9.00	8.00	8	4
SUNDAY	7.33	7.00	3	
SUNDAY	2.33	2.33	0	
SUNDAY	9.33	9.33	0	
SUNDAY	5.00	5.33	5	
SUNDAY	8.00	8.00	0	
SUNDAY	9.50	9.42	1	
TANWAX	5.75	5.50	3	4
TANWAX	5.50	5.30	3	
TANWAX	6.00	6.60	7	
TANWAX	6.00	6.00	0	
TANWAX	7.30	7.00	3	
TANWAX	5.00	4.75	4	
TANWAX	4.67	4.67	0	
TANWAX	7.75	8.25	4	
THOMAS	11.00	11.00	0	4
THOMAS	12.00	12.50	3	
THOMAS	12.00	11.50	3	
THOMAS	13.00	13.00	0	
THOMAS	15.00	16.00	5	
THOMAS	13.00	14.50	8	
THOMAS	13.25	13.25	0	
THOMAS	11.50	12.50	6	
THOMAS	14.50	14.00	2	
THOMAS	15.00	15.00	0	
THOMAS	18.00	18.00	0	
THOMAS	13.00	13.25	1	
THOMAS	13.00	11.50	9	
TWIN	32.60	32.00	1	2
TWIN	21.00	21.00	0	
TWIN	31.00	30.00	2	
VANCOUVER	0.50	0.00		0
VANCOUVER	0.50	0.00		
VANCOUVER	2.00	2.00	0	
VANCOUVER	2.50	0.00		
WAITTS	13.00	12.00	6	5
WAITTS	11.00	12.00	6	
WAITTS	14.00	14.00	0	
WAITTS	14.00			
WAITTS	11.00	13.00	12	
WAITTS	13.00	13.00	0	
WAITTS	14.00	14.00	0	
WAITTS	19.00	18.00	4	
WAITTS	20.00	21.00	3	
WAITTS	21.00	21.00	0	
WAITTS	19.00	18.00	4	
WAITTS	23.00	23.00	0	
WAITTS	19.00	17.00	8	
WANNACUT	16.00	16.00	0	0
WANNACUT	13.00	13.00	0	
WANNACUT	10.00	10.00	0	
WANNACUT	11.00	11.00	0	
WANNACUT	11.00	11.00	0	

LAKE	SECCHI1 (FEET)	SECCHI2 (FEET)	CV %	ROOT MEAN SQUARE %
WANNACUT	12.00	12.00	0	
WANNACUT	11.00	11.00	0	
WANNACUT	10.00	10.00	0	
WANNACUT	10.00	10.00	0	
WANNACUT	11.00	11.00	0	
WANNACUT	10.00	10.00	0	
WARD 2	22.00	22.00	0	2
WARD 2	18.00	18.00	0	
WARD 2	22.00	21.00	3	
WARD 2	22.00	22.00	0	
WARD 2	20.00	21.00	3	
WARD 1	17.00	19.00	8	3
WARD 1	17.00	17.00	0	
WARD 1	18.00	18.00	0	
WARD 1	20.00	20.00	0	
WARD 1	20.00	20.00	0	
WARD 1	20.00	20.00	0	
WARD 1	22.00	21.00	3	
WARD 1	20.00	20.00	0	
WARD 1	19.50	20.00	2	
WARD 1	19.00	19.00	0	
WARD 1	18.00	18.00	0	
WARD 1	18.00	18.00	0	
WENATCHEE	18.00	18.00	0	1
WENATCHEE	14.00	14.00	0	
WENATCHEE	17.00	17.00	0	
WENATCHEE	20.00	20.50	2	
WENATCHEE	24.00	24.50	1	
WHATCOM 1	20.00	17.00	11	6
WHATCOM 1	17.00	18.00	4	
WHATCOM 1	17.00	18.00	4	
WHATCOM 1	15.00	14.00	5	
WHATCOM 1	18.00	19.00	4	
WHATCOM 1	19.00	19.00	0	
WHATCOM 1	20.00	21.00	3	
WHATCOM 2	22.50	21.00	5	4
WHATCOM 2	15.00	17.00	9	
WHATCOM 2	23.00	24.00	3	
WHATCOM 2	24.00	23.50	1	
WHATCOM 2	24.00	24.00	0	
WHATCOM 2	26.00	27.00	3	
WHITMAN	10.00	10.50	3	3
WHITMAN	11.50	11.50	0	
WHITMAN	10.75	10.50	2	
WHITMAN	9.00	8.50	4	
WHITMAN	8.50	8.75	2	
WHITMAN	8.50	8.00	4	
WHITMAN	8.00	8.50	4	
WHITMAN	9.75	9.50	2	
WHITMAN	8.25	8.75	4	
WHITMAN	8.00	8.50	4	
WILLIAMS	13.50	14.00	3	3
WILLIAMS	13.00	13.50	3	
WILLIAMS	11.00	10.50	3	
WILLIAMS	10.00	9.50	4	
WILLIAMS	10.00	9.50	4	
WILLIAMS	10.00	10.00	0	
WILLIAMS	10.00	10.50	3	
WILLIAMS	13.00	13.50	3	
WOOTEN	27.75	28.00	1	3
WOOTEN	26.33	28.60	6	
WOOTEN	24.50	25.00	1	
WOOTEN	25.50	26.75	3	
WOOTEN	27.25	27.00	1	
WOOTEN	27.75			
WOOTEN	20.00	19.75	1	
WOOTEN	22.75	22.50	1	
WOOTEN	21.75	21.50	1	
WOOTEN	20.75	19.75	3	

Appendix D

Hydrolab Postcalibration Data for Quality Assurance

Appendix D. Hydrolab Postcalibration Data for Quality Assurance.

Date 1990	Parameter	Comparison value	Hydrolab value	Postcalibration for the following lakes
5/21	DO	7.7 mg/L	7.7 mg/L	Cortez
	pH	77.0	7.1	
	pH 10	10.1	10.0	
5/22	DO	12.3 mg/L	12.5 mg/L	Horseshoe, Lacamas, Round (DO only)
5/23	pH 7	7.0	6.9	Blue (pH only)
	pH 10	10.1	10.1	
5/24	DO	12.4 mg/L	12.5 mg/L	Kitsap, Long (Kitsap), Phillips
	pH 7	7.1	7.0	Horseshoe, Lacamas, Round (pH only)
	pH 10	10.1	10.1	
5/24	DO	8.0 mg/L	8.2 mg/L	Williams
	pH 7	7.0	7.3*	Blue (DO only)
	pH 10	10.1	10.1	
5/25	DO	12.3 mg/L	12.2 mg/L	Limerick, Nahwatzel, Phillips, Spencer
	pH 7	7.0	6.8*	
	pH 10	10.1	10.1	
5/25	DO	8.3 mg/L	8.2 mg/L	Deep, Deer, Leo, Thomas
	pH 7	7.0	7.2*	
	pH 10	10.1	10.0	
5/26	DO	12.3 mg/L	12.2 mg/L	Mason
	pH 7	7.1	7.0	
	pH 10	10.1	10.1	
	cond	147. µmho/cm	146. µmho/cm	
5/27	DO	12.3 mg/L	12.4 mg/L	Long (Spokane), Newman
	pH 7	7.0	6.9	
	pH 10	10.1	10.1	
5/29	DO	12.4 mg/L	12.2 mg/L	Vancouver
	pH 7	7.0	7.1	
	pH 10	10.1	10.1	
	cond	147. µmho/cm	147. µmho/cm	
5/29	pH 7	7.0	7.1	Starvation
	pH 4	4.0	4.0	
5/30	DO	12.6 mg/L	12.6 mg/L	Long (Thurston), Ward
	pH	7.0	7.1	
	pH	10.1	10.1	
	cond	147. µmho/cm	147. µmho/cm	
5/30	DO	6.8 mg/L	6.9 mg/L	Big Meadow, Black, Davis, Sacheen
	pH 7	7.0	7.0	
5/31	DO	12.5 mg/L	12.4 mg/L	Clear, Patterson, St. Clair
	pH	7.0	7.0	
	pH	10.0	10.0	
	cond	147. µmho/cm	148. µmho/cm	
6/01	DO	12.5 mg/L	12.5 mg/L	American, Louise, Spanaway, Whitman
	pH	7.0	7.0	
	pH	10.1	10.0	
	cond	147. µmho/cm	151. µmho/cm	
6/03	DO	12.7 mg/L	12.8 mg/L	Ohop, Tanwax
	pH	7.0	6.6*	
	pH	10.1	10.0	
	cond	147. µmho/cm	147. µmho/cm	
6/04	pH	7.0	7.0	Big, Samish, Whatcom (pH only)

Methods:

DO = Azide-modified Winkler titration
pH 7 = standard pH 7 buffer
pH 10 = standard pH 10 buffer
cond = standard 0.02N KCl conductivity solution, 147 µmho/cm
* = Postcalibration data exceeded acceptable QA limits. Data for this parameter are flagged.

Appendix D. Hydrolab Postcalibration Data for Quality Assurance, cont'd.

Date 1990	Parameter	Comparison value	Hydrolab value	Postcalibration for the following lakes
6/04	pH 7	7.0	7.0	Crawfish, Twin, Wenatchee (pH)
6/05	DO	11.5	12.2*	Crawfish, Twin, Wenatchee (DO)
	pH 7	7.0	7.1	
	pH 4	4.0	4.0	
6/06	unit failed; no postcalibration data			Bosworth, Stevens
6/07	DO	12.3 mg/L	12.5 mg/L	Blackmans, Flowing**, L. Martha, Panther, Shoecraft, Storm
	pH	7.0	7.4*	Sunday
	pH	10.1	10.1	Big, Samish, Whatcom (DO only)
	cond	147. μmho/cm	147. μmho/cm	
6/07	DO	10.0 mg/L	9.7 mg/L	Hicks
	pH 7	7.0	7.0	
	pH 10	10.1	10.1	
6/08	DO	12.3 mg/L	12.4 mg/L	Leech
	pH	7.0	7.0	
	pH	10.1	10.0	
	cond	147. μmho/cm	148. μmho/cm	
6/09	DO	14.2 mg/L	14.9* mg/L	Steilacoom
	pH 7	7.0	7.0	

Methods:

DO = Azide-modified Winkler titration
pH 7 = standard pH 7 buffer
pH 10 = standard pH 10 buffer
cond = standard 0.02N KCl conductivity solution, 147 μmho/cm
* = postcalibration data exceeded acceptable QA limits. Data for this parameter are flagged.
** = field notes indicate that response from pH probe was erratic

Appendix D. Hydrolab Postcalibration Data for Quality Assurance, cont'd.

Date 1990	Parameter	Comparison value	Hydrolab value	Postcalibration for the following lakes
8/09	DO	8.6 mg/L	8.4 mg/L	Deer, Newman, Waitts
	pH	7.0	7.1	
8/11	DO	8.1 mg/L	8.1 mg/L	Williams
	pH 7	7.0	7.0	
	pH 10	10.0	10.0	
8/13	DO	8.6 mg/L	8.6 mg/L	Crawfish, Sidley
	pH 7	7.0	6.9	
	pH 10	10.0	10.0	
	cond	147. μmho/cm	147. μmho/cm	
8/13	DO	8.6 mg/L	8.7 mg/L	Horseshoe
	pH	7.0	7.1	
	pH	10.0	10.0	
8/14	DO	8.5 mg/L	8.5 mg/L	Long (Kitsap), Mission, Wooten
	pH	7.0	7.1	
	pH	10.0	10.0	
8/15	DO	8.7 mg/L	8.8 mg/L	
	pH	7.0	7.0	
	pH	10.0	10.0	
8/15	DO	8.4 mg/L	8.5 mg/L	Big, Cranberry, Samish, Whatcom
	pH 7	7.0	7.1	
	pH 10	10.0	10.0	
	cond	147. μmho/cm	149. μmho/cm	
8/16	DO	9.2 mg/L	9.3 mg/L	Limerick, Nahwatzel, Phillips, Spencer
	pH	7.0	7.0	
	pH	10.0	10.0	
	cond	147. μmho/cm	147. μmho/cm	
8/17	DO	8.8 mg/L	8.9 mg/L	Island, Mason, Ohop, Tanwax
	pH	7.0	6.9	
	pH	10.0	10.1	
	cond	147. μmho/cm	152. μmho/cm	
8/17	DO	8.8 mg/L	8.9 mg/L	Hicks
	pH 7	7.0	7.0	
	pH 10	10.0	10.0	
	cond	147. μmho/cm	149. μmho/cm	
8/20	pH	7.0	7.0	Lacamas, Round (pH)
	pH	10.0	10.0	
8/21	DO am	8.8 mg/L	8.6 mg/L	Lacamas, Round (DO)
	pH	7.0	7.0	
	pH	10.0	10.0	
8/21	DO	8.4 mg/L	8.5 mg/L	Chelan, Cortez, Wenatchee
	pH 7	7.0	7.0	
	pH 10	10.1	10.0	
8/22	DO	9.0 mg/L	8.9 mg/L	Clear, Long (Thurston), Patterson, St. Clair, Summit, Ward
	pH	7.0	6.9	
	pH	10.0	10.0	
8/22	DO	8.4 mg/L	8.5 mg/L	Davis, Long (Spokane), Sacheen
	pH 7	7.0	7.1	
	pH 10	10.1	10.1	
8/23	DO	9.2 mg/L	9.3 mg/L	Whitman
	pH	7.0	7.0	
	pH	10.0	10.1	

Methods:

DO = Azide-modified Winkler titration
pH 7 = standard pH 7 buffer
pH 10 = standard pH 10 buffer
cond = standard 0.02N KCl conductivity solution, 147 μmho/cm

Appendix D. Hydrolab Postcalibration Data for Quality Assurance, cont'd.

Date 1990	Parameter	Comparison value	Hydrolab value	Postcalibration for the following lakes
8/23	DO	8.4 mg/L	8.5 mg/L	Kahlotus
	pH 7	7.0	7.0	
	pH 10	10.1	10.0	
8/24	DO	9.1 mg/L	9.0 mg/L	American, Louise, Spanaway
	pH	7.0	7.1	
	pH	10.0	10.0	
	cond	147. μmho/cm	143. μmho/cm	
8/24	DO	9.1 mg/L	9.0 mg/L	Blue
	pH 7	7.0	7.1	
	pH 10	10.0	10.0	
	cond	147. μmho/cm	150. μmho/cm	
8/27	DO	8.8 mg/L	8.8 mg/L	
	pH 7	7.0	7.1	
	pH 10	10.0	10.0	
8/30	DO	9.0 mg/L	9.1 mg/L	L. Martha, Martha L., Shoecraft, Sunday
	pH 7	7.0	7.1	
	pH 10	10.1	10.0	
8/31	DO	8.9 mg/L	8.9 mg/L	Flowing, Leech, Panther, Stevens, Storm
	pH 7	7.0	7.1	
	pH 10	10.0	10.1	
	cond	147. μmho/cm	151. μmho/cm	
9/04	DO pm	9.0 mg/L	8.7 mg/L	Kitsap
	pH 7	7.0	7.1	
	pH 10	10.0	10.0	
	cond	147. μmho/cm	144. μmho/cm	

Methods:

DO = Azide-modified Winkler titration
pH 7 = standard pH 7 buffer
pH 10 = standard pH 10 buffer
cond = standard 0.02N KCl conductivity solution, 147 μmho/cm

Appendix E

Attachments for Individual Lake Assessments

Data Evaluation

One of the main objectives of the Citizen Lake Monitoring Project is to use volunteer-collected data to estimate the trophic state of each monitored lake. The trophic state describes a lake with respect to a lake's capacity to support plant and algal growth.

To estimate the trophic state for each lake, we used Secchi data measurements taken from June through September, 1990. These are the months during which there are the worst water quality problems, algal growth is the heaviest and there is the most recreational use. The average Secchi values for these months was then used to calculate a trophic state index (TSI) which rates each lake on a scale from 1 to 100. Using the TSI values, we estimated the trophic state of each monitored lake and ranked the lakes in order of their average water clarity. Figure 1 shows the monitored lakes in order of best to worst average water clarity. In this figure, please note that lakes with good water clarity have low TSI values (less than 40), whereas lakes with poor water clarity have high TSI values (greater than 50). For example, Lake Chelan had a mean Secchi depth of 49 feet and a TSI (Secchi) value of 21. Duck Lake had a mean Secchi depth of 16 inches, and a TSI (Secchi) value of 73.

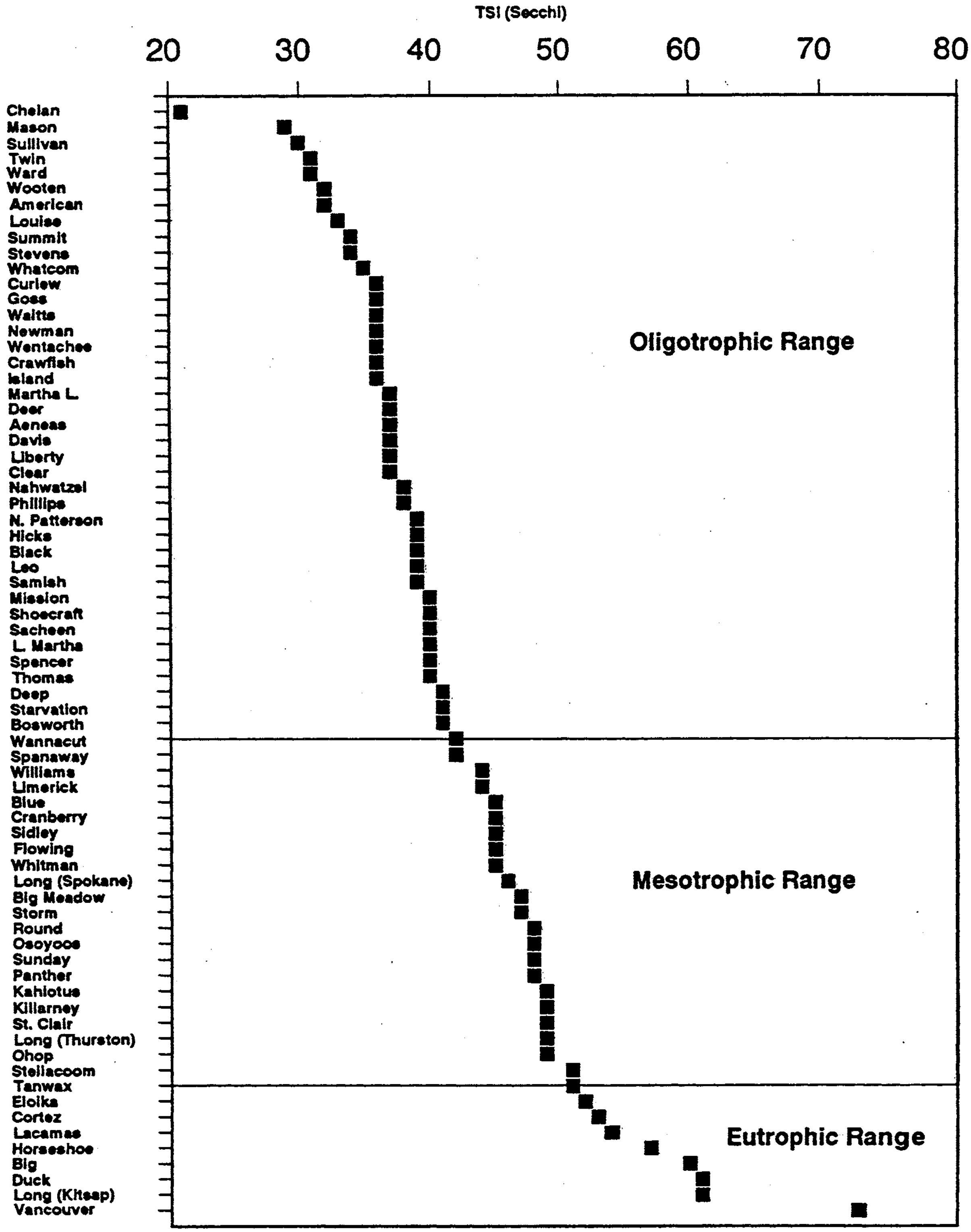
We also evaluated the total phosphorus data because in most lakes, the amount of algal growth depends on the amount of this nutrient in the water. The TSI values calculated from the total phosphorus data are usually, but not always, similar to the TSI value calculated from the Secchi depth data. If the TSI (Secchi) and the TSI (total phosphorus) values were different, we then used other characteristics of the lake (such as dissolved oxygen concentrations, amount of plant growth) to refine the trophic state estimation. This is one of the reasons we collected the profile data from the lakes. Figure 2 shows the lakes in order of lowest to highest concentrations of total phosphorus. Please note that total phosphorus samples were not collected from all the volunteer-monitored lakes.

General Physical and Chemical Parameters Associated with Trophic State

Trophic State	Trophic State Index	Secchi Disk (ft)	Total Phosphorus (mg/L)	Chlorophyll *a* (μg/L)
Oligotrophic	20	52.5	0.003	0.34
	30	26.2	0.006	0.94
Oligo-Mesotrophic	39	14.1	0.011	2.4
Mesotrophic	41	13.1	0.012	2.6
Meso-Eutrophic	49	7.0	0.022	6.5
Eutrophic	50	6.5	0.024	6.4
	60	3.3	0.048	20
	70	1.6	0.096	56

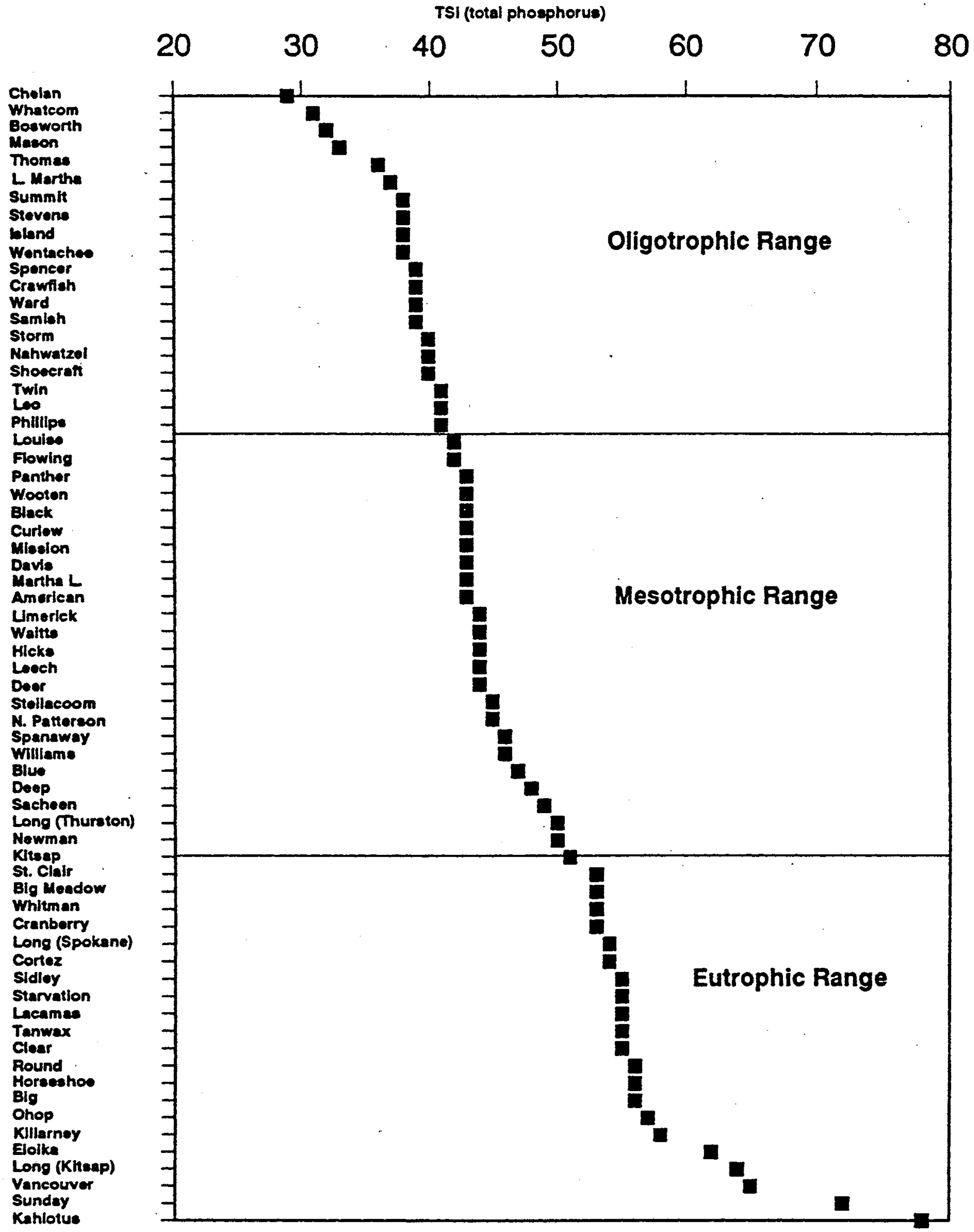
(Information source: Carlson, 1977)

Fig. 1 Lakes Ranked by Secchi Depth Trophic State Index (TSI)



Washington's Citizen Lake Monitoring Project, 1990

Fig. 2 Lakes Ranked by Total Phosphorus Trophic State Index (TSI)



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Glossary

Algae - microscopic plants that grow in fresh or salt water.

Algae Bloom - abundant growth of algae that results in mats or scums forming in or on the water. Not all types of algae form blooms.

Ambient Water Quality Monitoring - monitoring to collect baseline information on a water resource, which can therefore be used to determine if a water quality problem exists and how water quality is changing.

Bathymetric Map - a contour map of a lake's depth.

Blue-Green Algae - a type of algae that, when found in bloom concentrations, is usually associated with polluted or eutrophic water bodies. Because most blue-green species are not eaten by fish or zooplankton, and because of visual and olfactory effects from blue-green algae, most blue-green algae are considered to be a nuisance species.

Chlorophyll *a* - a pigment found in the cells of photosynthesizing plants. The quantity of chlorophyll *a* in a water sample indicates the amount of photosynthesizing algae per volume of water.

Clean Water Act (Federal Clean Water Act) - this law requires water quality to be kept at an acceptable level to support both swimming and fishing in all surface waters. The authority to enforce this law is with the EPA, but this authority can be delegated to individual states; it has been delegated to Washington.

Conventional Parameters - in this report, conventional parameters are pH, conductivity, dissolved oxygen, alkalinity, fecal coliform bacteria, and nutrients.

Cultural Eutrophication - eutrophication that is caused or accelerated by human activities.

Dissolved Oxygen - oxygen content in water that comes from being in contact with the surface, from agitation (as in streams), or from being released by photosynthesizing aquatic plants. Oxygen is depleted by bacteria that decompose vegetation or other organic material, and from respiration by plants and animals.

Emergent Macrophyte - aquatic plants (larger than algae) that root in lake sediments and have some part of the plant above (but not floating in) water. Examples: Cattails, reeds, and rushes.

Epilimnion - the "top" (closest to the surface) layer of water in a thermally stratified lake. See metalimnion, hypolimnion.

Eutrophic - describes a lake that has high nutrient concentrations, abundant plant and algae growth, and low water clarity. Eutrophication can occur naturally over time, or can be accelerated by human activities (see Cultural Eutrophication).

Fecal Coliform Bacteria - bacteria that are associated with mammal feces. Fecal coliform bacteria tests determine if feces have entered and contaminated a water body.

Floating-leaved Macrophyte - aquatic plants that grow partially in the water, with the primary leaves floating on the water surface. Examples: lily pads and pondweed.

Hydrolab - an instrument used to measure temperature, pH, dissolved oxygen, and conductivity at various depths in water.

Hypereutrophic - describes a lake in advanced eutrophication which has very high nutrient concentrations, and very abundant plant and algae growth. In this report, hypereutrophic lakes will have a trophic state index value greater than 70.

Hypolimnion - when a lake is thermally stratified, the hypolimnion is the cooler layer of water at the bottom of the lake. See Epilimnion.

Limnology - the science of lakes and streams, including the factors that influence the biology and chemistry of inland waters.

Macrophyte - any aquatic plant larger than algae that grows on, or in, water.

Meso-eutrophic - a trophic state that is borderline between mesotrophic and eutrophic.

Mesotrophic - describes a lake that has moderate concentrations of nutrients, a moderate amount of plant and algae growth, and moderate water clarity (generally 7 to 13 feet, as measured with a Secchi disk).

Metalimnion - the middle layer of water between the epilimnion and hypolimnion of a thermally stratified lake. The metalimnion is located at the thermocline.

mg/L - milligrams per liter. A unit used to describe the concentrations of a substance in solution.

Nitrogen - a plant nutrient that can be present in water in various forms such as nitrate, nitrite, ammonia, or dissolved nitrogen gas.

Nutrients - substances, especially nitrogen and phosphorus compounds, that fertilize the growth of aquatic plants and algae. The amount of nutrients in water will affect the amount of plants and algae that can grow.

Oligotrophic - describes a lake that has low nutrient concentrations, little plant or algae growth, and very clear water.

Oligo-mesotrophic - a trophic state that is borderline between oligotrophic and mesotrophic.

pH - represents on a scale of 0 to 14 the acidity of a solution. A pH of 7 is neutral; acid solutions such as vinegar have a pH less than 7, and basic solutions have a pH that is greater than 7.

Phosphorus - a plant nutrient that can be present in water in various forms. Phosphorus can be dissolved in water (orthophosphorus), adsorbed onto particles or taken up by plants.

Profile Data - data collected at various depths to characterize a sampling site from surface to bottom. In this report, profile data parameters are temperature, pH, dissolved oxygen, and conductivity.

Runoff - water that washes over a ground surface or within the soil column as groundwater. Runoff can pick up suspended and dissolved substances from areas it has washed, and carry the substances to streams and lakes.

Secchi Disk - a black and white, 20 cm diameter disk that is attached to a rope. The disk is used to measure water transparency in open water. See Transparency.

Stratification (Thermal Stratification) - the state in which a lake forms distinct layers (the epilimnion and hypolimnion), usually because of the temperature differences between the surface and the bottom of the lake. These layers do not mix while the lake is completely stratified.

Submerged Macrophyte - aquatic plants that grow completely under the water surface. Submerged macrophytes are usually rooted in sediments, although some may be free-floating. Examples: elodea, coontail.

Thermocline - when measuring temperature from the top to the bottom of a lake, the thermocline is characterized by a considerable change in temperature with little change in depth. It is the transition area between the epilimnion and the hypolimnion.

Transparency - generally, water clarity of open water measured by a Secchi disk is called Secchi disk transparency. Secchi disk transparency is a measurement of the depth that sunlight can penetrate water and then reflect from the disk back up to the surface.

Trophic State - characterizes a lake according to the amount of plants that grow in a lake. Trophic State also characterizes the water clarity and the amount of nutrients in the water. See Oligotrophic, Mesotrophic, and Eutrophic.

Trophic State Index - a number that rates a lake according to the extent of eutrophication. In this report, oligotrophic lakes have lower trophic state values, and eutrophic lakes have a higher trophic state index value.

Turbidity - a measurement of the effects of light-absorbing and light-scattering substances that are suspended in water. Turbidity is determined by passing light through a sample and measuring the amount of light that is scattered by the suspended particles. Turbidity is not the same as transparency.

Turnover (Lake Turnover) - the seasonal mixing of water layers that occurs when temperature differences lessen between the top and bottom layers of water. Turnover occurs during the fall in most lakes. Lakes that freeze over during winter will also turnover after spring thaw.

Water Clarity - another term for Water Transparency.

Water Quality Standards - criteria established by Washington State for surface waters. Water quality standards (for dissolved oxygen, pH, fecal coliform bacteria, temperature, and other parameters) are established for classes of rivers, streams, and marine waters (Class A, AA, etc., depending on their characteristic uses), and lakes (Lake Class).

Watershed - all area that drains to a lake via streams, surface runoff, or ground water.

Winterkill - fish kill in lakes generally caused by the depletion of oxygen in water while the lake is frozen over.

Zooplankton - microscopic animals in water that eat algae and are eaten by fish.

μg/Kg - micrograms per kilogram. A unit of concentration used to describe how many micrograms of a chemical or contaminant are present in one kilogram of the analyzed substance (such as sediment or fish tissue). One μg/Kg is equal to one ppb (parts per billion).

μg/L - micrograms per liter. A unit of concentration used to describe how many micrograms of a substance that are in one liter of solution. One μg/L is equal to one milligram per cubic meter (mg/m^3), and 1000 μg/L is equal to one mg/L. Because very small amounts of nutrients will affect algal growth, nutrients are often reported in μg/L.