Methods and Sources

This report presents results of lake monitoring conducted from 1992 through 2002 as part of the Snohomish County Lake Management Program. Both citizen volunteer monitors and SWM staff collected the data. In addition, the report incorporates lake data from several other historical and recent sources.

Volunteer Monitoring

The volunteer monitoring program began in 1992 with volunteers at 14 lakes. Since that time, the number of lakes monitored by volunteers has averaged about 25, with a high of 28 lakes. Most of the lakes have public access, although seven are private lakes. Some volunteers have continued with the program for all eleven years. At other lakes, there have been several different volunteers through the years.

SWM staff trained each new volunteer at the lake monitoring site and provided necessary equipment, forms, and the "Snohomish County Lake Management Program Monitoring Manual" (Appendix A in Tetra Tech, 2003). In addition, SWM staff conducted a training workshop for new and returning volunteers each May before the start of the monitoring season.

There are two levels of volunteer lake monitoring—basic and detailed.

♦ Basic Monitoring—All volunteers performed basic monitoring by conducting measurements and observations of their lake every two weeks from mid-May through October each year. (Some volunteers were not able to conduct monitoring every two weeks. The number of completed monitoring events during any one season ranged from two to as many as twenty for some lakes.) The basic monitoring measurements and observations were conducted at the deepest point in the lake, preferably between 10 a.m. and 2 p.m.

Volunteers performing basic monitoring measured water clarity, surface water temperature, and lake level. To measure water clarity, volunteers lowered a black and white Secchi disk into the lake and measured the exact point at which the disk disappeared from sight. Readings were recorded to the nearest 0.1 meter. Volunteers used armored LaMotte thermometers accurate to 0.5° C to measure surface water temperatures at 0.2 meters depth. Lake levels were determined by measuring down to the water surface from a fixed point near the lake shore. In addition to these measurements, volunteers recorded observations about the apparent amount of algae in the water, the abundance of aquatic plants, water color, the weather, and any other unusual conditions at or around the lake. The "Snohomish County Lake Management Program Monitoring Manual" contains complete protocols for the basic lake monitoring.

♦ Detailed Monitoring—Some volunteers also conducted detailed monitoring in addition to the basic monitoring. Detailed monitoring includes measuring dissolved oxygen and temperature profiles once per month from May to October and collectiing total phosphorus samples for laboratory analysis monthly from June through September. Monthly chlorophyll *a* and phaeophytin samples were added in 2002. All detailed monitoring was conducted while anchored at the deepest point in the lake.

To measure dissolved oxygen concentrations, volunteers collected water samples using LaMotte water bottles or Van Dorn-type vertical samplers. Samples were taken from 0.5 meters, 3 meters, 6 meters, and one meter above the bottom and analyzed for dissolved oxygen content using LaMotte dissolved oxygen titration kits. Volunteers measured water temperatures at one meter

intervals down to 10 meters and then at two meter intervals to the lake bottom. Thermometers were placed inside the samplers and the water temperature read immediately after each water sample was brought to the surface.

Volunteers also used the samplers to collect water samples for lab analysis of total phosphorus and chlorophyll *a* during one weekend each month designated by SWM staff. Discrete samples were collected from both 1.0 meter deep and from approximately 1 meter above the bottom for total phosphorus, and from 1.0 meter deep for chlorophyll *a*. Volunteers refrigerated the samples and held them for pick-up by SWM staff early the following week.

The "Snohomish County Lake Management Program Monitoring Manual" contains complete protocols (including duplicate sampling and other quality control procedures) for the detailed lake monitoring. Figure 12 is a copy of the lake monitoring form used by volunteers doing detailed monitoring. The forms for basic monitoring are exactly the same but without spaces for temperature and dissolved oxygen profile data.

As of mid-2002, all raw data collected by volunteer monitors may be found online at the Snohomish County SWM website: www.co.snohomish.wa.us/publicwk/swm/.

FIGURE 12. VOLUNTEER MONITORING FORM (DETAILED)

SNOHOMISH COUNTY VOLUNTEER LAKE MONITORING PROJECT

Lake Name: _____ **Monitoring Date:** _____

Names of Volunteers: _____ **Monitoring Time:** _____

MEASUREMENTS:

Secchi Disk Depth (to nearest 0.1 meter):

1st Secchi Reading _____ meters

2nd Secchi Reading _____ meters

Did the Secchi disk ❑ hit bottom? ❑ enter weeds?

(If the Secchi disk hits bottom or enters weeds, please take another set of Secchi readings at another nearby location.)

Air Temperature _____ degrees C

Near-Surface Water Temperature _____ degrees C

Lake Level _____ inches (distance from water to marker)

Depth (meters)	Temperature (degrees C)	Dissolved Oxygen (mg/L)	Depth
1	_____		
2	_____	A _____	Surface
3	_____		
4	_____	B _____	3 meters
5	_____		
6	_____	C _____	6 meters
7	_____		
8	_____	D _____	1 meter above bottom
9	_____		
10	_____		
12	_____	**Duplicate Dissolved Oxygen**	
14	_____		
16	_____	____ meters _____ mg/L	
18	_____		
20	_____	**Lake Depth** _____ meters	

OBSERVATIONS:

(Please check any of the following that apply):

	None	Slight	Moderate	Heavy
Algae in water				
Algae Scum				
Aquatic Plants				
Odor				
Odor (circle if any)	fishy	rotten egg	musty	septic-like

Approximate number of ducks/geese on the lake: _____

Percent Cloud Cover:
❑ 0% ❑ 10% ❑ 25% ❑ 50% ❑ 75% ❑ 90% ❑100%

Rain within last 2 days:
❑ none ❑ trace ❑ light ❑ moderate ❑ heavy

Current Wind Conditions:
❑ calm ❑ light ❑ breezy ❑ strong ❑ gusty

Water Color:
❑ light green ❑ greenish-brown ❑ black
❑ moderately green ❑ light brown ❑ milky green
❑ pea-soup green ❑ dark brown ❑ clear
❑ other _____

Other Lake and Watershed Conditions: (e.g. oil, garbage, etc)
(Please describe:)_____
_____
_____
_____.

♦ Volunteer Monitors—Many dedicated citizen volunteers have participated in the Snohomish County lake monitoring program through the years. Without the efforts of volunteer monitors it would not have been possible to collect adequate data to evaluate the condition of most lakes.

Table 12	Citizen Volunteer Lake Monitors
ARMSTRONG	Brian Seguin, LeAnn Anderson, Eric Nordstrom, Kenneth Black
BEECHER	Nan McGuire
BLACKMAN	Julie Callebert, Mary Keppler
BRYANT	Josh Shalan
CASSIDY	John Naples, Glenn Phipps
CHAIN	Brian Vanover, Laura Reed, Travis Powell, Michael Manson
COCHRAN	Don Foltz, John Ruhnke, Mike Durick
CRABAPPLE	Deb Kocher, Mary Smith
ECHO	Gerald Dickson, Bernice Engel
FLOWING	Glen & Sherry Smith, Bob & Karen Birdseye, John Vardenega
GOODWIN	Karen & Mark Thompson, Steve Nelson, Michael Brown, Wally Sullivan
HOWARD	Suzanne Cannon, Bill Crane, Tim Schmidt, Trudi Adams
KAYAK	Pat & Bill Waldrop, Terrie Foote
KETCHUM	Bob Arnold, Jane Hilleary, Anton Ehinger
KI	Pam & Scott Seiber, Kathy Nairn, Idell Nieforth
LOMA	Bernie & Elaine Fleming, Tom & Emily Smith, Karl Ostrom
LOST	Guy Borgen, Gwen DeFrank, Anita Robinson
MARTHA N.	Nancy Dean, Joan Lucas
MARTHA S.	Tom Eble, John Guentz, John Moore, Kathy Pike, Keith Johnson
MEADOW	Doug & Robin Schaffer
NINA	Kerry Mauer, Joan & Paul Perry, Fred Carpenter, Terry Larsen
PANTHER	Ken Chisholm, Charles Gilbert, Jeff Onstad
RILEY	Weldon Sorgen, Sonya & Liv Engelsen, Peggy Oard, Jeff Aylor
ROESIGER	Elsie Sorgenfrei, Robert & Joanne Miller
ROWLAND	Gerry & Vera Miller
RUGGS	Fred & Alita Jones
SERENE	Lennie Rae Cooke, Fred Murray, Gary Landvatter, Glen Shadduck
SHOECRAFT	Fred Dockendorf
SPRING	Jack Halbert
STICKNEY	Shirley, Dennis, Sean & Casey Nicholson, Doug Elrod, Gary Weston
STORM	Tom Piekarski
SUNDAY	Lee & Dee Vega, Damon & Leslie Darley, Noel Higa
WAGNER	Peter Mellinger, Jim Jaskowiak

SWM Staff Monitoring

SWM staff also conducted monitoring of 25 high priority public access lakes from 1996 through 2002. During 1996 and 1997, the monitoring occurred twice during the summer. Since 1998, the monitoring has been performed monthly from June through September. Many of the lakes monitored by SWM staff were the same as those monitored by volunteers. Where volunteers performed detailed monitoring, SWM staff only monitored as necessary to cover months missed by the volunteers or to provide checks of volunteer data.

SWM staff measured water clarity and made algae, color, weather and other observations exactly as the volunteer monitors. In addition, SWM staff took dissolved oxygen, temperature, pH, and conductivity profiles at every meter of depth at the deepest point of the lakes using a Hydrolab Datasonde 3. On occasion, dissolved oxygen and temperature profiles were taken with a YSI meter. SWM staff also collected discrete samples for total phosphorus analysis at 1.0 meters and approximately one meter above the bottom and discrete samples for chlorophyll *a*/phaeophytin at 1.0 meters. All samples collected by SWM staff and detailed volunteers since 1996 were analyzed at the laboratory of Aquatic Research, Inc. in Seattle, Washington using the SM18 4500PF method for total phosphorus and SM18 10200H for chlorophyll *a* and phaeophytin. Monitoring was conducted in accordance with the Quality Assurance Plan Snohomish County Lake Management Program (Tetra Tech, revised in 2003). Duplicate field samples were collected and blind samples submitted to the lab. All raw data collected by SWM staff may be found online at the Snohomish County SWM website (www.co.snohomish.wa.us/publicwk/swm/).

SWM staff performed visual surveys of aquatic plants at each public access lake one or more years since 1994. Plants were observed from a boat using a viewscope, and samples were retrieved by rake for identification. The locations and estimated densities of aquatic plants were then mapped for each lake. SWM staff also conducted surveys of shoreline development and modifications for most lakes.

Other Data Sources

In addition to lake data collected by volunteer monitors and SWM staff since 1992, this report also incorporates data from several other published and unpublished sources. The individual lake reports include summaries of the data from these other sources. Some of these data are also used in the county-wide comparisons of lake conditions in cases where the parameters and methods were comparable to volunteer and SWM-collected data.

- Department of Ecology Lake Assessment Program—The Washington State Department of Ecology conducted a lake water quality assessment program from 1989 through 2000. Data were collected by Ecology staff and by citizen volunteers. In the early 1990s, Ecology monitoring occurred at as many as 11 lakes in Snohomish County; but by the late 1990s, only four lakes were being monitored. Ecology and SWM staff made efforts to share data and avoid having volunteer monitors at the same lakes. The Snohomish County basic monitoring protocols were patterned closely after Ecology monitoring methods so that the data would be comparable. This report uses both published and unpublished Ecology lake water quality assessment data (including Brower and Kendra, 1990; Coots, 1991; Rector, 1994; Rector, 1996; Rector and Hallock, 1991; Smith and Rector, 1997; Smith, Parsons and Hallock, 2000).

- Lake Stevens Drainage Improvement District #8—Since 1997, Drainage Improvement District #8 has collected water quality data year round at Lake Stevens and, on occasion, at Lake Cassidy (Gray & Osborne, 1998, 1999, 2000, 2001, and 2002). SWM staff regularly

coordinate with the District on monitoring methods and parameters for Lake Stevens.

♦ Historical Sources—Limited historical water quality information is available for some lakes. The State of Washington conducted one-day reconnaissance sampling at numerous Snohomish County lakes in the early 1970s, including 26 lakes covered in this State of the Lakes report (Bortleson et. al., 1976). The State also monitored four lakes in the Seven Lakes area on several dates in 1973 (McConnell et. al., 1976). In 1981, the State again conducted one-day reconnaissance sampling of 15 Snohomish County lakes, including 10 of the lakes tested in the 1970s (Sumioka and Dion, 1985).

During the 1980s and early 1990s, Snohomish County, Washington State, and other local agencies conducted detailed Phase I diagnostic studies on several lakes with particular problems and strong public interest. Studies were completed for the Seven Lakes (Entranco, 1986), Lake Stevens (Reid, Middleton, & Associates, 1983 and KCM, 1987), Lake Roesiger (KCM, 1989), Martha Lake (Entranco, 1991), Blackman Lake (KCM, 1994), and Lake Ketchum (Entranco, 1997). These detailed studies include lake water quality data collected intensively for at least one year on the subject lakes.

Data Management and Analysis

The lake field data collected by citizen volunteers and by SWM staff were screened soon after they were received to determine if the data met the standards of the Lake Management Program. Likewise, all water quality data received from the lab were evaluated to be sure that the data met the data quality objectives. With limited exceptions, all the field data collected by volunteers and staff were acceptable for use in the characterizations of lake conditions contained in this report. Unfortunately, none of the nutrient data (phosphorus and nitrogen series) collected during the summers of 1994 and 1995 met the data quality objectives because of laboratory problems. These data were discarded. All the nutrient samples collected from 1996 through 2002 were analyzed at another laboratory—Aquatic Research, Inc.—and the results were acceptable.

Soon after screening each set of data, SWM staff entered all the data into a network database for archiving and analysis. Each year's data were displayed in simple tables. Secchi depth (water clarity), temperature, and dissolved oxygen readings were analyzed by simple graphing techniques. Further analyses were performed for water clarity and total phosphorus data because these data are numerous and the parameters are key for determining lake condition and trophic status.

The first step was calculating averages (means) as a way to characterize the central tendency of the data sets. May through October water clarity data for each year were combined into a "summer" average because this is the period of stratification for most lakes. These warm months of the year are also the period when the lakes are most heavily used and when algal and aquatic plant growth or other problems cause the most concerns. Averages were calculated for each "summer," even if only two measurements were available, because water clarity data for most lakes are relatively consistent and because the data provide at least a limited picture of lake conditions for that summer. However, analyses and conclusions based on larger data sets will always have more power and validity that those based on a few measurements.

Another problem with having only a few measurements during a summer is that one or more measurements taken near the same time might bias the average toward the lake conditions of that time. (For example, two Secchi depth measurements within a week in August would bias the summer average if there were only one other measurement, perhaps taken

in June, during that summer.) To address this problem, the summer water clarity averages were calculated based on a specific algorithm. First, multiple measurements taken on the same sampling trip (even if by different persons) were averaged to give a value for that day. Second, measurements (or "daily" values) taken five days or less apart were averaged to give a "weekly" value. (This interval combines one or more measurements taken near the same time, but does not group measurements if a monitor was taking readings each weekend.) Then, all weekly values from May through October were averaged to give a "summer" average, which is reported in the individual lake reports and in lake-to-lake comparisons. The long-term water clarity averages used in the lake-to-lake comparisons are the averages of each summer average over the period of record. Minimum and maximum water clarity values reported for each summer refer to the "daily" values recorded for the lake.

Total phosphorus measurements were also averaged to give a "summer" average for each year. However, total phosphorus samples were not closely spaced in time, so daily values and weekly averages were not calculated. Also, most phosphorus measurements were taken from June through September. Only total phosphorus data from samples collected at discrete depths (near the surface and near the lake bottom) were used in calculating summer and long-term averages. Composite samples—where portions of the sample come from more than one depth—are not directly comparable to discrete samples, so they were not included in the averages, but the results are summarized under Other Data in the individual lake reports. (The one exception to this procedure is the handling of total phosphorus data from Lake Roesiger. Composite sampling data are included in the averages because nearly all the phosphorus data for this lake are from composite samples. Care should be taken in comparing total phosphorus data and averages from Lake Roesiger with results from other lakes.)

The summer averages for water clarity and total phosphorus were also analyzed for apparent trends over time. Using Kendall's tau as a measure of trends revealed that several lakes are experiencing trends toward lower or higher water clarity. Most lakes have long enough water clarity records to be able to evaluate trends in this manner. However, the total phosphorus records were not yet long enough (generally 7 years) to discern any apparent trends in most cases.