Summary and Comparison of Snohomish County Lake Conditions

The following sections present comparative information about the lake and watershed characteristics, recreational uses, and water quality conditions of Snohomish County lowland lakes included in the Lake Management Program. Please refer to the individual lake reports for more detailed explanations of data for a specific lake.

Comparison of Physical Characteristics

The lakes being monitored as part of the Lake Management Program represent a wide, but not random, sample of the lakes located in the populated lowland areas of Snohomish County. Table 2 presents the physical characteristics of these lakes and their watersheds. The data are taken from Bortleson, et. al. (1976), Sumioka and Dion (1985), and analysis of Snohomish County GIS data. Lake Stevens, which is being monitored by another agency, is included because of its importance in the county.

Some notable physical characteristics include:

♦ Size and Volume—The monitored lakes range in size and volume from Ruggs Lake (11 acres and 77 acre-feet) to Lake Stevens (1040 acres and 65,000 acre-feet).

♦ Watersheds—The sizes of lake watersheds also cover a wide range, from only 36 acres for Nina Lake to over 4,000 acres for Beecher and Stevens. The ratios of watershed area to lake area reveal that some small lakes, such as Beecher, Ruggs, and Stickney, have very large watersheds. This means that these lakes have a high potential for watershed activities to affect lake water quality. Conversely, Ki, Storm, and Stevens have very small watersheds relative to the size of the lakes. This means that the watersheds have less potential to degrade these lakes. However, there is also less water flowing through these lakes to assimilate pollution, so the effects of any pollution reaching these lakes may be magnified.

♦ Depth—Average (mean) depth is one of the strongest indicators of natural lake conditions. Lakes with shallow average depth, such as Beecher, Cassidy, Ruggs, and Sunday, are some of the most eutrophic lakes in the county. Conversely, Bosworth, Ki, Martha N., Roesiger, and Stevens have the greatest average depth and should be the most oligotrophic lakes in the county. However, Martha N. and Stevens, in particular, show signs of eutrophication in spite of their great depths.

TABLE 2

PHYSICAL CHARACTERISTICS OF MONITORED SNOHOMISH COUNTY LAKES

Lake Name	Lake Area (acres)	Watershed Area (acres)	Watershed/ Lake Area Ratio	Maximum Depth feet (meters)	Average Depth feet (meters)	Lake Volume (acre-feet)	Shoreline Length (miles)
ARMSTRONG	30	369	12.3	24 (7.3)	15 (4.6)	450	1.1
BEECHER	20	4318	215.9	10 (3.0)	5 (1.5)	105	1.6
BLACKMAN	57	445	7.8	29 (8.8)	14 (4.3)	800	1.5
BOSWORTH	102	979	9.6	79 (24.1)	35 (10.7)	3700	2.0
BRYANT	21	468	22.3	23 (7.0)	14 (4.3)	295	0.9
CASSIDY	123	2477	20.1	20 (6.1)	11 (3.4)	1300	1.8
CHAIN	21	472	22.5	18 (5.5)	10 (3.0)	210	0.8
COCHRAN	33	323	9.8	54 (16.5)	26 (7.9)	870	0.9
CRABAPPLE	35	690/862*	19.7/24.6*	49 (14.9)	18 (5.5)	650	1.1
ECHO	16	172	10.8	50 (15.2)	17 (5.2)	290	0.6
FLOWING	131	538/748*	4.1/5.7*	69 (21.0)	28 (8.5)	3800	2.2
GOODWIN	535	2604/3466*	4.9/6.5*	50 (15.2)	23 (7.0)	13,000	5.4
HOWARD	26	265	10.2	50 (15.2)	29 (8.8)	790	0.9
KAYAK	16	222	13.9	>15 (4.5)	NA	NA	1.4
KETCHUM	24	352	14.7	21 (6.4)	12 (3.7)	296	1.3
KI	96	452	4.7	70 (21.3)	33 (10.1)	3300	1.9
LOMA	21	172	8.2	28 (8.5)	11 (3.4)	230	0.9
LOST	12	149	12.4	45 (13.7)	23 (7.0)	280	0.7
MARTHA N.	59	801/1066*	13.6/18.1*	70 (21.3)	33 (10.1)	2000	1.8
MARTHA S.	57	448	7.9	48 (14.6)	24 (7.3)	1300	1.4
MEADOW	12	868	72.3	21 (6.4)	14 (4.3)	170	1.1
NINA	14	36	2.3	39 (12.0)	24 (7.4)	343	0.8
PANTHER	45	619/1367*	13.8/30.4*	36 (11.0)	23 (7.0)	1100	1.3
RILEY	30	273	9.1	45 (13.7)	22 (6.7)	670	1.0
ROESIGER	340	2272	6.7	110 (33.5)	37 (11.3)	12,600	5.9
ROWLAND	9	404	44.9	60 (18.3)**	NA	NA	0.9
RUGGS	11	717/1665*	65.2/151.4*	16(4.9)	7 (2.1)	77	0.6
SERENE	43	223	5.2	23 (7.0)	14 (4.3)	580	1.3
SHOECRAFT	132	763/4230*	5.8/32.0*	35 (10.7)	18 (5.5)	2400	2.4
SPRING	26	620	23.8	10 (3.0)	NA	NA	1.3
STEVENS	1040	4371	4.2	155 (47.3)	63 (19.4)	65,000	7.1
STICKNEY	24	2761	115.0	34 (10.4)	15 (4.6)	360	1.0
STORM	73	211	2.9	46 (14.0)	22 (6.7)	1605	1.7
SUNDAY	38	790	20.8	20 (6.1)	8 (2.4)	305	1.3
WAGNER	19	369	19.4	22 (6.7)	13 (4.0)	250	0.7

*--for those lakes located downstream in a chain of lakes, the first acreage figure and the first watershed/lake area ratio refer to the watershed immediately draining to that lake; the second acreage figure and ratio refer to the total watershed draining to that lake (including the watershed of any upstream lake(s)).
**--reported but not confirmed

Comparison of Shoreline and Watershed Development

Table 3 presents a comparison of shoreline and watershed development around lakes in Snohomish County. The information comes from Bortleson, et.al. (1976) for some 1970s data, from aerial photographs, and from shoreline surveys conducted by SWM staff and volunteers. Some highlights from this comparison include:

♦ Shoreline Development—Development on the lake shore has a high potential to contribute nutrients and other pollution to a lake. In addition, development near the shore often removes native vegetation that serves to protect water quality by filtering out pollution before it reaches streams, ditches, or the lake. Therefore, the character of shoreline development may be an important factor in determining lake quality.

In general, the largest lakes have the most homes along their shorelines, while some small lakes have very few homes. However, housing density (the number of homes per 1000 feet of shoreline) gives a more accurate picture of the potential impacts of shoreline development. Echo, Goodwin, Martha S., and Serene had the highest housing densities in the mid-1990s. Armstrong, Beecher, Bryant, Cassidy, Chain, Kayak, Rowland, and Spring had the lowest densities. The most likely reasons for these differences are proximity to suburban population centers and the suitability of the shoreline soils and slopes for accommodating development.

Housing density showed the largest increases from the early 1970s to the 1990s at Cochran, Lost, and Wagner lakes. There has also been significant re-development with bigger homes and more paved areas at the large recreational lakes—Goodwin, Roesiger, and Stevens.

♦ Shoreline Modifications—Surveys conducted by SWM staff in the 1990s counted the number of homes where the lake shore has been modified by placement of either bulkheads or fill material. Such modifications can lead to increased erosion, reduced filtering of pollution, and loss of fish and wildlife habitat, especially when native vegetation is removed. More than 60% of the houses at Crabapple, Flowing, Goodwin, Ki, Martha S., and Serene had modified shorelines in the 1990s. Stevens and Roesiger were not surveyed, but also have highly modified shorelines.

On the other hand, property owners have retained some native vegetation along at least a portion of their waterfronts at many lakes. This vegetation helps prevent pollution from reaching the water. In general, those lakes with the most native vegetation are shallow, partially surrounded by wetlands, and the least developed. However, Crabapple and Serene are two lakes where significant shoreline vegetation has been retained in spite of dense development.

♦ Watershed Development—The amount and type of land development in the larger watershed also affects the water quality of a lake. Watersheds with dense commercial or residential development, or with active agriculture, have many sources of potential pollution. The estimates of watershed development in Table 3 are based on aerial photographs. Please note that watersheds refer to the immediate watersheds of each lake and include the lake surfaces, so 100% development is not possible.

Lakes with the highest percentage of development in their watersheds in the 1990s were Echo, Martha S., Ruggs, Serene, and Stickney. Martha S. and Stickney, along with Blackman, have experienced the most rapid watershed development from the 1970s to the 1990s. Several county lakes—Beecher, Blackman, Bryant, Martha S., Panther, and Sunday—had significant agricultural activity in their watersheds in the 1970s. By the 1990s, most of the agriculture in these watersheds, and significant forest lands in almost every lake watershed, had been replaced by residential development or large lot rural development. (Lake Ketchum suffered significant impacts from agricultural activity, but the overall percentage of agricultural land use there is not high.)

TABLE 3
SHORELINE AND WATERSHED DEVELOPMENT

Lake Name	Number of Nearshore Homes		Number of Homes per 1000 feet of shoreline		% of Homes with Modified Shoreline	% of Homes with native vegetation	Percent of Watershed Developed (residential or commercial)	
	Early 1970s	Mid-1990s	Early 1970s	Mid-1990s	Mid-1990s	Mid-1990s	Early 1970s	Mid-1990s
ARMSTRONG	8	11	1.3	1.9	36	64	3	5
BEECHER	8	10	0.9	1.2	NA	NA	8*	40
BLACKMAN	20	40	2.6	5.1	30	52	8*	50
BOSWORTH	81	116	7.7	11.0	41	37	10	15
BRYANT	0	0	0.0	0.0	NA	NA	4*	20
CASSIDY	22	18	2.3	1.9	6	78	1	18
CHAIN	3	3	0.7	0.7	0	100	0	5
COCHRAN	17	41	3.5	8.5	22	49	7	10
CRABAPPLE	33	41	5.7	7.1	63	49	2	20
ECHO	29	44	8.7	13.2	57	41	10	65
FLOWING	61	104	5.3	9.0	66	37	19	35
GOODWIN	381	377	13.4	13.2	82	18	14	30
HOWARD	22	32	4.8	7.0	50	10	4	15
KAYAK	0	11	0.0	1.5	18	55	0	10
KETCHUM	59	52	8.6	7.6	46	19	23	41
KI	82	90	8.2	9.0	71	29	11	40
LOMA	53	58	10.8	11.8	12	33	17	40
LOST	19	42	5.1	11.4	3	64	12	50
MARTHA N.	44	74	4.6	7.8	49	34	5	15
MARTHA S.	85	97	11.5	13.1	72	34	25*	80
MEADOW	0	22	0.0	3.8	0	100	<5	15
NINA	1	34	0.2	8.4	38	56	5	60
PANTHER	25	28	3.6	4.1	46	25	2*	13
RILEY	14	18	2.8	3.6	0	100	5	10
ROESIGER	344	386	11.0	12.4	NA	NA	9	10
ROWLAND	0	7	0.0	1.5	0	100	0	20
RUGGS	12	27	3.8	8.5	11	81	40	80
SERENE	93	94	13.5	13.7	60	64	56	75
SHOECRAFT	100	114	7.9	9.0	49	9	9	20
SPRING	2	12	0.3	1.8	8	100	2	5
STEVENS	330	349	8.8	9.3	NA	NA	20	55
STICKNEY	33	45	6.5	8.9	29	40	22	80
STORM	26	38	2.9	4.2	13	76	6	8
SUNDAY	23	31	3.4	4.5	13	87	2*	10
WAGNER	2	11	0.5	2.8	9	54	5	30

* -- indicates lakes with agricultural uses on more than 20% of their watersheds

Note—the watersheds include the lake surfaces, so 100% watershed development is not possible

Summary of Recreational Opportunities

Table 4 presents a summary of the public recreational facilities and opportunities available at each monitored lake. Access is important to the public because it expands the enjoyment of lakes to all the residents of Snohomish County and Washington State. However, public access, especially boating access, increases the risk of introducing invasive plant and animal species, such as Eurasian watermilfoil, to Snohomish County lakes. Regular monitoring for invasive species and enforcement of regulations that prohibit transport of invasive species will help to prevent new invasions of unwanted plants and animals.

♦ Public Access—The majority of the lakes included in the monitoring program are open for public access. In most cases, boat launches owned and operated by the Washington State Department of Fish and Wildlife provide public access for fishing and boating (but not for swimming). Blackman, Flowing, Goodwin, Martha S., Roesiger, and Stevens also have city, county, or state parks that provide additional public access, including swimming and picnicking. Seven of the lakes are private or have undeveloped public access parcels.

♦ Boating Activity—Snohomish County allows power boats and water skiing at Goodwin, Stevens, Roesiger, Shoecraft, and Flowing lakes. However, there are special skiing restrictions at the latter three lakes. Skiing is not permitted and power boats are restricted to 8 mph at Cassidy and Ki. At most other lakes, the County prohibits the use of internal combustion motor boats because of the small size of the lakes, the threat of pollution, and safety concerns. There are no specific regulations on boating at several lakes; however, the presumption is that motor boats would be discouraged because the lakes are quite small.

♦ Fisheries—The Washington State Department of Fish and Wildlife (WDFW) manages fish stocks and fishing on Snohomish County lakes. Currently, the WDFW stocks 24 of the public access lakes with catchable rainbow trout each spring. The State manages these lakes, plus Lake Stevens, for both cold and warm water fisheries. Bryant and Sunday lakes are managed for warm water fish only. The remaining eight private or limited access lakes generally support warm water fisheries, although there is no active management by the State.

TABLE 4 RECREATIONAL OPPORTUNITIES				
Lake Name	**Public Parks**	**Public Boating/ Fishing Access**	**Boating/ Skiing**	**Fish Species & Management**
ARMSTRONG		YES (APR-OCT)	No I.C. motors	RB*
BEECHER		WALK-IN	No regulations	LB, PS, YP
BLACKMAN	2 city parks	YES	No I.C. motors	RB*,LB,YP,BH
BOSWORTH		YES (APR-OCT)	No I.C. motors	RB*, CT, LB
BRYANT		WALK-IN	No I.C. motors	LB, BC
CASSIDY		YES	Power boats; 8 mph	RB*,LB,BC,PS,YP,BH
CHAIN		YES	No I.C. motors	RB*, LB, PS, BC
COCHRAN		NO	No I.C. motors	Unknown
CRABAPPLE		YES	No I.C. motors	RB*, LB, PS, YP
ECHO		YES	No regulations	RB*, PS
FLOWING	county park	YES	Power boats; Skiing	RB*, LB
GOODWIN	county & state parks	YES	Power boats; Skiing	RB*,CT,LB,SB,BC,PS,YP
HOWARD		YES (APR-OCT)	No I.C. motors	RB*
KAYAK		NO	No regulations	Unknown
KETCHUM		YES	No I.C. motors	RB*,LB,BG,PS,BC,YP,BH
KI		YES	Power boats; 8 mph	RB*, LB, YP
LOMA		YES	No I.C. motors	RB*, LB, PS
LOST		YES	No regulations	RB*, CT, LB
MARTHA N.		YES	No I.C. motors	RB*, LB, YP
MARTHA S.	county park	YES (APR-OCT)	No I.C. motors	RB*, LB, YP, BH
MEADOW		NO	No regulations	Unknown
NINA		NO	No regulations	Unknown
PANTHER		YES	No I.C. motors	RB*,LB,BC,PS,BH
RILEY		YES (APR-OCT)	No I.C. motors	RB*
ROESIGER	county park	YES	Power boats; Skiing	RB*,K,LB,BG,YP,PS,BC,BH
ROWLAND		NO	No regulations	Unknown
RUGGS		NO	No regulations	BH
SERENE		YES (APR-JUN,SEP-OCT)	No I.C. motors	RB*, LB
SHOECRAFT		YES	Power boats; Skiing	RB*,LB,SB,BC,PS,YP
SPRING		NO	No regulations	Unknown
STEVENS	2 city; 3 county parks	YES	Power boats; Skiing	RB,K,CT,LB,SB,BC,YP,BH
STICKNEY		YES (APR-JUN,SEP-OCT)	No I.C. motors	RB*,LB,YP,BC,BH
STORM		YES (APR-OCT)	No I.C. motors	RB*, LB
SUNDAY		WALK-IN	No I.C. motors	LB,YP,BC,PS,BH
WAGNER		YES (APR-OCT)	No I.C. motors	RB*, LB

I.C. -- refers to internal combustion power motors
Key to Fish Species: RB—rainbow trout; CT—cutthroat trout; K—kokanee; LB—largemouth bass; SB—smallmouth bass; BC—black crappie; YP—yellow perch; BG—bluegill; PS—pumpkinseed sunfish; BH—brown bullhead catfish
RB* -- indicates that lake is regularly stocked with rainbow trout by Washington Department of Fish and Wildlife

Source of fisheries information: Washington State Department of Fish and Wildlife (www.wa.gov/wdfw)

Comparison of Temperature and Dissolved Oxygen

From spring to early fall, most Snohomish County lakes stratify between warm upper waters (epilimnion) and cool bottom waters (hypolimnion). The stronger the stratification (i.e. the greater the temperature differences between upper waters and bottom waters) the less interaction occurs between the two layers. In a strongly stratified lake, little oxygen from the surface gets to the hypolimnion, and nutrients in the hypolimnion tend to remain there until the lake turns over in the fall. Therefore, strongly stratified lakes that have rich organic sediments usually experience a loss of dissolved oxygen that can lead to a steady build-up of nutrients in the hypolimnion.

Among Snohomish County lakes, the large deep lakes, such as Stevens, Roesiger, Ki, and Bosworth, develop strong stratification during the summer. Some small, but deep or sheltered, lakes are also strongly stratified, such as Armstrong and Lost. In strongly stratified lakes with depleted oxygen in the hypolimnion, the bottom sediments exert their greatest influence after fall turnover. Phosphorus may be spread throughout the water column at turnover, resulting in severe algal blooms, unless there are high levels of iron to precipitate the phosphorus back into the sediments.

In contrast, some lakes stratify weakly or only during periods of warm, calm weather. Mostly, these are shallow lakes, including Beecher, Chain, Loma, Ruggs, Serene, Spring, and Sunday. Goodwin and Shoecraft are large, moderately deep lakes that also stratify weakly because winds and boating activity continually mix the warm waters to great depths. In weakly stratified lakes, there is less opportunity for nutrients to build up in the hypolimnion, but nutrients that are released from the sediments may become available for algal growth more easily during the summer due to mixing.

Almost all Snohomish County lakes experience moderate to severe oxygen depletion in the bottom waters over the course of the summer. Exceptions are Serene, which almost never stratifies, and Cochran, which usually has dissolved oxygen present throughout most of its hypolimnion. The lakes that experience the most severe oxygen depletion are Ketchum, Meadow, and Rowland—eutrophic lakes that are deep or protected enough to enjoy stable stratification. Prior to installation of an aeration system to provide oxygen to the hypolimnion, Lake Stevens also experienced severe oxygen depletion.

Some lakes have unusual summertime dissolved oxygen profiles. In Martha N. and, to a lesser extent, Lost Lake, dissolved oxygen levels experience a sharp drop in the metalimnion, with somewhat higher levels in the upper hypolimnion. The most likely explanation for the dissolved oxygen decrease in the metalimnion of these lakes is the unique shapes of the lake bottoms. Large areas of the bottom lie at the same depth as the metalimnion, resulting in significant organic decomposition (and oxygen depletion) at this depth.

Several other lakes consistently have spikes of high dissolved oxygen (and usually pH) in the metalimnion, which indicate the presence of strong algal growth at that depth. Lake Howard, in particular, has this pattern of super-saturated oxygen levels in the metalimnion.

Water Clarity Comparisons and Trends

In the Snohomish County lake monitoring program, water clarity data (measured as Secchi depths) are perhaps the most important indicators of lake conditions. This is because Secchi depth measurements reflect the interaction of several water quality factors in a lake (algal abundance, turbidity, color); and, they focus on a characteristic that is directly meaningful to lake users (the clarity of the water). Secchi depth measurements are also simple, reproducible by different volunteers and staff, and form the longest data records for all the monitored lakes.

In general, high water clarity measurements suggest oligotrophic conditions in a lake. In contrast, low water clarity often results from heavy algal growth or suspended sediment, and usually indicates eutrophic conditions.

♦ Yearly Averages—Figure 7 shows the range of averages and the long term averages (arithmetic means) of summertime water clarity measurements recorded since 1990 for each monitored lake. The lakes are arranged from low water clarity to high water clarity. From Figure 7, it is clear that Meadow, Cassidy, and Beecher are at the eutrophic end of the spectrum—Secchi depths less than 2 meters average—while Ki, Howard, and Stevens are at the oligotrophic end—Secchi depths greater than 4 meters (using the approximate threshold values for water clarity). Please note that some lakes may have data for every year, while others have only limited data.

The lake names marked by an asterisk are those lakes that contain darkly colored water, the result of natural humic materials. The dark color reduces water clarity, but does not affect water quality. Without this natural color, these lakes might have somewhat greater water clarity (although more light might also lead to increased algae). Most likely, the effects of color are not enough to significantly change the lakes' positions in the overall county comparison.

♦ Year-to-Year Variability—Figure 7 reveals that the average water clarity in some lakes varies markedly from year to year. There is also a certain amount of variation among water clarity measurements at each lake within individual years. One way to measure the variability within the set of data for each lake is with the standard deviation. Standard deviation is a mathematical description of the dispersion of the sample data about the mean, or average, of that data. Table 5 lists the standard deviations of the summertime averages (arithmetic means) from the long-term average of water clarity for each lake over the period 1990 through 2002. This table shows that Armstrong, Martha N., Martha S., Nina, Panther, Stevens, and Sunday have the greatest variability by this measure. In particular, Armstrong and Sunday vary substantially despite having low Secchi depth averages. In contrast, Beecher, Cassidy, and Meadow exhibited the most uniform water clarity from year to year. (Beecher has fewer years of record, so the monitoring may have missed some of its natural variability.)

It also appears that the water clarity of most of the monitored Snohomish County lakes varies markedly in some years. For example, in 2001 and 2002, more than 75% of the monitored lakes had summer water clarity averages greater than their long term averages, while in 1996 and 1997 similar percentages of lakes exhibited lower than average water clarity.

Possible explanations for this group variability in any particular year include rainfall patterns, the amount of sunlight, and ambient temperature levels. Other factors may include ground water versus surface runoff patterns, water color changes caused by the amount of humic acids entering the lakes, and biological growth cycles. It is also possible that the monitoring record is too short to account for the natural variability of water clarity in Snohomish County lakes.

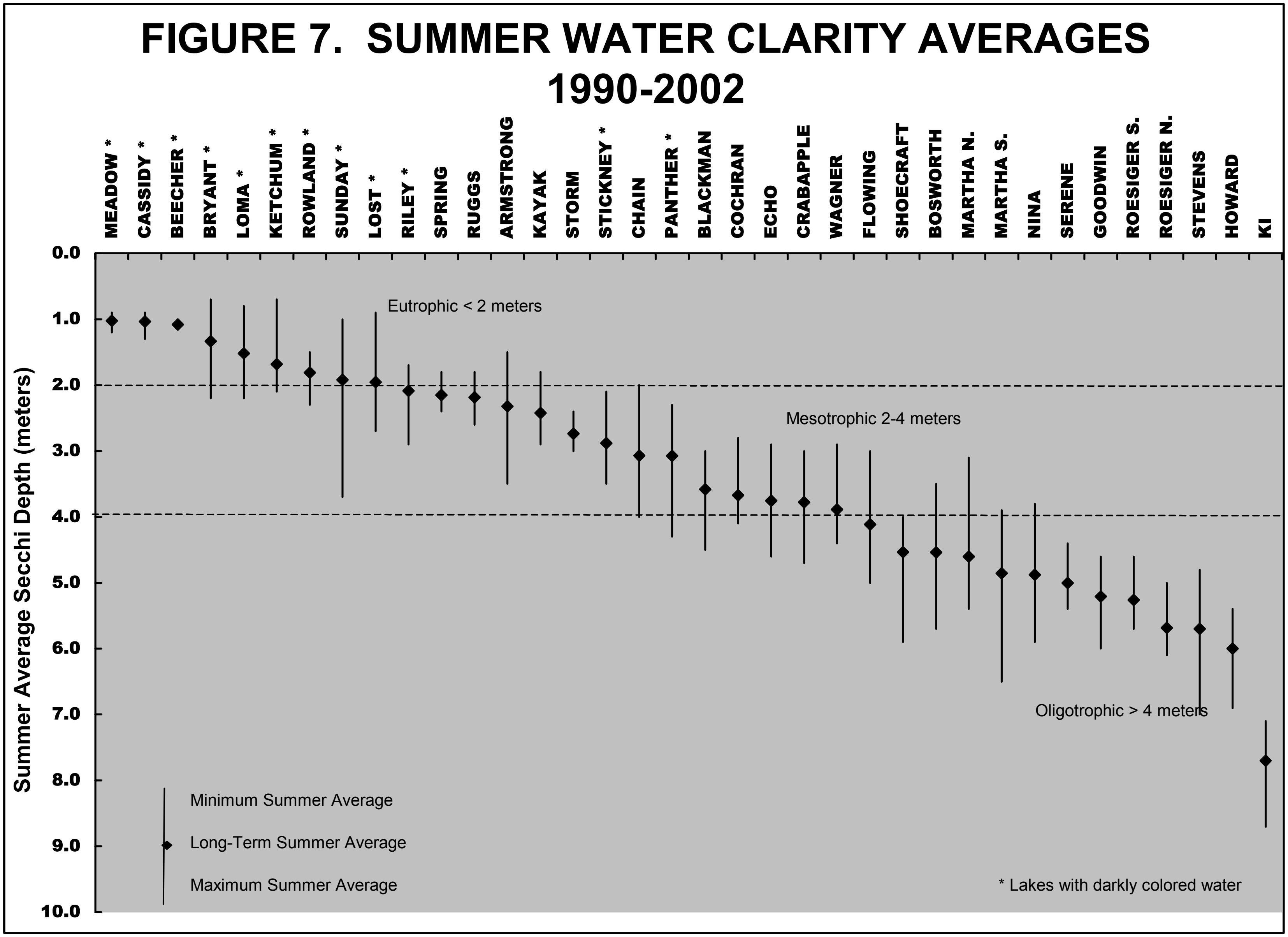


FIGURE 7. SUMMER WATER CLARITY AVERAGES
1990-2002
MEADOW *
CASSIDY *
BEECHER *
BRYANT *
LOMA *
KETCHUM *
ROWLAND *
SUNDAY *
LOST *
RILEY *
SPRING
RUGGS
ARMSTRONG
KAYAK
STORM
STICKNEY *
CHAIN
PANTHER *
BLACKMAN
COCHRAN
ECHO
CRABAPPLE
WAGNER
FLOWING
SHOECRAFT
BOSWORTH
MARTHA N.
MARTHA S.
NINA
SERENE
GOODWIN
ROESIGER S.
ROESIGER N.
STEVENS
HOWARD
KI
Summer Average Secchi Depth (meters)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Eutrophic < 2 meters
Mesotrophic 2-4 meters
Oligotrophic > 4 meters
Minimum Summer Average
Long-Term Summer Average
Maximum Summer Average
* Lakes with darkly colored water

TABLE 5
STATISTICAL ANALYSES OF WATER CLARITY AVERAGES

		DISTRIBUTION		TRENDS			
Lake Name	Years of Record (sample size)	1990-2002 Average Secchi Depth (meters)	Standard Deviation (meters)	Kendall's tau	p-value	Sen's slope	Apparent Trend
ARMSTRONG	9	2.3	0.70	-0.03	1.00	-0.04	
BEECHER	5	1.1	0.04	-0.20	0.82	0.00	
BLACKMAN	12	3.6	0.39	0.52	0.02	0.07	+
BOSWORTH	13	4.5	0.68	0.65	0.00	0.16	+
BRYANT	6	1.3	0.59	-0.20	0.72	-0.08	
CASSIDY	10	1.0	0.13	-0.07	0.86	0.00	
CHAIN	10	3.1	0.68	0.22	0.48	0.10	
COCHRAN	11	3.7	0.44	0.22	0.39	0.06	
CRABAPPLE	10	3.8	0.57	-0.27	0.38	-0.10	
ECHO	11	3.8	0.51	0.60	0.01	0.10	+
FLOWING	13	4.1	0.59	0.63	0.00	0.12	+
GOODWIN	11	5.2	0.48	-0.24	0.35	-0.05	
HOWARD	10	6.0	0.51	-0.07	0.86	-0.01	
KETCHUM	11	1.7	0.42	-0.07	0.81	-0.01	
KI	11	7.7	0.48	0.20	0.43	0.04	
LOMA	11	1.5	0.47	-0.51	0.04	-0.11	--
LOST	11	2.0	0.50	0.40	0.10	0.08	+
MARTHA N.	13	4.6	0.70	0.01	1.00	0.00	
MARTHA S.	13	4.9	0.71	-0.19	0.39	-0.05	
MEADOW	9	1.0	0.10	0.06	0.92	0.00	
NINA	9	4.9	0.70	-0.50	0.08	-0.15	--
PANTHER	11	3.1	0.70	0.35	0.16	0.10	
RILEY	9	2.1	0.41	0.39	0.18	0.05	
ROESIGER N.	12	5.7	0.30	0.44	0.05	0.05	+
ROESIGER S.	11	5.3	0.34	-0.27	0.26	-0.02	
ROWLAND	9	1.8	0.25	0.75	0.01	0.08	+
RUGGS	7	2.2	0.29	0.81	0.01	0.13	+
SERENE	11	5.0	0.38	0.25	0.30	0.03	
SHOECRAFT	12	4.5	0.61	0.05	0.89	0.00	
SPRING	6	2.2	0.21	-0.40	0.47	-0.05	
STEVENS	12	5.7	0.70	-0.35	0.13	-0.11	
STICKNEY	10	2.9	0.46	0.49	0.07	0.12	+
STORM	11	2.7	0.24	0.45	0.05	0.03	+
SUNDAY	13	1.9	0.71	-0.32	0.14	-0.09	
WAGNER	10	3.9	0.48	0.27	0.38	0.10	

Note -- Shaded rows identify lakes with statistically significant trends in water clarity at $p \leq 0.10$.
+ denotes lakes with apparent trends toward increasing water clarity
-- denotes lakes with apparent trends toward decreasing water clarity

♦ Trends—One of the main goals of the Snohomish County Lake Management Program is to identify long-term changes or trends in the water quality of individual lakes. Recognizing trends (especially trends toward poorer water quality or impaired beneficial uses) can alert citizens and government agencies to future problems while there is still time to address the causes and to prevent or mitigate such problems.

However, identifying trends accurately requires reliable data over a number of years. This is one reason that lake monitoring data become more and more valuable with each additional year of monitoring. Only recently has there been a long enough monitoring record to statistically evaluate water clarity trends at individual Snohomish County lakes.

Table 5 contains the results of one statistical analysis of water clarity trends in the monitored lakes. Kendall's tau is a statistic that describes the correlation between two variables—in this case summertime water clarity averages and time. If the water clarity average for a particular lake increased every single year (in other words, if the two variables were perfectly concordant), then Kendall's tau would be 1.0. If clarity decreased every year, tau would be -1.0. If there were no changes in clarity or only random changes from year to year, then tau would be 0. Kendall's tau can be thought of as the degree of consistency in the data to follow a trend toward either a positive or negative direction. The p-value that accompanies each tau indicates the significance of the trend in that direction—the smaller the p-value the more significant the trend. In this report, a p-value less than or equal to 0.10 means that the trend is considered statistically significant and that there is a higher likelihood that the water clarity in the lake really is increasing or decreasing over time. The slopes associated with the taus show how sharply the average water clarity values are increasing or decreasing over time.

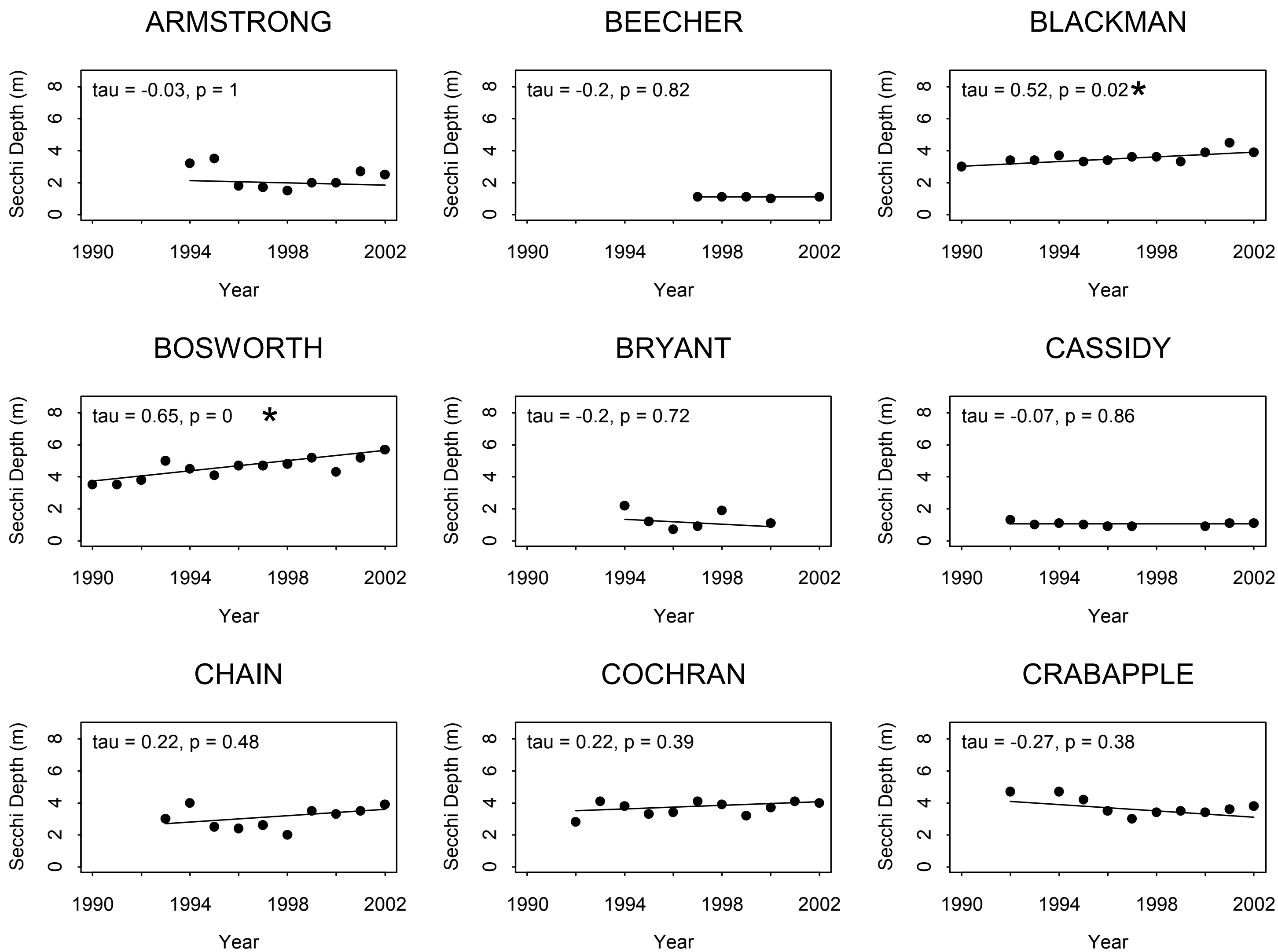
Figure 8 presents simple graphs of the Kendall's tau trend analysis for each monitored lake. The graphs show data points for summer water clarity averages from 1990 through 2002, together with the apparent trend lines.

The trend analyses in Table 5 and Figure 8 reveal that water clarity in most monitored lakes does not show a significant trend either way. This confirms the observation that there is substantial variability in water clarity from year to year in most lakes. Several lakes (shaded in Table 5) do show trends, however.

On the positive side, Blackman, Bosworth, Echo, Flowing, Lost, Roesiger N., Rowland, Ruggs, Stickney, and Storm show significant trends ($p \leq 0.10$) toward increased water clarity. The increases are modest, and the possible causes are unknown, but improvements in water clarity appear to be occurring. It is also unknown if the improved water clarities are within the natural ranges of variation for these lakes over several decades. Also, the general improvement in water clarity for more than 75% of the monitored lakes in 2001 and 2002 as a result of climatic or other factors may be a major reason for these positive trends. However, Secchi depth measurements from the early 1970s do suggest that water clarity in Echo, Flowing, Roesiger N., Stickney, and Storm lakes is better in recent years than in the past. So, at least for these lakes, it appears that water clarity is really improving.

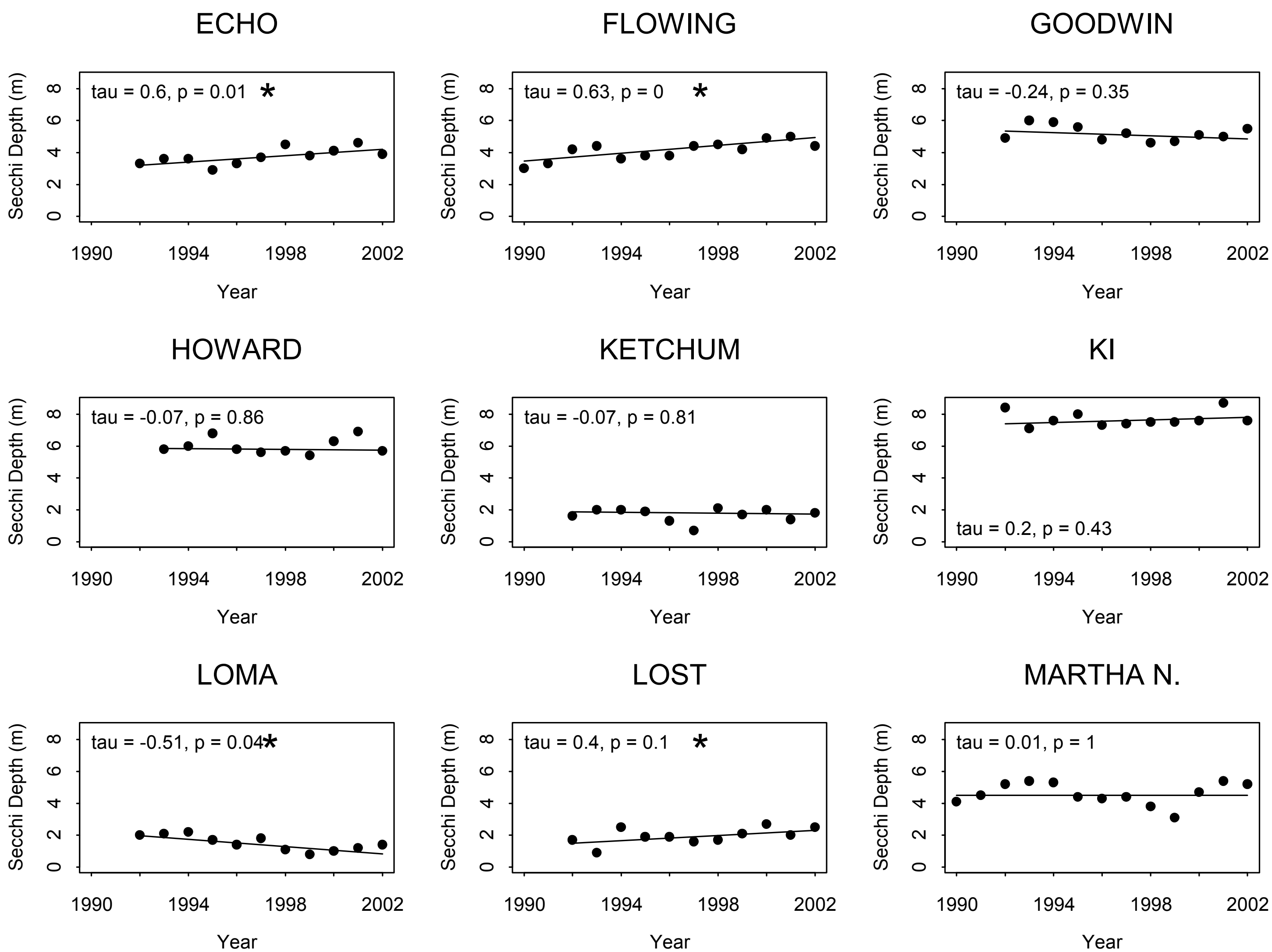
In contrast, the trend analyses for Loma and Nina suggest that water clarity is declining in these lakes. In addition, the p values indicate that Stevens and Sunday may be on the verge of significant declining trends in water clarity. It is possible that the declines in water clarity at these lakes are within the natural long-term variability of lake conditions. However, the wise course is for citizens and Snohomish County to take steps at these lakes to address the potential causes of declining water clarity.

FIGURE 8 -- TRENDS IN WATER CLARITY SUMMER AVERAGES 1990 – 2002



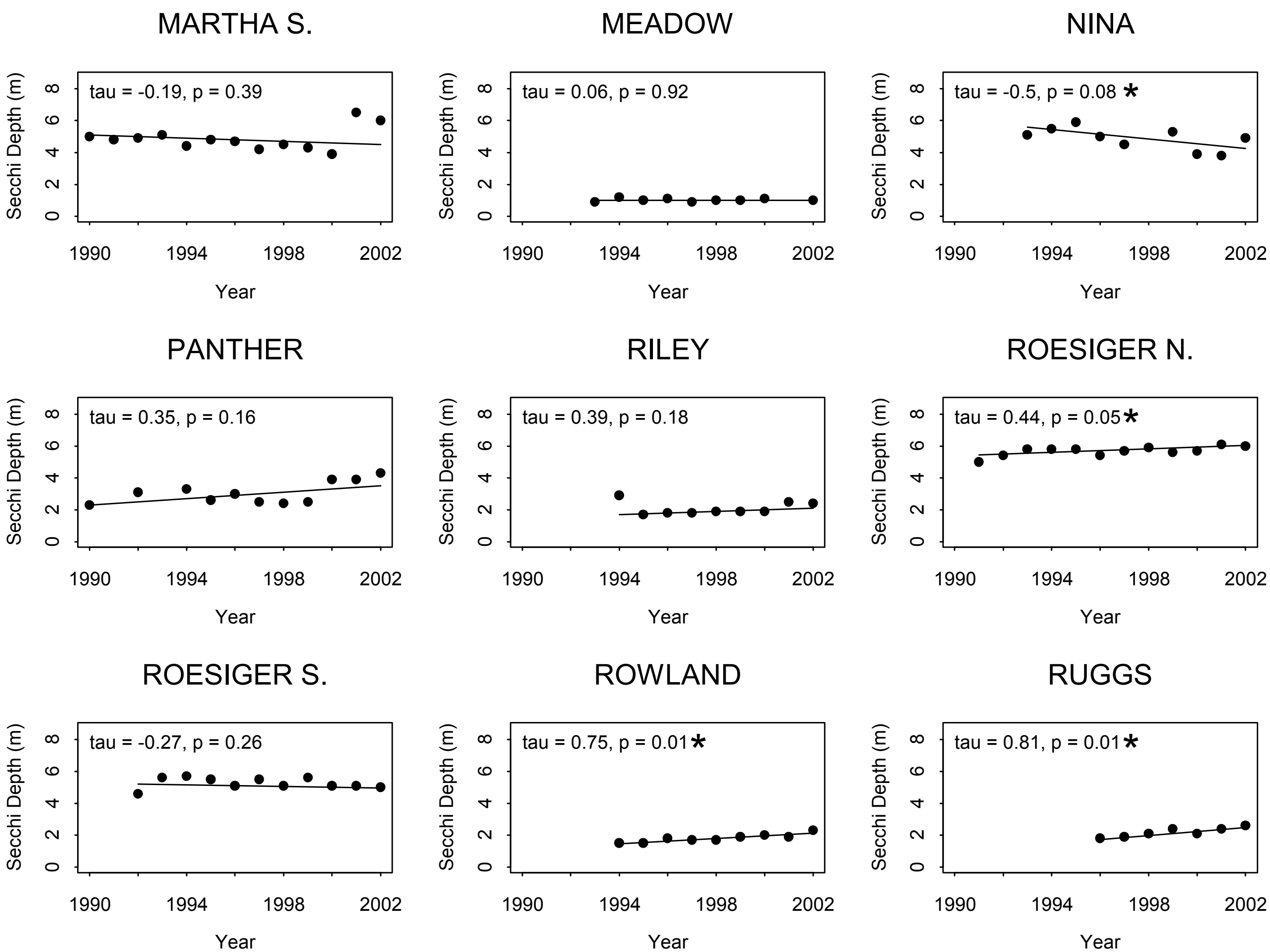
*Statistically significant trend ($p \leq 0.10$)

Figure 8 (continued)



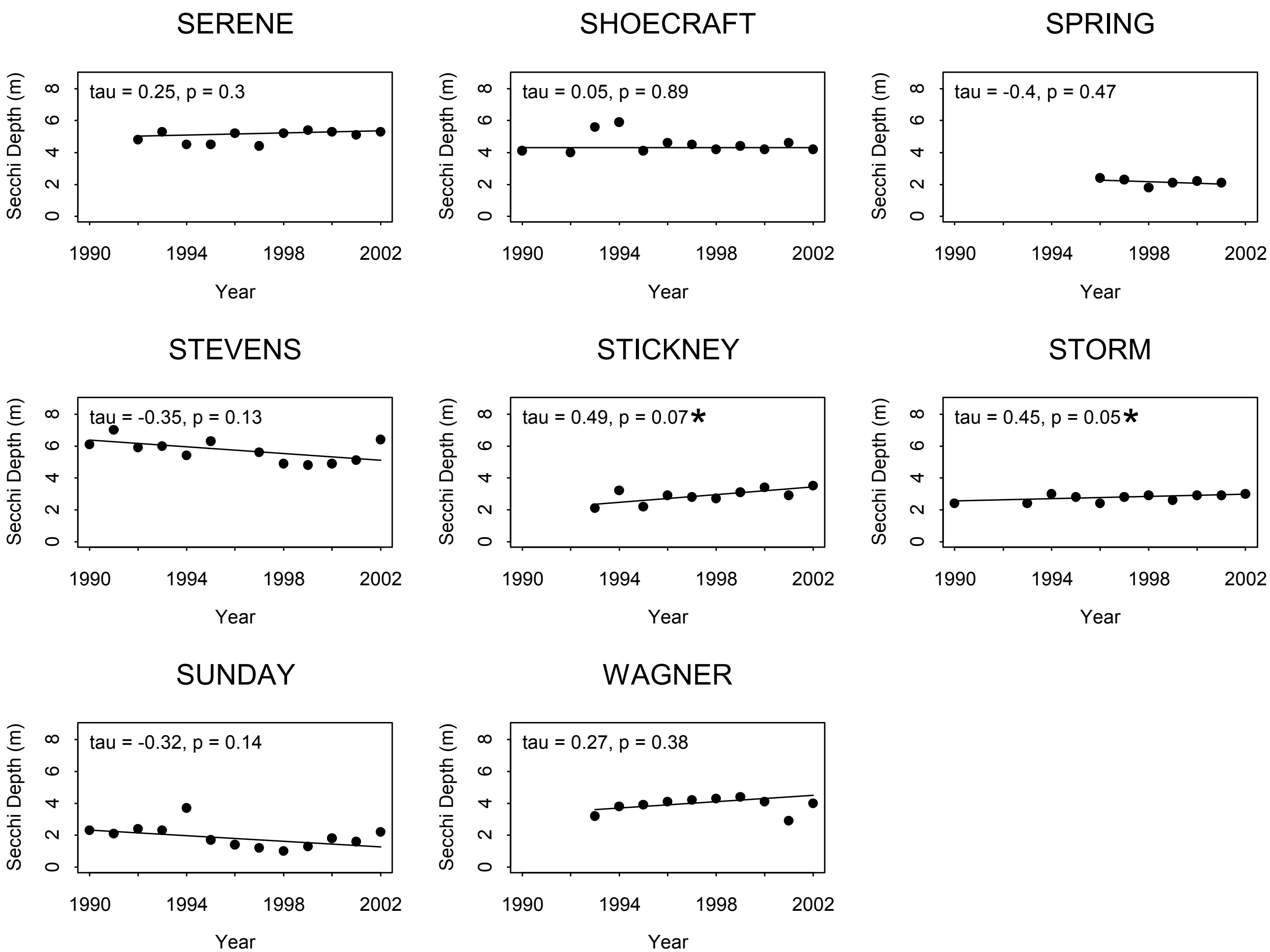
*Statistically significant trend (p ≤ 0.10)

Figure 8 (continued)



*Statistically significant trend ($p \leq 0.10$)

Figure 8 (continued)



*Statistically significant trend ($p \le 0.10$)

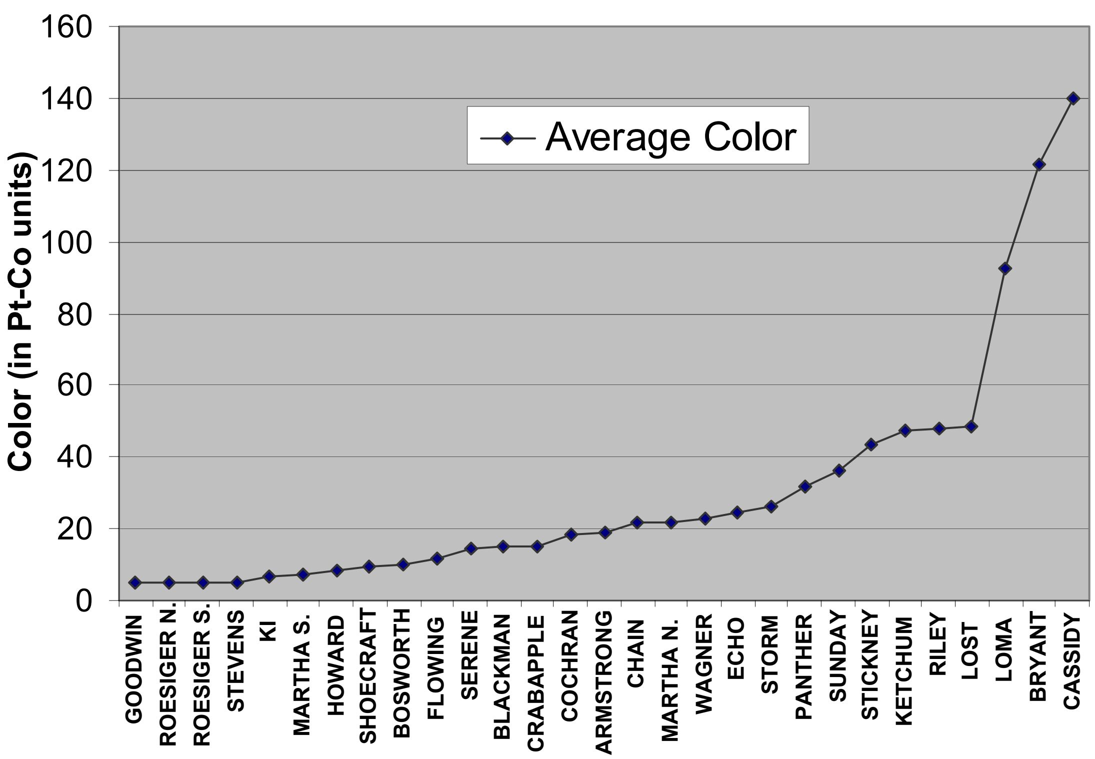
Comparison of Water Color

One of the factors affecting water clarity is the natural color of the water. Usually this color is the result of tannins absorbed in the water from humic organic matter that leaches into a lake from surrounding bogs and wetlands and from the lake sediments. This humic color—which ranges from yellow to dark brown—reduces water clarity but does not impair water quality. However, the reduced light that penetrates colored water can restrict algal and plant growth.

One or more measurements of water color (in units of platinum-cobalt) are available for most lakes during at least three years between 1973 and 1995. Although color varies somewhat from year to year in response to the amount of rainfall and runoff, these data provide a general comparison of natural water color in Snohomish County lakes. Figure 9 plots the overall average of the yearly averages of color measurements for each lake.

Clearly, Loma, Bryant, and Cassidy have the most darkly colored water. Panther, Sunday, Stickney, Ketchum, Riley, and Lost also have relatively dark water. Several other lakes, such as Meadow, Beecher, and Rowland, also have colored water, but no measurements are available for them. The dark water reduces the clarity in all these lakes somewhat and, combined with steep lake shores, significantly restricts the available habitat for aquatic plants in Bryant, Lost, Panther, and Riley. However, many of the darkly colored lakes still experience vigorous algal blooms. So, although the dark water color reduces the light available for algal growth, it appears that light is not the main factor limiting algae in these nutrient-rich lakes.

FIGURE 9. LAKE WATER COLOR



Total Phosphorus Comparisons and Trends

Another important indicator of lake conditions is the concentration of nutrients present in the water. Phosphorus is typically the nutrient that limits the growth of algae in Snohomish County lakes because it is the nutrient in shortest supply. For this reason, measurements of phosphorus concentrations can be used to predict the potential for algal production in a lake, as well as the overall trophic state. However, algal growth does not always correlate directly with phosphorus concentrations in the lake because other factors can also control algal production. Other factors include the amount of sunlight, the availability of nitrogen and other nutrients, and grazing by zooplankton. In addition, some forms of phosphorus are not readily available for use by algae, so measurements of total phosphorus may not accurately predict the level of algal production. Nevertheless, measuring total phosphorus in a lake is an important indicator of lake productivity.

The lake monitoring program sampled lakes for total phosphorus concentrations each summer from 1996 through 2002, usually once per month. Discrete samples were collected at a depth of one meter for the epilimnion and at approximately one to two meters above the bottom for the hypolimnion. (Because of budget limitations, the program has not sampled other useful nutrient parameters, such as soluble reactive phosphorus and the various forms of nitrogen.)

Several lakes also have a limited record of total phosphorus measurements from the 1980s and 1990s taken by other agencies. However, most of these measurements are from composite samples combining water from multiple depths within the epilimnion or hypolimnion. These composite sampling results are not included in the following analyses (except in the case of Lake Roesiger) because composite samples cannot be directly compared to Snohomish County's 1996-2002 discrete samples.

♦ Yearly Averages—Figure 10 shows the range of summertime (June through September) averages of total phosphorus concentrations in the epilimnion of the monitored lakes from 1996 through 2002. The graph also shows the long-term average of the summer averages for each lake over the monitoring period. Figure 11 shows the range of total phosphorus summer averages and the long-term average for the hypolimnion of the monitored lakes. In both graphs the lakes are arranged in order from high total phosphorus concentrations to low concentrations. Table 6 lists the summer total phosphorus epilimnion and hypolimnion averages for each lake by year.

(Please note that the scales for total phosphorus in Figure 10 and Figure 11 are logarithmic to accommodate the wide range of values among lakes. Therefore, a small vertical difference may represent a large difference in values in the upper portions of the graphs. For example, the total phosphorus epilimnion averages for Lake Ki range from 3 µg/l to 12 µg/l with a long term average of 7 µg/l, while Lake Ketchum averages range from 209 µg/l to 484 µg/l with a long term average of 299 µg/l.)

Figure 10 and Table 6 reveal that Ketchum, Beecher, Meadow, and Sunday have high concentrations of total phosphorus in the epilimnion, while Lake Roesiger, Lake Ki, and several other lakes have total phosphorus concentrations consistently within the oligotrophic range. Figure 11 shows that Ketchum, Sunday, Armstrong, Blackman, Howard, and Rowland have high average total phosphorus concentrations in the hypolimnion during the summer. Moreover, Armstrong, Blackman, Howard, Ketchum, Lost, Martha N., and Stickney experience substantially higher total phosphorus concentrations in the hypolimnion than in the epilimnion.

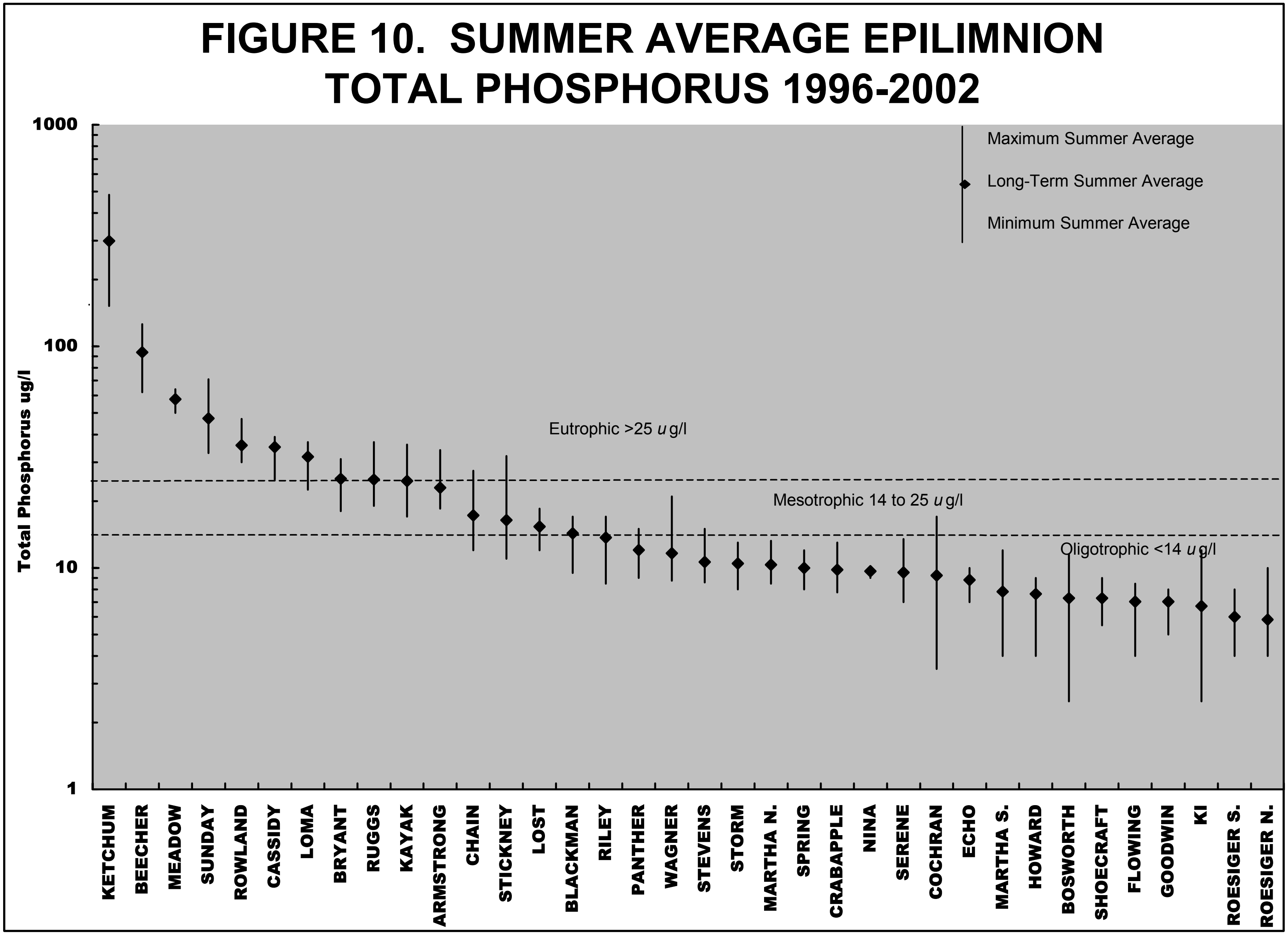


FIGURE 10. SUMMER AVERAGE EPILIMNION
TOTAL PHOSPHORUS 1996-2002
Total Phosphorus ug/l
1000
100
10
1
Maximum Summer Average
Long-Term Summer Average
Minimum Summer Average
Eutrophic >25 ug/l
Mesotrophic 14 to 25 ug/l
Oligotrophic <14 ug/l
KETCHUM
BEECHER
MEADOW
SUNDAY
ROWLAND
CASSIDY
LOMA
BRYANT
RUGGS
KAYAK
ARMSTRONG
CHAIN
STICKNEY
LOST
BLACKMAN
RILEY
PANTHER
WAGNER
STEVENS
STORM
MARTHA N.
SPRING
CRABAPPLE
NINA
SERENE
COCHRAN
ECHO
MARTHA S.
HOWARD
BOSWORTH
SHOECRAFT
FLOWING
GOODWIN
KI
ROESIGER S.
ROESIGER N.

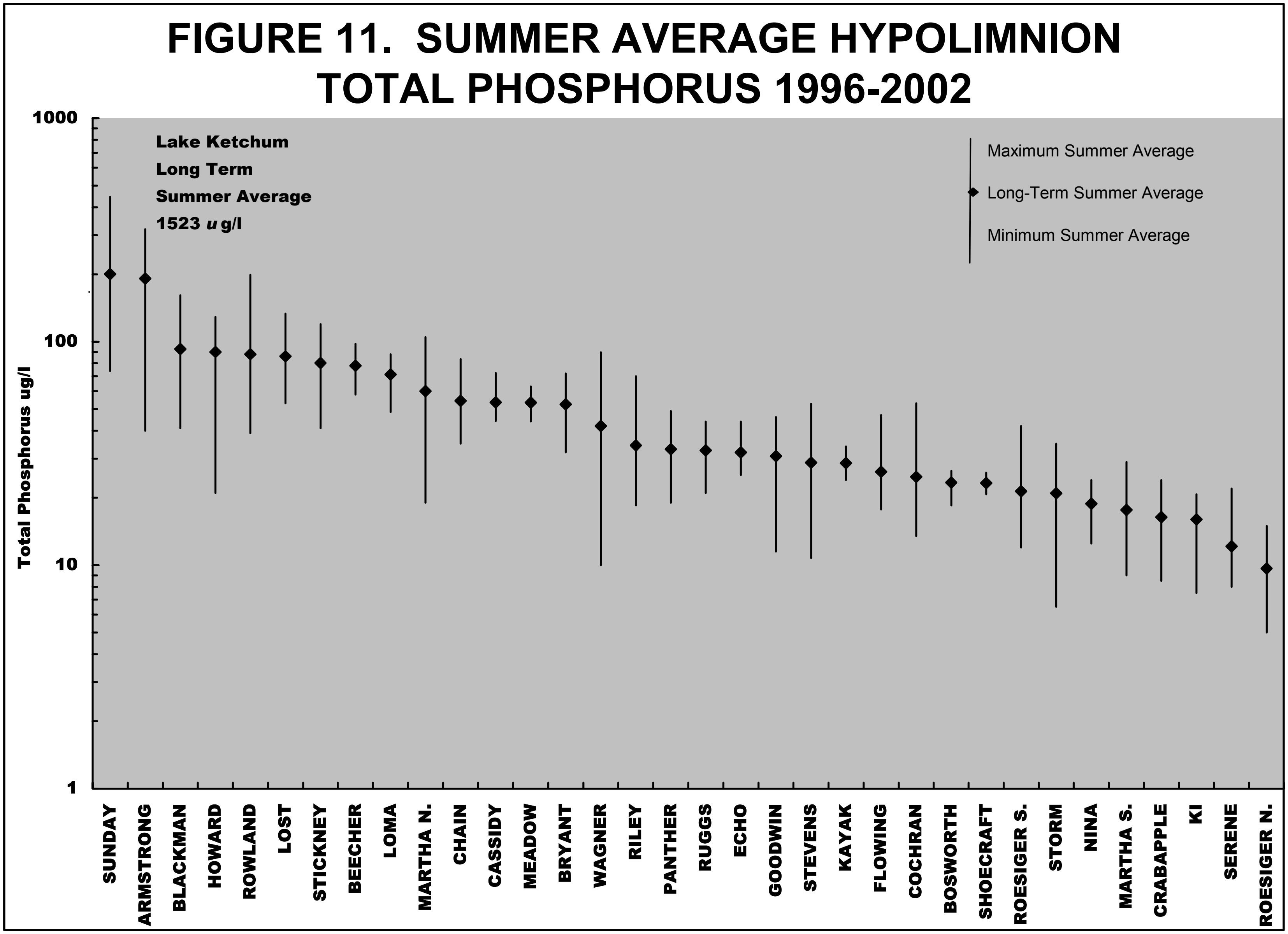


FIGURE 11. SUMMER AVERAGE HYPOLIMNION TOTAL PHOSPHORUS 1996-2002
Total Phosphorus ug/l
1000
100
10
1
Lake Ketchum
Long Term
Summer Average
1523 u g/l
Maximum Summer Average
Long-Term Summer Average
Minimum Summer Average
SUNDAY
ARMSTRONG
BLACKMAN
HOWARD
ROWLAND
LOST
STICKNEY
BEECHER
LOMA
MARTHA N.
CHAIN
CASSIDY
MEADOW
BRYANT
WAGNER
RILEY
PANTHER
RUGGS
ECHO
GOODWIN
STEVENS
KAYAK
FLOWING
COCHRAN
BOSWORTH
SHOECRAFT
ROESIGER S.
STORM
NINA
MARTHA S.
CRABAPPLE
KI
SERENE
ROESIGER N.

Elevated total phosphorus concentrations in the deepest part of the hypolimnion may be caused by the settling of organic and other matter down toward the lake bottom, as well as by the release of phosphorus from the sediments which can occur in the absence of oxygen. Typically, phosphorus concentrations in the hypolimnion build up as the summer progresses due to these processes. However, high concentrations of phosphorus near the bottom in these lakes do not necessarily mean that the nutrients will become available for algal growth in the upper waters. The phosphorus has to be moved upward by mixing, uptake by blue-green algae, or diffusion. Additional monitoring and nutrient loading analyses would be necessary to identify the actual impacts of hypolimnetic phosphorus build-up in each lake. Nevertheless, these elevated hypolimnion phosphorus concentrations serve as warning signs indicating the potential for excess nutrients to fuel algal growth, especially in late summer or after fall turnover.

♦ Year-to-Year Variability—As stated above, total phosphorus concentrations can vary from month to month within a particular summer, especially in the hypolimnion. Table 6 shows that average total phosphorus concentrations in some lakes also varied significantly from year to year. (Caution should be used in interpreting year to year changes because 1996 and 1997 total phosphorus averages for most lakes are based on only two summer samples.) Ketchum and Sunday had the most year-to-year variation in average summer epilimnion total phosphorus, while Armstrong, Blackman, Howard, Ketchum, Lost, Sunday, and Wagner had substantial variation in hypolimnion phosphorus averages. In addition, Armstrong, Cochran, and Martha S. had at least one individual measurement of total phosphorus that was markedly higher than their typical values.

Looking at all lakes together, total phosphorus summer averages were generally lower in 1996 in both the epilimnion and hypolimnion. In contrast, most lakes had higher summer averages in 2001 in the epilimnion and hypolimnion. Possible explanations for this group variability include the influence of rainfall and runoff patterns (bringing more or less nutrients into the lakes) and temperature and sunlight patterns (affecting the amount of algal production and organic decomposition in the lakes). However, no clear relationships are apparent. More likely, the monitoring records are too short to account for the natural variability of nutrient levels in many lakes.

♦ Trends—In general, the periods of record for total phosphorus data are not long enough to establish or refute the existence of trends in most lakes. However, using Kendall's tau analysis, several lakes do show statistically significant trends toward increasing or decreasing total phosphorus concentrations. Sunday Lake appears to exhibit decreasing total phosphorus levels in the epilimnion (but not in the hypolimnion) between 1996 and 2002. In Lake Martha (N.), hypolimnion total phosphorus concentrations appear to be increasing, but no such trend is evident in the epilimnion. At Lake Ketchum, total phosphorus levels in both the epilimnion and hypolimnion appear to be declining (although less surely in the epilimnion). It is probable that reduced pollution from a former dairy farm accounts for the declining (but still very high) nutrient levels in Lake Ketchum. Reasons for possible trends at the other lakes are unknown. More years of data will be necessary to accurately analyze total phosphorus trends.

TABLE 6 TOTAL PHOSPHORUS SUMMER AVERAGES 1996—2002																
	Epilimnion								**Hypolimnion**							
LAKE	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**1996-2002 Average**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**1996-2002 Average**
ARMSTRONG	19	34	22*	24	22	20	20	23	40	118	319	278	192	157	237	192
BEECHER		126					62	94		58					98	78
BLACKMAN	10	17	13	12	15	17	17	14	97	162	43	91	129	87	41	93
BOSWORTH	3	12	6	7	9	8	7	7	25	27	24	19	27	20	24	23
BRYANT	30	31	18		22			25	63	72	43		32			53
CASSIDY	38	25		35	39	41	37	36	73	44	51			47	53	54
CHAIN	12	28	17	18	16	16	14	17	84	35	38	64	57	59	45	54
COCHRAN	4	9	7	17*	12	8	9	9	18	14	31	21	16	53	21	25
CRABAPPLE	11	9	8	9	10	13	9	10	9	16	16	14	18	24	20	16
ECHO	8	10	10	9	7	10	9	9	38	44	27	25	26	36	27	32
FLOWING	4	9	7	8	6	8	8	7	23	28	18	24	18	47	26	26
GOODWIN	8	8	7	8	5	7	7	7	12	30	28	36	29	46	36	31
HOWARD	4	8	8	9	8	9	8	8	99	94	129	126	104	57	21	90
KAYAK				21	36		17	25				24	34		28	29
KETCHUM	428	216	484	274	209	332	152	299	1875	1760	1968	1460	1157	1285	1155	1523
KI	3	8	5	5	6	12	9	7	8	17	20	21	18	13	17	16
LOMA	33	23	35	32	29	35	37	32	49	64	74	72	74	88	78	71
LOST	16	16	15	19	12	17	14	15	66	75	134	61	123	92	53	86
MARTHA N.	9	10	12	13	10	9	10	10	19	45	65	51	53	84	105	60
MARTHA S.	4	9	6	9	8	12	7	8	9	13	20	18	29*	18	18	18
MEADOW		64		59			50	58		53		44			63	53
NINA	9			10			10	10	20			13			24	19
PANTHER	9	15	13	13	9	15	11	12	19	36	49	42	24	32	30	33
RILEY	9	15	12	17	16	17	11	14	19	26	22	27	21	70	57	34
ROESIGER N.	4	5	6	6	10		5	6	14	15	6	8	10		5	10
ROESIGER S.	4	4		7	7		8	6	42	21		16	16		12	21
ROWLAND			47		30	35	31	36			61		39	53	199	88
RUGGS				19		19	37	25				44		21	33	33
SERENE	7	10	9	14	7	12	9	10	8	22	15	9	8	11	12	12
SHOECRAFT	6	7	7	8	6	9	9	7	24	26	21	25	21	21	26	23
SPRING			12		8			10								
STEVENS		8.6	8.6	11	10	15		11		52	53	11	15	14		29
STICKNEY	12	32	15	13	11	17	15	16	72	74	65	93	97	120	41	80
STORM	10	12	11	12	8	13	8	10	7	35	24	19	18	29	16	21
SUNDAY	71	61	40	49	42	36	33	47	331	74	195	175	89	445	96	201
WAGNER	9	9	9	9	12	21	13	12	10	21	38	90	16	74	45	42

NOTES: Values are from total phosphorus samples taken at discrete depths, except for Roesiger N. and S. which are a mix of discrete and composite samples.
* For values marked with asterisk, median is shown rather than the average (mean) to avoid bias from one extremely high individual measurement.

Comparison of Algae

Microscopic floating algae (phytoplankton) play an important role in the ecology of a lake. Zooplankton and fish depend on algae for food. However, when algal growth becomes excessive, it can interfere with use and enjoyment of a lake and threaten the health of a lake.

The data on algae types and abundance are limited for Snohomish County lakes. In most cases, the data come from the summer season only. This means that certain types of algae that are more prevalent in other seasons were missed. Also, algal blooms can come and go quickly, so the data likely missed significant episodes of algal growth during the summer. Nevertheless, a comparison of the available information does help paint a picture of the relative impacts of algae in Snohomish County lakes.

The primary measure of algal productivity is chlorophyll *a*, the active green pigment used for photosynthesis in algae. Lakes with average chlorophyll *a* levels greater than 8.7 µg/l may be considered eutrophic. Chlorophyll *a* levels less than 2.8 µg/l are usually associated with oligotrophic lakes. Mesotrophic lakes generally have average chlorophyll a levels between 2.8 and 8.7 µg/l.

As expected, in Snohomish County the shallow eutrophic lakes with high nutrient concentrations produce the highest levels of algae. Lake Cassidy (with chlorophyll *a* values up to 90 µg/l), Ketchum (up to 139 µg/l), Loma (up to 70 µg/l), and Sunday (up to 120 µg/l) consistently display the highest levels of algae. Other lakes, such as Blackman, Chain, and Stevens, also regularly have severe algal blooms. Even lakes with low nutrient levels—Goodwin, Roesiger, and Shoecraft—produce occasional widespread algal blooms.

Blue-green algae (more properly called Cyanobacteria) cause the majority of surface scums and odor problems affecting lakes. Analysis of limited algal samples from each lake in the summers of 1994 and 1995 revealed that Cassidy, Chain, Cochran, Ketchum and Lost had the highest numbers of blue-green algae cells, while the same lakes, except for Cochran, also had the highest volumes of blue-greens.

Occasionally, certain blue-green algae can also produce very poisonous toxins. These toxins can be harmful or, under certain conditions, deadly to animals or humans who drink the water. The reasons and conditions under which blue-greens produce toxins are poorly understood, but toxins usually appear only during severe algal blooms. During the summer of 2000, a toxic algal bloom was identified in Lake Ketchum. Information signs were posted, and no illnesses were reported. Toxic blooms have not been identified at any other Snohomish County lake. However, toxins could have been present at times but not sampled. Observation and identification of toxic algal blooms is one objective of the SWM lake monitoring program.

Comparison of Aquatic Vegetation

Aquatic plants growing within and immediately adjacent to a lake are key components of a healthy lake ecosystem. These plants provide habitat for fish and other aquatic life and help stabilize the shorelines. The diversity, distribution, and density of aquatic plants can also indicate the productivity and trophic status of a lake, as well as provide clues about lake health.

Table 7 lists the main aquatic plant species found in the monitored lakes of Snohomish County. The table is divided into the four major types of aquatic plants—rooted floating-leafed plants, free floating plants, submersed (underwater) plants, and emergent plants. Plants listed in the table were identified by SWM or Washington State Department of Ecology staff during reconnaissance shoreline and boat surveys.

The densities and species composition of aquatic plant communities in lakes can vary significantly from year to year. For this reason, there may be additional plant species actually present in some lakes that are not included in Table 7 if the species were not encountered during the vegetation surveys. In addition, certain plants found around some lakes, such as willows, douglas' spiraea, and reed canary grass are not included because they usually grow elsewhere than lakes. Please refer to the individual lake reports for maps showing the general locations and densities of aquatic plants in particular lakes.

♦ Distribution and Diversity—Table 7 shows that *Nuphar polysepalum* (Yellow water-lily), *Elodea canadensis* (Common elodea), and several *Potamogeton* spp. (Thin-leaf pondweeds) are the most widely distributed aquatic plants in the monitored lakes. These species are found in almost every lake and are the dominant plants in most lakes. In contrast, several species, such as *Azolla mexicana* (Mexican water-fern) have been observed in only one lake.

The lakes which support the widest variety of aquatic plant species are Ketchum, Loma, Serene, Stevens, Stickney, and Sunday. Most of these lakes are shallow, which provides large areas for aquatic plant growth. Lake Stevens likely supports a diversity of plants because, despite its great depth, the lake's large size also provides abundant shallow water areas that are suitable for plant growth.

Armstrong, Crabapple, Lost, and Storm are the lakes with the least diversity, especially of plants that grow completely in the water. These lakes all have steep shorelines combined with somewhat colored water which limits the available habitat for aquatic plants to a narrow zone around the shoreline.

♦ Density—The aquatic plant surveys did not include quantitative measurements of plant biomass. However, the surveys were thorough enough to provide a reliable estimate of the relative density of aquatic plants in the monitored lakes. The surveys revealed that Blackman, Cassidy, Chain, Ketchum, Loma, Serene, Stickney, and Sunday lakes contain high densities of aquatic plants. In addition, more limited surveys of Meadow, Rowland, and Ruggs showed high plant densities. In general, these lakes are shallow, have large areas available for plant growth, and have enriched bottom sediments.

In contrast, Armstrong, Bosworth, Bryant, Ki, Lost, and Storm lakes do not support dense growths of aquatic plants, except for a few small patches. Plant densities appear to be limited by dark color (Armstrong, Bryant, and Lost) or lack of nutrient rich sediments (Bosworth, Ki, and Storm). Many of these lakes also have very steep shorelines which restrict the zone available for plant growth.

♦ Non-native Invasive Plants—Several exotic (or non-native) aquatic plants have invaded Snohomish County lakes. *Myriophyllum spicatum* (Eurasian watermilfoil), *Myriophyllum aquaticum* (Parrotfeather), *Lythrum salicaria* (Purple loosestrife), and *Egeria densa* (Brazilian elodea) are particularly aggressive weeds that are on the Washington State Noxious Weed list. The plants are classified as Class B; in Snohomish County the Weed Board requires that these plants be controlled. *Nymphaea odorata* (Fragrant water-lily) and *Iris pseudacorus* (Yellow iris) are ornamental non-native plants that are widespread in many lakes. *Iris pseudacorus* (Yellow iris) is a Class C noxious weed (control not required).

Eurasian watermilfoil, the most notorious of the exotic aquatic plants, has been found in Goodwin, Roesiger, and Shoecraft lakes during the 1990s. SWM is working with local citizens and the State to control milfoil at these sites. Parrotfeather has been discovered and controlled in two sites in Nina Lake. Brazilian elodea is growing in Swartz Lake, near Granite Falls. Meadow Lake is infested with *Hydrocharis morsus-ranae* (European frog-bit), a non-native plant that is on the State Noxious Weed Board's quarantine list to prohibit its sale, transport, or planting. European frog-bit has caused serious problems in other parts of North America.

TABLE 7. AQUATIC PLANTS FOUND IN SNOHOMISH COUNTY LAKES

	Floating Leaf			Free Floating									Submersed									
LAKE NAME / **PLANT NAMES**	*Brasenia schreberi* (Watershield)	*Nuphar polysepalum* (Yellow water-lily)	# *Nymphaea odorata* (Fragrant water-lily)	*Azolla mexicana* (Mexican water-fern)	# *Hydrocharis morsus-ranae (European Frog-bit)*	*Hydrocotyle ranunculoides* (Floating pennywort)	*Lemna minor* (Duckweed)	*Ricciocarpus natans* (Purple-fringed riccia)	*Spirodela polyrhiza* (Greater duckweed)	*Wolffia spp.* (Watermeal)	*Ceratophyllum demersum* (Coontail)[1]	*Utricularia vulgaris* (Common bladderwort)[1]	*Chara* sp. (Stonewort, Muskgrass)	*Eleocharis* sp. (Spikerush)	*Elodea canadensis* (Common elodea)	*Fontinalis* sp. (Water moss)	*Isoetes* sp. (Quillwort)	*Myriophyllum hippuroides* (Native watermilfoil)	# *Myriophyllum spicatum* (Eurasian watermilfoil)	*Najas flexilis* (Naiad)	*Nitella* sp. (Brittlewort)	*Potamogeton amplifolius* (Large-leaf pondweed)
ARMSTRONG		X										X										
BEECHER																						
BLACKMAN		X	X								X				X					X	X	X
BOSWORTH		X	X												X							X
BRYANT		X					X						X									
CASSIDY		X									X	X			X						X	
CHAIN		X					X				X				X						X	X
COCHRAN	X	X	X												X							
CRABAPPLE		X	X												X						X	
ECHO	X	X											X	X	X							
FLOWING		X	X												X						X	X
GOODWIN													X						X	X	X	X
HOWARD		X	X										X	X	X							X
KETCHUM		X	X	X			X	X		X	X				X						X	X
KI		X	X										X	X	X							
LOMA		X	X								X	X				X		X				
LOST	X	X	X																			X
MARTHA N.		X	X										X	X	X							
MARTHA S.		X	X									X	X		X					X	X	
MEADOW		X			X		X		X													
NINA						X			X													
PANTHER		X	X									X			X						X	X
RILEY	X	X										X			X			X			X	
ROESIGER		X	X									X			X		X		X		X	
ROWLAND		X																				X
RUGGS		X	X								X	X			X					X		X
SERENE		X	X								X	X	X		X						X	X
SHOECRAFT		X	X										X		X				X	X		X
SPRING	X	X																				X
STEVENS	X	X	X										X		X					X	X	
STICKNEY		X	X								X	X	X		X	X					X	
STORM		X																				
SUNDAY	X	X	X				X			X	X	X	X		X						X	X
WAGNER		X									X	X	X		X						X	

Note: Common wetland species found around many lakes, such as *Carex* spp. (Sedges), *Juncus* spp. (Rushes), *Salix* spp. (Willows), *Spiraea douglasii* (Spiraea), and *Phalaris arundinacea* (Reed canary grass), are not included in table.

-- These species are noxious, non-native, invasive aquatic plants.

TABLE 7 (CONTINUED)

Submersed (continued)									Emergent													
Potamogeton epihydrus (Ribbon-leaf pondweed)	*Potamogeton gramineus* (Grassy pondweed)	*Potamogeton praelongus* (White-stalked pondweed)	*Potamogeton* spp. (Thin-leaf pondweeds)[2]	*Sagittaria graminea* (Slender arrowhead)	*Sagittaria subulata* v. *gracillima* (Awl-leaf arrowhead)	*Scirpus subterminalis* (Water bulrush)	*Vallisneria americana* (Tapegrass)	# *Myriophyllum aquaticum* (Parrotfeather)[1]	*Dulichium arundinaceum* (Three-way sedge)	*Equisetum fluviatile* (Water horsetail)	# *Iris pseudacorus* (Yellow iris or water-flag)	*Ludwigia palustris* (False loosestrife)	# *Lythrum salicaria* (Purple loosestrife)	*Menyanthes trifoliata* (Bog bean)	*Polygonum amphibium* (Water smartweed)	*Potentilla palustris* (Marsh cinquefoil)	*Sagittaria latifolia* (Broad-leaf arrowhead)	*Scirpus* spp. (Bulrushes)	*Sparganium* sp. (Bur-reed)	*Typha* spp. (Cattails)	*Veronica americana* (American speedwell)	**PLANT NAMES** / **LAKE NAME**
			X																			ARMSTRONG
																						BEECHER
			X										X									BLACKMAN
			X																			BOSWORTH
X			X																X			BRYANT
			X						X				X					X		X		CASSIDY
			X																			CHAIN
X			X							X				X						X		COCHRAN
																						CRABAPPLE
			X		X									X	X					X		ECHO
			X				X				X	X										FLOWING
			X																			GOODWIN
																						HOWARD
			X																	X	X	KETCHUM
			X				X															KI
			X	X		X									X							LOMA
																						LOST
			X								X					X				X		MARTHA N.
			X								X							X		X		MARTHA S.
X			X						X					X	X	X				X		MEADOW
								X												X		NINA
			X																	X		PANTHER
X			X						X					X								RILEY
X			X	X			X				X	X	X					X		X		ROESIGER
			X																	X		ROWLAND
																						RUGGS
			X	X									X									SERENE
			X								X							X				SHOECRAFT
			X												X	X						SPRING
	X		X		X						X		X									STEVENS
			X				X					X	X									STICKNEY
			X											X								STORM
			X													X		X		X		SUNDAY
		X	X									X					X					WAGNER

[1] Plant species listed between the shaded categories share the characteristics of the two adjacent categories.
[2] "*Potamogeton* spp. (Thin-leaf pondweed)" refers to one or more pondweed species with narrow leaves, including *P. pusillus, P. foliosus, P. pectinatus, and P. Berchtoldii*.

Comparison of Trophic States

The trophic state of a lake refers to its degree of biological productivity (primarily of aquatic plants and algae) resulting from nutrient and sediment enrichment. It is often useful to categorize lakes by their trophic states as a means of comparing conditions among lakes. Although trophic states are not value judgments, they can help in understanding when a lake is suffering from increased eutrophication.

Trophic states describe a continuum of conditions from oligotrophic (clear water with few plants and algae) to eutrophic (limited clarity with abundant plants and algae). Mesotrophic lakes fall between these extremes. The categories are not precise. Some lakes show characteristics of more than one category, so they may be placed between the three main categories.

The trophic state of a lake can be estimated in several ways. There are numeric indices based on water quality measurements that calculate the approximate trophic state, most notably the Trophic State Index of Carlson, 1977. Various scientists have also suggested threshold values for water clarity, total phosphorus, chlorophyll *a*, and other parameters that correspond to trophic states (see Table 1). Lake scientists also look at other variables, such as the density and types of aquatic plants and algae, oxygen depletion, and phosphorus build-up, to provide clues to the trophic state of a lake.

Table 8 lists the monitored lakes of Snohomish County by estimated trophic state. This categorization is based on threshold values for water clarity and total phosphorus, as well as best professional judgment using all the other information known about these lakes.

TABLE 8
ESTIMATED TROPHIC STATES OF SNOHOMISH COUNTY LAKES

Oligotrophic	Oligo-Mesotrophic	Mesotrophic	Meso-Eutrophic	Eutrophic
KI	BOSWORTH	BLACKMAN	ARMSTRONG	BEECHER
	FLOWING	COCHRAN	CHAIN	BRYANT
	GOODWIN	CRABAPPLE	KAYAK	CASSIDY
	NINA	ECHO	LOST	KETCHUM
	ROESIGER	HOWARD	RILEY	LOMA
	SHOECRAFT	MARTHA N.	STICKNEY	MEADOW
	STEVENS	MARTHA S.		ROWLAND
		PANTHER		RUGGS
		SERENE		SUNDAY
		SPRING		
		STORM		
		WAGNER		

Many of the lakes do not fit neatly into the trophic categories in this table because they exhibit characteristics of more than one category. For example, Lake Serene and Lake Wagner have high water clarity, which is a characteristic of oligotrophic lakes. But, they are also shallow lakes with abundant aquatic plants and occasional severe algal blooms, which is more typical of eutrophic lakes. The best overall description of these lakes is that they are mesotrophic. Likewise, Lake Roesiger has very high water clarity, but is classified as oligo-mesotrophic because of moderate algal growth and aquatic plants.

Lake Stevens is one lake that is classified in a more productive category than it would be without the impacts of human activity. Because of its great depth and small watershed, the lake should exhibit oligotrophic conditions. However, Lake Stevens experiences regular, severe algal blooms as a result of nutrients coming from the watershed and the lake sediments. For this reason, Lake Stevens is classified as oligo-mesotrophic rather than oligotrophic.

Summary of Lake Problems

A number of lakes currently have specific problems that may be early warning signs of future trouble. Table 9 lists the most severe problems identified by lake monitoring results and by lake users in recent years. Other lakes may also experience some of the same problems, but to a lesser degree.

TABLE 9. SUMMARY OF LAKE PROBLEMS	THE MOST AFFECTED LAKES
Declining Water Clarity Water clarity in the first two lakes showed a statistically significant decline during the period of 1992-2002. The other two lakes showed evidence of possible water clarity decreases. Continued declines in water clarity will harm public use and enjoyment of these lakes.	LOMA NINA STEVENS SUNDAY
Nuisance Algal Blooms These lakes experience regular algal blooms that are severe enough to interfere with human enjoyment of the lakes. In most cases, blue-green algae cause the nuisance conditions.	ARMSTRONG BLACKMAN CASSIDY HOWARD KETCHUM LOMA RUGGS STEVENS SUNDAY
Toxic Algal Blooms Occasionally, some blue-green algae produce toxins during bloom conditions. These toxins can be deadly to animals, and even people, should they drink the water. So far, toxic algae have been confirmed in only one lake during a single summer episode.	KETCHUM
Noxious Non-native Invasive Aquatic Plants Aggressive non-native aquatic plants have invaded these lakes. These plants displace native plants, interfere with boating, swimming, and fishing, and may harm wildlife.	Eurasian watermilfoil GOODWIN ROESIGER SHOECRAFT[1] Parrotfeather NINA Brazilian Elodea SWARTZ European Frog-bit MEADOW Purple Loosestrife BLACKMAN CASSIDY ROESIGER SERENE STEVENS STICKNEY

TABLE 9 (CONTINUED) SUMMARY OF LAKE PROBLEMS	THE MOST AFFECTED LAKES
Nuisance Levels of Native Aquatic Plants Native aquatic plants grow in such profusion in these lakes that they create nuisance conditions for boating, swimming, and fishing.	KETCHUM LOMA ROWLAND RUGGS SUNDAY
Severe Oxygen Depletion Oxygen loss in the bottom waters of these lakes during the summer is so severe that it threatens the survival of fish and other aquatic life in the lakes.[2]	CASSIDY KETCHUM LOMA LOST
Sedimentation (or Lake Filling) Sediment from runoff and dying aquatic vegetation is filling this lake to the point that boating, swimming, and fishing are threatened.	RUGGS
Lake Flooding The water level in these lakes rises high enough during the winter to cause damage to yards, septic systems, and homes.	CASSIDY CRABAPPLE
Nuisance Waterfowl Excess numbers of ducks and geese at these lakes are creating serious impacts. Waterfowl droppings leave a mess, contribute nutrients that feed algal growth, and cause bacterial pollution.	BLACKMAN ECHO LOMA MARTHA S. NINA SERENE STEVENS STICKNEY SUNDAY

[1] Eurasian watermilfoil has been eradicated in Lake Shoecraft; however, there is risk that the plants may re-infest the lake from nearby Lake Goodwin.

[2] Lake Stevens has an aeration system that prevents severe oxygen depletion in the hypolimnion.

Summary of Lake Conditions

One general conclusion that can be reached about the monitored lakes in Snohomish County is that the condition of most lakes is adequate to support public use and enjoyment of the lakes. In spite of rapid changes in lake watersheds around the county, many lakes remain healthy. In fact, several lakes show signs of improving water clarity.

However, lakes have a finite capacity to absorb impacts from human activity (and some lakes have less capacity than others). As nutrient runoff into lakes from fertilizers, failing septic systems, and impervious surfaces continues and surrounding development expands, problems may become noticeable in some lakes. In fact, several lakes already show signs of declining water quality.

Table 10 and the individual lake reports provide an overall assessment of the health of each monitored lake in Snohomish County. These assessments are subjective. They are based on the best judgments of SWM staff and regional lake scientists and on feedback from citizens. The assessments take into consideration such factors as recent trends in water clarity, the frequency of nuisance algal blooms, and the problems reported at a lake.

Lakes listed in "healthy" condition do not show signs of declining water clarity or nutrient build-up. The existing conditions in these lakes are more than adequate for recreation and other uses. These lakes "need protection" to maintain their existing water quality.

TABLE 10
SUMMARY OF LAKE CONDITIONS

Need Protection (Healthy)	**Need Improvement** (At Risk)	**Need Restoration** (Impaired)
BOSWORTH	ARMSTRONG	CASSIDY
BRYANT	BEECHER	KETCHUM
CHAIN	BLACKMAN	LOMA
COCHRAN	CRABAPPLE	RUGGS
FLOWING	ECHO	SUNDAY
GOODWIN	HOWARD	
KI	KAYAK	
PANTHER	LOST	
RILEY	MARTHA N.	
ROESIGER	MARTHA S.	
SHOECRAFT	MEADOW	
STORM	NINA	
WAGNER	ROWLAND	
	SERENE	
	SPRING	
	STEVENS	
	STICKNEY	

Lakes listed as "need improvement (at risk)" either show signs that water quality is beginning to decline or suffer from at least one important problem, such as excess nutrients, severe oxygen depletion, nuisance algal blooms, excess aquatic plants, or overabundant waterfowl. Unless improvements are made in one or more areas, future use and enjoyment of these lakes may be threatened.

The lakes listed as "need restoration (impaired)" suffer from at least two serious problems that are currently affecting the use and enjoyment of the lakes. Although these lakes are still healthy enough to provide many benefits to local residents and other lake users, they need restoration to return to a healthier condition. Restoration will insure the full benefits of these lakes for the people of Snohomish County.

These assessments of lake conditions are not to be confused with trophic states, which are measures of nutrient enrichment and biological productivity. A lake can be mesotrophic in terms of trophic state and still be assessed as "needing restoration" if it has much lower water clarity and higher nutrient levels than it should have naturally. Conversely, a eutrophic lake might be in healthy condition if it does not show signs of increasing algal blooms or nutrient build-up or some other serious problem.

It should also be noted that the assessments of lake conditions in this report are different from designations in the official Washington State 303(d) list. To comply with the federal Clean Water Act, every two years the State prepares a formal list of all the streams, rivers, estuaries, and lakes that do not meet State surface water quality standards. This 303(d) list indicates which specific pollutants impair or threaten the beneficial uses of these water bodies. The most recent 303(d) list includes several Snohomish County lakes. Ketchum, Martha Lake (S.), and Stevens lakes are listed for impacts from total phosphorus. Blackman is listed for total phosphorus and fecal coliform bacteria, while Sunday is listed for total phosphorus and total nitrogen.

The purpose of the lake conditions summary in this report is to provide a simple, balanced overall assessment of the health of individual lakes and of lowland Snohomish County lakes in general. Residents, lake users, and public agencies can use this summary to help set targets for lake health and identify steps to protect, improve, or restore these valuable lakes.