2003-2004

BEAR LAKE MONITORING DATA SUMMARY

Prepared for:

BEAR LAKE REGIONAL COMMISSION
Fish Haven, Idaho

Prepared by:

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Logan, Utah

August 2004

INTRODUCTION

Water quality conditions were monitored in a single mid-lake station on Bear Lake during 2003-2004. The purpose of the Bear Lake monitoring program has been to:

1) Evaluate current water quality conditions in Bear Lake; and

2) Maintain the current water quality database.

Data was collected from the middle station of Bear Lake on six dates between September 25, 2003 and June 1, 2004. A map designating the sample location as well as long-term water quality plots are included in Appendix A. Raw data are presented in Appendix B. The following is a summary of the Bear Lake data.

BEAR LAKE WATER QUALITY

Bear Lake was sampled from September 2003 to June 2004. Bear Lake was sampled during both summer and winter stratifications as well as spring and fall turnovers. Samples were taken from the middle station (approximately 60 meters in depth) at ten meter intervals. Samples were collected and returned to the laboratory for nutrient and chlorophyll-*a* analysis. Field data were collected with an In-Situ MP-Troll 9000 field instrument. Field measurements for turbidity, temperature, dissolved oxygen, pH, and conductivity were taken every meter in depth.

Surface, through the bottom samples for total phosphorus (TP) concentrations were less than detection (5 μg/L) in nearly 70 percent of the samples (Figure 1). When results were less than the detection limit, half the value (2.5 μg/L) was used for sample values for statistical analysis. During the 2003 to 2004 sampling period, the total phosphorous levels were as low as the previous year's monitoring efforts which were as low as any recorded since monitoring commenced in 1980. The average surface total phosphorus concentrations in Bear Lake ranged from 3 to 4.3 μg/liter. Bottom concentrations ranged from to 2.5 to 23.4 μg/liter. With the exception of the October 2003 and the June 2004 data, all total phosphorous concentrations were at or near detection. As in the previous year's monitoring, the reason for the low phosphorous concentrations may be the result of increased calcium carbonate precipitation in the lake. This is reflected in the loss of transparency (to be discussed in a later section of this report).

Average surface and bottom orthophosphorous (OP) concentrations were similar during the 2003 to 2004 monitoring program (Figure 2), ranging from less than 1.0 μg/liter to 4.4 μg/liter in the epilimnion and less than 1.0 μg/liter to 3.5 μg/liter in the hypolimnion. Less than detection results (<1 μg/L) accounted for only 7 percent of the samples. The highest concentration of OP was observed in April 2004, which was also the month when the highest OP concentration was recorded in 2003. February 2004 had the lowest concentrations, during which three out of seven depths exhibited less than detection levels.

Surface total inorganic nitrogen (TIN) concentrations have stabilized at pre-1997 levels, with almost all TIN expressed as ammonia (Figure 3 and Figure 4). During the summer and fall of 2003, total inorganic nitrogen (NH_3+NO_3+NO_2) surface concentrations ranged from 30 μg/liter to a high of 77 μg/liter at the end of October. Compared to the historical dataset, this peak was only 8 percent of the TIN encountered in 1997. The majority of the TIN was present as ammonia. Average surface ammonia ranged from 28 to 75 μg/liter during the summer-fall of 2003 (highest concentrations observed in this sample period). The November 2003 and June 2004 TIN profiles had the overall lake-wide highest concentrations. During the 2003 to 2004 sample period, there was a noticeable hypolimnetic buildup of ammonia and nitrate (Figure 5, bottom). This occurred during the winter stratification period and peaked in April 2004.

Water transparency, measured with a secchi disk, ranged from 3.9 meters in November 2003 to a maximum of 5.8 meters in April 2004 (Figure 6, top). During this monitoring season, the secchi disk had transparencies greater than 5.0 meters only 75 percent of the time. It is interesting to note that the transparency has been systematically decreasing since a recorded maximum of 11.2 meters in 1996. This corresponds to the decrease in the elevation of Bear Lake.

Chlorophyll-*a* concentrations did not follow transparency patterns during this monitoring period. It should be noted that the same pattern was evident last year with little or no relationship to chlorophyll-*a* (Figure 6, bottom). It is believed that the transparency pattern is the result of abiotic turbidity and not biological particles (algae). The data indicates that the amount of algae (expressed as chl-*a*) was higher in 2004 than in previous years. The highest concentrations were in late winter and early spring 2004.

The depth distribution of oxygen in Bear Lake is a key integrating parameter which incorporates all of the external loading of organic material as well as any internal primary production. The hypolimnetic dissolved oxygen concentrations ranged from 4.6 to 8.4 mg/liter during the monitoring period (Figure 7). Average epilimnetic concentrations of dissolved oxygen ranged from 7.94 to 12.17 mg/liter. With the exception of lower concentrations of oxygen in the hypolimnion during the summer sampling events,and a sightly higher surface winter concentration, the seasonal pattern this year was similar to the last two monitoring seasons (2000-2002). Oxygen depressions were not as great as those seen in the 1996 monitoring period.

Bottom temperatures during the entire monitoring period did not exceed 2.45˚C, and the highest temperature in the epilimnion was 14˚C, recorded in October 2003.Compared to the data collected since 1996, the average epilimnetic temperature (surface and 10 meters) during this monitoring period has not changed The lake was stratified during both summer sampling events, and had started the stratification process during the second spring turnover sampling event.

As noted in the opening section of this report, detailed depth profiles were collected using an In-Situ MP-Troll 9000 field instrument. These profiles are shown in Figure 8 for each sample date and parameter.

SUMMARY

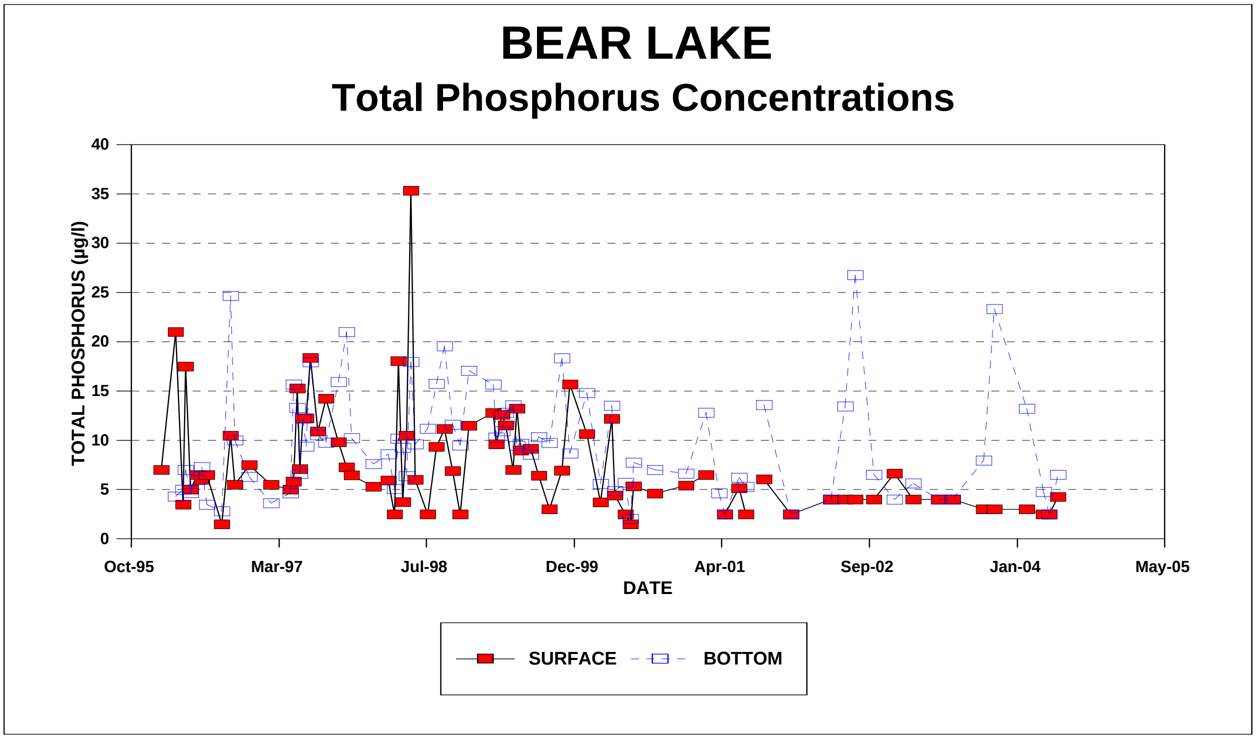
Plots of the long-term water quality data and a map of the long-term monitoring location are presented in Appendix A. Tables of raw data for Bear Lake are included in Appendix B.

During the 2003-2004 monitoring season, total phosphorus was stable at relatively low levels. Higher concentrations were seen in the June 2004 data. The lake averaged 6.5 µg/liter for the entire monitoring season. Orthophosphorus remained low as well, ranging from below detection (<1 µg/L) to 6 µg/liter, and averaging only 2.2 µg/liter for the entire monitoring season (up slightly from the previous monitoring year). Total inorganic nitrogen remained stable in 2003-2004 and seemed to have returned to pre-1997 levels. Most of the TIN in the system was present as ammonia. A slight increase in lake-wide ammonia levels was observed during the fall and winter of 2003, with a hypolimnetic increase seen as well. In the summer of 2004, chl-*a* also demonstrated a lake-wide increase. This increase corresponded to an increase in turbidity and a decrease in water transparency.

The system is currently calculated to be phosphorus limited.

RECOMMENDATIONS

1. The revised Bear Lake monitoring program is sensitive in its ability to detect changes in the physical and chemical water quality conditions in Bear Lake and should be continued.
2. Research is needed to define the relationship between Bear River inflowing water including sediments, calcium and phosphorus and Bear Lake. This has been an ongoing recommendation. The relationship between calcium carbonate chemistry, total and orthophosphate and water transparency as well as the secondary effects on Bear Lake's trophic structure is ill defined.
3. During the technical exchange at Bear Lake in the spring of 1998, it was suggested that a detailed hydrologic budget be conducted on the lake. It is recommended that the Bear Lake Regional Commission take the lead on this task and link a nutrient budget to this effort. A detailed nutrient budget is needed for the lake. The last budgets were produced 20 years ago. Significant urban development has occurred in the basin over the last two decades.



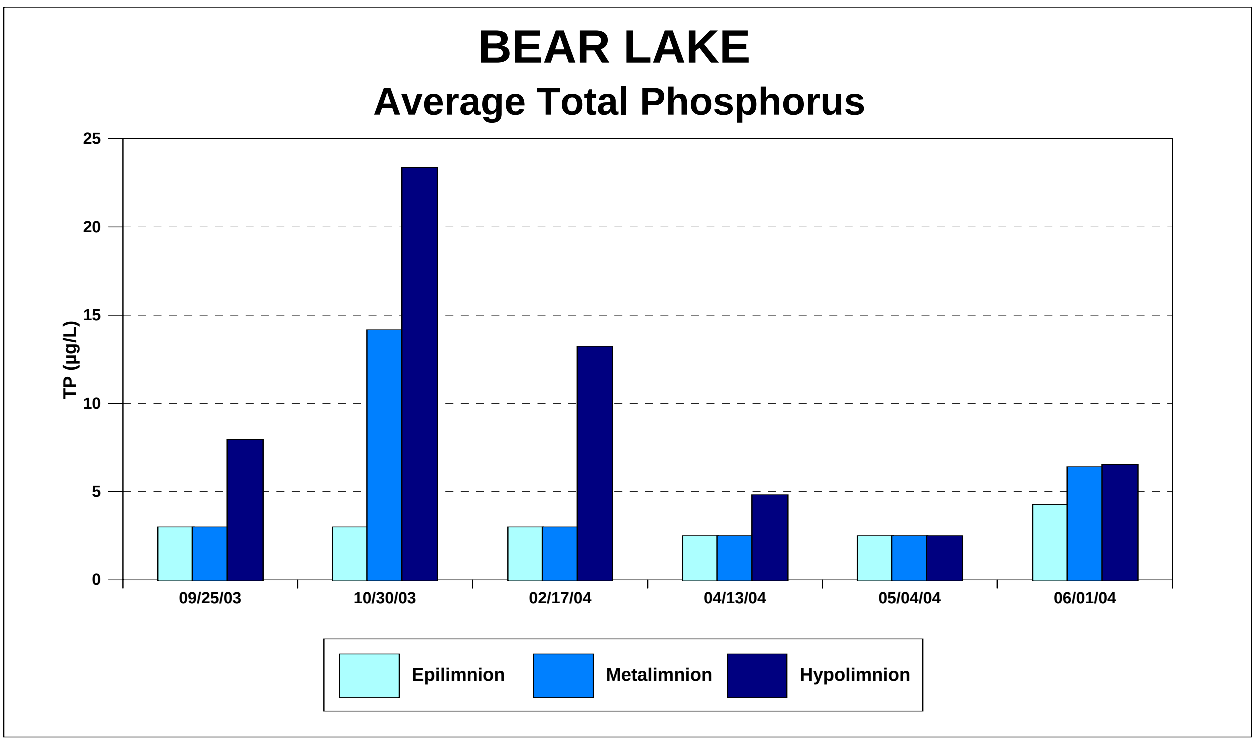
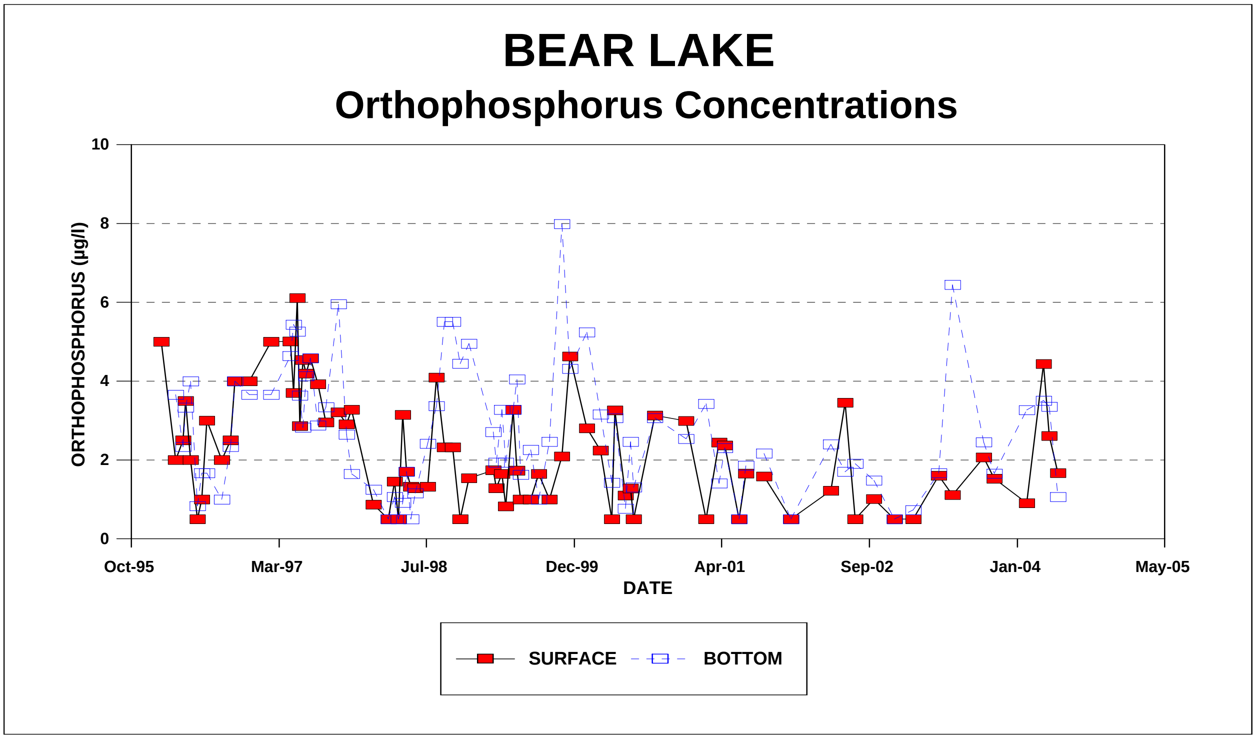


Figure 1. Concentrations of total phosphorus in the surface and bottom waters of Bear Lake since 1996 (above) and average concentrations within each layer of the lake for the monitoring period (below).



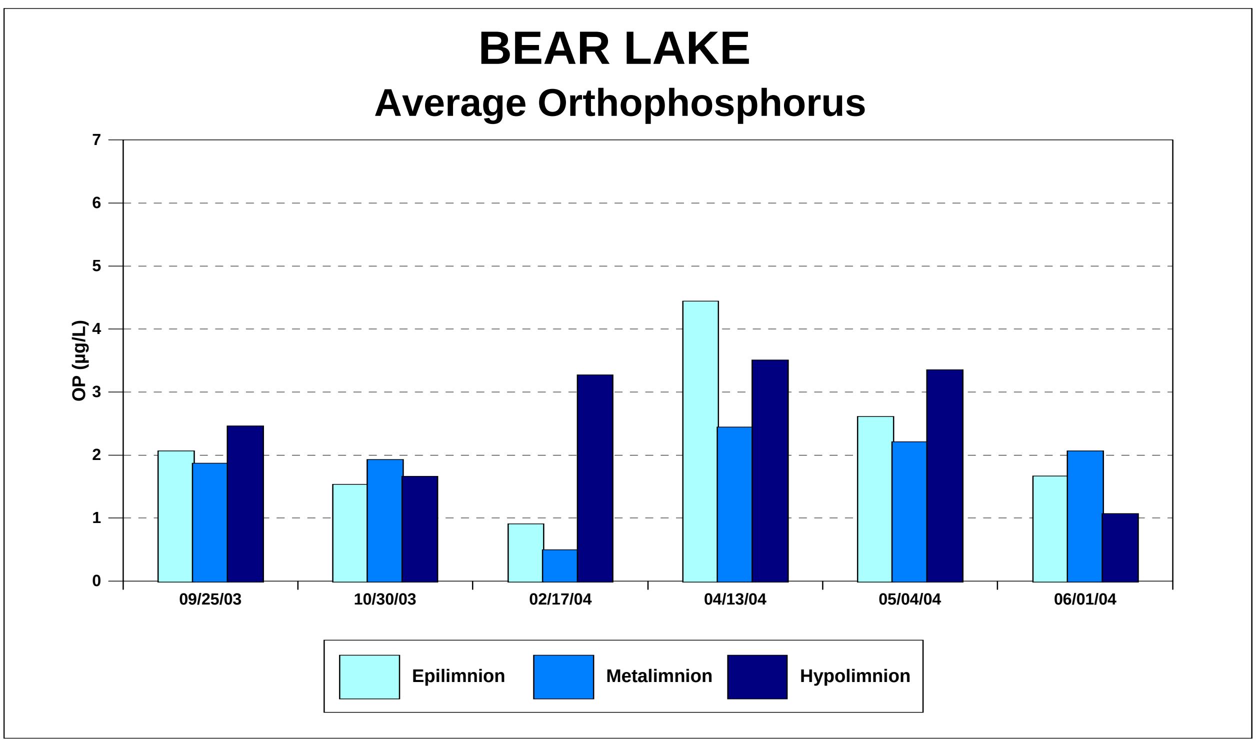
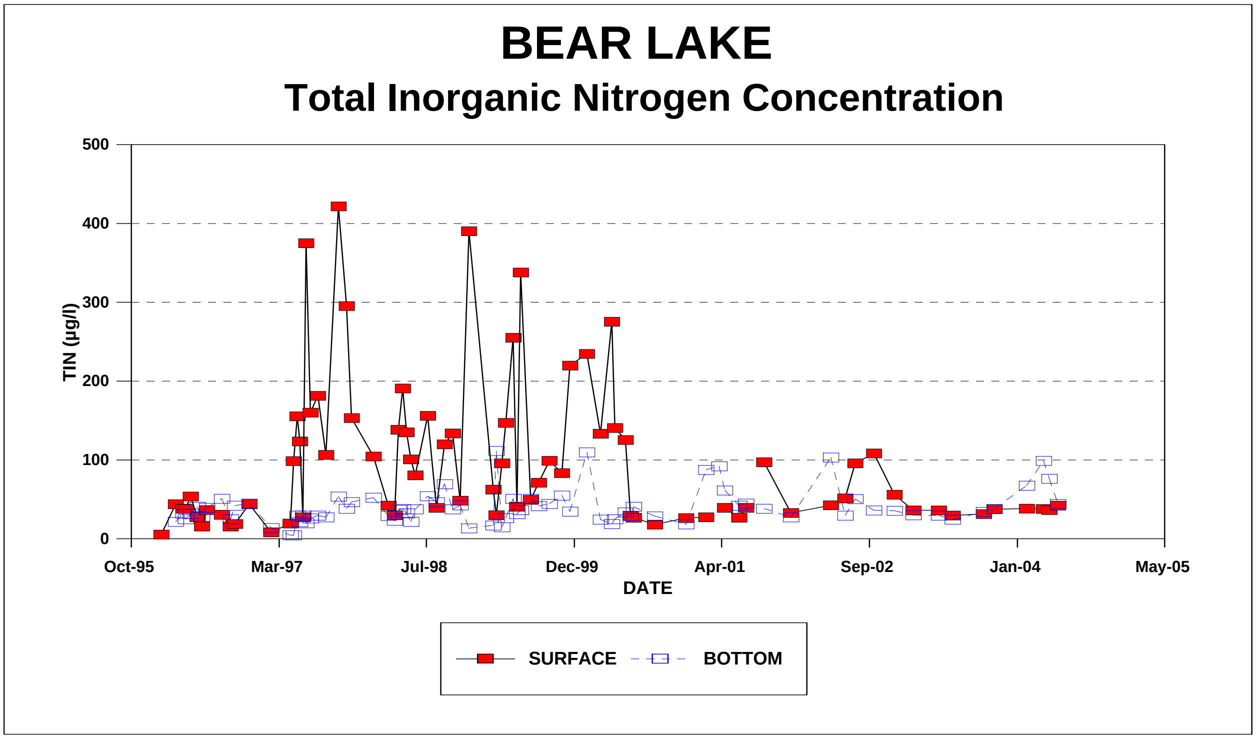


Figure 2. Concentrations of orthophosphorus in the surface and bottom waters of Bear Lake since 1996 (above) and average concentrations within each layer of the lake for the monitoring period (below).



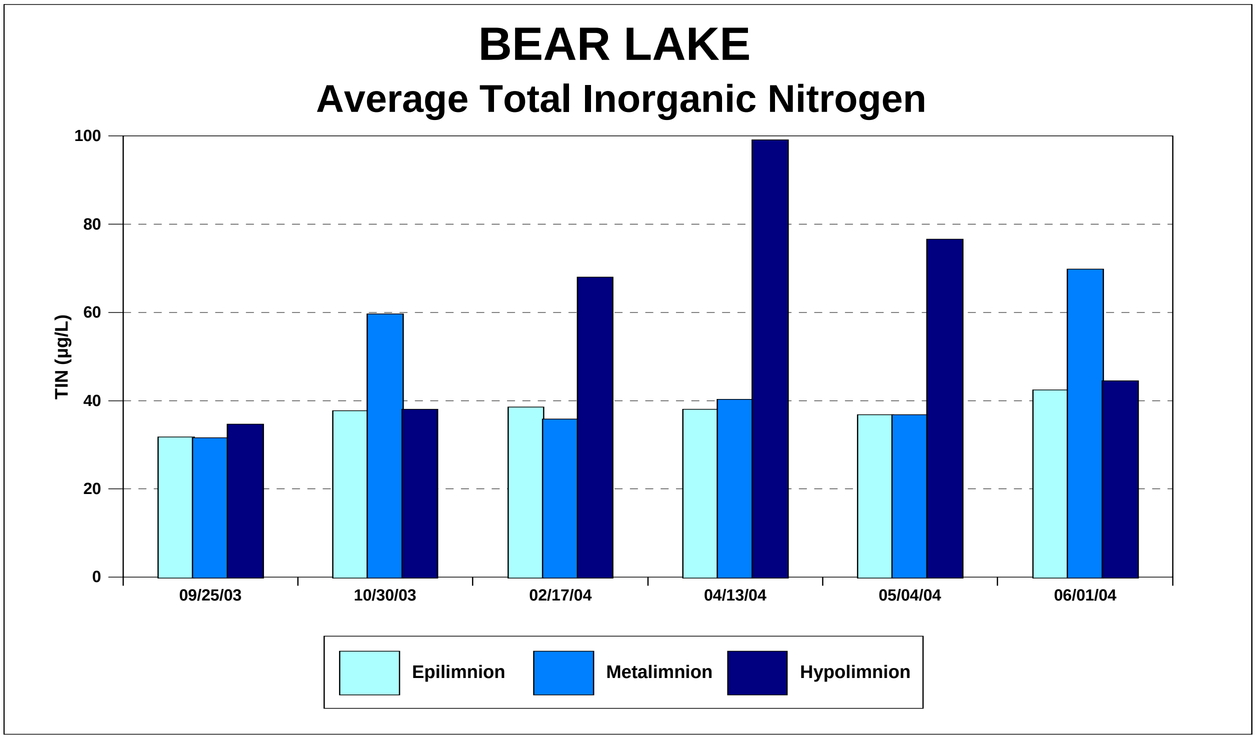


Figure 3. Concentrations of total inorganic nitrogen (NH_3+NO_3+NO_2) in the surface and bottom waters of Bear Lake since 1996 (above) and average concentrations within each layer of the lake for the monitoring period (below).

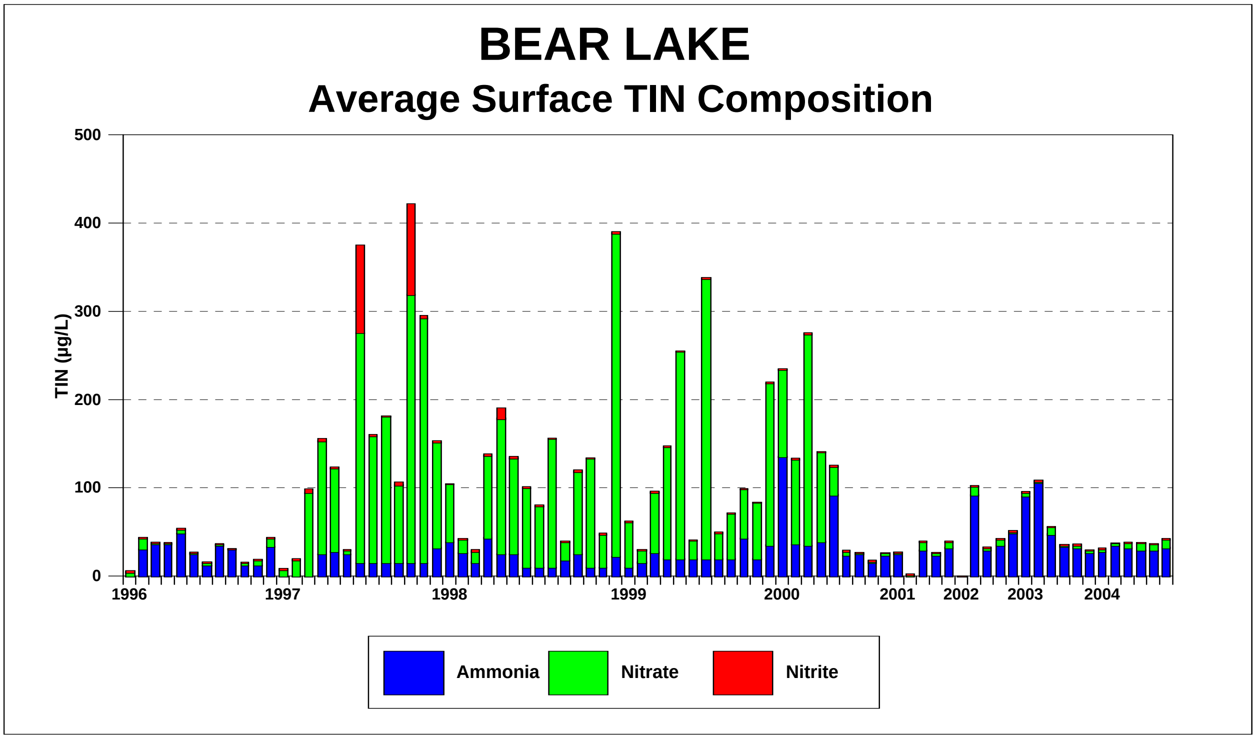
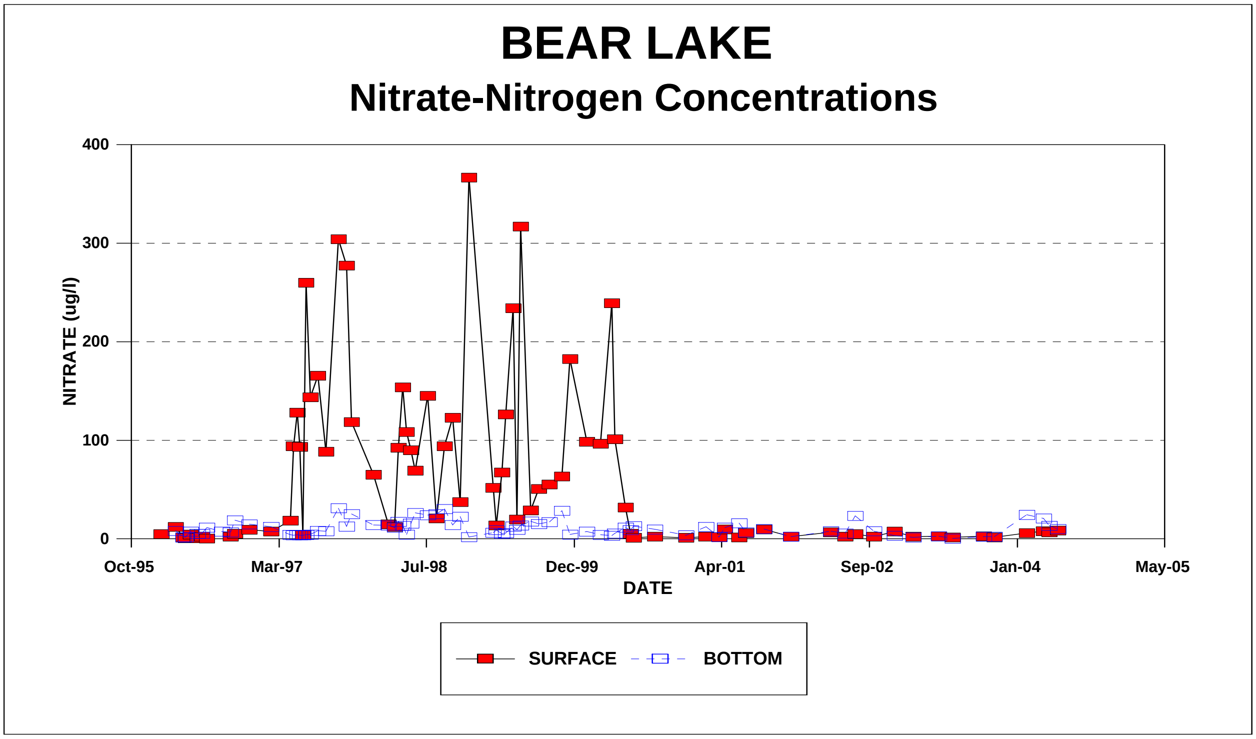


Figure 4. Total inorganic nitrogen composition of the epilimnion in Bear Lake since 1996.



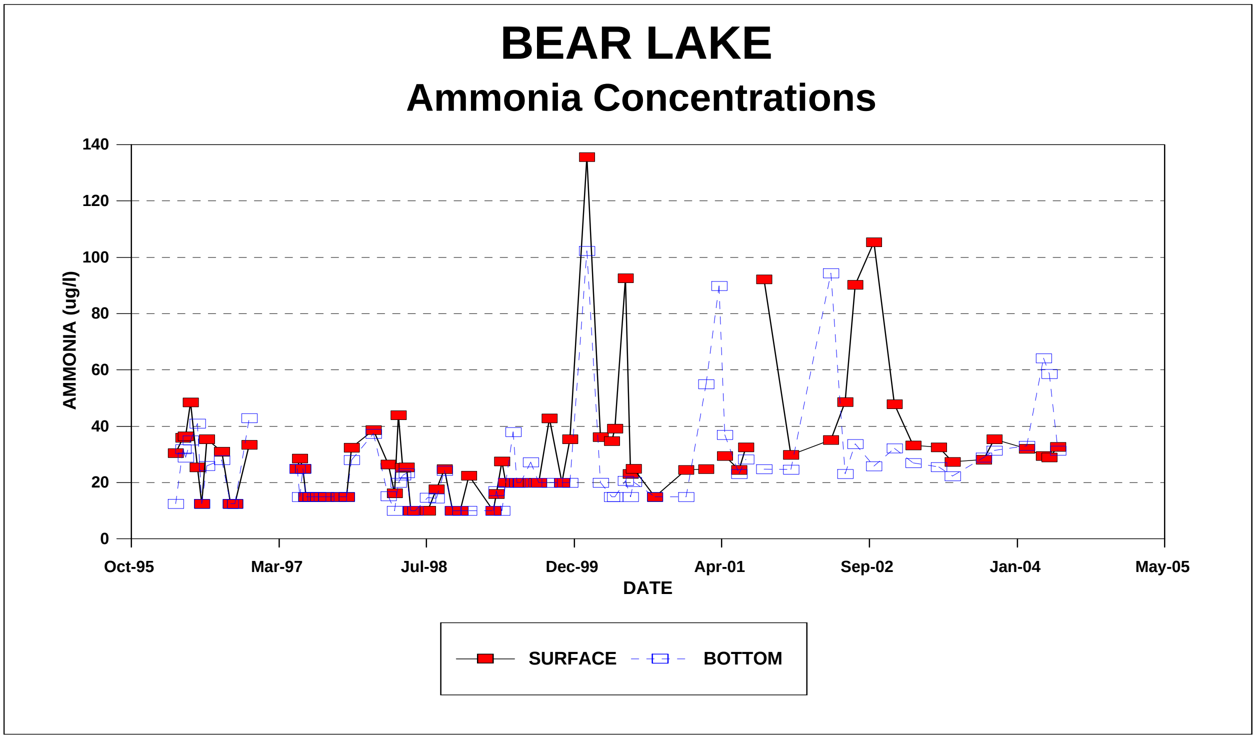
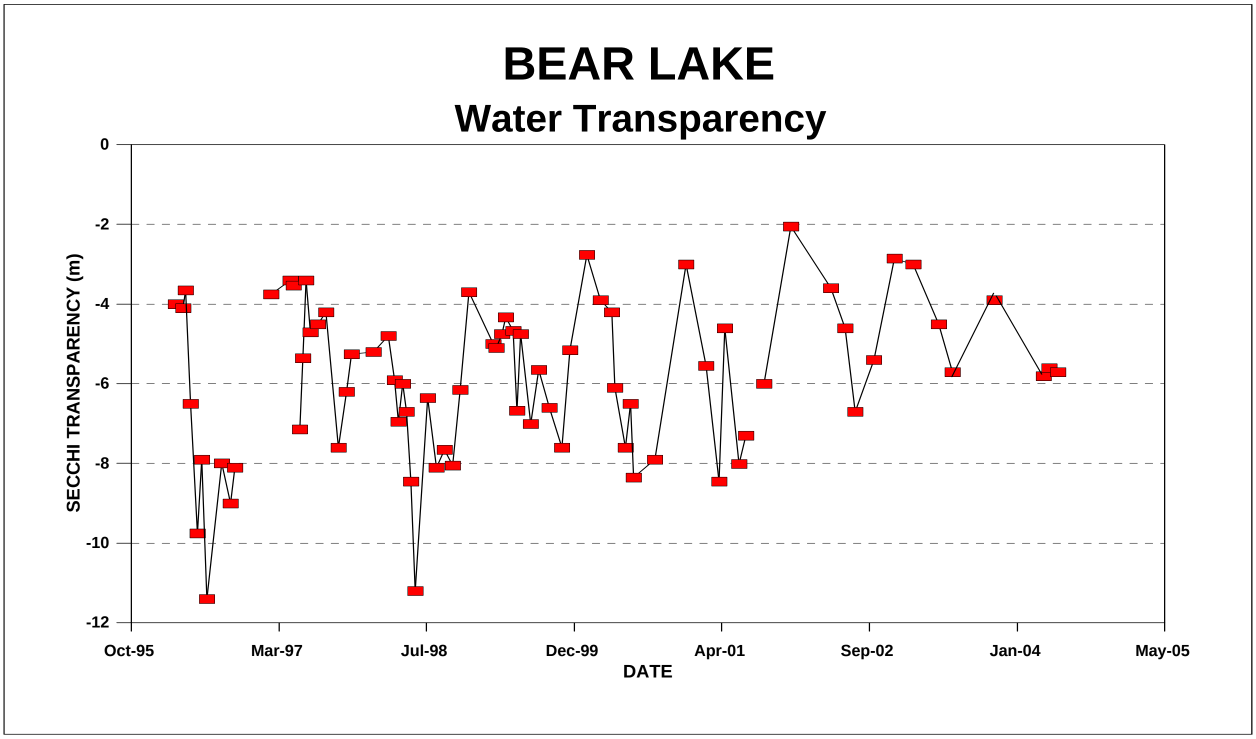


Figure 5. Concentrations of nitrate-nitrogen (above) and ammonia (below) in the surface and bottom waters of Bear Lake since 1996.



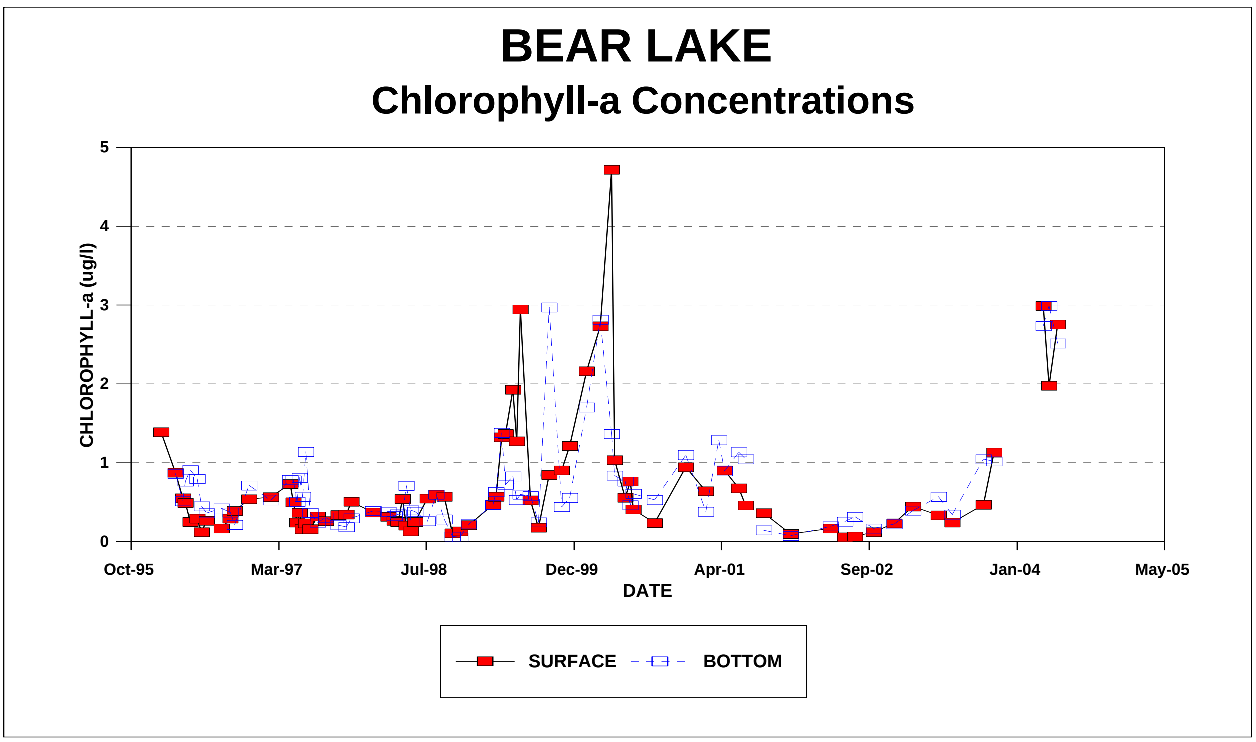
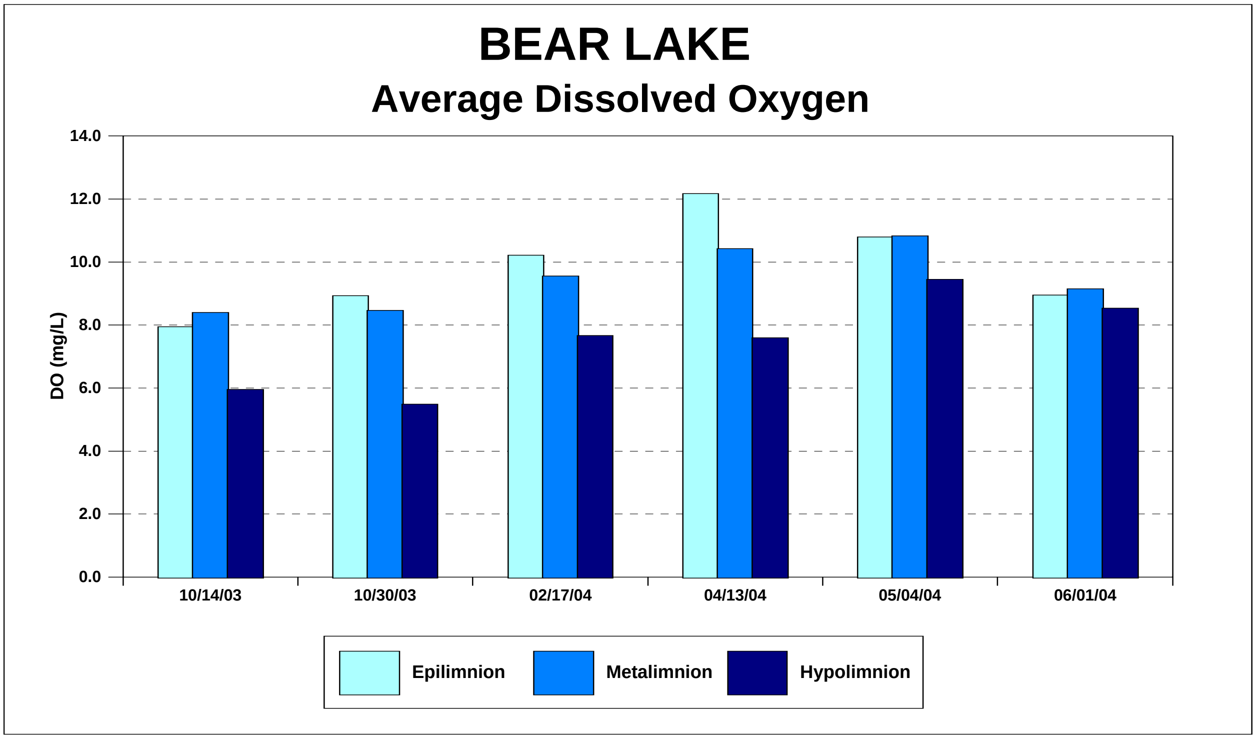


Figure 6. Water transparency (above) and surface and bottom chlorophyll-a concentrations in Bear Lake since 1996.



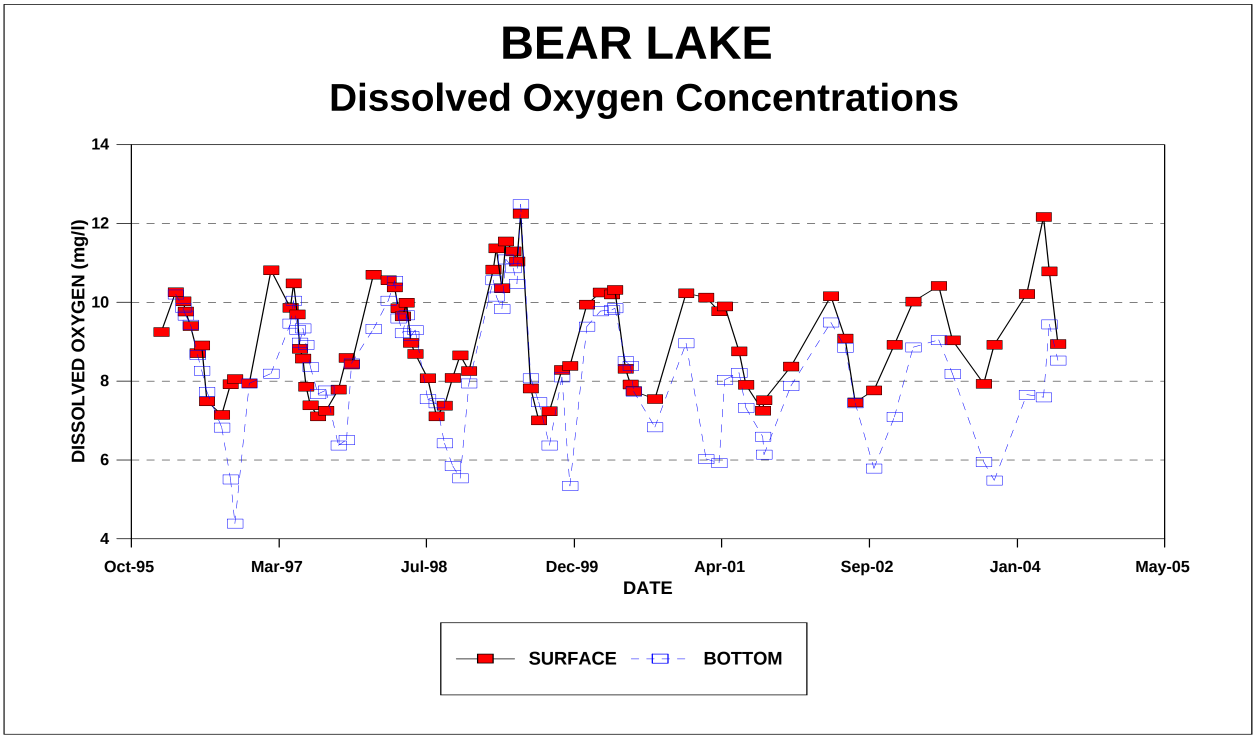
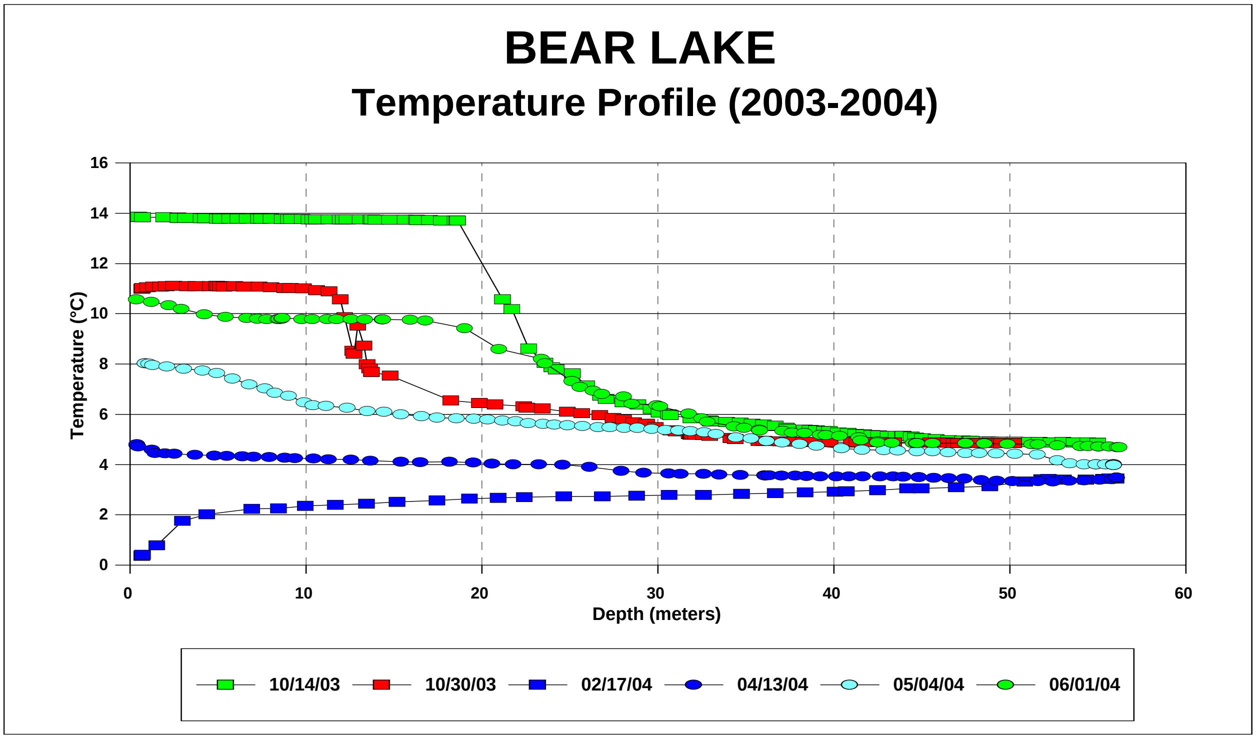


Figure 7. Dissolved oxygen concentrations in the surface and bottom waters of Bear Lake since 1996 (above) and average concentrations within each layer of the lake for the monitoring period (below).



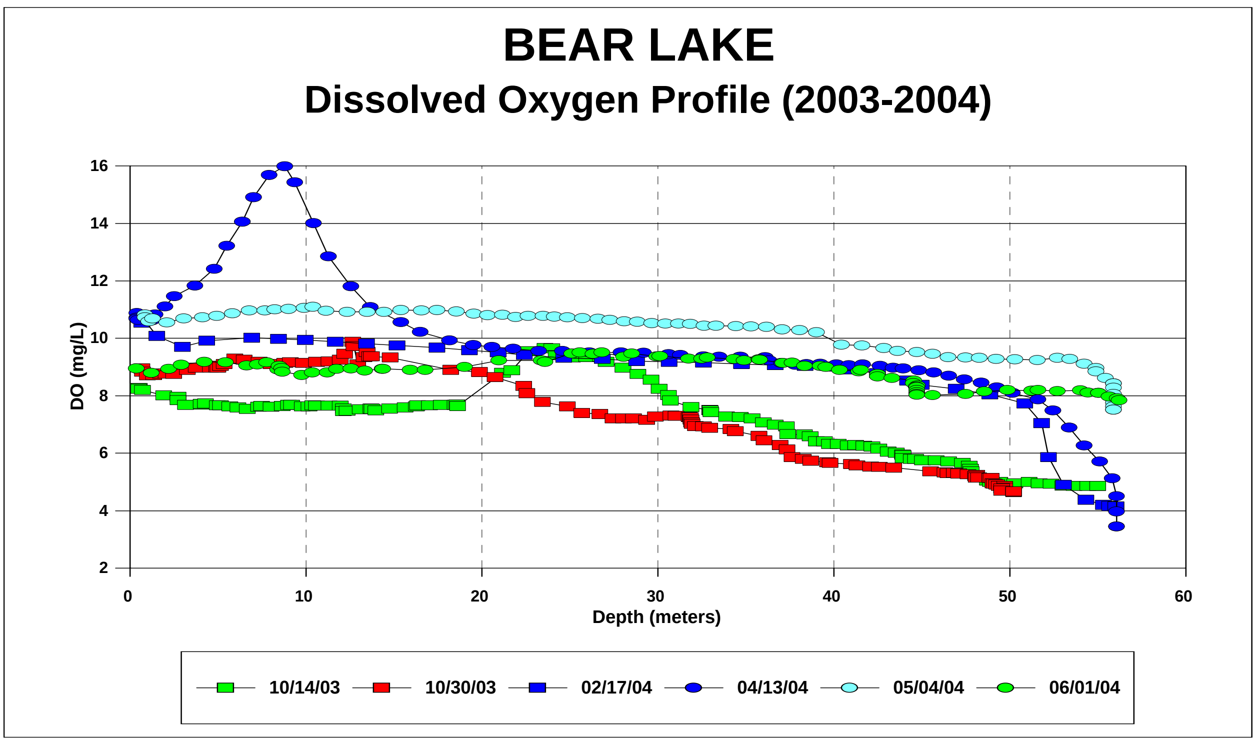
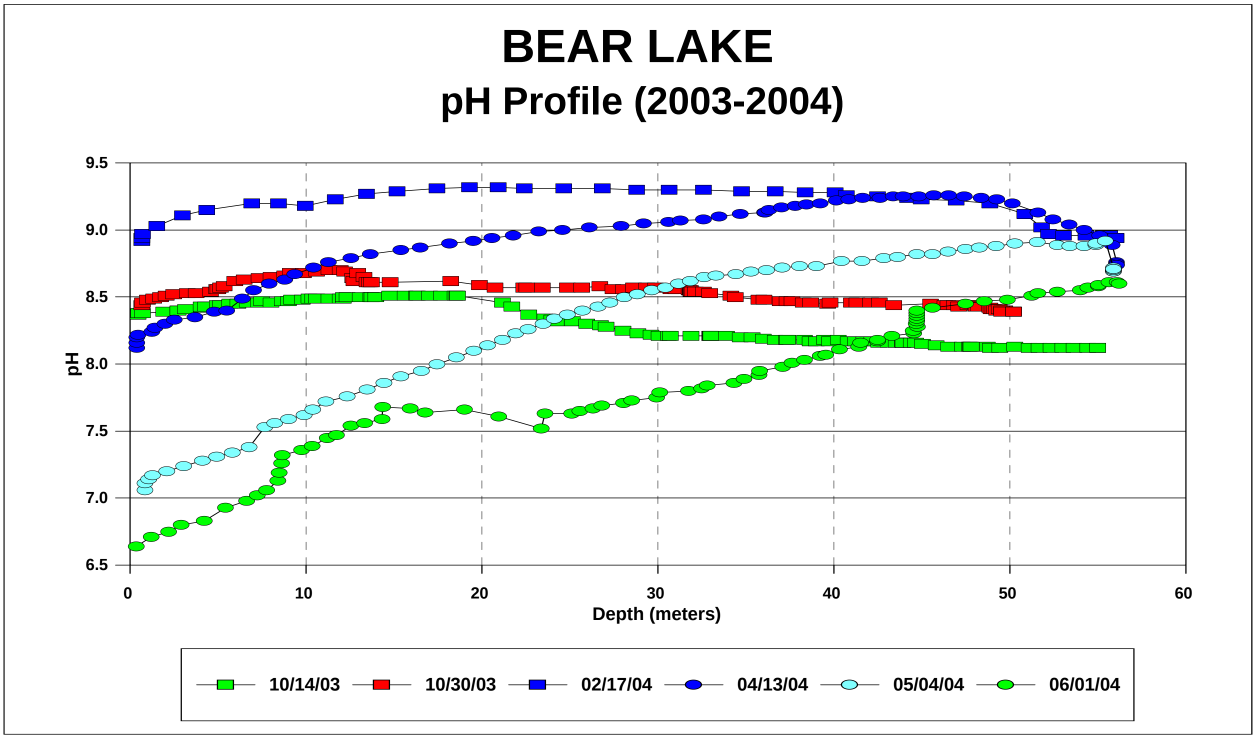


Figure 8. Temperature and dissolved oxygen profiles of Bear Lake for each sampling event during the monitoring period. Green indicates summer stratification, cyan is spring turnover, red and blue are fall and winter conditions, respectively.



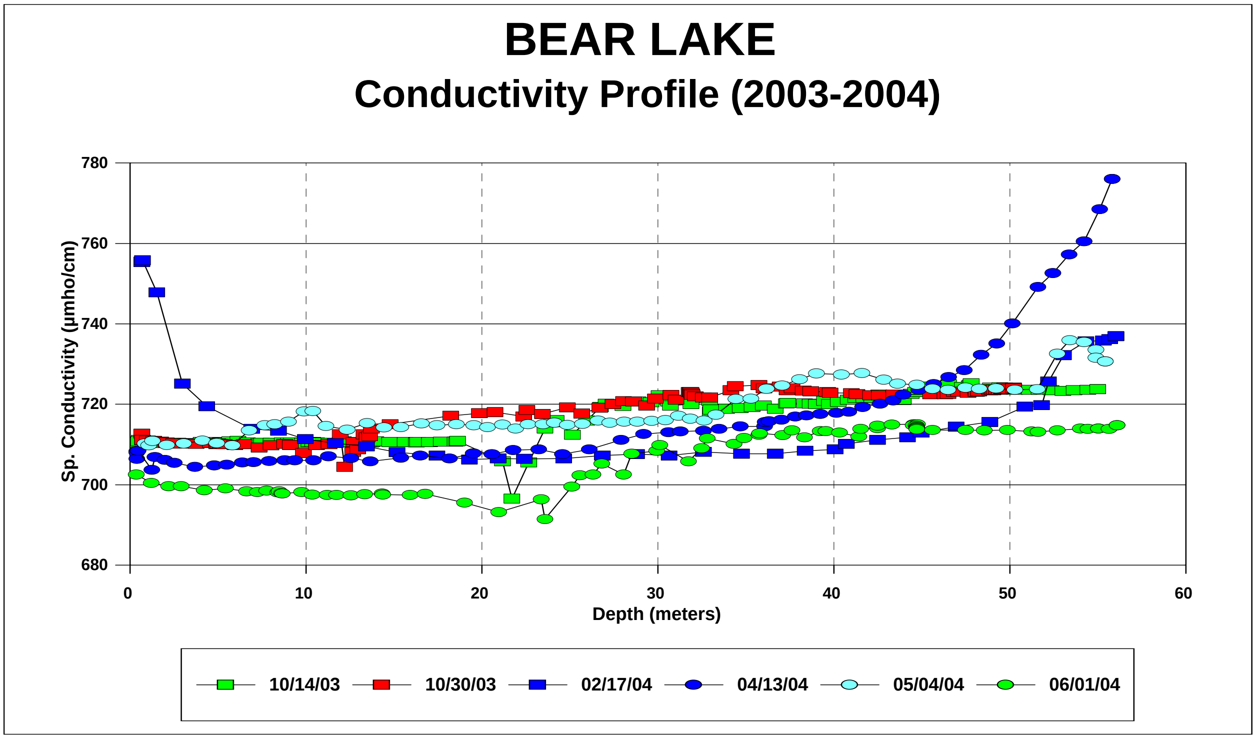
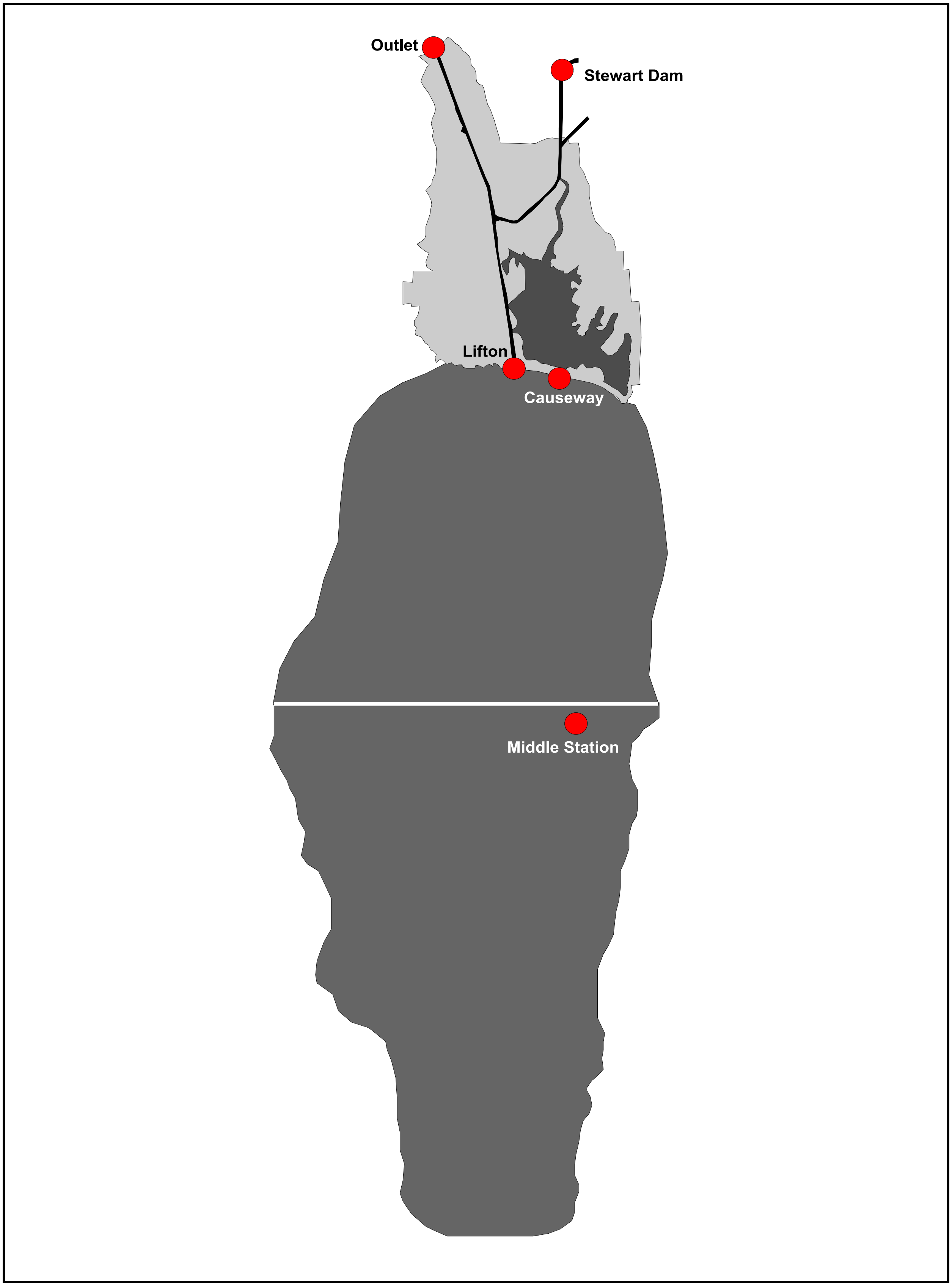
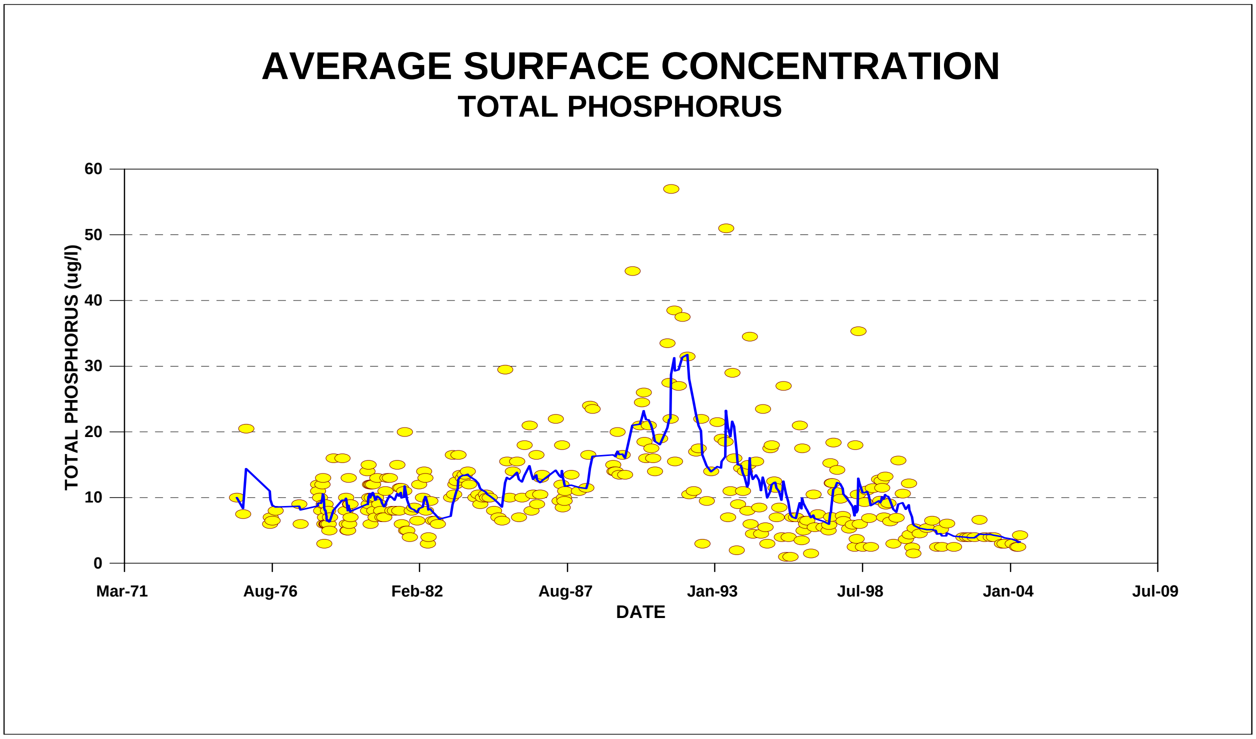


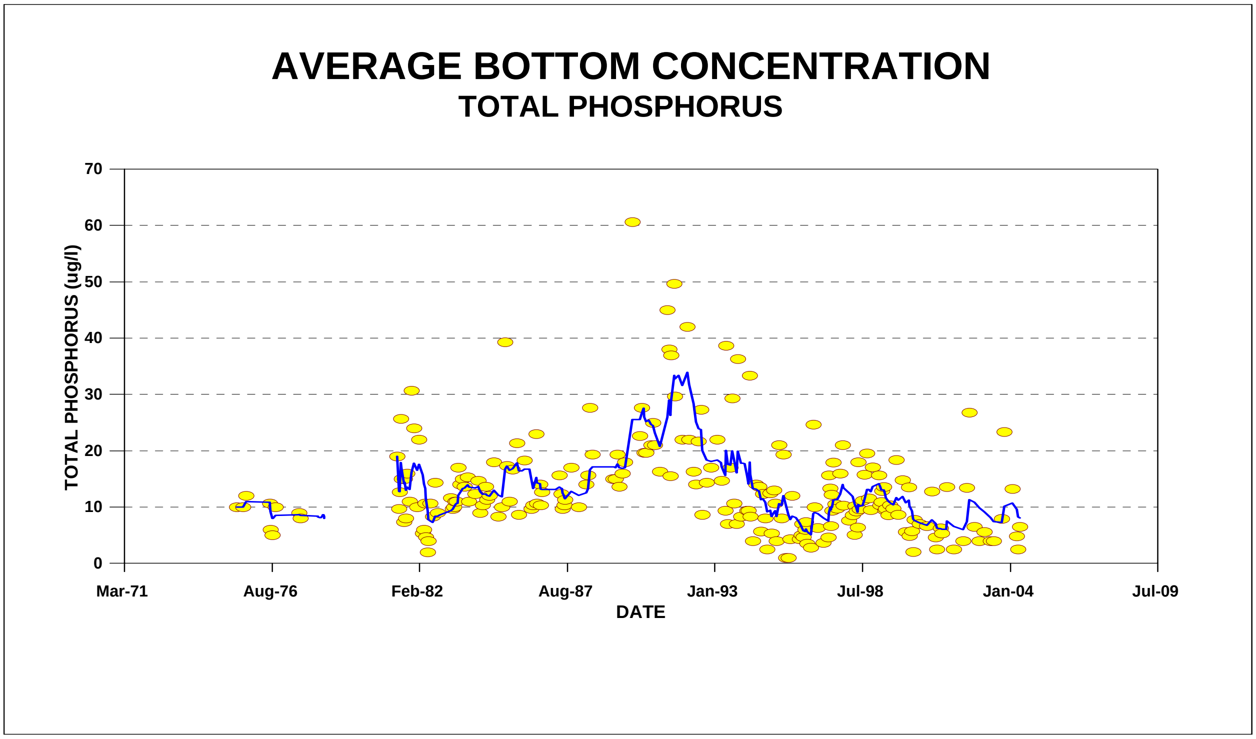
Figure 8. pH and conductivity profiles of Bear Lake for each sampling event during the monitoring period. Green indicates summer stratification, cyan is spring turnover, red and blue are fall and winter conditions, respectively.

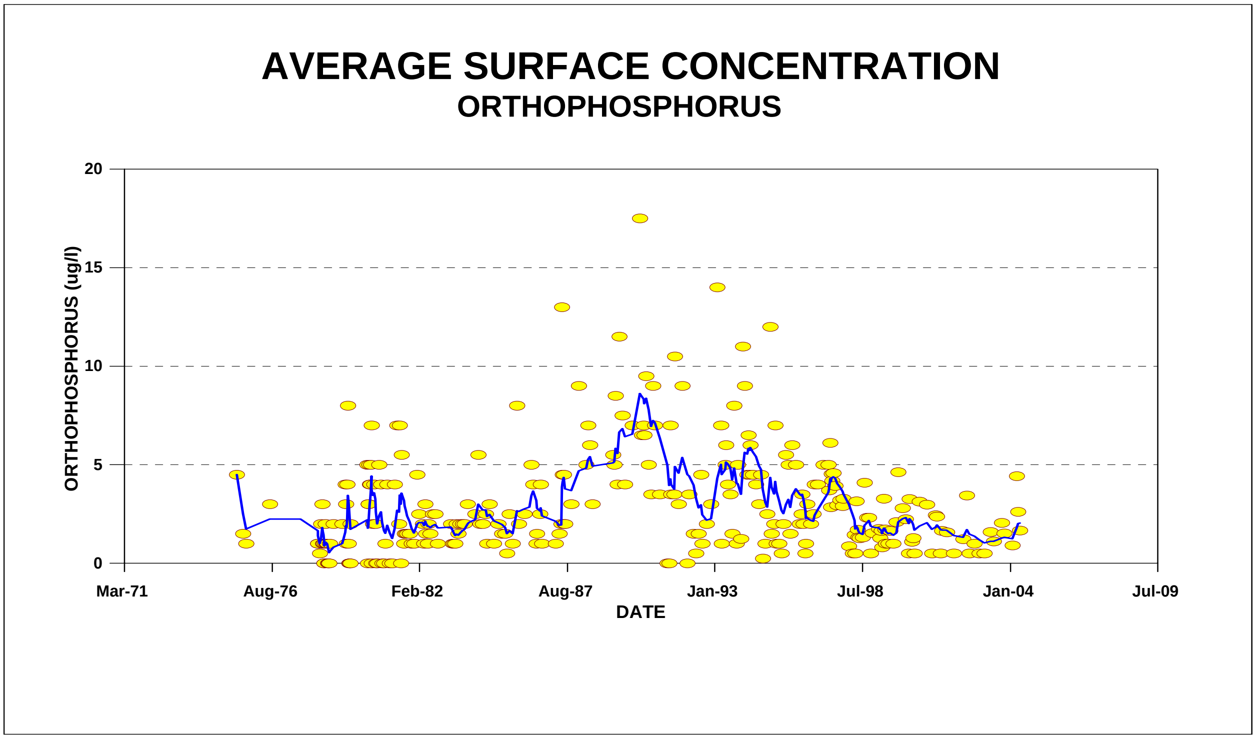
APPENDIX A

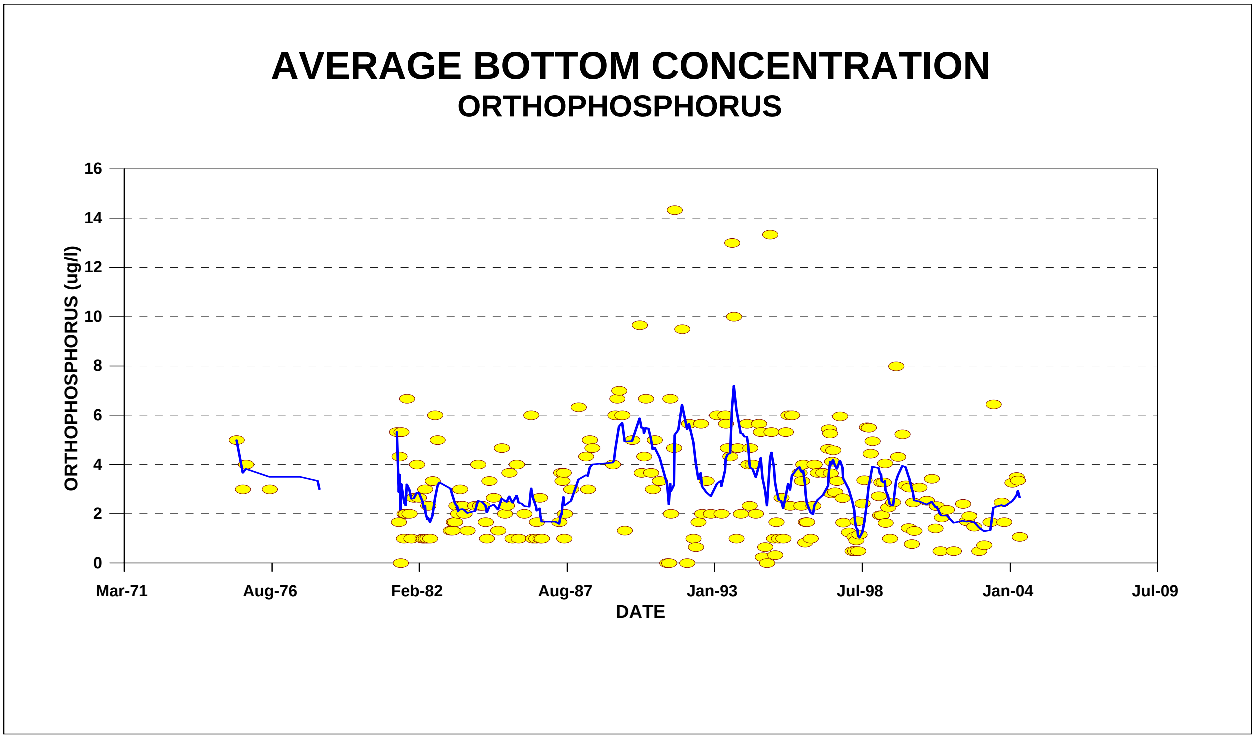
Graphs of Long-term Water Quality Data Monitoring Locations

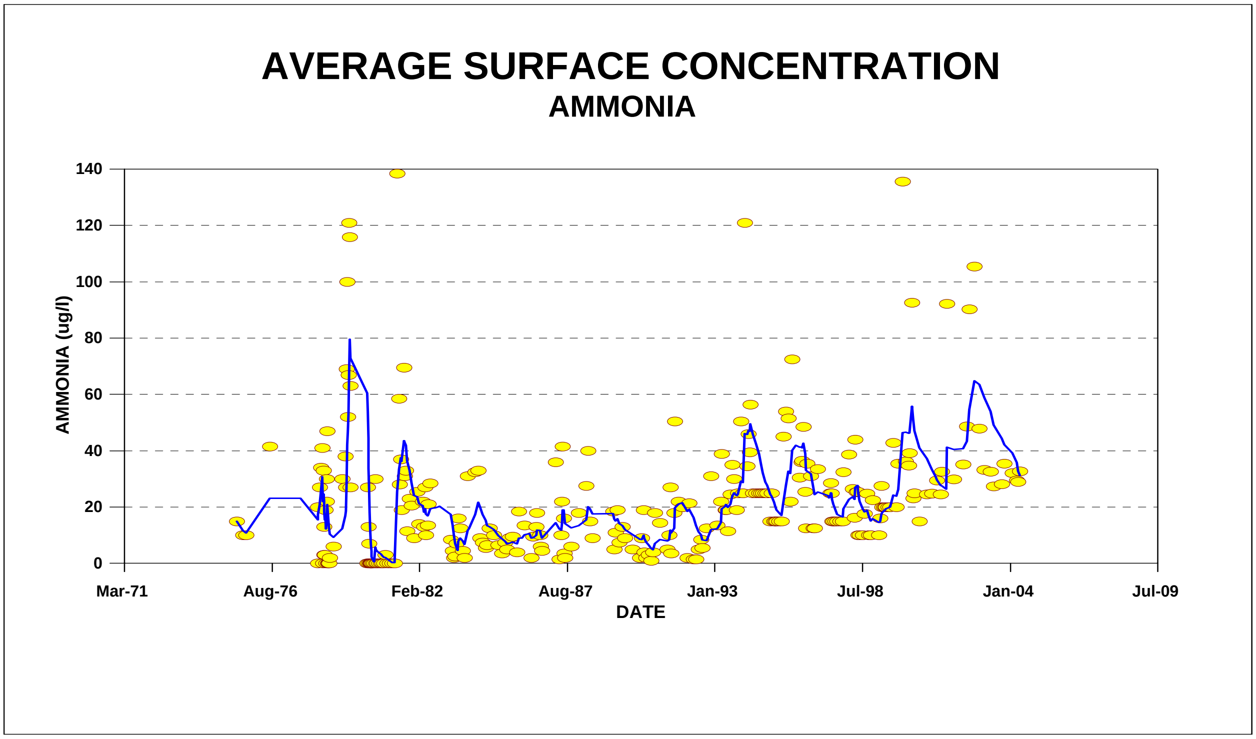

Outlet
Stewart Dam
Lifton
Causeway
Middle Station

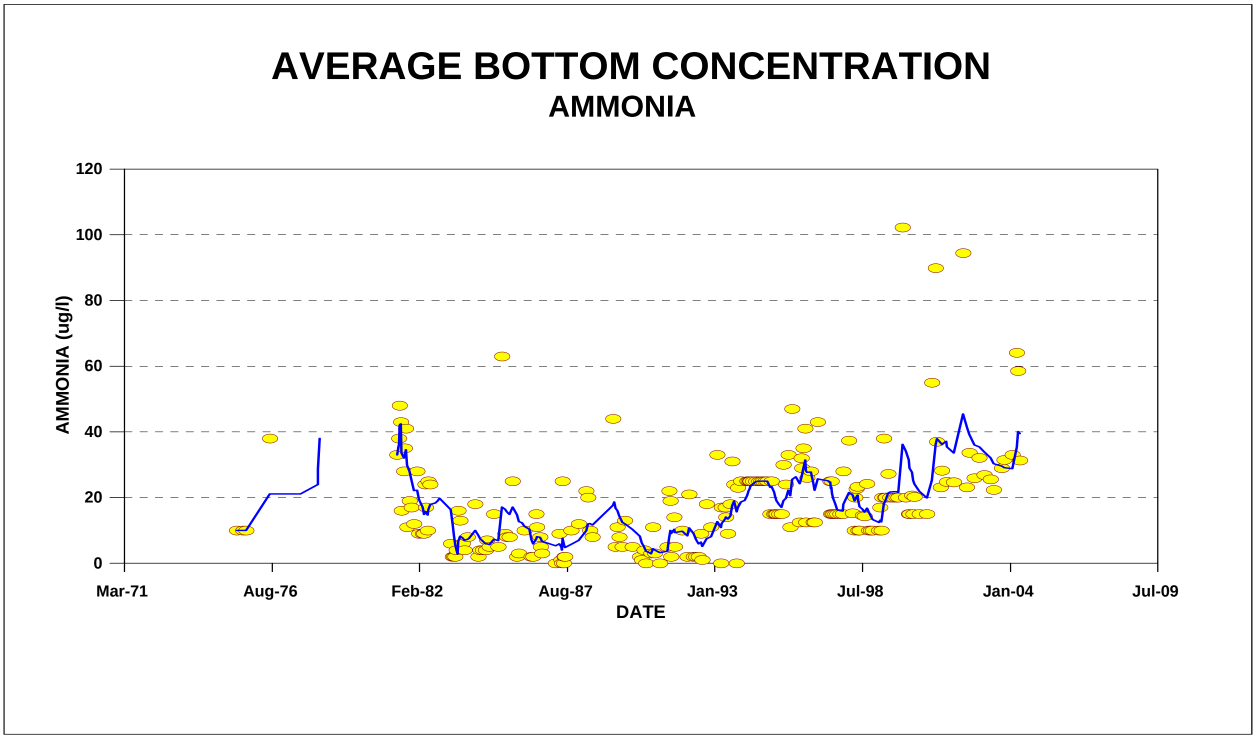

AVERAGE SURFACE CONCENTRATION
TOTAL PHOSPHORUS
TOTAL PHOSPHORUS (ug/l)
0
10
20
30
40
50
60
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE

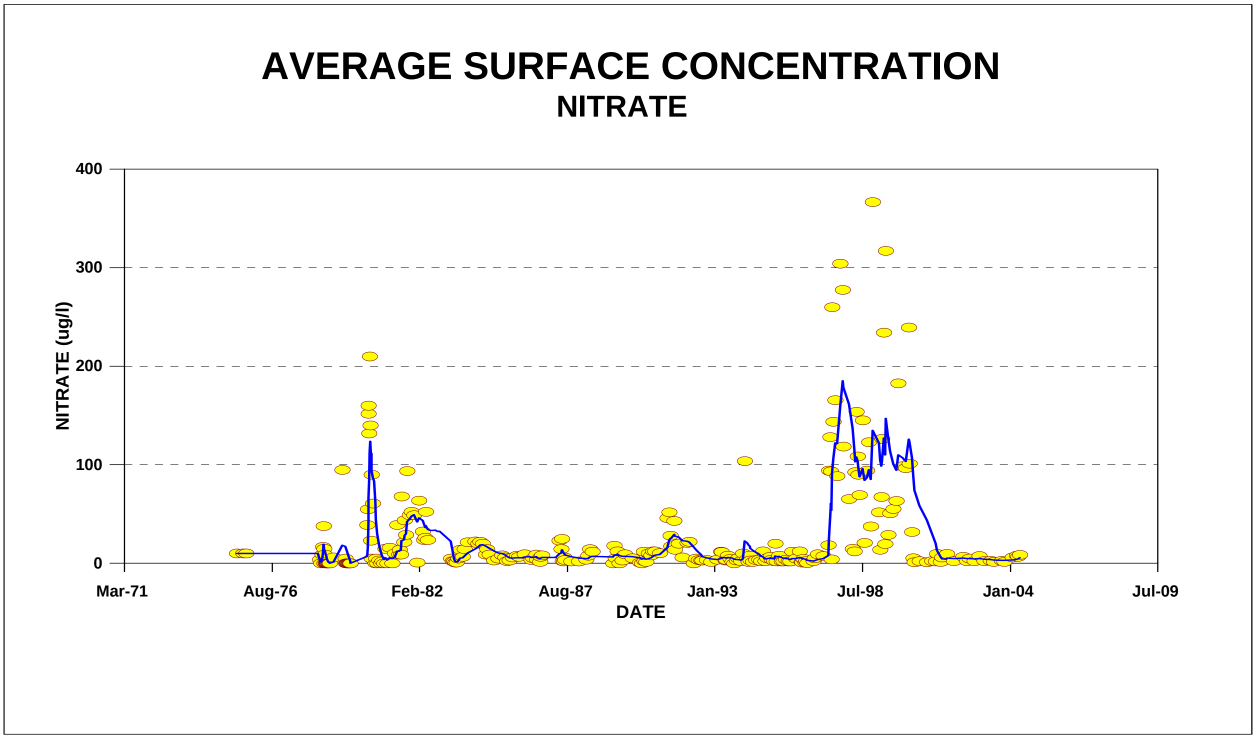

AVERAGE BOTTOM CONCENTRATION
TOTAL PHOSPHORUS
TOTAL PHOSPHORUS (ug/l)
0
10
20
30
40
50
60
70
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE

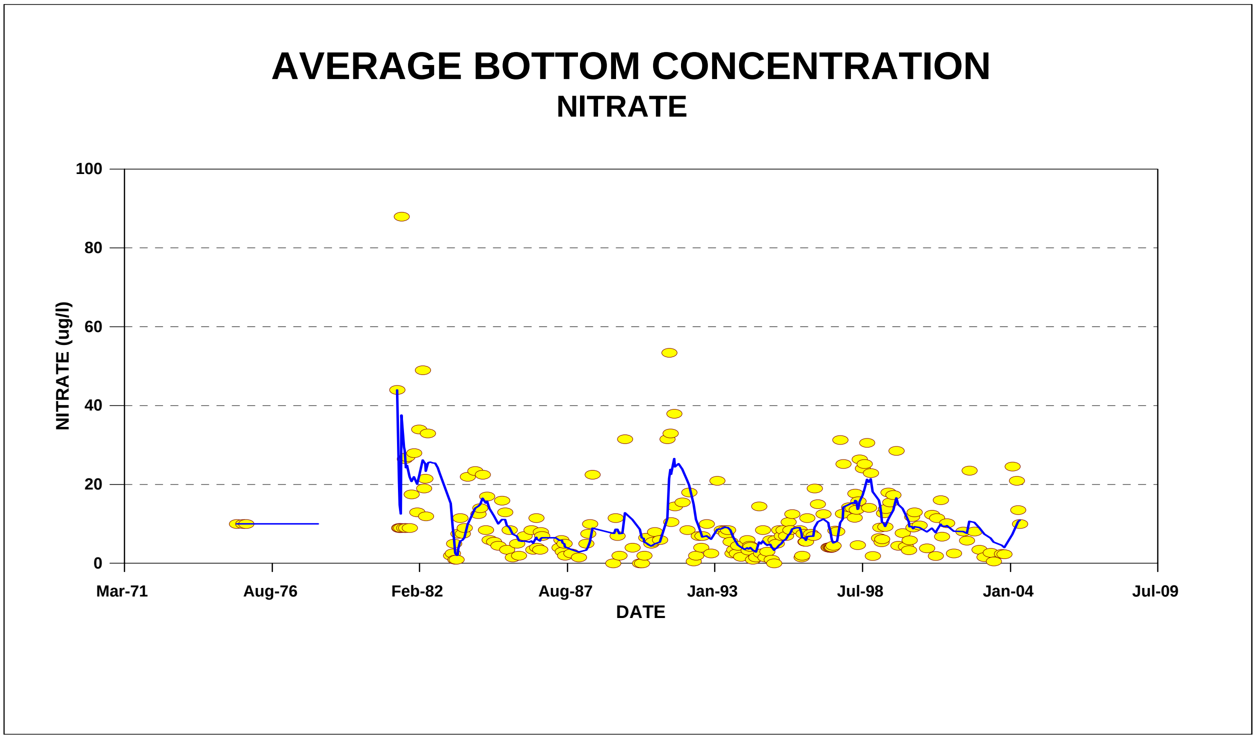

AVERAGE SURFACE CONCENTRATION
ORTHOPHOSPHORUS
ORTHOPHOSPHORUS (ug/l)
20
15
10
5
0
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE

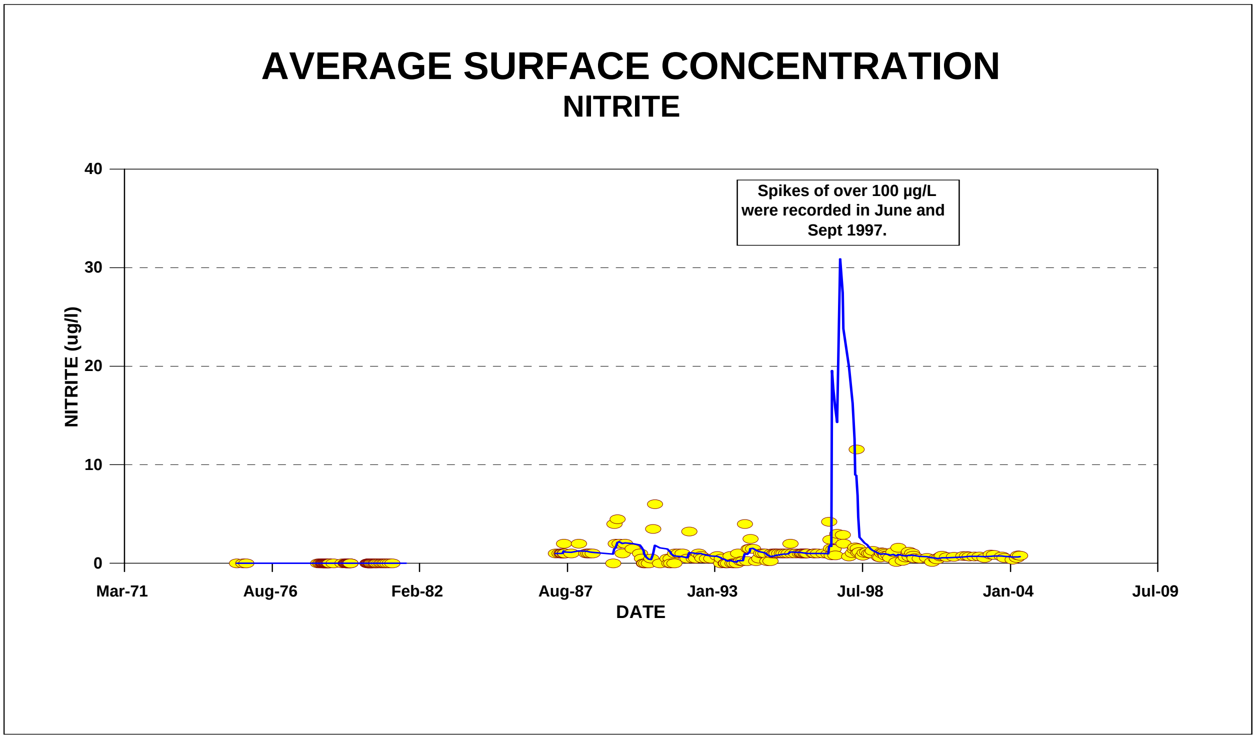

AVERAGE BOTTOM CONCENTRATION
ORTHOPHOSPHORUS
ORTHOPHOSPHORUS (ug/l)
16
14
12
10
8
6
4
2
0
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE

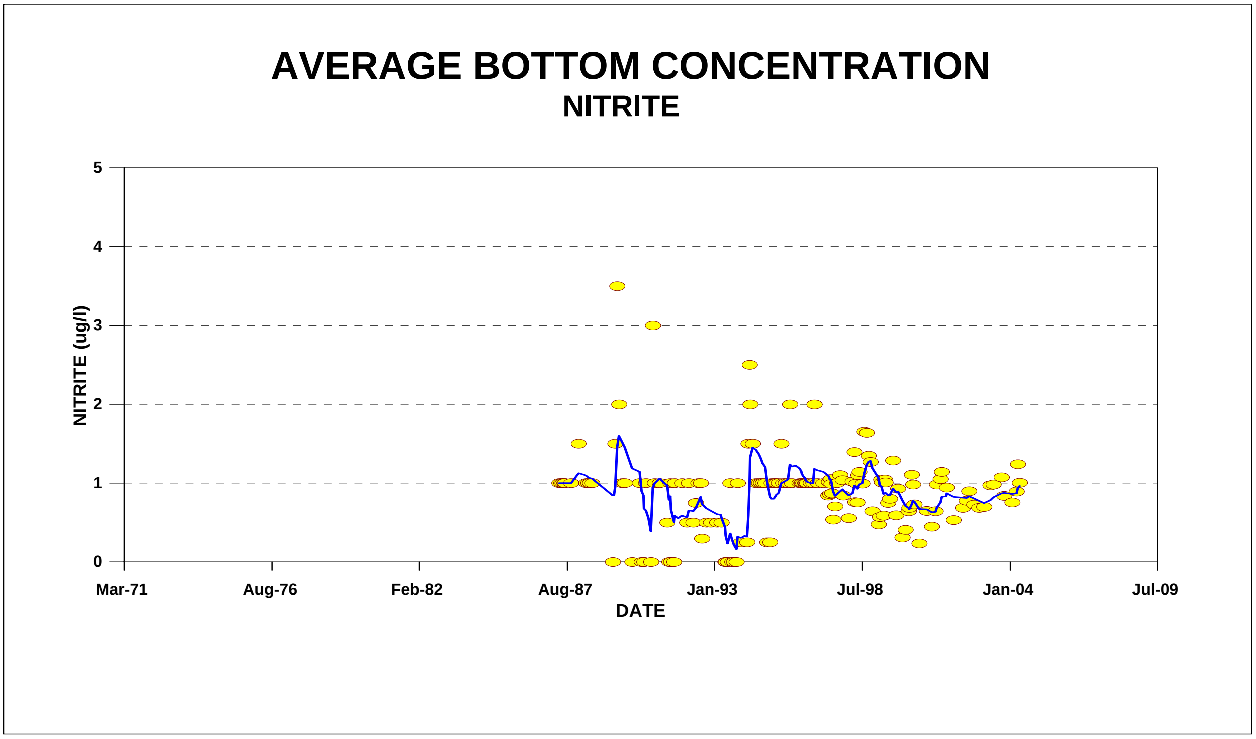

AVERAGE SURFACE CONCENTRATION
AMMONIA
AMMONIA (ug/l)
140
120
100
80
60
40
20
0
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE

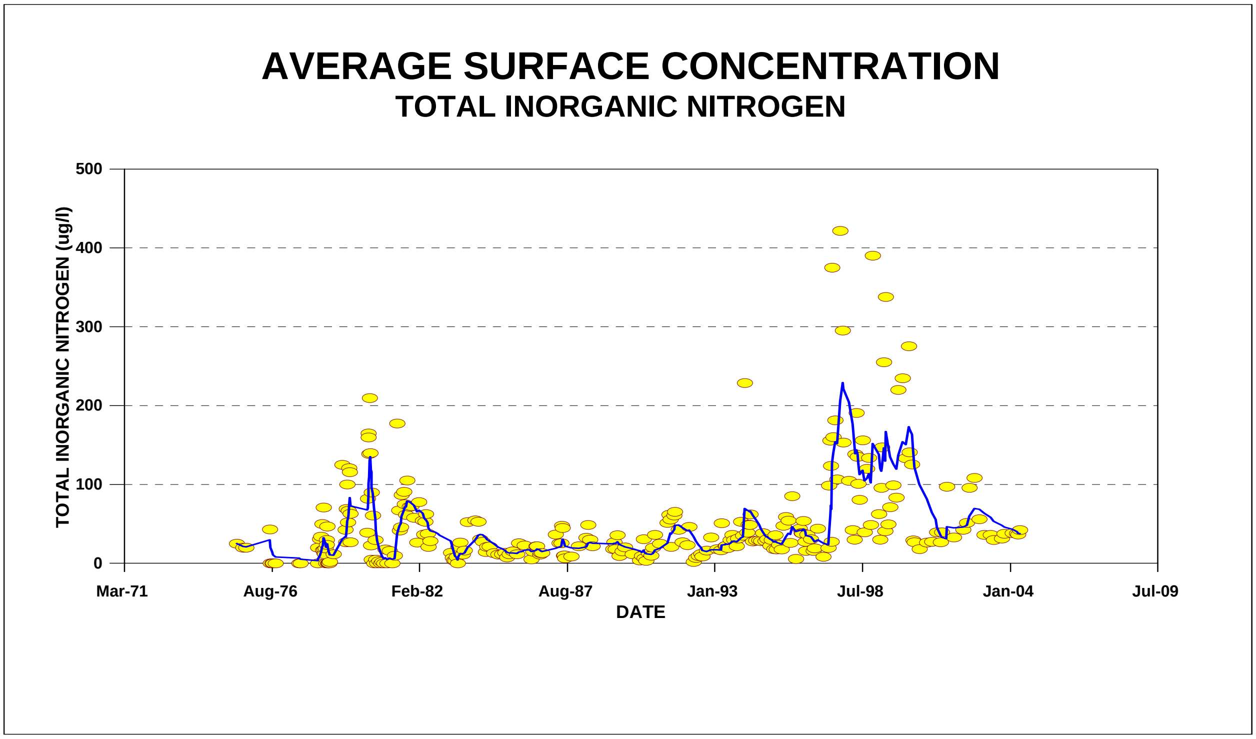

AVERAGE BOTTOM CONCENTRATION
AMMONIA
AMMONIA (ug/l)
120
100
80
60
40
20
0
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE

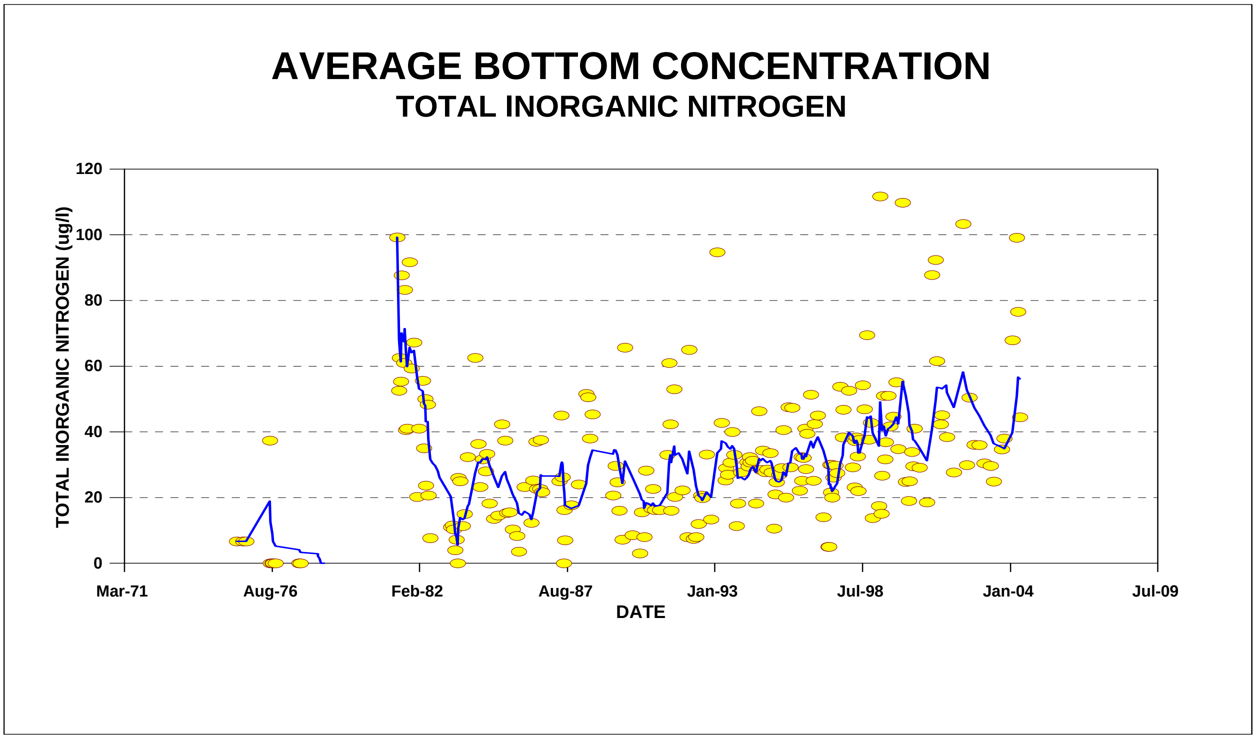

AVERAGE SURFACE CONCENTRATION
NITRATE
NITRATE (ug/l)
400
300
200
100
0
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE

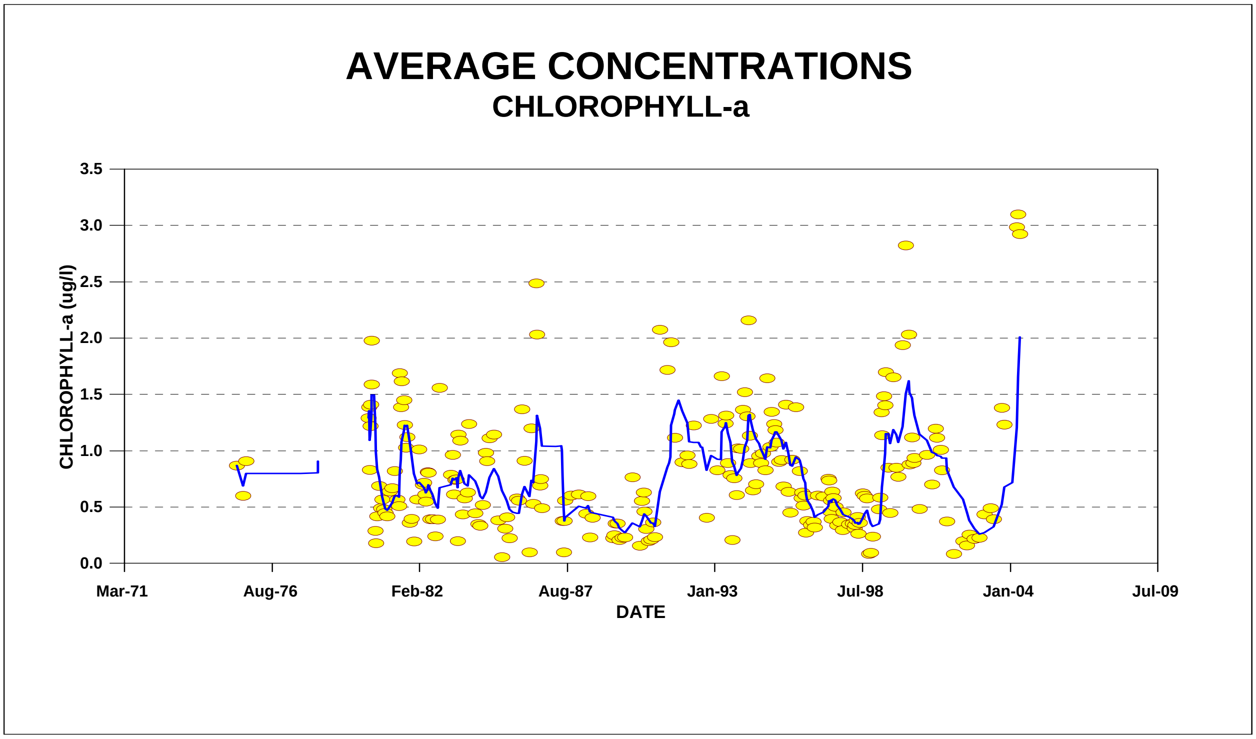

AVERAGE BOTTOM CONCENTRATION
NITRATE
NITRATE (ug/l)
100
80
60
40
20
0
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE

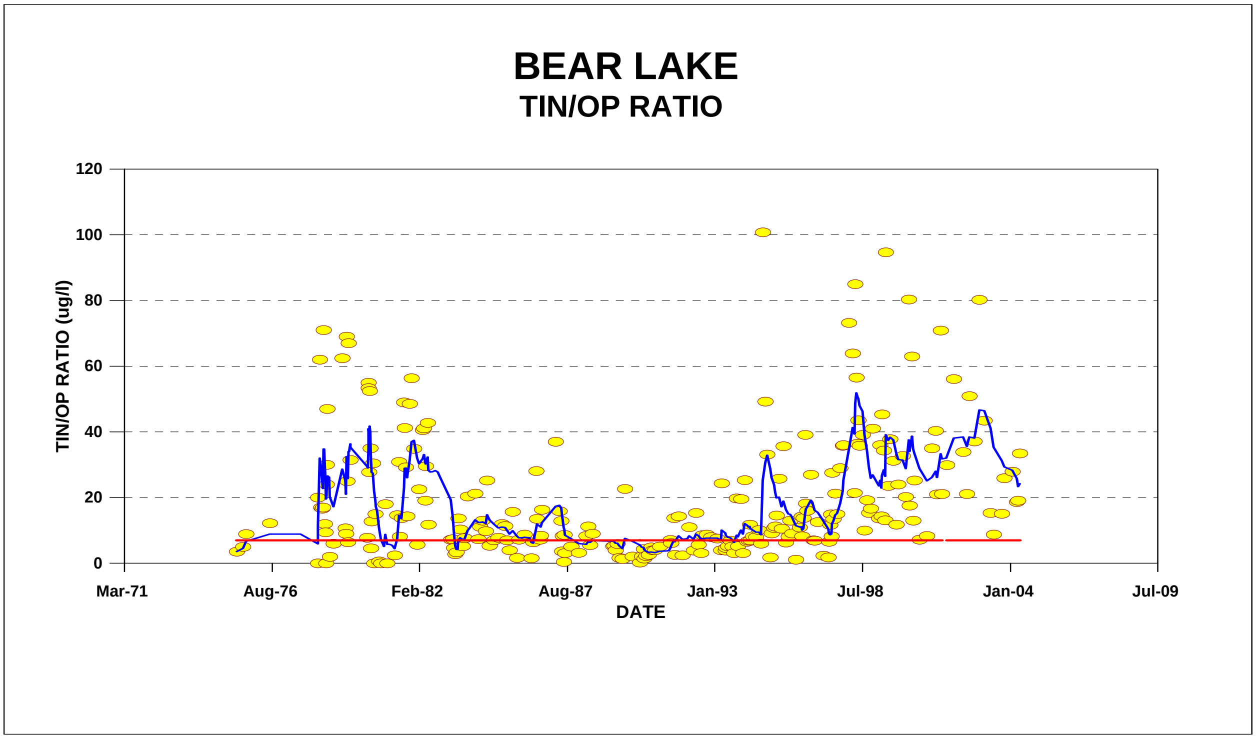

AVERAGE SURFACE CONCENTRATION
NITRITE
Spikes of over 100 µg/L were recorded in June and Sept 1997.
NITRITE (ug/l)
0
10
20
30
40
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE


AVERAGE BOTTOM CONCENTRATION
NITRITE
NITRITE (ug/l)
0
1
2
3
4
5
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE


AVERAGE SURFACE CONCENTRATION
TOTAL INORGANIC NITROGEN
TOTAL INORGANIC NITROGEN (ug/l)
500
400
300
200
100
0
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE


AVERAGE BOTTOM CONCENTRATION
TOTAL INORGANIC NITROGEN
TOTAL INORGANIC NITROGEN (ug/l)
120
100
80
60
40
20
0
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE


AVERAGE CONCENTRATIONS
CHLOROPHYLL-a
CHLOROPHYLL-a (ug/l)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE


BEAR LAKE
TIN/OP RATIO
120
100
80
60
40
20
0
TIN/OP RATIO (ug/l)
Mar-71
Aug-76
Feb-82
Aug-87
Jan-93
Jul-98
Jan-04
Jul-09
DATE

APPENDIX B

Raw Data

	DEPTH (meters)						
	0	**10**	**20**	**30**	**40**	**50**	**60**
Dissolved Oxygen (mg/L)							
10/14/03	8.20	7.69	7.61	9.19	7.16	5.80	4.92
10/30/03	8.80	9.05	9.32	7.62	6.62	5.18	4.66
02/17/04	10.52	9.92	9.75	9.35	9.12	8.56	5.31
04/13/04	10.73	13.62	11.28	9.57	9.28	8.83	4.67
05/04/04	10.72	10.87	10.96	10.71	10.41	9.51	8.42
06/01/04	8.88	9.02	8.91	9.38	9.21	8.40	7.98
Temperature (°C)							
10/14/03	13.9	13.8	13.7	7.7	5.6	5.1	4.9
10/30/03	11.1	11.1	8.7	6.0	5.1	4.9	4.9
02/17/04	0.5	2.1	2.5	2.7	2.8	3.0	3.4
04/13/04	4.7	4.3	4.2	3.9	3.6	3.5	3.4
05/04/04	8.0	7.3	6.1	5.6	5.1	4.5	4.1
06/01/04	10.5	9.9	9.7	7.3	5.5	4.9	4.7
pH (SU)							
10/14/03	8.38	8.45	8.50	8.32	8.19	8.15	8.12
10/30/03	8.47	8.59	8.64	8.57	8.51	8.43	8.39
02/17/04	8.97	9.17	9.28	9.31	9.29	9.24	8.99
04/13/04	8.20	8.47	8.83	9.00	9.13	9.24	8.94
05/04/04	7.12	7.41	7.88	8.36	8.67	8.82	8.79
06/01/04	6.68	7.05	7.57	7.66	7.92	8.30	8.57
Specific Conductivity (µmho/cm)							
10/14/03	711	711	711	714	720	723	724
10/30/03	711	710	712	719	723	723	724
02/17/04	754	717	708	707	708	712	730
04/13/04	707	706	707	709	715	724	739
05/04/04	710	713	715	715	721	725	704
06/01/04	702	699	697	701	711	714	703
Turbidity (NTU)							
10/14/03	10.3	8.6	8.1	10.3	12.4	15.1	26.3
10/30/03	9.5	8.5	8.8	11.5	11.9	18.4	24.5
02/17/04	9.0	7.2	6.9	6.9	7.1	9.6	
04/13/04	7.7	7.1	6.8	7.1	7.4	9.0	
05/04/04	10.3	9.9	9.5	9.3	9.3	10.6	6.1
06/01/04	4.5	4.5	4.5	4.6	4.3	4.9	

	DEPTH (meters)						
	0	**10**	**20**	**30**	**40**	**50**	**60**
Secchi Transparency (m)							
09/25/03	ND						
10/30/03	3.9						
02/17/04	ND						
04/13/04	5.8						
05/04/04	5.6						
06/01/04	5.7						
Total Phosphorus (μg/L)							
09/25/03	<6	<6	<6	<6	<6	<6	18
10/30/03	<6	<6	<6	25	<6	10	58
02/17/04	<6	<6	<6	<6	<6	11	25
04/13/04	<5	<5	<5	<5	<5	<5	9
05/04/04	<5	<5	<5	<5	<5	<5	<5
06/01/04	<5	6	7	6	5	7	7
Orthophosphorus (μg/L)							
09/25/03	2	2	2	2	2	2	2
10/30/03	1	2	2	2	1	2	2
02/17/04	1	<1	<1	<1	2	2	5
04/13/04	3	6	1	4	2	2	6
05/04/04	3	2	2	2	2	4	3
06/01/04	2	1	3	1	1	1	1
Nitrate+Nitrite (μg/L)							
09/25/03	5	<4	<4	<4	<4	5	9
10/30/03	<4	<4	<4	<4	<4	4	13
02/17/04	7	6	4	<4	5	46	54
04/13/04	7	10	12	8	10	34	62
05/04/04	8	8	8	8	13	16	23
06/01/04	10	9	49	9	9	14	17
Nitrite (μg/L)							
09/25/03	0.6	0.6	0.8	0.7	0.8	0.8	0.8
10/30/03	0.6	<0.3	0.8	0.7	0.8	0.7	0.9
02/17/04	0.6	0.5	0.5	0.5	0.8	1	1.2
04/13/04	0.8	0.9	0.8	0.8	0.9	1.6	2.5
05/04/04	0.8	0.8	0.8	1.1	1	1.1	1.1
06/01/04	1	1	1	1	1	1	1

	DEPTH (meters)						
	0	**10**	**20**	**30**	**40**	**50**	**60**
Ammonia (μg/L)							
09/25/03	28	28	28	31	28	28	31
10/30/03	36	35	75	41	33	31	30
02/17/04	33	31	35	30	31	33	35
04/13/04	31	28	29	32	35	95	62
05/04/04	29	29	29	29	30	29	117
Total Suspended Solids (mg/L)							
09/25/03	<1	<1	2.3	1.8	2.3	2.9	15.7
10/30/03	1.4	1.2	2.3	1.4	2.5	6.2	146
02/17/04	<1	<1	<1	<1	<1	<1	<1
04/13/04	<1	<1	<1	1.2	<1	2.5	7.6
05/04/04	<1	<1	<1	<1	<1	2	3.6
06/01/04	<1	<1	<1	<1	<1	1.3	2.3
Chlorophyll-a (μg/L)							
09/25/03	0.44	0.5	2.27	2.91	1.27	0.83	1.46
10/30/03	0.99	1.27	1.88	0.66	0.94	1.1	1.78
02/17/04	19.43	9.71	5.74	2.43	1.06	3.11	5.39
04/13/04	2.52	3.47	3.74	4.01	2.94	2.54	1.68
05/04/04	1.44	2.52	3.47	4.54	2.99	2.99	3.74
06/01/04	2.76	2.76	3.83	3.59	2.4	2.64	2.52