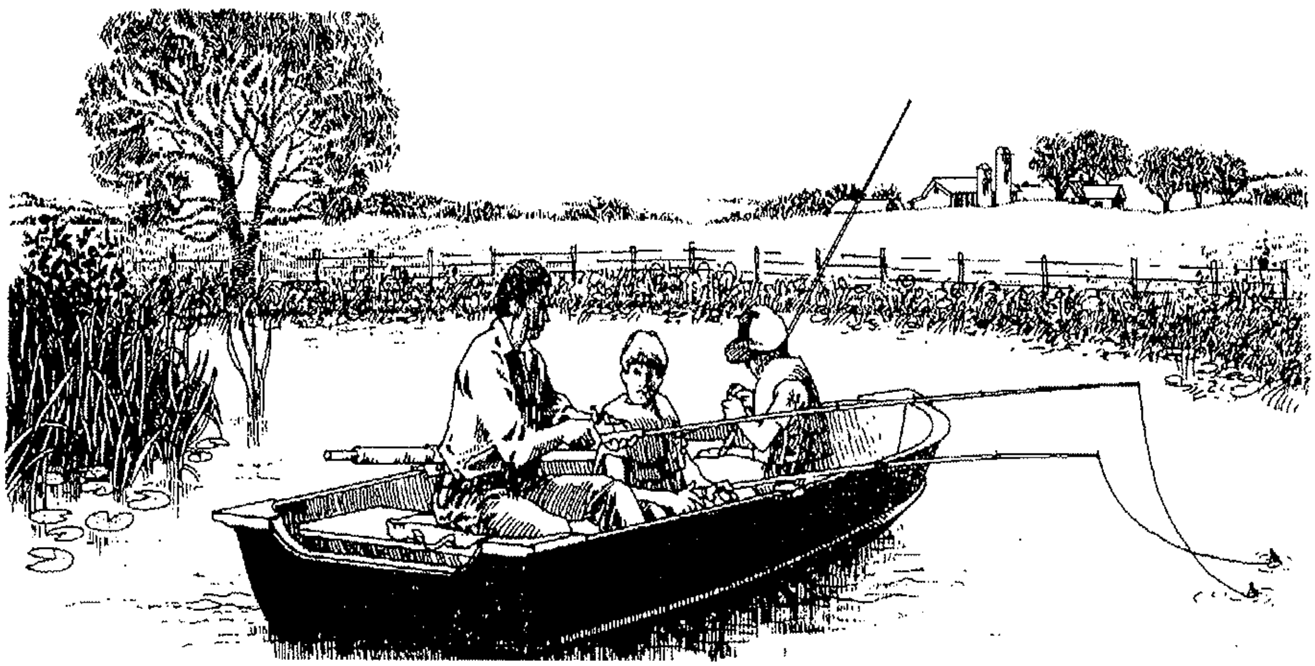
Bass Lake Restoration Project
Final Report

November 2008



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Project Setting

Bass lake, located in southwest Marinette County, is a 37.4 acre hard water drainage lake with a maximum depth of 62 feet and an average depth of 23 ft. Bass lake is dimictic and exhibits very strong thermal stratification due to its small surface area relative to mean depth (stratification factor = 42.7). The Bass lake shoreline is dominated by low-lying cedar swamp with limited upland areas. Development is limited to four private dwellings, giving the lake a strong wilderness character.

Bass Lake receives drainage from a 3.4 acre unnamed spring lake, a spring-fed farm pond and several spring seeps located north of the lake (Figure 1). Surface runoff from approximately 451 acres of land drains to the lake. Approximately 83% of the watershed is cropland. Prior to 1999 there were two dairy farms located north of the lake that owned or operated all of the cropland in the Bass Lake watershed.

Bass Lake has a long history of water quality problems caused primarily by animal waste runoff from unconfined manure stacks and feedlots. In the mid 1960's, the lake supported a diverse sport fishery and was popular with local anglers. The fish population included largemouth bass, northern pike, and panfish. The Wisconsin Department of Natural Resources (WDNR) also stocked trout in Bass Lake for several years. However, trout stocking was suspended in 1975 after hypolimnetic oxygen concentrations declined and the lake could no longer support a coldwater fishery. Subsequent

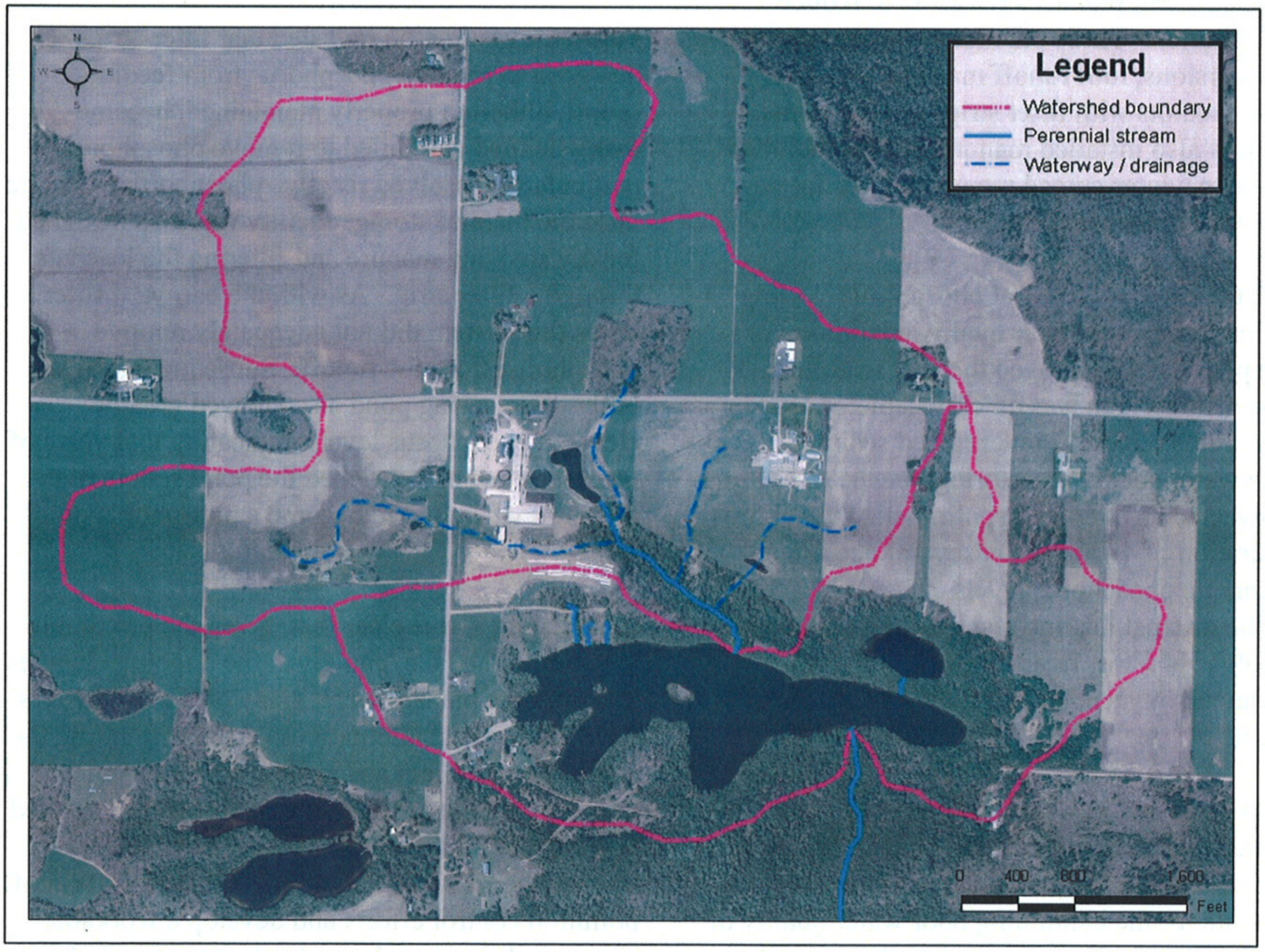

Figure 1. Bass Lake watershed and drainage patterns.

winter fish kills decimated the lake's warm water fishery as well. Between 1977 and 1991 the average dissolved oxygen concentration measured one meter below the ice in February was 2.24 mg/l with frequent periods of nearly complete anoxia. During the summer months massive algae blooms that reduced visibility and repressed aquatic macrophyte growth plagued Bass Lake.

History of Nonpoint Source Pollution Control Efforts

Bass Lake was selected as a small-scale priority watershed project under the Wisconsin DNR Nonpoint Source Pollution Control Program in 1984. The goal of the project was to reduce runoff pollution to Bass Lake from agricultural sources located in the watershed. Both farm operators cooperated fully and installed the recommended best management practices (BMP's) to reduce runoff pollution. These practices included clean water diversions, roof runoff management, and concrete feedlots with filter strips at both farms. Both farms also installed manure storage facilities to eliminate winter-spread manure and facilitate proper nutrient management.

Despite these efforts internal phosphorus loading continued to degrade water quality conditions. During periods of prolonged thermal stratification, hypolimnetic oxygen was quickly depleted leading to phosphorus release from enriched sediments. Routine water quality monitoring between 1977 and 1995 revealed an average hypolimnetic phosphorus concentration of 490 ug/l. On several occasions hypolimnetic phosphorus levels exceeded 1,000 ug/l. The internal loading resulted in continuing severe algae blooms, rapid depletion of hypolimnetic oxygen, and periodic incidences of winterkill.

By 1994 State and local resource agencies believed that watershed sources had been adequately controlled and that internal loading alone was responsible for the continuing poor water quality of Bass Lake. In an effort to complete the restoration the Marinette County Land & Water Conservation Division (LWCD) applied for and received a Wisconsin DNR Lake Protection Grant to inactivate phosphorus laden bottom sediment with alum. The alum treatment was originally scheduled for July 1996. However, on June 17, 1996 LWCD staff made a discovery that caused the alum treatment to be canceled.

Suspecting that some of the best management practices were not working as planned, staff collected several runoff samples throughout the watershed after a significant rain event. The results of these analyses were shocking. Samples collected from two waterways draining more than 90% of the watershed area contained an average of 351ug/l phosphorus. Samples collected below the two active farms contained 16,300 ug/l and 16,500 ug/l respectively. A sample collected at the mouth of the inlet contained 2,560 ug/l of phosphorus.

Further investigation revealed that filter strips designed to remove phosphorus from feedlot runoff, although properly maintained, became overwhelmed and failed to remove phosphorus, particularly dissolved reactive phosphorus. On one farm the manure storage facility was also designed for dry stacking manure and filtering the leachate through a filter strip. As with the barnyard filter strips this system did not adequately remove phosphorus from the runoff. Subsequent analysis of the farm spring pond also showed greatly elevated phosphorus levels, indicating that years of feedlot runoff had enriched the pond sediment to the point where it had become a phosphorus point source.

In hindsight it was clear that, given the proximate location to the lake, and given the ongoing changes in dairy cow management, many of the old BMP's were not the best alternatives. After discussing the continuing problem and reviewing management options with the farm operators the LWCD applied for and received a WDNR Targeted Runoff Management (TRM) Grant in 1999 to revisit runoff pollution control efforts and develop a workable plan to reduce phosphorus loading to Bass Lake. On one farm TRM funds were used to abandon the concrete feedlot. The landowner used the abandonment funds to build a freestall facility where animals could be permanently housed. A second liquid manure storage facility was also constructed and enriched sediment was dredged from the spring pond. With this move direct animal waste runoff from the farm was eliminated. General farmstead runoff was also diverted away from the spring pond and routed through a newly constructed wetland scrape and sediment control basin.

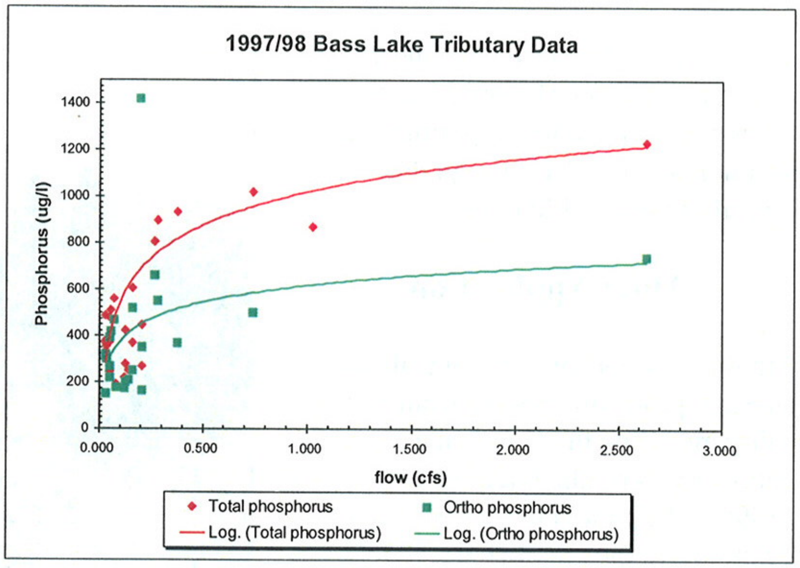

Figure 2. Relationship between phosphorus concentration and flow for the Bass Lake inlet.

On the second farm the operator entered into a farm abandonment agreement. All cattle were removed from the site and Wisconsin Stewardship Program funds were utilized to purchase a conservation easement on more than 55 acres of cropland and almost 2000 feet of Bass Lake's shoreline. Two water and sediment control basins were also installed in the easement area using U.S. Fish and Wildlife Service funds to further reduce sediment and nutrient runoff from cropped fields and to provide additional wildlife habitat.

Pre-Alum Treatment Water Quality Modeling

After canceling the alum treatment the County LWCD received a Lake Planning Grant to study phosphorus loading to Bass Lake and model in-lake water quality to more accurately determine if an alum treatment would be effective. In May 1997 a v-notch weir was constructed on the lake inlet approximately 120 feet from the lakeshore. A continuous stage recorder was installed to allow for daily flow monitoring and grab samples were collected at various flow levels throughout the monitoring period.

Two years of runoff monitoring clearly showed an increase in phosphorus concentration with increasing flow (Figure 2). Water quality analysis also revealed that during dry periods when surface runoff was absent (flows less than 0.15 cfs) the phosphorus concentration remained elevated with an average of 370 ug/l. This indicated that upstream wetland areas had received so much animal waste they acted as a phosphorus source.

The US Army Corps of Engineers Flux model was used to predict phosphorus loading to Bass Lake based on the flow record and periodic grab samples. The monitoring period covered most of the open water season (March to October) and predicted a phosphorus load of approximately 75 kg of phosphorus during the open water season. It was estimated that 15 kg/yr could be attributed to base flow with the balance coming from runoff events.

Using the Wisconsin Lake Model Spreadsheet (WILMS) it was estimated that Bass Lake would be able to assimilate the base phosphorus loading and still maintain acceptable water quality if internal loading could be addressed and runoff event loads could be drastically reduced. Assuming runoff event loading could be controlled the WILMS model predicted a post-alum treatment spring turnover phosphorus concentration of 12 - 24ug/l.

Long term monitoring also suggested the lake would be able to assimilate the elevated base flow loading without an appreciable decrease in water quality. Bass lake is a hard water lake and marl formation appears to remove a significant amount of phosphorus from the water. Indeed, between the spring of 1996 and the fall of 1998 Bass Lake did not experience complete mixing during spring or fall turnover and surface phosphorus levels remained at or below 33 ug/l. During the same period hypolimnetic phosphorus reached 1700 ug/l due primarily to internal loading.

Alum Application

Figure 3. Bass Lake alum treatment, November 3, 1999.

With the new phosphorus controls in place and promising results from water quality modeling the Bass Lake alum treatment was rescheduled for November 3, 1999. The contractor, Sweetwater Technologies Inc., applied 61,475 gallons of alum to the surface of Bass Lake during a two-day period. Weather conditions were favorable and the entire process was completed without complication (Figure. 3). The original grant project called for applying approximately 12,000 gallons of alum to Bass Lake for an in-lake concentration of 2.1 mg/l of Al^{+3}. However, after studying the success of past alum treatments and consulting a variety of lake management experts it was decided that increasing the dosage to maximize phosphorus control at the sediment water interface would improve the chances for long-term success (Rydin and Welch 1998), (Kennedy and Cooke 1982). A titration of lake water with liquid alum revealed that the lake had the buffering capacity to assimilate a dose of 21.9 mg/l of Al^{+3}. In the end, the grant budget was increased to allow for an alum dose of 61,000 gallons, resulting in an in-lake concentration of 10mg/l of Al^{+3}, far below the maximum safe dose. On an aerial basis 91g/m^2 of Al^{+3} was deposited on the sediment surface, more than twice the level of other successful alum treatments in Wisconsin lakes.

Post Application Water Quality

Prior to the November 3, 1999 alum application Bass Lake was still stratified with a hypolimnetic phosphorus concentration of 1,200 ug/l and a surface concentration of 36 ug/l. The Secchi disk depth was 11 ft. In the months following the treatment water quality was closely monitored to track reductions in hypolimnetic phosphorus.

Immediately after the alum application the lake turned a milky white as aluminum floc formed in the water column. Five days later there was still a significant amount of floc suspended in the water column and the Secchi disk depth had decreased to 9 feet, and the surface phosphorus concentration had fallen slightly to 26 ug/l. The most striking change was hypolimnetic phosphorus that declined 42% to 696 ug/l. After fall turnover the surface phosphorus concentration increased to 64 ug/l while the hypolimnetic phosphorus declined 93% to 82 ug/l. By the spring of 2000 phosphorus levels at the surface and in the hypolimnion had stabilized at 30ug/l and 26 ug/l respectively.

Long Term Trends in Water Quality

Internal Phosphorus Loading

In the nine years since the Bass Lake alum treatment water quality monitoring has been extensive, providing a nearly complete picture of water quality conditions during the open water season. The data clearly indicates a significant and lasting improvement in water quality (figure 4).

Prior to the alum application, between 1996 and 1999, the average hypolimnetic phosphorus concentration was 1,061 ug/l. Post-treatment hypolimnetic phosphorus levels fell dramatically,

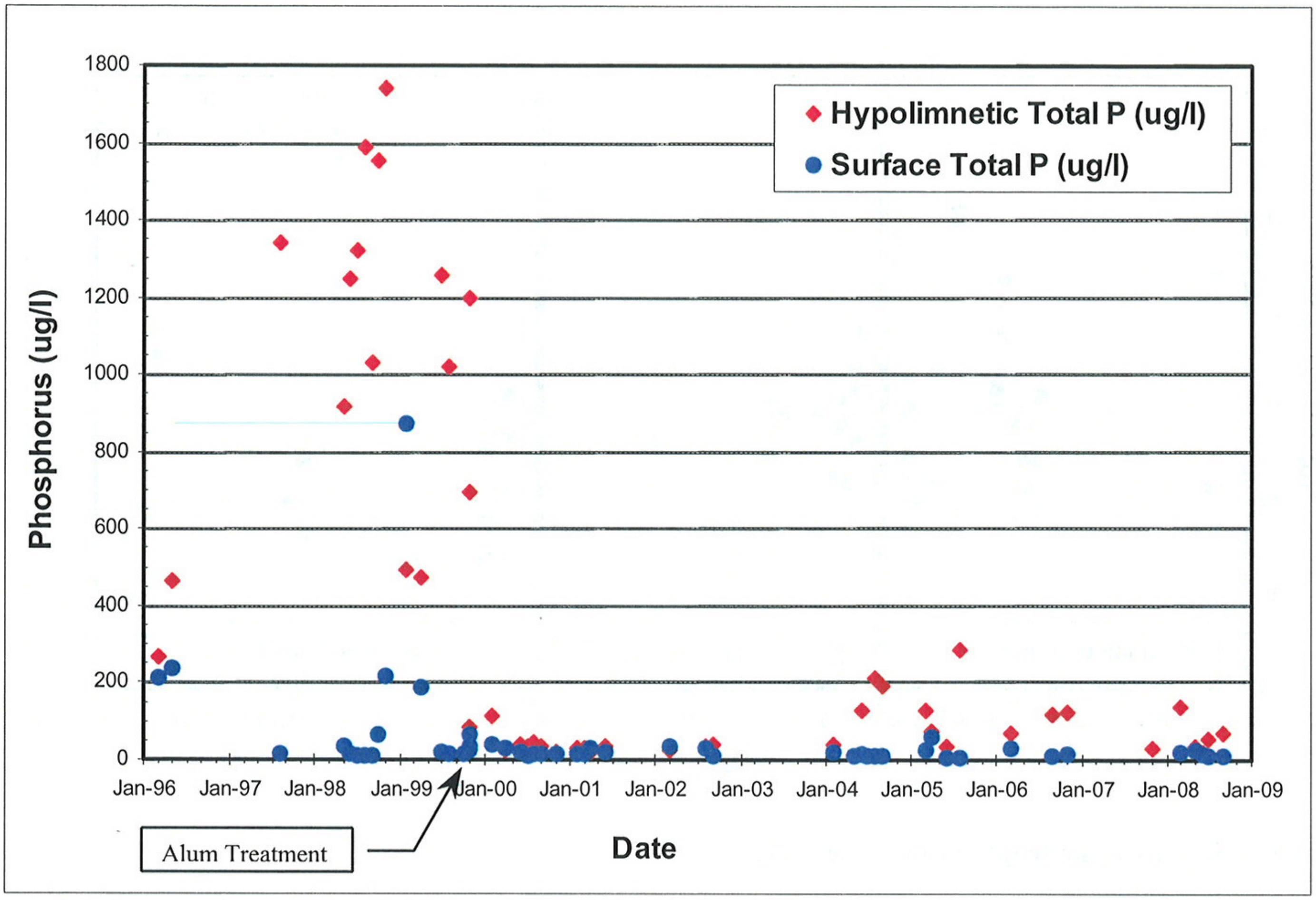

Figure 4. Bass Lake phosphorus levels.

averaging only 35.7 ug/l for the next three years, indicating a nearly complete disruption of internal phosphorus loading. This occurred despite routine hypolimnetic anoxia during periods of stratification. Between 2004 and 2008 the average hypolimntetic phosphorus level increased to 102.7 ug/l. While the increase is significant, there is no obvious trend upward during the period. It is unclear if the increase is due to phosphorus release from below the alum layer or if it's due to new sediment deposited above the alum layer.

The disruption of internal phosphorus loading mechanisms in Bass Lake has resulted in significant improvements in the lakes water quality. Long-term-trend monitoring conducted by the Wisconsin DNR shows a ten-year (1982-1992) average surface phosphorus concentration of 124.6 ug/l. In the four years prior to the alum application (1996-1999) surface total phosphorus averaged 123 ug/l. In the nine years since the alum treatment the average phosphorus concentration at the surface has fallen to 19ug/l, an 85% reduction.

The improved nutrient status of Bass Lake has led to significant improvements in the lakes trophic state. A review of Wisconsin trophic state index values shows water quality can be divided into three distinct periods during the last 13 years as seen in figure 5. Prior to the alum application trophic state values fluctuated wildly as the lake experienced massive algae blooms and extremely turbid water followed by crashes and crystal clear water. During this period the average phosphorus and chlorophyll-a TSI values were in the eutrophic range (50 or higher) while Secchi TSI's averaged 49.3.

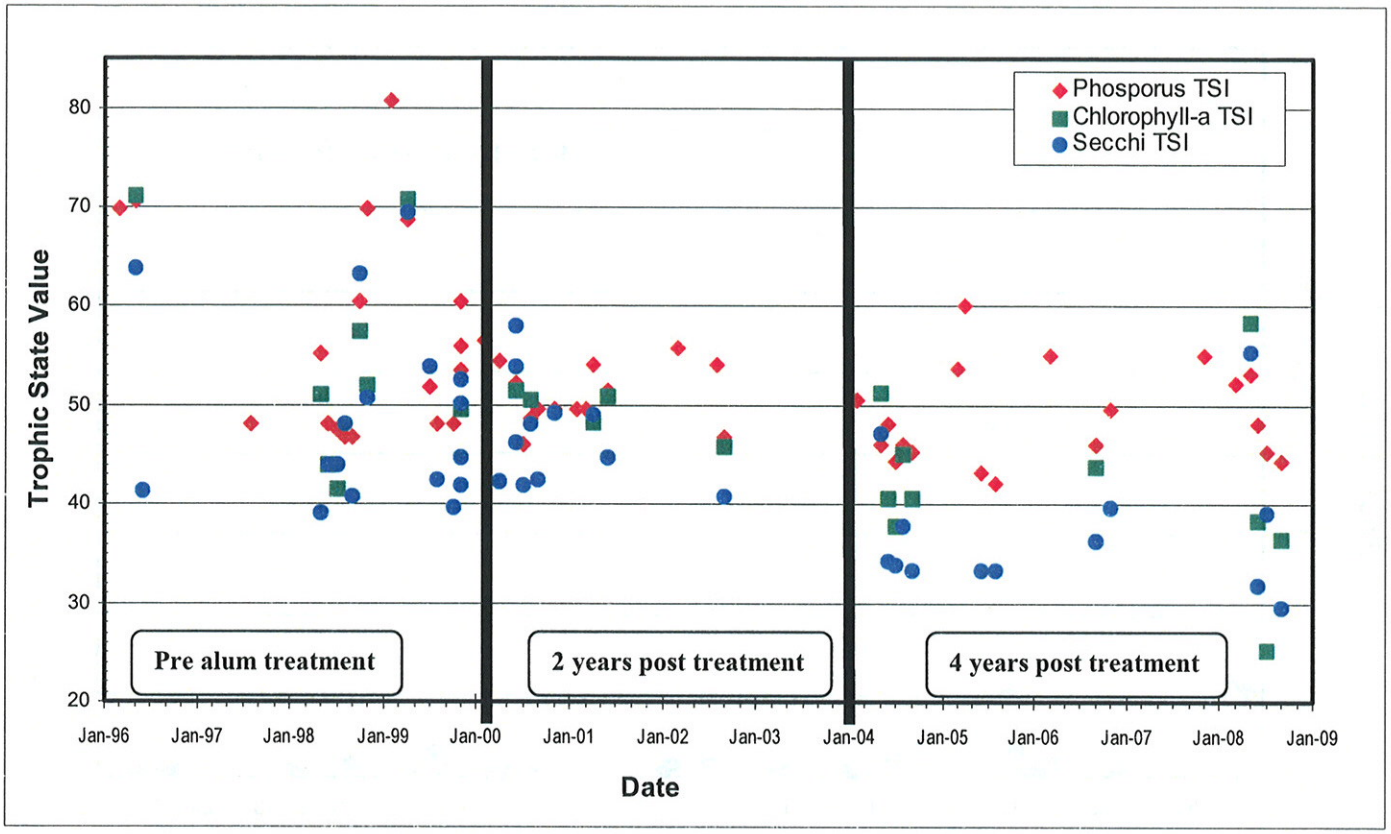

Figure 5. Bass Lake trophic state index values

The three years immediately following the alum application were marked by an absence of these wild swings in water quality. During this period phosphorus TSI's were in the upper mesotrophic to eutrophic range (average 51.3) while chlorophyll TSI (avg. 49.4) and Secchi TSI (avg. 47.0) were in the upper mesotrophic range.

Despite a slight increase in hypolimnetic phosphorus levels, surface water quality during the last five years has continued to improve. While spring turnover often resulted in slightly elevated phosphorus readings the average phosphorus TSI remained in the upper mesotrophic range (49.1). During this period water clarity has continued to improve. The average chlorophyll TSI during the period was 41.7 while the Secchi TSI was an impressive 37.3, solidly in the oligotrophic range. Indeed, the final monitoring event of 2008 revealed a 27-foot Secchi disk depth! A complete water chemistry record for Bass Lake can be found in Appendix A.

External Phosphorus Loading

The most recent monitoring program included an updated assessment of watershed phosphorus loading. To this end the original v-notch weir was reconstructed and a TELOG WLS-2109e Level Tracker was installed to record water levels from which a continuous flow record could be calculated. The Level Tracker was programmed to measure the water level every 5 minutes and record the minimum, average, and maximum water level every two hours. Grab samples were collected throughout the season at a variety of flow regimes.

A comparison of flow records for 1997/98 and 2008 (figure 6) shows that peak flows are similar as are the magnitude and duration of runoff events. Most of the variability occurs in the number of summer rain events. During both monitoring periods "base flow" representing spring seeps, wetland discharge and outflow from the spring-fed farm pond stabilized at 0.03-0.15 cfs during the summer months.

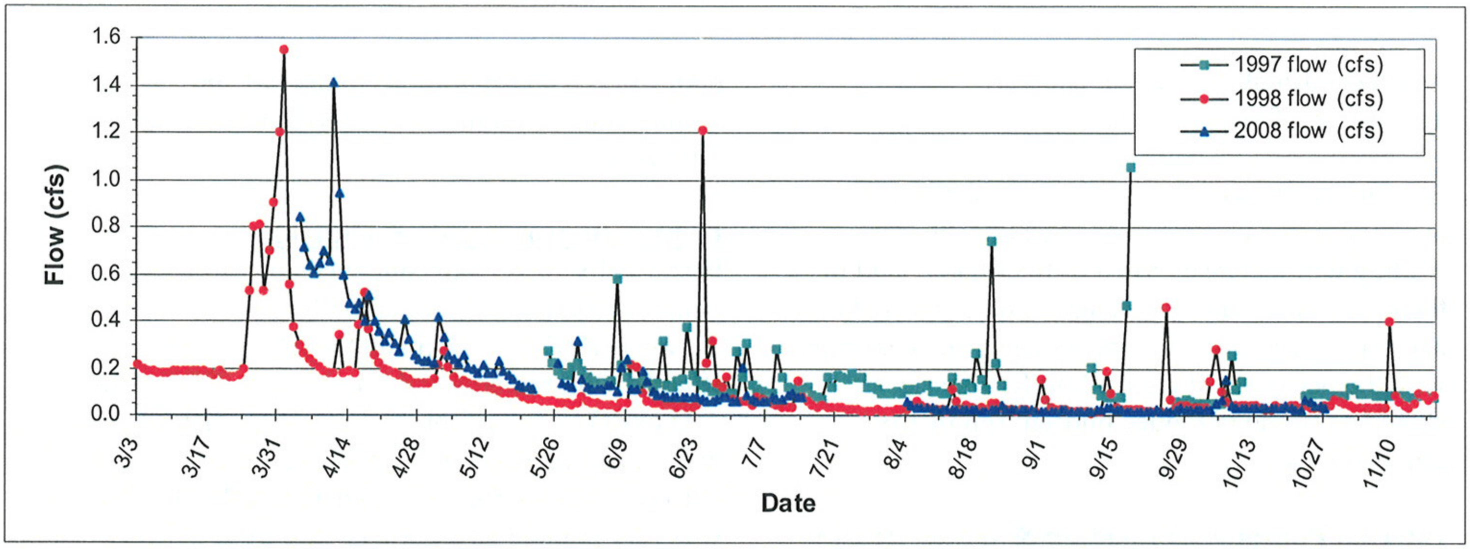

Figure 6. Bass Lake flow record.

An analysis of phosphorus data from the two sample periods shows some striking changes. In 1997/98 the average base flow phosphorus concentration (flows less than 0.15 cfs) was 370 ug/l. For all flows exceeding 0.15 cfs the average was 699 ug/l indicating a significant amount of phosphorus loading from runoff events. In 2008 the average base flow phosphorus concentration fell by 39% to 227 ug/l. At higher flow the change in phosphorus concentration was even more striking. For flows exceeding 0.15 cfs the average phosphorus concentration in 2008 was 127 ug/l, an 82% reduction. The reversal of the concentration/ flow relationship is clearly illustrated in figure 7.

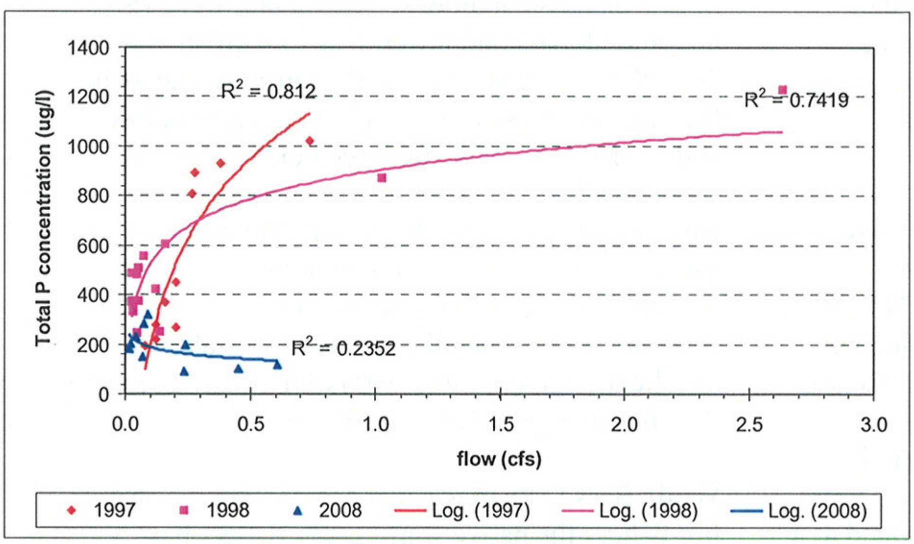

Figure 7. Bass Lake inlet phosphorus loading, concentration/flow relationship.

Watershed phosphorus loads for 1998 and 2008 were estimated using the US Army Corps of Engineers FLUX32 load estimation software (beta version 1.76). During the 1998 monitoring period (213 days) the Flux model predicted an annual phosphorus load of 75 kg/y. For the 2008 monitoring period (208 days) the predicted phosphorus load was 20 kg/y, a 73% reduction. A complete record of tributary monitoring results and FLUX model outputs can be found in Appendix B.

Water Quality Trends and the Future of Bass Lake

Watershed Phosphorus Loading

Water quality monitoring and load modeling clearly show a significant reduction in phosphorus loading to Bass Lake. These reductions have come primarily by eliminating feedlot runoff and ineffective animal waste storage facilities. If the water quality improvements are to be maintained it is imperative that farm operators continue to divert clean water from farmstead and feed storage areas, confine livestock to eliminated animal waste runoff, maintain adequate manure storage capacity, and manage nutrients to prevent excessive field application of phosphorus.

Barring any drastic changes in watershed land use it is unlikely that general watershed phosphorus loading will increase. Most of the tillable land in the watershed is already in agricultural production and improved nutrient management practices along with the necessity of controlling fertilizer costs should continue to reduce nutrient runoff from cropped areas.

Internal Phosphorus Loading & Water Quality Outlook

Nine years of monitoring data clearly illustrates the success of the 1999 Bass Lake alum treatment. The slight increase in hypolimnetic phosphorus loading seen during the past five years, while not inconsequential, represents a drastic improvement in internal loading. Currently average hypolimnetic phosphorus levels are still nearly 90% lower than they were in the two decades preceding the alum treatment. As noted, the recent increase in internal loading has not resulted in decreased water quality. On the contrary, all trophic state indices have continued to improve since the alum treatment.

Studies by Welch et al. (1999) and Smeltzer et al. (1999) show that the long-term success of alum treatments in stratified dimictic lakes is dependent on interruption of external loading. Given the greatly reduced watershed phosphorus loading experienced at Bass Lake it seems likely that water quality improvements will continue into the foreseeable future.

While the alum application has greatly reduced internal phosphorus loading, Bass Lake still experiences routine hypolimnetic anoxia. However, due to increased water clarity the photic zone has greatly expanded. Allowing for oxygen production below the thermocline. While the late-summer thermocline can generally be found between three and four meters depth, during the last several years well oxygenated water can commonly be found at a depth of 8 meters or more. This increased volume of oxygenated water has reduced the incidence of poor oxygen concentrations in the fall and eliminated winterkill conditions during the last nine years.

Fishery Improvements & Outlook

Historically Bass Lake contained a warm water fishery dominated by largemouth bass and bluegill. Between 1965 and 1975 and the lake was also stocked with rainbow and brook trout. While little data exists to document the state of the fishery prior to the discovery of water quality problems, Wisconsin DNR fish managers report that the lake was very popular as a put-and-take trout fishery.

By 1975 dissolved oxygen levels in Bass Lake had already declined to the point where trout stocking was discontinued. For the next 20 years the fishery was severely suppressed but never eliminated. Although winterkill conditions were common some fish always survive in the neighboring unnamed spring lake and repopulate Bass Lake as conditions improved.

Limited fish surveys were conducted in 1985, 2001, and again in 2008. The surveys were conducted with electrofishing equipment and consisted of one complete circuit of the lakeshore at night. Fish population estimates were not conducted. In 1985 the fishery consisted primarily of golden shiners and black bullhead, both tolerant of low oxygen conditions. Also found were 15 largemouth bass and fewer than 75 panfish. By 2001 the fishery showed marked improvements in the number and size structure of largemouth bass and panfish. In 2008 100 largemouth bass were sampled with 15% of the fish exceeding legal harvestable size (14 inches). The 08 survey also found an excellent panfish population with 250 bluegill and nearly 300 panfish in total. The size structure of the bluegill population was also excellent with more than 10% of the fish exceeding 7 inches in length (Kornely, 2008).

While Bass Lake may never again support a two-tier fishery the native warm water fishery has experienced an impressive comeback due to water quality improvements. The conservation easement protecting nearly 2000 feet of shoreline habitat from development will also help assure a quality fishery for years to come.

References

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Appendix A

Lake Data

Bass Lake surface water chemistry data

(all samples collected 1 meter below the surface at the deepest part of the lake)

Date	Total P (ug/l)	Ortho P (ug/l)	Chlor-a (UG/L)	Secchi (ft)	Phosporus TSI	Chlorophyll-a TSI	Secchi TSI
03/11/96	214	168			69.7		
05/02/96	236	18	121.0	2.5	70.5	71.1	63.9
06/17/96				12.0			41.3
08/06/97	13				48.1		
05/06/98	33	2	8.7	14.0	55.3	51.1	39.1
06/24/98	13	2	3.4	10.0	48.1	44.0	43.9
07/16/98	12	3	2.4	10.0	47.5	41.5	43.9
08/19/98	11			7.5	46.8		48.1
09/17/98	11	4		12.5	46.8		40.7
10/26/98	64		19.8	2.6	60.4	57.4	63.4
11/23/98	218	136	9.6	6.2	69.9	51.9	50.7
02/17/99	872	150			80.6		
04/14/99	186		115.0	1.7	68.7	70.7	69.5
07/30/99	21	2		5.0	51.8		54.0
08/31/99	13			11.0	48.1		42.5
10/04/99	13			13.5	48.1		39.6
11/01/99	36	2	7.0	6.5	56.0	49.5	50.1
Alum treatment 11/2/99 through 11/3/99							
11/04/99	no chemistries			11.5			41.9
11/08/99	26	ND		9.5	53.4		44.7
11/30/99	64	3	7.0	5.5	60.4	49.5	52.5
02/16/00	39	8			56.6		
04/26/00	30	ND		11.2	54.5		42.3
06/02/00	22	ND		8.5	52.1		46.3
06/13/00	20	ND	9.0	5.0	51.4	51.4	53.9
06/30/00	20	2		3.8	51.4		58.1
07/17/00	10	ND		11.5	46.0		41.9
08/16/00	14	ND	8.0	7.5	48.6	50.5	48.1
09/14/00	16	ND		11.0	49.7		42.5
11/22/00	16	2		6.9	49.7		49.3
02/12/01	16	ND			49.7		
03/07/01	16	ND			49.7		
04/26/01	28	ND	6.0	7.0	54.0	48.4	49.1
06/22/01	20	ND	8.4	9.5	51.4	50.9	44.7
03/13/02	35	ND			55.7		
04/05/02							
08/01/02	28	ND			54.0		
09/03/02	11		4.3	12.5	46.8	45.9	40.7
02/25/04	18	8			50.6		

Date	Total P (ug/l)	Ortho P (ug/l)	Chlor-a (UG/L)	Secchi (ft)	Phosporus TSI	Chlorophyll-a TSI	Secchi TSI
05/12/04	10		8.7	8.0	46.0	51.2	47.1
06/24/04	13		2.1	19.5	48.1	40.6	34.3
07/20/04	8		1.5	20.0	44.3	37.7	33.9
08/26/04	10		3.9	15.3	46.0	45.0	37.8
09/21/04	9		2.1	21.0	45.2	40.6	33.2
03/03/05	27	19			53.7		
04/14/05	61	ND			60.0		
06/22/05	7	3		21.0	43.3		33.2
08/25/05	6	ND		21.0	42.1		33.2
03/22/06	32	16			55.0		
09/21/06	10		3.3	17.0	46.0	43.8	36.3
11/08/06	16			13.5	49.7		39.6
11/28/07	32				55.0		
03/04/08	22	17			52.1		
05/05/08	25		22.7	4.5	53.1	58.4	55.4
06/24/08	13	ND	1.6	23.3	48.1	38.3	31.7
07/22/08	9	3	0.3	14.0	45.2	25.2	39.1
09/09/08	8	ND	1.2	27.0	44.3	36.4	29.6

Bass Lake hypolimnetic chemistry data

(all samples collected 1 meter from the bottom in 58 to 62 feet of water)

Date	Hypolimnetic Total P (ug/l)	Hypolimnetic Ortho P (ug/l)
03/11/1996	267.0	232.0
05/2/1996	463.0	408.0
08/6/1997	1340.0	1170.0
05/6/1998	915.0	810.0
06/24/1998	1250.0	1040.0
07/16/1998	1320.0	1140.0
08/19/1998	1590.0	1420.0
09/17/1998	1030.0	975.0
10/26/1998	1555.0	1500.0
11/23/1998	1740.0	1580.0
02/17/1999	491.0	374.0
04/14/1999	472.0	337.0
07/30/1999	1260.0	1150.0
08/31/1999	1020.0	
10/4/1999		
11/1/1999	1200.0	1120.0
11/8/1999	696.0	578.0
Alum treatment 11/2/99 through 11/3/99		
11/30/1999	82.0	11.0
02/16/2000	113.0	52.0
04/26/2000	26.0	ND
06/2/2000	23.0	ND
06/13/2000	38.0	ND
06/30/2000	25.0	5.0
07/17/2000	34.0	ND
08/16/2000	44.0	ND
09/14/2000	34.0	ND
11/22/2000	20.0	ND
02/12/2001	31.0	ND
03/7/2001	31.0	ND
04/26/2001	21.0	ND
06/22/2001	34.0	ND

Date	Hypolimnetic Total P (ug/l)	Hypolimnetic Ortho P (ug/l)
03/13/2002	23.0	5.0
08/1/2002	34.0	ND
09/3/2002	40.0	
02/25/2004	39.0	26.0
05/12/2004		
06/24/2004	128.0	
07/20/2004		
08/26/2004	212.0	
09/21/2004	193.0	
03/3/2005	128.0	19.0
04/14/2005	73.0	44.0
06/22/2005	36.0	ND
08/25/2005	284.0	193.0
03/22/2006	70.0	37.0
09/21/2006	116.0	
11/8/2006	122.0	
11/28/07	30	
03/04/08	137.0	100.0
05/05/08	33	
06/24/08	20	ND
07/22/08	55	13
09/09/08	70	17

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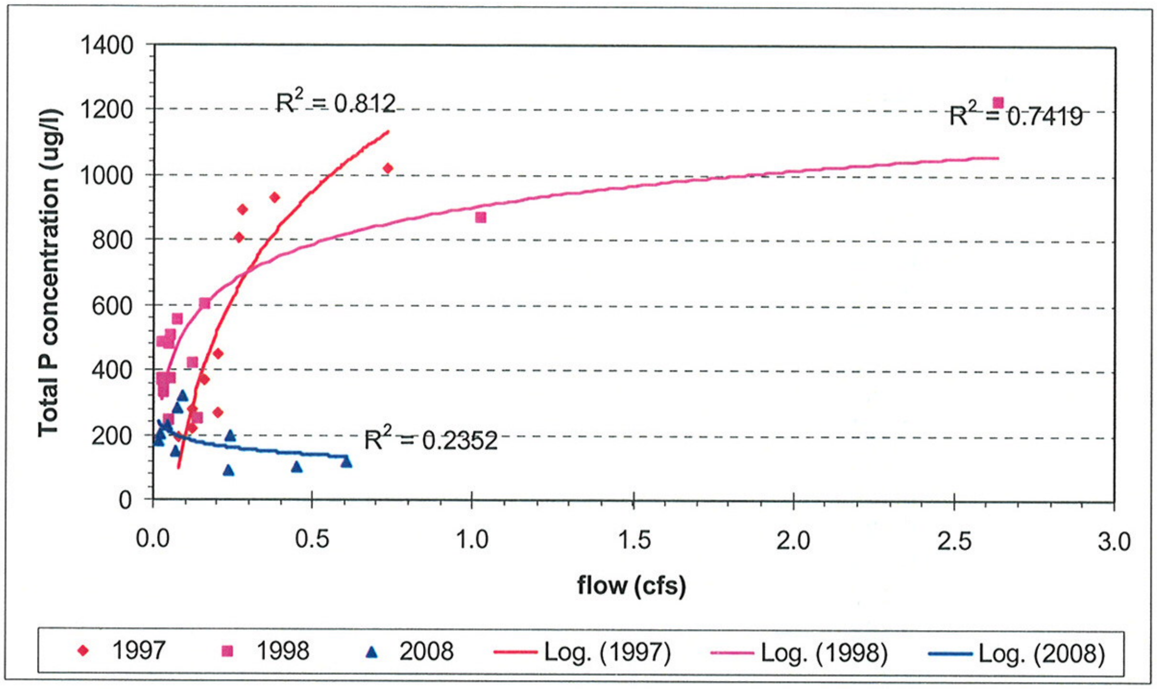
Appendix B

Tributary Data and Flux Model Results

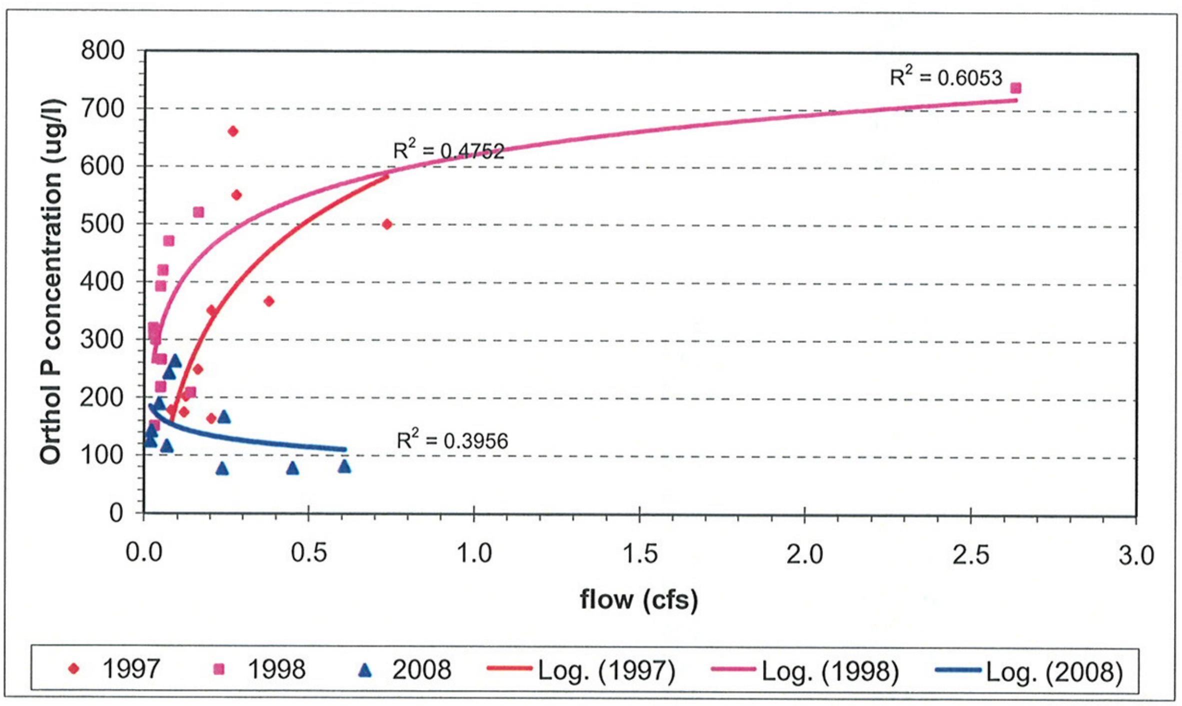
Tributary Water Quality Data

Grab samples were collected at the weir outlet, located approximately 120 feet from Bass Lake.

DATE	FLOW (cfs)	TOTAL P (ug/l)	ORTHO P (ug/l)
05/29/97	0.205	268	163
06/09/97	0.162	367	248
06/17/97	0.125	276	202
06/21/97	0.378	931	366
06/30/97	0.268	805	660
07/08/97	0.279	895	550
08/06/97	0.121	218	174
08/20/97	0.737	1020	500
09/09/97	0.204	447	350
11/06/97	0.082	190	178
04/01/98	1.027	870	
05/06/98	0.140	252	208
05/27/98	0.050	244	218
06/12/98	0.125	421	
06/24/98	0.052	375	266
06/25/98	2.634	1230	740
07/16/98	0.056	509	420
08/06/98	0.034	353	300
08/10/98	0.028	376	320
08/17/98	0.049	479	392
08/19/98	0.029	370	310
09/14/98	0.073	558	470
09/17/98	0.029	485	
10/05/98	0.163	606	520
10/26/98	0.033	330	151
04/07/08	0.608	115	82
04/15/08	0.451	104	79
05/05/08	0.237	90	78
06/09/08	0.242	200	167
06/24/08	0.068	151	117
07/18/08	0.092	319	264
07/22/08	0.074	281	243
09/09/08	0.019	180	125
09/22/08	0.021	202	143
10/09/08	0.044	230	190



Total P concentration (ug/l)
1400
1200
1000
800
600
400
200
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
flow (cfs)
R² = 0.812
R² = 0.7419
R² = 0.2352
1997
1998
2008
Log. (1997)
Log. (1998)
Log. (2008)



Orthol P concentration (ug/l)
800
700
600
500
400
300
200
100
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
flow (cfs)
R² = 0.6053
R² = 0.4752
R² = 0.3956
1997
1998
2008
Log. (1997)
Log. (1998)
Log. (2008)

Tribulary flow data

DATE	1997 flow (cfs)	1998 flow (cfs)	2008 flow (cfs)
3-Mar		0.214	
4-Mar		0.195	
5-Mar		0.188	
6-Mar		0.183	
7-Mar		0.177	
8-Mar		0.176	
9-Mar		0.180	
10-Mar		0.183	
11-Mar		0.188	
12-Mar		0.188	
13-Mar		0.188	
14-Mar		0.188	
15-Mar		0.188	
16-Mar		0.188	
17-Mar		0.177	
18-Mar		0.167	
19-Mar		0.184	
20-Mar		0.167	
21-Mar		0.163	
22-Mar		0.166	
23-Mar		0.170	
24-Mar		0.195	
25-Mar		0.526	
26-Mar		0.803	
27-Mar		0.809	
28-Mar		0.528	
29-Mar		0.700	
30-Mar		0.900	
31-Mar		1.200	
1-Apr		1.550	
2-Apr		0.551	
3-Apr		0.372	
4-Apr		0.300	0.847
5-Apr		0.262	0.712
6-Apr		0.235	0.634
7-Apr		0.220	0.608
8-Apr		0.206	0.648
9-Apr		0.187	0.696
10-Apr		0.175	0.654
11-Apr		0.182	1.413
12-Apr		0.340	0.944
13-Apr		0.179	0.594
14-Apr		0.186	0.475
15-Apr		0.175	0.451
16-Apr		0.385	0.477
17-Apr		0.522	0.402
18-Apr		0.366	0.507
19-Apr		0.257	0.402

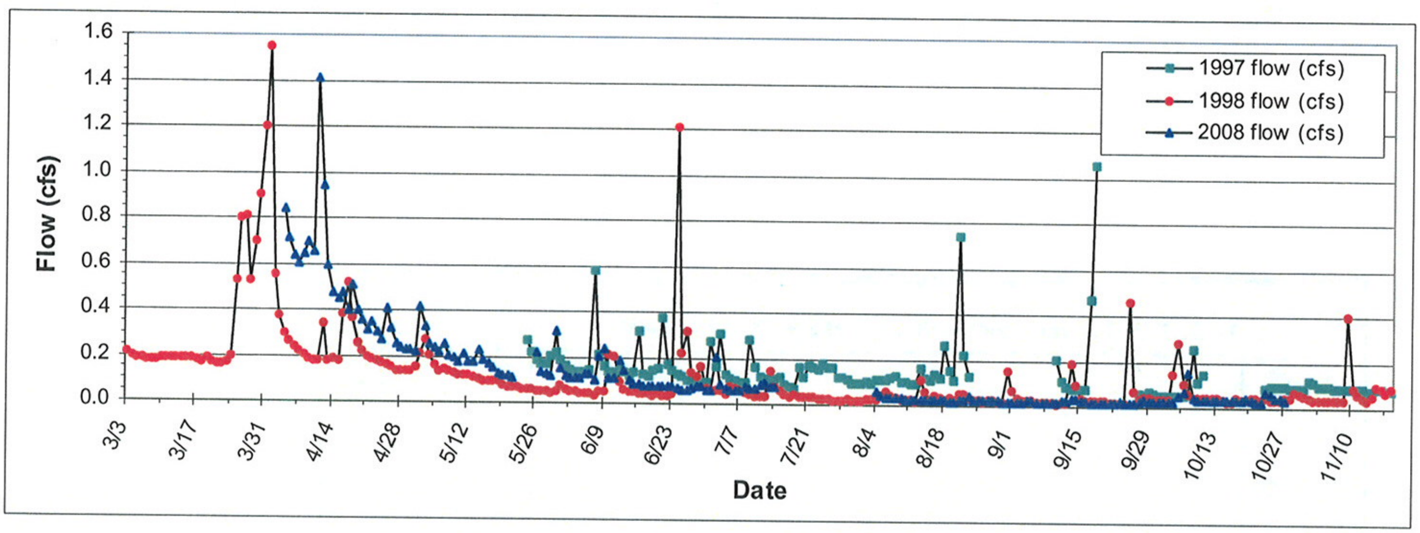
DATE	1997 flow (cfs)	1998 flow (cfs)	2008 flow (cfs)
20-Apr		0.220	0.354
21-Apr		0.196	0.317
22-Apr		0.188	0.349
23-Apr		0.183	0.304
24-Apr		0.170	0.273
25-Apr		0.163	0.405
26-Apr		0.156	0.323
27-Apr		0.140	0.258
28-Apr		0.140	0.241
29-Apr		0.140	0.232
30-Apr		0.140	0.227
1-May		0.156	0.225
2-May		0.214	0.417
3-May		0.276	0.330
4-May		0.204	0.252
5-May		0.163	0.237
6-May		0.140	0.223
7-May		0.144	0.253
8-May		0.135	0.204
9-May		0.125	0.193
10-May		0.122	0.183
11-May		0.122	0.214
12-May		0.119	0.182
13-May		0.112	0.180
14-May		0.102	0.229
15-May		0.096	0.189
16-May		0.093	0.174
17-May		0.090	0.156
18-May		0.090	0.131
19-May		0.080	0.122
20-May		0.070	0.117
21-May		0.070	0.114
22-May		0.070	
23-May		0.060	
24-May	0.27	0.060	
25-May	0.23	0.060	
26-May	0.18	0.050	0.223
27-May	0.17	0.050	0.137
28-May	0.17	0.050	0.124
29-May	0.20	0.046	0.117
30-May	0.22	0.052	0.314
31-May	0.18	0.077	0.155
1-Jun	0.16	0.056	0.121
2-Jun	0.15	0.053	0.110
3-Jun	0.13	0.048	0.114
4-Jun	0.13	0.043	0.112
5-Jun	0.14	0.043	0.126
6-Jun	0.15	0.042	0.128
7-Jun	0.58	0.038	0.105

DATE	1997 flow (cfs)	1998 flow (cfs)	2008 flow (cfs)
8-Jun	0.21	0.047	0.204
9-Jun	0.16	0.053	0.242
10-Jun	0.14	0.210	0.112
11-Jun	0.14	0.205	0.110
12-Jun	0.14	0.096	0.184
13-Jun	0.14	0.060	0.143
14-Jun	0.12	0.052	0.100
15-Jun	0.14	0.051	0.089
16-Jun	0.31	0.044	0.087
17-Jun	0.13	0.040	0.081
18-Jun	0.12	0.044	0.079
19-Jun	0.14	0.036	0.076
20-Jun	0.16	0.039	0.073
21-Jun	0.38	0.033	0.074
22-Jun	0.17	0.031	0.075
23-Jun	0.15	0.045	0.073
24-Jun	0.13	1.206	0.068
25-Jun	0.12	0.224	0.064
26-Jun	0.10	0.316	0.060
27-Jun	0.10	0.136	0.068
28-Jun	0.10	0.123	0.078
29-Jun	0.09	0.159	0.073
30-Jun	0.09	0.070	0.064
1-Jul	0.27	0.057	0.060
2-Jul	0.17	0.063	0.207
3-Jul	0.31	0.057	0.081
4-Jul	0.12	0.045	0.069
5-Jul	0.11	0.077	0.062
6-Jul	0.10	0.065	0.060
7-Jul	0.09	0.056	0.063
8-Jul	0.09	0.048	0.073
9-Jul	0.28	0.046	0.066
10-Jul	0.16	0.038	0.070
11-Jul	0.12	0.035	0.085
12-Jul	0.11	0.035	0.096
13-Jul	0.11	0.142	0.077
14-Jul	0.11	0.076	0.079
15-Jul	0.12	0.056	
16-Jul	0.09	0.046	
17-Jul	0.08	0.038	
18-Jul	0.07	0.039	
19-Jul	0.17	0.034	
20-Jul	0.12	0.033	
21-Jul	0.17	0.030	
22-Jul	0.17	0.030	
23-Jul	0.15	0.028	
24-Jul	0.18	0.026	
25-Jul	0.16	0.022	
26-Jul	0.16	0.021	

DATE	1997 flow (cfs)	1998 flow (cfs)	2008 flow (cfs)
27-Jul	0.12	0.021	
28-Jul	0.12	0.020	
29-Jul	0.11	0.022	
30-Jul	0.09	0.020	
31-Jul	0.09	0.019	
1-Aug	0.09	0.018	
2-Aug	0.10	0.022	
3-Aug	0.10	0.025	
4-Aug	0.11	0.027	0.059
5-Aug	0.11	0.043	0.043
6-Aug	0.11	0.058	0.037
7-Aug	0.12	0.041	0.034
8-Aug	0.13	0.033	0.032
9-Aug	0.11	0.029	0.031
10-Aug	0.10	0.027	0.029
11-Aug	0.09	0.023	0.029
12-Aug	0.09	0.020	0.028
13-Aug	0.16	0.112	0.029
14-Aug	0.12	0.055	0.027
15-Aug	0.11	0.028	0.024
16-Aug	0.14	0.043	0.024
17-Aug	0.12	0.033	0.024
18-Aug	0.26	0.028	0.022
19-Aug	0.15	0.033	0.021
20-Aug	0.11	0.027	0.021
21-Aug	0.74	0.054	0.021
22-Aug	0.22	0.048	0.022
23-Aug	0.12	0.032	0.046
24-Aug		0.027	0.027
25-Aug		0.024	0.024
26-Aug		0.021	0.023
27-Aug		0.026	0.022
28-Aug		0.023	0.025
29-Aug		0.019	0.023
30-Aug		0.017	0.020
31-Aug		0.157	0.019
1-Sep		0.069	0.017
2-Sep		0.033	0.019
3-Sep		0.028	0.020
4-Sep		0.024	0.022
5-Sep		0.023	0.023
6-Sep		0.020	0.021
7-Sep		0.020	0.019
8-Sep		0.017	0.020
9-Sep		0.014	0.019
10-Sep	0.20	0.011	0.018
11-Sep	0.11	0.017	0.028
12-Sep	0.08	0.017	0.027
13-Sep	0.08	0.186	0.034

DATE	1997 flow (cfs)	1998 flow (cfs)	2008 flow (cfs)
14-Sep	0.08	0.096	0.032
15-Sep	0.08	0.031	0.026
16-Sep	0.08	0.027	0.023
17-Sep	0.47	0.023	0.021
18-Sep	1.05	0.022	0.020
19-Sep		0.023	0.020
20-Sep		0.022	0.019
21-Sep		0.020	0.019
22-Sep		0.016	0.021
23-Sep		0.017	0.023
24-Sep		0.021	0.018
25-Sep		0.460	0.020
26-Sep		0.071	0.021
27-Sep	0.06	0.037	0.022
28-Sep	0.05	0.045	0.032
29-Sep	0.07	0.044	0.027
30-Sep	0.06	0.038	0.023
1-Oct	0.05	0.036	0.027
2-Oct	0.05	0.035	0.025
3-Oct	0.05	0.030	0.023
4-Oct	0.05	0.142	0.023
5-Oct	0.05	0.282	0.051
6-Oct	0.05	0.100	0.065
7-Oct	0.06	0.058	0.155
8-Oct	0.26	0.041	0.043
9-Oct	0.11	0.041	0.037
10-Oct	0.15	0.039	0.034
11-Oct		0.041	0.034
12-Oct		0.041	0.034
13-Oct		0.039	0.030
14-Oct		0.034	0.034
15-Oct		0.030	0.031
16-Oct		0.028	0.031
17-Oct		0.044	0.032
18-Oct		0.036	0.038
19-Oct		0.034	0.039
20-Oct		0.046	0.033
21-Oct		0.039	0.028
22-Oct		0.038	0.029
23-Oct	0.08	0.046	0.068
24-Oct	0.09	0.038	0.059
25-Oct	0.09	0.034	0.045
26-Oct	0.09	0.036	0.038
27-Oct	0.09	0.041	0.036
28-Oct	0.08	0.043	
29-Oct	0.08	0.071	
30-Oct	0.08	0.060	
31-Oct	0.08	0.047	
1-Nov	0.12	0.041	

DATE	1997 flow (cfs)	1998 flow (cfs)	2008 flow (cfs)
2-Nov	0.11	0.038	
3-Nov	0.10	0.037	
4-Nov	0.09	0.037	
5-Nov	0.09	0.037	
6-Nov	0.08	0.036	
7-Nov	0.08	0.035	
8-Nov	0.08	0.034	
9-Nov	0.08	0.402	
10-Nov	0.08	0.085	
11-Nov	0.08	0.059	
12-Nov	0.08	0.039	
13-Nov	0.08	0.038	
14-Nov	0.08	0.052	
15-Nov	0.08	0.093	
16-Nov	0.08	0.082	
17-Nov	0.08	0.067	
18-Nov	0.07	0.087	



FLOW AND LOAD SUMMARIES FOR TOTALP(UG/L)

SAMPLED VS. TOTAL FLOW DISTRIBUTION MEANS(CFS)
SLOPES

Stratum	Flow Obs	Chm Obs	Events	Vol %	All Flows	Sampled Flows
1	192	9	9	100.0	0.1442182	0.2040751

SLOPES

C/Q	p > C/Q
-0.2553	0.06342

FLOW STATISTICS

Flow Duration 192 Days = 0.526 Years
Mean Flow Rate 0.14 (CFS)
Total Flow Volume 0.08 (CFS)
Flow Date Range 04/04/2008 to 10/28/2008
Sample Date Range 04/07/2008 to 10/09/2008
Flow Separation Method: Local Minimum
Base Flow Volume 0.00 (CFS) Percent of Total 0.00
Storm Flow Volume 0.08 (CFS) Percent of Total 100.00

LOAD ESTIMATES FOR TOTALP(UG/L)

	Method	Mass(kg)	Flux(kg/y)	Flux Variance	Conc.(ppb)	C.V.
1	Average Load	13.64	25.95	42	201.32	0.251
2	Flw Wghted Conc.	9.64	18.34	9	142.27	0.162
3	Flw Wghted IJC.	9.34	17.76	7	137.80	0.145
4	C/Q Reg1	10.53	20.04	6	155.45	0.118
5	C/Q Reg2(VarAdj)	9.12	17.35	5	134.65	0.125
6	C/Q Reg3(daily)	10.84	20.61	7	159.94	0.128