APPENDIX C
CURRENT FLATHEAD LAKE MONITORING PROGRAM

MONITORING WATER QUALITY IN FLATHEAD LAKE, MONTANA
2000 PROGRESS REPORT

Submitted to:

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INTRODUCTION

The Flathead Lake Biological Station (FLBS) has monitored water quality in Flathead Lake continuously since 1977. From 1977 to 1982, baseline limnological data were collected as a part of the Flathead River Basin Environmental Impact Study. Thereafter, the lake was monitored with funds obtained through a cooperative agreement between the Flathead Lake Biological Station and a consortium of management agencies. The Flathead Basin Commission (FBC) coordinates the cooperative.

Monitoring results and basic limnological features of Flathead Lake have been reported in biennial technical reports and journal publications (e.g., Ellis and Stanford 1982; Flathead Basin Commission 1989, 1991, 1993, 1995, 1997, 1999; Dodds et al. 1989; Dodds and Priscu 1989, 1990; Perry and Stanford 1982; Spencer and Ellis 1990; Spencer 1991; Spencer et al. 1991; Spencer and Ellis 1998; Stanford et al. 1983; Stanford and Ellis 1988; Stanford et al. 1990). In recent years, the long-term data on nutrient loading and attendant responses in the lake have been supplemented with additional studies that examined cause and effect (Stanford et al. 1994, 1995, 1997).

These studies have been funded by the Environmental Protection Agency (EPA) and are the technical background for development of a Total Maximum Daily Load (TMDL) allocation for the purpose of managing nutrient loads reaching Flathead Lake. Based on these studies, the Flathead Basin Commission TMDL Technical Committee recommended the following interim targets for the protection of water quality in Flathead Lake:

1) no increase in the biomass of lakeshore periphyton,
2) no measurable blooms of *Anabaena flos-aquae* (or other pollution algae),
3) no declining trend in oxygen concentrations in the hypolimnion, and

4) average annual concentrations of the following variables in the photic zone of the midlake deep site in Flathead Lake will not exceed the values indicated:

primary production - 70 gC m^{-2} yr^{-1}

chlorophyll *a* - 1.0 μg/L

soluble reactive phosphorus - <0.5 μg/L

total phosphorus - 5.0 μg/L

total nitrogen - 95 μg/L

ammonium - <5.0 μg/L

nitrate + nitrite - 30 μg/L

After reviewing the recommendations, the Flathead Basin Commission opted not to accept the committee's recommendation of 70 gC m^{-2} yr^{-1} as the primary productivity target for Flathead Lake and increased the interim target to 80 gC m^{-2} yr^{-1}. The FBC also did not adopt the interim targets for soluble reactive phosphorus, total phosphorus, total nitrogen, ammonium and nitrate plus nitrite.

Herein we provide a progress report pertaining to the primary objectives that are crucial to the monitoring of TMDL targets for Flathead Lake. The report summarizes the annual rate of primary production and mean concentrations of the TMDL target parameters (i.e., recommended targets and adopted targets) for the 1999 water year (WY) in comparison to long-term averages for the midlake deep site in Flathead Lake. Nutrient loading to Flathead Lake from the major tributaries and precipitation is also presented for WY 1999. Additional monitoring funds made available by the 1999 Montana State Legislature will allow completion of phytoplankton and zooplankton community analysis as well as the annual loading record for the period during which funds were lacking (i.e., 1996-1998). Those results will be included in the final report due November 2001.

STUDY SITES

Monitoring sites discussed herein include:

- midlake deep (110 m depth) ca. 1 mile west of Yellow Bay Point in a pelagic area of Flathead Lake (site number: FBC05014);
- Flathead Lake at the outlet sill near the Highway 93 bridge in Polson (FBC05021);
- Stoner Creek near Lakeside, a small lakeshore tributary stream (FBC05018);
- Ashley Creek below the Kalispell sewage treatment plant outfall, a small upstream tributary (BSC05023);
- Swan River in Bigfork, a large upstream tributary (FBC06009);
- Stillwater River in Evergreen, a large upstream tributary (FBC04022);
- Flathead River near Holt (Sportsmen Bridge), the primary upstream tributary (FBC05012);
- the bulk precipitation collector located at the Flathead Lake Biological Station on the east shore of the lake (BSC05016);
- "B" Beach, a shoreline periphyton monitoring site located at the Flathead Lake Biological Station on the west side of Cape Montana (TMP00884); and,
- Horseshoe Island, a shoreline periphyton monitoring site with a westerly aspect (TMP 00885).

A description of Flathead Lake and its catchment basin can be found in the following publications: Stanford et al. (1983, 1992, 1994, 1995 and 1997).

METHODS

All tributary sites were sampled 15-17 times during the funding period (i.e., July 1, 1999 – June 30, 2000) and the lake site was sampled 15 times. Additional tributary samples were collected at some sites to examine changes in nutrient concentrations during rain events. Bulk precipitation was sampled after every major precipitation event (29 times).

The sampling protocol for each date was as follows:

-- Midlake sampling:

- discrete samples for chemistries (Table 1) at 5 and 90 m;
- one integrated (0 - 30 m) sample for chemistries (Table 1);
- integrated (0 - 30 m) samples, subsampled for chlorophyll *a*;
- duplicate chlorophyll *a* samples from the depth of maximum fluorescence (as determined *in situ* using a shipboard fluorometer);
- depth profiles: primary productivity, photosynthetically-active radiation, specific conductance, pH, temperature, dissolved oxygen and secchi depth.

-- Lake shoreline sampling:

- ten periphyton samples from 5 m depth analyzed for chlorophyll *a*.

-- Watershed sampling:

- analyses of chemistries (Table 1) in shoreline grab samples or mid-channel collections with Van Dorn water bottle deployed from bridges;
- field metering of specific conductance, pH, dissolved oxygen, and temperature at all sites (lab meters are used for bulk precipitation), and flow calibration of data loggers at Stoner Creek and Ashley Creek; and,
- a continuous record of air and water temperatures, photosynthetically-active radiation, wind speed and direction are obtained with a data logger maintained on Yellow Bay point.

Methods for all of these analyses are referenced in Table 1. Every tenth field sample for chemistries was duplicated to obtain a variance estimate.

Following the discovery in 1992 of declining oxygen in the bottom waters of Big Arm Bay, water column profiles of dissolved oxygen were measured whenever possible (funding not available after 1993) during late summer and early fall. To aid in the monitoring effort, the Confederated Salish and Kootenai Tribes (CSKT) agreed to monitor dissolved oxygen and other physico-chemical variables throughout the water column at the Ross Deep site in Big Arm Bay and to collect the water sample from the Polson outlet site for chemical analysis. Physico-chemical variables were also measured at the Polson outlet.

Long-term monitoring of periphyton biomass in Flathead Lake was initiated in 1999 when additional funds became available. The two sites selected for monitoring were the "B" Beach site on the east shore (located on the lake side of Yellow Bay Point) and a site on Horseshoe Island. Both sites are adjacent to Flathead Lake Biological Station property, assuring no future pollution in the local area. The "B" Beach site is the location of the first periphyton study on Flathead Lake (Bauman 1988); thus, data from 1987 is available for comparison. Methods of periphyton biomass collection and analysis followed those given in Stanford et al. (1997), with the modification of increased replicates (i.e., 10) at a depth of 5 m only.

Loading of nitrogen and phosphorus to Flathead Lake for WY 1999 was determined from measurements of nitrogen and phosphorus forms made by the Biological Station from time-series collections on the major tributaries to the lake (Flathead River at Holt, Swan River at Bigfork, Stoner Creek at Lakeside, Ashley Creek below Kalispell STP, Stillwater River below Whitefish River confluence in Evergreen) and the airshed (bulk precipitation at the Biological Station). Stream discharge data were obtained from the U. S. Geological Survey (USGS), except on Ashley and Stoner Creeks, where flow is monitored by the Biological Station using USGS procedures. Precipitation volume was determined from the National Weather Service (National Oceanic and Atmospheric Administration) Monitoring Station located at the Biological Station.

Methods of calculating loading estimates from nutrient concentrations and discharge or precipitation volume are given in Stanford et al. (1997).

Analytical Quality Control

Precision of the analytical analyses of water samples is determined by ±1 SD of replicated analyses on individual samples, whereas accuracy is determined by 110% > x > 90% recovery of a known addition of standard solution to selected samples. These quality control criteria are tested on approximately 1 out of every 15 samples run in the Freshwater Research Laboratory at the Biological Station. Analytical performance of lab personnel is also evaluated about every 6 months by analyses of quality control samples (unknown concentrations) from Inorganic Ventures IV Lab (NIST traceable). These performance evaluations are on file at the Biological Station. All sample data, laboratory standard curves and quality control information are electronically archived by the FLBS Data Manager in the Biological Station's data storage and retrieval system (FLATDAT).

Physical variables (e.g., temperature, secchi disk depth; Table 1) were determined with electronic meters or other standard limnological gear. Meters were calibrated with ASTM standards prior to each sampling period, and calibration records for all meters and analytical instruments are maintained at the Biological Station.

RESULTS AND DISCUSSION

Mean annual discharge in the Flathead River at Columbia Falls in WY 1999 was similar to that in WY 1998 (i.e., 9,149 versus 8,092 cfs) and similar to the long-term mean (i.e., 9,695 cfs for 1928-present) (U.S. Geological Survey, National Water Information System Files, Helena).

Results of chemical analysis of samples collected from the tributary and bulk precipitation sites during WY 1999 are shown in Table 2. As was observed in WY 1998, total nitrogen (TPN) values for the Stillwater River at Conrad Drive were higher than the long-term mean (i.e., 1977-1992) reported in Stanford et al. (1992). Although the mean TPN in WY 1999 was not as high as that reported for 1998, it was 56 μg/L higher than the long-term mean. Mean TPN for WY 1999 was 349 μg/L compared to 293 μg/L for the 1977-1992 period of record. In addition, a comparison of nitrate nitrogen (NO_3-N) data from 1977-1992 to nitrate plus nitrite ($NO_{2/3}$-N) data from WY 1999 indicated higher levels of inorganic nitrogen in the Stillwater River during the last sampling period; the mean $NO_{2/3}$-N for WY 1999 was 251 μg/L compared to a mean of 164 μg/L NO_3-N for the 1977-1992 period. Although NO_2-N data were not reported for the Stillwater River for the 1977-1992 period, additional data indicated that >98% of the nitrogen in $NO_{2/3}$-N was in the form of NO_3-N. The mean concentration of $NO_{2/3}$-N was also higher in the mainstem Flathead River at Holt for WY 1999 than for the 1977-1992 period (i.e., 81 μg/L $NO_{2/3}$-N compared to 69 μg/L NO_3-N, respectively).

Mean total phosphorus (TP) and soluble reactive phosphorus (SRP) concentrations in the Stillwater River were much lower for WY 1999 than for the 1977-1992 period. Mean TP in WY 1999 was 15 μg/L compared to 25 μg/L for the long-term mean, while mean SRP for 1999 was 1.4 μg/L compared to the long-term mean of 8.9 μg/L. The mean 1999 TP concentration in the Flathead River at Holt was also lower than the long-term mean (i.e., 14 versus 23 μg/L, respectively).

Mean and maximum concentrations for all nutrients in Ashley Creek exceeded values observed in all the other tributaries (see Table 2). Although nutrient concentrations in Ashley Creek were lower than the long-term means reported by Stanford et al. (1992), the long-term average for Ashley Creek included very high values associated with discharges from the Kalispell Sewage Treatment Plant before it was upgraded to tertiary treatment. However, $NO_{2/3}$-N concentrations in WY 1999 were not much lower than the long-term average, suggesting that any reduction in this labile form of nitrogen from the upgrading of the sewage treatment plants was offset by increased transport in the catchment upstream of the plant. In comparison to the 1998 mean, average $NO_{2/3}$-N concentrations in WY 1999 were about 200 µg/L higher (i.e., 753 µg/L in WY 1998 versus 968 µg/L in WY 1999).

In general, mean nutrient concentrations in Stoner Creek and the Swan River were similar to the long-term means reported by Stanford et al. (1992) (see Table 2). Total phosphorus values in Stoner Creek remain quite high compared to other streams in the Flathead Basin (see Stanford et al. 1997). The maximum TP concentration of 80 µg/L recorded during WY 1999 was outside the long-term range for Stoner Creek (i.e., 77 µg/L for 1985-1992 period). Additional work is needed in the Stoner Creek catchment to determine the source of relatively high phosphorus and total nitrogen concentrations. In addition to the primary tributary sites, approximately 43 streams (perennial and intermittent) flow directly into Flathead Lake and little is known about the transport of nutrients from these sites. Although the flow is small in comparison to the major tributaries that are regularly monitored, localized impacts may occur, particularly in areas of reduced circulation.

Total phosphorus and $NO_{2/3}$-N concentrations in bulk precipitation samples were similar to concentrations from previous years, but SRP, TPN and NH_4-N concentrations were considerably higher during WY 1999 (see Stanford et al. 1992; Table 2). The mean concentration of TPN for WY 1999 was almost twice the mean for the 1982-1992 period (i.e., 2,345 µg/L versus 1,216 µg/L, respectively), while the 1999 mean NH_4-N concentration was more than twice the 1982-1992 mean (i.e., 1,301 µg/L versus 574 µg/L, respectively). Increased concentrations of some nutrient forms during WY 1999 could be due to many factors, such as a change in weather patterns that facilitated air inversions in the Flathead valley, an increase in wildfires and slash burning or more road dust due to a drier summer and/or fall. However, the data will be investigated further by comparisons to State air quality data collected during the same time period in Polson and Kalispell. State air quality data were still unavailable at the time of this report.

Nutrient loads reaching Flathead Lake are primarily controlled by water yield within the watershed (i.e., flows in the Flathead and Swan Rivers). However, precipitation on the lake surface can be a major source of both nitrogen and phosphorus. Preliminary data from WY 1999 indicated that the load of total nitrogen from precipitation was higher than normal and accounted for about 17% of the total annual load (Figure 1). However, the bulk precipitation loading estimates remain preliminary until comparisons to State air quality data can be made. Total nitrate plus nitrite nitrogen loading was relatively high in WY 1999 in comparison to years of similar total discharge at Holt (i.e., 1979, 1986 and 1989; see Figure 2). The annual total phosphorus load, adjusted for bioavailability (see Stanford et al. 1997), was mid-range between the loads observed during high and low water years (Figure 3).

For the TMDL target variables, mean concentrations were determined for the 1999 water year (October 1, 1998 – September 30, 1999) for 0 to 30 m integrated samples collected from the midlake deep site in Flathead Lake (Figure 4). The higher inorganic nitrogen concentrations that were measured in the Stillwater River and the mainstem Flathead River were also mirrored at the midlake deep site in Flathead Lake and the lake outlet site at Polson (Tables 2 and 3; Figure 4). Means for WY 1999 were compared to WY means for the period of record (i.e., integrated samples collected from 1987-1998). The mean $NO_{2/3}$-N for WY 1999 was at the very upper limit of previous annual means (Figure 4). This was not too surprising given the relatively high

$NO_{2/3}$-N loading to Flathead Lake in WY 1999. As was observed in 1997 and 1998, concentrations of $NO_{2/3}$-N as well as TPN were higher than the recommended TMDL targets for midlake deep (Table 4).

Concentrations of SRP and chlorophyll *a* in 0-30 m samples from the midlake deep site were close to the long-term means and the TMDL interim targets (Figure 4; Table 4). The mean concentration of TP was somewhat higher than the 1977-1992 mean and the TMDL interim target, but was well within the range of previously reported means.

In 1998, the annual rate of primary production at the midlake monitoring site was the second highest value ever recorded (i.e., 120 gC m^{-2} yr^{-1}; see Figure 5) and exceeded the TMDL interim target by 40 gC m^{-2} yr^{-1} (Table 4). Mean primary productivity in 1999 was considerably lower than the WY 1998 mean, but was still higher than the TMDL interim target by 28 gC m^{-2} yr^{-1}. Our long-term record of primary productivity in Flathead Lake is a robust indicator of water quality that is strongly influenced by external nutrient loads (Stanford et al. 1997). Experiments strongly support the conclusion that growth of algae in Flathead Lake is controlled by nitrogen and phosphorus supply (Dodds and Priscu 1989, 1990; Spencer and Ellis 1990). However, it is important to remember that under certain conditions, food web changes may also influence primary production by altering the density of organisms that cycle these nutrients within the lake. The annual survey of *Mysis* in 1999 revealed a mean density almost identical to that for 1998; the 1999 mean was 44 organisms/m^2 (unpublished data) compared to 45 organisms/m^2 in 1998. These are some of the higher densities recorded since the major peak in 1986-87. Clearly, alterations in the lake food web will continue as *Mysis* densities fluctuate so dramatically. Experiments have shown that if nutrient levels in Flathead Lake increase, organisms such as *Mysis* will become more important in regulating primary production; but, at current nutrient levels, nitrogen and phosphorus appear to be more important in controlling the algal community in the lake (Spencer and Ellis 1998).

Oxygen in oligotrophic lakes does not vary much from saturation in the epilimnion or hypolimnion (10 $\pm$ 10%) (Horne and Goldman 1994). Thus, one of the TMDL interim targets states that there shall be no declining trend in oxygen concentrations in the hypolimnion of Flathead Lake. Profiles of dissolved oxygen at the midlake deep site during the late summer and fall of 1999 revealed a decline in oxygen concentrations with depth as the period of thermal stratification in the lake continued through early fall. Percent oxygen saturation dropped to 79.5% (9.29 mg/L) near the bottom at midlake deep by 21 October 1999. The lowest oxygen concentration observed at the midlake site was 70.1% in WY 1998. At the time of this report, CSKT physical-chemical profiles of the Ross Deep water column were unavailable. The lowest oxygen concentration measured by FLBS personnel at Ross Deep during WY 1999 was 65% (7.25 mg/L) on 15 September. The largest decline in oxygen ever measured in Flathead Lake was at the Ross Deep site on 16 September 1998 (i.e., % saturation of oxygen decreased from 102.4% at the surface to 50.7% (5.67 mg/L) at the bottom).

The TMDL interim targets recommend no measurable blooms of *Anabaena flos-aquae* (or other pollution algae) at the midlake deep site. Surface algal scum was not visually observed at the midlake deep site during WY 1999, but surface samples collected during the late summer have not been analyzed microscopically. Additional funds will allow complete analysis of the algal community by project end in November 2001.

The TMDL interim targets also state that there shall be no increase in the biomass of lakeshore periphyton. Long-term monitoring of periphyton biomass began in 1999. The mean chlorophyll *a* concentration ($\pm$ 1 standard deviation) at the "B" Beach site was 6.9 $\pm$ 1.3 μg/cm^2 when measured on August 5th. The mean for the Horseshoe Island site on the same date was 2.2

$\pm$ 0.6 μg/cm^2. Periphyton biomass at the "B" Beach site was significantly higher in August 1999 than in August 1987 (i.e., 6.9 versus 1.2 μg/cm^2, respectively; $p<0.0001$, independent-samples t test). At this early stage of monitoring, with means from 1987 and 1999 only, it is not possible to determine a trend in periphyton biomass. Continued monitoring is needed to assess natural interannual variation.

The significantly higher periphyton biomass at "B" Beach than at Horseshoe Island in 1999 suggests that access to nutrients was greater at the "B" Beach site than the Horseshoe Island site. Both sites have very similar aspects; thus, the insolation to both shorelines should be quite similar. The prospect of regionally higher nutrient concentrations in the "B" Beach area is worthy of additional investigation. One possibility is that upwelling currents on the east shore bring higher nutrient concentrations from the hypolimnion to the upper waters during the growing season. It is also possible that groundwaters, which are typically higher in nutrients, are influent in the area of the "B" Beach. Increased nutrient pollution in the east shore area is also a potential concern. Additional sampling of nutrients and other physico-chemical parameters will be proposed at both sites during the 2001 growing season to provide more insight into the observed differences.

During the 1999 water year, the Flathead Lake Biological Station was able to assess all interim TMDL targets established for the protection of water quality in Flathead Lake, except the periphyton biomass and algal bloom targets. Analysis of surface samples for any evidence of algal blooms will be completed by project end (November 2001). Long-term periphyton biomass monitoring just began and data must be collected over many years before any determination of trends can be made. The mean chlorophyll *a* concentration in WY 1999 was right on the target value, but the dissolved oxygen target was not met (i.e., a decline in oxygen was observed) and primary production at midlake deep exceeded the target value by 35%. Three of the targets that were recommended by the FBC TMDL Technical Committee also were exceeded (i.e., TPN, $NO_{2/3}$-N and TP), but only the $NO_{2/3}$-N mean was substantially higher than the target (i.e., exceeded target by 43%).

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Table 1. Biophysical variables, methods and sites used in monitoring water quality in Flathead Lake. Abbreviations are as follows: MLD, midlake deep site 2 km west of Yellow Bay Point; TRIBS, all river and creek sites; H&P TRIBS, Flathead River at Holt and Polson only; PREC, bulk precipitation collected on the weather tower on Yellow Bay Point.

Variable (units)	Method (references)	Detection limit	Sites
Analyses of water samples			
phosphorus (µg/L-P)			
total (TP)	persulfate digestion; modified automated ascorbic acid (1)	0.4	MLD, TRIBS, PREC
soluble total (SP)	filtration; persulfate dig.; mod. auto. ascorbic acid (1)	0.4	MLD, TRIBS
soluble reactive (SRP)	filt.; mod. auto. ascorbic acid (1)	0.4	MLD, TRIBS, PREC
nitrogen (µg/L-N)			
total persulfate (TPN)	persulfate digestion (2); auto. cadmium reduction (1)	20.0	MLD, TRIBS, PREC
nitrite + nitrate ($NO_{2/3}$-N)	auto. cadmium reduction (1)	0.6	MLD, TRIBS, PREC
ammonium (NH_4-N)	auto. phenate (1)	5.0	MLD, TRIBS, PREC
sulfate (mg/L-$S0_4$)	ion chromotography (1)	0.05	PREC
dissolved silica (mg/L-SiO_2)	auto. molybdate-reactive silica (1)	0.2	MLD
carbon (mg/L-C)			
non-dissolved (NDOC) and dissolved organic (DOC)	persulfate dig.; infrared CO_2 detection (3)	0.03	MLD, H&P TRIBS
dissolved inorganic (DIC)	acid liberation; infrared CO_2 detection	0.03	MLD, H&P TRIBS
carbonate alkalinity (mg/L-$CaCO_3$) (Alk)	titration (1)	0.5	MLD
turbidity (NTU) (Turb)	nephelometry (1)	0.10	MLD, H&P TRIBS
total suspended solids (mg/L) (TSS)*	filt.; gravimetric (1)	0.5	MLD, TRIBS
Biological analyses			
chlorophyll *a* (mg/m^3) (Chl *a*)	acetone extraction (1,4)	1.00	MLD
relative fluorescence (units)	continuous flow *in situ* fluorometry (5)	0.05	MLD
photosynthetically active radiation (µEinsteins/m^2/sec)	submarine/deck quantum meter (6)	0.01	MLD
phytoplankton primary productivity	^{14}C uptake in light and dark bottles; acid-bubbling technique (7)		MLD

Table 1 (continued).

Variable (units)	Method (references)	Detection limit	Sites
Physical profiles			
temperature (°C)	thermistor (9)	0.15	MLD, TRIBS
dissolved oxygen (ppm)	electrode (9)	0.20	MLD, TRIBS
pH (units)	electrode (9)	0.1	MLD,TRIBS, PREC
conductivity (µmhos/cm)	electrode (9)	1.5	MLD, TRIBS
secchi depth (m)	secchi disk (8)	0.25	MLD

[1]APHA, 1985

[2]D'Elia *et al.*, 1977

[3]Menzel and Vaccaro, 1964

[4]Marker *et al.*, 1980

[5]Turner Designs, 1981

[6]Licor 188 integrating quantum meter

[7]Theodorssen and Bjarnason, 1975; Wetzel and Likens, 1991

[8] Wetzel and Likens, 1991

[9]measured *in situ* using Hydrolab Surveyor III and SeaBird CTD systems

*TSS run when turbidity exceeds 0.3 NTU

Table 2. Mean, minimum and maximum values for chemical analysis of grab water samples at five tributary sites and the outlet site for Flathead Lake for the 1999 water year (i.e., October 1, 1998 to September 30, 1999). Results from the analysis of bulk precipitation samples collected at the Flathead Lake Biological Station point for the same period are also presented. See Table 1 for a description of variable abbreviations.

site		pH units	*Cl (mg/l)	*SiO_2 (mg/l)	*SO_4 (mg/l)	*DIC (mg/l)	DOC (mg/l)	*NDOC (mg/l)	*TURB (NTU)	**TSS (mg/l)
Ashley Creek below	mean						7.36			
Kalispell STP	min			0.2	11.65	22.7	3.89		2.0	2.8
	max			4.6	12.50	27.1	9.39		4.5	38.9
Flathead River	mean					18.7	1.87	0.27	9.8	
at Holt	min			4.0	3.17	12.0	1.13	0.16	1.4	1.9
	max			4.1	3.23	25.0	3.65	1.32	73.7	101.2
Stillwater River at	mean						2.61			
Conrad Drive	min			7.9	2.27	18.8	1.40	0.27	3.2	2.6
	max			8.3	2.89	21.5	4.48	0.47	4.8	45.3
Stoner Creek at	mean						3.18			
Flathead Lake	min			13.3	2.40	24.3	1.54	0.16	1.0	0.5
	max			14.4	2.70	27.7	5.68	0.49	2.0	77.5
Swan River at	mean						1.83			
Bigfork	min			5.6	1.19	13.2	1.13	0.24	1.2	<0.5
	max			5.9	1.31	15.6	3.02	0.26	1.3	1.9
Bulk Precipitation at	mean	5.7	0.28		0.89					
Yellow Bay point	min	4.6	<0.04		0.10					
	max	6.7	1.20		4.82					
Flathead Lake	mean					18.4	1.64	0.24	1.1	
outlet at Polson	min			4.4	2.89	15.0	1.43	0.14	0.7	0.6
	max			4.7	2.99	22.2	1.84	0.36	2.3	1.3

Table 2. (continued)

site		TPN (µg/l)	*NH_4-N (µg/l)	$NO_{2/3}$-N (µg/l)	TP (µg/l)	SP (µg/l)	SRP (µg/l)
Ashley Creek below	mean	1428	34	968	47.9	24.0	7.0
Kalispell STP	min	771	6	249	24.0	12.7	1.3
	max	2263	126	1689	97.0	36.3	17.1
Flathead River	mean	138	8	81	13.5	3.8	1.5
at Holt	min	83	5	30	5.6	2.4	0.5
	max	314	14	177	88.3	7.1	11.0
Stillwater River at	mean	349	19	251	14.9	5.6	1.4
Conrad Drive	min	148	<5	35	8.2	4.4	0.9
	max	569	57	461	41.9	7.4	2.6
Stoner Creek at	mean	130	5	25	20.0	13.2	5.4
Flathead Lake	min	72	<5	<0.6	12.8	10.6	3.0
	max	368	6	115	80.4	18.4	10.6
Swan River at	mean	104	6	29	6.1	3.5	1.0
Bigfork	min	71	<5	5	4.1	2.4	0.6
	max	178	13	70	8.7	4.9	1.5
Bulk Precipitation at	mean	2345	1301	290	197		147
Yellow Bay point	min	164	85	74	2.1		<0.4
	max	9622	5077	558	1979		1560
Flathead Lake	mean	103	5	26	6.1	3.3	0.9
outlet at Polson	min	80	<5	<0.6	4.1	1.8	0.5
	max	143	10	61	8.4	4.8	1.9

* Due to lack of funding prior to July 1, 1999, range represents July - September period only,
except when means are given (e.g., Holt and Polson sites).
** Analysis only run during spring runoff (i.e., March through June).

Table 3. Mean, minimum and maximum values for chemical analysis of integrated (0-30 m) and discrete grab (5 m and 90 m) samples collected during the 1999 water year (i.e., October 1, 1998 to September 30, 1999) at the midlake deep site (MLD) on Flathead Lake. See Table 1 for description of variable abbreviations.

site		ALK (mg/l $CaCO_3$)	SiO_2 (mg/l)	*SO_4 (mg/l)	DIC (mg/l)	DOC (mg/l)	NDOC (mg/l)	TURB (NTU)	**TSS (mg/l)
MLD 0-30 m	mean		5.0		17.8	1.75	0.17	1.1	
	min		4.6	2.91	13.6	1.06	0.13	0.4	<0.5
	max		5.4	3.12	23.0	2.96	0.21	2.3	0.7
MLD 5 m	mean	89.9	5.3		18.4	1.78	0.19	0.9	
	min	84.3	4.3	2.81	15.0	1.28	0.13	0.4	<0.5
	max	98.6	6.8	3.05	23.1	2.52	0.26	3.2	1.5
MLD 90 m	mean		5.5		18.5	1.79	0.11	1.2	
	min		5.1	3.03	12.5	1.19	0.08	0.4	<0.5
	max		6.1	3.30	21.9	2.88	0.13	2.4	0.5

site		TPN (mg/l)	NH_4-N (mg/l)	$NO_{2/3}$-N (mg/l)	TP (mg/l)	SP (mg/l)	SRP (mg/l)	CHL *a* (mg/l)
MLD 0-30 m	mean	101	5.1	43.4	5.9	3.5	0.7	0.988
	min	79	<5.0	28.4	4.2	1.8	<0.3	0.634
	max	137	5.6	60.4	12.5	13.6	2.4	1.506
MLD 5 m	mean	95	6.0	35.8	5.3	2.8	0.7	
	min	63	<5.0	1.4	3.9	1.6	<0.3	
	max	143	20.4	64.4	6.8	3.5	1.6	
MLD 90 m	mean	114	5.5	66.9	5.4	3.1	0.7	
	min	78	<5.0	52.5	3.9	1.6	0.3	
	max	147	8.4	90.6	8.6	8.0	1.5	

* Analyses run as additional money became available during the year.

** Analysis only run during the lake plume from spring runoff (i.e., ~April through July).

Table 4. Interim numeric TMDL targets for the midlake deep site (0–30 m integrated water column) in Flathead Lake and mean concentrations of those target variables for the 1997, 1998 and 1999 water years. All nutrient and chlorophyll *a* concentrations are in µg/l and primary productivity is given in gC m^{-2} yr^{-1}. Targets shown in the lower half of the table were recommended by the FBC TMDL Technical Committee but were not accepted by the FBC.

target variable	TMDL target value	WY1997 mean	WY1998 mean	WY1999 mean
chlorophyll *a* (Chl *a*)	1.0	0.7	0.8	1.0
primary productivity	80	101	120	108
no declining trend in oxygen concentrations in the hypolimnion		x	xx	xxx
no increase in the biomass of lakeshore periphyton		*	*	
“B” Beach site				6.9
Horseshoe Island site				2.2
no measurable blooms of *Anabaena flos-aquae* (or other pollution algae)		*	*	**
total nitrogen (TPN)	95	117	100	101
nitrate + nitrite nitrogen ($NO_{2/3}$-N)	30	44	46	43
ammonium nitrogen (NH_4-N)	5.0	6.4	*	5.1
total phosphorus (TP)	5.0	5.4	5.3	5.9
soluble reactive phosphorus (SRP)	0.5	0.6	0.5	0.7

X Decline in DO down to 70.6% at Ross Deep and 77.1% at midlake in 1997.
XX Decline in DO down to 50.7% at Ross Deep and 70.1% at midlake in 1998.
XXX Decline in DO down to 65.0% at Ross Deep and 79.5% at midlake in 1999.
* Funding not available for monitoring.
** Analysis to be completed November 2001.

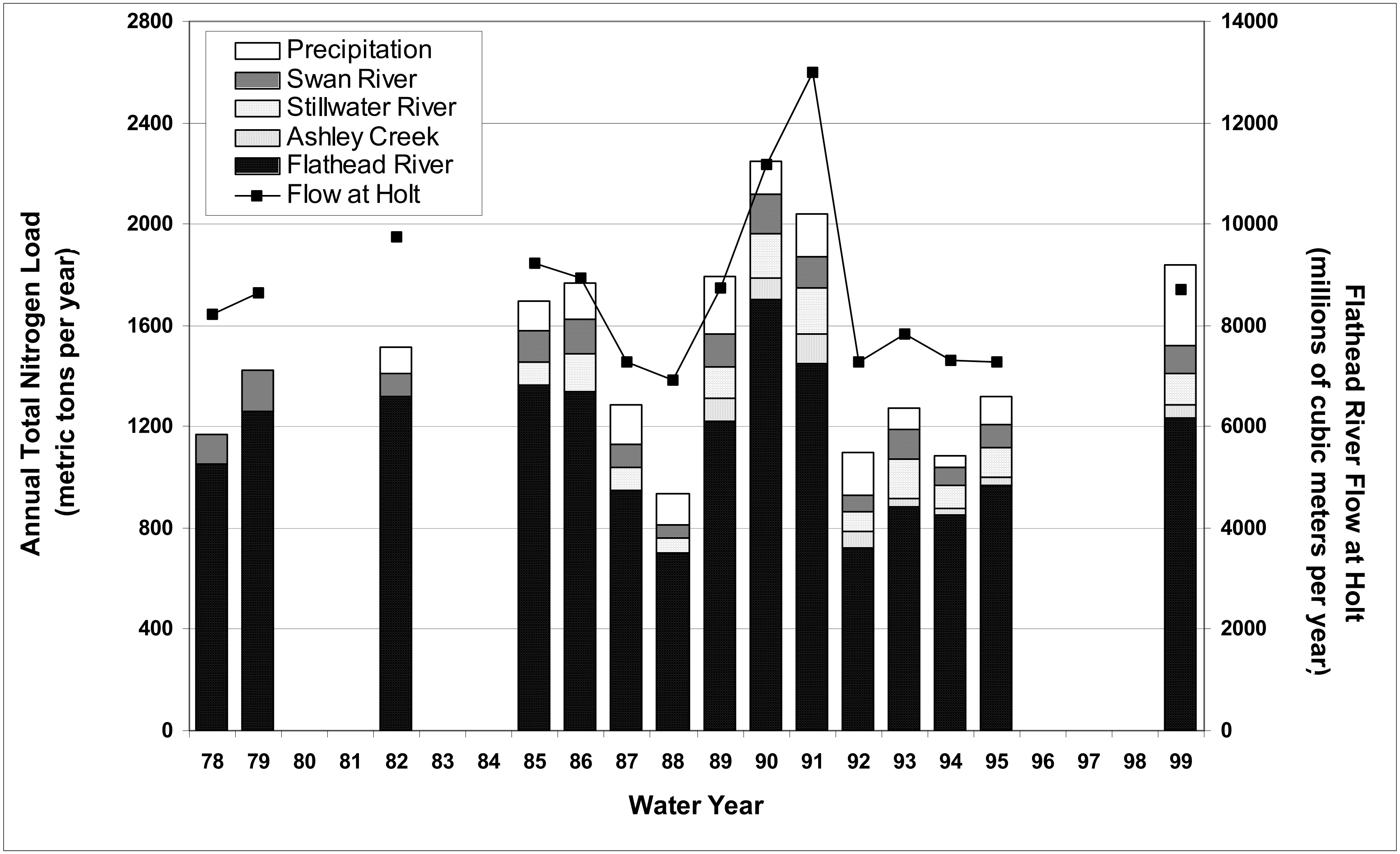

Figure 1. Mass of total nitrogen by source reaching Flathead Lake annually in relation to annual inflow from the Flathead River (closed squares). Precipitation data were not available in 1978-79. Prior to 1985, Ashley and Stillwater River (below confluence with the Whitefish River) are included in the Flathead River. Prior to 1989, Ashley included in Flathead River. Stoner Creek load too small to be visible.

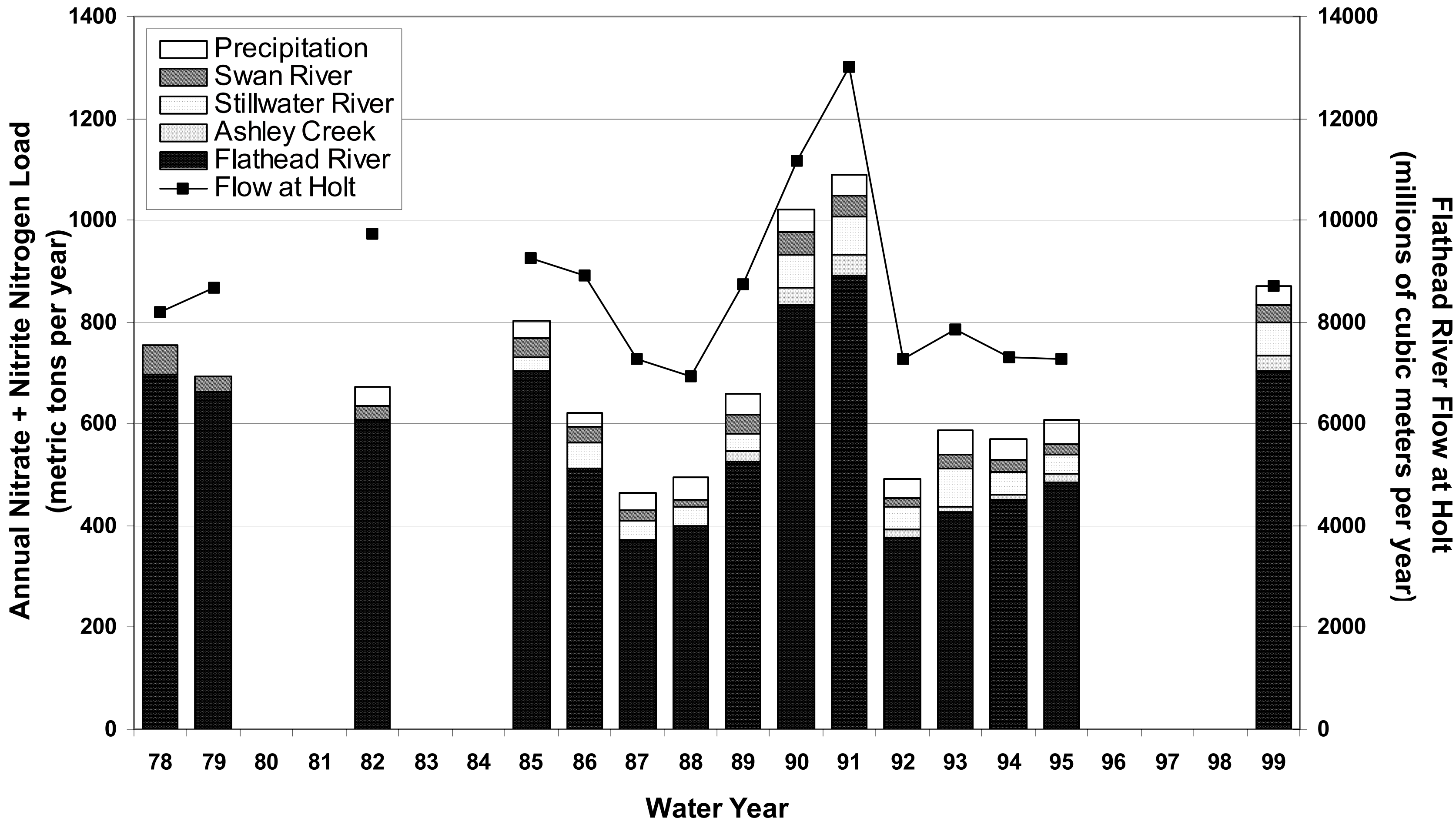

Figure 2. Mass of nitrate plus nitrite nitrogen by source reaching Flathead Lake annually in relation to annual inflow from the Flathead River (closed squares). Precipitation data were not available in 1978-79. Prior to 1985, Ashley and Stillwater River (below confluence with the Whitefish River) are included in the Flathead River. Prior to 1989, Ashley included in Flathead River. Stoner Creek load too small to be visible.

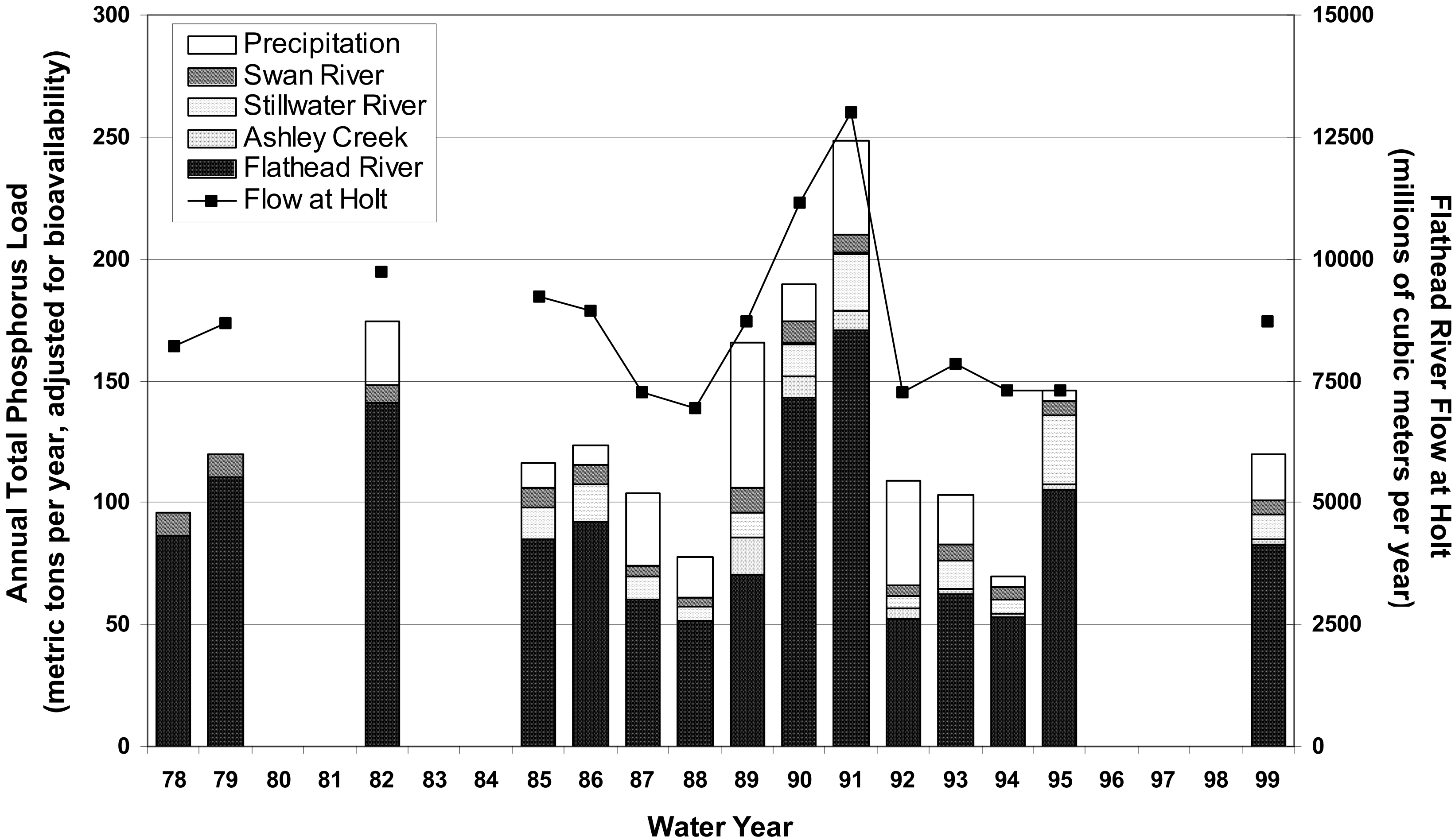

Figure 3. Mass of biologically available phosphorus by source (histograms) reaching Flathead Lake annually in relation to annual inflow from the Flathead River (closed squares). Precipitation data were not available in 1978-79. Prior to 1985, Ashley and Stillwater River (below confluence with the Whitefish River) are included in the Flathead River. Prior to 1989, Ashley included in Flathead River. Stoner Creek load is too small to be visible.

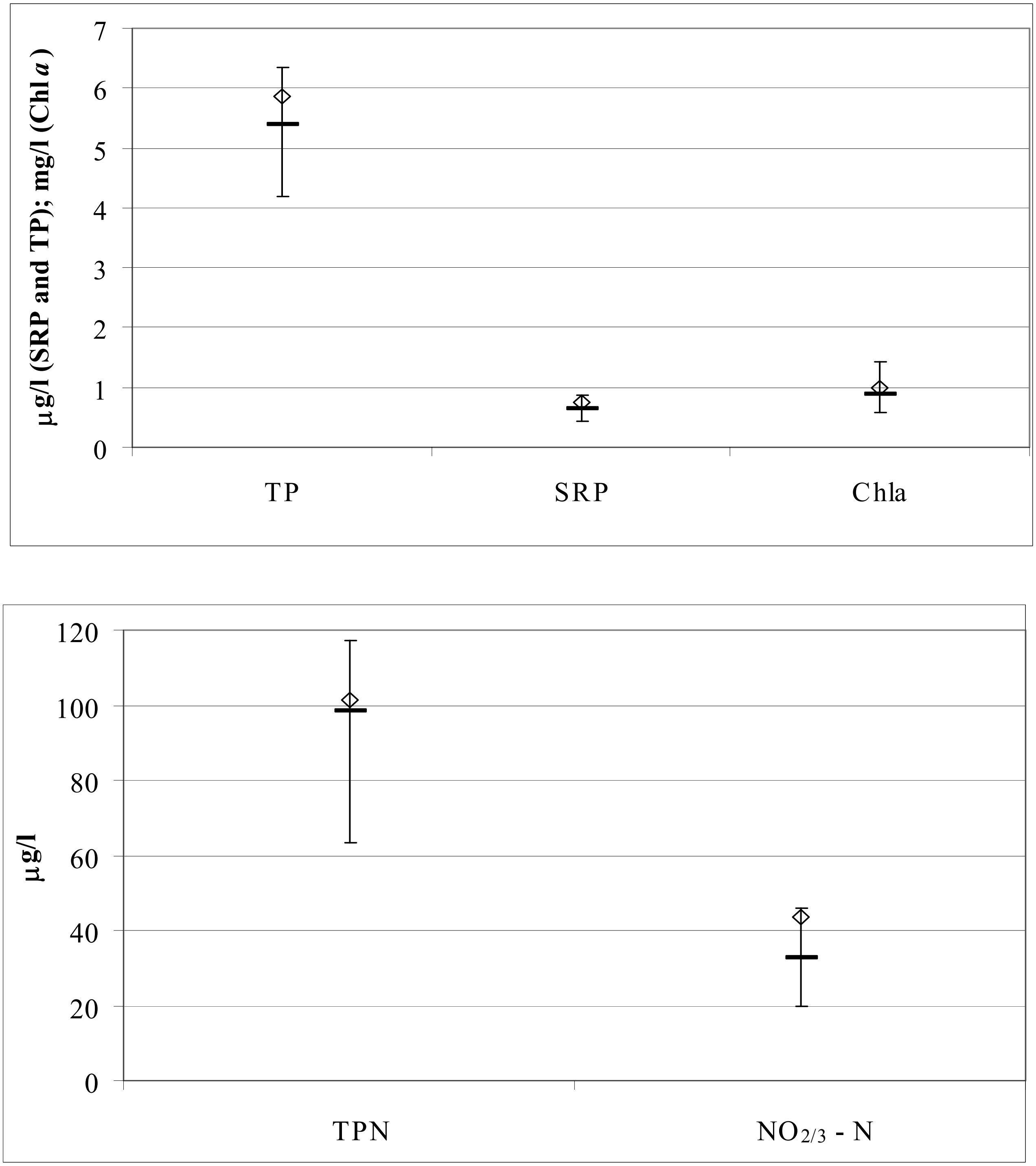

Figure 4. Long-term mean (thick bar) and range of means (thin bars) for nutrient and chlorophyll *a* concentrations of 0-30 m integrated samples collected from 1987 to 1998 at the midlake deep site on Flathead Lake. Means were calculated for each water year (i.e., October 1 - September 30). Mean concentrations for the 1999 water year, October 1, 1998 to September 30, 1999, (diamonds) are also presented for comparison.

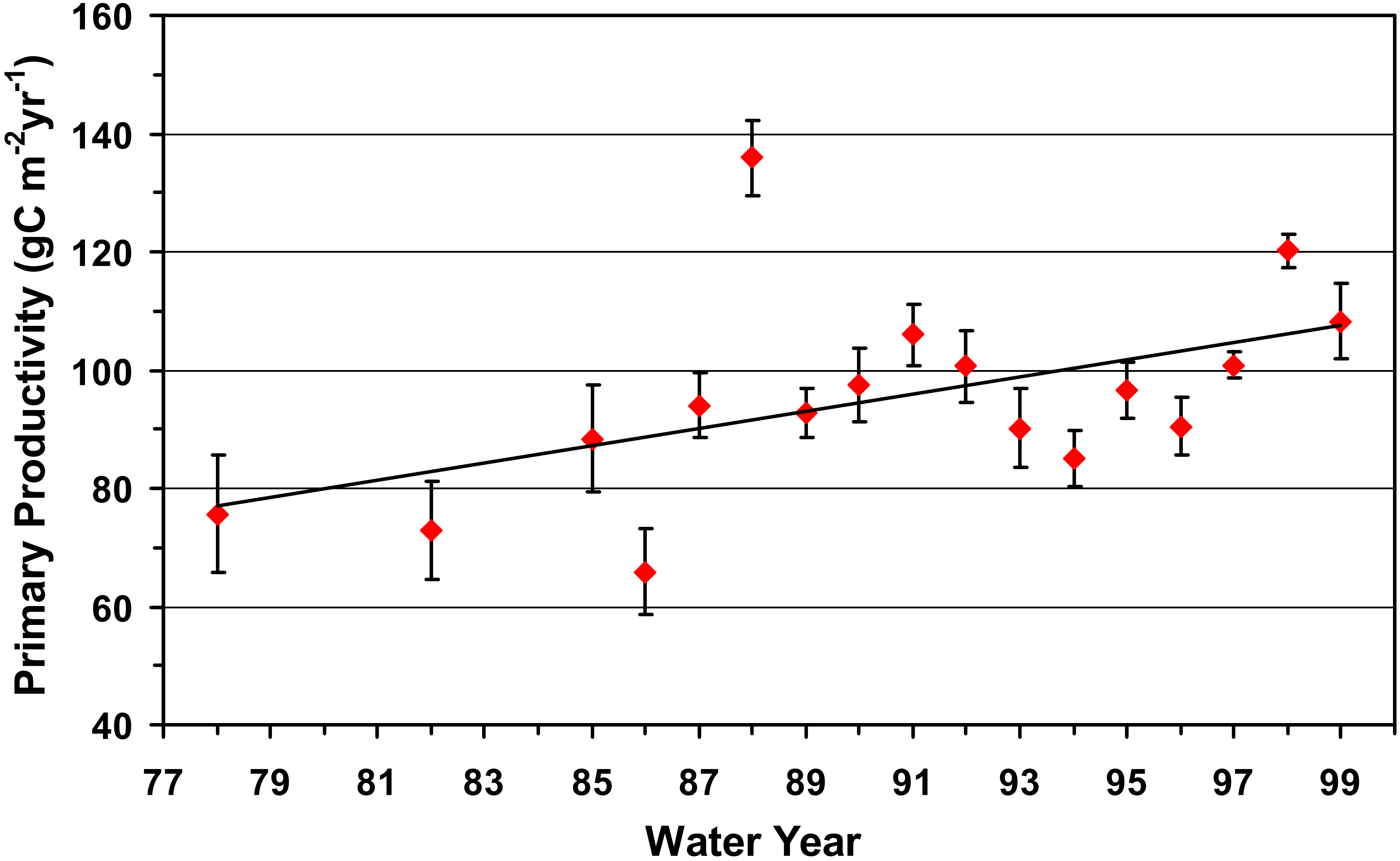

Figure 5. Mean annual pelagic primary productivity (gC m^{-2} yr^{-1}) at the midlake deep site for Flathead Lake from 1978 to 1999. Bars represent minimum and maximum yearly estimates.