PHOSPHORUS EXPORT FROM THE PINE RIVER

CASS AND CROW WING COUNTIES, MINNESOTA

By The Pine River Watershed Protection Foundation

December, 2003

Report prepared by J.O. Wallschlaeger.

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CREDITS

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INTRODUCTION

The objective of this study was to determine the amount of phosphorus entering the main stems of the Pine River from feeder streams over one growing year with the intent of identifying feeder streams or land areas that contribute significant amounts of phosphorus to the Pine River. There are five main feeder streams to the South Fork of the Pine River that will be monitored for phosphorus levels. Elimination or reduction of these phosphorus sources is beyond the scope of this study.

This study was funded by a grant from the Crow Wing County Water Plan to the Pine River Protection Foundation (PRWPF). Volunteers from the PRWPF and Whitefish Area Property Owners Association (WAPOA) conducted the study.

The PRWPF undertook this study as a follow-on to a one year Phosphorus Loading Study on the Whitefish Chain Of Lakes in 2000 and 2001 by the WAPOA. The WAPOA study was undertaken because the Association's water quality data over the last 15 years indicated a gradual reduction in water transparency of two to four feet. The WAPOA study showed that 40 per cent of the phosphorus, from all sources, entering the Whitefish Chain (tributaries, precipitation, septics and run off) came from the Pine River via Delta Bay. This 40 percent import amounted to 15,664 pounds of phosphorus annually. Based on four flow volume measurements the WAPOA study estimated annual flow from the Pine at 270,000,000 m^3/year. Although the WAPOA study was limited in scope, and therefore subject to some uncertainty, it clearly indicated that the major source of phosphorus was the Pine River and hence the reason for this study.

A plan was developed to do a yearlong study to determine the phosphorus loading from the feeder streams to the North and South Forks of the Pine River. There are five feeder streams to the South Fork of the Pine, which were expected to be the major contributors since they originated in, or passed through varying degrees of agricultural lands. The North Fork was of lesser concern because its watershed is largely undeveloped forest, water and wetland. Monthly measurements of flow rate, flow area and total phosphorus concentrations were planned at 12 primary sites, which would allow phosphorus export calculation.

Secondary sites were designated on feeder streams upstream of the primary sites to localize phosphorus sources. The most upstream site is number one with the site numbers increasing to 12, which is where the Pine flows into Whitefish Lake. A map of these Pine River sampling sites is shown in Figure 1.

The watershed terrestrial area, which drains into the Pine, is 140,171 (76.7%) acres and the open water/wetland area is 42,536 (23.3%) acres for a total drained area of 182,734 acres.

Table 1 below, shows land use for the primary basins that drain to the Pine River from the 1996 National Wetlands Inventory. The Upper Pine River Watershed drains to the North Fork of the Pine while the South Fork Pine River Watershed drains to the South Fork. Several preliminary observations can be made comparing the two primary watersheds.

- The Upper Pine River WS is 33 % larger
- The Upper Pine River WS has 35 % more forested land
- There is 13 times more open water in the Upper Pine River WS
- There is 35 % more grassland in the South Fork WS
- There is 1.6 times more cultivated land in the South Fork WS

Table 1

Land Use	Upper Pine River Watershed	Upper PR WS %	South Fork Pine River Watershed	So. Fk. PR WS %	Arvig Ck. Sub Watershed	Arvig SWS %	Total Area (acres)	%
Bare Rock	1.8 a.	0	0.4a.	0	0a.	0	0.4a.	0
Conif. Forest	7,394.1	7.8	5,289.5	7.4	779.1	5.0	13,462.7	7.4
Cultivated	1,060.8	1.1	2,786.2	3.9	510.1	3.2	4,357.1	2.4
Decid. Forest	37,038.1	38.8	25,016.7	34.9	6,102.1	38.9	68,156.9	37.3
Farmsteads	445.7	0.5	448.7	0.6	133.8	0.9	1,028.2	0.6
Grassland	9,443.2	9.9	13,669.6	19.1	4,414.1	28.1	27,526.9	15.1
Gravel	164.3	0.2	9.7	0	0.6	0	174.6	0.1

Land Use	Upper Pine River Watershed	Upper PR WS %	South Fork Pine River Watershed	So. Fk. PR WS %	Arvig Ck. Sub Watershed	Arvig SWS %	Total Area (acres)	%
Pits								
Mixed Wood	4,601.3	4.8	2,024.9	2.8	394.7	2.5	7,020.9	3.8
Open Water	12,414.3	13.0	1,612.7	2.3	371.4	2.4	14,398.4	7.9
Other Rural	1,359.2	1.4	291.9	0.2	63.4	0.4	1,714.5	0.9
Reg./Young For	6,842.4	7.2	4,324.6	6.0	604.1	3.9	11,771.1	6.4
Shrubby Grass	2,008.9	2.1	1,581.5	2.2	41.9	0.3	3,632.3	2.0
Cities/Towns	906.6	1.0	243.3	0.3	162.5	1.0	1,312.4	0.7
Bogs-Wetland	636.6	0.7	1,218.5	1.7	3.8	0	1,858.9	1.0
Marsh/Fen Wet.	11,069.3	11.6	13,131.3	18.3	2,134.5	13.6	26,335.1	14.4
TOTAL	95,386.6	100	71,640.5	100	15,706.1	100	182,734.2	100

METHOD OF ANALYSIS

Initially a land use study of the National Wetlands Inventory maps was undertaken to identify potential sampling locations, accessibility and watershed features. The potential locations were confirmed or adjusted by site surveys. The specific locations selected are listed below and shown on a map as Figure 1.

Primary Sites:

1. South Fork of the Pine at 48th Avenue. (4 culverts)
2. Dabill/Brittan Creeks at 48th Avenue. (1 culvert)
3. Bungo Creek at Cass County Highway 2. (2 span bridge)
4. South Fork of the Pine at Cass County Highway 2. (1 span bridge)

5. South Fork of the Pine at 36th Avenue. (3 culverts)
6. Wilson/Hobin Creeks at 36th Avenue. (1 culvert)
7. Behler Creek at 28th Avenue. (1 culvert)
8. South Fork of the Pine at 23rd Avenue. (1 span bridge)
9. North Fork of the Pine at State Highway 371. ((3 span bridge)
10. Pine River at State 371. (3 span bridge)
11. Arvig Creek at RV Park off Cass County Highway 44. (1 span bridge)
12. Pine River at Crow Wing County Highway 15. (3 span bridge)

Secondary Sites:

S1. Dabill Creek at Cass County Highway 2. (1 culvert)
S2. Bungo Creek at 32nd Street. (4 culverts)
S3. Wilson Creek at 32nd Street. (1 culvert)
S4. Behler Creek at 32nd Avenue. (1 culvert)
S5. North Fork of the Pine at 12th Street. (2 span bridge)

Stream cross section profiles were measured at each site monthly. The bridge water depth profiles were recorded in feet as averages over two or five foot horizontal increments. The culvert cross sectional areas were calculated from culvert diameter, top of culvert to water distance and top of culvert to bottom distance. Sedimentation was inferred by the difference between culvert diameter and culvert to bottom distance. A nonograph on calculations for "Flow in Partially Filled Round Pipes" from Global Water Instrumentation Inc. was then used to calculate cross sectional area. Depth measurements were made to +- 0.1 feet. Staging devices were not available and the numbers of measurements were not adequate to accurately estimate volume.

Average flow velocities were measured concurrently over the same horizontal increments as the area measurements. The average velocities were measured at one third of the water depth up from the bottom on the bridges and averaged across the entire flow for the culverts. A Global Flow Probe model FP201 Velocimeter on loan from Cass County Environmental Services was used for the first four months and a Marsh McBurney model 201D on Loan from the Crosslake Corps of Engineers was used for the remaining measurements. The two instruments agreed within 5 percent.

Total phosphorus water grab samples were taken in 500-ml. acid washed bottles after rinsing the bottle and cap three times at a central location in the flow. The water samples were identified, stored on ice and delivered for analysis to the Minnesota Chippewa Research Laboratory in Cass Lake, MN the same day.

Total phosphorus analysis was conducted in accordance with USEPA 365.1 with a minimum detection level of 2.0 micro grams per liter (ug/l). Blind samples were not collected to minimize cost, because five years of experience with the Chippewa Laboratory had not shown any significant differences in blind checks during the period.

Data input sheets were developed for the required field measurements to insure consistency and so that no measurements would be overlooked. Two of these data sheets are appended to this report as Appendices 1 and 2 for review because the 150 data sheets produced were considered too voluminous to warrant publishing. The data resulting from the data sheets is summarized on Tables 2 and 2a which presents flow rate (CFS), total phosphorus concentration (ug/l) and the calculated phosphorus mass (lbs./month). Because the cadre of volunteers varied from month to month, new or refresher training was conducted each month as needed.

Monthly precipitation data is shown on Table 2-5 for reference. The precipitation data is from the Minnesota State Climatology Office, DNR Waters for the area just west of Pine River, Minnesota.

DISCUSSION OF RESULTS

The phosphorus exported from the feeder streams of the Pine River, the accumulating loads to the river main stem and finally to Whitefish Lake, were measured once monthly for a year beginning in June 2002 to satisfy the objectives of this investigation. Difficult ice-on conditions during December 2002 January, February 2003 shortened our efforts somewhat but did not compromise the objectives because of very low flow conditions due to scant precipitation. October 2002 data was used in Table 5 for the three months to present annual mass data.

All of the raw data measurements are presented in Table 2, as previously mentioned, and the monitored locations are displayed in Figure 1. Data summaries, by location, for monthly flow volume, total phosphorus concentration and phosphorus export are discussed in the following sections.

Flow Volumes

Measured monthly flow volumes are presented in Table 3 and graphically shown in Figures 2 and 3 in relation to precipitation. The total flow volume to Whitefish Lake over nine months was 186,555,072 cubic meters and when extrapolated to a year is 248,740,096 cubic meters which is in general agreement with the 270, 000,000 reported in the Whitefish Phosphorus Loading Study (2001) mentioned earlier. Annual precipitation for the 2001 Loading Study was reported as 35.51 inches versus precipitation shown in Table 3 for this export study is 25.91 inches or 27 per cent less. Mean precipitation according to the Minnesota Climatologist's Office for the Pine River Watershed area is 26 to28 inches annually. Figure 3 shows very good correlation between monthly precipitation and flow volume as might be expected. It is notable that nearly half of the annual flow at Highway 15 (Location 12), into Whitefish occurred during July following the 8.08 inch rainfall (31% of the annual precipitation).

Four Creeks (Dabill/Brittan #2, Wilson/Hobin #6, Behler #7 and Arvig #11) had no flow for most of the year, presumably due to lack of precipitation and therefore contribute very little flow or phosphorus export.

Total Phosphorus Concentration

Monthly total phosphorus concentrations are presented in Table 4 for all sampling sites and graphically in Figures 4 and 5. Average concentrations for all 12 sampling locations are not of great value but they do demonstrate a dependency on the amount of precipitation. July after the 8 inches of rain shows the highest monthly average at 117 ug/l with the spring months of March and April not far behind at 109 and 101 respectively. The spring phosphorus levels are somewhat surprising because of the insignificant snow precipitation in the range of 0.1 to 0.4 inches of moisture which produced very little spring runoff. In considering individual feeder stream concentration levels the upstream feeder creeks of Bungo (#3), Dabill/Brittan (#2) and Cedar (#1) displayed the highest concentrations. Cedar (#1) averaging 69 ug/l is of particular interest because it flows through public lands that are normally not nutrient rich. Bungo levels were consistently high, averaging 93 ug/l for nine measurements as it drains from agricultural lands.

The monthly phosphorus level of the Pine River as it enters Whitefish is shown in Figure 4. The high levels in March and April is not explainable but would seem to infer that was surface run off due to spring melt and not due to high flow from the feeder streams. The variation of average phosphorus levels with time is graphically shown in Figure 5 and generally follows the flow rates of

Figure 2. Again, the precipitation flush in July is quite dominant but the low spring runoff in 2003 carries significant levels of nutrient not related to major rain events. Also notable is the fact that phosphorus levels in the North Fork of the Pine remain relatively low even though that portion of the watershed is 33 per cent larger than the watershed that feeds the South Fork. It should be noted that location S6 on the North Fork which is upstream, and above Norway Lake, (see Table 2) had virtually the same concentrations as the down stream site (location 9) indicating that there is no contribution from Norway Lake.

Of major concern is the fact that the average total phosphorus levels for all South Fork feeder streams and the Pine River main stem exceed the established stream criteria for total phosphorus in the Northern Lakes and Forests ecoregion of 30 to 50 ug/l. This criterion was reported in the 2003 Volunteer Surface Water Monitoring Guide by the Minnesota Pollution Control Agency from data derived from McCollor and Heiskary (1993). Fifty nine percent of all total phosphorus measurements made (51 of 87) exceeded the criterion. Seventy five per cent of all measurements on the five feeder streams that feed the south fork exceeded the criterion (24 of 32) for phosphorus.

Phosphorus Export and Coefficients

The summary for phosphorus export for the Pine River and its tributaries is presented in Table 5. It should be noted that October 2002 data was used to estimate the data for December 2002, January and February 2003 because of no data for ice on conditions. The export for October is on the order of one percent of the total for the year, so using October data for the ice on months should not introduce a significant error. The phosphorus export was calculated using the flow-weighted average formula recommended by the U.S. Environmental Protection Agency.

$T=5.394\ QCI$

Where

T= the total amount of phosphorus in pounds
Q= the average flow for the period in cubic feet per second
C= the phosphorus Concentration of the flow in micro grams per liter
I= the number of days in the period

The total annual export from the Pine River to Whitefish Lake was calculated to be 25,683 pounds as compared to that reported in the Whitefish Phosphorus Loading Study as 15,664 pounds. The values are significantly different and may be understandable recognizing that the Loading Study was based on just four quarterly measurements while this study involved nine monthly

measurements and three months of estimated data. Figure 6 shows the monthly variation of phosphorus export to Whitefish with a July peak influenced by heavy precipitation.

Figure 7 shows the annual export from six individual South Fork streams with Bungo Creek and the South Fork at 48th Street dominating the field. Figure 8 clearly demonstrates the cumulative effect of increasing phosphorus levels from the feeder streams to the South Fork and Pine River. Figure 9 presents an annual feeder stream phosphorus percentage distribution. Not surprisingly, two streams provide 67 per cent of the export. A Stick Figure representation of phosphorus export for the entire stream complex is provided in Figure 10 to help visualize the dependencies of the system.

Table 6 below, presents the calculated phosphorus export coefficients based on the terrestrial area of the respective watersheds. These export coefficients can be compared to values reported in the Water Resources Center Primer on Limnology and adapted from Reikhow and Simpson, 1980. The most likely values reported for various land use cover are as follows:

Urban	0.713 to 2.68 pounds per acre per year
Rural/Agricultural	0.367 to 1.52
Forest	0.125 to 0.268
Precipitation	0.178 to 0.446

In general the calculated export coefficients are in the range of expectations but notable is the high value for Bungo Creek and South Fork at 48th Avenue. The Bungo value is particularly undesirable but understandable considering the agricultural nature of its watershed. However, the South Fork at 48th Avenue passes through public lands with very little active agriculture.

TABLE 6
Phosphorus Export Coefficients

Location	Watershed Description	Terrestrial Area (acres)	Annual Phos. Export (lbs.)	Export Coeff. (lbs./acre/yr.)
1. So Fork @48th Av.	Upper So. Fork Pine River sub-watershed	15,631	7,715	0.49
2. Dabill/Brittan @ 48 Av.	Dabill Creek sub-watershed.	8,081	1,936	0.24

3. Bungo @ Hwy. 2.	Bungo Creek sub-watershed.	9,800	10,379	1.06
4. So. Fork @ Hwy. 2	So. Fork Pine River watershed minus Lower So. Fork sub- watershed.	40,439	9,874	0.24
5. So Fork at 36 Av.	So. Fork Pine River watershed minus Lower So. Fork sub-watershed.	40,439	11,497	0.28
6. Wilson/Hoblin @ 36 Ave.	Hoblin Creek sub watershed.	6,925	2,650	0.38
7. Behler @ 28 Av.	Behler Creek sub-watershed.	3,499	4	0.001
8. So Fork @ 23 Av.	So. Fork Pine River watershed.	55,678	8,430	0.15
9. No. Fork @ Hwy 371.	Upper Pine River watershed.	71,266	3,798	0.05
10.Pine River @ Hwy 371	So. Fork Pine River watershed plus Upper Pine River watershed.	126,945	21,710	0.17
11. Arvig Ck. @ RV Park	Arvig Creek sub-watershed.	13,226	473	0.04
12. Pine @ Hwy 15. (Whitefish Lake)	Location 10 plus Arvig Creek sub-watershed.	140,171	25,683	0.18

A review of the land uses in the five sub watersheds that comprise the South Fork of the Pine River Watershed reveal very little contrast between the watersheds as shown in Table 7. Note that Deciduous Forest (37%), Grassland (20%), and Marshes (15%) comprise 70 percent of land usage which offers no indication of abnormal nutrient export or a reason to look at Bungo Creek and, or the Upper South Fork of the Pine River Sub Watershed.

CONCLUSIONS

The average phosphorus levels for all Pine River locations monitored exceeded the established total phosphorus stream criteria for this Northern Lakes and

Forests ecoregion of 30 to 50 ug/l except the North Fork of the Pine which averaged 26 ug/l (Table 4).

The average phosphorus concentration of the Pine River as it enters Whitefish Lake is 52 ug/l which slightly exceeds the criteria for this ecoregion. The average phosphorus concentration of the North Fork before it joins the South Fork is 26 ug/l and the South Fork concentration is 66 ug/l just before it joins the North Fork. The average flow volume of the South Fork before they join is 142 percent higher than the North Fork. The North Fork dilutes the higher concentration of the South Fork to 52 ug/l after they join.

Four of the six main feeder streams on the South Fork contribute 22,680 pounds of phosphorus annually, which is 88 percent of the phosphorus exported (25,683 pounds) to Whitefish Lake (Table 5). The streams are South Fork at 48th Avenue, Dabill/Brittan, Bungo and Wilson/Hobin. Seventy percent (18,094 pounds) of the export to Whitefish Lake comes from the first two – South Fork at 48th Avenue and Bungo Creek. The single largest contributor is Bungo Creek exporting 10,379 pounds or 41 percent. Clearly, any remedial action should start with Bungo Creek.

Today there is only one major farm and permitted feedlot, operated by Randy Norman, in the Bungo Creek Sub Watershed. All available intelligence indicates that the farm is operated within the constraints of the permit and should not be a contributor to the flashy discharges from Bungo Creek. Twenty-five and thirty years ago there were many more farms in the area, all located along Bungo Creek for its water supply. One could speculate that the residual and rotting remains of these farming operations provides or at least contributes to the flashy phosphorus delivery from Bungo Creek. If the phosphorus problem is in fact due to the residual rotting there may be other undesirable materials not considered in this study.

Since we know that most of the phosphorus export from Bungo Creek occurs as the result of heavy rains we considered the possibility of damning the creek at Highway 2, before the confluence with the South Fork main stem, in order to hold the nutrient level and allow it to settle and be absorbed by aquatic plants. We also considered a large collection basin to retain and treat the nutrient run off resulting from heavy rains. After due consideration the ideas were rejected because the land profile of the lower Bungo Creek sub watershed is so flat that the damning would flood the private cropland, and a collection basin would

TABLE 2

Monthly Pine River Total Phosphorus Export, Tributary Flow Rate and Total Phosphorus Concentration

		Jun (6/13)			Jul(7/8)			Aug (8/7)			Sep(9/5)			Oct(10/2)			Nov(11/13)	
	Flow	T.P.Conc.	P Mass	Flow	T.P.Conc.	TP Mass	Flow	T.P.Conc.	P Mass	Flow	T.P.Conc.	P Mass	Flow	T.P.Conc.	P Mass	Flow	T.P.Conc.	P Mass
LOCATION	CFS	ug/L	lbs./mo.	CFS	ug/L	lbs./mo.	CFS	ug/L	lbs./mo.	CFS	ug/L	lbs./mo.	CFS	ug/L	lbs./mo.	CFS	ug/L	lbs./mo.
1.So. Fork @ 48th Ave.	21	73	249	311	117	5,950	3	54	29	2	39	12	5	47	40	2	36	14
2.Dabil/Brittan @ 48th Ave.	0	65	2	58	168	1,582	0	0	0	1	58	1	1	47	5	1	31	6
3.Bungo @ Hwy 2	11	128	516	298	188	9,192	2	71	20	3	69	33	3	74	40	ice		
S2.Bungo @ 32nd St.				35	168	833	0	0	0	0	0	0		0	0	ice		
4.So. Fork @ Hwy. 2	4	12	8	244	156	6,236	99	51	823	54	56	477	5	42	211	ice		
5.So.Fork @ 36th Ave.	57	73	583	310	129	6,546	16	46	118	14	56	132	18	41	119	26	36	131
6.Wilson/Hobin @ 36th Ave.	0	142	6	71	210	2,446	1	19	3	1	64	11	0	0	0	ice		
7.Behler @ 28th Ave.	0	108	0	1	50	4	0	0	0	0	0	0	0	0	0	ice		
8.So.Fork @ 23rd Ave.	31	53	269	110	91	1,641	14	30	71	14	42	94	19	37	116	ice		
S6.No.Fork @ 12th St.				159	31	678	67	20	221	50	20	165						
9.No.Fork @ Hwy.371	116	28	532	173	29	840	47	19	146	45	18	131	37	22	132	65	37	396
10.Pine @ Hwy.371	226	31	1,146	886	68	9,861	79	90	1,162	88	27	391	86	14	197	92	23	345
11.Arvig @ RV Park	0	93	7	17	127	362	0	66	0	0	0	0	0	0	0	ice		
12.Pine @ Hwy. 15	325	28	1,482	1,044	67	11,415	152	33	820	145	24	571	124	11	223	91	19	284
Monthly Precipitation (in.)		1.07			8.08			2.98			2.73			1.53			2.31	

TABLE 2a
Monthly Phosphorus Export, Tributary Flow Rate and Total Phosphorus Concentration

		Dec.02			Jan. 03			Feb.			Mar.(3/26)			Apr.(4/24)			Jun.(6/4)		9 mo.Flow
	Flow	T.P.Conc.	P Mass	Flow	T.P.Conc.	TP Mass	Flow	T.P.Conc.	P Mass	Flow	T.P.Conc.	P Mass	Flow	T.P.Conc.	P Mass	Flow	T.P.Conc.	P Mass	Average
LOCATION	CFS	ug/L	lbs./mo.	CFS	ug/L	lbs./mo.	CFS	ug/L	lbs./mo.	CFS	ug/L	lbs./mo.	CFS	ug/L	lbs./mo.	CFS	ug/L	lbs./mo.	
		ICE			ICE			ICE											
1.So. Fork @ 48th Ave.										19	115	362	60	93	913	3	48	26	
2.Dabil/Brittan @ 48th Ave.										0	0	0	19	102	310	0	78	15	
3.Bungo @ Hwy 2										6	148	140	16	106	277	3	91	41	
S2.Bungo @ 32nd St.										0	0	0	0	0	0	0		0	
4.So. Fork @ Hwy. 2													96	107	1,680	5	47	236	
5.So.Fork @ 36th Ave.										36	113	673	173	112	2,628	23	57	210	
6.Wilson/Hobin @ 36th Ave.										0	0	0	13	90	184	0		0	
7.Behler @ 28th Ave.										ice			0	0	0	0		0	
8.So.Fork @ 23rd Ave.										42	117	797	172	113	3,197	123	94	1,897	
S6.No.Fork @ 12th St.																			
9.No.Fork @ Hwy.371										79	44	570	88	39	575	19	25	80	
10.Pine @ Hwy.371										141	81	1,864	304	107	5,324	141	36	829	
11.Arvig @ RV Park										ice			5	137	104	0		0	
12.Pine @ Hwy. 15										160	148	3,865	313	109	5,594	154	30	760	279
Monthly Precipitation in.		0.38			0.08			0.22			0.46			2.58			3.53		yr. 25.91

T.P. Conc Total 469 ug/l
9 Mo Av. : 52 ug/l
= .052 mg/l

TABLE 3
Monthly Flow Volumes-
Pine River. (cubic m./month)

Location	6/13/02	7/8/02	8/7/02	9/5/02	10/2/02	11/13/02	Dec '02	Jan '03	Jan '03	3/26/03	4/23/03	6/4/03	9 mo. Total	Ave. Flow	
							ice on	ice on	ice on .				m.^3/9 mo.	m^3/mo.	
Feeder Streams															
1.So. Fork @ 48th Ave	1,562,064	23,133,424	223,152	148,768	371,920	148,768				1,413,296	4,463,040	223,152	31,687,584	3,520,843	
2.Dabill/ Brittan @ 48th Ave	0	2,432,550	0	0	74,384	74,384				0	1,338,912	0	3,920,230	560,033	
3.Bungo @ Hwy. 2	818,224	22,166,432	148,768	148,768	223,152	ice				1,100,824	1,190,144	223,152	25,201,240	3,150,155	
m^3/sec	11	298	2												
6.Wilson/Hobin @ 36th Ave	0	5,281,264	74,384	74,384	0	ice				0	966,992	0	6,397,024	1,279,405	
7.Behler @ 26th Ave	0	74,384	0	0	0	ice				0	0	0	74,384	74,384	
9.No. Fork @ Hwy 371	8,565,440	12,868,432	3,496,048	3,347,280	2,752,208	483				327,272	6,545,792	1,413,296	30,750,811	3,416,757	compare to 8
11.Arvig @ RV Park	0	1,264,528	0	0	0	ice				0	371,920	0	1,636,448	409,112	
Main Stem Stream															
4.So. Fork @ Hwy. 2	297,536	18,149,696	7,364,016	4,016,736	371,920	ice				0	7,140,864	371,920	37,712,688	5,387,527	=1+2+3
5.So. Fork @ 36th Ave.	4,239,888	23,059,040	1,190,144	1,041,376	1,338,912	1,933,984				2,677,824	12,868,432	1,710,832	50,060,432	5,562,270	
8.So. Fork @23rd Ave	2,305,904	8,182,240	1,041,376	1,041,376	1,413,296	ice				3,124,128	12,794,048	9,149,232	39,051,600	4,881,450	=1+2+3+6+7
10.Pine @ 371	16,810,784	65,904,224	5,876,336	6,545,792	7,257,024	6,843,328				10,488,144	22,612,736	10,488,144	152,826,512	16,980,724	
12.Pine @ Hwy. 15	24,174,800	77,656,896	11,306,368	10,785,680	9,223,616	6,768,944				11,901,440	23,262,192	11,455,136	186,555,072	20,728,341	
Precipitation (inches)	1.07	8.08	2.98	2.73	1.53	2.31	0.36	0.08	0.22	0.46	2.56	3.53	Annual Prec. 25.91		

file:monthly flow volumes pine river
sheet 1

Blank cells are ice-on conditions.
Zero indicates no flow.

TABLE 4
Monthly Total Phosphorus Concentrations for the Pine River and Tributaries (ug/l)

Location	6/12/02	7/8/02	8/7/02	9/5/02	10/2/02	11/13/02	Dec '02	Jan '03	Jan '03	3/26/03	4/23/03	6/4/03	Total	Ave. TP
							ice on	ice on	ice on .				Year	/mo.(ug/l.)
1.So. Fork @ 48th Ave	73	117	54	39	47	36				115	93	48	622	69
2.Dabill/ Brittan @ 48th Ave	65	168	0	58	47	31				0	102	78	484	69
3.Bungo @ Hwy. 2	128	188	71	69	74					148	106	91	747	93
4.So. Fork @ Hwy. 2	12	156	51	56	42						107	47	459	66
5.So. Fork @ 36th Ave.	73	129	46	56	41	36				113	112	57	590	66
6.Wilson/Hobin @ 36th Ave	142	210	19	64	0					0	90	0	383	77
7.Behler @ 26th Ave	108	50	0	0	0						0	0	158	79
8.So. Fork @23rd Ave	53	91	30	42	37					117	113	94	524	66
9.No. Fork @ Hwy 371	28	29	19	18	22	37				44	39	25	233	26
10.Pine @ 371	31	68	90	27	14	23				81	107	36	446	50
11.Arvig @ RV Park	93	127	66	0	0	0					137	0	330	83
12.Pine @ Hwy. 15	28	67	33	24	11	19				148	109	30	469	52
Monthly TOTAL	834	1400	479	453	335	182				766	1115	506		794
Monthly AVERAGE	70	117	48	45	37	30				109	101	56		66
Precipitation (inches)	1.07	8.08	2.98	2.73	1.53	2.31	0.36	0.08	0.22	0.46	2.56	3.53	25.91	

Blank cells are ice-on conditions.
Zero indicates no flow.

TABLE 5
Monthly Phosphorus Export (lbs) Summary for the Pine River and Tributaries

Location	6/12/02	7/8/02	8/7/02	9/5/02	10/2/02	11/13/02	Dec '02	Jan '03	Jan '03	3/26/03	4/23/03	6/4/03	Total
							ice on est.	ice on est.	ice on est.				Year
1.So. Fork @ 48th Ave	249	5,950	29	12	40	14	40	40	40	362	913	26	7,715
2.Dabill/ Brittan @ 48th Ave	2	1,582	0	1	5	6	5	5	5	0	310	15	1,936
3.Bungo @ Hwy. 2	516	9,192	20	33	40		40	40	40	140	277	41	10,379
4.So. Fork @ Hwy. 2	8	6,236	823	47	211		211	211	211		1,680	236	9,874
5.So. Fork @ 36th Ave.	583	6,546	118	132	119	131	119	119	119	673	2,628	210	11,497
6.Wilson/Hobin @ 36th Ave	6	2,446	3	11	0		0	0	0	0	184	0	2,650
7.Behler @ 26th Ave	0	4	0	0	0		0	0	0		0	0	4
8.So. Fork @23rd Ave	269	1,641	71	94	116		116	116	116	797	3,197	1897	8,430
9.No. Fork @ Hwy 371	532	840	146	131	132	396	132	132	132	570	575	80	3,798
10.Pine @ 371	1146	9,861	1,162	391	197	345	197	197	197	1,864	5,324	829	21,710
11.Arvig @ RV Park	7	362	0	0	0		0	0	0		104	0	473
12.Pine @ Hwy. 15	1482	11,415	820	571	223	284	223	223	223	3,865	5,594	760	25,683
Precipitation (inches)	1.07	8.08	2.98	2.73	1.53	2.31	0.36	0.08	0.22	0.46	2.56	3.53	26

file:monthly phos. export summary

Blank cells are ice-on conditions.
Zero indicates no flow.

Precipitation Data - MN State Climatology Office.
Dec.- Jan estimated based on October.

TABLE 7
Land Use for Watersheds of the South Fork of the Pine River (acres)

Feeder Stream Watershed	Stream Location	Cultiv. Land	Decid. Forest	Open Water	Grass-land	Mixed Forest	Marshes & Fens	Bogs	Farm-steds	Coniferous Forest	Other Rural Dev.	Shrubby Grassland	Young Forest	Gravel Pits	Urban Cities/Twns.	TOTAL
"UPPER SO. FK. PINE	1															
RIVER SUB WATERSHED".																
Cedar Creek W/S			2,637	296	51	234	1,002	31	2	424	18		454			5,149
Cow Lake W/S		513	1,873	191	1,151	222	1,773	109	50	486	42	151	330			6,891
Scribner Lake W/S			3,398	190	204	228	1,029	67	8	25	41	28	767			5,985
Lake 636 W/S			380	36	6	70	660	149		371	22	4	443			2,141
TOTAL SUB W/S		513	8,288	713	1,412	754	4,464	356	60	1,306	123	183	1,994			20,166
%		*3*	*41*	*4*	*7*	*4*	*22*	*2*	*0*	*6*	*1*	*1*	*10*			
"HOBLIN CREEK SUB-	6															
WATERSHED"																
Hoblin Creek W/S		207	759	24	1,155	85	761	10	18	266	8	67	77			3,437
Wilson Creek W/S		353	1,623	31	1,593	16	657		38	90	2	328	241			4,972
TOTAL SUB W/S		560	2,382	55	2,748	101	1,418	10	56	356	10	395	318			8,409
%		*7*	*28*	*1*	*33*	*1*	*17*	*0*	*1*	*4*	*0*	*5*	*4*			
"DABILL CREEK SUB-	2															
WATERSHED"																
Dabill Creek W/S		28	1,824	57	303	228	1,067	27	14	658		97	299			4,602
Brittan Creek W/S		51	2,060	125	530	467	1,217	74	11	878		52	578	5		6,048
TOTAL SUB W/S		79	3,884	182	833	695	2,284	101	25	1,536		149	877	5		10,650
%		*1*	*36*	*2*	*8*	*7*	*21*	*1*	*0*	*14*	*0*	*1*	*8*	*0*		
"BUNGO CREEK SUB-	3															
WATERSHED"																
Minnie Lake W/S		23	2,748	123	523	39	899	75	7	180		49	129			4,795
Bungo Creek W/S		387	4,878	139	3,133	140	1,781	83	55	713		260	234			11,803
TOTAL SUB W/S		410	7,626	262	3,656	179	2,680	158	62	893		309	363			16,598
%		*2*	*46*	*2*	*22*	*1*	*16*	*1*	*0*	*5*	*0*	*2*	*2*	*0*		
"LOWER SO. FK. PINE	7															
RIVER SUB WATERHED"																
Behler Creek W/S		136	860	18	1,880	8	760	41	29	85	4	148	299			4,268
Eagle Lake W/S		349	1,942	321	2,361	98	1,868	164	95	664	120	302	284	5	194	8,767
Clam Lake W/S		763	1,784	185	1,303	227	556	495	128	631	36	145	319		40	6,612
TOTAL SUB W/S		1,248	4,586	524	5,544	333	3,184	700	252	1,380	160	595	902	5	234	19,647
%		*6*	*23*	*3*	*28*	*2*	*16*	*4*	*1*	*7*	*1*	*3*	*5*	*0*	*1*	
"WATERSHEDS OF THE																
SO.FORK OF THE PINE"																
TOTAL WATERSHEDS		2,810	26,766	1,736	14,193	2,062	10,846	1,426	455	5,471	293	1,631	4,454	10	234	72,387
USE DISTRIBUTION %		*3.9*	*37.0*	*2.4*	*19.6*	*2.8*	*15.0*	*2.0*	*0.6*	*7.6*	*0.4*	*2.3*	*6.2*	*0.0*	*0.3*	100.0

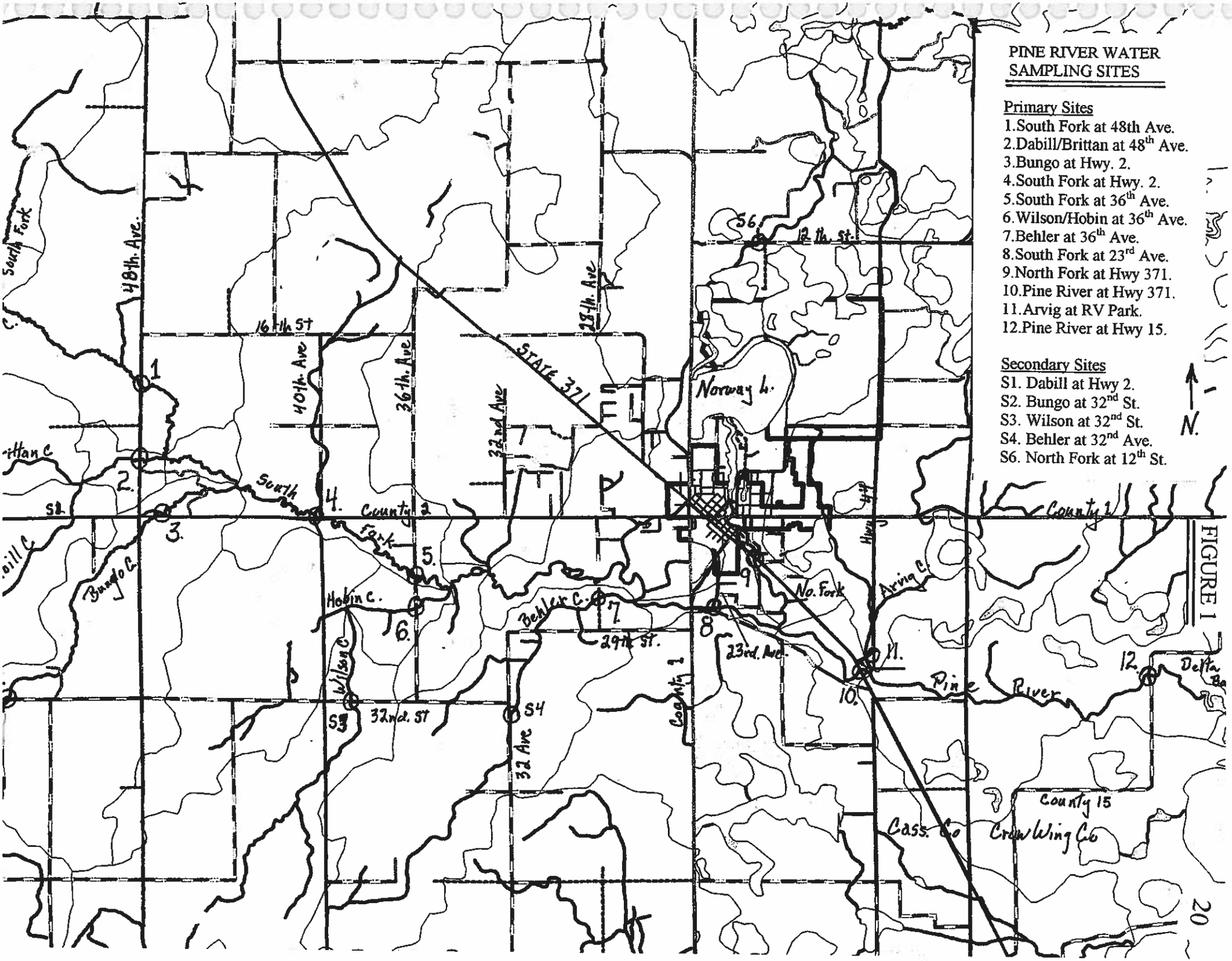
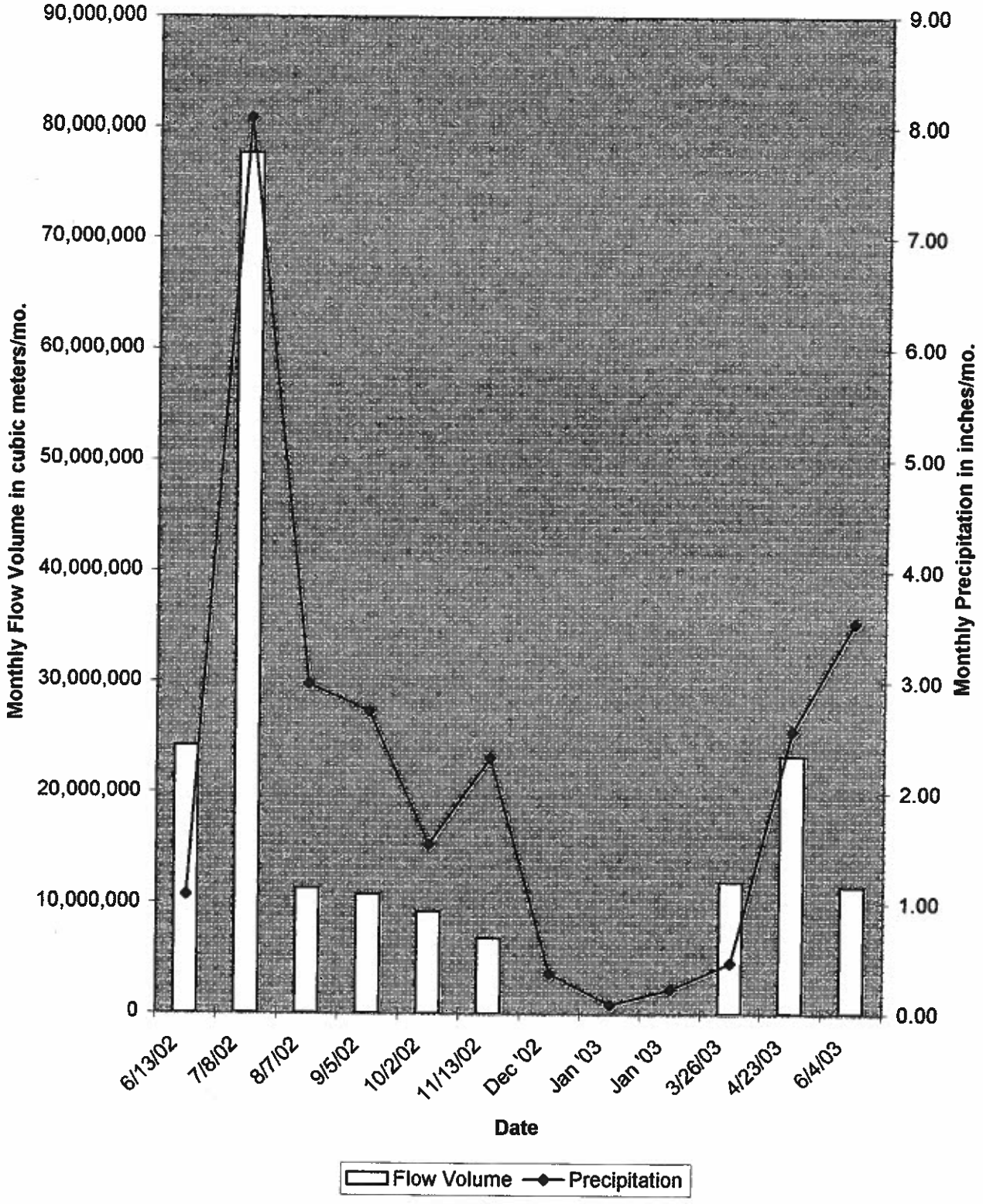

PINE RIVER WATER
SAMPLING SITES
Primary Sites
1.South Fork at 48th Ave.
2.Dabill/Brittan at 48th Ave.
3.Bungo at Hwy. 2.
4.South Fork at Hwy. 2.
5.South Fork at 36th Ave.
6.Wilson/Hobin at 36th Ave.
7.Behler at 36th Ave.
8.South Fork at 23rd Ave.
9.North Fork at Hwy 371.
10.Pine River at Hwy 371.
11.Arvig at RV Park.
12.Pine River at Hwy 15.
Secondary Sites
S1. Dabill at Hwy 2.
S2. Bungo at 32nd St.
S3. Wilson at 32nd St.
S4. Behler at 32nd Ave.
S6. North Fork at 12th St.
N.
South Fork
48th Ave.
16th St
40th Ave
36th Ave.
32nd Ave
State 371
28th Ave
Norway L.
56
12th St.
Brittan C.
South Fork
County 2
County 1
Bungo C.
Hobin C.
Behler C.
Wilson C.
29th St.
23rd Ave.
No. Fork
Arvig C.
Pine River
32nd St
32 Ave
County 1
County 15
Cass Co
Crow Wing Co
Delta Br
1
2
3
4
5
6
7
8
9
10
11
12
S1
S2
S3
S4
S6

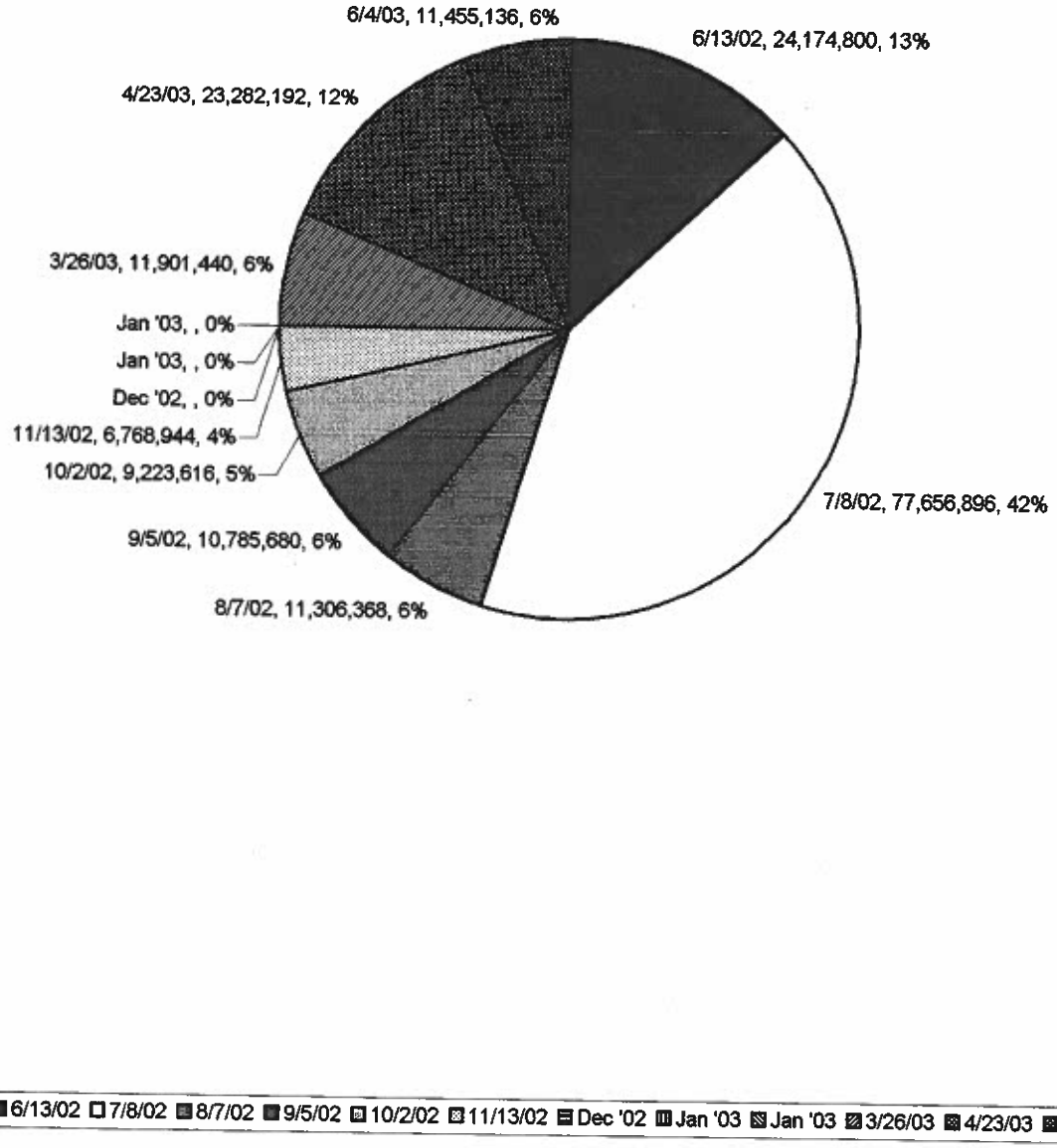
FIGURE 1

FIGURE 2. Pine River Flow Volume At Hwy. 15



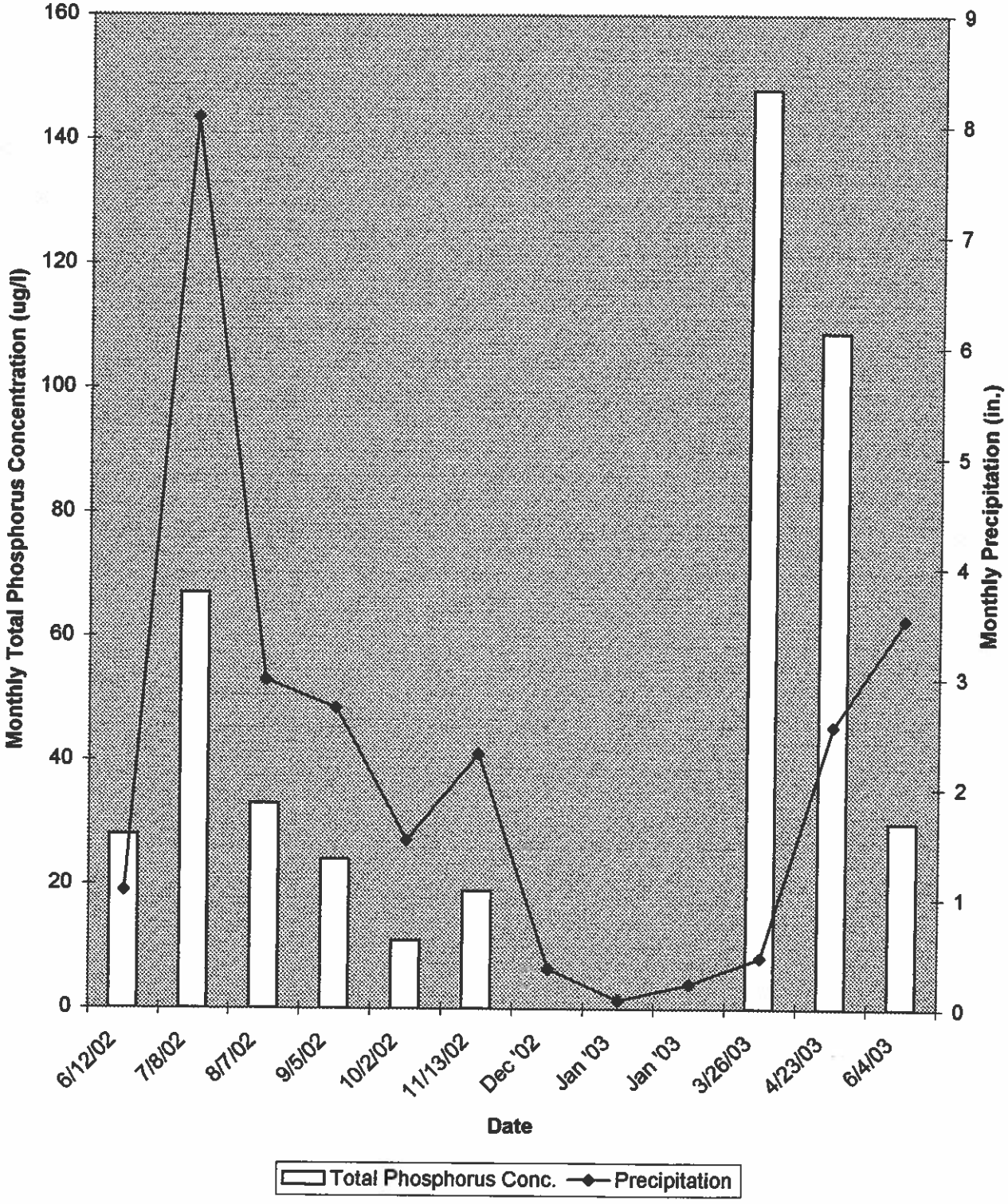
file: monthly flow volumes chart 1

FIGURE 3. Monthly Pine River Flow at Hwy. 15, in cubic m. /mo.



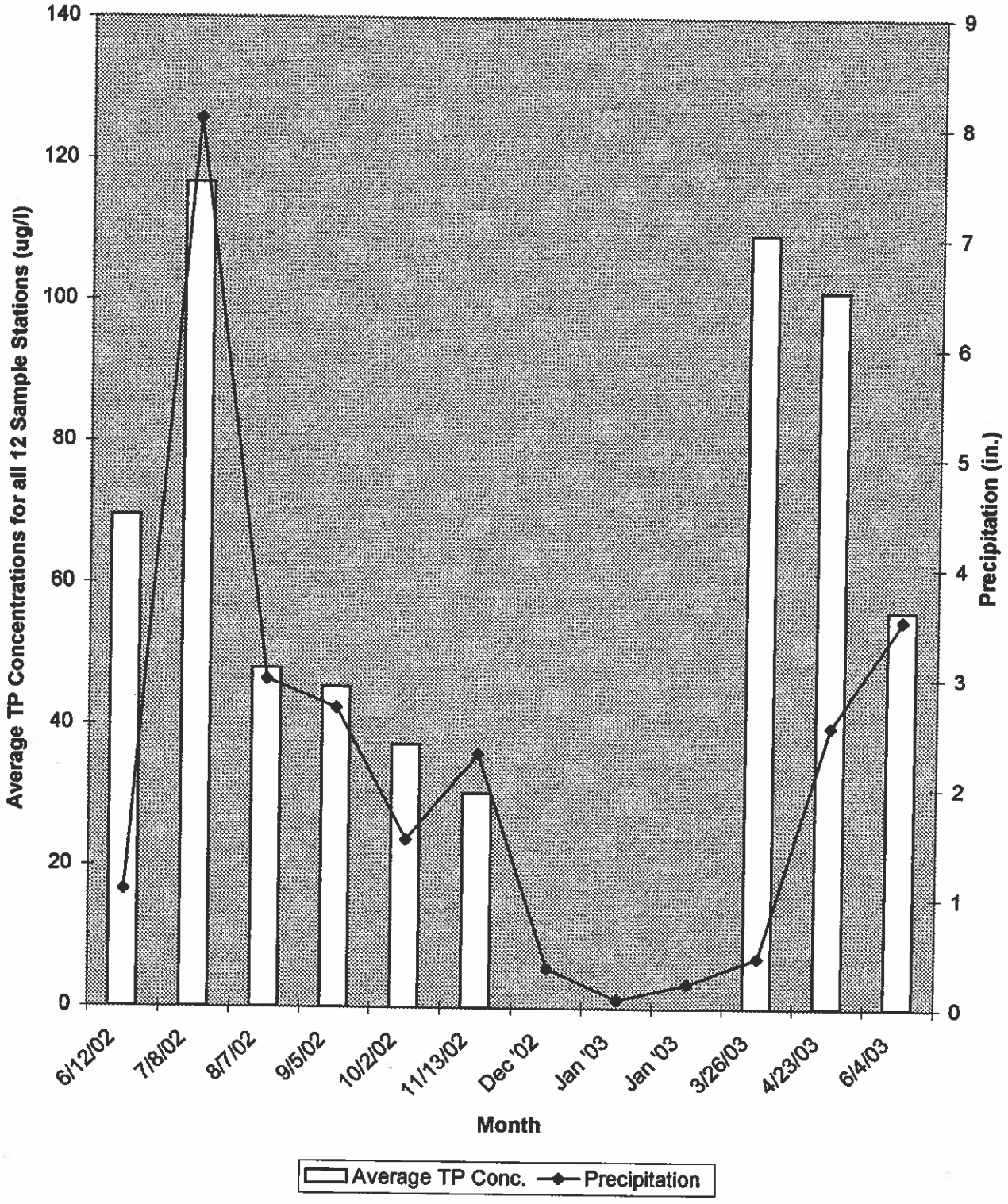
file:monthly flow volumes - pine river - chart 2

FIGURE 4. Monthly Total Phos. (ug/l) of the Pine River Export to Whitefish and Precipitation (in.)



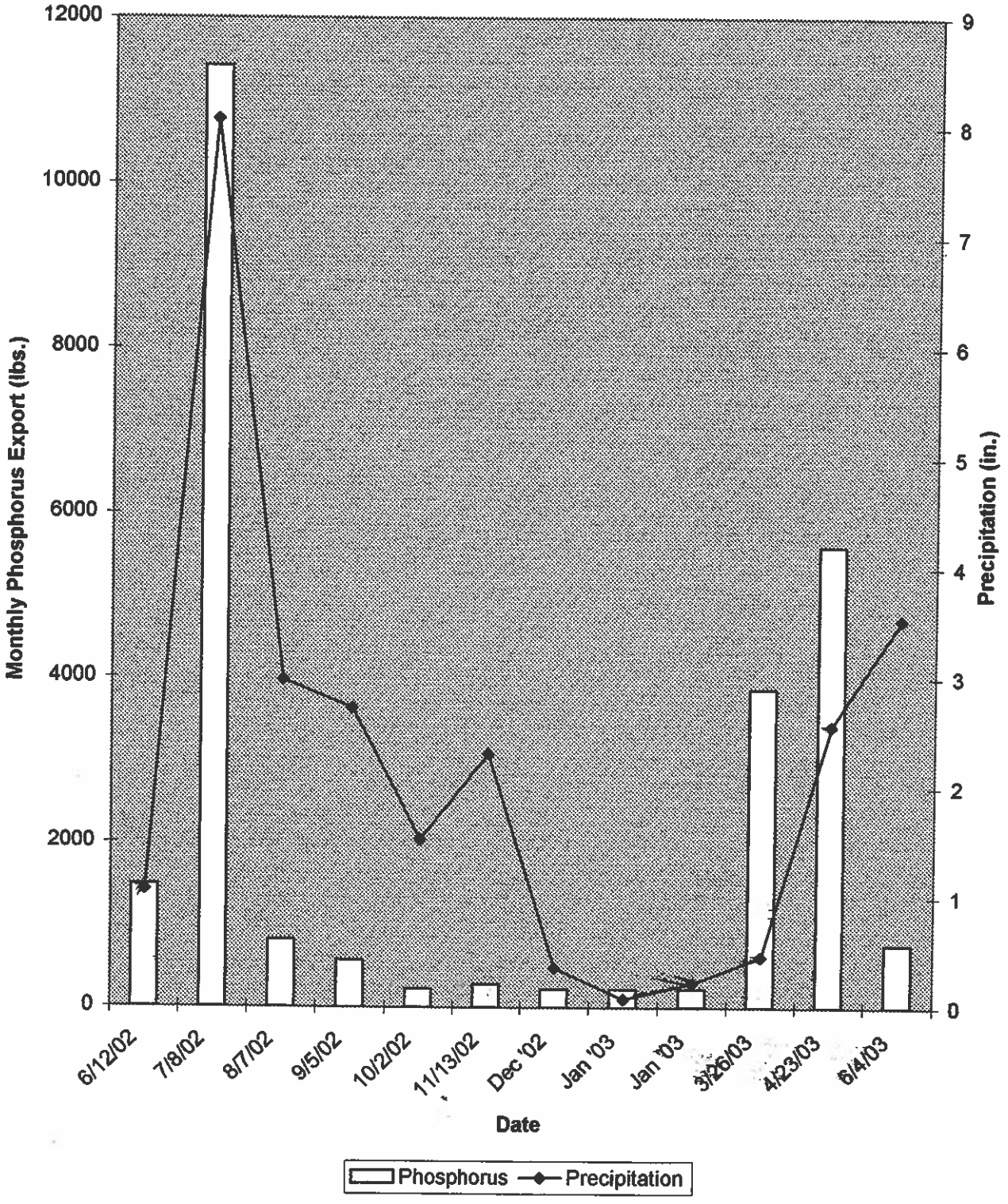
file ;monthly total phosphorus concentration - tpc.pr

FIGURE 5. Average Total Phosphorus Concentrations for all 12 Pine River Sample Stations and Precipitation



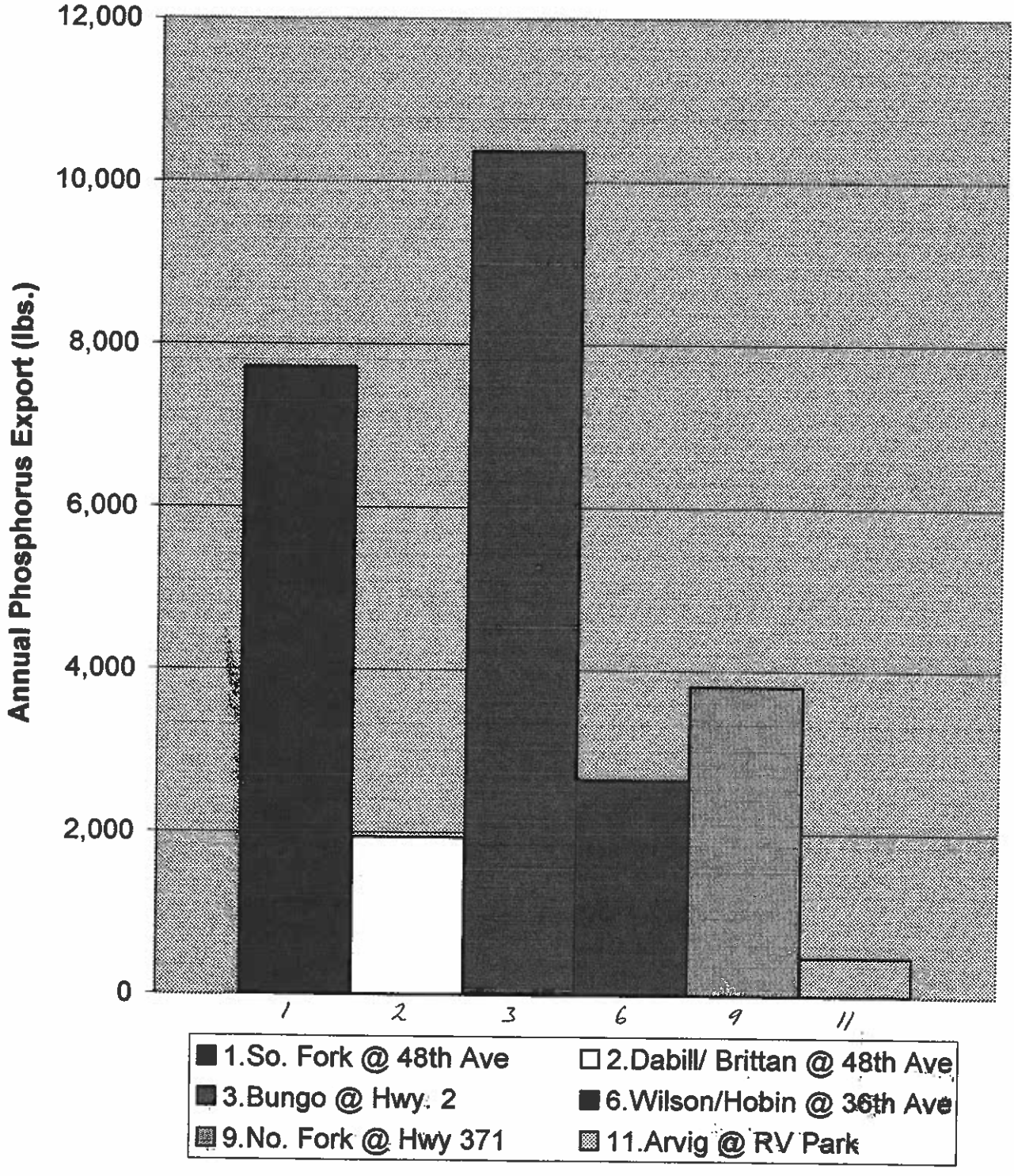
file:monthly total phosphorus concentration - tp.12 loc

FIGURE 6. Monthly Phosphorus Export of Pine River to Whitefish (Loc 12) and Precipitation



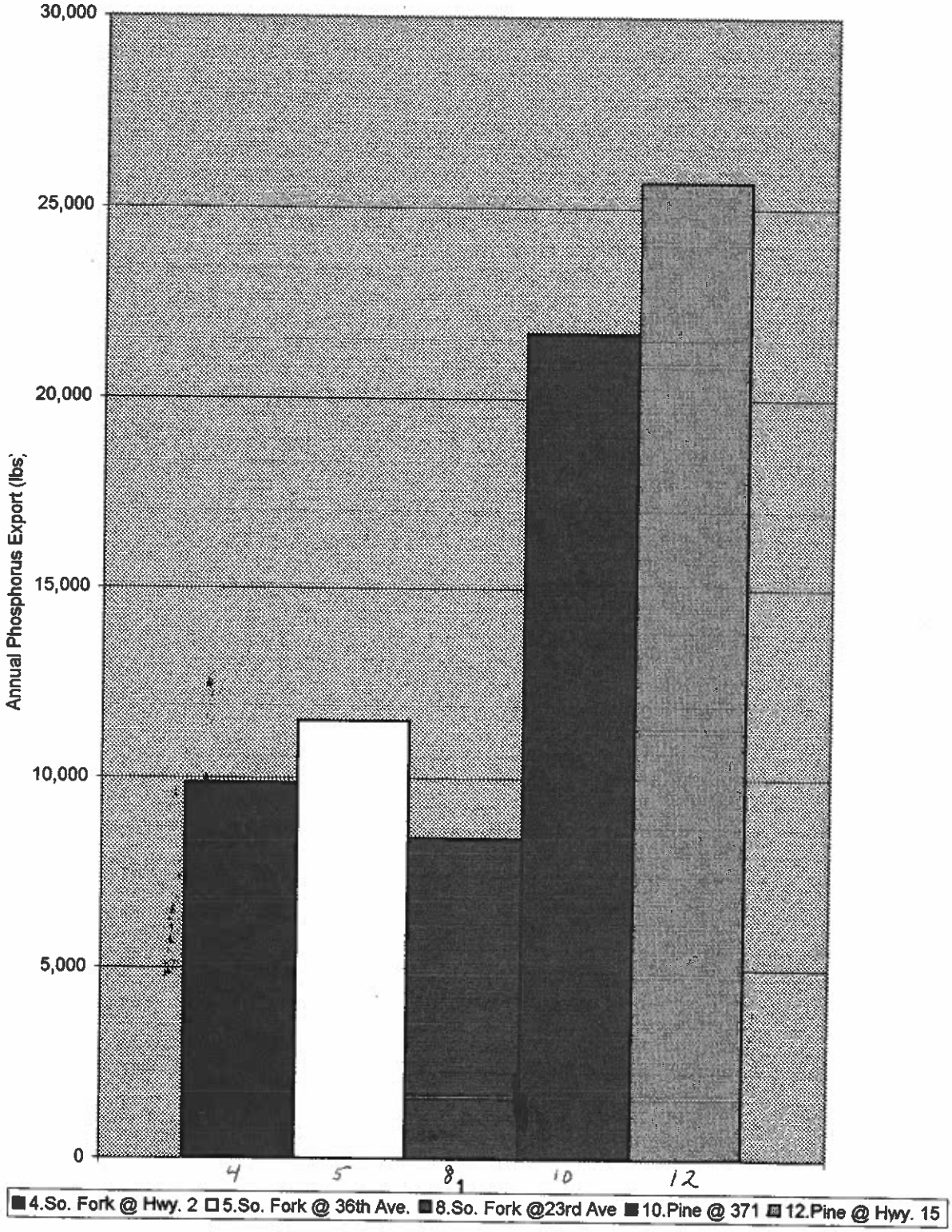
file: monthly phos. export summary - chart1

FIGURE 7. Annual Phosphorus Export from Feeder Streams (lbs.)

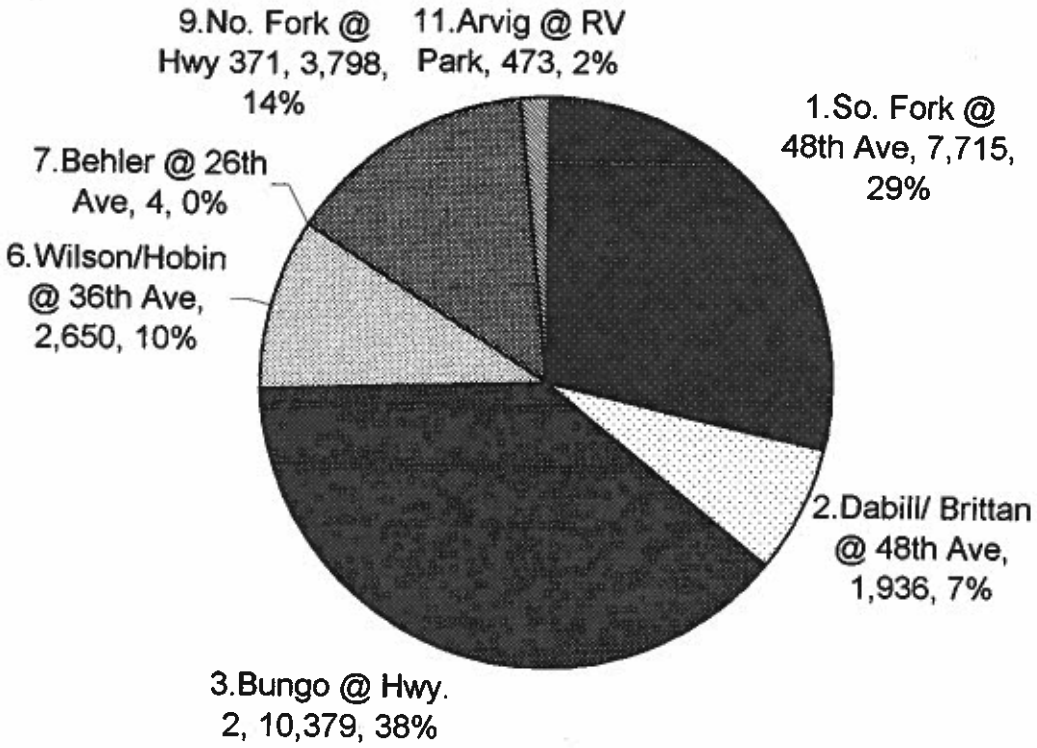


file:monthly phos. export - chart 2

FIGURE 8. Impact of Feeder Streams On Main Stem Sample Points

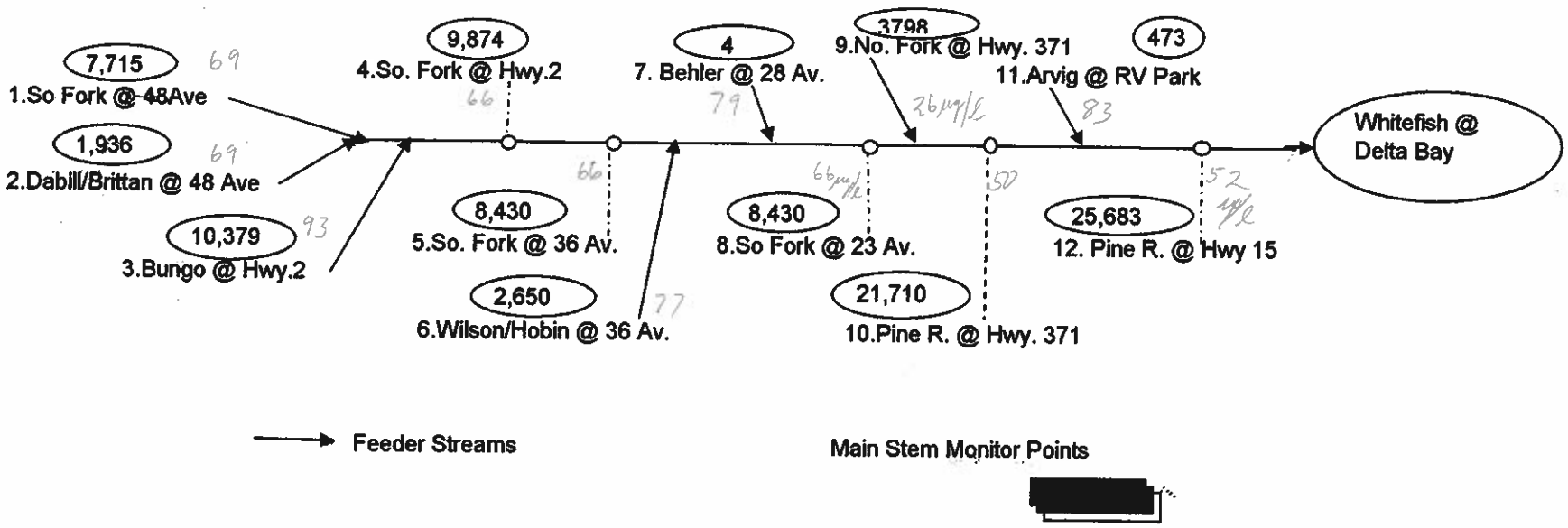


Annual Phosphorus from Feeder Streams (lbs & %)



file; Monthly Phos. Export Summary Pine River. Chart 4.

FIGURE 10
Pine River Annual Phosphorus Export (lbs)
Stick Figure



Culvert Locations
Date:7/8/02

APPENDIX 1
Pine River Phosphorus Export
file:culvert data sheet 3

	B	C	D	E(d-c)	F(b-d)	G(e+f/b)	H(f/b)	I	J	K(I-j)	L(k*b^2)	M	N(l*m)		
Culvert	Pipe Dia.	Pipe-Water	Pipe-Bottom	Water Depth	Sed. Depth	H/D	H2/D	Factor	Factor	Water	Area	Velocity	Flow	T.Phos	P.Mass
Location	feet(D)	feet	feet	feet(H)	feet(H2)			C	C2	Factor C	sq. ft.	ft/sec	cu.ft/sec.	u.gms/l	lbs/mo
1a south	5.00	0	4.9	4.9	0.1	1	0.02	0.7854	0.0037	0.7817	19.5	5.30	103.6		
1b	5.00	0	4.7	4.7	0.3	1	0.06	0.7854	0.0192	0.7662	19.2	3.38	64.7		
1c	5.00	0	4.4	4.4	0.6	1	0.12	0.7854	0.0534	0.732	18.3	3.50	64.1		
1d north	5.00	0	3.4	3.4	1.6	1	0.32	0.7854	0.2167	0.5687	14.2	5.5	78.2		
Total #1													**310.6**	117	**5950.4**
2	5	1.1	5	3.9	0	0.78	0	0.6573	0	0.6573	16.4	3.50	**57.5**	168	**1582.3**
5a south	8	2	5.2	3.2	2.8	0.75	0.35	0.6318	0.245	0.3868	24.8	3.80	94.1		
5b	8	2	5.8	3.8	2.2	0.75	0.28	0.6318	0.18	0.4518	28.9	4.11	118.8		
5c north	8	2.1	5.7	3.6	2.3	0.74	0.29	0.6231	0.189	0.4341	27.8	3.49	97.0		
Total #5													**309.9**	129	**6546.1**
6	5.5	2	5.5	3.5	0	0.64	0	0.5308	0	0.5308	16.1	4.43	**71.1**	210	**2446.2**
7	4.5	0.8	3.6	2.8	0.9	0.82	0.2	0.6893	0.1118	0.5775	11.7	0.05	**0.6**	50	**4.8**
S2a west	3	0.35	3	2.65	0	0.88	0	0.732	0	0.732	2.3	2.3	5.3		
S2b	2	0	1.5	1.5	0.5	1.00	0.25	7854	0.1535	7853.8465	0.5	0.05	0.0		
S2c	3	1.3	2.3	1	0.7	0.33	0.23	0.2266	0.1281	0.0985	3.3	0.33	1.1		
S2d east	2	0.1	2	1.9	0	0.95	0	0.7707	0	0.7707	5.3	5.3	28.1		
Total #S2													**35.1**	145	**833.0**

1. South Fork at 48 th Ave
2. Dabill/Britan at 48 th Ave
5. South fork at 36 th Ave
6. Wilson/Hobin at 36 th Ave
7. Behler at 28 th Ave
S2. Bungo at 32nd St

Bridge
Location #3 Bungo at Hwy 2
Date: 7/8/02

APPENDIX 2
Pine River Phosphorus Export
file: bridge data sheet 3-3

Interval	Width	Ave. Depth	Area	Av. Vel.	Volume	Total Phos.	Mass
feet	feet	feet	sq. feet	feet/sec.	cu.ft./sec	u.gms/L	lbs/mo.
West Span							
0 to 2	2	4.6	9.1	3.35	30.49		
2 to 4	2	4.5	9.0	3.60	32.4		
4 to 6	2	4.5	9.0	2.35	21.15		
6 to 8	2	4.5	9.0	3.90	35.1		
9 to10	2	4.5	9.0	1.95	17.55		
10 to 12	2	4.5	9.0	0.65	5.85		
Total West					**142.54**	188	**4388.2**
East Span							
0to2	2	4.8	9.5	3.20	30.4		
2 to 4	2	4.5	9.0	3.30	29.7		
4 to 6	2	4.5	9.0	3.25	29.25		
6 to 8	2	4.9	9.8	3.15	30.87		
8 to 10	2	4.8	9.5	2.97	28.22		
10 to 12	2	4.8	9.5	0.80	7.60		
Total East					**156.04**	188	**4803.8**
East and West Total					**298.57**	188	**9192**
2 ft. bridge to water							