Total Suspended Sediment Loadings
Red Lake, Thief, Mud and Moose Rivers
Pennington County Soil and
Water Conservation District
June 6, 2003

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Engineer under the laws of the State of Minnesota.

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For
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I. INTRODUCTION

As part of the Total Suspended Sediment study of the Red Lake, Thief, Mud and Moose Rivers, Houston Engineering, Inc. (Houston) was requested to provide engineering services to estimate the flow and to compute the suspended sediment load to each sampling site during the monitoring period, and to briefly describe the methods, assumptions and results of the hydrology and load computations.

Houston performed this work in three phases. Phase 1 analyzed the Thief River Falls Reservoir sites consisting of two inflow-sampling sites (Thief River and Red Lake River) and one outflow-sampling site (Thief River Falls Reservoir Dam). Phase 2 analyzed the Thief Lake sites consisting of one inflow-sampling site (Moose River Crossing) and one outflow-sampling site (Thief Lake Dam). Phase 3 analyzed the Agassiz National Wildlife Refuge sites consisting of two inflow-sampling sites (Thief River at Thief Bay Bridge and Mud River at Highway 89) and one outflow-sampling site (Judicial Ditch 11 at Mud Lake outlet).

II. METHODS

A. Hydrology

The following sections describe the methods used to estimate daily flow rates at the sediment sampling sites.

1. Thief River Falls Reservoir

Flows at sites within the Thief River Falls reservoir were based upon recorded flows at the USGS stream gauge sites on Red Lake River at Highlanding and Thief River near Thief River Falls. Flows in each river were increased to account for the increased drainage area between the USGS gauging stations and Thief River Falls. Table 1 lists the drainage areas at the USGS gauging stations and at Thief River Falls.

TABLE 1	Drainage Area at USGS Gauging Station	Drainage Area at Thief River Falls	Difference
	(square miles)	(square miles)	(square miles)
Thief River	985	1064	79
Red Lake River	2300	2386	86

A simplified runoff model was used to estimate the local runoff resulting from precipitation over the contributing drainage area between the USGS gauges and Thief River Falls. This model used precipitation data from Thief River Falls and the SCS Curve Number hydrology method to compute direct runoff from precipitation. A curve number of 80 was assumed and flow to the Red Lake and Thief Rivers was computed as the direct runoff at a uniform rate over 24 hours.

The Thief River and Red Lake River flows were further increased by 24%, 6% and 7% for 1995, 1996 and 1997, respectively in order to split the

difference between flows computed by the method described above and by rating curve of tailwater levels measured at the Thief River Falls hydropower dam. Outflow for the Thief River Falls reservoir was computed as the sum of the estimated inflows from the Thief and Red Lake Rivers.

2. Thief Lake

a) Thief Lake Dam

Flow at the Thief Lake outlet was estimated by the Minnesota DNR staff at the Thief Lake Wildlife Management Area using weir and orifice flow equations in conjunction with observed headwater and tailwater levels (and weir and gate settings) at the Thief Lake dam. Linear interpolation was used to estimate flow at the dam on intervening days between DNR observations of stage.

b) Inflow to Thief Lake

Flow at the Moose River inlet to Thief Lake was estimated using a water budget method. Groundwater inflow and outflow were neglected and inflow was determined using the following equation:

Inflow = Outflow + Evaporation + Change in Storage – Precipitation

Outflow was determined by the DNR at the outlet dam using headwater and tailwater levels and hydraulic equations. Change in storage per day was determined using the recorded lake levels (headwater at dam) and elevation versus storage rating curves. Evaporation rates used were the Minnesota Hydrology Guide listed average monthly evaporation rates from shallow lakes and

reservoirs. Records of precipitation at Thief Lake WMA were obtained from the Minnesota DNR Climatology website.

Linear interpolation was used to estimate lake levels and outflow on days between gauge readings. This water budget process allows the computation of total inflow to the lake—not only inflow at the Moose River inlet. Negative inflow values were determined on many dates as a consequence of summing the other estimated parameters. Negative inflow values were rounded to 1 cfs to allow sediment load calculations, however, rounding the negative ordinate values to 1 cfs effectively over predicts the total inflow to the lake. Table 2 provides a comparison of computed inflow volumes for each sampling period with and without rounding negative inflows to 1 cfs.

TABLE 2	Sampling Period		
	1995	1996	1997
	Acre-feet	Acre-feet	Acre-feet
Inflow volume computed for balanced water budget	19,555	82,265	71,013
Inflow volume used in load estimates (computed by rounding negative inflow values to 1 cfs)	34,394	90,935	83,040
Over prediction	76 %	11 %	17 %

3. Agassiz National Wildlife Refuge

a) Thief River at Thief Bay Bridge

Flows at the Thief Bay site within the Agassiz National Wildlife Refuge were based upon estimated flows at the Thief Lake dam. Flows in the Thief River at Thief Bay Bridge were increased to account for the increased drainage area between Thief Lake and the Thief Bay Bridge. Table 3 lists the drainage areas at the Thief Lake dam and at the Thief Bay Bridge.

TABLE 3	Drainage Area at Thief Lake	Drainage Area at Thief Bay Bridge	Difference
	(square miles)	(square miles)	(square miles)
Thief River	215.2	262.4	47.2

A simplified runoff model was used to estimate the local runoff resulting from precipitation over the contributing drainage area between Thief Lake and the Thief Bay Bridge. This model used precipitation data from Thief Lake and the SCS Curve Number hydrology method to compute direct runoff from precipitation. A curve number of 75 was assumed and flow to the Thief River was computed as the direct runoff at a uniform rate over 24 hours.

b) Mud River

Water levels in the Mud River near Grygla were measured when sediment samples were collected. A rating curve was developed from measured flows and stages at this USGS partial record gauge site. Flows on sampling dates were estimated using the observed stage and the rating curve (regression equation). Linear interpolation was used to estimate flows on dates between stage measurements. Water levels at this site were not measured during

either the 1996 or 1997 spring floods, so no flow data is available for those runoff events at this site.

c) Judicial Ditch 11

Flow at the Judicial Ditch 11 (JD 11) outlet from Mud Lake in the Agassiz National Wildlife Refuge was computed by two methods. Minnesota DNR Hydrologist Jim Solstad computed spring outflow rates at the JD-11 outlet using headwater and tailwater records and hydraulic equations. Solstad's computed flows were used as available (for dates 4-15 to 5-29 in 1996 and 4-4 to 6-30 in 1997).

Water levels were recorded at the JD-11 site during the sediment sampling period. Records of the JD-11 water level about 150 feet downstream from the Mud Lake outlet structure were measured from a bridge railing. Loren Sanderson, of the Red Lake Watershed District, measured the railing elevation on May 14, 2003. A tailwater rating curve at JD-11 was developed from Solstad's computed flows. This rating curve was used to compute flows in JD-11 for the dates when "measure down" distances were recorded. Linear interpolation was used to estimate flows between dates when measurements were taken.

B. Load Estimation (FLUX)

The computer program FLUX was used to calculate tributary loads and flow-weighted mean concentrations. FLUX is an interactive menu driven program, which consists of six unique methods for load estimation (Walker 1986). The program uses daily stream volume and chemistry data, and is supported by the Corps of Engineers, Vicksburg, Mississippi.

The goal of the load estimation procedure is to minimize the error associated with the load estimate. This is accomplished by first estimating the load using each of the techniques and noting the variance associated with each estimate. Often, stratifying the data, either by flow or season, can reduce the variance. We typically evaluated whether the variance of the estimate was reduced by using two flow strata, one greater and one less than the mean flow. After stratification, most of the estimation methods resulted in greater variance. Therefore, we used the estimation method with the lowest variance without stratifying the data. The method with the lowest variance tended to be "Regression Applied to Individual Daily Flows," (see page 2-5, Walker 1986). The method selected is shown in Equation 1.

$$W = \Sigma_j \exp [a + (b + 1) \ln(Q_j) + SE^2/2] \qquad \textit{Equation 1}$$

Where

W = estimated mean flux over N days (kg/yr)
Σ_j = sum over N dates in daily flow record
a = intercept of ln(c) versus ln(q) regression
b = slope of ln(c) versus ln(q) regression
Q_j = mean flow on day j (hm3/yr)
SE = standard error of estimate for ln(c) versus ln(q) regression

The lowest coefficient of variance (CV) was used as the measure to determine the best load estimation method of the six calculated in FLUX. The CV is calculated by dividing the standard error of the mean loading by the mean loading. A CV value less than 0.1 is considered optimal for mass-balance modeling but is difficult to achieve for small, flashy streams. A CV value between 0.1 and 0.2 is considered adequate for modeling purposes, especially for minor tributaries (see page 2-11, Walker 1986).

The FLUX program ignores all flow and concentration data that have values less than or equal to zero. Tables within the following Results Section list the "Number of TSS Samples Collected." The sample numbers listed in the tables include only those paired data points having both flow and concentration greater than zero.

III. RESULTS

A. Thief River Falls Reservoir

1. Site Name: Thief River Inflow

Table 4 provides a summary of the TSS samples collected, Table 5 provides a summary of the runoff volumes computed for each year, and Table 6 provides the results of the TSS load computation for the Thief River inflow site. Figure 1 is the hydrograph for 1995-1997 at the Thief River inflow site.

Table 4
Total Suspended Sediment Measurements

	1995	1996	1997	Total
Number of TSS Samples Collected	84	53	67	204
First Sampling Date	3/31	4/23	1/14	N/A
Last Sampling Date	11/1	12/12	9/24	N/A
Average Concentration (mg/l)	24.73	24.77	17.46	22.35
Minimum Concentration (mg/l)	1.91	4.52	2.32	1.91
Maximum Concentration (mg/l)	157.60	128.30	67.45	157.60

Table 5
Volume of Runoff for Each (Portion) Year Sampled
Thief River Inflow Site Drainage Area = 1064 square miles and primary area contributing sediment is estimated as 448 square miles (i.e. the area downstream from Agassiz NWR))

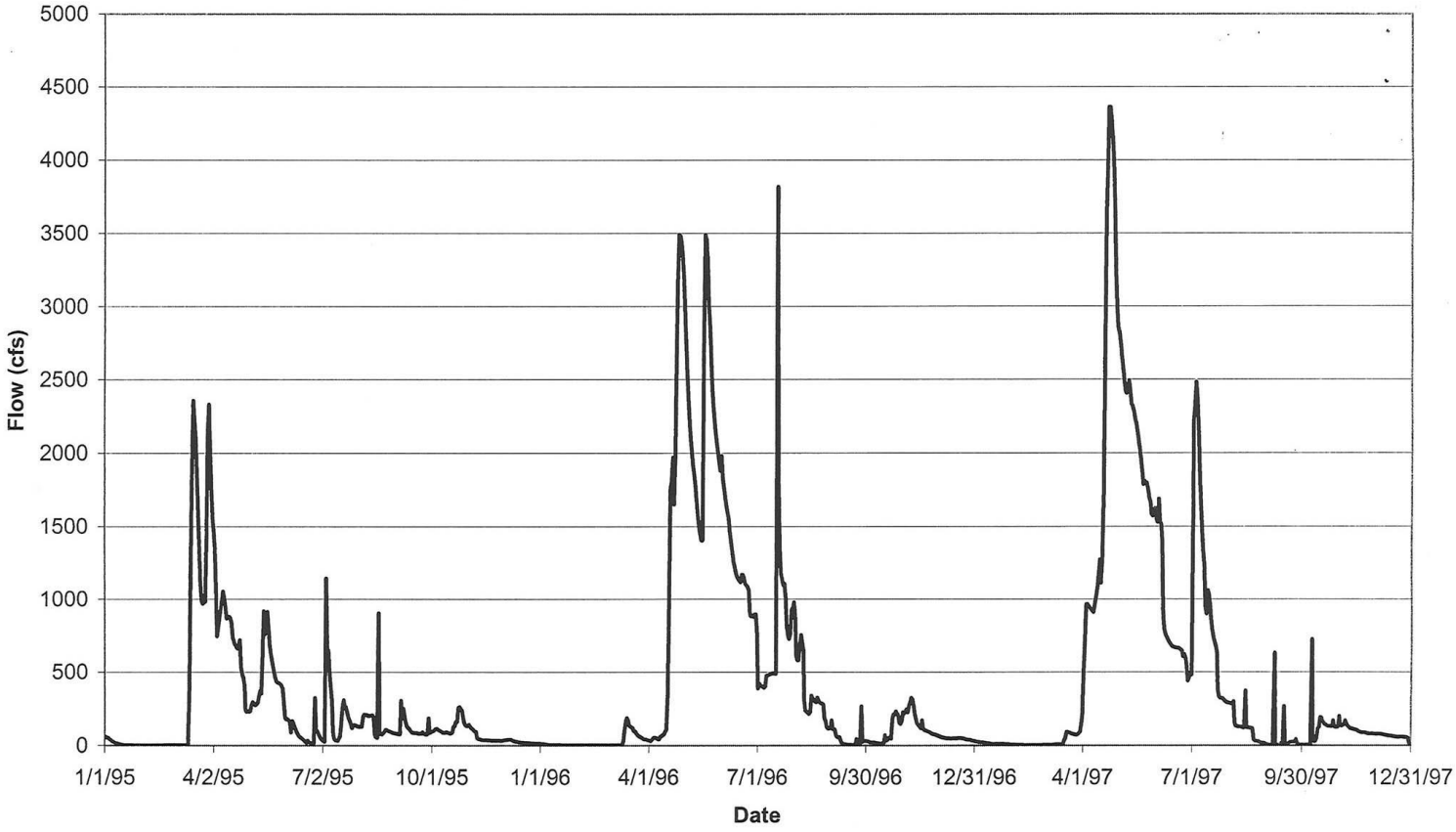
	1995	1996	1997	Total for Period Studied
Runoff Volume (cubic hectometers)	228	468	488	1,184
Runoff Volume (acre-feet)	184,542	379,277	395,990	959,810
Runoff Volume (inches)	3.3	6.7	7.0	16.9

Table 6
Total Suspended Sediment Load Results
CV = 0.068

	1995	1996	1997	Total Sampling Period
TSS Load (Kg)	5,146,845	10,703,970	11,188,310	27,039,140
TSS Load (metric ton)	5,147	10,704	11,188	27,039
TSS Load (US ton)	5,673	11,799	12,333	29,806
TSS Load (US ton/sq. mi.)	5.3	11.1	11.6	28.0
TSS Load (US ton/acre)	0.008	0.017	0.018	0.044

Figure 1

Thief River Estimated Inflow to Thief River Falls for 1995-1997



2. Site Name: Red Lake River Inflow

Table 7 provides a summary of the TSS samples collected, Table 8. provides a summary of the runoff volumes computed for each year, and Table 9 provides the results of the TSS load computation for the Red Lake River inflow site. Figure 2 is the hydrograph for 1995-1997 at the Red Lake River inflow site.

Table 7
Total Suspended Sediment Measurements

	1995	1996	1997	Total
Number of TSS Samples Collected	79	52	69	200
First Sampling Date	3/31	4/29	1/14	N/A
Last Sampling Date	11/01	12/12	11/05	N/A
Average Concentration (mg/l)	15.83	18.49	14.22	15.96
Minimum Concentration (mg/l)	2.28	3.48	0.70	0.70
Maximum Concentration (mg/l)	55.09	122.96	48.71	122.96

Table 8
Volume of Runoff for Each (Portion) Year Sampled
Red Lake River Inflow Site Drainage Area = 2386 square miles and the primary area contributing sediment is estimated as 436 square miles (i.e. the area downstream from Red Lake)

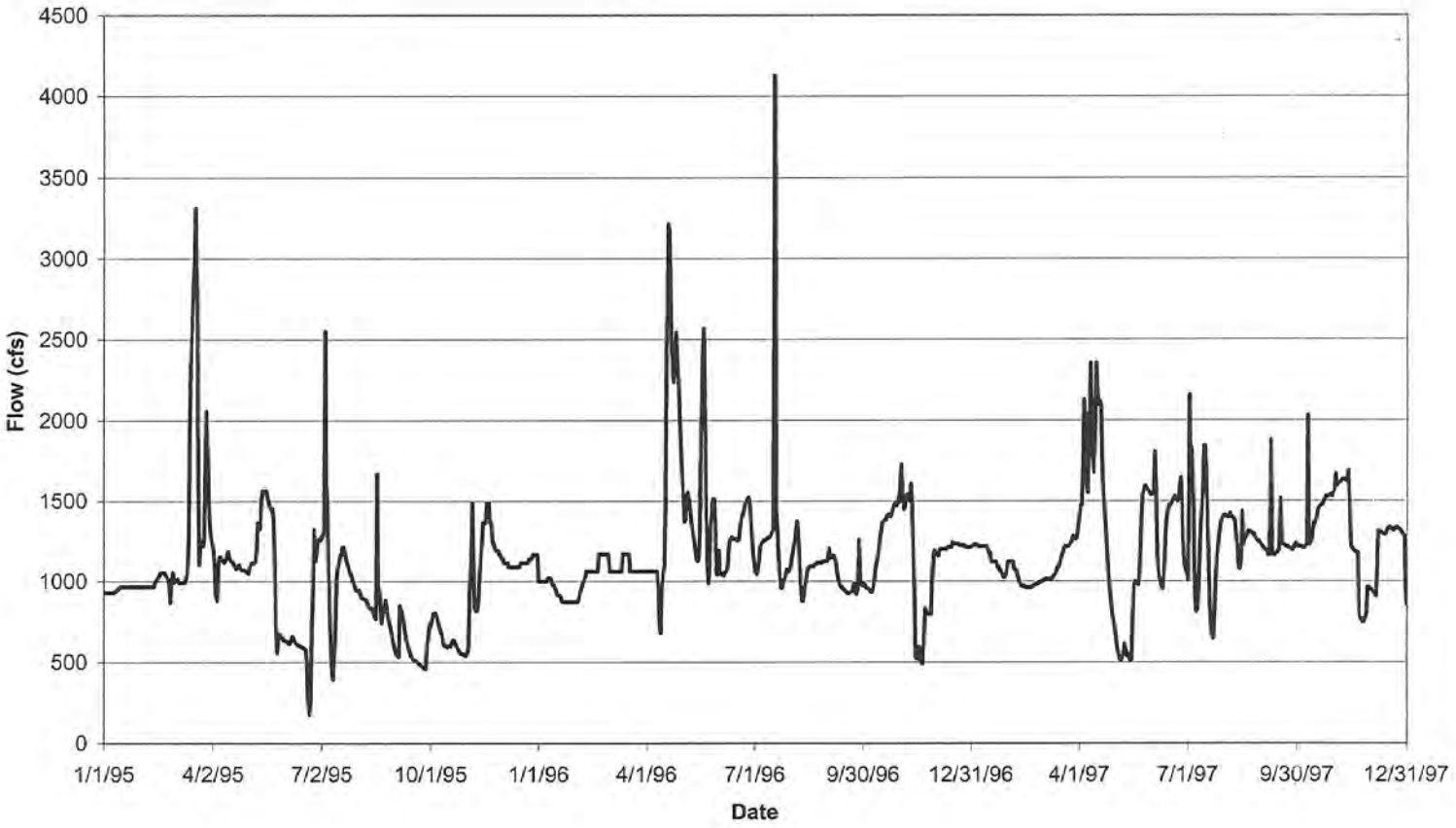
	1995	1996	1997	Total for Period Studied
Runoff Volume (cubic hectometers)	888	1071	1108	3068
Runoff Volume (acre-feet)	719,767	868,609	898,668	2,487,046
Runoff Volume (inches)	5.7	6.8	7.1	19.5

Table 9
Total Suspended Sediment Load Results
CV = 0.053

	1995	1996	1997	Total Sampling Period
TSS Load (Kg)	14,328,580	18,165,070	18,992,270	51,485,900
TSS Load (metric ton)	14,329	18,165	18,992	51,486
TSS Load (US ton)	15,795	20,024	20,935	56,753
TSS Load (US ton/sq. mi.)	6.6	8.4	8.8	23.8
TSS Load (US ton/acre)	0.010	0.013	0.014	0.037

Figure 2

Red Lake River Estimated Inflow to Thief River Falls for 1995-1997



3. Site Name: Red Lake River Outflow

Table 10 provides a summary of the TSS samples collected, Table 11 provides a summary of the runoff volumes computed for each year, and Table 12 provides the results of the TSS load computation for the Red Lake River outflow site. Figure 3 is the hydrograph for 1995-1997 at the Red Lake River outflow site.

Table 10
Total Suspended Sediment Measurements

	1995	1996	1997	Total
Number of TSS Samples Collected	80	53	68	201
First Sampling Date	3/31	4/29	1/14	N/A
Last Sampling Date	11/1	12/12	11/5	N/A
Average Concentration (mg/l)	19.11	21.52	14.06	18.03
Minimum Concentration (mg/l)	1.61	5.75	0.48	0.48
Maximum Concentration (mg/l)	118.33	100.00	36.39	118.33

Table 11
Volume of Runoff for Each (Portion) Year Sampled
Red Lake River Outflow Site Drainage Area = 3450 square miles and the primary area contributing sediment is estimated to be 884 square miles (i.e. the area downstream from Red Lake and Agassiz Refuge)

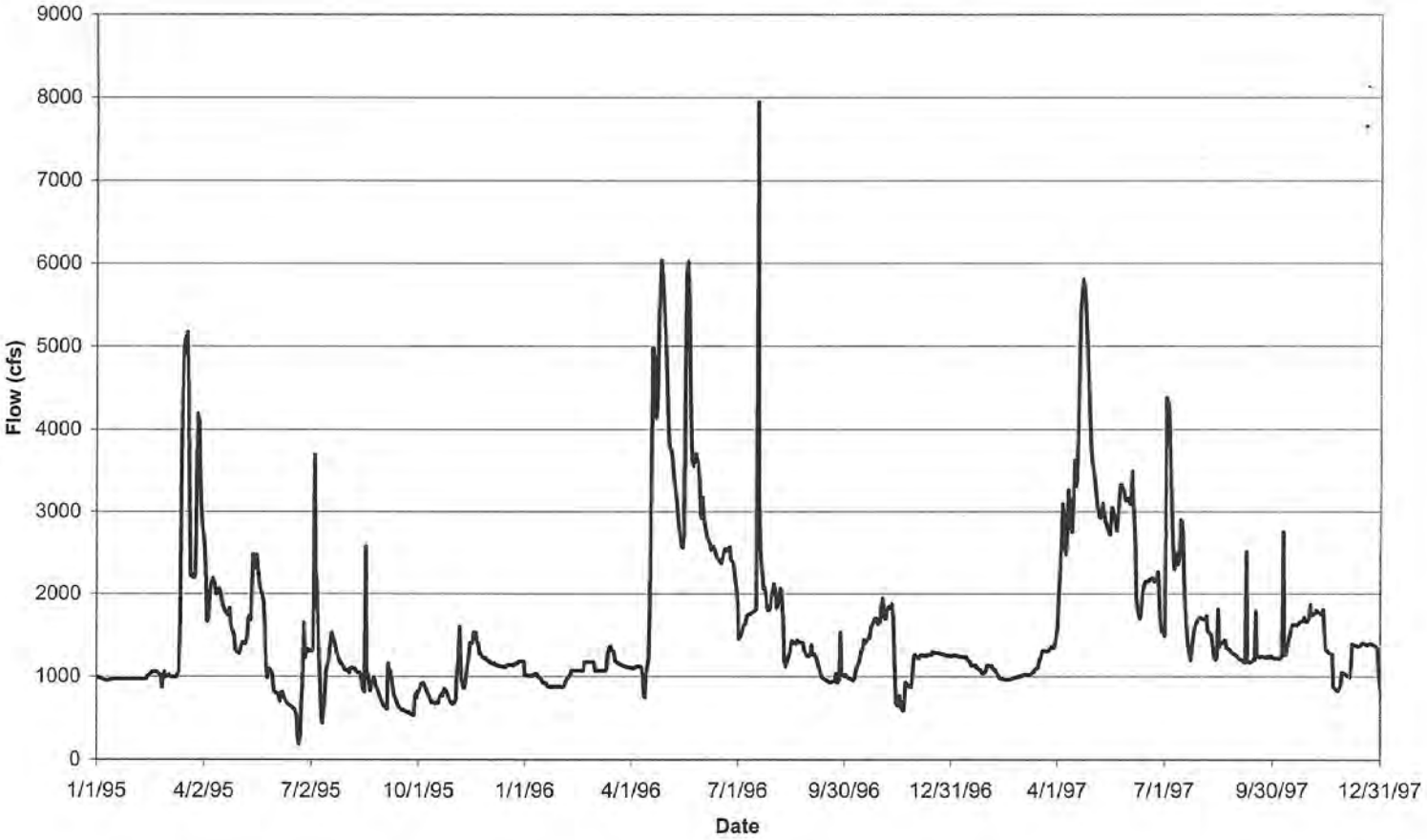
	1995	1996	1997	Total for Period Studied
Runoff Volume (cubic hectometers)	1,115	1,539	1,597	4,252
Runoff Volume (acre-feet)	904,309	1,247,886	1,294,660	3,446,855
Runoff Volume (inches)	4.9	6.8	7.0	18.7

Table 12
Total Suspended Sediment Load Results (CV = 0.050)

	1995	1996	1997	Total Sampling Period
TSS Load (Kg)	19,366,150	28,730,000	28,076,380	76,172,580
TSS Load (metric ton)	19,366	28,730	28,076	76,173
TSS Load (US ton)	21,348	31,669	30,949	83,966
TSS Load (US ton/sq. mi.)	6.2	9.2	8.9	24.3
TSS Load (US ton/acre)	0.010	0.014	0.014	0.038

Figure 3

Red Lake River Estimated Outflow from Thief River Falls Reservoir for 1995-1997



B. Thief Lake

1. Site Name: Thief Lake Inflow

Table 13 provides a summary of the TSS samples collected at the Moose River inlet to Thief Lake. Table 14 provides a summary of the inflow runoff volumes computed for Thief Lake for each year. Table 15 provides the results of the TSS load computation for the inflow to Thief Lake. Figure 4 is the hydrograph for 1995-1997 of the estimated inflow to Thief Lake.

Table 13
Total Suspended Sediment Measurements

	1995	1996	1997	Total
Number of TSS Samples Collected	43	15	33	91
First Sampling Date	3/31	5/7	5/7	N/A
Last Sampling Date	10/30	7/31	8/29	N/A
Average Concentration (mg/l)	7.32	18.57	10.09	10.17
Minimum Concentration (mg/l)	0.50	1.92	1.17	0.50
Maximum Concentration (mg/l)	45.02	66.67	41.00	66.67

Table 14
Volume of Runoff for Each (Portion) Year Sampled
Moose River Crossing Inflow Site Drainage Area = 184 square miles, however, the water budget method estimates the total inflow to Thief Lake–from an area of approximately 203 square miles.

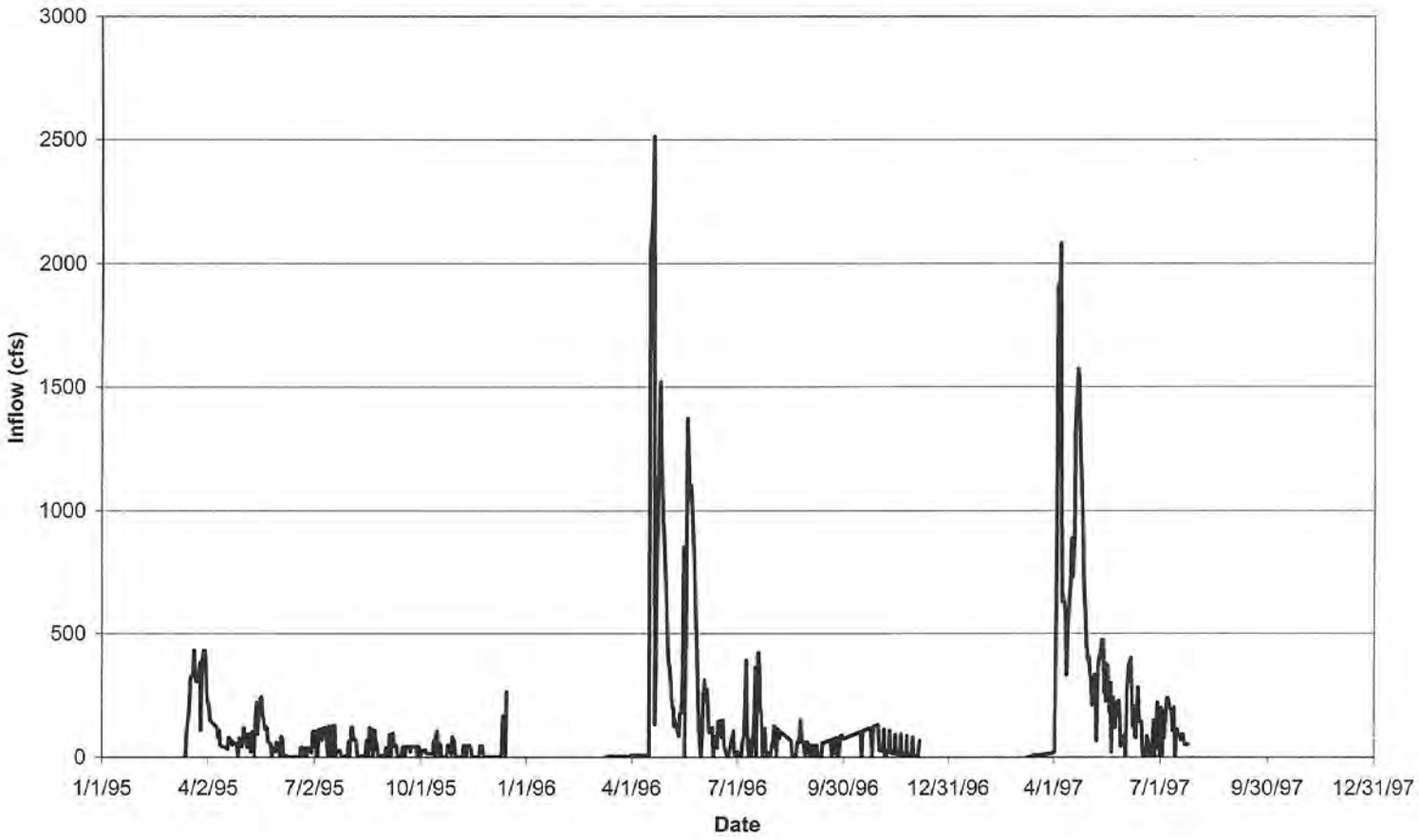
	1995	1996	1997	Total for Period Studied
Runoff Volume (cubic hectometers)	43	112	102	258
Runoff Volume (acre-feet)	34,925	90,943	83,050	208,918
Runoff Volume (inches)	3.2	8.4	7.7	19.3

Table 15
Total Suspended Sediment Load Results
CV = 0.132

	1995	1996	1997	Total Sampling Period
TSS Load (Kg)	384,471	984,161	896,752	2,265,386
TSS Load (metric ton)	384	984	897	2,265
TSS Load (US ton)	424	1,085	988	2,497
TSS Load (US ton/sq. mi.)	2.1	5.3	4.9	12.3
TSS Load (US ton/acre)	0.003	0.008	0.008	0.019

Figure 4

Moose River Estimated Inflow for 1995-1997



2. Site Name: Thief Lake Dam Outflow

Table 16 provides a summary of the TSS samples collected, Table 17 provides a summary of the runoff volumes computed for each year, and Table 18 provides the results of the TSS load computation for the Thief Lake Dam outflow site. Figure 5 is the hydrograph for 1995-1997 at the Thief Lake Dam outflow site.

Table 16
Total Suspended Sediment Measurements

	1995	1996	1997	Total
Number of TSS Samples Collected	42	16	32	90
First Sampling Date	3/31	5/7	5/7	N/A
Last Sampling Date	10/30	7/31	8/29	N/A
Average Concentration (mg/l)	14.99	17.25	15.12	15.42
Minimum Concentration (mg/l)	1.30	4.27	1.77	1.30
Maximum Concentration (mg/l)	55.44	69.76	58.55	69.76

Table 17
Volume of Runoff for Each (Portion) Year Sampled
(Thief Lake Dam Outflow Site Drainage Area = 215.2 square miles)

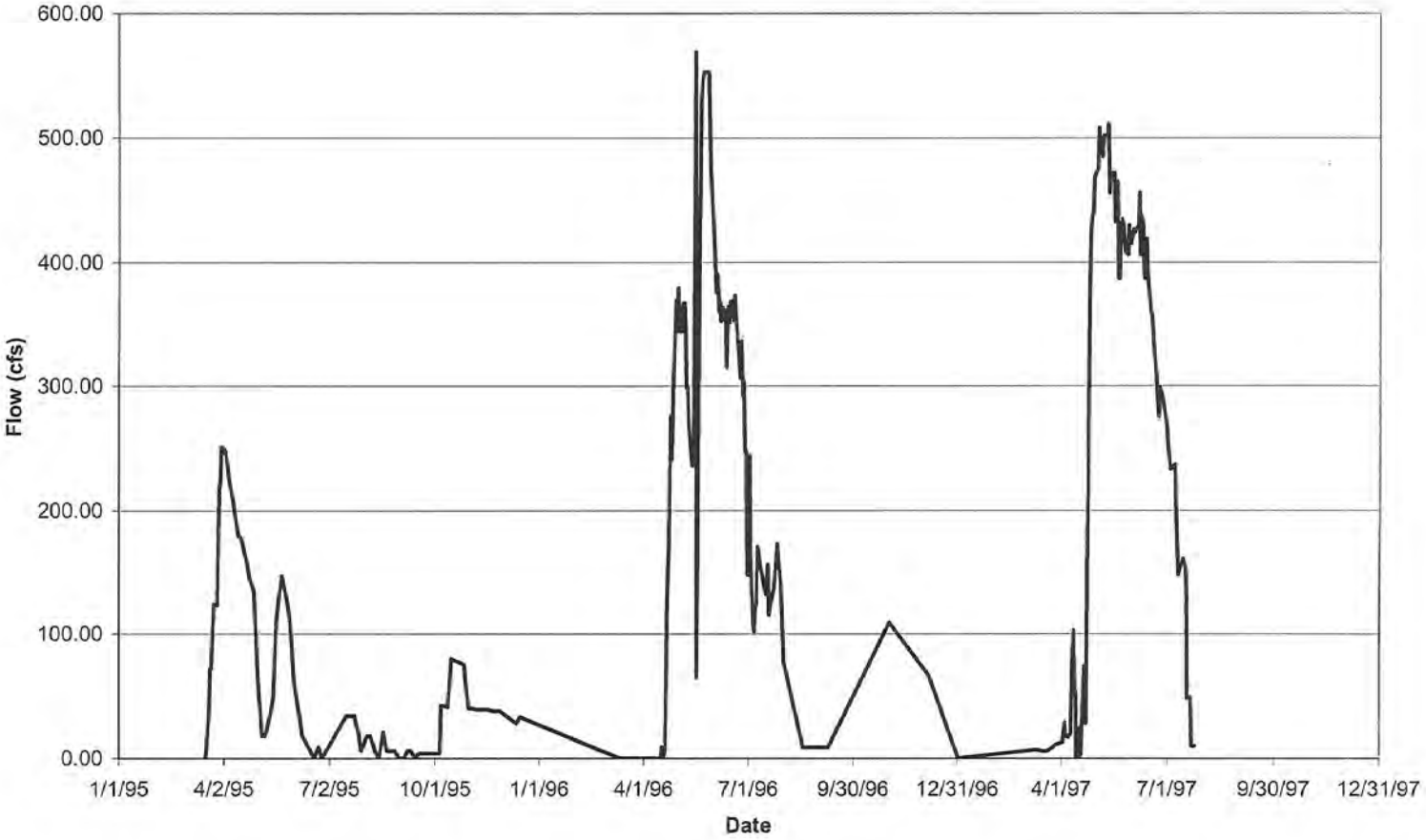
	1995	1996	1997	Total for Period Studied
Runoff Volume (cubic hectometers)	35	89	80	204
Runoff Volume (acre-feet)	28,612	72,519	64,486	165,617
Runoff Volume (inches)	2.5	6.3	5.6	14.4

Table 18
Total Suspended Sediment Load Results
CV = 0.103

	1995	1996	1997	Total Sampling Period
TSS Load (Kg)	560,868	1,251,351	1,051,109	2,863,329
TSS Load (metric ton)	561	1,251	1,051	2,863
TSS Load (US ton)	618	1,379	1,159	3,156
TSS Load (US ton/sq. mi.)	2.9	6.4	5.4	14.7
TSS Load (US ton/acre)	0.005	0.010	0.008	0.023

Figure 5

Thief Lake Dam Estimated Outflows for 1995-1997



C. Mud Lake at Agassiz National Wildlife Refuge

1. Site Name: Thief Bay Bridge Inflow

Table 19 provides a summary of the TSS samples collected, Table 20 provides a summary of the runoff volumes computed for each year, and Table 21 provides the results of the TSS load computation for the Thief Bay Bridge inflow site. Figure 6 is the hydrograph for 1995-1997 at the Thief Bay Bridge inflow site.

Table 19
Total Suspended Sediment Measurements

	1995	1996	1997	Total
Number of TSS Samples Collected	78	34	30	142
First Sampling Date	3/31	5/2	4/30	N/A
Last Sampling Date	11/2	9/16	11/7	N/A
Average Concentration (mg/l)	20.23	32.59	25.28	24.18
Minimum Concentration (mg/l)	0.95	3.26	2.97	0.95
Maximum Concentration (mg/l)	270.00	226.22	79.09	270.00

Table 20
Volume of Runoff for Each (Portion) Year Sampled
Thief River Inflow Site at Thief Bay Bridge Drainage Area = 262.4 square miles and the primary area contributing sediment is estimated to be 47.2 square miles (i.e. the area downstream from Thief Lake)

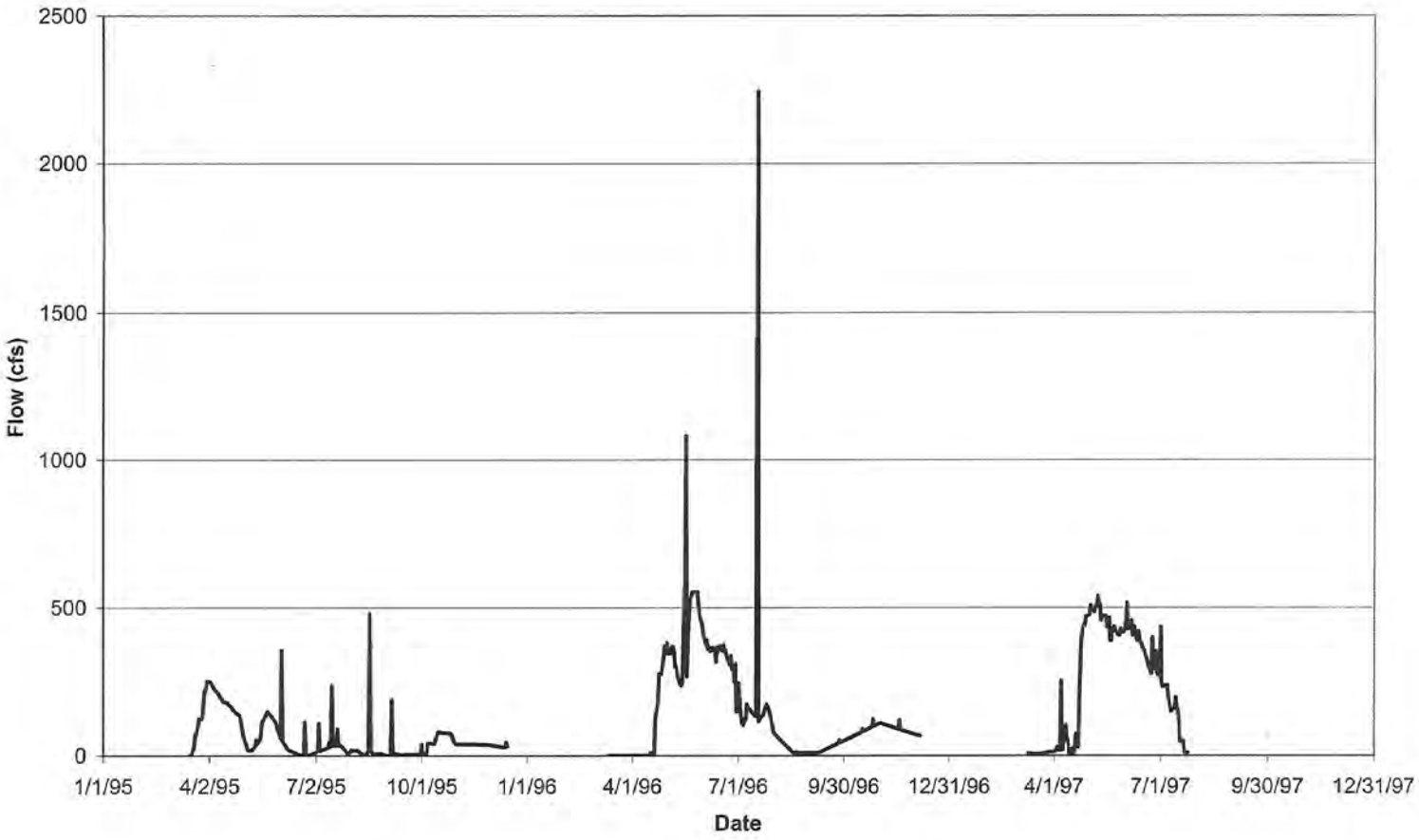
	1995	1996	1997	Total for Period Studied
Runoff Volume (cubic hectometers)	39	98	81	218
Runoff Volume (acre-feet)	31,581	79,225	65,963	176,770
Runoff Volume (inches)	2.3	5.7	4.7	12.6

Table 21
Total Suspended Sediment Load Results
CV = 0.131

	1995	1996	1997	Total Sampling Period
TSS Load (Kg)	929,129	2,831,919	2,476,331	6,237,379
TSS Load (metric ton)	929	2,832	2,476	6,237
TSS Load (US ton)	1,024	3,122	2,730	6,876
TSS Load (US ton/sq. mi.)	3.9	11.9	10.4	26.2
TSS Load (US ton/acre)	.006	.019	.016	.041

Figure 6

Thief Bay Bridge Estimated Flow for 1995-1997



2. Site Name: Mud River Inflow

Table 22 provides a summary of the TSS samples collected, Table 23 provides a summary of the runoff volumes computed for each year, and Table 24 provides the results of the TSS load computation for the Mud River Inflow site. Figure 7 is the hydrograph for 1995-1997 at the Mud River inflow site.

Table 22
Total Suspended Sediment Measurements

	1995	1996	1997	Total
Number of TSS Samples Collected	82	32	30	144
First Sampling Date	3/31	5/2	4/30	N/A
Last Sampling Date	11/2	9/11	10/16	N/A
Average Concentration (mg/l)	8.88	43.00	30.76	21.75
Minimum Concentration (mg/l)	1.40	1.01	2.36	1.01
Maximum Concentration (mg/l)	35.15	646.7	181.25	646.7

Table 23
Volume of Runoff for Each (Portion) Year Sampled
(Mud River Inflow Site Drainage Area = 170 sq. mi.)

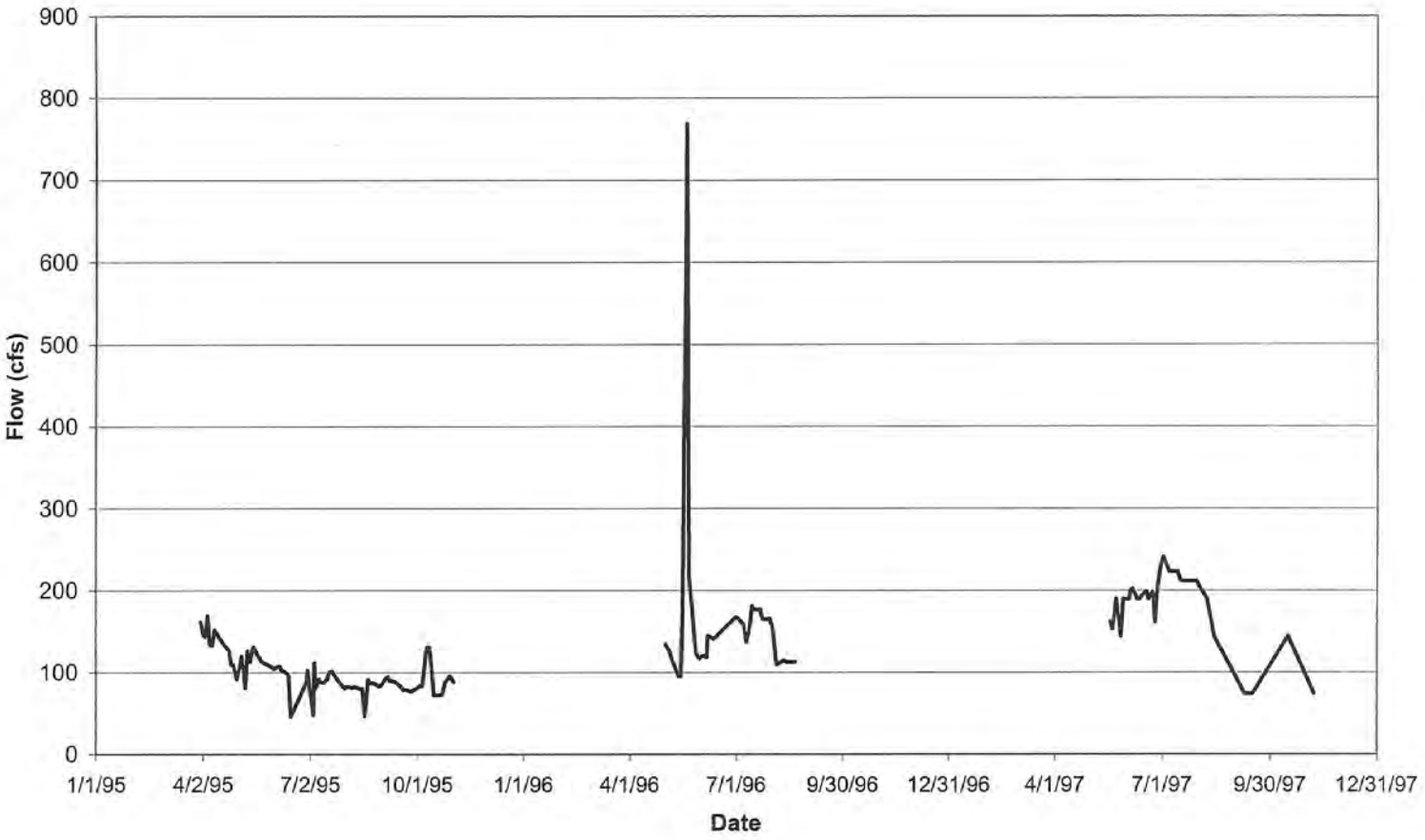
	1995	1996	1997	Total for Period Studied
Runoff Volume (cubic hectometers)	51	43	65	160
Runoff Volume (acre-feet)	41,641	35,198	52,811	129,649
Runoff Volume (inches)	4.6	3.9	5.8	14.3

Table 24
Total Suspended Sediment Load Results
CV = 0.162

	1995	1996	1997	Total Sampling Period
TSS Load (Kg)	655,001	1,050,364	1,329,973	3,035,341
TSS Load (metric ton)	655	1,050	1,330	3,035
TSS Load (US ton)	722	1,158	1,466	3,346
TSS Load (US ton/sq. mi.)	4.2	6.8	8.6	19.7
TSS Load (US ton/acre)	0.007	0.011	0.013	0.031

Figure 7

Mud River Estimated Flow For 1995-1997



3. Site Name: Judicial Ditch 11 Outflow

Table 25 provides a summary of the TSS samples collected, Table 26 provides a summary of the runoff volumes computed for each year, and Table 27 provides the results of the TSS load computation for the Judicial Ditch 11 outflow site. Figure 8 is the hydrograph for 1995-1997 at the Judicial Ditch 11 outflow site.

Table 25
Total Suspended Sediment Measurements

	1995	1996	1997	Total
Number of TSS Samples Collected	81	34	36	151
First Sampling Date	4/1	5/2	4/30	N/A
Last Sampling Date	11/2	9/16	11/7	N/A
Average Concentration (mg/l)	6.39	15.70	7.70	8.88
Minimum Concentration (mg/l)	0.50	1.24	1.09	0.50
Maximum Concentration (mg/l)	86.19	125.90	27.79	125.90

Table 26
Volume of Runoff for Each (Portion) Year Sampled
Judicial Ditch 11 Outflow Site Drainage Area = 609 square miles and the primary area contributing sediment is estimated to be 394 square miles (i.e. the area downstream from Thief Lake)

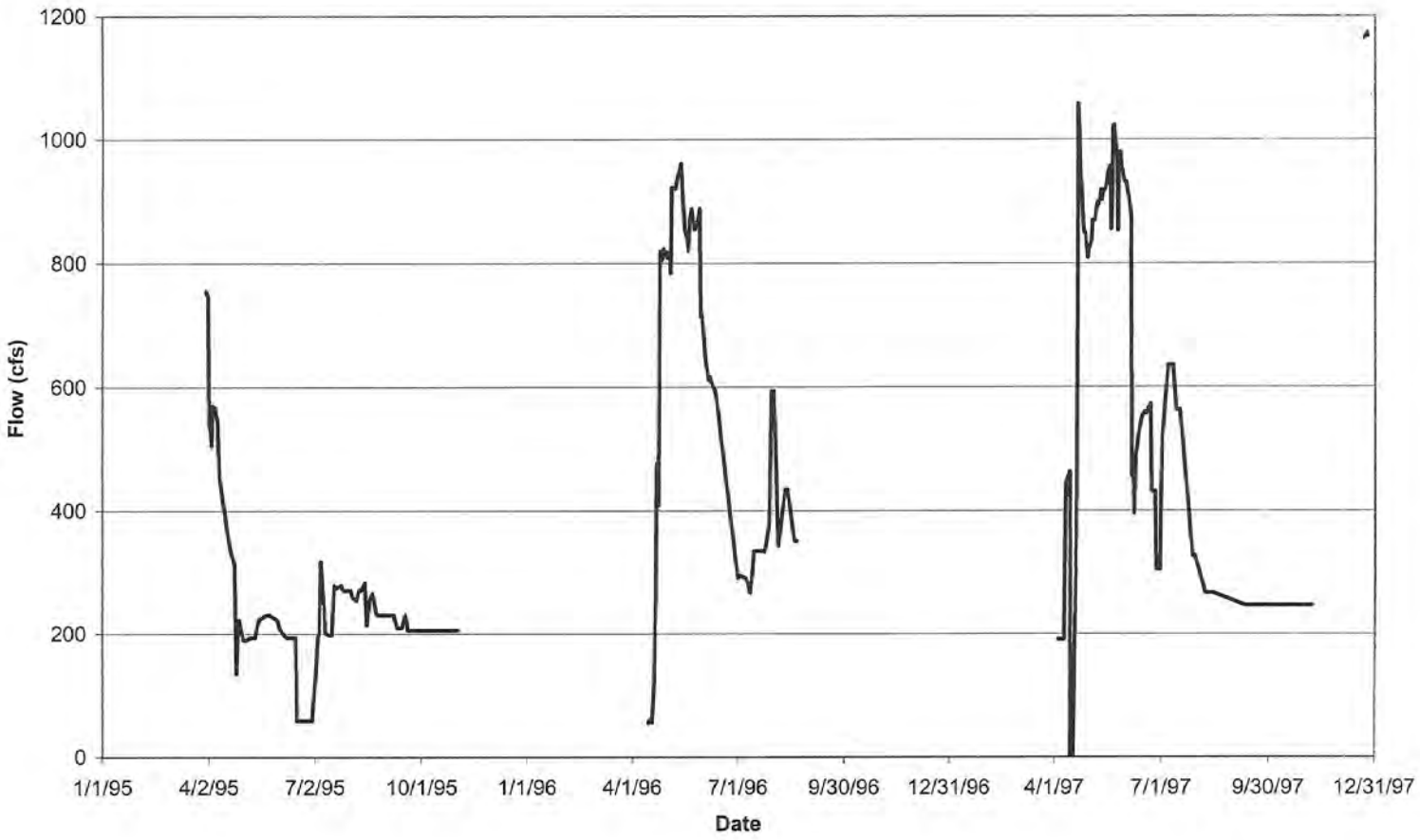
	1995	1996	1997	Total for Period Studied
Runoff Volume (cubic hectometers)	127	167	242	537
Runoff Volume (acre-feet)	103,126	135,632	196,355	435,109
Runoff Volume (inches)	3.2	4.2	6.0	13.4

Table 27
Total Suspended Sediment Load Results
CV = 0.104

	1995	1996	1997	Total Sampling Period
TSS Load (Kg)	923,063	1,547,519	2,184,354	4,654,946
TSS Load (metric ton)	923	1,548	2,184	4,655
TSS Load (US ton)	1,018	1,706	2,408	5,131
TSS Load (US ton/sq. mi.)	1.7	2.8	4.0	8.4
TSS Load (US ton/acre)	0.003	0.004	0.006	0.013

Figure 8

JD11 Estimated Flow for 1995-1997



IV. DISCUSSION

The results are tabulated by sampling year. Sampling periods were generally the open water season, and except for the Thief River Falls reservoir, load estimates do not include the full calendar years.

The TSS loadings appear to be similar to those computed by the USGS in the Red River Valley (USGS Water Resources Investigations Report 85-4312) and by the Red Lake Watershed District (Thief River Falls Reservoir Study, March 1992). Table 28 provides a listing of the average annual total suspended sediment yield at seven sites within the Red River Valley. The listed sediment yield values appear to be within the same order of magnitude as determined in this study.

TABLE 28

Location	Data Source	Suspended Sediment Yield (Tons/square mile/year)
Pelican River near Fergus Falls	USGS	1.0
Buffalo River near Hawley	USGS	5.0
South Branch Buffalo River near Sabin	USGS	3.2
Buffalo River near Dilworth	USGS	4.5
Wild Rice River at Twin Valley	USGS	17.2
Middle River at Argyle	USGS	4.9
Red Lake River at Thief River Falls and Crookston	RLWD	22.1

The large reservoirs at Thief Lake and Agassiz National Wildlife Refuge are discharging a significant amount of sediment, although the Agassiz Pools appear to be retaining about 2/3 of the sediment inflow. The load estimates and average TSS concentration data for Thief Lake indicate that more sediment is flowing out of Thief Lake than is flowing in. This seems contrary to "common sense" and may be a result of assumptions made to compute discharge.