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Streamflow and Sediment Study of Hosanna Creek near Healy, Alaska: 1987 Progress Report

By

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EXECUTIVE SUMMARY

Division of Geological and Geophysical Surveys' (DGGS) investigators measured discharge and collected water samples for selected water quality analyses at six sites in the Hosanna Creek drainage in 1987. In addition, we had a Wyoming precipitation gage at Gold Run Pass. Based on the Gold Run Pass record, rainfall in 1987 was near normal, however, storm events appeared to be smaller than normal. Approximately 40,000 tons as suspended load moved past the Hosanna Creek at Bridge 3 site between May 21 and October 12. Most of this moved during high flows resulting from a relatively mild spring breakup high flow and high flows resulting from the two rain fall events. Sanderson Creek and the mid-basin site at Hosanna Creek above North Hosanna Creek had suspended loads proportional to their basin areas when compared to the results from Hosanna at Bridge 3. North Hosanna Creek had loads higher than would be expected based on basin area and Frances and Popovitch Creeks had loads smaller than would be expected. At Popovitch Creek bed load is the major component of the total sediment load and becomes more predominant as discharge increases.

Samples for analysis of selected water chemistry characteristics were collected three times in 1987 at sites located on Hosanna Creek at

Bridge 3 (above the Poker Flats mine) and on Hosanna Creek at Bridge 1 (below the Poker Flats mine). Generally, values of field-determined parameters at the two sites were similar and no appreciable differences existed between the ionic composition of samples from the two sites. High nitrate (21.6 mg/l) was found at the Bridge 1 site in the early June sample. Other than that no primary contaminant results exceeded state standards. Secondary standards were exceeded with manganese and color at both sites on all three sampling dates.

INTRODUCTION

This report presents and discusses data collected by investigators from the Alaska Division of Geological and Geophysical Surveys (DGGS) for the Hosanna Creek Streamflow and Sediment Study (hereafter called the Hosanna Creek Study). Hosanna Creek (also known as Hoseanna Creek or Lignite Creek) basin is located near Healy, Alaska, and has a total area of approximately 48.1 square miles. The creek is tributary to the Nenana River. Presently, coal mining occurs in the lower part of the basin at Poker Flats. An earlier, now abandoned mine site is near Gold Run Pass in the upper part of the basin. The basin geology includes the five formations of the coal bearing group described by Wahrhaftig and others (1969), Nenana Gravel, schists, alluvium and landslide deposits (Wahrhaftig, 1970). The lithologies of the coal bearing formations are mostly poorly consolidated claystones, siltstones, sandstones, and shales with high erosion potential. Due to the high permeability of the soils and sedimentary rock formations, many slopes within the basin are unstable, resulting in landslides and other forms of mass wasting that intrude upon stream channels and contribute sediment during runoff events. Because of the unusual lithologies and presence of mass wasting, the natural sediment transport of Hosanna Creek and its tributaries is remarkably high. The purpose of our study is to estimate discharge and sediment yield of Hosanna Creek and selected tributaries above present day mining.

A work program to collect data to estimate sediment yield of the Hosanna Creek basin was initiated during the 1986 summer. Five sites were chosen as being representative of the basin: Sanderson Creek (above any past mining), North Hosanna Creek (an unmined subbasin but with silty discharge), Popovitch Creek (unmined), Frances Creek (downstream of future mining), and Hosanna Creek at Bridge 3 (above present mining). The results of the first season's work were reported in the 1986 progress report (Mack, 1987). At an upper basin site in Gold Run Pass, a Wyoming type precipitation gage was installed in late September 1986.

The results from the 1986 season indicated that the largest proportion of sediment was moving during major flow events, that Parshall flumes were the best method of estimating flows in the smaller tributaries, and that, in Popovitch Creek, bed load is greater than suspended load. We changed our 1987 data collection program to take into account these findings. The automated samplers were programmed to collect multiple samples during peak events. The results from the automated samplers could be combined with normal flow TSS results to develop regression equations that estimate TSS from discharge over a wide range of flows. Those equations can be used to develop daily and seasonal suspended load estimates at our monitoring sites. Parshall flumes were installed in Popovitch and Frances Creeks and a bed load sampler was constructed to fit the flume on Popovitch Creek. We intended to use the regression techniques to estimate seasonal bed load at Popovitch Creek.

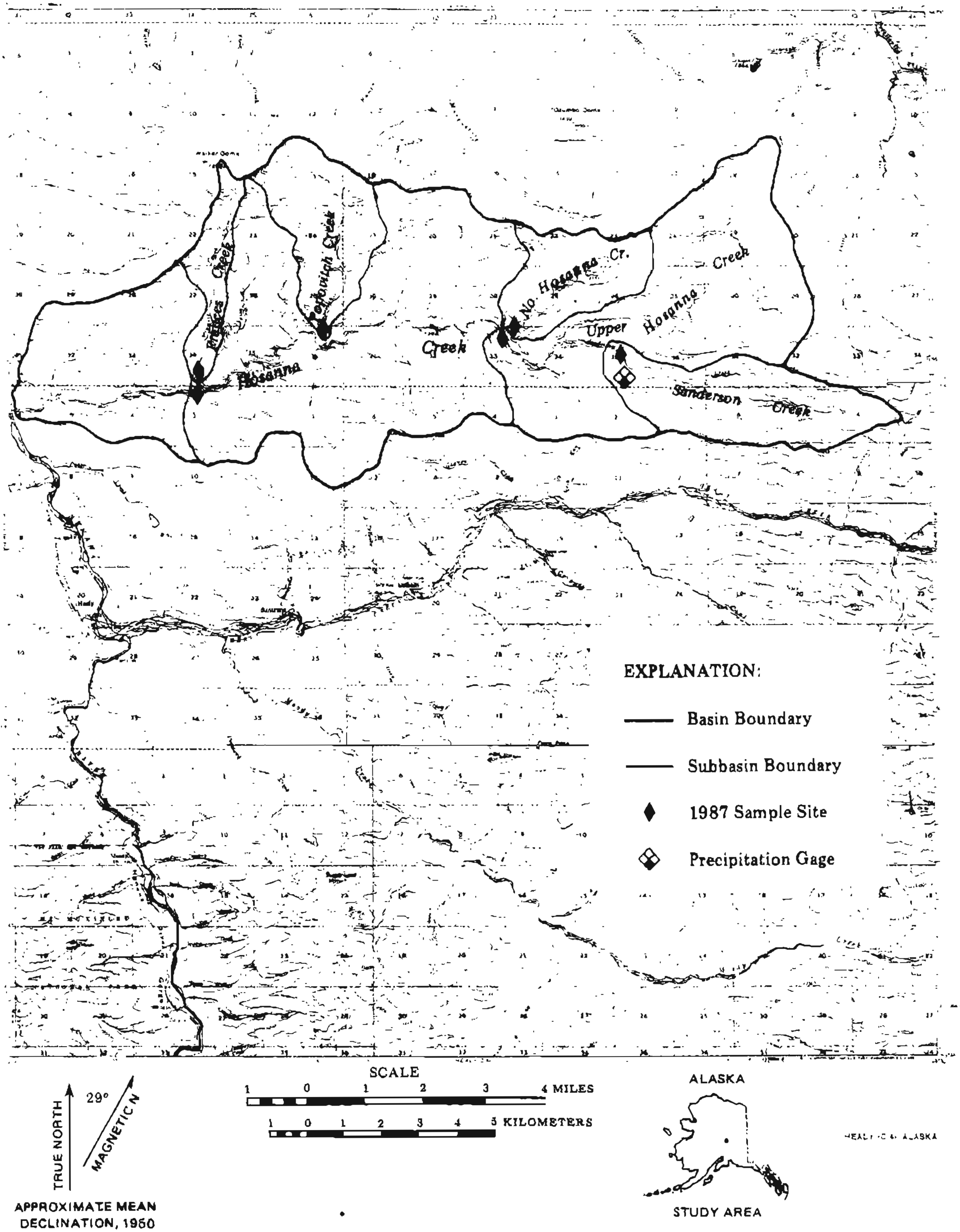
We added an upper Hosanna Creek site at a location above the confluence with North Hosanna Creek. The purpose of data collection at this site was to attempt to acquire more information on upper basin flows and sediment transport levels. We did not make this an automated site because of the uncertainty of the location of a road under construction and because no site in the vicinity was appropriate for developing a stage-discharge relationship nor had an on-bank location sufficiently above the flood plain for safely placing the sampling and recording equipment. At this upper basin site we collected samples and measured flows during each site visit. Figure 1 shows the locations of sampling sites within the basin with the corresponding drainages outlined. Table 1 lists the basin characteristics of the sampling sites.

Table 1. Characteristics of Hosanna Creek sites

Location	Area (sq mi)	Percent of Total Area	Principal Lithology	2 year * peak flow (cfs)
Sanderson Cr ab Mining	5.07	11.58	Schist	103
Upper Hosanna Cr	16.6	37.90	Mixed	295
North Hosanna Creek	3.13	7.15	Coal Bearing Sandstone	66.8
Popovitch Creek	4.06	9.27	Nenana Gravel	84.2
Frances Creek	1.71	3.90	Nenana Gravel	39.0
Hosanna Cr ab Bridge 3	43.8	100.00	Mixed	699

* based on area-discharge regression of the published records of five local-area streams gaged by the U.S. Geological Survey (Jones 1983).

Figure 1. Hosanna Creek Drainage.



METHODS

A. Precipitation gage. Precipitation is collected in a Wyoming type precipitation gage located at Gold Run Pass in the SE1/4, SW1/4, Sec 35, T11S, R6W, Fairbanks Meridian. A Wyoming gage is a structure consisting of two concentric windshields of 5 and 10 feet outer radii each supported to a height of 8 and 10 feet respectively. The inner shield has an outward slope of 45 degrees while the outer shield has an outward slope of 30 degrees down from the vertical. The shields are supported by 2x4's or 4x4's with various bracing materials for extra support. This large structure is required in exposed locations to break the often strong winds that can occur. The wind shield reduces the force and effect of the wind, allowing the precipitation to fall vertically into the collection can and mix with a glycometh solution (to prevent freezing). The water level in the collection can is monitored in a hydraulically attached stilling well located in a nearby equipment shelter. Water levels are recorded with an Omnidata stage recorder attached to a float and pulley system. The recorder monitors water levels every 30 minutes and has a sensitivity of one one-hundredth of a foot.

B. Discharge. Velocities used to calculate discharge were measured with a Marsh McBirney Model 201 Flowmeter. Velocities were measured six tenths of the depth from the surface. Discharges were calculated using the standard midpoint method (USDOI, 1981) from at least twenty velocity measurements taken across the stream cross section where width permitted (most cases). At sites with flumes (Frances and Popovitch Creeks) discharges were estimated from the ratings established for the Parshall flumes (USDOI, 1981). It should be noted that flumes for Popovitch and Frances Creeks were sized based on the estimated peak flows for each drainage. Because of this, the sensitivity of the rating equations at normal flows at these sites is poor.

The gage location at Hosanna Creek at Bridge 3 was chosen because it is the furthest downstream Hosanna Creek point above mining near a bridge. The sites on Sanderson Creek and North Hosanna Creek were chosen by looking for a cross section that would provide the most change in stage for change in stream discharge and the least turbulence around the staff gage. The flume sites were chosen by looking for a stream reach that provided a relatively straight stream approach section and high stream banks to direct high flows through the flume. At all sites continuous water surface levels were recorded with Omnidata DP320 Stream Stage Recorders. The DP320 is a small, battery operated device with a submersible pressure transducer which measures and records water levels between 0 to ten feet to the nearest hundredth of a foot. Water level data are stored in a solid state memory called a data storage module. At all sites the water level recorders monitored water levels at 30 minute intervals.

Rating curves were developed for each site by taking discharge measurements at different water levels throughout the season. At the non-flume sites, peak flows were estimated using the slope-area method (Dalrymple and Benson, 1984). The rating curves were then used to estimate discharge from the observed or recorded water levels.

C. Water Quality. Water quality analyses done in 1987 for this report were conducted in the field and in the DGGS hydrology lab located on the University of Alaska, Fairbanks campus in the Water Research Center. Some trace metal analyses were also performed with the generous help and use of equipment of the UAF Forest Soils Laboratory.

Procedures prescribed in the EPA publication no. EPA-600/ 4-79-020, "Methods for Chemical Analyses of Water and Wastes," were followed whenever possible (EPA, 1983). Other sources of methods were the USGS "Techniques of Water-Resources Investigations, Book 5, Chapter A1"; the APHA-AWWA-WPCF "Standard Methods for the Examination of Water and Wastewater, Sixteenth Edition"; and procedures outlined in the user manuals of certain instrumentation (Skougstad et al., 1979; APHA, 1985). The lab is a participant in EPA analytical quality assurance studies, and has participated in the USGS Standard Reference Water Sample Quality Assurance program since 1980. For all analyses calibrations were performed using in-house analytical standards and blanks, and were monitored and verified by running previously analyzed Standard Reference Water Samples along with the water samples collected for this study.

1. Turbidity and total suspended solids. Samples for these analyses were collected from automated samplers, by grab methods in well-mixed reaches at sampling sites, or with a depth integrating suspended sediment sampler. When automated samplers were employed, the intake hose for the sampler was installed at a well-mixed location in the stream at middepth with the intake nozzle pointing upstream. The automated samplers were programmed to start sampling once stream water levels reached a predetermined level indicating that a rainstorm event was happening. During these events the samplers collected samples in intervals ranging from 90 minutes to three hours.

Turbidity determinations were done in the lab because the lab served as a receiving point for samples coming in from more than one collecting agency, and because some of the more turbid samples required several serial dilutions to bring their turbidity down to readable levels. During 1987 the instrument used was a Turner Designs Model 40 laboratory turbidimeter.

Total suspended solids (TSS) samples were filtered through prewashed, dried and weighed glass fiber filters, according to EPA specifications. The size of the aliquot was dependent upon the amount of material suspended, but ranged from 25 ml to a liter. Sediment load was calculated by multiplying discharge (in cfs) by TSS (in mg/l) and a constant of 0.0027 to convert the units into tons per day. Sediment yield was calculated by multiplying the seasonal average suspended load by an assumed 120 day field season and dividing by drainage area.

2. Bed load samples. Bed load samples from Popovitch Creek were collected in a frame that had an opening six inches by 48 inches backed by a 250 micron mesh bag. The bed load collector was held behind the Popovitch Creek flume for time periods ranging from one to ten minutes. The collector would collect all material larger than the mesh size transported by Popovitch Creek. Observations showed this larger material moving along the bottom of the flume. From these observations we assumed that the material collected in the mesh bag could be considered bed load.

For analysis of total weight and particle size distribution, the bed load samples were dried overnight in a convective oven at 100 ÏC. They were then weighed and sieved on a Ro-Tap for 15 minutes. The mesh sizes used were 32 mm, 16 mm, 8 mm, 4 mm, 2 mm, 1.18 mm, 0.425 mm, 0.250 mm, 0.125 mm, and 0.063 mm. For sandy samples additional screens (sizes 0.850, 0.600, 0.300, and 0.212 mm) were included to prevent clogging of the screens. Larger samples were sieved in batches and weights were combined in the results.

3. Water chemistry. Water temperature, dissolved oxygen, and specific conductance were measured in the field with a digital 4041 Hydrolab. An

Orion digital pH meter was used to measure _in situ_ pH. Alkalinity was measured electrometrically in the field with an Orion pH meter and a Hach digital titrator, according to the methods of the Environmental Protection Agency (EPA, 1983). Settleable solids were determined in the field with Imhoff Cones according to APHA's Standard Methods (1985).

Water for chemical analysis was obtained from the stream with a depth-integrating suspended-sediment sampler and composited in a churn splitter, according to the methods of the U.S. Department of the Interior (1977). Samples collected from the splitter at each site were: a filtered, untreated bottle for determining dissolved major anions; a nonfiltered, untreated bottle for determining turbidity, color, and acidity; a nonfiltered, untreated bottle for determining suspended solids; and a filtered acidified bottle for determining dissolved trace metals and major cations. All acidified samples were collected in pre-acid-washed bottles, and acidified with Ultrex grade nitric acid, to a concentration of 1.5 ml acid per liter sample. The filtered samples passed through 0.45 micron membrane filters.

Color was determined with a color comparator. Acidity was determined by titrimetric methods (EPA, 1983).

Sodium (Na), potassium (K), and arsenic (As) were analyzed by atomic absorption spectrophotometry using various techniques and instruments.

Na and K were analyzed on a Perkin-Elmer (P-E) 5000 using an air-acetylene flame and As on a P-E 603 using a hydride system (MHS-1) with 5% $NaBH_4$ in 2% NaOH as the reductant. The remaining trace elements and major cations were determined on a Beckman SpectroSpan V DCP plasma located in UAF Forest Soils Laboratory. They include barium (Ba), chromium (Cr), cadmium (Cd), iron (Fe), manganese (Mn), lead (Pb), silicon (Si), zinc (Zn), calcium (Ca), and magnesium (Mg). DCP spectrophotometry has been favorably received throughout the scientific community and is being reviewed by EPA for certification in the very near future as an acceptable analytical technique for trace metals.

Total dissolved anions were determined in filtered untreated samples on a DIONEX ion chromatograph according to method 429 of Standard Methods for the Examination of Water and Wastewater (APHA 1985). Detectable levels of Cl, NO_3, and SO_4 only were found.

Total dissolved solids were calculated from the above analytical data.

D. Regression equation development. In open channels where supply is a constant, stream sediment levels are a function of stream discharge. Typically, plots of sediment levels (TSS, turbidity, or suspended load) versus discharge will approximate a straight line on logarithmic graph (Leopold and Maddock, 1953). Our intention was to combine the peak event TSS data and normal flow data with seasonal discharge data to develop regression equations estimating TSS from daily discharge at each site with automated equipment.

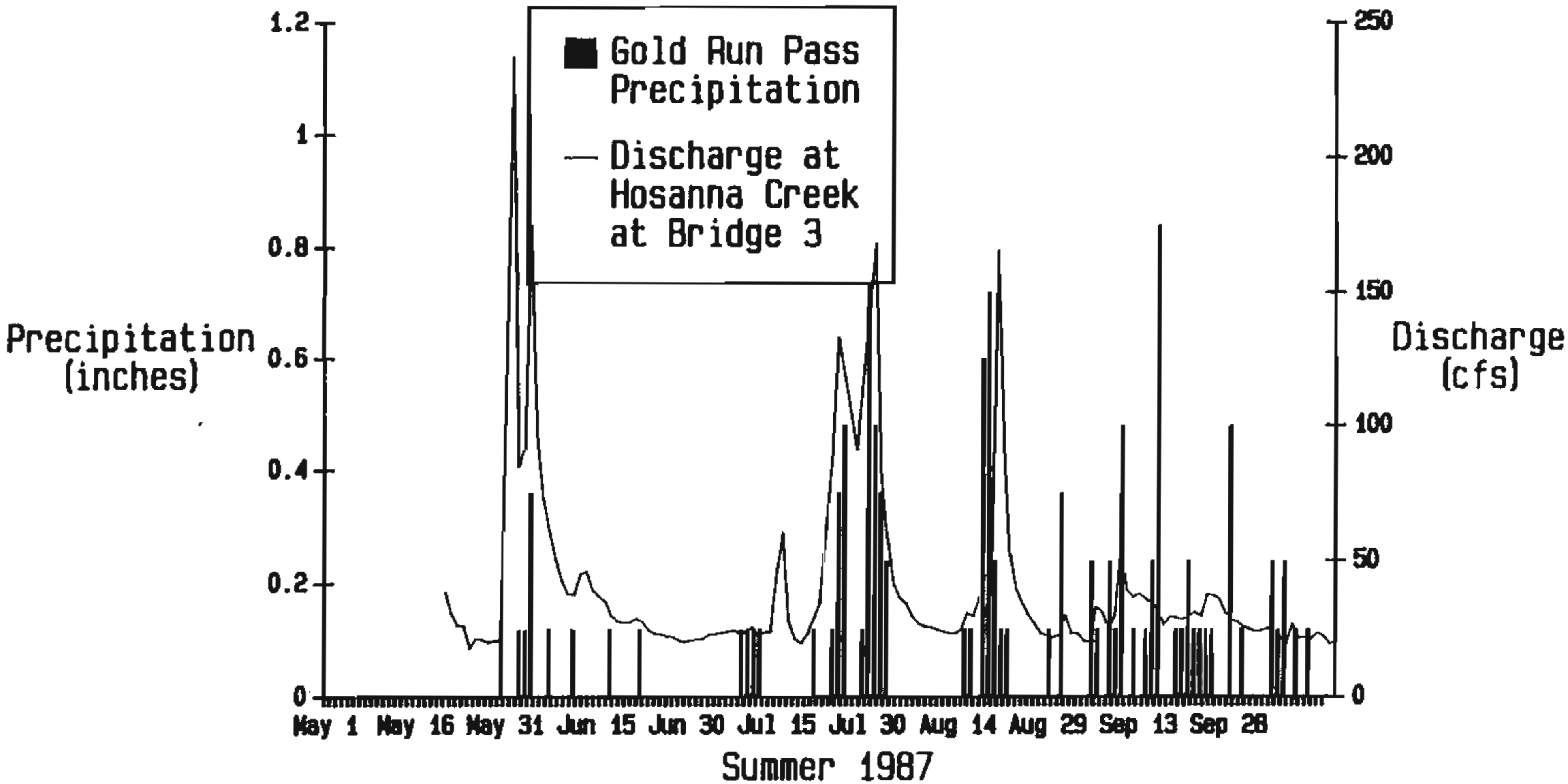
At each site we used paired TSS-discharge data to evaluate the TSS-discharge relationship of the data and to develop TSS-estimating equations in the form of $y = a*x^b$, where y is TSS, x is discharge and a and b are coefficients. If the coefficient of determination (r^2) was larger than 0.60 and the seasonal discharge record complete, we used the regression equation to estimate TSS from daily average discharge. The TSS estimates were combined with discharge to estimate daily suspended load. An exception to this was suspended load estimates for Hosanna Creek at Bridge 3 and Sanderson Creek above mining for peak flow events. At these sites we had analysis results from peak flow samples from the automated samplers. Daily suspended load was estimated from the results of these samples. The suspended load estimates were summed to produce a seasonal suspended load estimate.

RESULTS

A. Precipitation. Figure 2 shows the daily precipitation recorded at the Gold Run Pass Wyoming-type precipitation gage from May 1, 1987 to October 13, 1987. Daily discharge at the Hosanna Creek at Bridge 3 site is superimposed to show how rainfall at Gold Run Pass relates to flow in Hosanna Creek. The precipitation data in tabular form is contained in Appendix 1. The discharge data is discussed in a later section.

Total precipitation for the May 1 - October 13 period was 12.2 inches. Average rainfall at the Poker Flats Mine area for the May - September period has been 12.8 inches for 1979-86. Comparisons of the Poker Flats precipitation data and precipitation data collected at Gold Run Pass during 1979-82 indicate that average precipitation is very similar, but individual storms at Gold Run Pass appear to be larger (Wilbur, 1988). The maximum daily value recorded at the Gold Run Pass gage was 0.84 inches. The two year, 24 hour probable maximum storm intensity is in the 1.5-2 inch range (Miller, 1963). During 1987, while the seasonal precipitation was near average, storm events near the expected size did not occur. In mid summer the rainfall peaks coincided with discharge peaks in Hosanna Creek. In late May-early June Hosanna Creek had a peak flow with little rainfall input recorded at the Gold Run Pass gage. That was probably due to snowmelt runnoff along with the precipitation. In September and October precipitation occurred with

Figure 2. Gold Run Pass precipitation

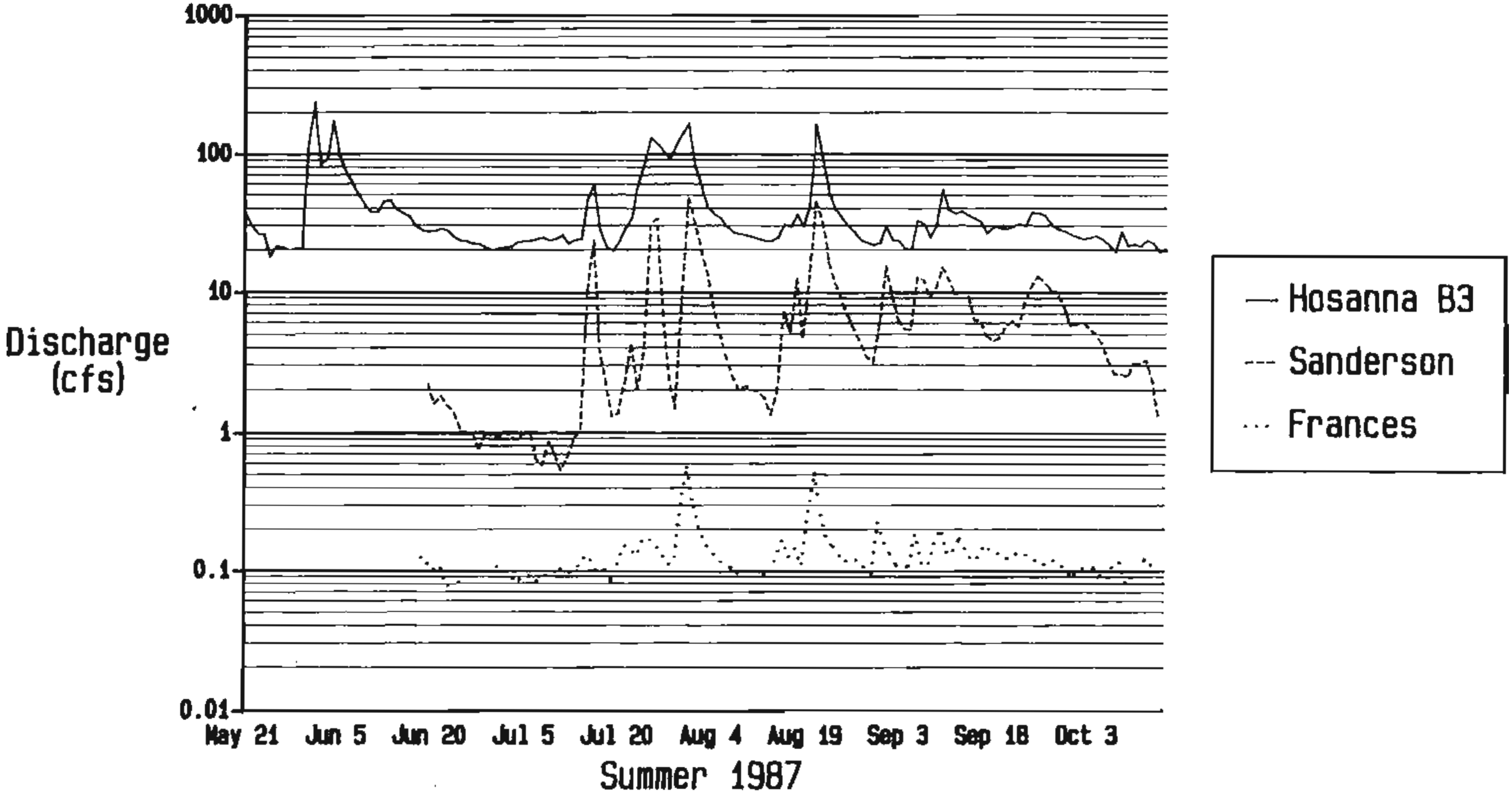


little immediate impact on stream flow. That was probably due to the precipitation falling as snow at higher altitudes in the basin.

B. Discharge. Season-long discharge estimates from the five sites with automated equipment are not complete. The records are good at Hosanna Creek at Bridge 3, Sanderson Creek above Mining and Frances Creek. We started recording stage at the Hosanna Creek site on May 21. Because of aufeis buildup, we could not start recording at Frances Creek and Sanderson Creek until June 18 and June 19, respectively. At Popovitch Creek the recorder attached to the flume recorded spurious data during much of the summer. At North Hosanna Creek the stream reach in which the transducer was located changed during the summer so that a reliable stage-discharge relationship could not be established. Recorded data were used to estimate peak flows at these sites. Figure 3 shows the seasonal flows at Hosanna at Bridge 3, Sanderson Creek and Frances Creek. Daily discharge values from these sites are in Appendix 2.

Compared to the results from 1986 and the two-year return period peak flows estimated for the 1986 report, peak flows in 1987 were low. Three storm peaks occurred at Hosanna Creek at Bridge 3. As discussed above the first peak was probably related to snowmelt runoff; the latter two to summer rainfall events. None of these peaks approached the magnitude of the peaks observed in 1986. The latter two events also were recorded at the Sanderson and Frances Creek sites.

Figure 3. Discharge at sites in the Hosanna Creek basin



C. Sediment load. The program for estimating suspended load worked best at the Hosanna at Bridge 3 and Sanderson Creek above mining sites. At those two sites, there was a good discharge record through the summer, the automated samplers collected samples during the peak flows (three at Hosanna at Bridge 3 and two at Sanderson), and the calculated discharge-TSS relationship at both sites was reasonable. The Frances Creek discharge record was good for the whole summer; however, no flow events was large enough to activate the automated sampler. Also, the relationship between discharge and TSS was not good. At North Hosanna Creek the discharge-TSS relationship was good but the seasonal discharge record was inadequate and the extreme events were not large enough to activate the automated sampler more than once.

Popovitch Creek, because of its high bed load component, is a special case. An automated sampler was not used at that site, but samples were collected manually during the highest flows of the summer. Both the discharge-bed load and discharge-TSS relationships were reasonably good, but because of recorder and transducer malfunctions an inadequate seasonal record was obtained. At Hosanna Creek above North Hosanna (where we did not have automated equipment) the discharge-TSS relationship was not good. The sediment and discharge data from each site is contained in Appendix 3. Table 2 shows the equations and statistics for estimating TSS from discharge based on 1987 data. These data and results are discussed in more detail below.

Table 2. Summary of equations for estimating TSS from discharge. equations in the form TSS=a*(discharge^{b}) n is the number of observations used for model development

location	n	a	b	r2	SEE*	+%SEE	-%SEE
Hosanna at Bridge 3	113	1.81	1.59	0.71	0.383	242	41
Sanderson ab mining	18	1.50	2.02	0.81	0.635	432	23
Frances Creek	32	7260	1.47	0.28	0.861	726	14
Popovitch Creek, TSS	24	730	4.38	0.65	0.572	373	27
Popovitch, Bed load	10	6010	6.54	0.89	0.335	216	46
North Hosanna Creek	21	425	1.10	0.65	0.365	232	43
Hosanna ab N Hosanna	8	796	-0.27	-0.13	0.311	205	49

*SEE is the standard error of estimate.

1. Hosanna at Bridge 3. Figure 4 shows the TSS data from this summer plotted against discharge with the regression line fit to these data. The coefficient of determination (r^2) for the regression is 0.71. Figure 4 has the data points differentiated based on time and sampling technique. The first flood event shows considerable scatter due to hysteresis which is the temporal lag between TSS peaks and discharge peaks. Hysteresis is common during flood events and is thought to be due to supply depletion (VanSickle and Beschta, 1983).

Figure 5 shows daily discharge and estimated daily suspended load for the 1987 summer. At Hosanna at Bridge 3 the total suspended load between May 21 and October 12 was 40,000 tons. Graphically illustrated in Figure 5 is the large amount of sediment transported during the three relatively short and small flood events during 1987. More than 77 percent of the total suspended load moved during nine days between May 21 and October 12 .

Figure 4. TSS and discharge at Hosanna Creek at Bridge 3

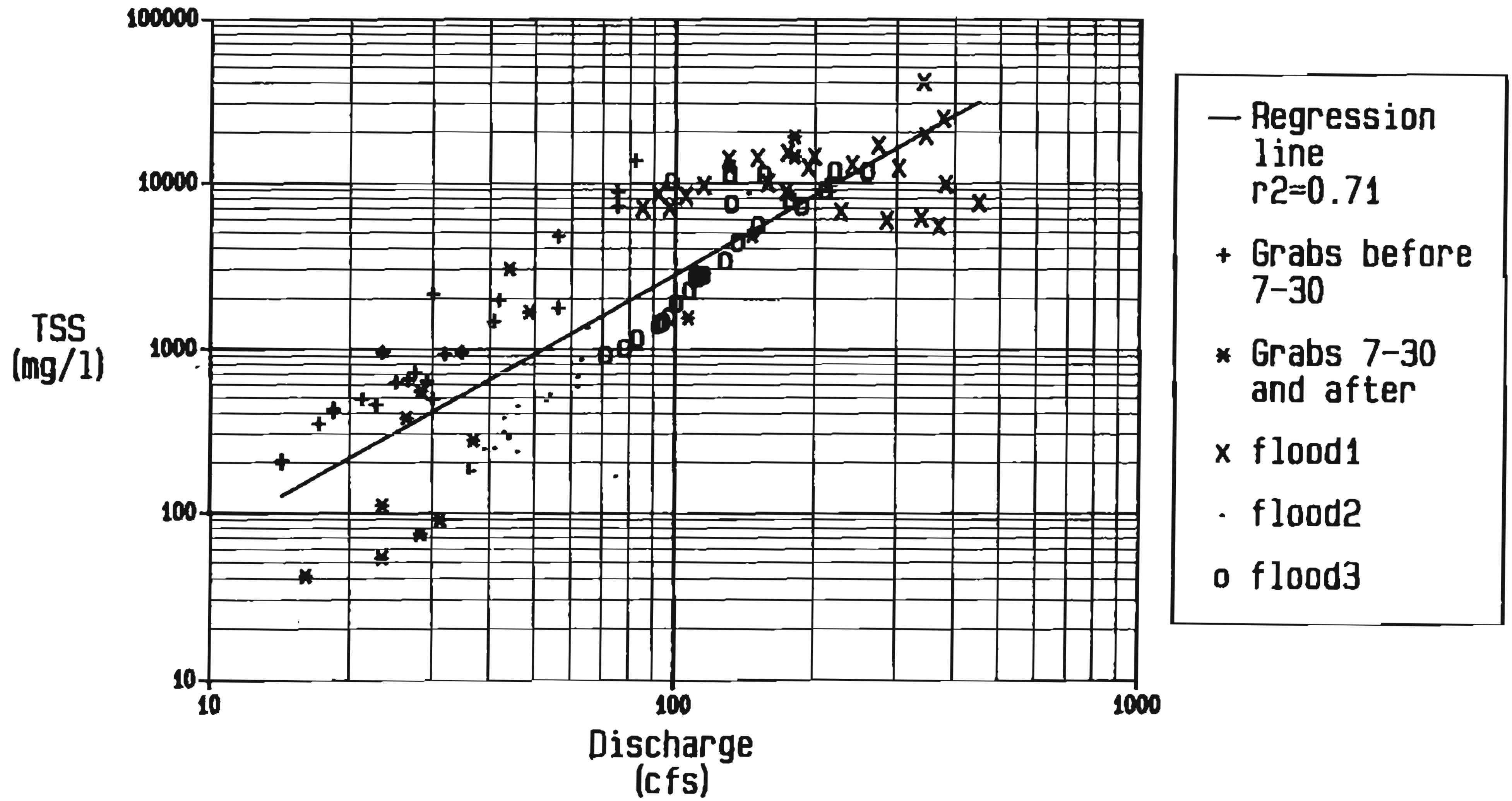
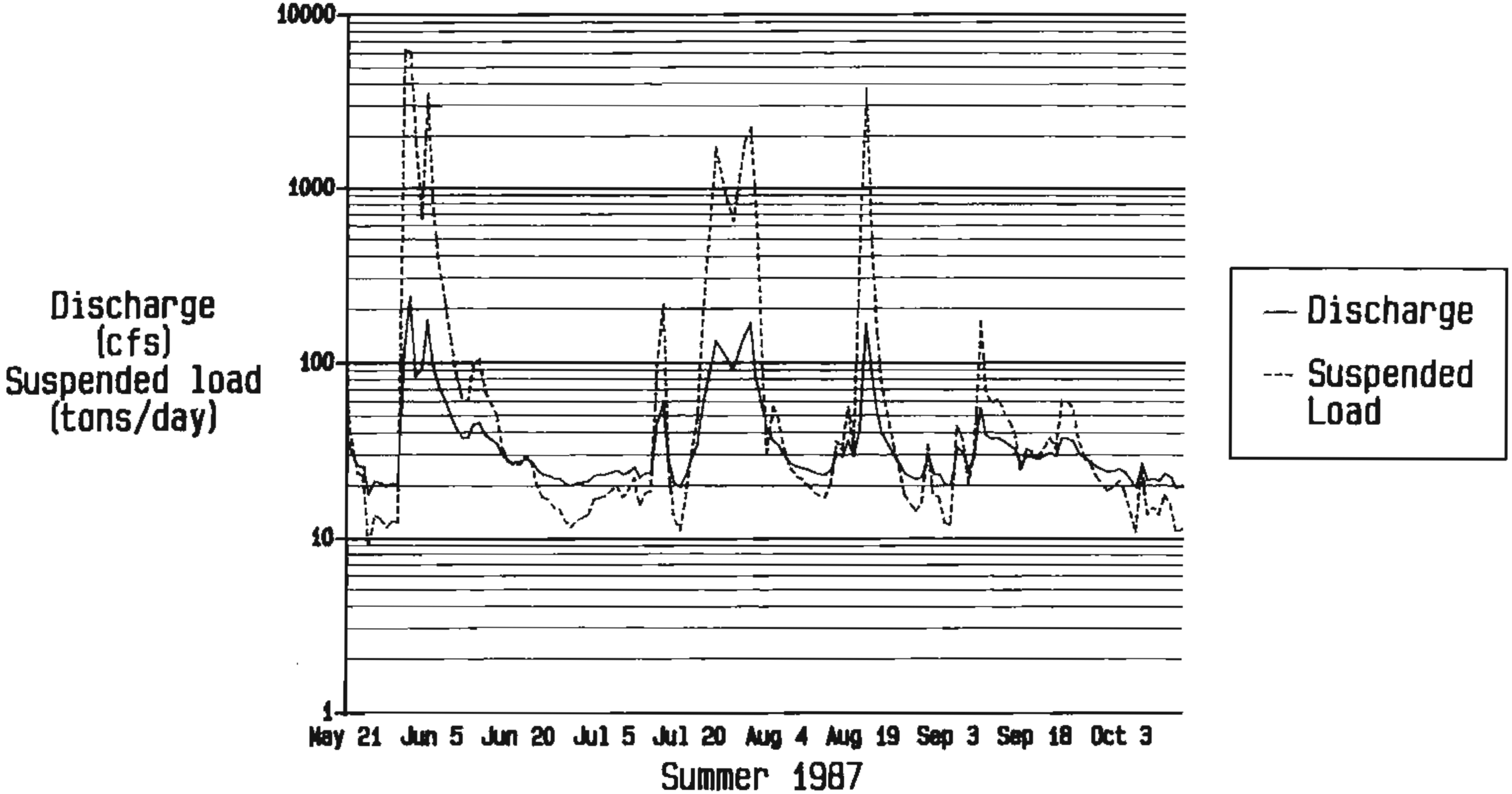


Figure 5. Discharge and suspended load at Hosanna Creek at Bridge 3



2. Sanderson Creek above mining. Figure 6 shows the TSS-discharge relationship at this site. Hysteresis during flood events is also evident with these data. Because this hysteresis is so severe, we averaged the TSS and discharge data into daily values before developing a regression equation. The resulting regression equation has an r^2 of 0.83. Figure 7 shows the estimates of daily suspended load at this site. Again, only a few days are responsible for most of the load. At Sanderson Creek, 83 percent of the load moved during six days between June 19 and October 12. The estimated suspended load for the June 19-October 12 period is 2700 tons which is 14 percent of the load at Hosanna Creek at Bridge 3 for the same time period.

3. Frances Creek. The TSS-discharge relationship (data plotted in Figure 8) at Frances Creek was not good with an r^2 of 0.28. At lower discharges considerable scatter existed in the data. Even though the coefficient of determination is poor, we used the regression equation calculated from the Frances Creek data to estimate the relative magnitude of suspended load from Frances Creek compared to Hosanna Creek. Using that equation and seasonal discharge from the Frances Creek flume, we estimate that in 1987 Frances Creek contributed 0.1 percent of the load estimated at Hosanna Creek at Bridge 3.

4. North Hosanna Creek and Hosanna Creek above North Hosanna. The TSS-discharge data from North Hosanna Creek are shown in Figure 9. The

Figure 6. TSS and discharge at Sanderson Creek above mining

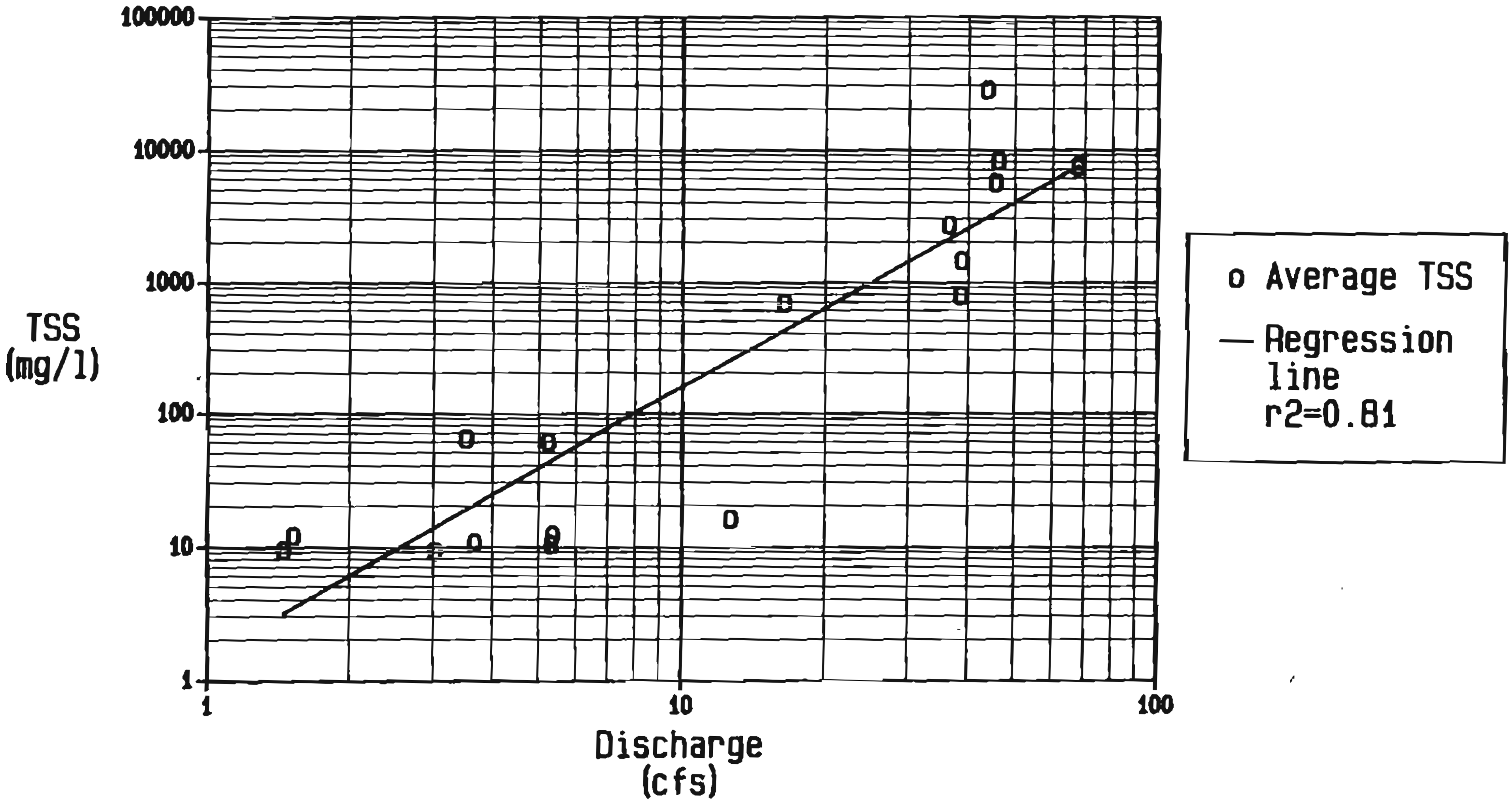


Figure 7. Discharge and suspended load at Sanderson Creek above mining

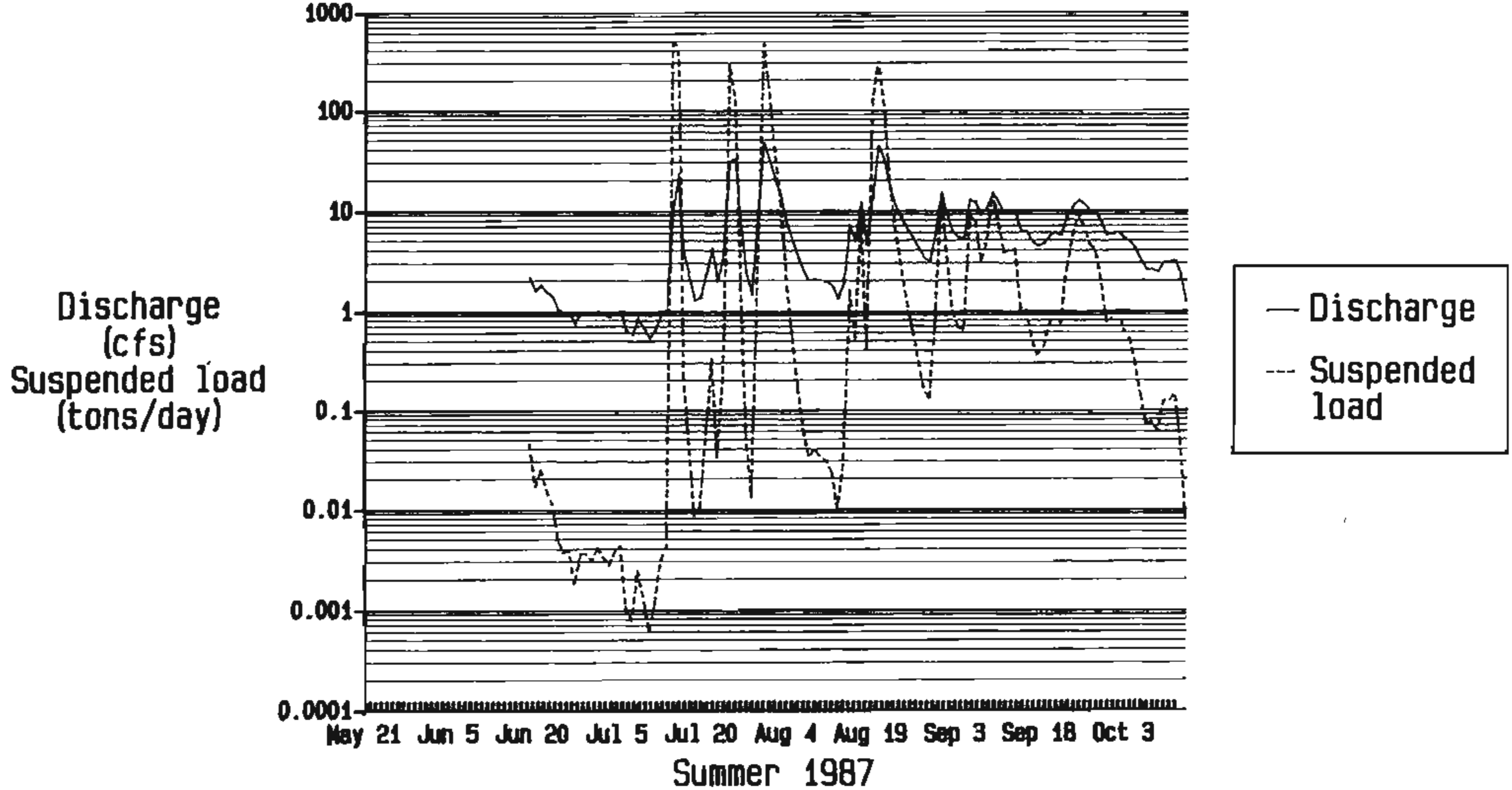


Figure 8. TSS and discharge at Frances Creek

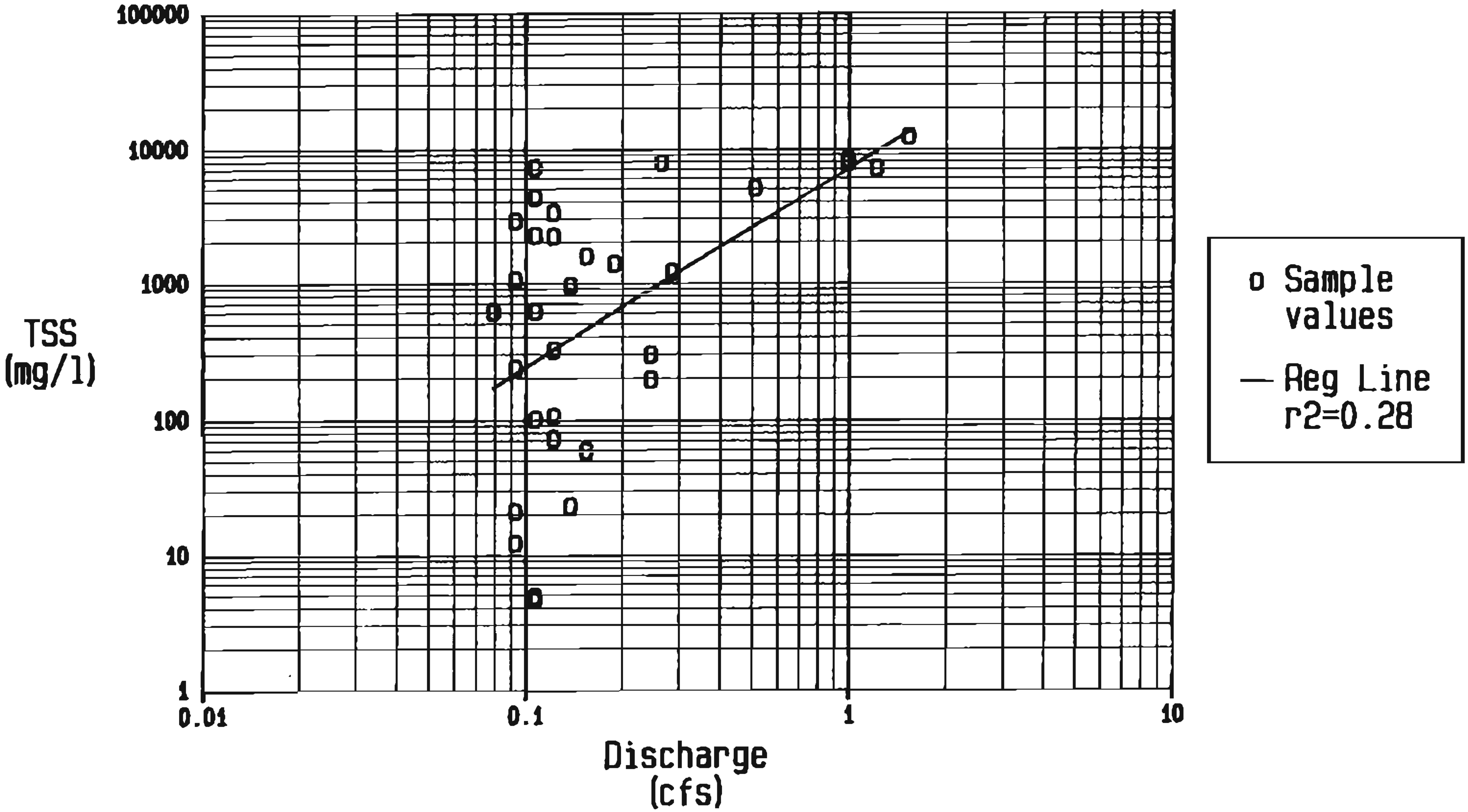
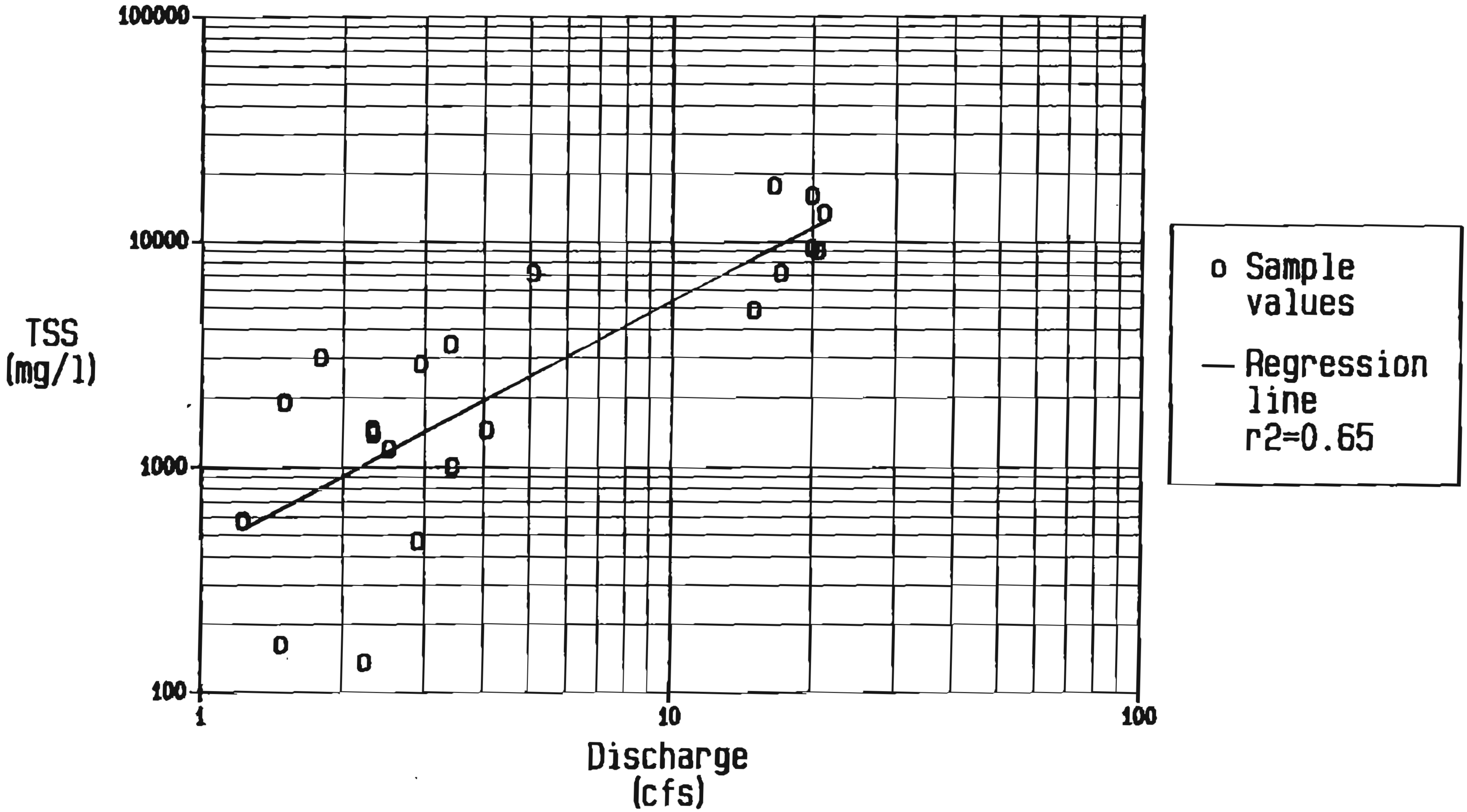


Figure 9. TSS and discharge at North Hosanna Creek

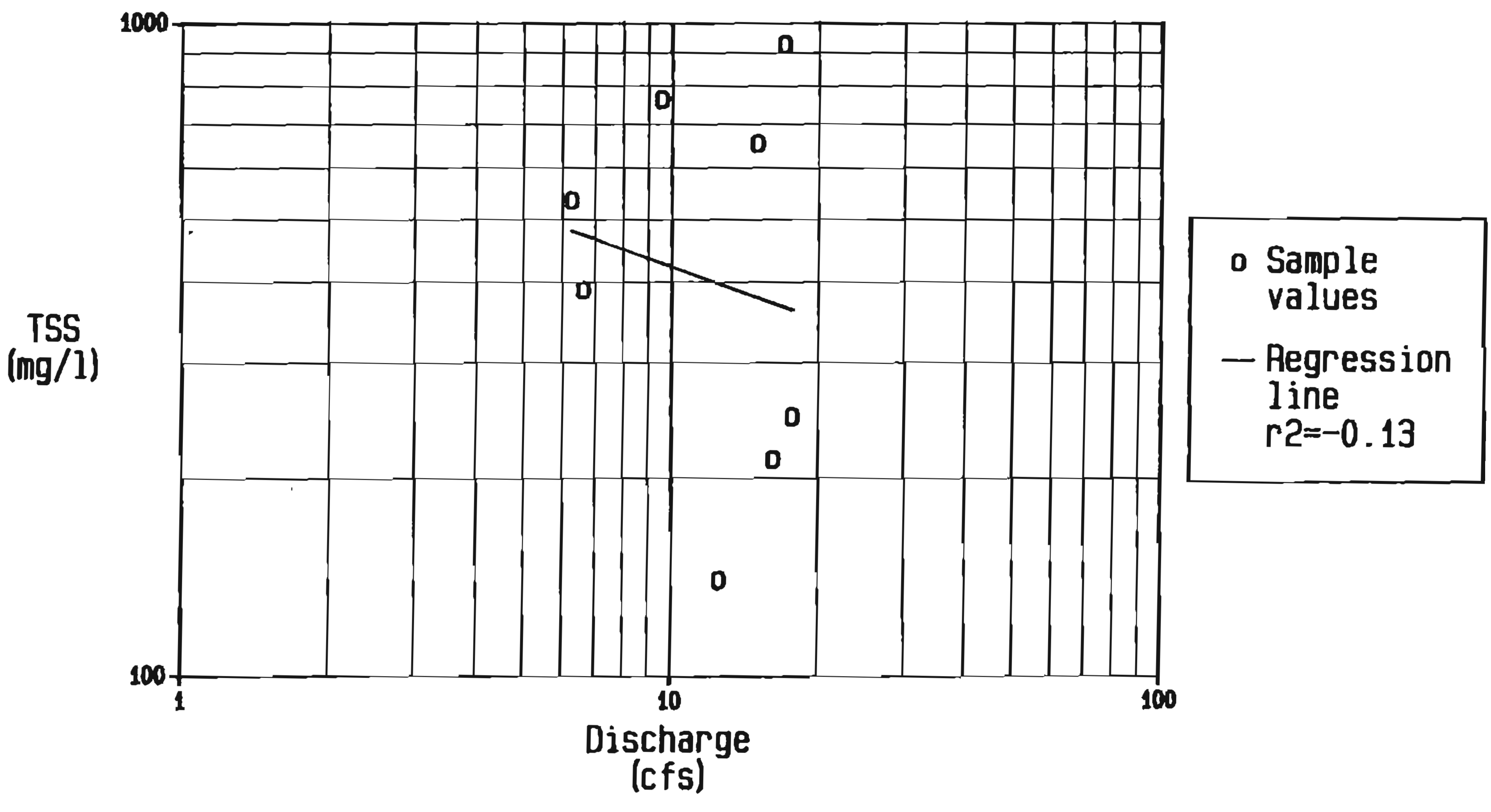


data have an acceptable relationship (r^2=0.65); unfortunately we do not have reliable stage data from this site.

No significant relationship exists between the discharge and TSS data collected at the Hosanna above North Hosanna Creek site (Figure 10). This is partly due to the sampling methods at this site. Because we had no automated equipment all our data were collected in a relatively narrow range of discharges, that is, we acquired no data during high flows, as was done at the sites with automated equipment or sites with easy road access. If the data from this site are compared to those from North Hosanna, the pattern of the Hosanna above North Hosanna Creek data is similar to the lower discharge values from North Hosanna Creek. The only apparent difference is the lack of samples from the high flow events that were collected with the automated equipment at North Hosanna Creek.

These two sites are important for estimating the distribution of sediment loads in the Hosanna Creek basin. North Hosanna Creek is believed to be a major contributor of sediment to Hosanna Creek and the Hosanna above North Hosanna site is located approximately mid basin. Data from this site describes the upper basin discharge and sediment contributions. Seasonal estimates are not available for the reasons discussed above. Estimates of contributions from North Hosanna and Hosanna above North Hosanna can be made by comparing same-day data from these sites to those from Hosanna at Bridge 3.

Figure 10. TSS and discharge at Hosanna Creek ab North Hosanna

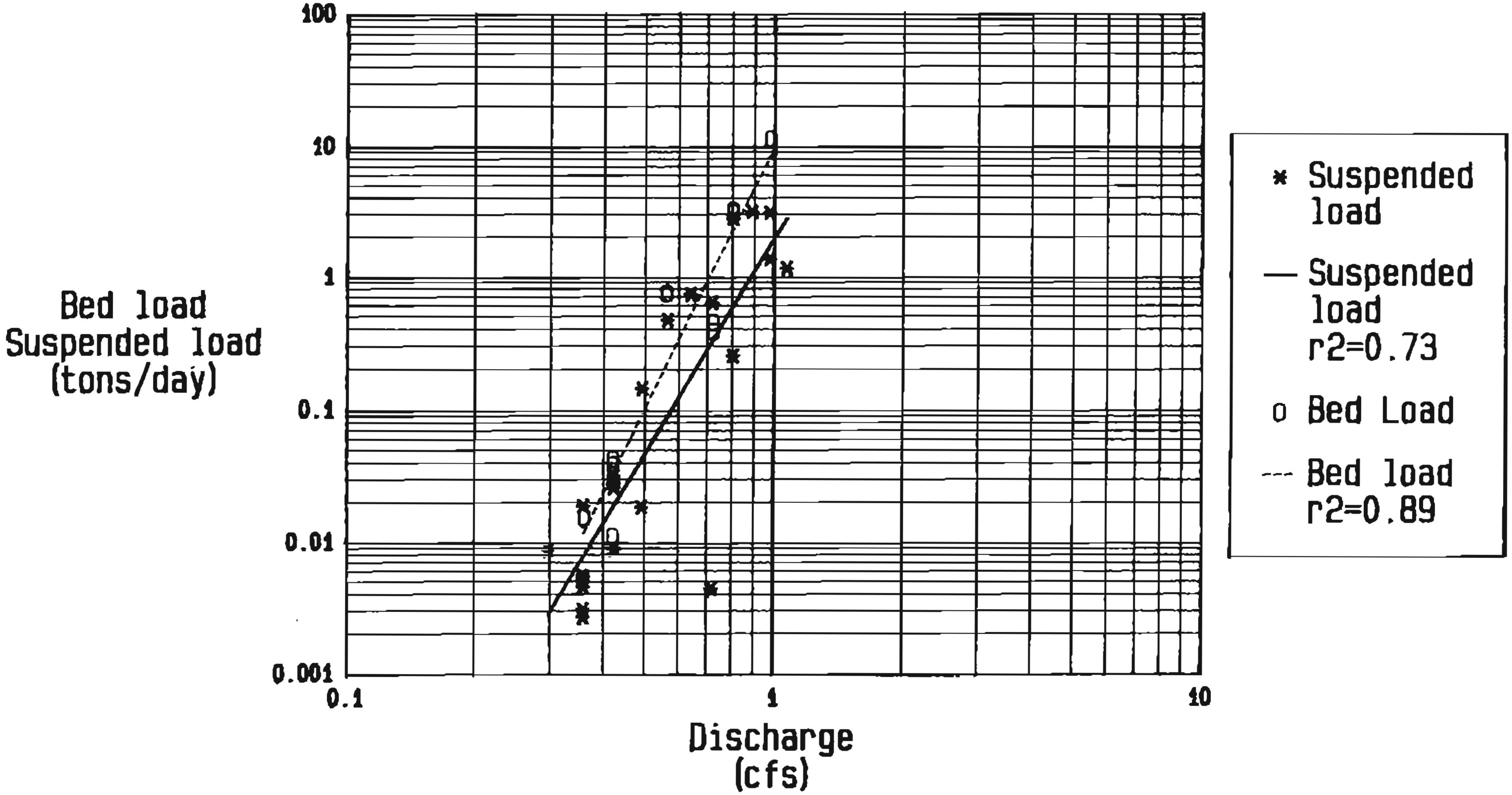


Comparing the same-day North Hosanna Creek data to Hosanna at Bridge 3, deleting the one high flow event data, and data from days where stage or sediment levels were changing at either site, indicate that the North Hosanna Creek sediment levels are approximately 40 percent of the Hosanna at Bridge 3 levels. The one high flow event at North Hosanna Creek for which we had sediment samples and discharge estimates had suspended load levels 16 percent of those at Hosanna at Bridge 3. If one applies those percentages to the seasonal load estimated for Hosanna at Bridge 3, approximately 7500 tons was transported by North Hosanna Creek between May 21 and October 12.

Using the same techniques for Hosanna above North Hosanna, this site had approximately 37 percent of the load at Hosanna at Bridge 3. We have no high flow data for this site. Assuming this relationship applies to the entire range of flows, approximately 13,000 tons was transported at Hosanna above North Hosanna between May 21 and October 12.

5. Popovitch Creek. The bed load and suspended load data from Popovitch Creek are plotted in Figure 11. The data for developing this figure are in Appendix 4. Important to note is that the slope of the regression line for the bed load data is much steeper than that of the

Figure 11. Bed load and suspended load at Popovitch Creek



suspended load. As discharge increases at this site bed load becomes an increasingly more important component of the total load. Based on these data, at 1 cfs bed load is almost ten times greater than suspended load.

The seasonal discharge at this site is inadequate to develop reliable seasonal load estimates. The contribution from this creek was not a significant part of the load at Hosanna Creek at Bridge 3. The maximum total load (bed load and suspended load combined) collected this summer was approximately 15 tons per day on August 18. The calculated suspended load at Hosanna Creek at Bridge 3 for that day is 555 tons and on August 19 it was 3740 tons.

D. Surface water chemistry. Appendix 5 contains the results of the water chemistry analyses of the samples collected three times in 1987 at sites located on Hosanna Creek at Bridge 3 (above the Poker Flats mine) and on Hosanna Creek at Bridge 1 (below the Poker Flats mine). Generally, values of field-determined parameters at Hosanna Creek at Bridge 1 (Bridge 1) and Hosanna Creek at Bridge 3 (Bridge 3) were similar. Water temperature was 0.2 to 2.1 °C warmer at site 1. Both sites showed slightly acidic pH in Hosanna Creek in June and August and slightly basic pH in September. Dissolved oxygen concentrations exceeded 100 percent saturation at both sites on all three sampling dates. The specific conductance and alkalinity values were slightly higher at site 1. Specific conductance ranged from 441 and 582 ìmhos/cm at Bridge 3 and 456 to 631 μmhos/cm at Bridge 1. Alkalinity, expressed at $CaCO_3$, ranged from 94 to 133 mg/l at Bridge 3 and 103 to 140 mg/l at Bridge 1.

No appreciable difference existed between the ionic composition of Hosanna Creek at Bridges 1 and 3. Chloride concentrations were slightly higher at Bridge 1. Nitrate concentrations were also higher at Bridge 1, particularly on June 8 when Bridge 1 had a NO_3 concentration of 21.6 mg/l, ninety-three times higher than Bridge 3. The NO_3 concentration at Bridge 1 decreased to 0.257 mg/l on August 3 and to 0.195 mg/l on September 14, about three to four time higher than the concentration at Bridge 3 on these dates. The mean total dissolved solid concentration, calculated from analytical data, was 330 mg/l at Bridge 1 and 300 mg/l at Bridge 3.

The percentages of the major ions did not change among sampling dates (Table 3). The surface water at both sites is a mixed-type because no single cation or anion predominates.

Values obtained for trace metal concentrations at Bridges 1 and 3 were similar. Little variability was evident over the three sampling dates. Cadmium, iron, lead, chromium, and zinc concentrations were below the detection limits of the laboratory analysis. The mean arsenic concentration was 0.0011 mg/l at Bridge 1 and 0.0008 mg/l at Bridge 3. As a point of reference, the Alaska Department of Environmental Conservation lists primary maximum contaminant concentrations for public drinking water supplies for As (0.05), Ba (1.0), Cd (0.010), Cr (0.05), Pb (0.05), and NO3 (10.0) in milligrams per liter. Secondary maximum contaminant concentrations are Cl (250), Cu (1.0), Fe (0.3), Mn (0.05), pH (6.5-8.5), color (15 units), Na (250), SO_4 (250), TDS (500), and Zn (5) in mg/l with the exception of pH. Primary contaminant concentrations are established for protection of public health. Secondary concentrations represent reasonable goals for drinking water quality and mainly affect the aesthetic qualities of drinking water (DEC, 1982).

Table 3. Percentages of the major ion composition, in meq/l, at Hosanna Creek sites on June 8, August 3, and September 14, 1987

	Bridge 3 (upstream)			Bridge 1 (downstream)		
	June 8	Aug. 3	Sept. 14	June 8	Aug. 3	Sept. 14
Cations						
Calcium	36	38	37	37	39	38
Magnesium	43	44	47	42	43	45
Sodium	18	15	14	18	15	14
Potassium	3	3	2	3	3	3
Anions						
Bicarbonate	56	55	58	54	55	58
Sulfate	33	35	33	26	32	30
Chloride	10	10	9	11	13	11
Nitrate	0	0	0	9	0	0

The maximum contaminant concentration was exceeded for nitrate (NO_3) at Bridge 1 on June 8. The manganese (Mn) concentration exceeded the maximum contaminant concentration on all three sampling dates at both sites. The mean Mn concentration was 0.27 mg/l at Bridge 3 and 0.25

mg/l at Bridge 1. Color also exceeded the maximum contaminant concentrations on each date at both sites. The mean value for color was 27 PCU units at Bridge 3 and 25 PCU units at Bridge 1.

DISCUSSION

1. The most striking aspect of the sediment load data collected this summer is the proportion of material that moves during high flow events. Peak flows this summer were not even high enough to be considered floods, yet at sites where we had enough data to evaluate seasonal loads (Hosanna at Bridge 3 and Sanderson above mining), most of the material transported this summer moved during the relatively short high flow events. At the other sites similar activity was observed, although the seasonal data are inadequate to evaluate these sites.

2. The sediment contributions of the studied basins are not identical to basin size. Based on our estimates from this summer's data, North Hosanna Creek contributes 21 percent of the load of that observed at Hosanna at Bridge 3 but has only 7.2 percent of the drainage area. Sanderson Creek and Hosanna above North Hosanna contribute loads proportional to their drainage areas. Popovitch and Frances Creeks contributed less than might be expected from their drainage areas.

Other sources of sediment load would be drainages below North Hosanna Creek and the main channel of Hosanna Creek below North Hosanna Creek. Table 4 summarizes these observations.

Table 4. Seasonal Loads at Hosanna Creek sites

Location	Seasonal Load (tons)	Sediment Yield (tons/mi^2)	% of Hosanna at Bridge 3 load	% of basin area
Hosanna at B3	40,000	910	100	100
Sanderson	5600	1100	14.0	11.6
North Hosanna	7500	2400	18.8	7.1
Hosanna ab North Hosanna (-Sanderson)	7400	620	18.5	27.2
Popovitch	60?	15	0.15	9.3
Frances	45	26	0.11	3.9
Other sources	19,400	1080	48.5	40.9

3. The results from Popovitch Creek point out the importance of bed load in the sediment budget of the Hosanna Creek basin. Bed load movement at other sites is not as obvious as that at Popovitch, yet it still could be an important component. The boundary between bed load and suspended load is not distinct. Bed load is commonly defined at the material that move near the channel bottom by sliding, rolling, or bouncing (Guy and Norman, 1982). In common sampling practice, bed load is considered that material moving in a zone three inches from the bottom that does not pass through a 250 micron mesh. As flow increases (such as during a flood event) material that was sliding, etc., may become suspended, thus move from the bed load category into suspended

load. During large flows and flows in transition (increasing or decreasing), determination of bed load as defined above may be difficult.

The sediment load at Popovitch Creek is an extreme example of the potential for bed load movement in the Hosanna Creek basin. The drainage and stream channel has a steep gradient, an abundance of small gravels, and an apparent lack of finer grain material that would remain suspended in the range of flows that occur there. Observation of the white floor of the flume installed in 1987 dramatically illustrated the movement of these small gravels by sliding, rolling, and bouncing. At higher flows some of these particles may be moving in suspension and with our sampling technique will still be collected as bed load.

4. One should note the possible error involved in the estimates given here. Regression techniques are used to develop TSS estimates from which the suspended load is calculated. The standard errors of estimate (an estimator of the standard deviation for the regression model) for these equations are as high as +726, -14 percent. These error values appear to be the norm for regression models using discharge to estimate TSS or suspended load (Walling 1977). In practice the error for a single value may be large, but using the equations for a large number of estimates, the plus and minus errors should come close to cancelling each other out. At Hosanna Creek at Bridge 3 and at Sanderson Creek, the suspended loads during high flows are estimated from TSS values from

samples collected from the automated samplers. Because most of the suspended load at these sites occurred during these high flow events, the effect of the possible regression error should be reduced.

CONCLUSIONS AND FUTURE WORK

Rainfall during 1987 was near average but storm events appeared to be smaller than normal. Because of this breakup was mild and no large floods occurred at the sites we monitored during 1987.

The data collection methodology employed in 1987 worked, in general. At Hosanna Creek at Bridge 3 and at Sanderson Creek above mining, river stage was recorded through the summer and numerous grab samples during normal flows were collected. The automated water samplers operated during all of the peak flow events collecting samples through the rise and fall of the individual storm hydrographs. With these data we able to estimate suspended loads for the summer open water season. At our other sites we were not as successful, either because of problems in developing seasonal discharge or because the discharge-TSS relationship was not adequate. At Popovitch Creek our bed load sampling method worked well. At all sites we were able to calculate estimates of seasonal loads. Because of the relatively small peak flow events this summer, we do not know how well our methods will work during floods similar to those experienced in 1986. Data collection during these events will be important. Our results continue to show that the majority of the load carried by streams in the Hosanna Creek basin moves during these peak events.

In 1988 the methods used in 1987 will be continued. The mid-basin Hosanna Creek site will be located at the new bridge site on the upper basin road now under construction. This site is downstream of the Hosanna Creek above North Hosanna Creek site, but should provide better conditions for use of automated equipment. At North Hosanna Creek it will be important to find a site that is stable enough for development of a season long discharge record. Earlier site selection was limited because the upper basin road was supposed to traverse this creek. The road alignment has been moved so that this is no longer a problem. The upper basin road will also greatly facilitate access to this site.

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APPENDIX 1. Gold Run Pass Precipitation, Summer 1987
values in inches

Total= 12.24 inches
Max= 0.84 inches

Day	May	June	July	August	September	October
1				0.48	0.36	0.12
2				0.36		
3		0.12		0.24		
4		0.12				
5		0.36				
6					0.24	0.24
7					0.12	0.12
8		0.12				0.24
9					0.24	
10			0.12		0.12	0.12
11			0.12		0.48	
12		0.12	0.12			0.12
13			0.12		0.12	
14						
15					0.12	
16				0.12	0.24	
17				0.12	0.84	
18		0.12				
19				0.6		
20				0.72	0.12	
21				0.24	0.12	
22			0.12	0.12	0.24	
23		0.12		0.12	0.12	
24					0.12	
25			0.12		0.12	
26			0.36		0.12	
27			0.48			
28						
29					0.48	
30			0.12	0.12		
31	0.12		0.84			
Total	0.12	1.08	2.52	3.24	4.32	0.96

APPENDIX 2. Summary of daily average discharge values.

Hosanna at Bridge 3
Discharge in cubic feet per second

Max	449
Min	14.3
Avg	35.9

	May	June	July	August	September	October
1		237	21.1	58.3	23.3	24.5
2		84.7	21.4	41.6	20.6	25.3
3		92.6	23.1	36.5	20.2	24.0
4		175	23.2	34.1	33.3	21.8
5		96.4	23.5	29.7	31.0	19.6
6		72.4	24.1	26.9	25.0	27.0
7		61.1	24.6	25.9	29.8	21.4
8		50.8	23.3	25.5	55.4	22.2
9		42.9	24.1	24.7	39.0	21.4
10		37.6	25.6	24.0	36.8	23.6
11		37.5	22.3	23.5	38.0	22.5
12		45.0	23.8	23.3		19.5
13		46.2	24.1	24.7		19.9
14		39.3	46.5	30.8	32.2	
15		36.9	60.5	29.5	26.5	
16		34.9	27.5	36.4	29.6	
17		29.7	21.0	29.8	29.1	
18		27.7	19.8	42.1	28.4	
19		27.2	23.1	165.4	29.8	
20		27.4	28.9	92.3	31.2	
21	38.4	28.7	34.6	52.1	29.7	
22	30.5	27.6		39.6	37.6	
23	26.3	24.7		34.4	37.3	
24	25.9	23.2		30.1	35.8	
25	18.1	23.0		26.9	30.8	
26	21.4	22.1		23.6	28.5	
27	20.9	21.9		22.6	27.5	
28	20.0	20.7		21.7	25.8	
29	20.7	20.0		22.7	24.8	
30	20.5	20.8		30.2	24.0	
31	121		81.3	23.6		
Mon Avg	33.0	51.2	29.4	37.2	30.7	22.5

APPENDIX 2. Summary of daily discharge values

Sanderson Creek above mining
Discharge in cubic feet per second

Max	96.1
Min	0.26
Avg	6.98

	May	June	July	August	September	October
1			1.01	19.86	6.31	5.38
2			0.94	13.61	5.45	5.01
3			0.88	7.62	5.34	4.24
4			0.97	5.07	12.70	3.23
5			1.02	3.43	12.16	2.61
6			0.64	2.47	9.08	2.62
7			0.58	1.99	10.61	2.45
8			0.85	2.14	14.99	3.09
9			0.69	2.00	12.16	3.09
10			0.53	1.95	9.59	3.27
11			0.66	1.78	9.85	2.29
12			0.91	1.35	9.87	1.25
13			1.02	1.93	6.30	
14			10.24	7.27	6.22	
15			23.55	5.04	4.89	
16			3.77	12.55	4.41	
17			2.22	4.60	4.69	
18			1.28	13.22	5.56	
19		2.21	1.37	44.77	6.17	
20		1.59	2.34	31.75	5.63	
21		1.82	4.30	16.14	8.55	
22		1.56	2.01	11.52	10.90	
23		1.40	3.83	8.56	12.95	
24		1.07	31.43	6.69	11.72	
25		0.97	33.60	5.34	10.27	
26		0.98	7.54	4.35	9.75	
27		0.76	2.43	3.41	7.78	
28		0.96	1.47	3.12	5.70	
29		0.96	9.57	5.77	5.82	
30		0.91	47.49	15.34	6.24	
31			31.47	9.26		
Mon Avg		1.27	7.44	8.84	8.39	3.21

APPENDIX 2. Summary of daily discharge values

Frances Creek at Road
Discharge in cubic feet per second

Max	1.53
Min	0.08
Avg	0.13

	May	June	July	August	September	October
1			0.10	0.20	0.11	0.11
2			0.10	0.16	0.11	0.11
3			0.08	0.14	0.11	0.09
4			0.09	0.12	0.19	0.09
5			0.09	0.11	0.11	0.11
6			0.08	0.11	0.11	0.12
7			0.09	0.10	0.16	0.08
8			0.09	0.10	0.20	0.09
9			0.10	0.10	0.14	0.10
10			0.10	0.10	0.14	0.12
11			0.10	0.09	0.17	0.11
12			0.10	0.09	0.14	0.11
13			0.11	0.13	0.12	
14			0.13	0.17	0.13	
15			0.11	0.13	0.16	
16			0.09	0.15	0.14	
17			0.10	0.11	0.14	
18		0.13	0.08	0.27	0.12	
19		0.11	0.11	0.51	0.12	
20		0.10	0.15	0.25	0.14	
21		0.11	0.15	0.16	0.14	
22		0.08	0.13	0.15	0.12	
23		0.08	0.17	0.13	0.12	
24		0.08	0.17	0.12	0.11	
25		0.08	0.15	0.12	0.12	
26			0.13	0.12	0.12	
27			0.11	0.10	0.11	
28			0.12	0.10	0.09	
29			0.34	0.22	0.09	
30		0.11	0.57	0.16	0.10	
31			0.30	0.13		
Mon Avg		0.10	0.14	0.15	0.13	0.10

APPENDIX 3. TSS, turbidity and discharge data from sites in the Hosanna Creek basin.
'i' indicates sample collected by automated sampler

Location Date Time TSS (mg/l) Turbidity (NTU) Discharge (cfs)

APPENDIX 3. TSS, turbidity and discharge data from sites in the Hosanna Creek basin.
'i' indicates sample collected by automated sampler

Location	Date	Time	TSS (mg/l)	Turbidity (NTU)	Discharge (cfs)
Hosanna Bridge 1	060887	1715	1850	700	36.4
Hosanna Bridge 1	080387	1600	198	100	31.7
Hosanna Bridge 1	091487	1625	625	180	35.5
Hosanna Bridge 3	052187	1642			28.3
Hosanna Bridge 3i	053187	1715	19200	4700	346
Hosanna Bridge 3i	053187	1845	24400	7400	377
Hosanna Bridge 3i	053187	2015	40700	6700	342
Hosanna Bridge 3i	053187	2145	16900	5100	273
Hosanna Bridge 3i	053187	2315	12400	4500	193
Hosanna Bridge 3i	060187	45	9980	3300	158
Hosanna Bridge 3i	060187	215	8870	2500	173
Hosanna Bridge 3i	060187	345	6700	2300	227
Hosanna Bridge 3i	060187	515	6140	1800	338
Hosanna Bridge 3i	060187	645	5950	1600	285
Hosanna Bridge 3i	060187	815	5510	1600	369
Hosanna Bridge 3i	060187	945	7600	2200	449
Hosanna Bridge 3i	060187	1115	9830	2500	381
Hosanna Bridge 3i	060187	1245	12200	2800	302
Hosanna Bridge 3i	060187	1415	12900	2700	240
Hosanna Bridge 3i	060187	1545	14400	4400	199
Hosanna Bridge 3i	060187	1715	15200	5100	174
Hosanna Bridge 3i	060187	1845	14200	4200	150
Hosanna Bridge 3i	060187	2015	13900	3600	130
Hosanna Bridge 3i	060187	2145	9670	2400	115
Hosanna Bridge 3i	060187	2315	8330	2300	105
Hosanna Bridge 3i	060287	45	8560	2300	92
Hosanna Bridge 3i	060287	215	7040	1800	85
Hosanna Bridge 3i	060287	345	7080	2200	97
Hosanna Bridge 3	060887	1534	1770	2000	56.0
Hosanna Bridge 3	060887	1555	1970	600	41.8
Hosanna Bridge 3	060987	1731	1480	600	40.8
Hosanna Bridge 3	061887	1827	953	450	34.7
Hosanna Bridge 3	061987	1705	932	400	31.9
Hosanna Bridge 3	062687	0645	454	150	22.7
Hosanna Bridge 3	063087	1240	492	250	21.2
Hosanna Bridge 3	070187	1030	201	114	14.3
Hosanna Bridge 3	070187	1030	208	98	14.3
Hosanna Bridge 3	070387	1425	431	95	18.4

APPENDIX 3. TSS, turbidity and discharge data from sites in the Hosanna Creek basin.
'i' indicates sample collected by automated sampler

Location	Date	Time	TSS (mg/l)	Turbidity (NTU)	Discharge (cfs)
Hosanna Bridge 3	070687	1830	412	60	18.4
Hosanna Bridge 3	070987	0930	348	31	17.1
Hosanna Bridge 3	071287	1530	955	110	23.4
Hosanna Bridge 3	071487	1845	2140	400	30.0
Hosanna Bridge 3	071587	0820	8850	2200	75.2
Hosanna Bridge 3	071587	0845	7180	2800	75.2
Hosanna Bridge 3	071587	1125	4780	1700	56.0
Hosanna Bridge 3	071987	1150	622	130	25.0
Hosanna Bridge 3	072087	1810	646	236	26.6
Hosanna Bridge 3	072087	1810	657	270	26.6
Hosanna Bridge 3	072187	1630	637	290	29.2
Hosanna Bridge 3	072387	1315	714	120	27.5
Hosanna Bridge 3	072487	1045	13600	4500	82.1
Hosanna Bridge 3	072787	0945	492	130	30.0
Hosanna Bridge 3	073087	1100	19000	5400	180
Hosanna Bridge 3	073087	1330	14300	3600	180
Hosanna Bridge 3i	073087	1750	8680	2000	144
Hosanna Bridge 3i	073087	1850	6230	2800	
Hosanna Bridge 3i	073087	1950	9530	2200	
Hosanna Bridge 3i	073087	2050	6800	2300	
Hosanna Bridge 3i	073087	2150	6230	1600	
Hosanna Bridge 3i	073087	2250	5270	1400	
Hosanna Bridge 3i	073087	2350	4850	2700	
Hosanna Bridge 3i	073187	2450	6100	2300	
Hosanna Bridge 3i	073187	150	4510	1800	
Hosanna Bridge 3i	073187	250	4680	1700	
Hosanna Bridge 3i	073187	350	4850	1700	
Hosanna Bridge 3i	073187	450	4110	1400	
Hosanna Bridge 3i	073187	550	3850	1400	
Hosanna Bridge 3i	073187	650	2780	1000	
Hosanna Bridge 3i	073187	750	2490	1100	
Hosanna Bridge 3i	073187	850	2300	1100	
Hosanna Bridge 3i	073187	950	2090	700	
Hosanna Bridge 3i	073187	1050	2420	650	
Hosanna Bridge 3	073187	1510	1540	650	107
Hosanna Bridge 3i	073187	1515	1470	600	99.0
Hosanna Bridge 3i	073187	1815	1250	450	80.0
Hosanna Bridge 3i	073187	2115	166	500	75.0
Hosanna Bridge 3i	080187	2415	979	500	73.0
Hosanna Bridge 3i	080187	315	1350	550	65.0
Hosanna Bridge 3i	080187	615	863	370	63.0
Hosanna Bridge 3i	080187	915	678	340	62.0
Hosanna Bridge 3i	080187	1215	589	300	62.0
Hosanna Bridge 3i	080187	1515	529	260	54.0
Hosanna Bridge 3i	080187	1815	482	240	53.0

APPENDIX 3. TSS, turbidity and discharge data from sites in the Hosanna Creek basin.
'i' indicates sample collected by automated sampler

Location	Date	Time	TSS (mg/l)	Turbidity (NTU)	Discharge (cfs)
Hosanna Bridge 3i	080187	2115	446	230	46.0
Hosanna Bridge 3i	080287	2415	378	190	43.0
Hosanna Bridge 3i	080287	315	310	190	43.0
Hosanna Bridge 3i	080287	615	296	170	44.0
Hosanna Bridge 3i	080287	915	283	160	44.0
Hosanna Bridge 3i	080287	1215	235	150	46.0
Hosanna Bridge 3i	080287	1515	247	150	41.0
Hosanna Bridge 3i	080287	1815	243	120	39.0
Hosanna Bridge 3i	080287	2115	182	140	36.0
Hosanna Bridge 3i	080387	2415	192	120	36.0
Hosanna Bridge 3i	080387	315	175	140	36.0
Hosanna Bridge 3i	080387	615	179	110	36.0
Hosanna Bridge 3i	080387	915	279	140	37.0
Hosanna Bridge 3i	080387	1215	179	100	37.0
Hosanna Bridge 3	080387	1500	275	100	36.9
Hosanna Bridge 3	080487	1445			33.7
Hosanna Bridge 3	081087	1340	110	28	23.4
Hosanna Bridge 3	081387	1550	53	20	23.4
Hosanna Bridge 3	081887	1740	3040	870	44.0
Hosanna Bridge 3i	081887	2215	10200	2800	98.0
Hosanna Bridge 3	081887	2345	12400	3400	131
Hosanna Bridge 3i	081987	15	11200	3600	131
Hosanna Bridge 3i	081987	215	7480	2600	132
Hosanna Bridge 3i	081987	415	11100	3600	155
Hosanna Bridge 3i	081987	615	11800	3500	220
Hosanna Bridge 3i	081987	815	11700	3300	259
Hosanna Bridge 3	081987	0950	9710	2500	216
Hosanna Bridge 3i	081987	1015	9010	2900	210
Hosanna Bridge 3i	081987	1215	7230	1900	187
Hosanna Bridge 3i	081987	1415	7870	1500	176
Hosanna Bridge 3i	081987	1615	5580	1700	150
Hosanna Bridge 3	081987	1645	4810	900	146
Hosanna Bridge 3i	081987	1815	4390	1300	136
Hosanna Bridge 3i	081987	2015	3380	950	128
Hosanna Bridge 3i	081987	2215	2690	800	112
Hosanna Bridge 3i	082087	15	2810	900	113
Hosanna Bridge 3i	082087	215	2780	850	115
Hosanna Bridge 3i	082087	415	2660	950	110
Hosanna Bridge 3i	082087	615	2250	750	107
Hosanna Bridge 3i	082087	815	1880	650	100
Hosanna Bridge 3i	082087	1015	1570	600	97.0
Hosanna Bridge 3i	082087	1215	1450	550	94.0
Hosanna Bridge 3i	082087	1415	1410	500	92.0
Hosanna Bridge 3i	082087	1615	1160	450	83.0
Hosanna Bridge 3i	082087	1815	1010	500	78.0

APPENDIX 3. TSS, turbidity and discharge data from sites in the Hosanna Creek basin.
'i' indicates sample collected by automated sampler

Location	Date	Time	TSS (mg/l)	Turbidity (NTU)	Discharge (cfs)
Hosanna Bridge 3i	082087	2015	916	400	71.0
Hosanna Bridge 3	082487	1750	90.4	42	31.2
Hosanna Bridge 3	082587	1350	74.3	41	28.3
Hosanna Bridge 3	091487	1438	378	120	26.4
Hosanna Bridge 3	091587	1630	1680	450	48.6
Hosanna Bridge 3	101287	1732	550	220	28.3
Hosanna Bridge 3	101387	0945	41.7	27	16.1
Frances Creek	061887	1815	1590	550	0.15
Frances Creek	061987	1700	2270	950	0.11
Frances Creek	062687	0700	2910	350	0.09
Frances Creek	063087	1235	960	230	0.14
Frances Creek	070187	0950	622	200	0.11
Frances Creek	070387	1415	617	80	0.08
Frances Creek	070687	1845	1060	17	0.09
Frances Creek	070987	0940	239	11	0.09
Frances Creek	071287	1500	4350	900	0.11
Frances Creek	071487	1900	7350	1500	0.11
Frances Creek	071587	0850	3350	350	0.12
Frances Creek	071987	1200	2220	210	0.12
Frances Creek	072087	1715	7930	2500	0.26
Frances Creek	072187	1625	323	45	0.12
Frances Creek	072387	1325	1400	110	0.19
Frances Creek	072787	0955	102	16	0.11
Frances Creek	073087	0740	7910	1800	0.99
Frances Creek	073187	1355	1210	450	0.28
Frances Creek	080387	1740	106	27	0.12
Frances Creek	080487	1436	72.9	23	0.12
Frances Creek	081087	1350	21.2	4.7	0.09
Frances Creek	081387	1600	12.2	5.5	0.09
Frances Creek	081887	1730	5110	850	0.51
Frances Creek	081887	1930	8330	2400	0.99
Frances Creek i	081987	0300	7200	1700	1.22
Frances Creek i	081987	0430	12500	3000	1.53
Frances Creek	082487	1724	59.3	14	0.15
Frances Creek	082587	1340	23.3	12	0.14
Frances Creek	091487	1440	300	120	0.24
Frances Creek	091587	1625	198	90	0.24
Frances Creek	101287	1705	4.9	12	0.11
Frances Creek	101387	1050	4.6	5.3	0.11
Popovitch Creek	061887	1540	407	32	1.07
Popovitch Creek	061987	1608	522	13	0.98
Popovitch Creek	062687	0730	110	5.9	0.49
Popovitch Creek	063087	1150	4.8	2.0	0.36

APPENDIX 3. TSS, turbidity and discharge data from sites in the Hosanna Creek basin.
'i' indicates sample collected by automated sampler

Location	Date	Time	TSS (mg/l)	Turbidity (NTU)	Discharge (cfs)
Popovitch Creek	070387	1400	2.8	1.2	0.36
Popovitch Creek	070687	1930	5.3	1.0	0.36
Popovitch Creek	070887	0945	3.2	0.5	0.36
Popovitch Creek	071087	1610	429	12.5	0.64
Popovitch Creek	071487	1915	5.6	1.0	0.36
Popovitch Creek	071987	1230	28.3	2.9	0.42
Popovitch Creek	072087	1630	329	26	0.72
Popovitch Creek	072187	1540	8.0	2.7	0.42
Popovitch Creek	072387	1330	14.2	1.4	0.49
Popovitch Creek	072787	1010	5.8	1.6	0.36
Popovitch Creek	073087	0940	1300	220	0.80
Popovitch Creek	073187	1320	313	6.6	0.56
Popovitch Creek	080387	1720	23.2	2.1	0.42
Popovitch Creek	080487	1405	25	2.1	0.42
Popovitch Creek	081387	1625	19.9	2.9	0.36
Popovitch Creek	081887	1710	1330	270	0.89
Popovitch Creek	081987	1010	1190	140	0.98
Popovitch Creek	082587	1330	11.1	0.9	0.30
Popovitch Creek	091587	1355	119	19	0.80
Popovitch Creek	101287	1643	2.3	0.6	0.72
North Hosanna	060987	1600	7200	1200	5.08
North Hosanna	061987	1245	2840	450	2.93
North Hosanna	061987	1420	3450	600	4.05
North Hosanna	063087	1622	3030	200	1.79
North Hosanna	070887	1640	1920	130	1.50
North Hosanna	072187	1145	1200	120	2.51
North Hosanna	080487	1215	1460	70	2.31
North Hosanna	081087	1530	163	26	1.48
North Hosanna	081387	1725	581	12	1.23
North Hosanna	081887	1625	1450	260	4.05
North Hosanna i	081987	0245	17800	3200	16.6
North Hosanna i	081987	0415	16100	2800	19.9
North Hosanna i	081987	0545	13400	2700	21.1
North Hosanna i	081987	0715	9060	2000	20.5
North Hosanna i	081987	0845	9340	2100	19.9
North Hosanna i	081987	1015	7190	1400	17.1
North Hosanna i	081987	1145	4910	1200	15.0
North Hosanna	082187	1200	1010	160	3.43
North Hosanna	082587	1105	1400	50	2.32
North Hosanna	091587	1155	136	17	2.23
North Hosanna	101287	1556	473	65	
Hosanna ab NH	060987	1546	656	270	15.0
Hosanna ab NH	061987	1240	765	95	9.57

APPENDIX 3. TSS, turbidity and discharge data from sites in the Hosanna Creek basin.
'i' indicates sample collected by automated sampler

Location	Date	Time	TSS (mg/l)	Turbidity (NTU)	Discharge (cfs)
Hosanna ab NH	063087	1550	390	32	6.61
Hosanna ab NH	070887	1700	537	50	6.26
Hosanna ab NH	072187	1125	928	320	17.0
Hosanna ab NH	080487	1150	214	85	16.2
Hosanna ab NH	082587	1035	249	240	17.7
Hosanna ab NH	091587	1122	141	70	12.6
Hosanna ab NH	101287	1550	1390	280	
Sanderson ab mining	060987	1155	9.28	11	3.02
Sanderson ab mining	061987	1045	12.1	20	1.52
Sanderson ab mining	063087	1800	9.4	30	1.45
Sanderson ab miningi	071487	2150	33900	12000	35.4
Sanderson ab miningi	071487	2320	59300	13000	30.5
Sanderson ab miningi	071587	0050	15900	4000	60.0
Sanderson ab miningi	071587	0350	3010	1800	49.0
Sanderson ab mining	071587	1225	692	170	16.4
Sanderson ab mining	072187	1005	60.4	23	5.23
Sanderson ab miningi	072487	0450	4200	1000	31.4
Sanderson ab miningi	072487	0620	7970	2400	44.0
Sanderson ab miningi	072487	0750	8260	4100	39.0
Sanderson ab miningi	072487	0920	5400	1200	48.0
Sanderson ab miningi	072487	1050	4150	1300	46.4
Sanderson ab miningi	072487	1220	4100	850	38.0
Sanderson ab miningi	072487	1350	1760	850	38.5
Sanderson ab miningi	072487	1520	1760	600	40.0
Sanderson ab miningi	072487	1650	1400	400	38.5
Sanderson ab miningi	072487	1820	972	360	23.5
Sanderson ab miningi	072487	1950	857	400	28.0
Sanderson ab miningi	072487	2120	783	360	27.7
Sanderson ab miningi	072487	2250	931	260	28.0
Sanderson ab miningi	072587	0020	3120	850	38.0
Sanderson ab miningi	072587	0150	2260	650	29.0
Sanderson ab miningi	072587	0320	1870	550	48.8
Sanderson ab miningi	072587	0450	1810	550	51.3
Sanderson ab miningi	072587	0620	1820	550	56.6
Sanderson ab miningi	072587	0750	1290	500	50.0
Sanderson ab miningi	072587	0920	1260	400	39.6
Sanderson ab miningi	072587	1050	877	300	44.7
Sanderson ab miningi	072587	1220	725	230	37.4
Sanderson ab miningi	072587	1350	548	210	30.5
Sanderson ab miningi	072587	1520	525	210	23.5
Sanderson ab mining	080487	1015	12.2	14	5.35
Sanderson ab miningi	081887	1920	1560	450	38.5
Sanderson ab miningi	081887	2050	5790	1700	53.9
Sanderson ab miningi	081887	2220	5520	1000	47.0

APPENDIX 3. TSS, turbidity and discharge data from sites in the Hosanna Creek basin.
'i' indicates sample collected by automated sampler

Location	Date	Time	TSS (mg/l)	Turbidity (NTU)	Discharge (cfs)
Sanderson ab miningi	081887	2350	3580	650	42.8
Sanderson ab miningi	081987	0120	1600	390	41.8
Sanderson ab miningi	081987	0250	1770	340	41.8
Sanderson ab miningi	081987	0420	4710	400	41.8
Sanderson ab miningi	081987	0550	4710	950	60.7
Sanderson ab miningi	081987	0720	2380	650	59.3
Sanderson ab miningi	081987	0850	5630	750	52.6
Sanderson ab miningi	081987	1020	1960	550	47.6
Sanderson ab miningi	081987	1150	3390	370	47.6
Sanderson ab miningi	081987	1320	2570	400	47.6
Sanderson ab miningi	081987	1450	2720	320	56.4
Sanderson ab miningi	081987	1620	1770	280	38.5
Sanderson ab miningi	081987	1750	1540	170	39.6
Sanderson ab miningi	081987	1920	760	180	38.0
Sanderson ab miningi	081987	2050	613	130	41.0
Sanderson ab miningi	081987	2220	835	250	41.9
Sanderson ab miningi	081987	2350	1200	200	40.7
Sanderson ab miningi	082087	0120	1600	220	38.5
Sanderson ab miningi	082087	0250	648	170	41.0
Sanderson ab miningi	082087	0420	456	140	35.4
Sanderson ab miningi	082087	0550	467	140	39.6
Sanderson ab mining	082187	1750	16.1	8.6	12.7
Sanderson ab mining	082587	0945	10.4	16	5.31
Sanderson ab mining	082987	2220	2720	400	36.4
Sanderson ab mining	091587	1000	10.7	23	3.66
Sanderson ab mining	101287	1435	64.1	85	3.51
Sanderson b mining	072187	1235	1050	330	5.53
Sanderson b mining	082587	1135	162	110	6.15
Hosanna ab Sandersn	072187	1245	1030	240	12.4
Hosanna ab Sandersn	082587	1145	793	24	9.42
Hosanna b Sanderson	072187	1247	1030	160	

APPENDIX 4. Results of bed load sampling at Popovitch Creek

Date	Sample weight (g)	Time (min)	Bedload tons/day	Suspended load tons/day	Total load tons/day	%Bedload
7-08-87	49.4	5	0.016	0.003	0.019	84
7-20-87	489	2	0.39	0.64	1.03	38
7-20-87	570	2	0.46	0.64	1.10	42
7-21-87	272	10	0.043	0.009	0.053	83
7-30-87	2040	1	3.27	2.81	6.08	54
7-31-87	1890	4	0.75	0.47	1.23	61
8-03-87	123	5	0.039	0.026	0.066	60
8-04-87	70.8	10	0.011	0.028	0.040	29
8-19-87	7240	1	11.6	3.15	14.7	79
9-15-87	3930	2	3.15	0.26	3.40	92

APPENDIX 5. Water chemistry at Hosanna Creek sites, 1987. All values in mg/l unless otherwise noted

Stream Reach	Date	Time	Tw °C	TSS mg/l	SS ml/l	TURB NTU	TDS mg/l	COND	DISCHARGE	pH	ALK mg/l as CaCO3	ACIDITY mg/l as CaCO3	COLOR PCU
Hosanna at B1	6-8-87	1708	13.3	1850	1.4	700	285	456	36.4	6.70	103	3.5	20
Hosanna at B3	6-8-87	1510	13.1	1970	2.0	600	245	441	41.8	6.68	94	6.1	15
Hosanna at B1	8-3-87	1630	16.5	198	0.1	100	338	583	31.7	6.79	120	4.6	25
Hosanna at B3	8-3-87	1515	15.6	275	tr	95	314	554	36.9	6.85	116	5.7	40
Hosanna at B1	9-14-87	1540	4.1	625	0.5	180	364	631	35.5	7.56	140	7.9	30
Hosanna at B3	9-14-87	1400	2.0	378	tr	120	341	582	26.4	7.36	133	8.1	25

Stream Reach	Date	DO mg/l	DO % sat	NO3	CL	SO4	F	Na	K	Mg	Ca	Ba	As D
Hosanna at B1	6-8-87	10.5	100	21.6	14.1	47.2	0.157	14.6	3.99	17.8	25.3	0.098	0.0013
Hosanna at B3	6-8-87	10.7	100	0.233	12.2	53.0	0.094	14.6	3.80	18.2	25.6	0.089	0.0011
Hosanna at B1	8-3-87	9.5	100	0.257	20.6	67.2	0.196	15.1	5.08	22.1	33.9	0.117	0.0008
Hosanna at B3	8-3-87	10.0	100	0.089	15.3	71.4	0.171	14.7	4.68	22.3	31.6	0.096	0.0007
Hosanna at B1	9-14-87	14.4	100	0.195	19.1	69.5	0.202	14.7	5.14	25.5	36.0	0.116	0.0012
Hosanna at B3	9-14-87	15.4	100	0.053	14.9	72.8	0.159	14.7	4.70	26.5	34.7	0.094	0.0005

Stream Reach	Date	Al D	B D	Cd D	Cr D	Co D	Cu D	Fe D	Mn D	Mo D	Pb D	Se D	Si D	Zn D
Hosanna at B1	6-8-87	0.057	0.137	<0.01	<0.002	<0.01	0.003	0.085	0.198	0.021	<0.03	<0.02	1.919	<0.02
Hosanna at B3	6-8-87	0.055	0.134	<0.01	<0.002	<0.01	0.002	0.077	0.226	0.018	<0.03	<0.02	1.912	<0.02
Hosanna at B1	8-3-87	0.057	0.186	<0.01	<0.002	<0.01	0.004	<0.03	0.241	0.022	<0.03	<0.02	2.313	<0.02
Hosanna at B3	8-3-87	0.066	0.174	<0.01	<0.002	<0.01	0.006	0.065	0.258	0.018	<0.03	<0.02	2.294	0.025
Hosanna at B1	9-14-87	0.05	0.189	<0.01	<0.002	<0.01	<0.005	<0.03	0.323	0.023	<0.03	<0.02	2.239	<0.02
Hosanna at B3	9-14-87	0.055	0.189	<0.01	<0.002	<0.01	0.003	<0.03	0.326	0.023	<0.03	<0.02	1.716	0.034