University of Nevada

Reno

A Study of Bedload and Total Sediment from the East-Central Sierra Nevada

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science
in Hydrology

by

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ABSTRACT

Suspended sediment and bedload were measured for fifteen small watersheds on the east side of the Sierra Nevada, during the 1978 snowmelt period. Bedload was measured using a modified flume, and the addition of bedload and suspended sediment was considered to be the total sediment. Empirical equations were developed to predict suspended sediment, bedload, and total sediment, in units of both yield and production rate. Mean channel slope, channel area, maximum discharge/minimum discharge ratio, and width/depth ratio were found to be statistically significant in the predictive equations.

Another predictive equation was developed to explain the suspended sediment/total sediment ratio. Geology and energy of the flowing water were the main variables used. The Meyer, Peter & Muller (1948) and the Einstein (1950) bedload formulas were found to overestimate the observed values by up to three orders of magnitude.

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INTRODUCTION

Sediment transport and sediment yield have been studied for over 100 years. Sediment is made up of two fractions: fine material in suspension and larger material traveling along the streambed. This defines suspended sediment and bedload, respectively. Total sediment is expressed as the sum of these two fractions.

Predicting sediment yield has been approached from two directions. The classical approach is to use sediment transport principles to predict sediment yield. Over time, the formulas have evolved around different principles. The central theme changed from shear stress relationships (du Boys, 1879) to discharge relationships (Schoklitsch, 1914, 1934, 1943; Gilbert, 1914; and Meyer-Peter, 1934) to lift force relationships (Kalinske, 1947; Meyer, Peter & Muller, 1948; Einstein, 1942, 1950; and Colby, 1954).

The other method of study has been to try to define the source of sediment and erosion processes. Empirical regression equations are used where the variables attempt to define meterologic, geologic, geomorphic, vegetative, and land use characteristics. The study of these variables is recent (Anderson, 1954, 1957, 1970; Wischmeir, et. al., 1958; Schumm & Haley, 1961; Jansen & Painter, 1974; Brown & Skau, 1975; and Robinson, 1976). These equations are usually limited to regions similar to where they were developed. However, the watershed characteristics that they represent can be used as criteria for selecting future predictive equations.

Many of these equations are designed to predict the total sediment yield. Often times, bedload is not actually measured but is estimated by use of predictive equations. Predicted bedload usually accounts for 3 to 78 percent of the total sediment (Hindell, 1975; Robinson, 1976; Ward, 1976; Gerson, 1977; and Fisher, 1978).

Actual measurements of bedload in mountainous streams is difficult and has rarely been achieved (Milhous, 1973). Usually suspended sediment is measured and bedload is estimated.

It was not until 1943 that a depth-integrating suspended sediment sampler was perfected (Graf, 1971). Bedload samplers have evolved in many forms. The drop-bucket or scoop-bucket takes instantaneous samples over a small area of the stream or river. Catch basins usually allow for a full capture of the bedload, however, it does not allow for short period sampling; i.e., hourly or even daily. A basket type collector has been found to be useful on smooth bottomed streams. However, its accuracy on gravel-bottomed streams has not been verified. On small streams, a flume may be used to carry the entire capacity of the stream over a slot to drop the bedload into a capture device.

This study concentrates on mountainous streams of the east-central Sierra Nevada. Initial studies (Morris, Skau, and Vitale, 1969; Brown, 1972; Howe, 1972; Brown, Howe, and Skau, 1973; Brown, Skau and Read, 1974; Brown, Lohrey, and Skau, 1977; and Lohrey, 1977) concentrated on relating watershed characteristics to dissolved nutrients and suspended sediments. Sampling of the total sediment load was studied by Fisher (1978).

Objectives

There are two main objectives:

1.) to develop empirical regression equations that explain the variance found in sediment yield, the sediment production rate, and the suspended sediment/ total sediment ratio and

2.) to explore the applicability of established bedload formula in mountainous streams of the study area.

The empirical equations that were used attempt to explain the dependent variables, sediment yield or sediment production rate, by giving a numerical rating on known variables that represent chosen meterologic, geomorphic, and vegetative principles. The different principles may be explained by several variables; i.e., a high peak discharge, a variable representing stream energy, may be explained by drainage density or bifurcation ratio (Branson, Gifford & Owen, 1972). Either drainage density or bifurcation ratio may be used to modify peak discharge. However, using both drainage density and bifurcation ratio would be redundant. One year drainage density may combine with peak discharge in such a way that the variance of the dependent variable is explained better than the combination of bifurcation ratio and peak discharge. The next year it may be reversed. Therefore, the criteria used in selecting the independent variables is as important as the variables themselves.

To achieve the objectives, suspended sediment and bedload were monitored and documented within the study area. Sediment yield is defined as the "total amount of eroded material which does complete the journey from source to a downstream control point." (Chow,1964). The dimensions for sediment yield are mass per unit time. Sediment production rate is defined as sediment yield per unit of drainage area (Chow, 1964). Sediment production rate has dimensions of mass per unit time per unit length squared. The production rate allows for comparisons between watersheds of differing size.

Several authors have used established bedload formula in mountainous streams. The second objective of this study is to explore the applicability of two of the more commonly used bedload formula: Meyer-Peter & Muller (1948) and Einstein (1950). The United States Geological Survey has used the Meyer-Peter & Muller formula for predicting bedload yield for several years. Einstein's formula is the classical equation using the tractive force concept to predict bedload yield.

STUDY AREA

The Sierra Nevadas are a young mountain system located on the eastern side of California. The system, running in a north-south trend, has a history of granitic uplift, followed by extensive volcanic activity. This study covers an area approximately 170 kilometers (100 miles) long and 40 kilometers (25 miles) wide, crossing the California-Nevada border, bounded on the north by Reno, Nevada and on the south near Bridgeport, California. (See Figure 1.). Three rivers, the Truckee, the Carson, and the Walker Rivers, drain the area. These basins headwater in the steeply sloping eastern front of the Sierra Nevada. The research watersheds range in elevation from 1700 meters (5600 feet) to 3780 meters (12,400 feet).

Vegetation of these watersheds includes pinyon pine *(Pinus monophylla)* and western juniper *(Juniperus occidentalis)* at lower elevations. Jeffrey pine *(Pinus jeffrey)*, Ponderosa pine *(Pinus ponderosa)*, lodgepole pine *(Pinus contorta)*, and white fir *(Abies concolor)* are

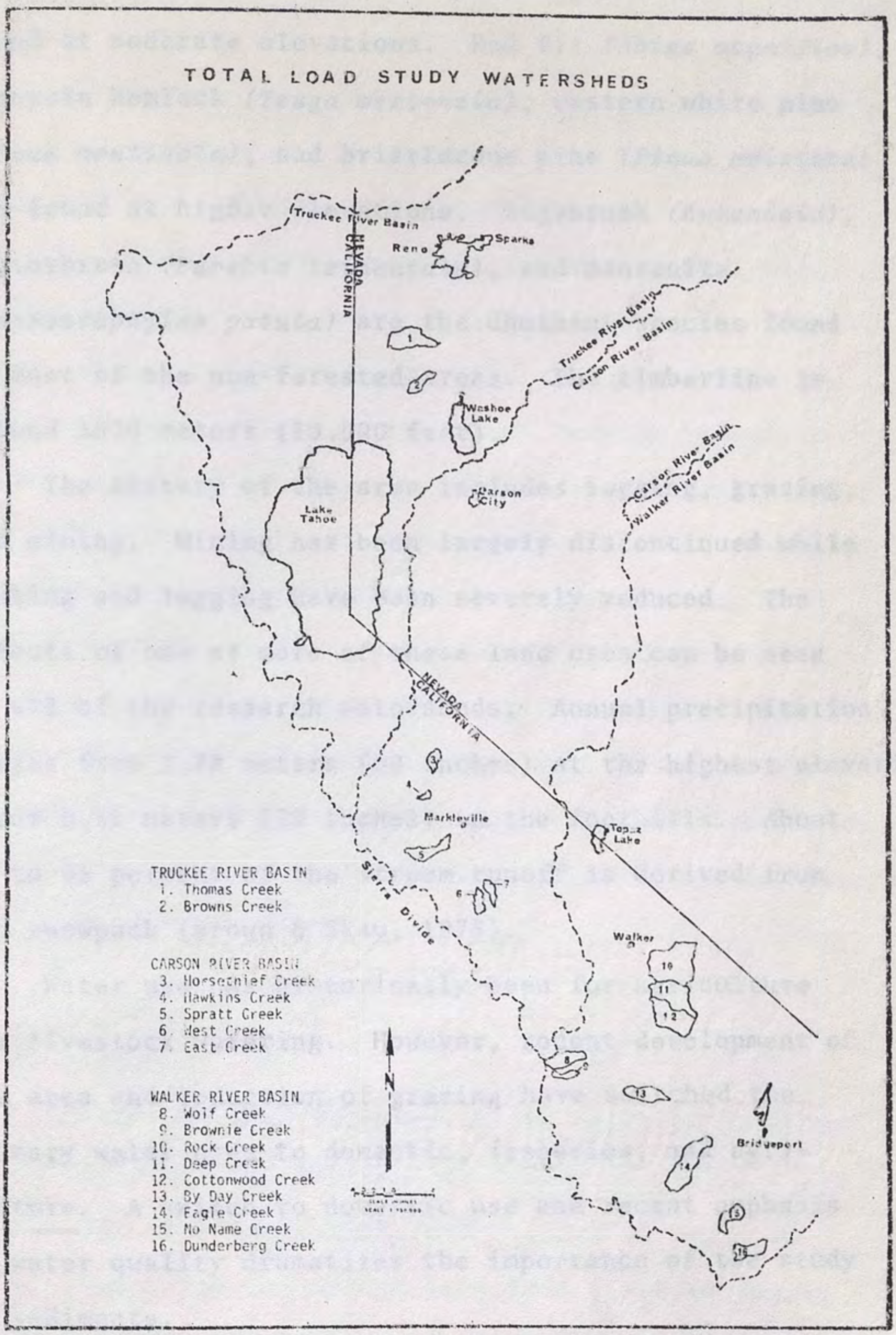
TOTAL LOAD STUDY WATERSHEDS
Truckee River Basin
Reno
Sparks
NEVADA
CALIFORNIA
Truckee River Basin
Carson River Basin
Washoe Lake
Carson River Basin
Walker River Basin
Carson City
Lake Tahoe
NEVADA
CALIFORNIA
Markleville
Topaz Lake
Sierra Divide
Walker
Bridgeport
N
TRUCKEE RIVER BASIN
1. Thomas Creek
2. Browns Creek
CARSON RIVER BASIN
3. Horsethief Creek
4. Hawkins Creek
5. Spratt Creek
6. West Creek
7. East Creek
WALKER RIVER BASIN
8. Wolf Creek
9. Brownie Creek
10. Rock Creek
11. Deep Creek
12. Cottonwood Creek
13. By Day Creek
14. Eagle Creek
15. No Name Creek
16. Dunderberg Creek

Figure 1.

found at moderate elevations. Red fir *(Abies magnifica)*, mountain hemlock *(Tsuga mertensia)*, western white pine *(Pinus monticola)*, and bristlecone pine *(Pinus aristata)* are found at higher elevations. Sagebrush *(Artemisia)*, bitterbrush *(Purshia tridentata)*, and manzanita *(Arctostaphylos patula)* are the dominant species found in most of the non-forested areas. The timberline is around 3050 meters (10,000 feet).

The history of the area includes logging, grazing, and mining. Mining has been largely discontinued while grazing and logging have been severely reduced. The effects of one or more of these land uses can be seen in all of the research watersheds. Annual precipitation varies from 1.78 meters (60 inches) at the highest elevations about 0.51 meters (20 inches) in the foothills. About 75 to 95 percent of the stream runoff is derived from the snowpack (Brown & Skau, 1975).

Water use has historically been for agriculture and livestock watering. However, recent development of the area and reduction of grazing have switched the primary water uses to domestic, fisheries, and agriculture. A switch to domestic use and recent emphasis on water quality dramatizes the importance of the study of sediments.

Information gained in this study can be used to estimate total sediment yield of the east-central portion of the Sierra Nevada. Recent growth of the area has sent urban sprawl to the foothills of the mountains. The headwater areas are being affected by more intense foot and recreational vehicle traffic.

Sediment has been measured in all water supplies, both undisturbed and man-controlled. In excess quantities, sediment impairs recreation, increases cost for water control projects, and can be harmful to aquatic life. Sediment decreases both the capacity and the useful life of a reservoir. Therefore, sediment is considered as a pollutant (National Water Commission, 1973). Man's activity usually increases the sediment load in streams. However, before this can be verified, the stream load for undisturbed areas must be measured and documented. A thorough knowledge of how and from where sediment is derived may influence planners and developers to avoid problem areas.

METHODOLOGY

Site Selection

Watersheds were selected on the basis of perennial flow, diversity and representativeness of geologic and geomorphic characteristics, and absence of upstream diversions. The watersheds have from first to fourth order streams, and areas range from 1.61 km.^{2} (0.62 mi.^{2}) to 39.86 km.^{2} (15.43 mi.^{2}). Sampling points were located at the outlet of each watershed.

The total sediment study started in the spring of 1977, using six watersheds. An unusually dry winter and spring caused the study to be extended through the spring snowmelt of 1978. The data base was also extended to include sixteen watersheds. One sampling site was abandoned when high flows destroyed the gaging site. It is on the 1978 snowmelt data that most of the analysis was based.

Data Collection

Snowmelt data collection for 1978 was started in early April, on a weekly basis, and was continued through August. The sampling period ranged from 77 to 121 days, depending upon how long it took for the snow to melt off each watershed in question. Daily samples are composed of three to five separate instantaneous samples spaced throughout the day. This procedure concentrates on measuring near the daily peak discharge. During the summer months, bi-weekly sampling replaced weekly sampling. This period was far into the recession limb of the annual hydrograph where very little loss of accuracy is thought to occur due to length of time between samples.

Sediment Load

Total sediment data was collected using a flume-type structure, developed and described by John Fisher (Fisher, 1978). The flume installation on Thomas Creek is shown in Figure 2. The structure smoothly funnels the entire flow of the stream over a slot where the bedload is piped to an accessible outlet where the bedload is captured using an 0.08 mm mesh sleeve and transferred to storage containers. Loss of bedload in the transfer process is assumed to be less than 5 percent by weight, based upon field observations. Sampling times varied from 5 seconds to 120 seconds, depending upon flow conditions and the amount of sediment. The most common sample length was 30 seconds.

Suspended sediment samples were taken using a U.S. DH-48 depth integrating sampler. Depth integrating samplers obtain the average concentration of the suspended sediment throughout the sampling cross-section. Concentration is expressed in dimensions of mass per unit volume. All samples, both bedload and suspended sediment concentration, were triplicated to insure a representative data base. "Flume" suspended sediment concentrations were taken at the downstream end of the flume after the bedload had dropped out. The sum of "flume" suspended sediment yield and bedload yield is considered to equal the total sediment yield.

It was found that under high flows some of the bedload was caught up in the turbulence over the slot and was not captured. Later modifications of the Fisher flume solved this problem by building a trough

Figure 2. A view of the Thomas Creek flume. Streamflow and vegetation of the stream are typical of the study area.

through which the bedload can travel and by increasing the width of the slot to two inches. The flume is designed to handle flows of up to 2.26 m^3/sec. (80 ft^3/sec.).

Values for total sediment and "flume" suspended sediments were compared to a suspended sediment sample taken just upstream of the flume. Suspended sediment concentration taken at this upstream site is defined as the "natural" suspended sediment. The purpose of this sample is twofold. First, the "flume" suspended sediment sample was dominated by more turbulence than in normal stream cross-section. Thus, in order to get more representative data for comparing suspended sediment concentrations documented by other authors, a natural cross-section had to be used. Secondly, an estimate of the percent of the total sediment measured by suspended sediment alone can be obtained. This information can be combined with measured suspended sediment data now available for the east-central Sierra Nevada to arrive at a more accurate idea of the total sediment yield.

The sampling site of the "natural" suspended sediment was also used as the cross-section for discharge readings. These measurements were taken after the "flume" suspended sediment and bedload measurements were taken. A Price or pygmy current meter, depending upon flow conditions, was used to estimate the discharge.

Each watershed was field surveyed to inventory and rate the perennial and ephemeral channels that flowed during the 1978 snowmelt period. A modified version of the classification developed by Lohrey (1977) was used. The inventory for each site included geology, slope, estimated snowmelt flow, stream channel and upper bank sediment composition, stability of the stream channel, vegetation, and mass wasting of the area. The survey also noted sediment traps, i.e., lakes and diffuse meadows, as well as sediment and water source areas. (See appendix A).

Laboratory Analysis

Suspended sediment concentrations for both the "flume" and the "natural" samples were obtained using the standardized procedure explained by Lohrey (1977). Suspended sediment yield values were obtained by multiplying concentration times its associated discharge to derive values in units of Kg/day (lb/day). Daily sediment hydrographs of yield values were planimetered to obtain daily values which were then used as points on a snowmelt sediment hydrograph. The snowmelt sediment hydrograph was planimetered to obtain the total yield of sediment. Representative sediment hydrographs for both daily and snowmelt periods can be seen in Figures 2 and 3. Associate values for "flume" and "natural" suspended sediment, bedload, and total sediment are labeled.

An assumption was made that the snowmelt sediment

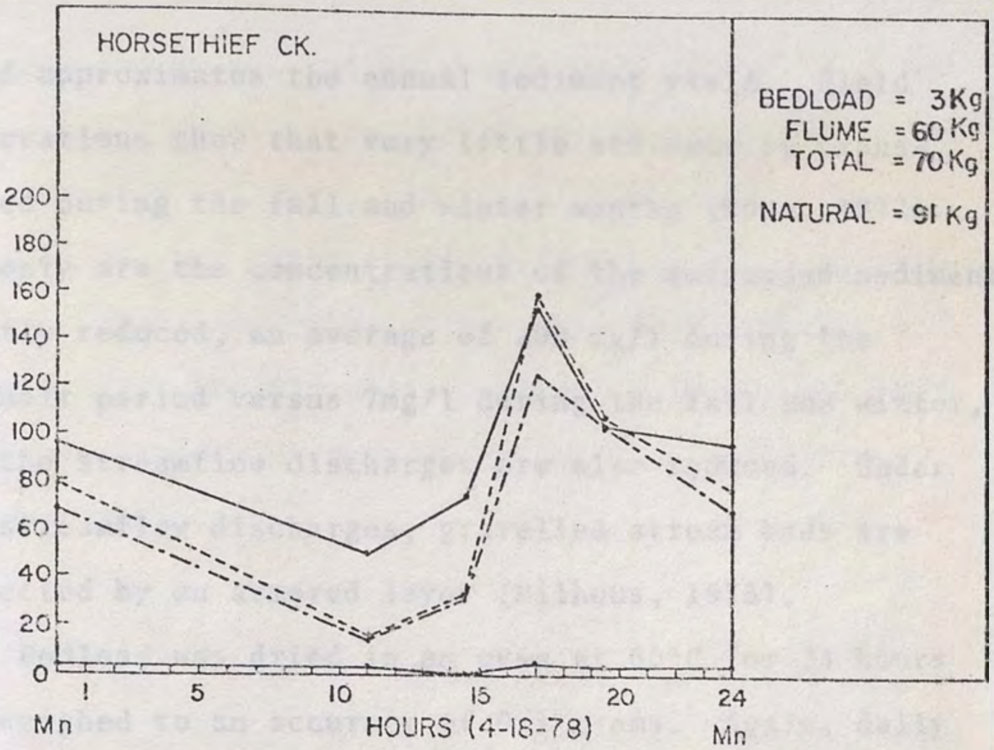

Figure 3.

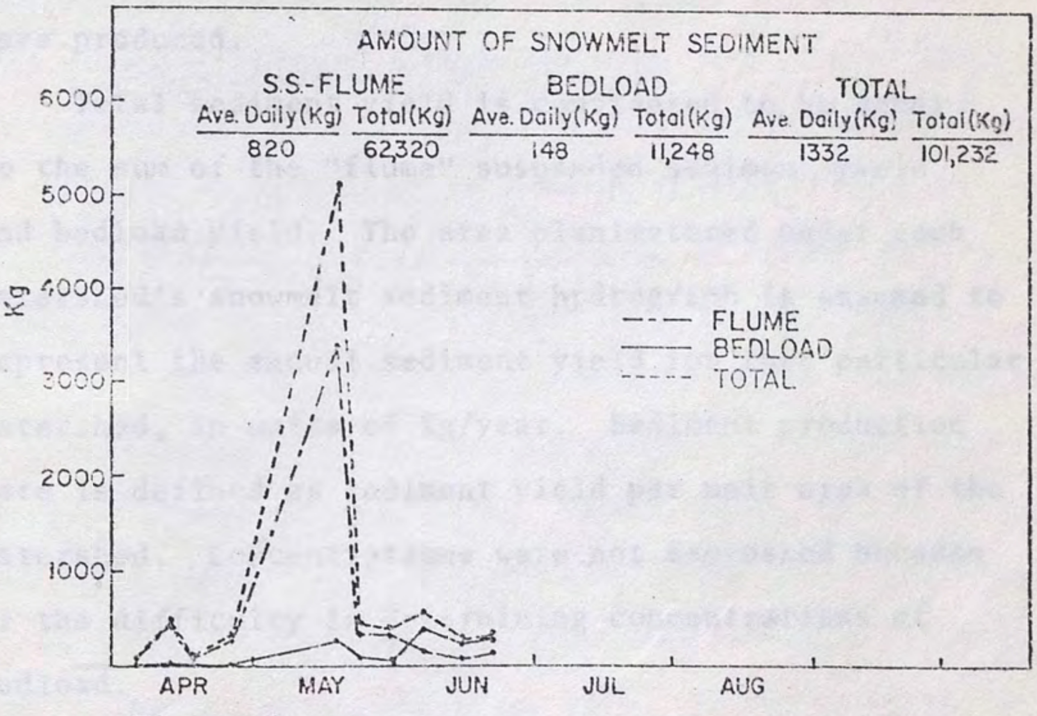

Figure 4.

yield approximates the annual sediment yield. Field observations show that very little sediment is transported during the fall and winter months (Howe, 1972). Not only are the concentrations of the suspended sediment greatly reduced, an average of 200 mg/l during the snowmelt period versus 7mg/l during the fall and winter, but the streamflow discharges are also reduced. Under low streamflow discharges, gravelled stream beds are protected by an armored layer (Milhous, 1973).

Bedload was dried in an oven at 60°C for 24 hours and weighed to an accuracy of 0.1 grams. Again, daily sediment hydrographs and snowmelt sediment hydrographs were produced.

Total sediment yield is considered to be equal to the sum of the "flume" suspended sediment yield and bedload yield. The area planimetered under each watershed's snowmelt sediment hydrograph is assumed to represent the annual sediment yield for that particular watershed, in units of Kg/year. Sediment production rate is defined as sediment yield per unit area of the watershed. Concentrations were not expressed because of the difficulty in determining concentrations of bedload.

After drying and weighing, the bedload was sieved using standard techniques (AASHO, 1970) in a RO-TAP sieve shaker. Log - log graphs of grain size diameter vs. cummulative percent by weight were developed. Two grain size diameters were obtained: grain size where 65 percent by weight is finer and where 50 percent is finer by weight. This is defined as D_{65} and D_{50}, respectively. These two sizes, along with depth, width, and slope of the channel section were used to predict bedload using the Meyer-Peter & Muller and Einstein's bedload equations.

Data Analysis

Sediment yield is controlled by the interaction and inter-dependence of many variables. Many variables can be expected to have high dependence on each other; for example, channel length and watershed area. Other variables show more independent characteristics, although separately each will often have an influence in predicting sediment yield. Frequently, it takes the combination of several of these variables to form a more realistic prediction of sediment yield. The use of a reverse step-wise regression analysis has been used in earlier studies (Howe, 1972; Brown, 1972; Brown, Howe, and Skau, 1973). Its use has been found to be applicable to watershed processes involving water quality (Anderson, 1954; Brown, Howe, and Skau, 1973; Hindall, 1976; and Robinson, 1976).

The reverse step-wise regression was used in this analysis to develop predictive equations for sediment yield and sediment production rates of suspended sediments, bedload, and total sediment. A seventh predictive equation was derived to predict the suspended sediment/total sediment ratio.

Independent Variables

The thirteen independent variables used in this analysis are listed in Table 1. The criteria for selection of the variables is often times as important as the variables themselves. It was found that variables describing the energy of the flowing water, stability of the stream channel, and source of the sediment explains the variation that occurs in sediment yield. Two other criteria for selection of variables were also considered. They are annual precipitation and land use. An assumption was made that the annual precipitation varied very little in the study area during the study period. No major land use activities were present in any of the study watersheds. One or more of the criteria considered for selecting variables, energy of the flowing water, stability of the stream channel, source of the sediment, annual precipitation, and land use has been found to be useful in other areas for predicting sediment yield (Anderson, 1954, 1970; Robinson, 1976; . and Gerson, 1977). These variables are easily measured by an on-site investigation with the aid of a topographic map. The methodology for measuring

Table 1. Independent Variables Used

Variables	Mean	Minimum	Maximum
1. Channel Area (Km^2)	53.99	12.02	116.20
2. Mean Channel Slope (%)	12.0	7.2	20.0
3. Peak Width/Depth Ratio	12.9	2.8	26.6
4. Max/Min Discharge Ratio	27	4	116
5. Streamflow (mm)	193.9	7.6	543.8
6. Peak Discharge (m^3/sec)	0.54	0.07	1.64
7. Peak Depth of Flow (m)	0.66	0.39	1.06
8. Drainage Density (mi/mi^2)	2.29	1.18	4.87
9. Mean Bifurcation Ratio	4.3	1.0	5.5
10. % of Basin Bare of Vegetation	8	1	45
11. % Hard Geology	60	1	100
12. Mean Grain Size, by weight (mm)	1.74	0.38	4.90
13. Elevation of Sampling Point (m)	2066	1725	2806

each variable along with the values obtained in the study area can be found in Appendix B.

Several of the variables are based upon an on-site stream inventory. Even variables as elementary as drainage density were found to be different when the values obtained using a standard U.S. Geological Survey topographic map were compared to values obtained from an on-site survey. The simple correlation found when comparing the drainage densities obtained when using the two methods was 0.11. A stream survey measures the stream reaches that showed evidence of streamflow.

An attempt was made to use the Forest Service Stream Reach Inventory (Pfankuch, 1975). It was found not to be statistically significant when correlated with any of the dependent variables. Based on use of the Forest Service inventory, it appears that the streams in this study area are too small to be adequately represented by the inventory.

Several geologic and soil variables were tried although none were found to be statistically significant. One reason for this may be that geologic and soil maps for the study area are usually broad in their coverage. They often do not give the detail necessary to separate geologically similar but erosively dissimilar rock and soil type. For example, on a geologic map there is usually no distinction made between andesite and

and hydrothermally altered andasite or rhyolite, rhyolitic pyroclastics, and indurated rhyolite. Interbedding of the material and closeness of contacts make such detailed mapping difficult. However, their erosive properties are greatly different.

A list of variables found to show statistical significance when correlated with the dependent variables can be found in Appendix C.

RESULTS AND DISCUSSION

Predictive equations showing strong statistical significance have been developed for sediment yield and sediment production rate by using variables that explain energy of the flowing water, stream channel stability, and source of the sediment. The general form of the equation is as follows:

$$\text{Ln } Y = \sum_{i=1}^{n} a + b_i x_i$$

where:

Y = dependent variable

a = constant

b = regression coefficient

x = independent variable

n = number of independent variables used.

Several dependent variables were used. They are suspended sediment yield and production rate, bedload yield and production rate, total sediment yield and production rates, and suspended sediment/total sediment ratio. Total sediment is considered to equal the sum of "flume" suspended sediment and bedload. Values of yield and production rates for "natural" suspended sediment represent suspended sediment as a dependent variable. Statistical information for the predictive equations based on the seven dependent variables are listed in Tables 2 through 5.

The multiple correlation coefficient, R^2, represents the fraction of the variation in the dependent variable explained by the equation. Large simple correlation coefficients are used to detect important independent variables. The 't' values provide a guideline as to the relative importance of the independent variable. The standard error of the estimate is abbreviated "SEE". If the regression equation is explaining a large part of the variation, the standard error of the equation will be less than the standard deviation of the dependent variable (Haan, 1977).

There are four variables found to be important in predicting both sediment yield and sediment production rate. These variables are maximum discharge/minimum discharge ratio; mean channel slope, peak width/depth ratio, and channel area. Others are used in combination in predicting the different dependent variables.

The maximum discharge/minimum discharge ratio explains how much the peak discharge deviates from baseflow. The higher the ratio, the more concentrated

Table 2. Statistical Information for Total Sediment Equations

Ln Total Yield

R*R = 0.966** Mean = 4.842
SEE = 0.332 Std. Dev. = 1.452
Constant = 2.6781

Variable	Regression Coefficient	Simple Correlation Coefficient	t-value
Channel Area	.0128	.727**	9.55**
Mean Channel Slope	-.1772	-.518*	-6.55**
W/D Ratio	-1.3464	.355	-5.86**
Streamflow Ln	.7830	.272	5.28**
Max/Min Discharge	.0146	.676*	3.53**

Ln Total Production Rate

R*R = 0.868* Mean = 2.588
SEE = 0.658 Std. Dev. = 1.362
Constant = 0.2839

Variable	Regression Coefficient	Simple Correlation Coefficient	t-value
Streamflow Ln	1.2815	.618*	3.71**
W/D Ratio	-.1734	.408	-3.04**
Mean Channel Slope	-.1407	-.340	-2.59*
Max/Min Discharge	.0237	.777**	2.94*
Channel Area	.0091	.321	2.83*
Depth of Flow	-9.1395	.513*	-1.83

** Statistically significant at the 99% level.
* Statistically significant at the 95% level.

Table 3. Statistical Information for Suspended Sediment Equations

Ln Suspended Sediment Yield

R*R = 0.962**
SEE = 0.341
Constant = 0.4367

Mean = 4.389
Std. Dev. = 1.396

Variable	Regression Coefficient	Simple Correlation Coefficient	t-value
Channel Area	.0125	.647*	9.02**
Streamflow Ln	1.0835	.466	7.11**
Mean Channel Slope	-.1518	-.473	-5.54**
W/D Ratio	-.1171	.488	-4.95**
Max/Min Discharge	.0079	.698*	1.86

Ln Suspended Sediment Production Rate

R*R = 0.912**
SEE = 0.518
Constant =-2.3936

Mean = 2.110
Std. Dev. = 1.400

Variable	Regression Coefficient	Simple Correlation Coefficient	t-value
Streamflow Ln	1.0151	.786**	4.55**
Bifurcation Ratio	-.3284	-.330	-3.01**
Channel Area	.0078	.204	3.42**
Max/Min Discharge	.0117	.754**	1.79
W/D Ratio	-.0364	.485	1.15

**Statistically significant at the 99% level.
* Statistically significant at the 95% level.

Table 4. Statistical Information for Bedload Equations

Ln Bedload Yield

R*R = 0.927**
SEE = 0.594
Mean = 3.120
Std. Dev. = 1.659
Constant = 6.2931

Variable	Regression Coefficient	Simple Correlation Coefficient	t-value
Channel Area	.0144	.704**	6.88**
W/D Ratio	-.1552	.111	-4.41**
Mean Channel Slope	-.1909	-.591*	-4.31**
Peak Disch. Ln	.7829	.432	3.34**
Bifurcation Ratio	-.2992	.052	-2.56*

Ln Bedload Production Rate

R*R = 0.899**
SEE = 0.594
Mean = 0.847
Std. Dev. = 1.410

Variable	Regression Coefficient	Simple Correlation Coefficient	t-value
Bifurcation Ratio	-.7889	-.373	-4.70**
Channel Area	.0105	.390	4.13**
Max/Min Discharge	.0258	.572*	3.96**
W/D Ratio	-.1220	.187	-3.27**
% Bare	.0565	-.233	2.88**

** Statistically significant at the 99% level.
* Statistically significant at the 95% level.

the streamflow is. The more water that is concentrated over a short period of time, the higher the energy of that water and the more sediment is transported. Also, baseflow often does not have the needed energy to transport sediment. Therefore, the higher the difference between peak discharge and baseflow, the higher the probability of sediment transport. When defining maximum discharge/minimum discharge ratio, the minimum discharge was terminated at 0.50 cfs. This was done to avoid the problem of streams turning ephemeral in dry years.

In the study area, the snowmelt period contributes the greatest bulk of suspended sediments, about 90 percent (Skau and Brown, unpublished). This was also noted in small streams in the Rocky Mountains of west-central Alberta (Nanson, 1974). The effects of concentrated streamflows can also be seen in intense summer rainfalls and floods.

Floods not only have the obvious effects on greatly increasing sediment carried downstream by the flood (McPherson and Rannie, 1969; Anderson, 1970), but the watershed characteristics in regard to sediment supply are changed for a number of years after the flood. Suspended sediment concentrations were found to be 2 to 3.7 times greater after the flood than before in sixteen northern California watersheds (Anderson, 1970). Flood damage was found to effect fragile higher elevations of the watershed three times more severely than the lower elevations (Anderson, 1970).

Mean channel slope was used to represent the energy of the flowing water. The negative correlation can be explained if one looks closely at the steep stream sections. Steep reaches often flow over bedrock and boulders. These areas are very poor sediment sources. Also, steeper sections have a step-like profile which causes much of the available energy to be dissipated. Channel sections with lesser slopes are usually in areas of deeper soils and smoother channel profile. Milder slopes, 5 to 15 percent, may provide the best combination of energy and sediment source to produce highest sediment yields .

The peak width/depth ratio has a positive simple correlation. Channel capacity, over time, adjusts to the size and streamflow of the watershed above the reach. The lift force acting on the channel sediments is in part associated with depth of flow. Lift force can be broken into two components: pressure effects from the velocity gradient impinging on particles lying on the streambed, and momentary upward velocity components of turbulence. The former component is defined as the Bernouli lift.

Bernouli lift is maximized in shallow, rapid flow. Particle motion is initiated in streams of this type at shear stresses lower than predicted. At greater depth of flows, Bernouli lift exerts a smaller influence on particle motion (Baker and Ritter, 1975). The Forest Service Stream Reach Inventory uses this variable to rate the stability of a stream reach.

When the peak width/depth ratio is combined in a multiple regression matrix, a negative correlation coefficient results. This may be due to inter-correlation among the independent variables.

Using the variable source concept, it is seldom that rainfall intensity exceeds infiltration in forested areas (Hewlett and Troendle, 1975). Because of this, true overland flow is rarely seen. The main contributing area of sediment is the stream channel network. The portion of the channel network that has had water flowing in it during the past year is defined as the channel area. Therefore, the variable "channel area" expresses the source of the sediment. The larger the channel area, the larger the available supply of sediment.

In mountainous areas, streambank erosion accounts for the largest part of the total sediment source. Values range from 54 percent in the mountain and valleys of western Oregon (Anderson, 1954) to an estimated 66 to 90 percent in the intermountain areas of the west (Robinson, 1976). Streambank erosion is caused by cutting and cave-ins of the streambank, soil encroachment on channel banks (up to 15 percent of the total sediment yield as defined by Anderson, 1970), and mass wasting. Streambank erosion in agricultural lands has been estimated at only 26 percent of the total sediment source (Robinson, 1976).

These four variables: maximum discharge/minimum discharge ratio, mean channel slope, width/depth ratio, and channel area, alternate as to which one is most statistically significant in explaining the variance of the dependent variable. The fact that all four variables are consistent in the predictive equations is very encouraging from the viewpoint of understanding sediment yield.

Streamflow is always an important variable when trying to explain sediment transport. The more water available, the higher the probability of sediment transport (Anderson, 1954; Hindall, 1976).

The mean bifurcation ratio relays an idea of the drainage pattern. A high bifurcation ratio, like drainage density, indicates infiltration rates and capacities of the soil are low. This causes water to concentrate in the stream channels quicker, causing higher peak flows (Branson, Gifford, and Owen, 1972).

Suspended Sediment/Total Sediment Ratio

A predictive equation that describes the suspended sediment/total sediment ratio is the first step toward obtaining a working estimate of the total sediment yield without actually measuring bedload. The equation described in Table 5 attempts to explain complex interactions between suspended sediment and bedload even though the equation does not meet the requirements to be statistically significant at the 95 percent level. Most of the variables used in this equation can be obtained in the same manner as in the other equations. However, some new variables have been introduced. Again, the methodology used to obtain values for the new variables can be found in Appendix B.

Hard geology is defined as volcanics, except pyroclastics, and glaciated granitics. Differences between glaciated and nonglaciated granites is important in mountainous terrain. Erosion has been accelerated since the original granitic uplifts some 160 million years ago. Granites are noted for their rapid decomposition. Glaciation removes most of the accululated material. The amount of material moved can be seen in glacial moraines and areas of glacial till. The result is that glaciation leaves an area of glaciated granites with less of a sediment source than an area of nonglaciated granites.

Different geologies not only have different erosivity indexes (Anderson, 1954; Thompson and White, 1964; and Bailey, 1973), but they also tend to form

Table 5. Statistical Information for Suspended Sediment/Total Sediment Ratio Equation

Suspended Sediment/Total Sediment Ratio

R*R = 0.732^{NS}
SEE = 16.542
Constant = 237.64

Mean = 67.00
Std. Dev. = 24.163

Variable	Regression Coefficient	Simple Correlation Coefficient	t-value
Peak Discharge Ln	-42.726	.233	-3.48**
% Hard Geology	.976	.604*	3.48**
Mean Grain Size	19.137	.014	2.55*
Elev. at Sampling Pnt.	-.0240	.212	-2.55*
Streamflow Loge	30.028	.486	2.40*
Drainage Density	-17.97	.242	-2.28

**Statistically significant at the 99% level.
* Statistically significant at the 95% level.

different sized material (Bailey, 1973). Volcanics tend to form finer particles while granitics often weather into coarse sands and gravels. It is easier for a fine sized particle to stay in suspension that a larger particle. The implication is that the higher the percentage of fine material, the higher the probability that suspended sediment makes up a large percentage of the total sediment. This accounts for the positive simple correlation of % Hard Geology.

The higher streamflows have a higher probability of transporting sediment. This has been stated in previous discussions, but it is also demonstrated with a positive simple correlation for both streamflow and peak discharge. It must be remembered that suspended sediment concentrations are multiplied by stream discharge to obtain sediment yield. Because of this, streamflow is automatically weighted toward suspended sediments.

The study area has a history of limestone and sandstone deposition, uplifted and metamorphosed by granitic blocks. Extensive Pliocene and Pleistocene volcanics cut through and topped the granite blocks, leaving the area with metamarine, metasedimentary and/or volcanic rocks in the higher elevations. Granitics appear on the surface as the result of erosion. The higher the elevation, the higher the percentage of hard geology. Again, hard geology will tend to weather into finer material which has higher probability of being transported in the suspended phase.

The correlation of drainage density with the suspended sediment/total sediment ratio shows a trend along the same lines as geology. Higher drainage densities are associated with more impermeable material, usually harder geology (Branson, Gifford, and Owen, 1972).

Explanation of variables is based on the simple correlation coefficients. The variables act to modify each other which may change the sign of the regression coefficient as compared to the simple correlation coefficient. Two groups of variables can be separated when explaining the suspended sediment/total sediment ratios: those that describe the energy of the flowing water and geology. Geology determines both the source of the sediment as well as the stability of the stream channel. Again, the same criteria that was used for predicting sediment has shown to be useful for predicting the suspended sediment/total sediment ratio.

Applicability of Bedload Formulas

The predictive equations discussed were calibrated by direct determination of the total sediment. Direct determination is always difficult and often impossible due to lack of time, funds, or expertise. Bedload formula are often used to estimate the amount of bedload transported (McPherson, 1971, 1974; Robinson, 1976). It has been assumed that at least an "order of magnitude" approximation can be made using accepted formulas (Dunne and Leopold, 1978). The Meyer, Peter & Muller (1948) and the Einstein (1950) bedload formulas were used in this study in combination with measured bedload to check this assumption.

All bedload and total load equations give the maximum capacity of sediment that can be carried under a given hydraulic condition. Therefore the actual bedload transport may be less than the transporting capacity. Formulas should be selected that were developed or adapted to areas of similar geography to that of the study area.

The Meyer, Peter & Muller equation was studied because of its increasing popularity within the U.S. Geological Survey and with other researchers, both in Europe (Graf, 1971) and in America (McPherson, 1971). Also, Meyer and Peter researched this equation in alpine and subalpine rivers (Graf, 1971). The working equations for both the Meyer, Peter, & Muller (1948) and the Einstein (1950) bedload formulas can be found in Appendix D.

Observed rates of bedload transport for the Sierra Nevada study area ranged from 0.001 Kg/sec. (0.001 lb/sec.)

to 0.150 Kg/sec. (0.068 lb/sec.) with a mean of 0.022 Kg/sec. (0.010 lb/sec.). Observed rates on the East Fork River, Wyoming, were found to range from 0.008 Kg/sec. (0.004 lb/sec.) to 2.84 Kg/sec. (1.29 lb/sec.) with a mean of 0.600 Kg/sec. (0.28 lb/sec.)(Leopold & Emmett, 1976). Both sets of observed rates show low bedload yield. Predictive values for the Sierra Nevada study area using the Meyer, Peter & Muller formula ranged from 10.8 Kg/sec. (4.91 lb/sec.) to 818.2 Kg/sec. (371.9 lb/sec.) with a mean of 187 Kg/sec. (85 lb/sec.). Therefore, the predictive values are three orders of magnitude higher than the observed values.

The high predicted values were largely the result of the high stream slopes found in the study area. Stream slope was used as an approximation of the energy slope. In mountainous areas this approximation does not hold. Streams are usually very turbulent, in part due to the stair-stepped profile of the channel. This profile can be seen even in the lower reaches of the channel. Turbulence releases some of the energy of the flowing water, reducing the energy slope but not the stream slope. Therefore, the stream slope is greater than the energy slope which may explain the over prediction found with use of the bedload formula.

Using the idea of over estimating the energy slope, this study used observed bedload to find predictive slopes.

The resulting slopes vary in a narrow range around 0.0005. This approaches the stream slope of many rivers where the strength of bedload formulas have been shown. Further studies are needed to determine an adequate approximation of the energy slope in mountainous areas.

Einstein's bedload formula relies on a relationship between a discharge parameter and a parameter that defines the intensity of bedload transport. To obtain the discharge parameter, grain size diameter is divided by slope and depth. A high slope causes the value of the discharge parameter to be too low to be used in the relationship. Again, the energy slope was approximated by the stream slope.

Stream slope was measured by taking the average slope of a 15 meter (50 foot) section while the energy slope should be measured precisely at each cross-section. Therefore, a better method of estimating energy slope is needed. Use of bedload formulas in mountainous areas should be approached with caution.

Although the Meyer, Peter & Muller equation grossly over-predicts bedload yield, the formula is better at predicting the shape of the sediment hydrograph. Figure 5 shows predicted versus observed snowmelt sediment hydrograph for a typical drainage basin. It appears that most of the bedload is transported during the short period of time of high discharges. Investigations on gravel bottomed streams have reported an armored layer

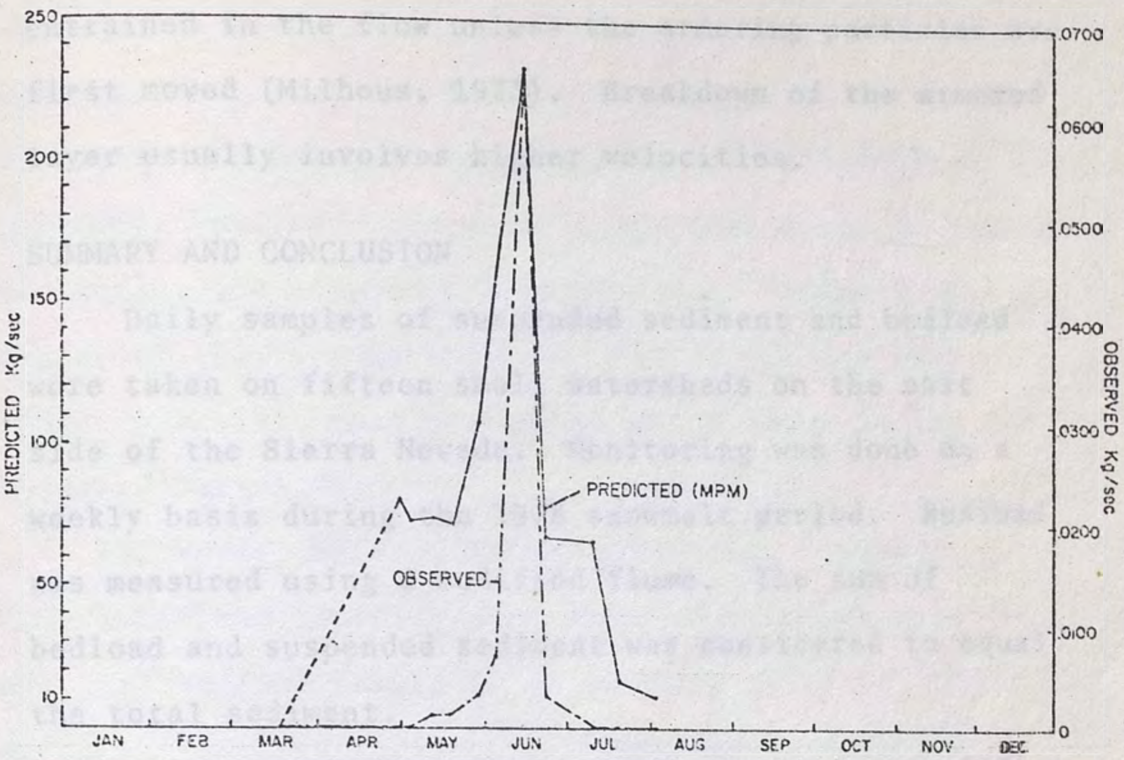

Figure 5. Observed versus predicted bedload. Note the differences in the scales used.

that controls bedload transport. The armored layer prevents sand and finer material of the bed from being entrained in the flow unless the armoring particles are first moved (Milhous, 1973). Breakdown of the armored layer usually involves higher velocities.

SUMMARY AND CONCLUSION

Daily samples of suspended sediment and bedload were taken on fifteen small watersheds on the east side of the Sierra Nevada. Monitoring was done on a weekly basis during the 1978 snowmelt period. Bedload was measured using a modified flume. The sum of bedload and suspended sediment was considered to equal the total sediment.

Analysis of the data included developing empirical equations for sediment yield and production rates as well as testing the applicability of other predictive equations. The developed predictive equations include estimates of suspended sediment, bedload, and total sediment. Watershed characteristics were found to explain a statistically significant amount of the variation found in the observed variables. The watershed characteristics describe the energy of the flowing water, stability of the stream channel, and source of the sediments. Each reflect an obvious though complex relationship with sediment yield. Quantifying the variables was achieved through a mixture of geomorphic and streamflow characteristics.

The most powerful variables, in terms of explaining sediment yield, were channel area, maximum discharge/ minimum discharge ratio, mean channel slope, and width/depth ratio. An on-site investigation is a requisite for determination of many of the variables. Different watershed characteristics were found to aid in predicting the suspended sediment/total sediment ratio. Energy of the flowing water as well as geology were found to explain most of the variation shown in the observed variables.

The Meyer, Peter & Muller (1948) and Einstein (1950) bedload formulas were found to over-estimate the observed bedload values by up to three orders of magnitude. The high predictive values are largely the result of assuming the stream slope approximates the energy slope. This approximation is not valid in mountainous areas where the stream slope is greater than the energy slope. Until a better method of estimating the energy slope is achieved, use of bedload formulas should be approached with caution.

Use of the developed predictive equations is limited to the small area of study. However, the basic criteria for choosing the independent variables should be valid in most mountainous areas. The total sediment yield data collection will be continued for at least two more years and should provide verification of the developed equations or derivation of better equations.

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APPENDICES

APPENDIX A - Stream Classification Forms

Date ____________ Time ____________ Crew ____________

PERENNIAL STREAM CLASSIFICATION

Stream ____________ Tributary ____________ Site ________ Channel Gradient ________

Snowmelt flow (.1 ft)

Width ____________

Depth 1/4 ____________

Depth 1/2 ____________

Depth 3/4 ____________

Roughness

(Scale to size of channel)

Smooth ____________

Intermediate ____________

Mostly turbulent (riffles and pools) ____________

Geology

1) Hard volcanics ____________

2) Soft volcanics ____________

3) Hard granitics ____________

4) Soft granitics ____________

5) Alluvium ____________

Channel Bottom

Composition

Boulders & bedrock (1'-) ________ %

Cobbles & Rock (2"-1') ________ %

Gravel (0.1"-2.0") ________ %

Fine sand, silt & clay ________ %

Fine dead organic ________ %

Live vegetation

grass & forbs ________ %

shrubs ________ %

Angularity

1) Sharp edges + corners, plant surfaces roughened ____________

2) Rounded edges + corners, plane surfaces roughened ____________

3) Well-rounded in all dimensions, plane surfaces smooth ____________

Stability (inorganics)

1) Particles packed, resist dislodgement when kicked ____________

2) Moderately packed, some dislodgement when kicked ____________

3) Unconsolidated, moves easily when walked on ____________

General

Source Area

Veg. type ____________

Veg. density ________ %

Area ____________ (acres)

Slope ____________ %

Sediment Traps

Area drains into lake ______ ____________

size of lake ____________ (acres)

Area drains into meadow

flow in channel ____________

flow diffuses ____________

size ____________ (acres)

Other ____________

Perennial Stream Classification, page 2.

Lower Banks

Composition	Left	Right
Boulders & bedrock (1'-∞)		
Cobbles & rock (2"-1')		
Gravel (0.1"-2.0")		
Fine sand, silt, clay		
Fine dead organic debris		
Live vegetation		
grass & forbs		
shrubs		

Stability	
1) Particles packed, resist dislodgement when kicked	
2) Moderately packed, some dislodgement when kicked	
3) Unconsolidated, moves easily when walked on	

Cutting	Left	Right
1) Little or none (<10%)		
2) Intermediate		
3) Nearly continuous (<75%)		

Upper Bank

Slope	Left	Right
0-30		
30-65		
65+		

Mass Wasting	Left	Right
1) No evidence of occurrence		
2) Infrequent or small slumps		
3) Frequent slumps, peak flow carries away new material		
4) Mass wasting extensive - large area affected		

Composition	Left	Right
Boulders & Bedrock (1'-)		
Cobbles & rock (2"-1')		
Gravel (0.1"-2.0")		
Fine sand, silt, clay		
Fine dead organic debris		
Live vegetation		
grass & forbs		
shrubs		

Stability (inorganics)	Left	Right
1) surface strongly resistant; 2mm		
2) surface moderately resistant		
3) surface not aggregate; single grain		

Current Data

Sta.	Dist.	Depth	Time	Count
1				
2				
3				
4				
5				
6				
7				
8				
9				

Date ______________ Time ______________ Crew ______________________

EPHEMERAL STREAM CLASSIFICATION FORM

Stream ______________ Tributary ______________ Site ________ Channel Gradient ____ %

Snowmelt flow (.1 ft)

Width ____________

Depth 1/4 ____________

Depth 1/2 ____________

Depth 3/4 ____________

Roughness

(Scale to size of channel)

Smooth ____________

Intermediate ____________

Mostly turbulent (riffles and pools) ____________

Geology

1) Hard volcanics ____________

2) Soft volcanics ____________

3) Hard granitics ____________

4) Soft granitics ____________

5) Alluvium ____________

Channel Bottom and Lower Banks

Composition

Boulders & bedrock (1'-∞) ________ %

Cobbles & rock (2"-1') ________ %

Gravel (0.1"-2.0") ________ %

Fine sand, silt & clay ________ %

Fine dead organic ________ %

Live vegetation

grass & forbs ________ %

shrubs ________ %

Sediments (up to 2")

Area of bottom sediments ________ %

Ave. depth of bottom sediments ________ (0.1')

Angularity

1) Sharp edges + corners, plane surfaces roughened ____________

2) Rounded edges + corners, plane surfaces roughened ____________

3) Well-rounded in all dimensions, plane surfaces smooth ____________

Stability (inorganics)

1) Particles packed, resist dislodgement when kicked ____________

2) Moderately packed, some dislodgement when kicked ____________

3) Unconsolidated, moves easily when walked on ____________

Cutting	Left	Right
1) Little or none (<10%)		
2) Intermediate		
3) Nearly continuous (<75%)		

Ephemeral Stream Classification, page 2.

Upper Banks

Slope	Left	Right
0-30		
30-65		
65+		

Mass Wasting	Left	Right
1) No evidence of occurrence		
2) Infrequent of small slumps		
3) Frequent slumps, peak flow carries away new material		
4) Mass wasting extensive - large area affected		

Composition	Left	Right
Boulders & bedrock (1'-∞)		
Cobbles & rock (2"-1')		
Gravel (0.1"-2.0")		
Fine sand, silt, clay		
Fine dead organic debris		
Live vegetation		
grass & forbs		
shrubs		

Stability (inorganics)	Left	Right
1) surface strongly resistant; 2mm		
2) surface moderately resistant		
3) surface not aggregate; single grain		

General

Source area

Veg. type ____________

Veg. density ________ %

Area ______________ (acres)

Slope ______________ %

Other

Sediment traps

Area drains into lake ______________

size of lake ______________ (acres)

Area drains into meadow

flow in channel ________

flow diffuses ________

size ________ (acres)

APPENDIX B - Methodology for Determining Independent Variables

Methodology for Determining Independent Variables

Several of the variables used have not been standardized. However, they appear in the predictive equations described in the text, and their method of measurement should be explained. This section will develop an understanding of the methodology used.

Values of some of the variables change from year to year because of the variation in annual precipitation pattern and resulting streamflow. The resulting change in values may be large even though the method developed to obtain the values remains constant. Variables will be discussed in two sections: those that may change annually and those that remain constant. Tables for both categories can be found after the methodology.

Variables that may change annually are:

1.) Streamflow production;

2.) peak discharge;

3.) maximum discharge/minimum discharge ratio;

4.) channel area;

5.) drainage density;

6.) peak width/depth ratio;

7.) peak depth of flow; and

8.) mean grain size diameter or d_{50};

Variables that remain constant are:

1.) mean channel slope;

2.) mean bifurcation ratio;

3.) percent of basin bare of vegetation;

4.) percent hard geology; and

5.) elevation of sampling site.

1.) Total streamflow is an estimate of the amount of water delivered out of a watershed by a stream. On gaged watersheds, total streamflow is determined by measuring the area under a streamflow hydrograph. Several methods have been developed to estimate streamflow for ungaged watersheds (Chow, 1964). Streamflow production is total streamflow divided by the drainage area of the basin.

2.) Peak discharge is a measure of the potential energy of the moving water. Stream discharge is equal to the channel cross-section area times the associated velocity. Area can be derived by measuring the peak depth of flow through use of a crest gage and determining the width. Velocity is estimated. For this study, the peak discharge was the maximum instantaneous velocity measured for each creek.

3.) The maximum discharge/minimum discharge ratio represents the flashiness of the stream. The maximum, or peak, discharge can be obtained using the method described above. Minimum discharge must be measured during winter flows. A value of 0.50 cfs was used to represent the minimum discharge for discharges less than 0.50 cfs.

4.) Assuming that the channel system is the source of the sediment (Anderson, 1954, 1970; Hewlett & Troendle, 1975; and Robinson, 1976), it is easy to visualize an expanding channel system giving rise to a greater sediment supply. The channel system expands and contracts throughout the year, due to changing moisture conditions. In mountainous areas, the greatest channel expansion is due to snowmelt (Dunne & Leopold, 1978).

Channel length was found to be highly correlated with channel area ($r = 0.91$). Channel length along with the depth of the snowmelt flow for individual years can be easily identified in the field. Minimum channel widths were about 10 cm.

$$\text{Channel Area} = \sum_{i=1}^{\eta}(W_i + 2D_i)L_i$$

where:

W = width of channel cross-section

D = average depth of channel cross-section

L = length of channel reach.

Topographic maps rarely show more than perennial stream channels. Expansion of the stream channel system can only be measured through use of an on-site investigation.

5.) Drainage density is equal to channel length, in miles, divided by the effective drainage area of the watershed.

6.) The width/depth ratio expresses the effects of different lift that forces have on sediment transport, along with the capacity of the stream channel to carry floods. Stream channels are constantly changing shape due to deposition and scour. At the same time, the streamflow changes from year to year, and even hour to hour. Therefore the width/depth ratio will vary over time. The peak width/depth ratio was used as a variable for convenience to the land planner. A crest gage can be used to measure the peak depth of flow. The associated width can be obtained by an on-site investigation.

7.) Peak depth of flow reflects the streamflow for the individual year. For some years, the channel is fuller than in other years. This is due to changes in precipitation amounts and patterns. Again, a crest gage can be used to measure the peak depth of flow.

8.) The mean grain size diameter of the bedload that is transported is obtained by seiving the bedload and plotting log - log graphs of grain size diameter versus percent of the bedload which is finer, by weight. It has not been documented as to whether this variable changes from year to year. However, field observations show large debris flow which are moved by intense streamflows. These debris flow have large sized material, much larger than the grain sizes that were moved during the study period. Further study is needed to determine whether this variable will change from year to year as the result of changing streamflows.

Variables that Remain Constant

1.) Mean channel slope is computed using USGS topographic maps as follows: (Chow, 1964).

i. The stream is broken up into a number of segments, each having approximately homogenous slope.

ii. The length of each segment is measured with an opsiometer on the USGS topographic maps, and converted to feet using the map scale.

iii. The difference in elevation is, in feet, recorded for each segment as being the difference between the highest and lowest points of elevation in the segment.

iv. Slope of each segment, in feet per foot, is computed by dividing the difference in elevation within the segment by the length of the segment.

v. The square root of the slope for each segment is recorded.

vi. Next the length of each segment divided by the square root of the slope of each segment is computed and recorded.

vii. The weighted mean slope for the main channel is computed by dividing the total length of all the segments by the sum of item 6 for all segments, and squaring this quantity. Dimensions are feet per foot and are converted to percent.

2.) Bifurcation ratio is an estimate of the drainage pattern. The bifurcation ratio will not be precisely the same from one stream order to the next because of chance variations in watershed geometry. However, there will be a trend toward a constant (Chow, 1964). A mean value for all stream orders was used to represent this constant. The bifurcation ratio is equal to the number of stream segments of a given order divided by the number of stream segments of the next higher order. A stream survey map was used to measure the number of stream segments for each order.

3.) Low altitude, color aerial photographs were obtained for each study watershed. Through use of photogrammetry techniques, the vegetation cover was divided into four classes: bare, shrub, meadow, and forest. The percent, by area, of the watershed covered by each vegetative type was determined through use of a dot grid.

4.) Geology was measured from the best available geologic map. The watershed boundaries were deliniated, and the percent of the watershed in each geologic category was determined. Hard geology was defined as volcanics, except pyroclastics, and glaciated granites.

5.) Elevation of the sampling site was measured off a standard USGS topographic map.

VARIABLES THAT SHOW ANNUAL CHANGE

Creek	Stream Flow (cm)	Peak Dschg (m^3/sec)	Max/ Min Dschg	Channel Area (km^2)	Drainage Density (mi/mi^2)	Peak W/D Ratio	Peak Depth of Flow (m)	d_{50} (mm)
Brownie	54.4	1.10	78	30.34	1.76	10.7	1.14	1.58
Browns	12.5	0.22	15	35.37	2.31	6.2	0.82	1.06
By Day	17.6	0.42	30	70.91	1.90	12.5	0.60	1.32
Cottonwood	8.4	0.38	6	60.05	1.24	10.3	0.66	3.13
Deep	5.9	0.30	11	65.13	1.55	10.3	0.69	1.70
Dunderberg	15.9	0.20	4	23.34	1.59	11.3	0.47	0.66
Eagle	37.4	1.47	19	106.44	1.95	21.5	0.87	3.46
East	12.0	0.11	8	22.81	4.87	10.8	0.49	0.38
Hawkins	22.3	0.34	24	12.02	2.74	10.4	0.57	1.32
Horsethief	22.9	0.99	31	23.82	1.18	17.9	0.71	4.90
No Name	12.0	0.23	10	23.06	1.67	21.2	0.42	1.20
Rock	0.8	0.07	5	94.39	1.35	2.8	0.64	1.11
Spratt	37.7	1.65	116	116.20	4.30	26.6	0.89	2.44
Thomas	6.7	0.19	15	77.03	2.00	11.8	0.90	1.02
West	24.6	0.37	26	48.94	3.91	9.7	0.74	0.84

VARIABLES THAT ARE CONSTANT

Creek	Mean Channel Slope(%)	Mean Bifurca-Ratio	% of Basin Bare of Vegetation	% Hard Geology	Elevation of Sampling Point (m)
Brownie	12.0	3.0	1	83	2180
Browns	11.5	2.5	4	22	1755
By Day	9.0	3.5	1	79	2170
Cottonwood	9.6	4.5	1	12	1950
Deep	10.0	5.3	9	35	1950
Dunderberg	15.4	7.0	45	89	2770
Eagle	9.4	5.0	20	97	2260
East	19.7	3.7	0	100	1880
Hawkins	13.3	1.0	0	91	2465
Horsethief	7.4	5.0	4	15	2115
No Name	7.2	3.0	12	43	2220
Rock	12.0	5.4	0	1	1740
Spratt	8.7	5.5	13	62	1725
Thomas	15.0	5.2	1	76	1850
West	20.0	4.7	10	100	1950

APPENDIX C - Variables Showing Statistical Significance

Some 54 variables were tested as to simple correlation with the dependent variables. Variables that showed statistical significance at the 95 percent level are shown on the next page. The objective of testing all of the variables was to develop the best regression equation. Therefore many combinations of variables were tested using the reverse step-wise regression process. Even if a variable showed a high simple correlation, it might have been so highly inter-correlated with other variables that its contribution to explaining the variance found in the dependent variable would have been small.

Simple Regression Coefficients Showing Statistical Significance at the 95% Level.

Variable	Suspended		Bedload		Total	
	Yield	Prod.	Yield	Prod.	Yield	Prod.
1. Streamflow Total	.86	.64	.63		.65	.54
2. Streamflow Production	.66	.82		.57		.60
3. Peak Discharge	.88	.79	.63	.60	.76	.70
4. Channel Length	.50		.72		.57	
5. Channel Area	.69		.82		.66	
6. Wetted Perimeter			.60			
7. Wetted Perimeter x Total Channel Composition	.60		.76		.66	
8. Wetted Perimeter x Cutting	.76		.72		.79	.61
9. Total Channel Composition ÷ Channel Length		.57		.71		.70
10. Relief Ratio	-.57		-.63			
11. Ave. Daily W/D Ratio	.69	.50			.69	.59
12. Peak W/D Ratio	.69	.52			.66	.58
13. % of Basin with Channel Slopes $\geq$ 20%			.60			
14. % of Basin with Slopes $\geq$ 40%			.55			

APPENDIX D - Bedload Formulas

The Meyer, Peter & Muller (1948) bedload formula is based upon the tractive force principle. The working equation is:

$$\gamma\left(\frac{K_B}{K_G}\right)^{3/2} R_h S - 0.047(\gamma_s - \gamma)D_E = 0.25\left(\frac{\gamma}{g}\right)^{1/3} (G_s'')^{2/3}$$

where:

γ = specific weight of water (Kg/m^3)

K_B = Strickler's roughness coefficient for the bed (m$^{1/3}$/sec)

K_G = grain roughness (m$^{1/3}$/sec)

R_h = hydraulic radius, which can be approximated by depth of streamflow (m)

S = stream slope

γ_s = specific weight of sediment (Kg/m^3)

D_E = effective grain size diameter, D_{50} (m)

g = acceleration due to gravity (m/sec^2)

G_s''= bedload transport weight, under water (Kg/sec·m).

An assumption was made that no bedforms were evident. Therefore $\frac{K_B}{K_G} = 1$. The term $\{0.047(\gamma_s - \gamma)D_E\}$ expresses the critical tractive force. In order to obtain the dry bedload rate, G_s', the following formula is used:

$$G_s' = \frac{\gamma}{\gamma_s - \gamma} G_s''$$

The units of the dry bedload transport is Kg/sec·m. In order to determine the total bedload transport for the channel width:

$$G_s = G_s'b$$

where:

b = width of sediment moving section of the channel (m)

G_s = bedload transport rate (Kg/sec)

The Meyer, Peter & Muller bedload formula and the Einstein bedload formula are based upon the tractive force principle, properties of the grain and the flow causes the movement.

The Einstein procedure is very complicated, composed of nearly thirty steps. However, the result is a bedload function. Einstein defines the bedload function as "the rate at which various discharges will transport different grain sizes of the bedload material in a given channel,"(Graf,1971). The relationship between a discharge parameter, Ψ, and a bedload parameter, Φ, is given in graphical form and represents the Einstein bedload equation. The equation to define the discharge parameter is:

$$\Psi = \frac{\frac{\gamma_s - \gamma}{g}}{\frac{\gamma}{g}} \quad \frac{D_E}{SR_h}$$

Experiments have determined the discharge-bedload relationship. Therefore, to obtain the bedload parameter, a graph is used. The bedload transport weight (Kg/sec·m) is:

$$G_s' = \frac{\Phi \gamma_s}{\frac{\gamma_s}{\frac{\gamma_s - \gamma}{g}} \quad \frac{1}{g(D_E)^3}}$$

Again, to obtain the total bedload transport weight (Kg/sec), G_s' is multiplied by the width of the sediment moving section the channel.

All of the bedload equations are derived such that they predict the maximum bedload that a stream in equilibrium can possibly carry under a given hydraulic and sedimentary condition. Except for a few cases, the bedload motion has been studied in small-scaled laboratory flumes. The application of bedload equations to field studies remain limited and should be approached with caution.

APPENDIX E Suspended Sediment and Bedload Data

note: (e) indicates estimated values.

Total Yield of Snowmelt Sediment

Creek	Suspended Sediment Flume metric tons	Suspended Sediment Natural metric tons	Bedload metric tons	Total metric tons	Watershed Area, Km^2	Suspended Sediment/ Total Sediment %
Brownie	320.78	368.55	51.60	372.37	5.96	86
Browns	59.43	46.80	75.39	134.82	8.24	44
By Day	409.63	362.83	68.68	527.29	9.97	78
Cottonwood	102.54	106.90	27.39	129.93	26.60	79
Deep	118.64	87.55	70.27	188.91	20.80	63
Dunderberg	26.00	15.85	1.91	27.91	6.29	93
Eagle	695.91	749.49	134.10	830.01	19.43	84
East	10.56	12.15	0.68	11.24	4.64	108
Hawkins	83.51	61.00	17.32	100.83	1.61	83
Horsethief	62.32	64.22	11.25	73.57	9.69	62
No Name	14.65	14.07	5.25	19.89	5.39	74
Rock	36.79	36.73	121.69	158.48	39.96	23
Spratt	2,477.38	1,073.64	216.45	2,693.83	12.95	92
Thomas	53.68	52.20	12.76	66.44	18.62	81
West	42.12	40.95	7.16	49.37	5.36	85

BROWNIE CREEK

					Suspended Sediment						
					Natural		Flume		Bedload		
Date	Time	Temp. C°	Disch. m³/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
4-29	1030	4	.12	.33	0	0	0	0	-	.23	.34
	1430	4	.12	.33	0	0	0	0	-	.23	.34
	1730	4	.12	.33	0	0	0	0	-	.23	.34
	1930	4	.12	.33	4.3	50	23.5	272	4	.23	.34
5-3	1200	4	.17	.43	6	83	1	14	4	.23	.35
	1500	4	.17	.43	3	47	5	78	20	.23	.35
	1800	4	.17	.43	46	774	46	774	-	.23	.35
	2000	4	.17	.43	33	662	40	802	-	.23	.35
5-12	1130	7	.22	.58	8	150	2	37	38	1.2	1.8
	1430	8	.25	.58	15	330	18	395	72	.84	1.5
	1700		.31	.60	114	3077	102	2753	134	.45	.68
	1945	3	.39	.71	129	4333	122	4098	184	.34	.51
5-18	1100	5	.55	.35	37	1753	4	53	59	1.2	2.5 (e)
	1400	6	.26	.59					101	2.8	5.0
	1700	5	.31	.61	8	212	1	26	94	1.2	2.0
	1900	4	.35	.66	13	390	8	240	180	1.5	2.5
5-28	1100	6	.24	.51	10	210	10	211	104	2.1	3.4
	1400	7	.33	.76	16	458	24	687	96	1.7	2.7
	1700	6	.43	.69	95	3540	77	2870	314	1.5	2.5
	1900	5	.54	.80	170	8015	124	5846	638	2.6	4.3
6-4	1100	6	.49	.80	7	295	10	422	197	1.3	2.1
	1500	6	.64	.89	77	4270	47	2606	704	1.0	1.7
	1715	5	.64	.83	307	17002	276	15285		1.3	2.1
	1930	4	.70	.88	306	18410	354	21298	979	1.0	1.7
6-13	1230		.68	.79	24	1415	48	2831	1284	2.6	3.7
	1430	11	.82	.75	165	11719	125	8878	3479	2.9	4.3
	1645	7	.98	.83	318	27107	337	28727	9079	2.4	3.7
	1900	8	1.10	.87	313	29812	446	42480	8578	3.2	5.0

BROWNIE #2

					Suspended Sediment						
					Natural		Flume		Bedload		
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
6-22	1045	7	.35	.71	11	330	19	571	218	2.2	3.3
	1330	9	.42	.79	24	875	17	620	214	1.75	2.6
	1600	9	.56	.84	25	1214	48	2330	190	1.1	1.7
	1745	8	.56	.84	40	1940	42	2037	531	2.1	3.3
7-9	1015	9	.14	.44	56	701	56	701	24	1.35	2.0
	1345	13	.15	.53	64	835	69	900	15	.84	1.25
	1600	13	.24	.53	67	1416	53	1120	27	1.5	2.6
	1800	11	.38	.73	12	390	10	325	43	1.2	2.0
7-19	1145	11	.15	.75	15	180	12	144	2	.89	2.0
	1500	11	.15	.75	0	0	2	23	4	.89	2.0
	1800	11	.15	.75	14	201	16	230	5	.89	2.0
8-2	0830	12	.05	.48	21	87	13	54	2	4.0	7.0
	1130	12	.05	.48	20	97	17	82	2	4.0	7.0
	1430	12	.05	.48	14	60	18	78	4	4.0	7.0
	1700	12	.05	.48	43	186	11	48	32	4.0	7.0

BROWN'S CREEK

Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Suspended Sediment Natural Conc. mg/l	Suspended Sediment Natural Yield kg/day	Suspended Sediment Flume Conc. mg/l	Suspended Sediment Flume Yield kg/day	Bedload Yield kg/day	D_{50} mm	D_{65} mm
4-01	0935	4	.13	.35	15	189	16	201		.76	1.05
	1250	4	.13	.35	38	410	30	324	20	.76	1.05
	1700	4	.13	.35	33	366	31	344	12	.76	1.05
4-09	0920	7	.06	.21			2	8	2	.88	1.25
	1230	7	.06	.21	9	45	10	50	1	.88	1.25
	1545	7	.06	.21	41	250	42	256	6	.88	1.25
	1840	7	.06	.21	13	76	14	82	6	.88	1.25
	2055	7	.06	.21	18	113	17	106	4	.88	1.25
4-16	0920	3	.07	.29	17	106	26	162	1687	1.5	2.0
	1220	2	.04	.16	23	89	18	69	829	1.5	1.9
	2050	2	.04	.16	14	54	19	73	340	1.5	1.9
4-23	0920	6	.06	.23	29	158	22	120	186	.9	1.3
	1230	8	.06	.22	9	45	26	130	178	1.2	1.6
	1640	8	.07	.27	21	119	15	85	328	1.35	1.7
	2030	6	.06	.27	33	175	42	223	159	1.1	1.45
4-28	1130	8	.09	.30	13	98	8	60	1588	1.1	1.5
	1445	8	.09	.30	10	80	14	112	853	.92	1.3
	1845	7	.11	.34	22	204	20	185	1090	1.0	1.4
	2030	7	.11	.34	21	195	33	306	894	1.0	1.4
5-06	1130	8	.09	.32	35	270	75	579	1298	1.3	1.75
	1500	8	.09	.32	25	193	42	325	749	1.3	1.75
	1745	8	.12	.40	58	607	80	837	817	1.15	1.55
	2200	8	.12	.40	38	398	62	649	2065	1.15	1.55
5-11	1045	8	.13	.37	18	207	46	530	2260	.9	1.4
	1415	8	.13	.38	41	477	33	384	1623	.74	1.1
	1700	9	.18	.45	39	593	65	988	1452	1.2	1.7
	1945	7	.18	.45	47	740	39	614	2151	1.5	1.95

BROWN'S CREEK #2

Date	Time	Temp. C°	Disch. m³/sec	Vel. m/sec	Suspended Sediment Natural Conc. mg/l	Suspended Sediment Natural Yield kg/day	Suspended Sediment Flume Conc. mg/l	Suspended Sediment Flume Yield kg/day	Bedload Yield kg/day	Bedload D_{50} mm	Bedload D_{65} mm
5-17	0930	8	.14	.36	24	268	140	1564	1519	.92	1.35
	1300	8	.14	.36	23	279	30	364	1043	.92	1.35
	1600	12	.19	.43	122	1918	140	2200	793	.92	1.45
	1845	12	.19	.43	197	3226	248	4061	2257	.92	1.45
5-25	1130	7	.09	.29	19	144	116	879	508	1.15	1.65
	1400	7	.09	.29	23	174	62	470	386	1.15	1.65
	1630	7	.09	.29	20	150	47	353	241	1.15	1.65
5-31	1015	8	.13	.32	57	677	82	974		.82	1.2
	1245	8	.13	.32	46	479	106	1105	607	.82	1.2
	1530	11	.16	.38	67	949	86	1218	895	.8	1.2
	1830	11	.16	.38	115	1467	111	1416	830	.8	1.2
6-7	1030	10	.17	.44	56	818	122	1781	2312	1.1	1.8
	1400		.14	.39	57	672	94	1108	1752	.76	1.1
	1645		.22	.52	127	2373	97	1812	1415	.94	1.4
	1915		.21	.47	160	2877	200	3595	4008	1.3	2.2 (e)
6-16	1130	11	.09	.27	12	95	32	252	373	1.45	2.1 (e)
	1430	11	.09	.27	18	142	22	173	127	1.45	2.1 (e)
	1700	11	.09	.27	25	197	12	95	136	1.45	2.1 (e)
6-27	1030	12	.07	.29	9	56	10	62	64	.9	1.3
	1310	12	.07	.29	10	62	9	56	27	.9	1.3
	1615	12	.07	.29	8	55	8	55	31	.9	1.3
	1845	12	.07	.29	9	56	8	50	37	.9	1.3
7-14	1015	18	.05	.31	82	407	75	372	17	.78	1.2
	1330	18	.05	.31	89	391	74	325	12	.78	1.2
	1600	18	.05	.31	89	341	57	218	21	.78	1.2
	1745	18	.05	.31	85	316	101	375	21	.78	1.2

BY DAY

Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Suspended Sediment Natural Conc. mg/l	 Yield kg/day	 Flume Conc. mg/l	 Yield kg/day	Bedload Yield kg/day	 D_{50} mm	 D_{65} mm
4-11	1200	6	.10	.45	160	1334	160	1334	300	.8	1.4
	1500	4	.14	.54	452	5369	905	10739	1024	2.35	3.8
	1730	-1	.16	.58	548	7658	766	10704	317	.3	.46
	2000	2	.15	.54	510	6764	922	12229	3299	1.8	2.8
4-22	1130	7	.10	.39	36	325	42	380	235	1.2	1.8
	1430	6	.14	.45	71	870	137	1680	156	.86	1.7
	1730	4	.14	.45	118	1435	142	1727	425	.86	1.7
4-26	1415	7	.20	.54	254	4403	293	5078	1660	1.6	2.7
	1800	4	.21	.56	462	8597	555	10327	2029	1.65	2.8
	2045	3	.21	.56	330	6140	531	9881	3551	1.65	2.8
5-05	1330	5	.13	.58	193	2125	261	2873	1017	4.6	10+
	1645	5	.24	.55	123	2581	198	4155	1383	2.05	3.6
	2015	3	.26	.66	90	2056	166	3792	845	1.7	3.3
5-15	0845	4	.38	.81	123	3796	157	4846	1603	2.6	4.5
	1300	9	.37	.80	184	5828	184	5828	1433	3.3	5.6
	1615	9	.42	.81	241	8827	264		181	.44	.6
	1900	6	.38	.81	142	4978	154	5399	986	2.6	4.5
5-24	1030	7	.24	.60	11	226	12	246	165	1.4	2.3
	1400	11	.23	.55	15	295	11	217	173	1.4	2.45
	1630	9	.23	.55	13	259	16	319	104	1.4	2.45
	1900	7	.25	.61	8	175	27	589	29	.41	.6
5-31	1400	12	.27	.60	568	13271	477	11145	481	.22	.47
	1645		.27	.60	496	11990	489	11820	579	.22	.47
	2030	8	.30	.62	414	10647	457	11753	834	.22	.47
6-8	1130	11	.32	.65	176	4884	187	5190	927	1.3	2.1
	1430	14	.32	.65	255	7077	210	5828	2004	1.3	2.1
	1715	14	.26	.53	235	5352	289	6578	664	1.4	2.5
	1915	12	.26	.53	274	6080	258	5939	1183	1.4	2.5

BY DAY #2

					Suspended Sediment						
					Natural		Flume		Bedload		
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
6-15	1000	8	.17	.43	32	469	37	542	189	1.3	2.3
	1330	13	.15	.40	41	515	36	453	133	1.3	2.5
	1600	13	.15	.40	37	499	41	553	110	.78	1.4
	1830	12	.16	.42	40	518	34	440	107	1.3	2.5
6-22	1150	15	.10	.30	18	149	22	182	28	.70	1.1
	1430	16	.10	.29	28	237	31	262	31	1.0	1.95
	1615	16	.10	.29	23	195	24	203	19	1.0	1.95
	1815	16	.10	.29	21	178	34	288	20	1.0	1.95
7-6	1045	11	.07	.52	85	542	63	401	12	1.0	2.0
	1330	14	.07	.52	75	458	97	592	33	1.0	2.0
	1600	14	.10	.62	81	707	78	680	18	1.15	1.8
	2045	13	.10	.62	80	675	78	658	12	1.15	1.8
7-21	1400	20	.03	.16	22	48	0	0	6	.3	.43
	1815	20	.02	.13	12	21	3	5	11	.32	.43

COTTONWOOD CREEK

					Suspended Sediment				Bedload		
					Natural		Flume				
Date	Time	Temp. C°	Disch. m³/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D50 mm	D65 mm
4-14	1310	8	.16	.53	51	677	50	664	183	1.30	2.00
	1715	9	.16	.53	64	861	72	969	380	1.30	2.00
	2030	4	.16	.53	57	762	68	909	264	1.30	2.00
4-20	1200	6	.13	.51	24	272	21	239	95	1.30	2.00
	1500	7	.13	.51	28	318	27	306	68	1.30	2.00
	1715	6	.13	.51	22	250	24	272	64	1.30	2.00
	1945	5	.13	.51	31	351	26	295	55	1.30	2.00
4-27	1415	11	.18	.53	25	389	20	312	472	1.25	1.85
	1720	12	.22	.62	45	859	78	1490	633	1.62	2.70
	2030	9	.22	.62	42	802	54	1031	789	1.62	2.70
5-06	1245	6	.20	.59	31	547	32	564	219	1.70	3.00
	1545	11	.17	.52	37	554	35	523	267	1.55	2.43
	1845	9	.23	.63	43	850	37	732	285	2.40	4.05
	2130	6	.20	.59						1.70	3.00
5-11	1130	8	.26	.68	79	1743	102	2250	489	3.40	5.80
	1445	13	.30	.75	57	1440	69	1743	338	2.40 (e)	4.00
	1745	12	.30	.75	125	3189	131	3342	1263	2.40 (e)	4.00
	2015	8	.34	.79	161	4655	178	5146	1800	8.00 (e)	10+ (e)
5-17	1145	7	.33	.81	110	3124	100	2840	288	4.80	9.00 (e)
	1500	12	.31	.77	98.5	2650	68	1814	1395	7.20	10+ (e)
	1800	11	.33	.81	103	2898	121	3404	756	4.80	9.00 (e)
	2000	9	.31	.72	93	2496	173	4645	632	5.50	10 (e)
5-25	1145	7	.37	.76	37	1165	56	1763	284	3.30	6.00 (e)
	1445	11	.35	.72	36	1068	35	1038	166	1.50	3.10
	1700	11	.33	.66	47	1344	49	1401	236	3.60	9.40 (e)
	1900	9	.37	.76	44	1389	35	1105	222	3.30	6.00 (e)
5-29	1230	9	.37	.75	80	2550	67	2135	215	4.0	7.6 (e)
	1600	14	.37	.75	91	2900	70	2231	265	4.0	7.6 (e)
	1900	12	.38	.72	116	3845	86	2851	269	3.6	7.0 (e)
	2130	9	.38	.72	100	3315	92	3049	384	3.6	7.0 (e)

COTTONWOOD #2

					Suspended Sediment						
					Natural		Flume		Bedload		
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
6-6	1050	10	.37	.77	29	938	29	938	374	3.70	5.6
	1410	14	.33	.69	42	1185	40	1129	259	4.1	6.4 (e)
	1650	16	.34	.69	43	1283	42	1253	315	4.6	7.6 (e)
	2000	13	.34	.69	43	1260	44	1289	145	4.6	7.6 (e)
6-14	1100	9	.18	.45	33	514	31	483	277	4.3	7.0 (e)
	1400	14	.28	.63	45	1071	38	905	114	2.7	4.0
	1645	14	.31	.71	42	1120	39	1040	189	2.7	4.0
	1900	13	.31	.71	41	1097	37	990	144	2.7	4.0
6-30	1215	12	.16	.49	22	307	24	335	69	3.2	6.0 (e)
	1600	16	.14	.45	17	205	13	157	43	1.85	3.2
	1900	16	.16	.49	13	172	20	266	53	3.2	6.0 (e)
	2045	11	.14	.45	19	227	19	227	38	1.85	3.2
7-12	1100	13	.11	.38	84	791	70	659	19	1.2	2.0
	1430	18	.11	.38	89	838	87	819	12	1.2	2.0
	1715	20	.09	.32	67	508	120	909	14	.8	1.5

DEEP CREEK

					Suspended Sediment				Bedload		
					Natural		Flume				
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
4-14	1345	10	.09	.43	78	579	128	951	980	1.2	1.8
	1745	6	.08	.37	66	453	72	494	163	1.1	1.5
	2100	4	.08	.41	60	428	61	435	194	1.0	1.4
4-20	1230	8	.09	.39	29	215	25	185	51	.80	1.1
	1530	7	.09	.39	36	267	23	170	38	.80	1.1
	1745	7	.09	.39	19	141	16	119	33	.80	1.1
	2015	4	.09	.39	28	207	25	185	27	.80	1.1
4-27	1500	11	.09	.37	17	139	30	245	278	1.0	1.4
	1800	9	.09	.40	75	601	84	673	317	.90	1.2
	2100	7	.09	.40	85	682	107	858	362	.90	1.2
5-06	1315	6	.11	.45	42	410	60	585	527	1.1	1.5
	1615	9	.08	.53	48	320	47	313	264	1.1	1.5
	1915	8	.08	.53	51	340	46	307	227	1.1	1.5
	2200	4	.12	.45	57	569	50	499	161	1.0	1.5
5-11	1215		.11	.50	84	811	115	1111	1213	1.1	1.5
	1515	12	.14	.59	97	1201	130	1609	632	1.1	1.6
	1800	10	.17	.62	208	3044	178	2605	831	.76	1.25
	2050	7	.17	.62	279	4084	209	3059	497	.76	1.25
5-17	1215	8	.17	.63	100	1461	134	1985	2074	1.8	2.8
	1530	11	.11	.47	162	1597	87	857	1127	1.5	2.3
	1830	9	.21	.71	243	4367	148	2660	1557	1.4	2.2
	2030	8	.23	.70	214	4192	221	4329	1529	1.2	2.1
5-25	1215	7	.13	.52	53	47	47	50	419	2.0	2.9
	1500	11	.12	.50	35	21	21	222	292	2.0	3.2
	1720	11	.18	.62	44	60	60	915	396	2.0	2.9
	1930	8	.14	.53	86	83	83	995	249	1.6	2.8
5-29	1320	9	.19	.55	94	1514	91	1465	559	.88	1.9
	1645	11	.25	.65	231	4899	192	4072	2183	3.5	6.0 (e)
	1945	8	.23	.60	321	6327	576	11354	3939	3.5	5.2
	2200	7	.25	.68	241	5265	296	6466	3833	3.8	6.0 (e)

DEEP #2

Date	Time	Temp. C°	Disch. m³/sec	Vel. m/sec	Suspended Sediment Natural Conc. mg/l	Suspended Sediment Natural Yield kg/day	Suspended Sediment Flume Conc. mg/l	Suspended Sediment Flume Yield kg/day	Bedload Yield kg/day	Bedload D_{50} mm	Bedload D_{65} mm
6-6	1140	9	.14	.42	71	842	66	783	360	1.4	2.5
	1445	13	.20	.55	199	3488	103	1805	859	1.4	2.2
	1730	13	.24	.64	183	3791	282	5842	970	1.0	1.8
	2030	11	.30	.65	195	5110	301	7889	5541	5.6	7.8 (e)
6-14	1200	10	.14	.54	26	318	60	734	1169	2.6	4.3
	1430	13	.13	.41	31	346	41	458	448	1.5	2.5
	1715	13	.14	.47	32	391	44	538	430	1.8	3.2
	1945	11	.15	.55	39	512	43	572	398	1.9	3.2
6-30	1300	12	.11	.40	9	84	5	47	41	.68	1.45
	1630	14	.10	.36	5	42	6	50	102	2.1	4.6
	1930	13	.11	.39	12	111	12	111	373	3.9	6.8
	2115	11	.10	.36	8	67	15	125	144	2.1	4.6
7-12	1130	14	.07	.33	90	578	59	379	28	1.3	2.0
	1400	17	.07	.33	88	511	59	343	37	1.3	2.0
	1740	17	.06	.29	81	409	66	333	36	.96	1.6

DUNDERBERG

					Suspended Sediment				Bedload		
					Natural		Flume				
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
6-8	1030	9	.11	.51			10	52	20	.33	.52
	1400	11	.11	.51	11	104	13	123	56	.33	.52
	1700	10	.11	.51	24	254	74	782	42	.33	.52
	1845	8	.11	.51	17	180	35	370	32	.33	.52
6-14	1145	8	.13	.63	9	95	3	32	16	.3	.45
	1430	10	.13	.63	13	154	2	24	19	.3	.45
	1630	9	.13	.63	16	187	8	93	30	.3	.45
	1815	8	.13	.63	7	80	3	34	25	.3	.45
6-22	1230	10	.05	.87	21	139	12	79	1	.205	.27
	1530	8	.05	.87	21	151	13	94	2	.205	.27
	1800	7	.05	.87	24	173	15	108	3	.205	.27
7-1	1230	9	.13	.62	4	49	6	73	8	.8	1.2
	1530	9	.13	.62	7	85	13	159	6	.8	1.2
	1815	8	.13	.52	4	42	0	0	7	.8	1.2
7-13	1030	13	.17	.76	72	1036	70	1007	23	.4	.58
	1350	16	.17	.73	65	958	71	1046	28	.47	.6
	1600	14	.19	.79	78	1260	76	1228	26	.37	.52
	1800	12	.20	.82	100	1768	86	1520	31	.32	.47
7-19	1115	11	.05	1.50	5	59	3	35	7	.43	.54
	1530	12	.05	1.50	0	0	1		7	.43	.54
	1830	12	.05	1.50	1	12	1	12	6	.43	.54
8-2	1020	9	.12	.46	17	179	19	200	19	.56	.74
	1330	13	.14	.52	19	225	13	154	16	1.75	2.8
	1600	11	.14	.52	16	189	12	142	14	1.75	2.8
	1815	9	.18	.67	14	224	13	208	15	2.0	3.05

EAGLE

					Suspended Sediment				Bedload		
					Natural		Flume				
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
5-14	1330	8	.46	.75	142	5668	148	5907	929	3.9	6.4 (e)
	1530	8	.54	.77	338	15794	354	16542	1514	5.0	6.4 (e)
	1845	4	.63	.79	282	15314	289	15694	1490	3.9	6.2 (e)
5-25	1145	9	.32	.62	11	323	7	205	469	3.9	5.5
	1400	11	.38	.63	7	212	11	333	468	3.4	5.5
	1630	11	.38	.63	16	523	20	653	294	4.4	6.6 (e)
	1815	9	.45	.63	21	816	45	1749	703	5.3	7.5 (e)
6-1	1115	7	.56	.71	37	1783	49	2362		3.4	5.6
	1330		.51	.65	42	1854	52	2296	2291	3.0	5.0
	1600	9	.66	.71	39	2219	15	854	2659	3.2	5.0
	1800	7	.70	.73	11	663	16	965	3257	4.2	6.2 (e)
6-9	1030	6	.98	.74	122	10391	140	11924	1843	3.0	4.5
	1300	9	.86	.63	132	9857	128	9559	4049	4.5	6.5 (e)
	1530	9	1.18	.77			250	25638	2475	8.0	9.1 (e)
	1815	7	1.19	.75	475	48991	445	45897	3329	3.6	5.5
6-15	1000	3	1.11	.76	88	8468	55	5292	1976	4.8	7.6 (e)
	1300	8	1.11	.76	52	5004	46	4426	2172	3.6	5.6
	1600	8	1.34	.82	85	9884	84	9729	2172	2.7	4.7
	1800	7	1.34	.82	113	13087	98	11350	3070	2.7	4.7
6-22	1400	10	1.25	.85	29	3137	25	2704	272	2.3	3.4
	1645	8	1.45	.90	41	5147	40	5022	539	2.2	3.3
	1845	7	1.47	.90	49	6246	51	6502	793	4.6	8.2 (e)
7-6	1200	10	.93	.75	76	6098			304	7.0 (e)	10+
	1500	11	1.16	.88	92	9263			151	1.4	2.2
	1720	10	1.21	.87	543	57030			301	2.7	6.2 (e)
	1830	9	1.24	.89	116	12410			198	1.3	2.4 (e)
7-21	1200	10	1.0	.80	15	6278	14	1211	38	2.1	3.4 (e)
	1500	14	1.0	.80	20	1730	17	1470	91	2.1	3.4 (e)
	1730	13	1.0	.80	17	1470	18	1557	43	2.1	3.4 (e)

EAGLE #2

					Suspended Sediment						
					Natural		Flume		Bedload		
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
8-2	1020	9	.70	.58	26	1572	22	1330	65	1.1	1.9
	1330	16	.58	.52	25	1258	34	1711	65	.90	1.5
	1630	16	.59	.51	26	1337	39	2006	55	1.0	1.7

EAST CREEK

					Suspended Sediment				Bedload		
					Natural		Flume				
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
4-5	1115	4	.06	.25	13	68	5	26	2	.28	.47
	1545	4	.06	.25	20	98	12	59		.28	.47
	1900	3	.06	.25	25	107	9	39	1	.28	.47
4-12	1215	5	.06	.27	65	344	44	233	14	.36	.54
	1400	6	.06	.27	57	324	56	319	12	.36	.54
	1730	4	.06	.37	56	288	55	283		.36	.54
4-19	1130	7	.06	.26	24	133	34	188	2	.44	.56
	1400	7	.06	.26	31	160	25	129	1	.44	.56
	1700	6	.06	.26	26	120	24	111	6	.44	.56
	1915	4	.06	.26	24	126	21	110	6	.44	.56
4-30	1100	5	.06	.26	17	101	14	83	4	.29	.45
	1400	5	.06	.26	23	108	13	61	4	.29	.45
	1645	4	.06	.26	17	83	15	74	5	.29	.45
	1945	4	.06	.26	29	142	12	59	4	.29	.45
5-07	0915	3	.07	.30	18	105	5	29	4	.32	.50
	1215	8	.07	.30	10	58	4	23	4	.32	.50
	1525	7	.07	.30	14	88	19	119	6	.32	.50
	1815		.07	.30	12	74	10	63	6	.32	.50
5-16	1200	6	.09	.31	44	332	47	355	25	.62	.90
	1515	7	.09	.31	36	292	40	325	33	.62	.90
	1730	6	.11	.37	24	223	26	242	18	.54	.76
	1930	4	.11	.37	14	130	31	288	18	.54	.76
5-24	1140	6	.07	.28	7	37	3	16		.27	.40
	1430	6	.07	.28	6	40	2	13		.27	.40
5-30	1230		.09	.41	15	115	14	108	3	.28	.43
	1530	13	.09	.41	14	114	16	130	4	.28	.43
	1800	10	.09	.41	16	125	14	109	6	.28	.43
	2000		.09	.41						.28	.43

EAST #2

					Suspended Sediment Natural		Flume		Bedload		
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
6-7	1100	9	.05	.23	7	34	11	54	17	.42	.74
	1400	11	.05	.23	9	53	8	47	21	.42	.74
	1630	11	.05	.23	4	16	3	12	18	.42	.74
	1830		.05	.23						.42	.74
6-16	1120	10	.07	.30	12	74	11	68	5	.30	.43
	1445	12	.05	.22	14	59	17	72	6	.67	.81
	1745	12	.05	.22	7	30	8	34	28	.67	.81
6-21	1415	11	.06	.26	10	53	11	58	3	.19	.30
	1645	10	.06	.26	13	69	12	64	2	.19	.30

HAWKINS

					Suspended Sediment						
					Natural		Flume		Bedload		
Date	Time	Temp. C°	Disch. m³/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D50 mm	D65 mm
6-7	1200	8	.17	.80	38	550	154	2227	833	.82	1.20
	1445	7	.34	1.39	210	6230	170	5043	300	.21	.37
	1730	6	.27	.90	317	7391	438	10212	426	.72	1.3
	1915	6	.26	.85	208	4722	248	5630	407	.72	1.4
6-15	1115	8	.11	.51	8	78	13	127	102	3.7	5.0 (e)
	1415	9	.11	.51	10	98	8	78	138	3.7	6.0 (e)
	1645	9	.11	.51	8	78	5	49	78	3.7	6.0 (e)
	1830	8	.11	.51	11	107	15	146	56	3.7	6.0 (e)
6-21	1130	8	.06	.42	22	119	9	49	12	2.6	4.7
	1430	9	.06	.43	15	83	19	105	16	2.6	4.7
	1730	9	.06	.43	10	55	2	11	20	2.6	4.7
6-29	1030	7	.04	.28	7	24	10	35		1.65	2.6 (e)
	1400	10	.04	.36	10	35	6	21	23	1.65	2.6 (e)
	1615	11	.04	.33	9	32	9	31	35	1.65	2.6 (e)
	1815	9	.05	.41	8	32	9	36	26	1.65	2.6 (e)
7-11	1130	9	.04	.32	2	7	1	4	2	.15	.26
	1430	11	.04	.31	1	4	1	4	2	.15	.26
	1700	12	.04	.28	1	3	2	6	1	.15	.26

HORSETHIEF CREEK

Date	Time	Temp. C°	Disch. m³/sec	Vel. m/sec	Suspended Sediment Natural Conc. mg/l	Suspended Sediment Natural Yield kg/day	Suspended Sediment Flume Conc. mg/l	Suspended Sediment Flume Yield kg/day	Bedload Yield kg/day	Bedload D_{50} mm	Bedload D_{65} mm
4-06	0500	2	.05	.75	3	23	7	53	.7	.50	.80
	0645	3	.05	.75	4	23	1	6	1.9	.50	.80
	0845		.05	.75	3	18	3	18	.4	.50	.80
	1130		.05	.75	9	45	7	35	1.2	.50	.80
	1330	1	.05	.75	11	65	6	35	.5	.50	.80
	1530	2	.05	.75	10	61	10	61	1.4	.50	.80
	1730	1	.05	.75	10	59	10	59	.7	.50	.80
	1945	0	.05	.75			2	12	.5	.50	.80
4-13	1100	4	.19	.72	26	288	29	321	2	.34	.42
	1515	4	.19	.72	26	359	26	359	3	.34	.42
	1700	3	.19	.72	35	791	30	678	5	.34	.42
	2130	1	.19	.72	36	658	30	560	3	.34	.42
4-18	1100	4	.13	.15	4	50	1	13	3	.50	.70
	1430	4	.13	.15	7	73	3	31	1	.50	.70
	1700	4	.13	.15	16	155	13	125		.50	.70
	1930	2	.13	.15	9	104			3	.50	.70
4-26	1100	5	.16	.34	20	243	22	267	2	.20	.31
	1400	5	.16	.34	18	249	20	276	3	.20	.31
	1630	4	.16	.34	20	283	15	212	4	.20	.31
	2000	3	.16	.34	17	231	25	314	4	.20	.31
5-19	1100	7	.42	.67	24	873	30	726	341	4.0	7.6 (e)
	1400	6	.68	.92	48	2837	64	3783	155	5.6	7.8 (e)
	1700	7	.99	1.08	57	4909	52	4479	968	4.0	6.2 (e)
	2000	4	.99	1.08	80	6890	79	6804	944	4.0	6.2 (e)
5-23	1230	4	.51	.79	22	966	14	615	154	6.2	7.6 (e)
	1500	4	.49	.77	10	424	0	0	53	1.8	2.4
	1800	4	.43	.73	3	112	.7	26	33	5.2	7.2 (e)
5-30	1230	7	.41	.74	4	127	8	354	26	.92	1.10
	1515	8	.41	.74	3	107	7	350	21	.92	1.10
	1815	5	.41	.74	4	152	5	190	14	.92	1.10

HORSETHIEF #2

					Suspended Sediment Natural		Suspended Sediment Flume		Bedload		
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
6-6	1130	10	.23	.64	6	122	8	163	501	10+	10+
	1430	13	.27	.67	3	70	8	186	41	10+	10+
	1700	14	.21	.58	7	124	8	142	432	10+	10+
6-15	1230	10	.17	.58	3	45	5	74	248	10+	10+
	1500	14	.12	.43	3	30	5	50	193	7.0 (e)	10+
	1745	13	.12	.43	2	20	2	20	717	7.0 (e)	10+
	1915	13	.12	.43	4	40	3	30	60	7.0 (e)	10+
6-21	1230	11	.12	.41	11	114	11	114	340	10+	10+
	1530	13	.12	.41	8	83	4	41	122	10+	10+
	1830	12	.12	.41	13	134	10	103	202	10+	10+
7-5	1000	8	.06	.30	0	0	5			5.6 (e)	7.5 (e)
	1350	12	.05	.28	0	0	0	0	2	1.2	2.0
	1620	13	.05	.28	0	0	0	0	2	1.2	2.0
	1840	12	.15	.28	0	0	0	0	2	1.2	2.0

NO NAME CREEK

					Suspended Sediment Natural		Suspended Sediment Flume		Bedload		
Date	Time	Temp. C°	Disch. m³/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
4-23	1100	6	.06	.33	10	45	14	63	2	.15	.21
	1340	7	.06	.33	25	145	21	122	2	.15	.21
	1640	4	.10	.47	106	923	106	923	17	.11	.16
	1915	3	.14	.62	99	1189	94	1129	37	.17	.3
4-26	1145	6	.10	.32	36	297	32	264	19	.17	.17
	1600	3	.14	.38	61	764	64	802	60	.35	.35
	1915	2	.14	.38	65	814	61	764	90	.35	.35
5-05	1200	4	.13	.48	38.2	432	25.7	291	209	.72	1.15
	1515	5	.14	.56	39	482	42.9	530	320	.92	1.4
	1845	4	.14	.53	3	36	10	119	110	1.15	1.65
5-15	1115	8	.17	.34	18	266	14	207	128	1.65	2.1 (e)
	1445	9	.21	.56	16	291	17	309	118	1.55	2.4 (e)
	1745	8	.23	.58	13	253	23	448	232	1.7	2.7 (e)
	2020	4	.23	.59	34	670	12	237	117	1.7	2.5 (e)
5-24	1130	10	.14	.66	20	248	5	64	24	1.4	2.1 (e)
	1500	12	.14	.63	4	48	5	60	212	2.2	3.5
	1745	10	.14	.66	1	12	4	49	42	1.4	2.1 (e)
	2015	7	.14	.63	7	83	.3	4	172	2.2	3.5
5-31	1230	13	.08	.58	24	167	17	118	20	1.55	2.6
	1545		.08	.58	29	201	16	111	21	1.55	2.6
	1945	9	.08	.58	53	368	20	139	16	1.55	2.6
6-8	1300	13	.05	.37					18	1.0	1.5
	1600	13	.04	.32	11	39	15	54	2	1.7	4.0 (e)
	1830	12	.04	.32	15	54	16	57	37	1.7	4.0 (e)
6-14	1230		.06	.24	5	25	3	15	24	2.25	3.5
	1515		.06	.24	4	20	10	50	93	2.25	3.5
	1800		.06	.24	4	20	3	15	177	2.25	3.5

NO NAME #2

					Suspended Sediment						
					Natural		Flume		Bedload		
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
6-22	1120	12	.42	.36	9	31	18	61	11	2.7	6.0
	1430	13	.26	.20	19	40	17	36	22	.9	1.4
	1700	13	.26	.20	16	32	22	44	25	.9	1.4

ROCK CREEK

					Suspended Sediment				Bedload		
					Natural		Flume				
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/1	Yield kg/day	Conc. mg/1	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
4-14	1145	10	.03	.33	57	148	51	133	14	.90	1.75
	1600	11	.04	.40	57	176	58	179	20	.70	1.25
	1900	9	.03	.35	60	140	48	112	32	.70	1.10
4-20	1100	8	.03	.69	31	89	27	77	28	1.0	1.45
	1415	10	.03	.69	25	72	25	72	457	1.0	1.45
	1630	9	.03	.69	33	95	29	83	19	1.0	1.45
	1845	7	.03	.69	27	77	25	72	24	1.0	1.45
4-27	1230	12	.03	.65	59	163	19	53	29	.79	1.20
	1600	12	.03	.52	6	17	26	74	25	.90	1.38
	1845	10	.03	.52	27	77	31	88	14	.90	1.38
5-06	1130	6	.05	.64	43	170	53	209	50	.80	1.50
	1430	7	.05	.64	51	201	49	193	13	.80	1.50
	1730	10	.04	.62	54	192	51	181	14	.80	1.39
5-11	1030	9	.05	.55	68	273	67	269	39	1.10	2.00
	1345	13	.05	.40	68	293	67	289	22	.35	.50
	1645	13	.05	.42	71	294	88	365	48	1.38	3.50 (e)
5-17	1100	7	.05	.47	72	305	53	225	49	.48	1.20
	1400		.05	.48	70	314	77	345	26	2.05	3.00
	1700	11	.04	.44	120	447	131	488	90	2.20	3.00
5-25	1100	8	.04	.38	57	197	52	180	45	.86	1.25
	1400	11	.06	.53	94	454	103	497	34	.48	.95
	1615	11	.04	.42	47	174	70	259	23	.50	.88
5-29	1130	7	.07	.59	135	788	134	782	109	.66	1.12
	1500	13	.06	.50	121	626	120	621	105	1.00	1.52
	1815	12	.04	.40	96	351	93	340	761	.69	1.02

ROCK #2

					Suspended Sediment				Bedload		
					Natural		Flume				
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
6-6	1240	12	.04	.49	224	857	182	696	3360	1.90	2.50
	1545	16	.04	.37	204	650	163	520	2263	1.62	2.50
	1830	13	.04	.37	166	529	165	526	761	1.62	2.50
	2145	12	.06	.52	292	1582	317	1718	2555	1.80	2.50
5-14	1015	11	.06	.70	321	1605	278	1390	7557	1.80	2.60
	1330	12	.05	.62	392	1547	295	1164	8008	1.25	1.90
	1700	13	.04	.55	164	575	130	456	1792	1.42	2.20
	2000	11	.05	.61	479	2149	197	884	8351	2.00	2.62
6-30	1115	12	.03	.40	43	117	43	117	286	1.20	1.72
	1500	14	.02	.34	45	96	51	109	750	1.20	1.74
	1800	14	.02	.35	28	50	26	47	156	.70	1.21

SPRATT CREEK

					Suspended Sediment				Bedload		
					Natural		Flume				
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
4-13	1230	4	.28	.45	50	1190	30	714	75	1.0	1.4
	1400	6	.28	.44	43	1054	42	1030	141	.98	1.4
	1745	2	.31	.47	56	1503	46	1235	180	.80	1.2
	1945	2	.27	.47	182	4225	130	3018	103	.82	1.35
4-18	1200	8	.24	.28	19	388	16	326	34	.88	1.2
	1600	7	.24	.28	13	265	17	347	228	1.10	1.60
	1810	4	.28	.30	18	436	14	339	38	.88	1.15
	2045	3	.30	.34	19	487	21	538	47	1.00	1.40
4-26	1000	6	.34	.30	41	1224	44	1314	76	1.10	1.50
	1300	6	.35	.34	42	1259	41	1230	65	1.25	1.80
	1600	6	.33	.27	41	1160	39	1103	72	1.05	1.55
	1900	4	.40	.30	43	1435	45	1554	96	1.10	1.65
5-23	1100	4	.85	.85	422	31007	338	24835	4928	8.8 (e)	10+ (e)
	1400	6	.98	.90	442	37309	578	48789	4409	3.4	5.5
	1700	4	.97	.86	466	39129	930	78090	3037	5.6	8.5 (e)
5-30	1130	6	1.04	.92	189	16977	314	28187	5504	4.6	7.8 (e)
	1415	9	.99	.82	300	25691	499	42732	8198	3.0	5.0
	1700	6	1.41	.82	610	74521	800	97732	9946	2.4	4.2
	1930	4	1.28	.84	324	35777	553	61063	5882	1.05	1.8
6-6	1030	9	1.01	.87	88	7670	338	29459	2939	3.4	4.6
	1330	9	1.01	.87	186	16211	257	22400	3006	3.4	4.6
	1600	12	1.23	.69	295	31396	641	68219	8050	7.2	10+ (e)
	1900	7	1.65	.84	351	50005	727	625601	3974	4.3	6.4 (e)
6-16	1300	12	.64	.77	44	2430	125	6904	692	1.5	2.5
	1645	11	.72	.82	73	4553	100	6237	679	1.9	3.4
	1930		.77	.79	56	3727	133	8853	906	2.1	3.1
6-21	1130	9	.56	.73	23	1123	23	1123	168	1.4	2.6
	1515	12	.66	.80	26	1477	67	3806	880	2.5	4.5
	1730	10	.84	.92	30	2190	32	2336	1400	3.0	5.3
	1930	10	.84	.92	15	1095	51	3722	2399	3.0	5.3

SPRATT #2

					Suspended Sediment				Bedload		
					Natural		Flume				
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
7-5	1110	11	.22	.61	0	0	0	0	22	2.0	4.6
	1500	13	.23	.57	0	0	12	240	21	1.1	1.8
	1730	11	.46	.96	63	2500	0	0	1014	8.0	10+
	1940	12	.33	.74	16	461.3	0	0	177	1.0	1.4

THOMAS CREEK

					Suspended Sediment				Bedload		
					Natural		Flume				
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
4-01	1145	4	.17	.24	28	421	18	271	11	.17	.24
	1445	6	.21	.26	49	872	36	641		.14	.19
	1940	2	.16	.23	30	425	31	439	13	.15	.21
4-9	1100	7	.12	.26	39	331	34	288	8	.45	.66
	1430	10	.12	.26	44	551	25	313	11	.45	.66
	1715	8	.12	.26	67	655	71	695	12	.45	.66
	1950	5	.12	.26	43	455	58	614	8	.45	.66
4-16	1040	1	.13	.27	32	370	28	323	50	.60	.82
	1315	2	.13	.27	28	314	21	236	36	.60	.84
4-23	1030	6	.09	.22	18	133	21	155	21	.82	1.1
	1530	9	.10	.26	21	176	15	125	29	.66	.84
	1940	6	.11	.20	16	147	17	156	42	.76	1.0
4-28	1000	7	.11	.23	9	88	14	136	103	.6	.90
	1300	8	.12	.25	11	115	7	73	45	.52	.78
	1600	9	.12	.25	17	188	16	177	54	.52	.78
	1900	6	.12	.25	6	64	10	107	47	.52	.78
5-6	1000	4	.14	.27	29	347	26	311	78	1.0	1.35
	1345	8	.14	.28	34	424	33	412	188	.76	.98
	1630	8	.14	.28	18	225	13	162	188	.76	.98
	2030	5	.15	.30	16	207	32	414	162	1.0	1.35
5-11	1200	9	.16	.28	27	384	24	341	276	.98	1.30
	1500	11	.19	.30	38	639	35	389	286	.98	1.25
	1830	8	.19	.29	72	1177	58	948	393	1.2	1.6
	2100	4	.19	.29	32	523	33	540	253	1.2	1.6
5-17	1045	7	.16	.31	19	266	26	365	194	1.2	1.6
	1400		.18	.34	33	523	60	950	243	1.0	1.4
	1700	12	.21	.34	58	2285	85	1523	169	1.1	1.5
	1945	9	.17	.30	48	723	72	1084	385	1.5	2.0

THOMAS #2

					Suspended Sediment				Bedload		
					Natural		Flume				
Date	Time	Temp. C°	Disch. m³/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
5-25	1030	4	.16	.28	31	421	25	340	112	1.25	1.8
	1300	8	.16	.29	32	457	39	556	127	1.0	1.55
	1530	7	.19	.32	36	582	44	711	144	1.15	1.7
	1730	7	.18	.31	35	547	36	563	139	1.3	1.85
5-31	1115	9	.18	.34	41	646	66	1040	200	1.0	1.55
	1415	12	.16	.30	52	699	61	819	154	2.0	3.6
	1700	11	.23	.35	71	1387	73	1426	280	.9	1.3
	1940	8	.22	.34	70	1351	96	1852	176	.94	1.5
6-7	1145	10	.20	.28	21	362	36	621	255	.84	1.3
	1500	-	.23	.30	100	2030	72	1462	390	1.0	1.6
	1800	-	.28	.31	166	3964	187	4465	519	2.65	3.5 (e)
	2015	-	.27	.32	140	3271	127	2965	369	2.65	3.5 (e)
6-16	1000	7	.19	.31	32	530	29	481	86	1.0	1.5
	1300	11	.18	.30	32	512	42	671	89	1.5	1.5
	1545	13	.18	.30	42	671	45	719	110	1.5	1.5
	1830	11	.19	.31	46	767	42	700	107	1.3	1.8
6-27	0915	8	.13	.29	22	239	23	250	51	1.0	1.45
	1415	12	.13	.29	31	337	28	305	57	1.0	1.45
	1720	11	.12	.29	25	267	25	267	173	1.1	1.45
	1930	11	.12	.29	21	222	27	285	122	1.0	1.4

WEST CREEK

					Suspended Sediment						
					Natural		Flume		Bedload		
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
4-05	1300	5	.03	.29	80	230	56	161	.6	.33	.50
	1500	3	.03	.29	58	90	58	90	.6	.33	.50
4-12	1120	5	.05	.31	52	237	46	210	.4	.50	.75
	1330	6	.05	.31	36	125	39	135	1.0	.50	.75
	1540	4	.05	.31	67	260	53	205	2.	.50	.75
	1830	3	.05	.31	59	237	59	237	.7	.50	.75
4-19	1215	7	.03	.21	16	35	25	54	.2	.067	.069
	1500	4	.03	.21	25	66	25	66	.5	.067	.069
	1730	3	.03	.21	35	89	31	79	.4	.067	.069
	2000	2	.03	.21	39	93	22	52	.9	.067	.069
4-30	1200	4	.05	.24	18	75	25	104	2	.33	.48
	1500	4	.05	.24	20	81	26	105	1	.33	.48
	1730	4	.05	.24	26	115	25	111	2	.33	.48
	2030		.05	.24	33	134	32	130	1	.33	.48
5-07	1020	4	.06	.30	1	5	7	34	3	.30	.55
	1330	8	.06	.30	6	31	6	31	2	.30	.55
	1615	6	.06	.30	15	91	16	97	3	.30	.55
	1915	3	.06	.30	12	58	13	63	4	.30	.55
5-16	1315	6	.13	.41	14	165	26	307	29	.77	1.10
	1600	6	.13	.41	21	241	13	149	26	.77	1.10
	1830	3	.13	.41	21	233	22	244	21	1.15	1.80
	2000	3	.13	.41	24	267	30	333	19	1.15	1.80
5-24	1100	4	.12	.40	2	20	3	30	46	.89	1.15
	1400	5	.14	.22	.7	8	4	48	30	1.05	1.45
5-30	1130	9	.13	.40	12	133	10	111	27	1.10	1.50
	1430	13	.14		20	240	22	264	59	.90	1.30
	1715	8	.15	.41	10	129	12	154	64	.90	1.30
	1845	6	.14	.41	67	828	42	519	59	.90	1.30

WEST #2

					Suspended Sediment						
					Natural		Flume		Bedload		
Date	Time	Temp. C°	Disch. m^3/sec	Vel. m/sec	Conc. mg/l	Yield kg/day	Conc. mg/l	Yield kg/day	Yield kg/day	D_{50} mm	D_{65} mm
6-6	1145	8	.26	.54	19	425	24	537	130	1.10	1.6
	1445	9	.29	.54	62	1642	79	2092	261	1.10	1.7
	1715	7	.37	.64	178	5664	143	4551	281	1.10	1.6
	1830	7	.33	1.0	103	2924	101	2867	226	.80	1.3
6-16	1200	9	.31	.52	17	449	16	423	216	1.45	1.60
	1545	12	.29	.49	41	1015	40	991	140	1.10	1.20
	1830	11	.29	.49	25	619	22	545	226	1.10	1.20
6-21	1330	11	.21	.50	19	348	17	311	92	1.00	1.55
	1620	10	.21	.47	21	387	17	313	89	.90	1.30
	1845	8	.21	.47	21	387	20	368	120	.90	1.30