NORMALIZED SUSPENDED SEDIMENT DISCHARGE RELATED TO WATERSHED ATTRIBUTES AND LANDSLIDE POTENTIAL

Henry W. Anderson

Formerly Chief Research Hydrologist, PSW Forest and Range Experiment Station, Forest Service, USDA, Berkeley, CA, U.S.A. 1/

ABSTRACT

Suspended sediment measurements from 61 northern California watersheds were utilized in relating average normalized suspended sediment discharge to 10 watershed attributes. Suspended sediment was normalized by using long-term streamflow of each watershed. Factor analysis showed no confounding among the 10 variables; regression on principal components gave an explained variance of 0.73. Landslide potential variables contributed 42 percent to explained variance; land-use variables, 30 percent; streamflow and rain-snow frequency, 14 percent; geology, including faults, 11 percent; and channel slope, the other 3 percent. The regression coefficients indicated that watershed shape was the least significant variable with palm-shaped watersheds having only 13 percent more sediment discharge than dendritic-shaped watersheds. Sediment discharge differences from watershed areas in the different landslide classes was most significant: sediment discharge from class 6 was 12 times that from class 1. The regression results may be used in estimating sediment yield in watersheds with deficient data.

1/ Presently, Consulting Hydrologist, 959 Sunnyhill Rd., Lafayette, California 94549, U.S.A.

RÉSUMÉ

Le cubage du sédiment suspendu effectué dans 61 bassins hydrographiques de la Californie du Nord a servi à établir le rapport entre la moyenne du débit du sédiment suspendu normalisé et 10 caractéristiques des bassins hydrographiques. Le sédiment suspendu a été normalisé en utilisant, sur une période prolognée, l'écoulement laminaire de chaque bassin hydrographique. L'analyse des facteurs n'a montré aucune confusion dans les 10 variables; la régression des principaux composants a donné une variable expliquée de 0,73. Les variables des possiblités d'éboulement représentaient 42 pour cent de la variable expliquée; l'utilisation du terrain, 30 pour cent; l'écoulement laminaire et la fréquence des pluies et des neiges, 14 pour cent; les types de roches et les failles géologiques, 11 pour cent; et la déclivité du lit, les derniers 3 pour cent. Les coefficients de régression ont montré que la forme du bassin hydrographique était la variable la moins importante, avec, pour les bassins en forme palmée, un débit du sédiment seulement 13 pour cent plus important que pour les bassins de forme dentritique. Les variations de débit du sédiment des zones hydrographiques dans les différentes catégores d'éboulements étaient les plus importantes: le débit du sédiment dans la catégorie d'éboulement 6 était 12 fois plus élevé que celui de la catégorie 1.

ZUSAMMENFASSUNG

Schwebstoffmessungen von 61 Nord-Kalifornischen Einzugsgebieten wurden verwendet, um den durchschnittlichen, normierten Schwebstofffluß mit 10 Einzugsgebietseigenschaften zu vergleichen. Schwebstoffe wurden durch Verwendung des Land-Zeit-Abflusses jedes Einzugsgebietes normiert. Faktorenanalysen zeigten keine Vermengung zwischen den 10 Variablen; die Regression mit den Hauptkomponenten ergab eine erklärte Varianz von 0,73. Rutschungs-Potential-Variable trugen bei 42 % zur erklärten Varianz bei, Bodennutzungsvariable 30 %, Abfluß- und Regen-Schnee-Häufigkeit 14 %, Geologie einschließlich Klüfte/Verwerfungen 11 %, und Gerinne-Gefälle die anderen 3 %. Die Regressions-Koeffizienten zeigten, daß die Einzugsgebietsform die letztsignifikante Variable war, wobei "Palm"-geformte Einzugsgebiete nur 13 % mehr Schwebstofffluß hatten als "dendritisch"-geformte Einzugsgebiete. Sedimentfluß-Differenzen von Einzugsgebietsflächen in den verschiedenen Rutschungsklassen waren am signifikantesten: Sedimentfluß von Klasse 6 war 12 mal größer als von Klasse 1. Regressionsergebnisse können zur Einschätzung von Sedimentfrachten von Einzugsgebieten mit unzulänglichen Daten verwendet werden.

NORMALIZING SEDIMENT DISCHARGE

So that sediment measurements from a watershed for a single year or for a short period of years may be more representative of long-term expectancy of sediment discharge, the measurements must be normalized. One technique of accomplishing normalization is known as the "flow duration-sediment discharge method". Basically the method utilizes, for each year or period of years, the relationship of sediment concentration to stream discharge. Sediment discharge is the product of sediment concentration and streamflow; however, instead of using each year's or period streamflow, the long-term frequency of streamflow is used; giving yearly or period sediment discharge expected under representative long term flow conditions. Perhaps a dozen people have "invented" this procedure, including the author (Anderson, 1954). That application recognized that water quality was also of interest, so the method incorporated the computation of frequencies of sediment concentration by classes from the same data. The method is illustrated by the relationship of sediment concentration to stream discharge for the Eel River and the streamflow flow duration for that stream. A typical computation is shown in Table 1, yielding sediment discharge for a year and the distribution of both frequency of sediment concentrations by percent of time and by percent of volume of the expected long-term flow. Application of the method gives rather consistent year to year estimate of sediment discharge from individual yearly measurements of sediment concentration and associated streamflow (Wallis and Anderson,1965). However, catastrophic events have been found to change watershed conditions at least temporarily (Anderson, 1970), so sediment data utilized in the study reported here were taken from periods in which such catastrophic events had not disturbed basic relationship between sediment concentration and discharge. Typically, the average of three years of estimation of sediment discharge were used as the measured suspended sediment discharge; these are given in the last column of Table 2. As may be seen, the sediment discharge varied widely between catchments from 4 to 2100 metric tons per square kilometer per year.

WATERSHED ATTRIBUTES

To determine the sources and causes of the wide variation in sediment discharge among catchments, the sources and causes were expressed as variables and the value for each variable was determined for each catchment. Aerial photographs were used to determine the land use and condition variables, U.S. Geological Survey topographic maps were used to obtain stream slope and catchment shape, State of California (1966) geologic maps were used to abtain geology, and geologic faults, stream-flow measurements were from U.S. Geological Survey Water Supply Papers, rain-snow frequency of storms were obtained from special relationships previously established (Anderson and Wallis, 1963), and a special U.S. Geological Survey Map of slide potential was used for that variable (Radbruch and Crowther, 1973). Values of the varables for the 61 catchments are given in Table 2 and the definitions of the variables are given in Table 3, together with the means, standard deviations, and the units in which the variables were expressed.

ANALYTICAL METHODS

The relation of suspended sediment discharge to catchment attributes, streamflow and land use variables was studied by use of this general model:

Sediment discharge = f (topography, geology, forest use and condition, streamflow, rain-snow frequency, landslides, geologic faults) (1)

The analysis technique used was priciple component analysis consisting of a factor analysis of the correlation matrix, Varimax rotation of the factors, and regression (Wallis, 1965).

FACTOR ANALYSIS RESULTS

The factor analysis showed no confounding among the 10 variables. The contribution to explain variance in suspended sediment discharge of each of factors was:

Factor	Explained Variance Percent	Factor	Explained Variance Percent
Landslide	31	Rain-Snow Frequency	6
Steep Grasslands	11	Streamflow	4
Poor Logging	9	Topography	4
Geology	8	Forest Fires	2
		Total	73

REGRESSION RESULTS

The regression model selected consisted on a log transformation of all variables except the landslide class. Regression was performed by using the 61 measurements of average suspended sediment discharge and the associated 10 catchment attributes. The 10 variable regression had a standard estimate of 0.359 log units and an explained variance of 73 percent. The regression equation and definition of variables are given in Table 3, with the regression coefficient giving the quantitative relationship between each variable and the suspended sediment discharge. The quantitative effects of each variable may be illustrated by showing the effect of the range in the data analyze and also the extreme effect if 100 percent of a catchment were in that class:

Variable	Multiplies Sediment Range of Data	Maximum Effect
Steep grasslands	2.73	12.9
Landslide potential	4.31	11.7
Watershed steepness	1.36	7.0
Rain-snow frequency	1.52	4.0
Streamflow volume	2.22	3.8
Logging	2.94	3.6
Watershed shape	1.69	3.2
Unconsolidated sediment	2.30	2.4
Geologic faults	1.65	2.0
Forest fires	1.08	1.1

The regression results add quantitative evalution of several important variables not reported previously by Wallis and Anderson (1965) and by Anderson (1975). However, the coefficient for logging in this model includes the effect of roads on sedimentation as part of the logging effects. Detailed evalutions of roads of different standards, in different locations in catchments, and in areas of steep slopes are given in Anderson (1975).

LANDSLIDE POTENTIAL

Because of the importance that the landslide map may have in predicting susceptibility of an area to extreme sediment discharge, the definition of and method of complication of that map need specification. Radbruch and Crowther say, "Data on slope, precipitation, and geologic units -- major factors contributing to landslide -- were generalized and plotted on maps for the entire State (California), which were then evaluated and combined. The resulting map units were subsequently modified by consideration of (1) other factor contributing to landslides; (2) information gained through correspondence or conversation with persons working on geologic mapping, some of it unpublished, in scattered parts of California; and (3) reconnaissance on-the-spot checking in the field, both on the ground and from the air. The map units, therefore, indicate only the estimated relative amount of area covered by landslides for each map unit."

Although no quantitative relationship between the classes numbers and amounts of landslides were implied, an analysis of the landslide classes taken as independent variables indicated a progression from low to high coeffiecients for classes 1 through 6. (This was in contrast with the lack of a consistant progression fround in the analysis of reservoir sedimentation previously reported (Anderson 1975).) The approximate linear progression of the effect on suspended sediment discharge for classes 1 to 6 justified the use of average landslide class for a catchment as the single variable reported here.

As independent analysis was made of the relationship of average landslide class in watersheds to the catchment attributes as a possible clue to how future landslide maps might be prepared. The factor analysis showed the relationship of the explained variation in landslide classes to the various factors:

Factor	Explained Variance Percent	Factor	Explained Variance Percent
Relative rain area	22.3	Poor Logging	3.2
Mean annual streamflow	11.2	Roads	2.3
Slope of tributary streams	6.2	Shape	1.5
Steep grasslands	6.0	Other	0.5
Faults	4.4	Total	57.6

The equation to predict landslide potential was obtained by regressing the average landslide class (AVLS) for the 61 catchements against six of the variables of Table 3, then adjusting for the proportion of each geologic rock types in an area. The equation was:

$$\begin{aligned} AVLS = -11.44 &+ 3.90 \text{ Log RRA} + 1.68 \text{ Log MAQ} + 2.21 \text{ Log S1} \\ &+ 0.59 \text{ Log IGS} + 0.23 \text{ Log FLTS} + 0.11 \text{ Log L1} \\ &+ 1.5 \text{ Franciscan rocks} + 0.2 \text{ Ultrabasic, Metamorphic, or Tertiary sediment rocks} - 0.3 \text{ Mesazoic rocks} \\ &- 2.0 \text{ Granitics, Precambrian sediments, or volcanic rocks} \qquad (2) \end{aligned}$$

The importance of the streamflow and rain area variables in predicting landslides is of particular interest in view of Radbruch and Crowther's (1973) reporting of a "lack of correlation between number of landslides and amount of precipitation." Some of the broad geologic rock types, such as the Tertiary Sediments, show wide variation in landslide potential: more detailed characterization of the geology is needed. It is beyond the scope of this paper to explore further the prediction of landslide potential, but the classification used here was found to be important in predicting sediment discharge. The Radbruch and Crowther map was a useful first attempt at evaluation of the landslide potential; the relations of equation 2 is an extention of their classification in the form of quantitative evaluation of some important variables in landslide prediction.

AN APPLICATION -- REDWOOD CREEK BASIN

One of the problems in evaluating sedimentation for any catchement is the natural or so called baseline of sediment expectation from the catchment. This baseline rate of sedimentation has been considered as the sedimentation rate from which management decisions for needed improvement or allowed increase in sedimentation may be evaluated. We may calculate this baseline, as being the expected sediment discharge from a catchment in the absence of any land use of disturbance such as conversion of forests or brushlands to grass, logging, or forest fires.

I have selected for an illutration a catchment of current management controversy between logging versus protection of the Redwood Park from possible sediment damage. The catchment is the Redwood Creek Basin in north coastal California (drainage area 720 km2). The natural or baseline sediment potential is calculated from the values of the landslide potential, faults, shape, slope, geology, rain area, and streamflow for the catchment, with the coefficients of Table 3 being applied. The resultant expected average annual sediment discharge is 297 MT/km2. Similarly, the average natural sediment discharge for the 61 catchments of Table 2 is 69 MT/km2/year. So the Redwood Creek basin is high in its natural sediment expectancy, 4.3 times as high as the average catchment of this study.

The land use and disturbance is also high. We can calculate the expected effects of the uses by applying the coefficients of Table 3 to the steep grasslands (IGS), the logging (L1), the past forest fires (F10), to give present expected sediment. The comparison of natural and present sediment discharge and average sediment concentration are given below:

Condition	Sediment Discharge MT/km2/Yr	Average Sediment Concentration mg / liter
Natural		
Average all catchments	69	125
Redwood Creek Basin	297	220
Present		
Average All catchments	454	854
Redwood Creek Basin	2,540	1,900

The sedimentation under present conditions in Redwood Creek Basin 2,540 is the average for the three years of measurement 1971-1973. The calculated sedimentation is similar, 2250 MT/km2/yr. We see that in the Redwood Creek Basin, both the natural rate of sedimentation and the increase in sedimentation associated with present land use are higher than average. Presumably more than average care will be needed in management for sediment control in the basin.

CONCLUSIONS

Both natural land attributes, such as slope, geology, and rainfall, and man-induced modifications of the lands resistance to erosion contribute to sedimentation from catchments. The individual contributions may be quantified by the analysis of measured sediment discharge from catchments, inventory of associated catchment attributes, and characterization of the degree and types of land use. In areas of high rainfall and steep terrain, landslides may be a major contributor to sedimentation hazard and to the result effects of land use on sediment production and reduced water quality resulting from sediment. The relationship found in this study have direct application to evaluating sedimentation problems and control in Northern California, and may give some first approximations to evaluations in other areas.

ACKNOWLEDGEMENTS

Much of the basic data assemblage and the computer programs used in the analyses were performed through the facilities of the U.S. Department of Agriculture, Forest Service, Berkeley, California. Those and the contributions of many individuals are gratefully acknowledged.

REFERENCES

Anderson, H.W., 1954: Suspended sediment discharge as related to streamflow, topography, soils and land use. Trans. Amer. Geophys. Union 35 (2), pp. 268-281.

- 1970: Principal components analysis of watershed variables affecting suspended sediment discharge after a major flood. Int. Assoc. Sci. Hydrol. Publ. No. 96, pp. 405-416.

- 1975: Realtion of reservoir sedimentation to catchment attributes, landslide potential, geologic faults, and predicted density. Proc. Int. Symp. Hydrologic Characteristics of River Basins, Dec. 1-8, 1975, Tokyo, Japan. Int. Assoc. Sci. Hydrol. Publ. No. 117, pp. 629-638.

Anderson, H.W. and Wallis, J.R., 1965: Sediment sources, Pacific Coast Basins in Oregon and California. Proc. Federal Inter-agency Sedimentation Conference 1963. U.S. Dept. Agric. Misc. Pub. No. 970, pp 22-30.

Busby, M.W. and Benson: Grid method of determining mean flow distance in a drainage basin. Bull. Int. Assoc. Sci. Hydrol. 20, pp. 32-36, 1960.

Radbruch, D.H. and Crowther, K.C., 1973: Map showing areas of estimated relative amounts of landslides in California. U.S. Geol. Survey, Misc. Geologic Investing. Map 1-747.

State of California, 1966: Geologic maps of California, 1958-1966. Div. Mines and Geol., Sacramento, CA. 17 sheets.

Wallis, J. R., 1965: WALLY1...A large pricipal component regression program with Varimax-rotation of the factor weight matrix. U.S. Forest Serv. Res. Note PSW-96, 6 p.

Wallis, J. R. and Anderson, H.W., 1965: An application of multivariate analysis to sediment network design. Int. Assoc. Sci. Hydrol. Publ. No. 67, pp. 357-378.

TABLE--1. Watershed suspended sediment analysis based upon flow duration and discharge relationship, Eel River at Scotia, USGS No. 11-4770, 1969 sediment concentration sampling

MEAN FLOW CFS	FREQUENCY PERCENT	AMOUNT FLOW	NO. SED SAMPLE	SEDIMENT CONC PPM	TOTAL LOAD
120	10.00	.002	11	0	.00
200	10.00	.003	11	3	.01
335	10.00	.005	11	8	.04
570	10.00	.008	6	16	.13
1280	10.00	.018	13	40	.72
2525	10.00	.036	0	82	2.92
3825	10.00	.054	1	126	6.81
5900	9.00	.075	15	196	14.73
8700	6.00	.074	9	618	45.64
12500	5.00	.088	6	738	65.27
18500	3.00	.078	8	927	72.84
28000	3.00	.119	10	1228	145.91
43000	2.00	.122	13	1701	207.04
64000	1.00	.091	8	2365	214.15
93000	.50	.066	3	3281	215.86
125000	.20	.035	2	4291	151.81
160000	.15	.034	2	5397	183.28
210000	.08	.024	2	6976	165.84
265000	.03	.011	0	8714	98.02
320000	.02	.009	0	10451	94.64
380000	.02	.011	0	12346	132.77
	100	.963	131		1818.4

MEAN FLOW 7067 cfs
Adjusted Mean Sediment Concentration 1818.4 /0.963 = 1890 PPM
Total Suspended Sediment Load In Tons 13140000
Suspended Sediment Load in Tons/SQMI 4221
Suspended Sediment Load in Metric Tons/SQKM 1478
(Susp. Sed. Conc.)= 3.5828 + .03384 ⋆(Flow), Q<7067 cfs.
(Susp. Sed. Conc.)= 343.1 + .03159 ⋆(Flow), Q≥7067 cfs.

Water Quality
Parts Per Million

	LT 5.5	5.5-12	13.-27.	28.-72.	73.-142	GT 142
% Samples	6.9	16.0	13.7	1.5	6.1	55.7
% Days	20.0	10.4	9.4	12.8	8.2	39.0
% Water	.5	.5	.8	2.8	3.1	92.4

Table 2. Catchment attributes and normalized suspended sediment discharge, northern California

Name	USGS No.	Area (Km2)	AVLS	FLTS	CV	S1	USED	IGS	L1	RRA	MAQ	F10	SED
Sagehen Cr.	10-3435	28	2.0	0	44	140	0	16	0	27	11.3	0	3
Piru Cr.	11-1100	1119	3.9	266	51	182	31	2	0	88	1.6	141	322
Sespe Cr.	11-1115	133	4.0	378	47	159	98	5	0	82	3.0	0	287
N. F. Matilija Cr.	11-1160	40	4.2	757	41	250	82	18	0	97	5.8	10144	481
Salispuedes Cr.	11-1325	122	3.9	42	55	102	76	102	0	100	2.0	0	188
Cuyama Rv.	11-1370	2362	4.0	93	55	273	76	399	0	86	0.2	0	256
Nacimiento Rv.	11-1488	363	2.8	98	46	170	52	12	0	100	12.6	16	215
San Francisquito Cr.	11-1645	98	3.7	233	40	140	80	9	0	100	6.0	0	154
Walnut Cr.	11-1835	199	2.9	137	47	100	85	103	0	100	2.0	280	286
Kern Rv.	11-1870	2613	2.0	40	50	278	0	87	0	31	11.8	106	190
Merced Rv.	11-2645	469	2.0	0	52	192	0	1	0	9	20.3	6	4
Cosumnes Rv.	11-3345	1111	2.0	20	44	104	0	9	111	84	11.5	311	33
Cosumnes Rv.	11-3350	1391	2.0	53	32	104	0	9	89	87	9.9	183	40
Cosumnes Rv.	11-3360	1891	2.0	42	47	83	10	13	66	90	8.7	327	106
Sacramento Rv.	11-3420	1106	3.1	25	51	233	0	0	145	72	27.5	80	29
McCloud Rv.	11-3680	1570	2.2	16	46	170	0	0	0	71	30.3	17	102
Clear Cr.	11-3710	298	2.1	0	60	197	0	3	0	86	21.1	574	36
M. F. Cottonwood Cr.	11-3744	645	3.2	44	40	223	46	12	0	92	9.8	672	120
Cottonwood Cr.	11-3760	2448	3.0	55	44	191	24	24	0	91	9.4	905	178
Battle Cr.	11-3765	938	1.8	14	37	81	3	1	0	74	13.7	98	16
Elder Cr.	11-3795	241	4.4	201	45	272	33	0	44	70	11.3	281	189
Thomes Cr.	11-3820	502	5.0	30	39	265	0	11	0	73	15.3	47	992
Grindstone Cr.	11-3865	404	4.8	44	47	252	25	12	141	85	10.8	325	1006
Last Chance Cr.	11-3914	219	2.0	61	33	123	0	22	0	39	4.5	0	84
Big Grizzly Cr.	11-3915	116	2.0	0	46	109	0	27	0	46	9.9	0	45
Indian Cr.	11-4015	1932	2.0	105	47	158	5	6	0	53	7.9	169	88
Castle Cr.	11-4139	10	2.0	0	57	158	0	52	0	20	40.9	0	82
Castle Cr. (logged)	11-4139	10	2.0	0	57	158	0	52	391	20	40.8	0	280
N. F. Cache Cr.	11-4515	513	5.9	105	55	203	4	14	0	96	9.5	1710	244
Bear Cr.	11-4517	251	3.7	177	50	129	0	53	0	99	5.2	297	289
Napa Cr.	11-4560	210	2.8	0	44	180	7	6	0	100	11.6	30	215

Table 2. (con't)

Name	USGS No.	Area (Km^2)	AVLS	FLTS	CV	S1	USED	IGS	L1	RRA	MAQ	F10	SED
Sonoma Cr.	11-4585	161	3.4	17	44	191	24	47	0	100	10.3	47	162
Russian Rv.	11-4610	258	3.8	59	43	133	22	89	22	99	19.0	1547	850
E. F. Russian Rv.	11-4620	269	3.8	47	35	170	5	71	0	99	11.0	652	384
Big Sulfur Cr.	11-4632	213	6.0	299	43	165	0	109	0	97	23.6	1601	1099
Dry Cr.	11-4652	420	5.0	158	47	142	3	179	44	100	17.8	580	650
S. F. Casper Cr.	11-4680	4	4.0	0	49	103	100	0	0	100	15.5	0	89
N. F. Casper Cr.	11-4681	5	4.0	0	49	146	100	0	0	100	15.0	0	47
Outlet Cr.	11-4722	417	5.4	55	47	129	12	83	63	98	25.1	960	277
Eel Rv.	11-4725	922	5.8	38	46	193	0	68	61	97	15.0	1586	1183
Black Butte Rv.	11-4729	420	5.5	61	45	199	0	18	425	74	18.0	38	2055
M. F. Eel Rv.	11-4730	951	5.6	51	47	180	0	8	28	69	31.2	63	1414
Williams Cr.	11-4731	79	6.0	0	43	239	0	14	0	90	45.0	0	772
Short Cr.	11-4736	39	6.0	0	46	188	0	28	0	96	22.0	503	385
Mill Cr.	11-4737	248	4.8	10	41	114	33	31	0	96	14.9	330	627
M. F. Eel Rv.	11-4739	2015	5.5	41	46	206	2	19	98	80	30.7	56	1439
Eel Rv.	11-4740	3836	5.9	39	46	197	15	31	66	80	21.4	727	1232
Hulls Cr.	11-4744	67	6.0	76	53	178	0	43	0	87	44.5	0	214
S. F. Eel Rv.	11-4755	114	4.7	0	50	121	0	8	792	98	45.5	1830	518
S. F. Eel Rv.	11-4765	1391	4.8	84	52	195	7	38	811	98	36.3	639	1747
Eel Rv.	11-4770	7317	5.5	42	41	196	2	41	574	90	24.7	442	1719
Van Duzen Rv.	11-4785	559	6.0	40	50	184	1	48	2165	89	39.2	41	2121
Mad Rv.	11-4805	360	5.7	151	47	231	0	56	0	84	23.6	39	260
Mad Rv.	11-4810	1254	5.9	178	63	215	2	32	900	90	28.7	67	995
Shasta Rv.	11-5175	1751	2.4	0	43	197	0	38	0	74	2.7	141	4
Scotts Rv.	11-5195	1645	2.9	17	46	307	0	18	172	68	9.5	556	98
Trinity Rv.	11-5255	1883	3.0	54	40	313	3	9	0	65	24.0	8	68
Weaver Cr.	11-5258	125	3.9	102	38	260	45	2	0	85	13.0	0	225
N. F. Trinity Rv.	11-5265	391	3.9	169	44	294	3	26	0	70	31.6	16	113
S. F. Trinity Rv.	11-5290	2328	4.3	87	42	259	3	8	0	83	17.6	158	161
Trinity Rv.	11-5300	7376	3.8	84	48	289	3	9	0	76	21.5	123	279
Means		986	4.0	82	45	184	18	37	118	80	17.5	483	454

Table 3.--Suspended Sediment Model, Coefficients, Units, Means, and Standard Deviation of Variables

	Symbol	Definition
Log SS =	-0.326	Regression constant, for suspended sediment in MT/km^2/yr., mean log SS=2.32, s.d. 0.625.
	+0.214 AVLS	Average landslide class from map by Radbruch and Crowther (1973), mean 3.88, s.d. 1.39.
	+0.294 Log IGS	Composite interaction variable made up of percent slope times percent grassland area, % x %/10, mean 1.227, s.d. 0.577.
	+0.139 Log L1	Area classed as logged with roads predominately in draws, m^2/ha, mean 0.754, s.d. 1.088.
	+0.185 Log USED	Area of unconsolidated sedimentary rock types, percent, mean 0.709, s.d. 0.731.
	+0.306 Log RRA	Relative rain storm versus snow frequency (Anderson and Wallis 1965), percent, mean 1.881, s.d. 0.192.
	+0.355 Log MAQ	Mean annual streamflow, liters/sec/km^2, mean 1.176, s.d. 0.316.
	+0.087 Log FLTS	Length of geologic fault zones per unit area of watershed, m/km^2, mean 1.446, s.d. 0.814.
	+0.297 Log S1	Slope of streams of 1500 m. mesh length, m/km^2, mean 2.241, s.d. 0.145.
	+0.010 Log F10	Area of forest fires in the ten years prior to sediment measurements, m^2/ha, mean 1.770, s.d. 1.135.
	-0.345 Log CV	Coefficient of variation of basin flowpath lengths (Wallis and Anderson 1965), with path lengths as suggested by Busby and Benson (1960), unitless, mean 1.672, s.d. 0.055.