

N O R M A L I Z E D   S U S P E N D E D   S E D I M E N T  
D I S C H A R G E   R E L A T E D   T O   W A T E R S H E D  
A T T R I B U T E S   A N D   L A N D S L I D E  
P O T E N T I A L

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.

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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 prolongée, 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 possibilités 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 dendritique. Les variations de débit du sédiment des zones hydrographiques dans les différentes catégories 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 obtain 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 variables 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:

$$\text{Sediment discharge} = f(\text{topography, geology, forest use and condition, streamflow, rain-snow frequency, landslides, geologic faults}) \quad (1)$$

The analysis technique used was principle 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<br>Variance<br>Percent | Factor              | Explained<br>Variance<br>Percent |
|------------------|----------------------------------|---------------------|----------------------------------|
| Landslide        | 31                               | Rain-Snow Frequency | 6                                |
| Steep Grasslands | 11                               | Streamflow          | 4                                |
| Poor Logging     | 9                                | Topography          | 4                                |
| Geology          | 8                                | Forest Fires        | 2                                |
|                  |                                  | Total               | <u>73</u>                        |

### 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 evaluation 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 evaluations 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 coefficients for classes 1 through 6. (This was in contrast with the lack of a consistent progression found in the analysis of reservoir sedimentation previously reported (Anderson 1975).) The approximate linear progression of the effect on suspended sediment dis-

charge 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<br>Variance<br>Percent | Factor       | Explained<br>Variance<br>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 catchments against six of the variables of Table 3, then adjusting for the proportion of each geologic rock types in an area. The equation was:

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

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 extension 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 catchment is the natural or so called baseline of sediment expectation from the catchment. This baseline rate of sedi-

mentation 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 illustration 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 km<sup>2</sup>). 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/km<sup>2</sup>. Similarly, the average natural sediment discharge for the 61 catchments of Table 2 is 69 MT/km<sup>2</sup>/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<br>MT/km <sup>2</sup> /Yr | Average<br>Sediment Concentration<br>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/km<sup>2</sup>/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 catch-

ments. 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

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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<br>CFS | FREQUENCY<br>PERCENT | AMOUNT<br>FLOW | NO. SED<br>SAMPLE | SEDIMENT<br>CONC PPM | TOTAL<br>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        |
|                  | <u>100</u>           | <u>.963</u>    | <u>131</u>        |                      | <u>1818.4</u> |

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.) =  $3.5828 + .03384 * (\text{Flow})$ ,  $Q < 7067$  cfs.

(Susp. Sed. Conc.) =  $343.1 + .03159 * (\text{Flow})$ ,  $Q \geq 7067$  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 (km <sup>2</sup> ) | AVIS | FI/S | 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  |
| Salispuedas 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 Francisco 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   | 1000 |
| 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  | 40.2 | 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 <sup>2</sup> ) | AVLS | FLTS | CV | SI  | USED | IGS | L1   | RPA | MAQ  | FI0  | 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  |
| Del 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

| <u>Symbol</u>   | <u>Definition</u>   |
|-----------------|---|
| Log SS = -0.326 | Regression constant, for suspended sediment in MT/km <sup>2</sup> /yr., mean log SS=2.32, s.d. 0.625.   |
| +0.214 AVL5     | Average landslide class from map by Radbruch and Crowther (1973), mean 3.58, 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 Ll   | Area classed as logged with roads predominately in draws, m <sup>2</sup> /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 <sup>2</sup> , mean 1.176, s.d. 0.316.  |
| +0.087 Log FLTS | Length of geologic fault zones per unit area of watershed, m/km <sup>2</sup> , mean 1.446, s.d. 0.814.  |
| +0.297 Log Sl   | Slope of streams of 1500 m. mesh length, m/km <sup>2</sup> , mean 2.241, s.d. 0.145.  |
| +0.010 Log F10  | Area of forest fires in the ten years prior to sediment measurements, m <sup>2</sup> /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. |

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Autor(en)/Author(s): Anderson Henry W.

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