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# ESTIMATING EROSION AND SEDIMENT YIELD FROM RANGELAND

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## INTRODUCTION

Sediment yields in many rangeland areas of the western United States are larger than might be expected with the low rainfall generally characteristic of the area. These high yields result from: (1) the general low vegetal density inadequately protects the soil against the erosion forces of raindrops and runoff; (2) land slopes are often steep and infiltration is generally low, which results in high shear from the water moving over the land surface; (3) high intensity thunderstorms and their associated high kinetic energy are relatively common, which leads to excessive splash erosion and overland runoff; and (4) channel slopes are generally steep and contain large amounts of alluvium for transport in the runoff.

The problems associated with erosion/sediment yield for downstream areas are well documented. The problems are important not only because of deposition in reservoirs (loss of storage) and channels (decreased conveyance capacity) but also because the sediments often contain appreciable quantities of adsorbed chemicals, which can severely degrade water quality. Recent water quality legislation and the mandates to correct pollution problems in the waters of the United States have created a new emphasis on this problem with water quality.

Another problem is that erosion in upland areas often reduces soil productivity. In western rangeland areas, the problem is often acute because the soil profile in such areas is already insufficient for adequate forage production. Soil erosion reduces a soil's potential for production of forage by: (1) loss of soil water storage capacity; (2) decreased infiltration rate (surface sealing) and increased opportunity for runoff and evaporation; (3) loss of soil nutrients; and to a lesser extent (4) increased weed production; (5) reduced seed germination; and (6) decreased root development.

Methods for estimating erosion and sediment yield from rangelands are based primarily upon the principles developed in parts of the U.S., where cultivated agricultural activities are prevalent. Techniques in corporating disturbance of the soil by tillage are not generally applicable to rangelands, so the erosion estimating techniques must be appropriately adjusted to reflect such differences. Typical problems unique to rangelands are those associated with the different soils of range, the existence of erosion pavements and the protection from raindrop

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impact and shear of surface runoff this affords, grazing and trampling by cattle, and the importance of channel erosion processes. In this paper, some sediment yield formulae are tested against sediment accumulation data from nine small watersheds in the Walnut Gulch Experimental Watershed.

## COMMON TECHNIQUES FOR ESTIMATING SEDIMENT YIELD

Sediment yield estimating techniques vary appreciably in their complexity depending in a large part upon the objective of the investigation and the availability of data. The methods commonly used in estimating sediment yield and some comments regarding problems of using each are:

1. The sediment rating-curve/flow duration method. This method is highly dependent upon the accuracy of sediment concentration measurements at field locations. Meaningful data are difficult to obtain for this method on small watersheds because discharges of water and sediment vary rapidly and there is not enough time to sample accurately without sophisticated permanent sampling equipment.
2. The sediment delivery ratio method. Sediment delivery ratio is a percentage relationship between sediment yield and gross erosion in a watershed. Sediment delivery ratios have been determined for many areas of the country and have been found to be related to the size of the drainage area. The method requires estimation of the erosion from all sources in the watershed, a value difficult to obtain.
3. Reservoir sediment deposition surveys. Rate of accumulation of sediment in a reservoir can be determined when the time period between consecutive surveys is known. Sediment yield is estimated by adding the estimated amount of sediment that passed through the reservoir, based on the reservoir's trap efficiency. These estimates can be used to relate sediment yield to drainage area. The approach provides good information on magnitude and variation of average annual sediment yield within a physiographic region, but has little value for forecasting sediment yield over a short time.
4. Field measurements of erosion and deposition. The difference between erosion and deposition estimates or measurements can be used to estimate sediment yield. The uncertainty of both the erosion and deposition measurements can lead to large error.
5. Bedload relationships. The coarse fraction of sediment yield can be estimated using bedload relationships. Most of these relationships were developed primarily from laboratory flume studies, and they often give widely differing estimates for the same set of field conditions. Furthermore, separate estimates must be made to include the fine sediments in transport.
6. Mathematical simulation models. Such models use relationships for the processes of soil detachment, transport and deposition. These relationships are incorporated into a hydrologic model to estimate sediment yield. This method, widely used in research, will undoubtedly be an important method in the future. However, there are presently many limitations concerning parameter definition, and the method is expensive because of data requirements and computer costs.

(7) Predictive equations based on watershed parameters such as drainage area, runoff, temperature, slope, soils, and cover. Even though such equations apply to a limited range of conditions, they are frequently used. Such predictive equations can be grouped into two categories, statistical and parametric. This latter method was studied, and the results are reported in this paper.

The following sediment yield prediction equations or techniques were tested.

Pacific Southwest Interagency Committee Method (PSIAC):

The method developed by the Water Management Committee of the PSIAC (9) was intended for broad planning rather than for specific project formulation where more intensive investigations are required. Although this method was intended for use in areas larger than 10 $mi^2$, I tested it here to demonstrate a method that might be readily used within a land resource area (1) to provide realistic answers for planners. Testing the method improves the confidence of the user in selecting parameter values that reproduce observed data.

Nine factors were recommended for consideration in determining the sediment yield classification for a watershed. The factors are (A) geology, (B) soils, (C) climate, (D) runoff, (E) topography, (F) ground cover, (G) land use, (H) upland erosion and (I) channel erosion/sediment transport. Each factor is assigned a numerical value from a rating chart (9) which is too long to reproduce here. Descriptive terms for three sediment yield levels (high, moderate, low) for each factor are used to select the numerical value. Summing the rating chart values for the nine factors defines a sediment yield rating classification, which in turn can be converted to the average annual sediment yield in ac-ft/$mi^2$/yr using Table 1.

TABLE 1.—SEDIMENT YIELD CLASSIFICATION

| RATING | CLASSIFICATION | ANNUAL SEDIMENT YIELD AC-FT/$MI^2$ |
|---|---|---|
| > 100 | 1 | > 3.0 |
| 75 to 100 | 2 | 1.0 to 3.0 |
| 50 to 75 | 3 | 0.5 to 1.0 |
| 25 to 50 | 4 | 0.2 to 0.5 |
| 0 to 25 | 5 | < 0.2 |

Numerical values for each of the nine factors range from 25 to minus 10. Although only three levels are suggested for general use in the rating chart, a footnote states that if experience so dictates, interpolation between the three sediment yield levels may be made. Such interpolation was used in the study.

Figure 1 was developed from the data in Table 1 to assist in interpolation between the classifications of the table. Although such precision was not intended for the original method, I felt that such a scheme could provide additional insight into the capacity of the technique to reflect differences in the observed data.

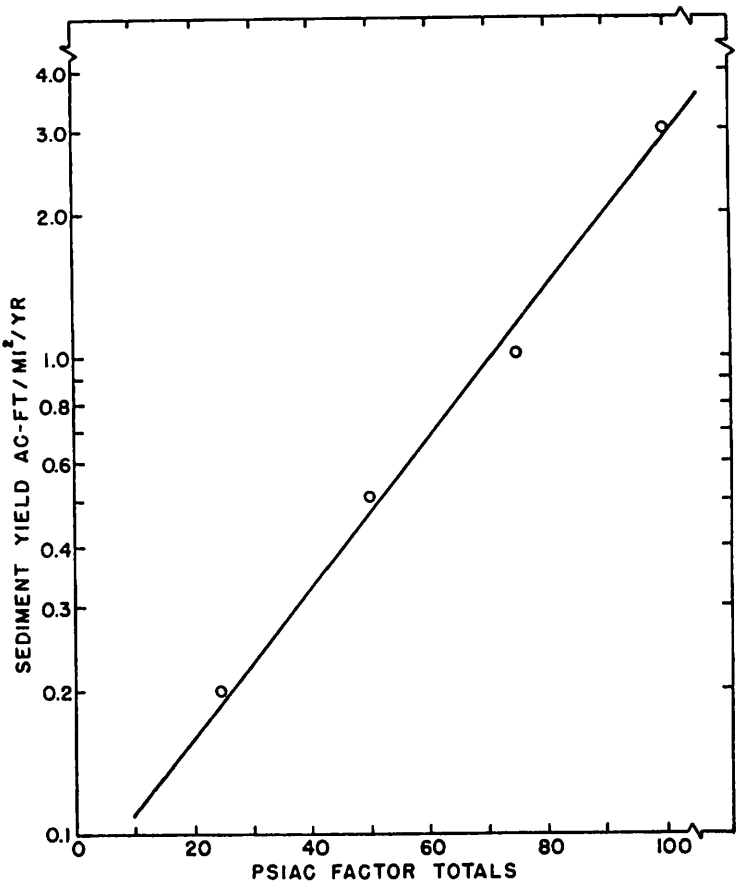


FIG. 1.—SEDIMENT YIELD FACTOR RELATIONSHIP FOR PSIAC SEDIMENT YIELD ESTIMATING METHOD

Dendy/Bolton Method:

Dendy and Bolton (2) derived sediment yield equations having widespread applicability because they used data from over 800 reservoirs throughout the country to obtain measured sediment yield values. They segregated the data into areas where runoff was either less than or greater than 2 in. per yr. In areas where runoff is less than 2 in., they derived the equation:

$$S = 1280\ Q^{0.46}(1.43 - 0.26 \log A) \qquad (1)$$

where $S$ = sediment yield ($t/mi^2/yr$)
$Q$ = annual runoff (in.)
$A$ = watershed area ($mi^2$).

Because of widely varying local factors the authors may not have intended for this equation to be used for a specific location. However, the equation does express a rational relationship for sediment yield that I think is realistic for conditions encountered in the southwest.

To estimate the average annual runoff for a watershed, I used the relationship developed by Renard (10) for the Walnut Gulch Experimental Watershed:

$$Q = 0.4501\ A^{-0.1449} \qquad (2)$$

where the terms are as defined above. Substituting Eq. 2 into Eq. 1 gives

$$S = 887\ A^{-.0667}\ (1.43 - 0.26 \log A) \qquad (3)$$

To convert the annual sediment yield to ac-ft/$mi^2$/yr, I assumed the sediment deposited weighed 90 lbs/$ft^3$.

Flaxman Method:

Flaxman (4) developed a regression equation for reservoir design on rangeland watersheds in the western U.S. relating sediment yield to four parameters. His expression is

$$\log (Y + 100) = 6.21301 - 2.19113 \log (X_1 + 100) + 0.06034 \log (X_2 + 100) - 0.01644 \log (X_3 + 100) + 0.04250 \log (X_4 + 100) \qquad (4)$$

where $Y$ = antilog of [log (Y + 100)] - 100.
$Y$ = average annual sediment yield (ac-ft/$mi^2$/yr)
$X_1$ = ratio of average annual precipitation (in) to average annual temperature
$X_2$ = average watershed slope (%)
$X_3$ = soil particles greater than 1.0 mm (%)
$X_4$ = soil aggregation index

The parameters are expressions of climate and also reflect vegetative growth ($X_1$ ), topography ($X_2$) and soil properties ($X_3$ and $X_4$). The equation explained about 91% of the variance in average annual sediment yield from 27 watersheds ranging in size from 12 to 54 $mi^2$ in 10 western states.

Renard Method:

A method for estimating sediment yield was developed by Renard (12) and Renard and Laursen (11). This method uses a stochastic runoff model (3), which generates hydrographs for semiarid watersheds in the southwestern United States, and it uses a deterministic sediment transport relationship (8). Sediment yield is then computed by simulating individual hydrographs and computing the sediment transport for the simulated hydraulic conditions. Annual yield is the sum of the yield of individual runoff events. Thus sediment yield is a function of runoff, hydrograph peak, Manning's roughness, slope, hydraulic radius and the size distribution of the sediment in the streambed. The method was applied and calibrated with sample data for several of the larger watersheds on Walnut Gulch in southeastern Arizona. With the model, a simplified relationship was developed which relates the annual sediment yield to watershed drainage area in the form

$$Y = 0.001846\ A_a^{-.1187} \tag{5}$$

where $Y$ = average annual sediment yield in ac-ft/ac/yr
$A_a$ = drainage area in acres

Thus, because of transmission losses (abstractions from runoff by the alluvial channels) in the watershed, water yield decreases with increasing drainage area and this same trend is reflected in the sediment yield relationship. Conversions are required to produce the units comparable to the other methods.

## WATERSHEDS CONSIDERED

The Walnut Gulch Experimental Watershed is a 58 $mi^2$ drainage in southeastern Arizona operated by the Science and Education Administration of USDA to evaluate the effect of land use and conservation practices on water and sediment yield of arid and semiarid rangelands. The watershed in the Southeastern Arizona Basin and Range land resource area (1) is typical of the intermountain alluvial areas of the southwest. Elevations in the watershed range from 4200 to 6000 feet above mean sea level. Cover in the watershed is a mixture of brush and grasses with vegetation basal areas less than 10%. Soils are typically calcareous with large amounts of gravel and larger material. A gravel pavement develops with erosion on the land surface, and in some areas it represents nearly a 100% cover.

Precipitation in the area, which averages about 14 in/yr, is dominated by summer rainfall (about two-thirds of the annual) consisting of high-intensity, short-duration thunderstorms of limited areal extent. Winter storms are generally of greater areal extent and of low intensity so that runoff is not common. The summer air-mass thunderstorms result in high peak flows that generally have high sediment loads.

Within the watershed, a number of small earthen dams (stock ponds) provide water for the grazing animals. Periodic topographic surveys of the pond storage area have been made to determine sediment accumulations. The nine ponds for which such information was available are shown in Table 2 along with data on the characteristics of the watershed area. The ponds generally have enough storage space that discharge through the emergency spillway is infrequent. Pond 223 spilled more often than the others.

TABLE 2.—CHARACTERISTICS OF STOCK TANKS AT WALNUT GULCH AND OF THE CONTRIBUTING WATERSHEDS

| Tank no. | Drainage area $mi^2$ | Record length | Soil association[1] | Vegetation | Measured annual sediment accumulation $ac\text{-}ft/mi^2$ |
|---|---|---|---|---|---|
| 201[2] | 0.170 | 1960-70<br>1971-79 | Rillito-Karro | Brush<br>Grass | 0.49<br>0.13 |
| 207 | 0.428 | 1962-77 | Rillito-Cave-Tortugas | Brush | 0.11 |
| 208 | 0.356 | 1973-77 | Hathaway-Bernardino | Grass | 0.13 |
| 212 | 1.316 | 1964-77 | Cave-Rillito-Laveen, and Tortugas | Brush | 0.11 |
| 213 | 0.616 | 1962-79 | Graham-House Mountain | Brush/Grass | 0.09 |
| 214 | 0.581 | 1957-77 | Hathaway-Bernardino | Grass | 0.37 |
| 215 | 0.136 | 1966-77 | Hathaway-Nickel | Brush | 0.70 |
| 216 | 0.325 | 1962-77 | Hathaway-Bernardino | Grass | 0.51 |
| 223 | 0.169 | 1962-77 | Rillito-Laveen | Brush | 0.30 |

[1] From Gelderman (1970)
[2] The tank drainage was root plowed and reseeded in 1971

## DISCUSSION OF RESULTS

Tables 3, 4, and 5 summarize the results of the investigation. The values assigned to each of the nine factors used in the PSIAC method (Table 3) were made using some interpolation between the three yield levels defined in the manual. This was consistent both with my knowledge of the watersheds and my familiarity with the method (I participated in its development). Several watershed estimates agree with the observed data.

TABLE 3.—SUMMARY OF THE VACTOR VALUES USED TO ESTIMATE SEDIMENT YIELD WITH THE PACIFIC SOUTHWEST INTERAGENCY COMMITTEE METHOD

| Tank number | Factor values[1]/ | | | | | | | | | | Computed annual sediment yield ac-ft/mi$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | Total | |
| 201 B | 5[2] | 5 | 8 | 2 | 1 | -5 | 0 | 10 | 10 | 36 | 0.28 |
| 201 G | 5 | 5 | 8 | 1 | 1 | 0 | -10 | 5 | 10 | 25 | 0.19 |
| 207 | 2 | 2 | 8 | 2 | 8 | -8 | - 5 | 10 | 5 | 24 | 0.18 |
| 208 | 5 | 3 | 8 | 2 | 1 | -5 | 2 | 5 | 0 | 21 | 0.16 |
| 212 | 3 | 5 | 8 | 1 | 1 | 0 | 0 | 10 | 10 | 38 | 0.30 |
| 213 | 2 | 2 | 8 | 2 | 5 | -5 | 0 | 5 | 5 | 24 | 0.18 |
| 214 | 5 | 5 | 8 | 2 | 2 | 0 | 2 | 5 | 15 | 44 | 0.38 |
| 215 | 5 | 3 | 8 | 2 | 1 | -2 | 0 | 15 | 15 | 47 | 0.42 |
| 216 | 5 | 5 | 8 | 1 | 2 | 0 | 0 | 10 | 5 | 36 | 0.28 |
| 223 | 5 | 2 | 8 | 2 | 0 | -5 | - 5 | 10 | 20 | 37 | 0.29 |

[1]The factors are defined on p. 3 of the text.
[2]Some interpolation between the three yield levels defined in the manual (9) was used.

TABLE 4.—PREDICTION OF SEDIMENT YIELD FROM WATERSHEDS AT WALNUT GULCH USING HAXMAN METHOD (EQUATION 4)

| Tank number | Factor values[1] | | | | Annual sediment yield Y ac-ft/mi$^2$ |
|---|---|---|---|---|---|
| | $X_1$[2] | $X_2$ | $X_3$ | $X_4$ | |
| 201 | 0.192 | 5.3 | 72 | 0 | -0.180 |
| 207 | 0.206 | 6.9 | 55 | 0 | 0.049 |
| 208 | 0.179 | 8.6 | 47 | 0 | 0.313 |
| 212 | 0.206 | 5.8 | 41 | 0 | 0.142 |
| 213 | 0.206 | 11.0 | 46 | 0 | 0.375 |
| 214 | 0.216 | 8.6 | 52 | 0 | 0.154 |
| 215 | 0.216 | 8.7 | 44 | 0 | 0.249 |
| 216 | 0.216 | 12.0 | 52 | 0 | 0.341 |
| 223 | 0.206 | 9.4 | 65 | 0 | 0.085 |

[1]Factor values are defined on p. 5 for use in Eq. 4.
[2]Average temperature at Tombstone is 63.1°F. Some adjustment was made based on elevation differences between the Tombstone weather station and the pond (3°F increase per 1000 ft elevation decrease).

TABLE 5.—MEASURED AND PREDICTED ANNUAL SEDIMENT YIELD (AC-FT/MI$^2$) FOR SELECT SEMIARID RANGELAND WATERSHEDS

| Tank number | Measured yield | Predicted yield | | | |
|---|---|---|---|---|---|
| | | PSIAC | Dendy/Bolton | Flaxman | Renard |
| 201 B[1] | 0.49 | 0.29 | 0.83 | -0.180 | 0.68 |
| 201 G | 0.13 | 0.19 | | | |
| 207 | 0.11 | 0.18 | 0.73 | 0.049 | 0.61 |
| 208 | 0.13 | 0.16 | 0.75 | 0.313 | 0.62 |
| 212 | 0.11 | 0.30 | 0.62 | 0.142 | 0.53 |
| 213 | 0.09 | 0.18 | 0.69 | 0.375 | 0.58 |
| 214 | 0.37 | 0.38 | 0.70 | 0.154 | 0.59 |
| 215 | 0.70 | 0.42 | 0.85 | 0.249 | 0.69 |
| 216 | 0.51 | 0.28 | 0.76 | 0.341 | 0.63 |
| 223 | 0.30 | 0.29 | 0.83 | 0.085 | 0.68 |

[1] The B and G refer to brush and grass cover associated with the 1971 treatment of the watershed.

The Flaxman method also agreed fairly well with the measured data because it was developed using data from a wide range of watershed conditions in the western United States including three watersheds in Arizona. In contrast with two of the other methods, it does not have a term reflecting drainage area. Historically, most sediment yield estimating equations include either runoff or watershed area or both.

The Dendy-Bolton method overestimated sediment yield in all cases. Prediction might have been more accurate if actual runoff data had been available to use in equation 1. Because the method involves only two parameters, it would not be expected to explain as much of the observed variance as other methods.

The Renard method also overestimated the sediment yield in all but one case. Predictions might improve if the technique was used to simulate the yield using channel characteristics and observed runoff for each individual watershed rather than the average conditions with which the model was calibrated. For example some of the ponds had grass swails; in other locations, the channels were more rectangular and contained large amounts of sand, which more nearly duplicated the conditions of the large watersheds. Thus sediment accumulation in tanks with sand channels (208, 214, 215, 216, and 223) would be expected to be closer to the predicted, as observed on all but tank 208.

A linear regression was computed between the measured and predicted sediment yields for each of the methods tested. The results are summarized in Table 6. It is not surprising that the $r^2$ values are as low as they are partly because of the relatively narrow range of sediment yield values for the data sets. At the same time, the very low value for the Flaxman method is surprising. This test indicated that the PSIAC method is statistically the best method to use.

TABLE 6.—REGRESSION OF ACTUAL VERSUS PREDICTED SEDIMENT YIELDS: PREDICTED = a(actual)+b

| METHOD | N | a | b | $r^2$ |
|---|---|---|---|---|
| PSIAC | 10 | .326 | .172 | 0.63 |
| Dendy-Bolton | 9 | .226 | .685 | 0.39 |
| Flaxman | 9 | .077 | .147 | 0.01 |
| Renard | 9 | .158 | .577 | 0.39 |

## REPRESENTATIVENESS OF SHORT RECORDS

When relatively short records are used in developing and testing prediction schemes such as the sediment yield method tested herein, one immediately wonders whether the sample includes all extremes of the climate and if the mean value indicates a long term mean. In the southwestern United States, the coefficient of variation of annual precipitation is maximum for any of the locations considered by Hershfield (6). Knisel et al. (7) investigated methods to evaluate the length of record necessary for water resource data collection. One of the methods investigated involved a cumulative surplus/deficit analysis of the annual precipitation. The surplus/deficit analysis depicts trends that may otherwise be obscure and is obtained by cumulating departures from a long term mean.

Figure 2 illustrates the long-term annual rainfall amounts and cumulative surplus/deficit from the 13.66-in. mean for the raingage at Tombstone, within the Walnut Gulch Experimental Watershed. In only one year was rainfall above the long term mean for the period considered for most of the watersheds used in the evaluation. The negative slope to the surplus/deficit graph for the period since 1957 illustrates the general dry trend during the study period, which since 1957 has been about 8% below normal. Thus the vegetation cover would be poor and runoff might be less than the long term mean.

The importance of an unusual storm in affecting long term trends has been well documented. Thus it is entirely possible that some of the observed yields are low because of low precipitation/runoff. Stock tanks 214, 215, and 216, on the other hand, have had some large storms during their short records, which may partly explain why the observed yields for these ponds are larger and somewhat closer to the predicted values.

## CONCLUSIONS

1. Predicting sediment yields in the western United States is difficult. Relatively large differences in the characteristics of the contributing watershed area over very short distance add to the problem.

2. Of the four methods investigated, the PSIAC method seems to provide the best results. Experienced people must select values of the nine parameters, which can then produce results consistent with observations. The PSIAC method is the only one tested which has factors which relate to management. Thus, it affords the opportunity to evaluate

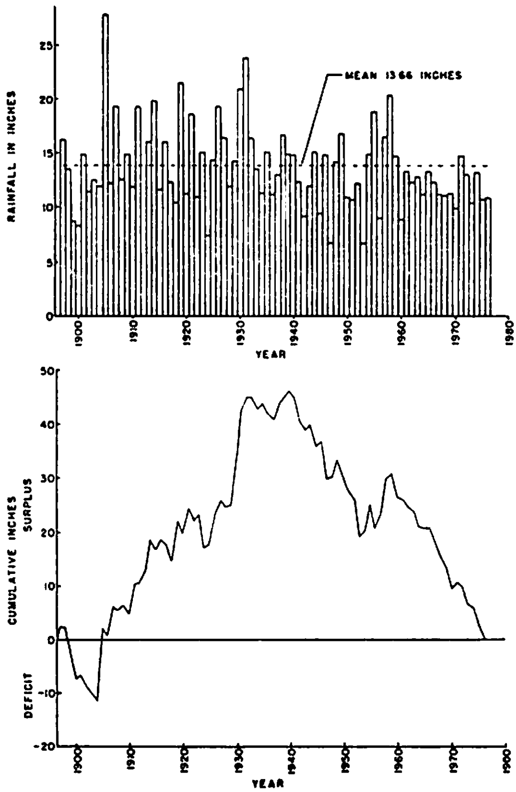


FIGURE 2.—ANNUAL PRECIPITATION AND CUMULATIVE SURPLUS AND DEFICIT FOR TOMBSTONE, ARIZONA [FROM KNISEL ET AL. (7)]

sediment yield changes with management changes. The other methods investigated are simpler to use.

The simplicity implies a hazard, however, because the physical processes associated with sediment yield are not simple.

3. The methods tested generally overpredicted sediment yield. The overprediction may in part be associated with the representativeness of the climatic sample for the period of observation. All but three of the watersheds were known to be deficient in precipitation/runoff, and thus those results are undoubtedly below what might be considered to be the mean annual sediment yield.

## ACKNOWLEDGMENT

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## APPEXDIX I.—REFERENCES


1. Austin, M. E., "Land Resource Regions and Major Land Resource Areas of the United States," U.S. Department of Agriculture, Soil Conservation Service, Agricultural Handbook 296, 1965, 82 pp.
2. Dendy, F. E., and G. C. Bolton, "Sediment Yield-Runoff Drainage Area Relationships in the United States," Journal of Soil and Water Conservation, Vol. 31, No. 6, 1976, pp. 264-266.
3. Diskin, M. H., and L. J. Lane, "A Basinwide Stochastic Model for Ephemeral Stream Runoff in Southeastern Arizona," International Association of Hydrologic Sciences, Bulletin 17, No. 1, 1972, pp. 61-76.
4. Flaxman, E. M, "Predicting Sediment Yield in Western United States," Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 98, No. 12, 1972, pp. 2073-2085.
5. Gelderman, F. W., "Soil Survey of the Walnut Gulch Experimental Watershed, Arizona," U.S. Department of Agriculture, Soil Conservation Service, Portland, Ore., 1970, 61 pp.
6. Hershfield, D. M., "A Note on the Variability of Annual Precipitation," Journal of Applied Meteorology, Vol. VI, No. 4, 1962, pp. 575-578.
7. Knisel, W. G., K. G. Renard, and L. J. Lane, "How Long is Long Enough," Proceedings, American Society of Civil Engineers Specialty Conference on Irrigation and Drainage, 1979, pp. 238-254.
8. Laursen, E. M., "The Total Sediment Load of Streams," Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 84, No. HY1, 1958, pp. 1530.1-1530.36.
9. Pacific Southwest Inter-Agency Committee, "Factors Affecting Sediment Yield and Measures for the Reduction of Erosion and Sediment Yield," 1968, 13 pp.
10. Renard, K. G., "Past, Present, and Future Water Resources Research in Arid and Semiarid Areas of the Southwestern United States," Australian Institution of Engineers 1977 Hydrology Symposium, 1977, pp. 1-29.
11. Renard, K. G., and Laursen, E. M., "A Dynamic Behavior Model of an Ephemeral Stream." Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 101, No. HY5, 1975, pp. 511-528.
12. Renard, K. G., "Sediment Problems in the Arid and Semiarid Southwest," Proceedings, 27th Annual Meeting, Soil Conservation Society of America, Portland, Ore., 1972, pp. 225-232.