PRELIMINARY APPRAISAL OF EPHEMERAL-STREAMFLOW CHARACTERISTICS AS RELATED TO DRAINAGE AREA, ACTIVE-CHANNEL WIDTH, AND SOILS IN NORTHWESTERN NEW MEXICO

By H. R. Hejl, Jr.

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INCH-POUND UNIT TO METRIC UNIT CONVERSION FACTORS

In this report, values for measurements are given in inch-pound units only. The following table contains factors for converting to metric units.

Multiply inch-pound units	By	To obtain metric units
foot	0.3048	meter
cubic foot per second	0.02832	cubic meter per second
acre-foot	1,233	cubic meter
mile	1.609	kilometer
square mile	2.590	square kilometer

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ABSTRACT

Regression equations are presented to predict ephemeral streamflow characteristics in the San Juan Basin in northwestern New Mexico. The standard error of estimate for predicting runoff for water year 1978 using drainage area as the independent variable was 152 percent. Indications are that reliable equations for predicating annual runoff can be developed and the standard error of estimate might be reduced significantly with additional years of record. The coefficient of regression when relating drainage area to runoff for water year 1978 was significant at the 1-percent level. Preliminary results also indicate it is feasible to predict streamflow characteristics using hydrologic soil-group classifications based on runoff potential. The standard error of estimate for predicting peak discharges with recurrence intervals of 2, 5, 10, 25, 50, and 100 years using active-channel width as the independent variable averaged about 50 percent, and the regression coefficient was significant at the 1-percent level. Using drainage area to predict peak discharges resulted in a standard error of estimate that averaged about 60 percent and a regression coefficient significant at the 5-percent level. The standard error of estimate averaged about 45 percent when active-channel width and drainage area were related to peak discharges in multiple regression analyses.

PURPOSE AND SCOPE

The purpose of this interim report is to present preliminary equations for predicting ephemeral-streamflow characteristics in northwestern New Mexico. The equations in this report were developed for the San Juan Basin in northwestern New Mexico and are not applicable statewide as are those in previous studies (Borland, 1970; Scott, 1971;

Scott and Kunkler, 1976). The equations presented can be used to estimate selected ephemeral-streamflow characteristics in the San Juan Basin. This report will be useful to Federal land managers in defining streamflow characteristics in areas underlain by strippable coal deposits located in the northwestern part of the State, and in developing mining stipulations for lease-permit applications; to agencies charged with enforcing the Surface Mining Control and Reclamation Act of 1977; and to coal companies in the development of mining plans for strippable coal.

The primary objectives of this study have been to relate runoff during water year 1978 to drainage area and soil-infiltration rates and to relate flood-peak characteristics to drainage area and to active-channel width. Equations presented in this report will be revised as additional data become available. Other data being compiled for enhancement of predictive methods include basin shape, length of main channel, drainage-basin slope, channel slope, and particle-size distribution of streambed material.

DEFINITION OF TERMS

Drainage area

The drainage area of a basin is the horizontal projection of the area whose surface directs water toward a stream upstream from a specified point on that stream. The drainage area is derived by outlining the drainage basin upstream from a specified point on a stream on topographic maps and planimetering the outlined area.

Hydrologic soils groups

Soils are classified into hydrologic groups A, B, C, and D by the U.S. Soil Conservation Service (John Carey, written commun., 1979). The hydrologic classification is based on runoff potential with group A having the least potential runoff and group D having the greatest. The area of each soil series within the outlined drainage area is planimetered on preliminary, third-order, soil-series maps to determine drainage area of each soil series in the drainage basin. The areas of each of the soil series within a specific hydrologic group are summed to determine the drainage area of that hydrologic group in a basin.

Active-channel width

A recent definition of active-channel geometry stated by Hedman and Kastner (1977, p. 286) is:

> "The active channel is a geomorphic expression of recent discharges. Depositional features within the active channel are altered and shifted regularly during the normal fluctuation of streamflow. Beyond the boundaries of the active channel the geomorphic features are generally permanent and vegetated. The sides of the active channel, which contain the discharge at normal stages, are formed by relatively steep sloped banks.
>
> "The reference level used to measure the geometry of the active channel is selected where the banks abruptly change to a more gently sloping surface. This level is associated with the stabilizing influence of riparian vegetation. Hence, the break in slope indentifying the active-channel reference level is generally coincident with the lower limit of permanent vegetation. However, caution is necessary in using the vegetation line. If high flows are infrequent, some grasses and sedges may grow down the banks into the water, and in arid regions banks may not support vegetation. The active-channel reference points are above and shoreward from the reference level defined by the more temporary depositional bars, and the width and average depth of the active-channel cross sections are about 30 and 130 percent greater, respectively, for the stations that have been measured.
>
> "Sculpturing of the active channel occurs at all discharges. Floodflows tend to enlarge the channels by caving and cutting the banks. If the width of the channel is larger than necessary for quasi-equilibrium, the unused parts of the wide channel are healed by vegetation which stabilizes these areas and induces deposition. The action of healing or reducing the channel is a slow but effective way of reducing a width that has been enlarged by high floodflows. The active-channel width represents a balance between the narrowing forces and the general regime of the stream. Reduction of the channel width toward an equilibrium width occurs much faster in humid regions that have ample vegetation. In some regions where vegetation is sparse the material in the channel is mostly sand, floods are frequent, and the channels may never heal except in reaches where the bank caving is restricted by extremely large bed material or a rock outcrop."

Selecting the active-channel reference point requires training and experience. Not all stream channels in northwestern New Mexico fit the above definition. Arroyos with their nearly vertical walls may lack the distinctive features that are used for defining the active-channel width. Active-channel widths at arroyo sites obtained from Scott and Kunkler's report (1976) may have been measured as the distance between the vertical walls near the channel bottom; however, the vertical-wall feature may not be present at sites in northwestern New Mexico. To date, no useful relation between active-channel width and peak runoff frequencies or annual runoff has been found for extremely wide, braided streams, and none were used in the active-channel width analysis. The active-channel width was measured with a tape or graduated tagline and recorded in feet.

STREAMFLOW DATA

The streamflow data in this study are from ephemeral streams located in northwestern New Mexico. The runoff data were collected at 12 continuous-record gaging stations. Only data for water year 1978 (October 1, 1977 to September 30, 1978) was used in the analysis because most of the gaging stations had only 1 water year of data available. The peak-discharge data are collected primarily at crest-stage gaging stations where only the peak discharge is determined for a given water year. The annual peak data are collected at 10 gaging stations that have from 17 to 29 years of records. Locations of the streamflow-gaging stations are shown in figure 1. The peak discharges for specified recurrence intervals of 2, 5, 10, 25, 50 and 100 years are determined from flood-frequency curves defined by applying a log-Pearson Type III distribution to annual peak discharges in accordance with guidelines found in a report by the U.S. Water Resources Council (1977). Anomalies in the relation of the peak characteristics to drainage-area size appear to be a function of the data because there are no apparent outliers of peak discharges during the data-collection period.

EQUATIONS FOR ESTIMATING RUNOFF FOR WATER YEAR 1978

Drainage area was used in a regression analysis to develop a relation for estimating runoff for water year 1978. Data available for this analysis are shown in table 1. Data from gaging sites on wide alluvial channels are included and are used in the analyses. The regression program used in all analyses in this report is the Statistical Package for the Social Sciences (SPSS) computer program developed at University of Chicago (Nie and others, 1975). All data in the analyses that follow were transformed to logarithms before defining the relations single-linear or multiple-regression techniques. The log transform allows a linear relation to be approached. Eliminating the logarithms by taking the antilogarithms results in the equation as follows:

$$Q_{78} = 47.1\ D_a^{0.57} \qquad SE = 152\ (235,\ -70) \qquad (1)$$

where

Q_{78} = runoff for water year 1978, in acre-feet;

D_a = drainage area, in square miles; and

SE = standard error of estimate in percent: the first number is the average and the others are the percentages above and below the regression line.

Table 1. Drainage area and runoff during water year 1978 at 12 ephemeral streamflow gaging sites

U.S. Geological Survey downstream station number 1/	Drainage area (square miles)	Runoff (acre-feet)
08334300	20.3	48
09356565	1,700	3,460
09357250	290	136
09367555	62.8	524
09367660	59.0	433
09367680	578	1,430
09367685	8.21	661
09367710	184	3,680
09367930	45.6	609
09367934	7.16	52
09367936	8.57	476
09367938	3,640	11,000

1/ See figure 1 for location and stream name.

EXPLANATION FOR FIGURE 1

U.S. Geological Survey downstream station number and name	
08334300	Papers Wash near Star Lake Trading Post, New Mexico.
08343100	Grants Canyon at Grants, New Mexico.
09346200	Rio Amargo at Dulce, New Mexico.
09350800	Vaqueros Canyon near Gobernador, New Mexico.
09355700	Gobernador Canyon near Gobernador, New Mexico.
09356400	Manzanares Canyon near Turley, New Mexico.
09356565	Canon Largo Wash near Blanco, New Mexico.
09357200	Gallegos Canyon Tributary near Nageezi, New Mexico.
09357250	Gallegos Canyon Wash near Farmington, New Mexico.
09367530	Locke Arroyo near Farmington, New Mexico.
09367555	Shumway Arroyo near Fruitland, New Mexico.
09367660	Chaco Wash near Star Lake Trading Post, New Mexico.
09367680	Chaco Wash at Chaco Canyon National Monument, New Mexico.
09367685	Ah-shi-sle-pah Wash near Kimbeto, New Mexico.
09367710	De-na-zin Wash near Bisti Trading Post, New Mexico.
09367840	Yazzie Wash near Mexican Springs, New Mexico.
09367860	Chuska Wash near Mexican Springs, New Mexico.
09367900	Black Springs Wash near Mexican Springs, New Mexico.
09367930	Hunter Wash near Bisti Trading Post, New Mexico.
09367934	Teec-ni-di-tso Wash near Burnham Trading Post, New Mexico.
09367936	Burnham Wash near Burnham Trading Post, New Mexico.
09367938	Chaco River near Burnham Trading Post, New Mexico.

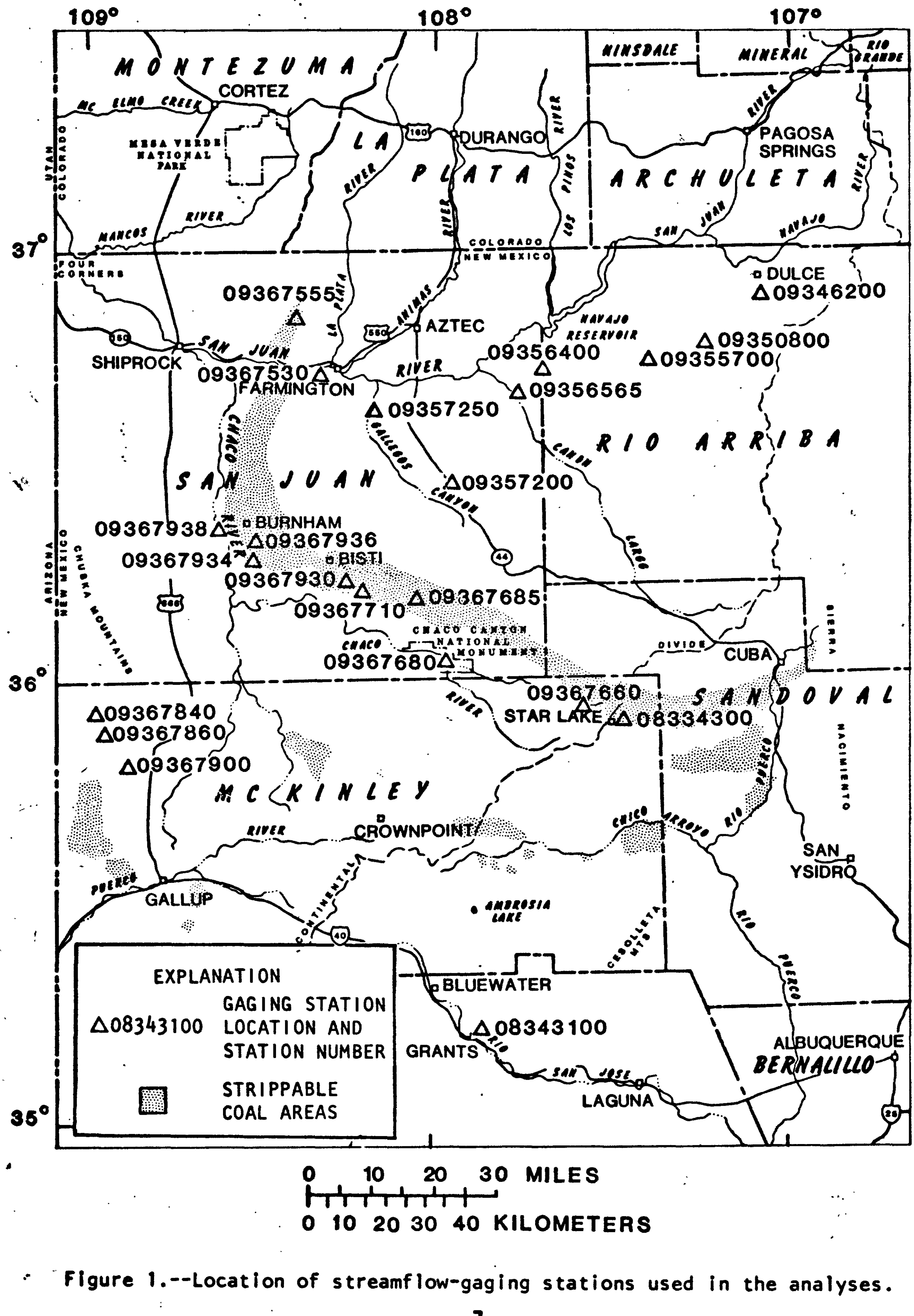

Figure 1.--Location of streamflow-gaging stations used in the analyses.

The areas covered by the various hydrologic soil groups in each basin were used to estimate runoff during water year 1978. Preliminary soils maps for the six drainage basins listed in table 2 were furnished by John Carey (U.S. Soil Conservation Service, written commun., 1979). Because there are data only for six drainage areas, the four soils groups were reduced to D+C and B+A. The areas of hydrologic soil groups were entered into the equations in order of greater runoff potential (hydrologic soil groups D+C first and hydrologic soil groups B+A second). No relation was found when hydrologic soil groups B+A were included in a multiple-regression analysis. Additional drainage areas will be added into the analysis after the U.S. Soil Conservation Service publishes the soils maps. Gaging sites on wide alluvial channels are included in the regression analysis. The defined regression equation from this analysis is:

$$Q_{78} = 75.6\,(D{+}C)^{0.71} \qquad SE = 126\ (186,\ -65) \qquad (2)$$

where

Q_{78} = runoff for water year 1978, in acre-feet;

$D{+}C$ = area of hydrologic soil groups D and C, in square miles; and

SE = standard error of estimate, in percent.

Table 2. Total drainage area, distribution of drainage area by hydrologic soil groups, and runoff for water year 1978 at six ephemeral-streamflow gaging sites

U.S. Geological Survey downstream station number[1/]	Drainage area (square miles)					Runoff (acre-feet)
		Hydrologic soil groups				
	Total	D	C	B	A	
09367555	62.8	47.2	1.7	13.1	0.8	524
09367685	8.21	7.13	0.25	0.69	0.14	661
09367710	184	98.0	1.0	57.0	28.0	3,680
09367930	45.6	24.5	0.3	10.9	9.9	609
09367934	7.16	3.81	0.15	1.21	1.99	52
09367936	8.57	3.33	0.14	3.78	1.32	476

1/ See figure 1 for location and stream name.

Equations 1 and 2 were developed for predicting runoff for the 1978 water year; equations for predicting average annual runoff can be developed only after additional years of record are available. The equations in this interim report are not directly applicable for predicting average annual runoff. Precipitation during water year 1978 was 10 to 25 percent greater than the normal recorded for 1941-70 at five National Weather Service raingages in the study area, indicating that runoff during water year 1978 might have been greater than average.

Hydrologic soil groups D and C summed in equation 2 resulted in a smaller average standard error of estimate than did drainage area in equation 1. The coefficient of regression (exponent) in equation 1 is significant at the 1-percent level (one chance in 100 the exponent equals zero, no correlation) and in equation 2 at the 5-percent level. The level of significance of the regression coefficient and standard error of estimate are dependent on the degrees of freedom. Because of the small number of gaged sites available for these analyses and the analyses that follow, a one-tail Student's "t" distribution was used to test the level of significance of the regression coefficients in this report.

Runoff for water year 1978 defined in equation 2 on the basis of hydrologic soil groups at six drainage areas precludes a sound statistical analysis. However, it appears feasible and logical to use hydrologic soil groups in regression analyses because a major objective is to predict changes in streamflow characteristics resulting from different land-management practices. Certainly, surface mining for coal will temporarily and perhaps permanently change the hydrologic soil group classification in mined areas. The drainage areas of the hydrologic soil groups in a drainage area could be adjusted to reflect the changes in land-management practices, and the change in streamflow characteristics could be estimated with the equations developed using regression techniques. The standard error of estimate will probably be reduced significantly with longer periods of records or an increased number of drainage basins in the regression analyses.

EQUATIONS FOR ESTIMATING PEAK DISCHARGES

Drainage area and active-channel width were used in regression analysis to develop relations which were used for estimating peak discharges with recurrence intervals of 2, 5, 10, 25, 50, and 100 years. Nine crest-stage gaging stations and one continuous-record gaging station with records ranging from 17 to 29 years were available for these analyses (table 3). Gaging sites at extremely wide alluvial channels were not used in these regression analyses because sufficient data were not available to define a relation between these channels and peak-runoff frequencies. The independent variables (drainage area and active-channel width) and dependent variables (peak discharges of selected recurrence intervals) were transformed to logarithms before defining the relation by simple-linear or multiple-regression techniques. The log transform allows a linear relation to be approached. Eliminating the logarithms by taking the antilogarithms resulted in the equations as follows:

$Q_2 = 218\ D_a^{0.24}$	SE = 73 (97, -49)	(3)
$Q_2 = 3.20\ W_{ac}^{1.60}$	SE = 57 (72, -42)	(4)
$Q_2 = 5.46\ W_{ac}^{1.32}\ D_a^{0.13}$	SE = 54 (68, -41)	(5)
$Q_5 = 474\ D_a^{0.23}$	SE = 63 (81, -45)	(6)
$Q_5 = 9.78\ W_{ac}^{1.47}$	SE = 50 (61, -38)	(7)
$Q_5 = 16.8\ W_{ac}^{1.20}\ D_a^{0.14}$	SE = 44 (54, -35)	(8)
$Q_{10} = 708\ D_a^{0.23}$	SE = 59 (75, -43)	(9)
$Q_{10} = 17.4\ W_{ac}^{1.41}$	SE = 48 (58, -37)	(10)
$Q_{10} = 30.1\ W_{ac}^{1.13}\ D_a^{0.14}$	SE = 42 (51, -34)	(11)
$Q_{25} = 1090\ D_a^{0.22}$	SE = 57 (72, -42)	(12)
$Q_{25} = 32.5\ W_{ac}^{1.34}$	SE = 48 (59, -37)	(13)
$Q_{25} = 56.0\ W_{ac}^{1.06}\ D_a^{0.14}$	SE = 42 (51, -34)	(14)
$Q_{50} = 1430\ D_a^{0.22}$	SE = 57 (72, -42)	(15)
$Q_{50} = 45.8\ W_{ac}^{1.30}$	SE = 49 (60, -38)	(16)
$Q_{50} = 83.9\ W_{ac}^{1.02}\ D_a^{0.14}$	SE = 44 (53, -35)	(17)
$Q_{100} = 1830\ D_a^{0.21}$	SE = 58 (73, -42)	(18)
$Q_{100} = 69.6\ W_{ac}^{1.26}$	SE = 51 (63, -39)	(19)
$Q_{100} = 120\ W_{ac}^{0.98}\ D_a^{0.14}$	SE = 46 (56, -36)	(20)

where

Q_2, Q_5, Q_{10}, Q_{25}, Q_{50}, or Q_{100} = peak discharge at specified recurrence interval (Q_2 = 2 years), in cubic feet per second;

D_a = drainage area of basin, in square miles;

W_{ac} = active-channel width, in feet; and

SE = standard error of estimate, in percent.

Table 3. Basin and streamflow characteristics at 10 ephemeral crest-stage gaging sites

U.S. Geological Survey downstream station number 1/	Length of record (years)	Drainage area (square miles)	Active-channel width (feet)	Discharge for indicated recurrence interval (cubic feet per second)					
				Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}
08343100	17	13.0	12	282	665	1,040	1,680	2,290	3,020
09346200	22	168	22	993	1,580	2,010	2,580	3,040	3,510
09350800	23	60.5	17	202	580	996	1,760	2,540	3,530
09355700	23	19.8	25	627	1,150	1,580	2,200	2,720	3,280
09356400	23	3.20	30	377	787	1,150	1,720	2,220	2,790
09357200	27	.20	10	125	259	378	565	730	919
09367530	28	2.96	15	115	274	430	694	943	1,240
09367840	29	2.10	18	315	614	867	1,250	1,580	1,960
09367860	29	8.70	28	1,110	2,400	3,590	5,490	7,230	9,240
09367900	28	7.05	25	453	1,050	1,620	2,590	3,490	4,580

1/ See figure 1 for location and stream name.

In a simple-linear regression, discharges estimated from active-channel width had a standard error of estimate about 10 percent less (on the average) than discharges estimated from drainage area when related to peak discharges of specified recurrence intervals. The standard error of estimate was decreased an additional 4 percent (on the average) when active-channel width and drainage area were related to the peak discharges in multiple-regression analyses.

The coefficient of regression when active-channel width was related to the peak discharges at the above recurrence intervals was significant at the 1-percent level. The coefficent of regression for drainage area was significant at the 5-percent level. The partial-regression coefficient for active-channel width was significant at the 2.5-percent level, and drainage area was significant at the 10-percent level in the multiple-regression analyses.

COMPARISONS WITH PREVIOUS STUDIES

Scott and Kunkler (1976) developed statewide equations relating peak discharges for selected recurrence intervals of as much as 50 years to active-channel width. Their constants for the statewide equations varied from 0.5 (at Q_2) to 0.7 (at Q_{50}) of the value of the constants for the equations developed in this report for northwestern New Mexico. There was no significant difference in the coefficients of regression. The standard errors of estimate of the equations to estimate peak discharges using active-channel width in this report are about 20 percent less (on the average) than the equations developed by Scott and Kunkler; this region may be more homogeneous than the whole State.

In an earlier study, Scott (1971) developed equations relating drainage area to peak discharges for selected recurrence intervals of as much as 50 years. Scott divided the State into three regions in that study. The constant of Scott's equations for his region that includes northwestern New Mexico varied from 0.5 (at Q_2) to 0.7 (at Q_{50}) of the value of the constant for the equation developed in this report. The coefficients of regression in Scott's report are about twice as large as the coefficients in this report for the respective peak discharges. The standard errors of estimate of the equations to estimate peak discharges using drainage area in this report are about 20 percent less (on the average) than the equations developed by Scott. However, the equations developed here do not include streams with wide alluvial channels.

Borland (1970) developed statewide equations to predict annual runoff and peak discharges. However, independent variables used in Borland's study do not correspond to those used in the equations in this study; therefore, no comparisons could be made.

LIMITATIONS

The equations in this report define relations only within the range of data used in the regression analyses. Equation 1 was developed from drainage areas ranging from 7.16 to 3,640 square miles, which include extremely wide alluvial channels. Because the sum of the drainage areas of hydrologic soil groups D+C is the most significant factor, equation 2 was developed from basins having a drainage area of these groups ranging from 3.47 to 99.0 square miles; this analysis includes extremely wide alluvial channels. Equations 3 to 20 were developed from drainage areas ranging from 0.2 to 168 square miles and active-channel widths ranging from 10 to 30 feet, excluding extremely wide alluvial channels. All equations in this report were developed from data on unregulated ephemeral streams. Equations are only valid in inch-pound units. If metric values are desired, the computations need to be made in inch-pound units and the answers transformed to metric equivalents with the conversion factors available in the front of this report.

APPLICATION OF EQUATIONS

The equations developed in this report are applicable to most ephemeral channels in the San Juan Basin in northwestern New Mexico. The exception is for extremely wide channels. Insufficient data were available to develop a relation to predict peak discharges for wide channels.

If a basin has a drainage area of 12 square miles, the runoff of this basin for water year 1978 is calculated from equation 1 as follows:

$$Q_{78} = 47.1\ D_a^{0.57} \qquad SE = 152\ (235, -70) \qquad (1)$$

$$D_a = 12 \text{ (square miles)}$$

$$Q_{78} = 47.1\ (12)^{0.57}$$

$$Q_{78} = 47.1\ (4.12)$$

$$Q_{78} = 194 \text{ (acre-feet)}$$

As previously stated, two-thirds of the points plot within one standard deviation (limits 235 percent and -70 percent) from the regression line; therefore, there is two-thirds probability that the runoff for this basin during water year 1978 was between 194 x (1 - 0.70) and 194 x (1 + 2.35) acre-feet, or 58 to 650 acre-feet. This illustrates the need for longer periods of record for defining runoff relationships. The length of record to develop equation 1 was 1 water year. There would be only 1 chance in 100 that the exponent would be equal to zero; that is, no relation between Q_{78} and D_a exists (significant at the 1-percent level).

SUMMARY AND CONCLUSIONS

The equations developed in this preliminary report to predict ephemeral streamflow characteristics in the San Juan Basin in northwestern New Mexico will be revised as additional data become available. In particular, the equations for predicting runoff for water year 1978 are not directly applicable for predicting mean annual runoff. Equations based on additional years of records would have significantly increased reliability and considerably reduced standard errors of estimate.

Equations developed to predict runoff for water year 1978 from drainage area or hydrologic soil groups D+C yielded standard errors of estimate from 126 to 152 percent using simple-linear regression analyses. Because of the small number (six) of gaged sites available for relating the drainage area of hydrologic soils group D+C (group with greatest runoff potential), the coefficient of regression was significant at the 5-percent level. It appears feasible to use hydrologic soil groups to predict annual runoff; a major goal of this and other efforts is to predict streamflow characteristics resulting from different land-management practices, whether temporary or permanent, such as surface mining for coal.

The standard errors of estimate to predict peak discharges with recurrence intervals of 2, 5, 10, 25, 50, and 100 years averaged 60 percent when using drainage area and 50 percent when using active-channel width. The standard errors of estimate in this study are about 20 percent less than in previous studies. However, no gaged sites at extremely wide alluvial channels were included in the development of the equations; therefore, these equations do not apply to extremely wide alluvial channels. The coefficient of regression was significant at the 1-percent level when active-channel width was related to peak discharges and was significant at the 5-percent level when drainage area was related to peak discharges. The standard error of estimate improved slightly for predicting peak discharges when both active-channel width and drainage area were entered as independent variables in multiple regression analysis.

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