Techniques for Estimating Monthly Mean Streamflow at Gaged Sites and Monthly Streamflow Duration Characteristics at Ungaged Sites in Central Nevada

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre-feet (acre-ft)	1,230	cubic meters
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NVGD of 1929, formerly called "sea-level datum of 1929") which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

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ABSTRACT

Techniques for estimating monthly mean streamflow at gaged sites and monthly streamflow duration characteristics at ungaged sites in central Nevada were developed using streamflow records at six gaged sites and basin physical and climatic characteristics. Streamflow data at gaged sites were related by regression techniques to concurrent flows at nearby gaging stations so that monthly mean streamflows for periods of missing or no record can be estimated for gaged sites in central Nevada. The standard error of estimate for relations at these sites ranged from 12 to 196 percent. Also, monthly streamflow data for selected percent exceedence levels were used in regression analyses with basin and climatic variables to determine relations for ungaged basins for annual and monthly percent exceedence levels. Analyses indicate that the drainage area and percent of drainage area at altitudes greater than 10,000 feet are the most significant variables. For the annual percent exceedence, the standard error of estimate of the relations for ungaged sites ranged from 51 to 96 percent and standard error of prediction for ungaged sites ranged from 96 to 249 percent. For the monthly percent exceedence values, the standard error of estimate of the relations ranged from 31 to 168 percent, and the standard error of prediction ranged from 115 to 3,124 percent. Reliability and limitations of the estimating methods are described.

INTRODUCTION

Surface water in central Nevada is scarce because of the lack of precipitation. Sound water-management decisions require reliable information about the magnitude and variability of streamflow. Monthly mean discharge is of particular interest to fish and wildlife managers, water-rights administrators, and other land- and water-use planners. Available techniques for estimating monthly mean streamflow at gaged sites for periods of missing or no record have not been developed for this area. Similarly, a method of regionalizing monthly streamflow duration characteristics for ungaged basins is needed. Streamflow duration curves at ungaged sites could be used with streamflow data and streamflow duration curves from nearby gaged sites to reconstruct probable historical monthly records at the ungaged site of interest. Because of the need for this type of information for upland streams in central Nevada, an investigation was undertaken in 1996 by the U.S. Geological Survey (USGS) in cooperation with the U.S. Department of Agriculture, U.S. Forest Service, Toiyabe National Forest.

Purpose and Scope

The purpose of this report is (1) to describe the data used to estimate monthly mean streamflow, (2) to describe techniques for estimating monthly mean streamflow at gaged sites and monthly streamflow duration characteristics for annual and monthly values at ungaged sites in central Nevada, and (3) to discuss the reliability and limitations of those techniques.

Previous Investigations

Methods of regionalizing selected streamflow characteristics and evaluating the reliability of each under various hydrologic conditions were described in Riggs (1973). Several examples of regionalizing streamflow characteristics for high and low streamflows were discussed.

Moore (1968) developed two methods for estimating mean annual runoff in ungaged semiarid areas. The first method, based on streamflow records, related annual runoff to altitude for a region. The second method, applicable to either perennial or ephemeral streams, established a relation between annual runoff, and channel width and depth.

Maurer (1986) determined regression equations for estimating streamflow at seven tributaries to the Carson River in Carson Valley based on an index gaging station and concurrent discharge measurements (U.S. Geological Survey, 1981-83). Hess (U.S. Geological Survey, unpublished data, 1996) later updated the equations developed by Maurer (1986) with additional concurrent discharge measurement data and extended the estimates to include six additional tributaries (U.S. Geological Survey, 1989-95) in the Carson Valley area.

Parrett and Cartier (1990) developed three methods applicable to western Montana basins for estimating mean monthly discharge and various points on the daily mean-flow duration curve for each month. The first method was based on multiple regression equations relating the monthly streamflow characteristics to various basin and climatic variables. The second method was based on regression equations relating the monthly streamflow characteristics to channel width. The third method required 12 once-monthly streamflow measurements at the ungaged sites of interest.

Myers and Swanson (1996) extended the record of monthly streamflows in northwest Nevada at a gaging station using multiple regression techniques. The purpose of these estimates was to aid in the comparison of different range management plans in the recovery of two abusively-grazed riparian habitats.

Description of Study Area

The study area is in northern Nye County, and parts of southern Lander and Eureka Counties, Nev. The study area, termed "central Nevada" for the purposes of this report, is composed largely of north-south trending mountain ranges separated by long narrow valleys (fig. 1). The study area includes basins above approximately 6,000 feet in the Shoshone, Toiyabe, Toquima, Monitor, and Hot Creek Mountain Ranges. The study area is bounded on the north by U.S. Highway 50 and on the south by U.S. Highway 6. The Shoshone and Hot Creek Mountain Ranges form the western and eastern boundaries of the study area, respectively. The study area is generally rugged and sparsely forested. Methods presented in this report are not applicable to the flatter valley floors, which are mostly open range but may be used for grazing or limited agriculture. Altitudes for the basins studied in this investigation ranged from about 6,400 to 12,000 feet.

Annual precipitation in the study area varies widely primarily because of the wide range in altitude and resultant orographic effects. Annual precipitation amounts can be as much as 30 inches at higher altitudes, whereas in the drier valley areas, annual precipitation can measure 6 inches or less. Annual runoff generally mimics the precipitation with greater quantities occurring at higher altitudes. Streamflows vary greatly on a seasonal basis, because snowmelt provides the bulk of annual runoff in April, May, and June. Streamflows generally are smaller in late fall and winter when they are almost entirely the result of groundwater discharge. Most smaller streams draining the valleys are ephemeral.

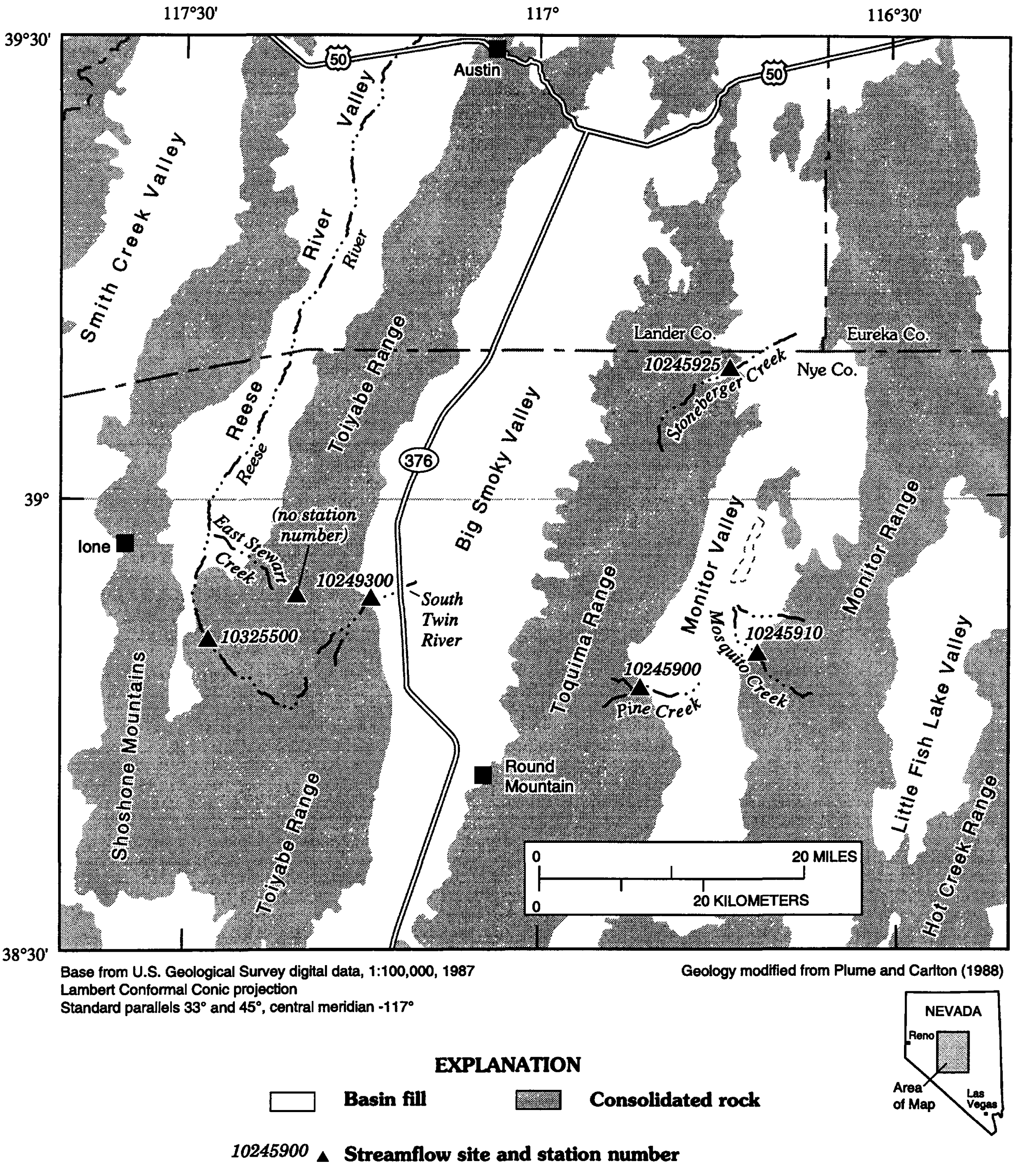

Figure 1. Location of streamflow-gaging stations.

Streamflow Data Used

Continuous streamflow data for central Nevada for water years 1951-95 (for site locations, see fig. 1 and table 1) were used in the analysis. Monthly streamflow statistics were computed from daily data at six streamflow-gaging stations within the study area. To be included in the study, each station had to have at least 5 years of record through water year 1995, although some stations did not have a complete record for all months. The period of record of data collection for all stations did not necessarily overlap. Data from streamflow-gaging stations where flows were substantially regulated or where large diversions substantially affected flows were excluded from the analysis. Ephemeral streams were not included in the analysis. The monthly mean streamflows computed for each station were published in the annual Water Resources Data-Nevada reports (U.S. Geological Survey 1962-95) and McKinley and Oliver (1994, 1995). Table 1 shows the six stations used in the analyses and the monthly mean streamflows for the period of record through 1994.

Partial record data, collected periodically over several years at other basins within the study area, would have been useful supplemental data in this study. However, the USGS has not collected concurrent miscellaneous discharge data on other streams in the central Nevada area.

METHOD FOR ESTIMATING MONTHLY MEAN STREAMFLOW AT GAGED SITES

Historical streamflow data at gaged sites may be related to concurrent flows at nearby "index" gaging stations. The relations so developed may be used to obtain estimates of the streamflow at gaged sites for periods of record when streamflow collection does not coincide and data are unavailable.

Monthly mean streamflows at gaged sites in central Nevada were related to the streamflow at an index gaging station by simple linear regression (SAS Institute, Inc., 1990). In the analysis, a set of relations was developed by relating the dependent variable (streamflow at desired gaged sites) to the independent variable (streamflow at the index gage site). A correlation matrix was first used to examine the strength of individual relations between concurrent monthly mean streamflows at all sites. The correlation matrix indicates that streamflow at South Twin River near Round Mountain (station number 10249300) is, statistically, the best indicator (index station) for monthly mean streamflow at the other five central Nevada sites. The South Twin River gage also has the longest period of record; 30 years from 1965 to 1994. Using streamflow at the South Twin River site as the independent variable, regression equations were developed for each of the five sites (1) for each individual month, and (2) for any month of the year. Using the equations, monthly mean streamflow for periods of missing or no record at the other five sites can be estimated using the observed data from South Twin River.

For the East Stewart Creek near Ione site, poor regression results allowed only a single regression equation for any month be determined. The poor regression results may be due to the extremely small size (0.36 mi^2) of the basin, the fact that the data collection period fell within a period of extreme drought (1987-92), or both.

Periods of missing or no record at the South Twin River site were estimated using streamflow data from the Reese River near Ione gaging station (station number 10325500). Records for the Reese River gage were available from 1951 to 1976. The period of concurrent record for the Reese and South Twin River sites (1965-76) was used to develop monthly and annual regression equations using Reese River as the index station for the South Twin River site.

Monthly streamflow data for the six gaged sites in the study area were transformed to logarithms and used in linear regression analysis to derive estimating equations of the following form:

$$Q = a\,A^{b} \qquad (1)$$

where:

Q is the monthly mean discharge estimate at the gaging station of interest;

A is the monthly mean streamflow at the index gaging station; and

a, b are the regression coefficients.

Table 1. Mean monthly streamflow of drainage basins in central Nevada

[Symbol: ---, no assigned station number]

Station number (see fig. 1)	Station name	Period of statistics	Mean monthly streamflow (cubic feet per second)											
			Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
10245900	Pine Creek near Belmont	1977-94	2.23	1.78	1.47	1.31	1.25	1.59	3.20	16.7	20.6	6.40	3.35	2.19
10245910	Mosquito Creek near Belmont	1977-94	.76	.69	.57	.50	.51	.68	1.61	6.35	7.56	2.32	1.24	.79
10245925	Stoneberger Creek near Belmont	1977-94	.55	.56	.53	.52	.56	.68	1.32	5.50	6.07	1.77	.99	.64
10249300	South Twin River near Round Mountain	1965-94	2.43	2.59	2.33	2.24	2.49	4.34	8.97	24.1	16.5	4.81	2.61	2.21
10325500	Reese River near Ione	1951-76	2.70	2.56	2.50	2.51	3.25	5.75	23.3	48.2	29.9	8.81	3.86	2.69
---	East Stewart Creek near Ione	1987-92	.20	.17	.15	.11	.08	.09	.18	.69	1.35	.53	.30	.19

The regression procedure also provided statistical measures of the accuracy and therefore the reliability of the derived equations such as standard error of estimate. The standard error of estimate is a measure of how accurately the regression equations will estimate the dependent variable at the sites used to determine the regression equations. The standard error of estimate is, by definition, one standard deviation on each side of the regression equation and contains about two-thirds of the data within this range. In general, the smaller the standard error, the more reliable is the estimating equation. The coefficient of determination, R^2, also is useful for evaluating regression results. The coefficient of determination indicates the proportion of the total variation of the dependent variable that is explained by the independent variables. For example, an R^2 of 0.90 would indicate that 90 percent of the variation is accounted for by the independent variables. The regression equations are shown in table 2. The coefficients of determination for the monthly equations ranged from 0.12 to 0.96 and, for the annual equations, ranged from 0.23 to 0.95. The standard errors for the monthly equations ranged from 12 to 196 percent. Standard errors for the equations, which may be used for any month, ranged from 19 to 103 percent.

The Stoneberger Creek near Belmont site yielded noticeably poorer regression results than other sites. This may be due to the possibility that the streamflow may be ephemeral upstream of the site.

METHOD FOR ESTIMATING MONTHLY STREAMFLOW DURATION CHARACTERISTICS AT UNGAGED SITES

Regression analysis cannot be used directly to estimate unique, historical streamflows at ungaged sites. However, certain statistical flow characteristics can be estimated for ungaged sites using selected basin and climatic characteristics. This method has been used in Montana (Parrett and Cartier, 1990) and technical methods are described in Riggs (1973).

In this study, duration curves of monthly streamflows were constructed for each of the six gaged sites based on a statistical analysis of available monthly data. Monthly streamflows are defined as the average streamflow for any given month. Streamflows with percent exceedence values of 1, 5, 10, 25, 50, 75, 90, 95, and 99 percent were regressed against certain basin physical and climatic characteristics for annual percent exceedence values. Streamflows with percent exceedence values of 5, 25, 50, 75, and 95 percent were regressed against certain basin physical and climatic characteristics for monthly percent exceedence values. Historical monthly streamflows can be grossly estimated by using the regression equations from this study to build a duration curve at the ungaged site. The streamflow for each month at the ungaged site could be assumed to be of similar percent exceedence as the concurrent streamflow at nearby gaged basins. The observed streamflows with percent exceedence values for the six sites are shown in table 3.

Basin characteristics at the six streamflow gaging stations in the study area were measured at each site on USGS topographic maps. Total drainage area was determined by delineating and planimetering basin boundaries on 1:24,000-scale topographic maps. Percentages of each basin above 8,000 and 10,000 feet altitude above sea level also were determined by planimetering the drainage area above the 8,000- and 10,000-foot contours. Mean annual precipitation was the basin average precipitation as determined from maps published by Hardman (1965). Mean basin altitude was determined by overlaying a transparent grid on the basin outline on a topographic map, reading the altitude at the grid intersections, and averaging the readings. The stream length was determined by measuring the distance in miles along the main channel from the gaging station to the basin divide. The channel slope was measured between points which are 10 percent and 85 percent of the main channel length upstream from the study site. A qualitative variable indicating whether a drainage basin is on the east- or west-facing slope of a mountain range also was included in the analyses to determine if a rain-shadow effect was discernible.

The measured drainage basin and climatic characteristics associated with each streamflow gaging station used in the regression analysis are listed in table 4. More accurate determinations of basin climatic characteristics could have been accomplished using geographic information system data bases (U.S. Geological Survey, 1987b), and more recent annual precipitation data (James, 1995). Those data bases were not used in this analysis because of time and funding constraints.

Table 2. Results of regression analysis used to determine monthly mean streamflow at gaged sites in central Nevada

[$Q_{XXXXXXXX}$, monthly mean streamflow for station XXXXXXXX; R^2, coefficient of determination from regression. Symbol: ---, no assigned station number]

Station number	Station name	Month or any month	Regression equation used to estimate monthly mean streamflows for periods of missing or no record	R^2	Standard error of estimate (percent)
10245900	Pine Creek near Belmont	January	$Q_{10245900} = 0.93\ Q_{10249300}^{0.423}$	0.64	15
		February	$Q_{10245900} = 0.86\ Q_{10249300}^{0.374}$	.35	21
		March	$Q_{10245900} = 0.74\ Q_{10249300}^{0.495}$	.65	20
		April	$Q_{10245900} = 0.66\ Q_{10249300}^{0.669}$	.50	37
		May	$Q_{10245900} = 1.54\ Q_{10249300}^{0.729}$	.61	50
		June	$Q_{10245900} = 1.86\ Q_{10249300}^{0.878}$	.87	27
		July	$Q_{10245900} = 1.38\ Q_{10249300}^{0.936}$	.84	31
		August	$Q_{10245900} = 1.44\ Q_{10249300}^{0.861}$	.91	22
		September	$Q_{10245900} = 1.30\ Q_{10249300}^{0.740}$	.77	29
		October	$Q_{10245900} = 1.02\ Q_{10249300}^{0.822}$	.62	28
		November	$Q_{10245900} = 1.06\ Q_{10249300}^{0.486}$	.35	28
		December	$Q_{10245900} = 0.94\ Q_{10249300}^{0.465}$	.43	22
		Any month	$Q_{10245900} = 0.87\ Q_{10249300}^{0.859}$	.69	61
10245910	Mosquito Creek near Belmont	January	$Q_{10245910} = 0.26\ Q_{10249300}^{0.730}$	.48	38
		February	$Q_{10245910} = 0.23\ Q_{10249300}^{0.730}$	.30	54
		March	$Q_{10245910} = 0.26\ Q_{10249300}^{0.610}$	.46	35
		April	$Q_{10245910} = 0.26\ Q_{10249300}^{0.773}$	.54	40
		May	$Q_{10245910} = 0.21\ Q_{10249300}^{1.073}$	.88	30
		June	$Q_{10245910} = 0.20\ Q_{10249300}^{1.356}$	.86	40
		July	$Q_{10245910} = 0.46\ Q_{10249300}^{1.083}$	.77	43
		August	$Q_{10245910} = 0.50\ Q_{10249300}^{0.894}$	.64	50
		September	$Q_{10245910} = 0.37\ Q_{10249300}^{1.015}$	.62	54
		October	$Q_{10245910} = 0.37\ Q_{10249300}^{0.723}$	.27	47
		November	$Q_{10245910} = 0.35\ Q_{10249300}^{0.627}$	.33	37
		December	$Q_{10245910} = 0.28\ Q_{10249300}^{0.715}$	.33	44
		Any month	$Q_{10245910} = 0.28\ Q_{10249300}^{0.970}$	.71	64
10245925	Stoneberger Creek near Belmont	January	$Q_{10245925} = 0.18\ Q_{10249300}^{1.017}$	.42	61
		February	$Q_{10245925} = 0.17\ Q_{10249300}^{0.966}$	.29	68
		March	$Q_{10245925} = 0.20\ Q_{10249300}^{0.585}$	.12	84
		April	$Q_{10245925} = 0.10\ Q_{10249300}^{0.953}$	.21	117
		May	$Q_{10245925} = 0.04\ Q_{10249300}^{1.296}$	.42	181
		June	$Q_{10245925} = 0.04\ Q_{10249300}^{1.510}$	.47	196
		July	$Q_{10245925} = 0.12\ Q_{10249300}^{1.410}$	.60	104
		August	$Q_{10245925} = 0.26\ Q_{10249300}^{1.107}$	.69	64
		September	$Q_{10245925} = 0.22\ Q_{10249300}^{1.087}$	.52	82
		October	$Q_{10245925} = 0.09\ Q_{10249300}^{1.760}$	.74	46
		November	$Q_{10245925} = 0.09\ Q_{10249300}^{1.514}$	.55	63
		December	$Q_{10245925} = 0.10\ Q_{10249300}^{1.495}$	.61	55
		Any month	$Q_{10245925} = 0.18\ Q_{10249300}^{0.899}$	.52	103
10249300	South Twin River near Round Mountain	January	$Q_{10249300} = 0.87\ Q_{10325500}^{0.850}$	.43	21
		February	$Q_{10249300} = 0.98\ Q_{10325500}^{0.738}$	.39	17
		March	$Q_{10249300} = 1.09\ Q_{10325500}^{0.627}$	.59	26
		April	$Q_{10249300} = 0.96\ Q_{10325500}^{0.714}$	.95	13
		May	$Q_{10249300} = 1.38\ Q_{10325500}^{0.712}$	.93	17
		June	$Q_{10249300} = 0.92\ Q_{10325500}^{0.820}$	.96	14
		July	$Q_{10249300} = 0.86\ Q_{10325500}^{0.779}$	.93	15
		August	$Q_{10249300} = 0.74\ Q_{10325500}^{0.825}$	.91	14
		September	$Q_{10249300} = 0.70\ Q_{10325500}^{0.967}$	.83	20
		October	$Q_{10249300} = 1.03\ Q_{10325500}^{0.662}$	.73	14
		November	$Q_{10249300} = 0.77\ Q_{10325500}^{0.942}$	.80	12
		December	$Q_{10249300} = 1.08\ Q_{10325500}^{0.643}$	.47	18
		Any month	$Q_{10249300} = 0.86\ Q_{10325500}^{0.804}$	.95	19

Table 2. Results of regression analysis used to determine monthly mean streamflow at gaged sites in central Nevada—Continued

Station number	Station name	Month or any month	Regression equation used to estimate monthly mean streamflows for periods of missing or no record	R^2	Standard error of estimate (percent)
10325500	Reese River near Ione	January	$Q_{10325500} = 1.93\ Q_{10249300}^{0.556}$	0.43	17
		February	$Q_{10325500} = 1.99\ Q_{10249300}^{0.584}$	.39	15
		March	$Q_{10325500} = 1.96\ Q_{10249300}^{0.986}$	.59	32
		April	$Q_{10325500} = 1.21\ Q_{10249300}^{1.331}$	.95	18
		May	$Q_{10325500} = 0.83\ Q_{10249300}^{1.317}$	.93	24
		June	$Q_{10325500} = 1.26\ Q_{10249300}^{1.172}$	.96	17
		July	$Q_{10325500} = 1.38\ Q_{10249300}^{1.198}$	.93	19
		August	$Q_{10325500} = 1.57\ Q_{10249300}^{1.114}$	.91	16
		September	$Q_{10325500} = 1.64\ Q_{10249300}^{0.872}$	.83	19
		October	$Q_{10325500} = 1.31\ Q_{10249300}^{1.137}$	.73	18
		November	$Q_{10325500} = 1.56\ Q_{10249300}^{0.863}$	.80	12
		December	$Q_{10325500} = 1.58\ Q_{10249300}^{0.784}$	.47	20
		Any month	$Q_{10325500} = 1.30\ Q_{10249300}^{1.187}$	.95	23
---	East Stewart Creek near Ione	Any month	$Q_{East\ Stewart} = 0.14\ Q_{10249300}^{0.505}$	.23	87

Table 3. Monthly streamflow duration characteristics of streams in central Nevada

[Symbol: ---, no assigned station number]

Station number	Station name	Monthly streamflow equalled or exceeded for indicated percentage of time (cubic feet per second)								
		1	5	10	25	50	75	90	95	99
10245900	Pine Creek near Belmont	52.9	20.2	14.9	4.43	1.89	1.33	1.08	1.00	0.83
10245910	Mosquito Creek near Belmont	17.3	9.35	4.44	1.75	.78	.50	.33	.25	.16
10245925	Stoneberger Creek near Belmont	24.4	7.09	3.19	1.41	.42	.23	.18	.15	.10
10249300	South Twin River near Round Mountain	57.5	23.3	14.2	6.25	2.84	1.95	1.41	1.15	.88
10325500	Reese River near Ione	139	60.0	33.6	9.56	3.86	2.42	1.53	1.20	.59
---	East Stewart Creek near Ione	2.04	1.22	.87	.38	.20	.12	.08	.07	.05

Table 4. Selected basin physical and climatic characteristics of selected drainage basins in central Nevada

[Symbol: ---, no assigned station number]

Station number	Station name	Latitude (decimal degrees)	Longitude (decimal degrees)	Period of record	Drainage area (square miles)	Gage altitude (feet above sea level)	Main channel slope (feet per mile)	Mean basin altitude (feet above sea level)	Stream length (miles)	Annual precipitation (inches)	West or east facing basin	Percentage of basin above 8,000 feet	Percentage of basin above 10,000 feet
10245900	Pine Creek near Belmont	38.80	116.85	1977-95	12.2	7,560	720	9,000	5.00	15.0	east	98.4	47.5
10245910	Mosquito Creek near Belmont	38.80	116.70	1977-95	15.1	7,200	447	7,800	7.85	10.0	west	95.4	24.5
10245925	Stoneberger Creek near Belmont	39.14	116.60	1977-95	35.6	6,880	204	8,000	12.55	10.0	east	73.0	.2
10249300	South Twin River near Round Mountain	38.88	117.24	1965-95	20.0	6,400	604	9,130	8.10	15.4	east	84.5	12.0
10325500	Reese River near Ione	38.85	117.47	1951-80	53.0	7,100	180	8,800	13.45	19.0	west	80.6	10.8
---	East Stewart Creek near Ione	38.89	117.36	1987-92	.36	9,455	1,590	10,170	.85	25.2	west	100	66.7

Monthly streamflow data and basin and climatic characteristics at the six gaged sites in the study area were transformed to logarithms and used in a multiple-regression analysis to derive estimating equations of the form:

$$Q_{xx} = a\,A^{b}\,B^{c} \tag{2}$$

where:

Q_{xx} is the monthly streamflow with a percent exceedence probability of xx;
A and B are the basin physical and climatic characteristics; and
a, b, and c are the regression coefficients.

Monthly streamflows for each percent exceedence level were related to the basin and climatic characteristics using a stepwise regression procedure (SAS Institute, Inc., 1990) that adds independent variables to the equation, one at a time, until all statistically significant variables have been included in the equation.

The results of the regression analyses indicated that total drainage area and percent of drainage area above 10,000 feet altitude are the most significant variables for estimating monthly streamflow duration characteristics for ungaged central Nevada streams. The computerized procedure also provided statistical measures of the reliability of the derived equations such as the coefficient of determination (R^2), the standard error of estimate, and the standard error of prediction (defined in next section). The equations and statistical results are shown in table 5 for the annual values and table 6 for the monthly values. The coefficient of determination ranged from 0.57 to 0.87 and the standard error of estimate ranged from 43 to 107 percent in the western Montana study by Parrett and Cartier (1990). The coefficients of determination and the standard errors of estimate for the relations in this study are comparable to those ranges. For the annual values, the coefficient of determination ranged from 0.73 to 0.92, the standard error of estimate of the relations ranged from 51 to 96 percent, and the standard error of prediction ranged from 96 to 249 percent. For the monthly values, the coefficient of determination ranged from 0.33 to 0.97, the standard error of estimate of the relations ranged from 31 to 168 percent, and the standard error of prediction ranged from 115 to 3,124 percent. The individual monthly statistical measures were much higher than the annual statistical measures probably due to the small number of observations (six) used in the monthly statistical analysis.

RELIABILITY AND LIMITATIONS OF ESTIMATING METHODS

The statistical reliability of many of the equations is poor because only six observations (gaging sites) were available for the analyses. The few observations did not allow proper definition of the true relation of each independent variable to the dependent variable in most equations (including equations for gaged sites and the regionalization for ungaged sites). More observations generally improves the reliability of regression equations. In addition to the standard error of estimate, another measure of reliability, the standard error of prediction, was computed in this study for the ungaged sites using the prediction sum of squares (PRESS) statistic. The PRESS statistic is computed by setting aside the first observation of the set of *n* observations, and using the remaining *n*-1 observations to estimate the coefficients for the regression model. The first observation is then replaced and the second observation withheld with coefficients estimated again. Each observation is removed one at a time, and the model is fit *n* times. The deleted observation is estimated each time, resulting in *n* prediction errors or PRESS residuals. The PRESS statistic is computed as the sum of the squares of these residuals. The PRESS residuals are true prediction errors being independent of the equation used to estimate them. So the PRESS-derived standard error of prediction is a truer measure of how accurately the regression equations will estimate the dependent variable at other than calibration sites.

The regression equations determined in this study are based on the basin characteristics method and may not be applicable beyond the range of values used to derive the equations (table 4). Extrapolation beyond the values listed may yield estimates with greater errors than those indicated in tables 2, 5, and 6.

Table 5. Results of regression analysis used to determine monthly streamflow duration characteristics at ungaged sites in central Nevada

[Q_{xx}, monthly streamflow exceeded xx percent of the time during any month, in cubic feet per second; A, drainage area, in square miles; E10, percentage of basin at altitudes greater than 10,000 feet; R^2, coefficient of determination from regression analysis]

Regression equation used to estimate monthly streamflow duration characteristic	R^2	Standard error of estimate (percent)	Standard error of prediction (percent)
$Q_1 = 1.53\ A^{0.903}\ E10^{0.265}$	0.91	63	249
$Q_5 = 0.618\ A^{0.855}\ E10^{0.340}$	.92	51	152
$Q_{10} = 0.334\ A^{0.826}\ E10^{0.398}$	.87	68	154
$Q_{25} = 0.187\ A^{0.736}\ E10^{0.326}$	.86	62	154
$Q_{50} = 0.070\ A^{0.710}\ E10^{0.398}$	.84	65	211
$Q_{75} = 0.037\ A^{0.744}\ E10^{0.443}$	.85	68	192
$Q_{90} = 0.027\ A^{0.742}\ E10^{0.426}$	.83	72	121
$Q_{95} = 0.024\ A^{0.722}\ E10^{0.424}$	.80	79	101
$Q_{99} = 0.018\ A^{0.684}\ E10^{0.426}$	.73	96	96

Table 6. Results of regression analysis used to determine mean monthly streamflow duration characteristics at ungaged sites in central Nevada

[Q_{xx}, monthly mean discharge exceeded xx percent of the time during the specified month, in cubic feet per second; Qmean, mean monthly discharge, in cubic feet per second; A, drainage area, in square miles; E10, percentage of basin at altitudes greater than 10,000 feet; R^2, coefficient of determination from regression]

Month	Regression equation used to estimate mean monthly streamflow duration characteristic	R^2	Standard error of estimate (percent)	Standard error of prediction (percent)
October	$Q_5 = 0.21 A^{0.73} E10^{0.20}$	0.88	58	188
	$Q_{25} = 0.09 A^{0.70} E10^{0.34}$	.86	57	275
	$Q_{50} = 0.06 A^{0.67} E10^{0.42}$	.84	63	366
	$Q_{75} = 0.05 A^{0.63} E10^{0.46}$	.82	65	371
	$Q_{95} = 0.03 A^{0.57} E10^{0.55}$	.71	101	349
	$Q_{mean} = 0.10 A^{0.64} E10^{0.33}$	.85	57	162
November	$Q_5 = 0.23 A^{0.71} E10^{0.15}$	.85	68	207
	$Q_{25} = 0.10 A^{0.69} E10^{0.31}$	.86	56	230
	$Q_{50} = 0.05 A^{0.69} E10^{0.42}$	.83	67	398
	$Q_{75} = 0.04 A^{0.66} E10^{0.46}$	.83	67	347
	$Q_{95} = 0.03 A^{0.59} E10^{0.51}$	.68	109	584
	$Q_{mean} = 0.09 A^{0.66} E10^{0.30}$	.83	61	227
December	$Q_5 = 0.22 A^{0.69} E10^{0.13}$	.88	54	161
	$Q_{25} = 0.10 A^{0.69} E10^{0.26}$	.84	64	308
	$Q_{50} = 0.05 A^{0.69} E10^{0.41}$	.83	67	474
	$Q_{75} = 0.04 A^{0.68} E10^{0.39}$	.77	84	486
	$Q_{95} = 0.03 A^{0.61} E10^{0.45}$	.65	115	445
	$Q_{mean} = 0.08 A^{0.66} E10^{0.28}$	.82	65	291
January	$Q_5 = 0.17 A^{0.74} E10^{0.14}$	.85	72	304
	$Q_{25} = 0.11 A^{0.70} E10^{0.20}$	.87	58	267
	$Q_{50} = 0.04 A^{0.74} E10^{0.40}$	.83	73	524
	$Q_{75} = 0.03 A^{0.75} E10^{0.39}$	.80	82	521
	$Q_{95} = 0.02 A^{0.64} E10^{0.41}$	.68	106	403
	$Q_{mean} = 0.07 A^{0.72} E10^{0.27}$	.83	69	115
February	$Q_5 = 0.12 A^{0.85} E10^{0.17}$	.89	67	190
	$Q_{25} = 0.09 A^{0.78} E10^{0.20}$	.87	67	370
	$Q_{50} = 0.04 A^{0.85} E10^{0.37}$	.86	72	534
	$Q_{75} = 0.03 A^{0.80} E10^{0.40}$	.79	93	661
	$Q_{95} = 0.02 A^{0.74} E10^{0.33}$	.60	168	793
	$Q_{mean} = 0.05 A^{0.83} E10^{0.28}$	.86	73	439
March	$Q_5 = 0.08 A^{1.06} E10^{0.29}$	.87	96	1,229
	$Q_{25} = 0.06 A^{0.97} E10^{0.29}$	.85	94	1,033
	$Q_{50} = 0.03 A^{0.95} E10^{0.45}$	.84	93	999
	$Q_{75} = 0.03 A^{0.89} E10^{0.44}$	.83	91	960
	$Q_{95} = 0.02 A^{0.83} E10^{0.43}$	.77	108	1,026
	$Q_{mean} = 0.05 A^{0.92} E10^{0.33}$	.84	91	867
April	$Q_5 = 0.14 A^{1.18} E10^{0.36}$	.88	103	1,526
	$Q_{25} = 0.11 A^{0.98} E10^{0.37}$	.80	120	2,273
	$Q_{50} = 0.06 A^{0.99} E10^{0.45}$	.84	100	1,506
	$Q_{75} = 0.03 A^{0.98} E10^{0.59}$	.85	96	1,888
	$Q_{95} = 0.02 A^{0.95} E10^{0.52}$	.82	105	1,609
	$Q_{mean} = 0.08 A^{1.03} E10^{0.39}$	.84	105	2,161

Table 6. Results of regression analysis used to determine mean monthly streamflow duration characteristics at ungaged sites in central Nevada—Continued

Month	Regression equation used to estimate mean monthly streamflow duration characteristic			R^2	Standard error of estimate (percent)	Standard error of prediction (percent)
May	Q_5	=	$1.36\ A^{1.00}\ E10^{0.19}$	0.94	55	230
	Q_{25}	=	$0.27\ A^{1.00}\ E10^{0.51}$	.89	77	980
	Q_{50}	=	$0.16\ A^{0.95}\ E10^{0.53}$	.88	75	360
	Q_{75}	=	$0.03\ A^{1.03}\ E10^{0.83}$	.90	83	518
	Q_{95}	=	$0.03\ A^{0.89}\ E10^{0.65}$	.79	121	3,124
	Q_{mean}	=	$0.36\ A^{0.95}\ E10^{0.36}$	.91	65	365
June	Q_5	=	$2.51\ A^{0.90}\ E10^{0.20}$	.97	31	362
	Q_{25}	=	$0.88\ A^{0.74}\ E10^{0.33}$	.90	50	218
	Q_{50}	=	$0.29\ A^{0.76}\ E10^{0.50}$	.83	76	454
	Q_{75}	=	$0.13\ A^{0.69}\ E10^{0.60}$	.87	63	244
	Q_{95}	=	$0.06\ A^{0.63}\ E10^{0.77}$	.93	52	178
	Q_{mean}	=	$0.76\ A^{0.72}\ E10^{0.31}$	.91	44	131
July	Q_5	=	$0.72\ A^{0.82}\ E10^{0.26}$	.94	42	575
	Q_{25}	=	$0.32\ A^{0.68}\ E10^{0.34}$	.92	40	162
	Q_{50}	=	$0.14\ A^{0.72}\ E10^{0.43}$	.93	40	255
	Q_{75}	=	$0.11\ A^{0.59}\ E10^{0.45}$	.88	48	204
	Q_{95}	=	$0.06\ A^{0.44}\ E10^{0.52}$	.84	55	215
	Q_{mean}	=	$0.28\ A^{0.66}\ E10^{0.31}$	.90	44	138
August	Q_5	=	$0.40\ A^{0.77}\ E10^{0.21}$	.91	49	470
	Q_{25}	=	$0.16\ A^{0.67}\ E10^{0.35}$	.93	38	147
	Q_{50}	=	$0.12\ A^{0.62}\ E10^{0.32}$	.84	56	290
	Q_{75}	=	$0.07\ A^{0.52}\ E10^{0.41}$	.83	53	192
	Q_{95}	=	$0.11\ A^{0.21}\ E10^{0.28}$	.34	108	442
	Q_{mean}	=	$0.17\ A^{0.61}\ E10^{0.28}$	.89	43	125
September	Q_5	=	$0.25\ A^{0.74}\ E10^{0.22}$	.92	46	254
	Q_{25}	=	$0.12\ A^{0.67}\ E10^{0.33}$	.88	49	182
	Q_{50}	=	$0.08\ A^{0.60}\ E10^{0.36}$	.80	63	322
	Q_{75}	=	$0.05\ A^{0.55}\ E10^{0.45}$	.80	64	313
	Q_{95}	=	$0.06\ A^{0.31}\ E10^{0.34}$	.33	158	464
	Q_{mean}	=	$0.10\ A^{0.64}\ E10^{0.29}$	.87	51	134

The following limitations apply to the use of the equations presented in this report: (1) The equations are valid only for streams located in the study area; (2) the equations are valid only for streams located on the mountain block areas, not for streams located in the valleys or on alluvial fans; (3) the equations are valid only for perennial streams; (4) the equations are valid only for streams with insignificant diversions and regulation upstream of the site of interest; (5) the equations are not valid for streams located in areas with fractured consolidated bedrock that tend to lose surface water streamflow to ground-water; and (6) the equations are not valid for estimating historical streamflows resulting from summertime convective storms which may have been caused by localized runoff in isolated parts of the study area.

SUMMARY

Techniques for estimating monthly mean streamflow at gaged sites and monthly streamflow duration characteristics at ungaged sites in central Nevada were developed using streamflow records at gaged sites and basin physical and climatic characteristics. Streamflow data were available from six sites within the study area.

Streamflow data at gaged sites were related by regression techniques to concurrent flows at nearby index gaging stations to determine monthly mean streamflows at gaged sites in central Nevada. The equations can be used to fill in periods of missing or no data at the gaging station sites. Standard error of estimate for gaged sites for the monthly equations ranged from 12 to 196 percent. Basin characteristics such as total drainage area, percentage of drainage area above 8,000 and 10,000 feet, channel slope, channel length, gage altitude, mean basin altitude and climatic characteristic such as annual precipitation were determined for each basin. Monthly streamflow data for selected percent exceedence levels were used in regression analyses with basin and climatic variables to determine relations for ungaged basins. Analyses indicate that the total drainage area and percent of drainage area at altitudes above 10,000 feet are the most significant variables. For the annual percent exceedence, the standard error of estimate of the relations for ungaged sites ranged from 51 to 96 percent and standard error of prediction for ungaged sites ranged from 96 to 249 percent. For the monthly percent exceedence values, the standard error of estimate of the relations ranged from 31 to 168 percent, and the standard error of prediction ranged from 115 to 3,124 percent. Reliability and limitations of the estimating methods were described.

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GLOSSARY

Some of the technical terms and acronyms used in this report are defined for convenience of the reader. See Langbein and Iseri (1960) for additional information regarding hydrological terminology.

Basin physical and climatic characteristics. Parameters that describe the physical and climatic factors of a drainage basin. Parameters include total drainage area, percentage drainage area above 8,000 and 10,000 feet altitude, stream length, channel slope, basin altitude, mean basin altitude, and mean annual precipitation.

Channel slope. The channel slope, in feet per mile, measured between points which are 10 and 85 percent of the main channel length upstream from the study site.

Coefficient of determination (R^2). A measure of the proportion of the total variance of the dependent variable that is accounted for by the independent variables in a regression analysis.

Drainage area. The drainage area of a stream at a specified location measured in a horizontal plane, which is enclosed by a drainage divide.

Duration curve. A cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded.

Ephemeral Stream. A stream that flows only in direct response to precipitation and thus discontinues its flow during dry seasons.

Mean. The value obtained by dividing the sum of a series of values by the number of values in the series.

Mean annual precipitation. The mean annual precipitation as determined from Hardman (1965).

Perennial stream. A stream that flows from source throughout all seasons.

PRESS. Prediction sum of squares.

Residual. The difference between a station value and a value predicted by a regression equation.

Standard error of estimate. A measure of the reliability of a regression equation. The standard error is the standard deviation of the residuals about the regression equation.

Standard error of prediction. A measure of how accurately regression equations will estimate the dependent variable at sites other than those used to calibrate the regression model.

Streamflow station. A gaging station where a continuous record of discharge is obtained. Within the U.S. Geological Survey, the term is used only for station where a continuous record of discharge is obtained.

Stream length. Distance in miles along the main channel from the gaging station to the basin divide.

USGS. U.S. Geological Survey.