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Methods for Estimating Magnitude and Frequency of Peak Flows for Natural Streams in Utah

Prepared in cooperation with the
UTAH DEPARTMENT OF TRANSPORTATION AND THE UTAH DEPARTMENT OF NATURAL RESOURCES,
DIVISIONS OF WATER RIGHTS AND WATER RESOURCES

Scientific Investigations Report 2007-5158

Version 2.0, October 4, 2007

U.S. Department of the Interior
U.S. Geological Survey

Cover photo: South Ash Creek at I-15 near Pintura, Utah, looking upstream (north), January 11, 2005. Photo by Dale E. Wilberg, U.S. Geological Survey.

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By Terry A. Kenney, Chris D. Wilkowske, and Shane J. Wright

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U.S. Department of the Interior
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Conversion Factors and Datums

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km2)
	Flow rate	
cubic foot per second (ft3/s)	0.02832	cubic meter per second (m3/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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ABSTRACT

Estimates of the magnitude and frequency of peak streamflows is critical for the safe and cost-effective design of hydraulic structures and stream crossings, and accurate delineation of flood plains. Engineers, planners, resource managers, and scientists need accurate estimates of peak-flow return frequencies for locations on streams with and without streamflow-gaging stations. The 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence-interval flows were estimated for 344 unregulated U.S. Geological Survey streamflow-gaging stations in Utah and nearby in bordering states. These data along with 23 basin and climatic characteristics computed for each station were used to develop regional peak-flow frequency and magnitude regression equations for 7 geohydrologic regions of Utah. These regression equations can be used to estimate the magnitude and frequency of peak flows for natural streams in Utah within the presented range of predictor variables. Uncertainty, presented as the average standard error of prediction, was computed for each developed equation. Equations developed using data from more than 35 gaging stations had standard errors of prediction that ranged from 35 to 108 percent, and errors for equations developed using data from less than 35 gaging stations ranged from 50 to 357 percent.

INTRODUCTION

Reliable estimates of peak streamflow are needed by engineers, land-use planners, resource managers, and scientists. The magnitude and frequency of peak flows are required for safe and cost-effective design of near-stream or instream structures, flood-plain delineation, and flood-hazard assessment. These types of data are readily available for streams with streamflow-gaging stations; however, data often are needed at locations lacking such stations. Techniques such as multiple-linear regression allow estimates of peak flows at ungaged locations to be obtained through defined statistical associations between physical characteristics and peak-flow data obtained from gaged sites. The U.S. Geological Survey (USGS), in cooperation with the Utah Department of Transportation and the Utah Department of Natural Resources, Divisions of Water Rights and Water Resources, completed this study to develop new regional regression equations for the State of Utah. The regional regression equations presented were developed by using annual peak flow-data from streamflow-gaging stations in Utah and bordering states through water year 2005.

Purpose and Scope

This report documents the development of regional regression equations that can be used to estimate peak flows at the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence intervals at ungaged sites in Utah. Methods for estimating peak-flow magnitude and frequency for gaged sites and at locations near gage sites are presented. A technique is discussed for weighting peak flows determined from both regional regression equations and gage data using the equivalent years of record metric and the number of years of annual peak record. Limitations associated with the regional regression equations are outlined, including the assessment of prediction errors and determination of ungaged sites applicable to the models. Finally, StreamStats, a USGS web-based computer program that allows for the application of the developed regression equations in an efficient and accurate manner, is introduced.

Acknowledgments

The authors would like to acknowledge the efforts of the dedicated hydrographers, past and present, from the Utah Water Science Center and surrounding Water Science Centers that are and have been responsible for the collection, computation, and analysis of streamflow data, particularly peak-flow data, used in this report. Special thanks go to Kenny Eng of the USGS who provided statistical expertise and a computer program that improved the efficiency of applying the generalized least-squares techniques of Stedinger and Tasker (1985) and Tasker and Stedinger (1989).

Previous Studies

Many previous studies in Utah have examined flood-frequency relations (table 1). The index-flood method was used in the earlier studies of Patterson and Somers (1966) and Butler and others (1966). The first multiple-linear regression study of regional flood frequency for Utah was completed by Butler and Cruff (1971). Since 1971, more than five multiple-linear regression studies have been completed. Aside from Fields (1975), which examined the relation between channel geometry characteristics and flood frequency, these studies used basin characteristics to develop regional equations to predict peak-flow frequency. Thomas and others (1997) developed regional regression equations for the entire southwestern United States, including Utah, from streamflow-gaging station data through 1986. Regression equations for the Virgin River basin were developed in Perica and Grenney (2003), and regression equations were developed for the Weber River basin in Perica and Stayner (2004).

Description of Utah

Located within both the Colorado River Basin and the Great Basin, Utah possesses a wide variety of physiographic characteristics. The landscape is diverse and includes high alpine regions, expansive arid desert, and vast slickrock canyonlands. The major drainage basins in Utah are the Green River basin, Colorado River Basin, Virgin River basin, Sevier River basin, and the Great Basin (Great Salt Lake) (fig. 1). Land-surface elevations range from 13,528 ft at Kings Peak in the Uinta Mountains of northeastern Utah, to about 2,000 ft near Beaver Dam Wash in southwestern Utah. The spatial variability in precipitation is quite large. More than 60 in/yr of precipitation, mostly as snow, falls in the mountains of the northern part of Utah, while the annual precipitation in the Great Salt Lake Desert is about 5 in (Daly and others, 1994). Average annual temperatures vary throughout the state as a function of both elevation and latitude. The diverse physiographic and climatic conditions throughout Utah create a unique flood-hydrology.

FLOODING IN UTAH

Floods and, to a similar degree, annual peak flows, result from three atmospheric conditions that produce substantial precipitation. Mountain snowpack, which accumulates from late fall through the spring, is generated by west-to-east-moving Pacific frontal systems (U.S. Geological Survey, 1991). Storms associated with upper-level low-pressure systems, which generally occur in the spring and early fall, often are widespread and slow moving (U.S. Geological Survey, 1991). Monsoonal thunderstorms, common in late summer, are precipitation events of short duration and high intensity.

Table 1. Previous flood-frequency studies for Utah.

Year	Study	Authors	Method
1966	Magnitude and frequency of floods in the United States, Part 9. Colorado River Basin	Patterson and Somers	Index-flood
1966	Magnitude and frequency of floods in the United States, Part 10. The Great Basin	Butler and others	Index-flood
1971	Floods of Utah, magnitude and frequency characteristics through 1969	Butler and Cruff	Ordinary least squares multiple regression basin and climate
1975	Estimating streamflow characteristics for streams in Utah using selected channel-geometry parameters	Fields	Ordinary least squares multiple regression channel geometry
1976	Estimating runoff volumes and flood hydrographs in the Colorado River Basin, Southern Utah	Eychaner	Ordinary least squares multiple regression basin and climate
1983	Methods for estimating peak discharge and flood boundaries of streams in Utah	Thomas and Lindskov	Ordinary least squares multiple regression basin and climate
1985	Manual for estimating selected streamflow characteristics of natural-flow streams in the Colorado River Basin in Utah	Christenson and others	Ordinary least squares multiple regression basin and climate
1997	Methods for estimating magnitude and frequency of floods in the Southwestern United States	Thomas and others	Generalized least squares multiple regression basin and climate
2003	Regional flood frequency analysis for selected basins in Utah Part I: Virgin River basin	Perica and Grenney	Ordinary least squares multiple regression basin and climate
2004	Regional flood frequency analysis for selected basins in Utah Part II: Weber River basin	Perica and Stayner	Ordinary least squares multiple regression basin and climate

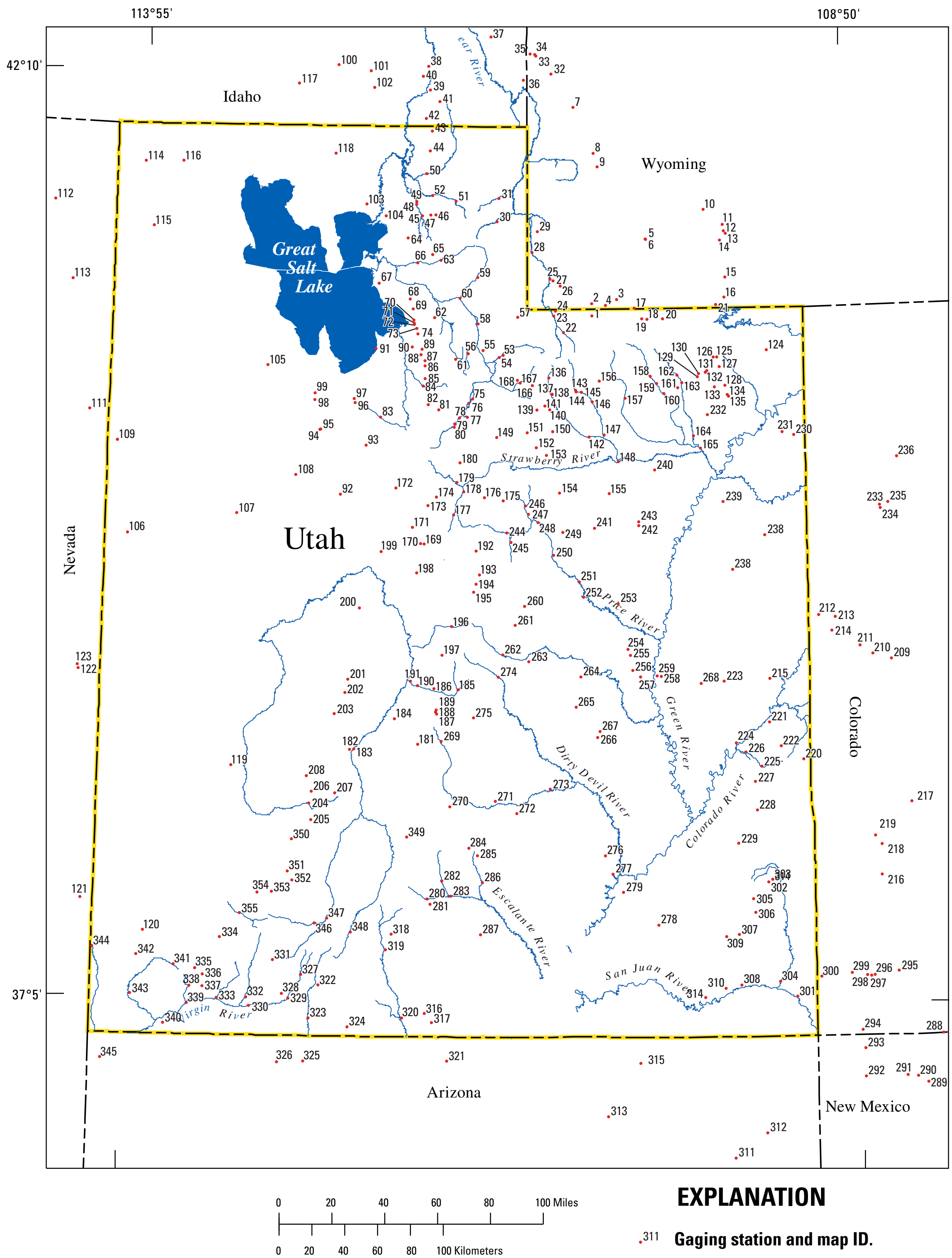

Figure 1. Location of streamflow-gaging stations in Utah and bordering states used in regional regression analysis.

Peak streamflows for most streams in northern and eastern Utah are dominated by snowmelt runoff. The snowmelt runoff period typically is between April and late June, with peaks occurring in late May and early June. Rapid melting of exceptionally large snowpacks can lead to statewide flooding, as was the case in 1983. The largest and most damaging floods in Utah generally are associated with rain that falls on melting snow, and the most common flooding in Utah comes in the form of flash floods related to heavy local precipitation (Wilkowske and others, 2006).

Envelope Curves

Envelope curves allow for a method of estimating potential maximum floodflows in a given geographic area. These curves are developed by plotting the largest peak flow for all gage sites against drainage area. With streamflow record length considered to be long enough to capture maximum peak flows at some of the stations in the dataset, a limiting relation between drainage area and peak flow can be interpreted. Physiographic and atmospheric characteristics are the determining factors of a maximum floodflow, and therefore different locales possess different envelopes of drainage area and streamflow. A number of studies have examined this relation for different geographic areas for which envelope curves were developed (Creager, 1939; Hoyt and Langbein, 1955; Matthai, 1969; Crippen and Bue, 1977; Jensen and others, 1978; Crippen, 1982; and Costa, 1987).

For perspective, the maximum instantaneous natural peak flows for any site in Utah stored in the USGS National Water Information System (NWIS) database are plotted along with three envelope curves developed in Crippen and Bue (1977) and an envelope curve developed in Costa (1987) (fig. 2). Crippen and Bue (1977) defined 17 flood regions for the conterminous United States, and most of Utah is contained within region 14 (fig. 3). However, much of the western part of the state falls into region 16, and some of the northeastern part of the state is in region 13. Regions 13 and 16 contain

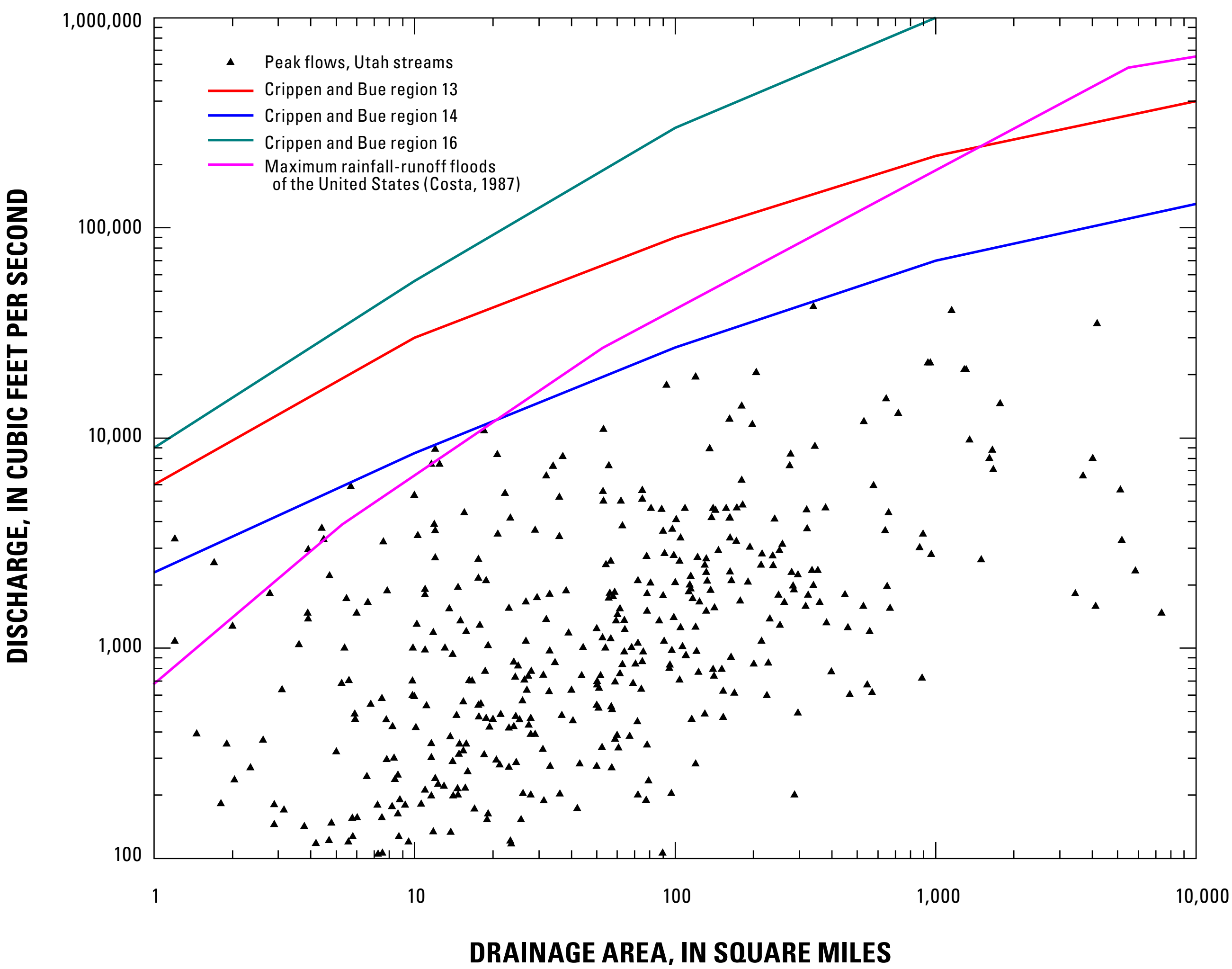

Figure 2. Maximum instantaneous natural peak flows for any site in Utah plotted with Crippen and Bue's (1977) envelope curves for regions 13, 14, and 16, and the Costa (1987) envelope curve of maximum rainfall-runoff floods of the United States.

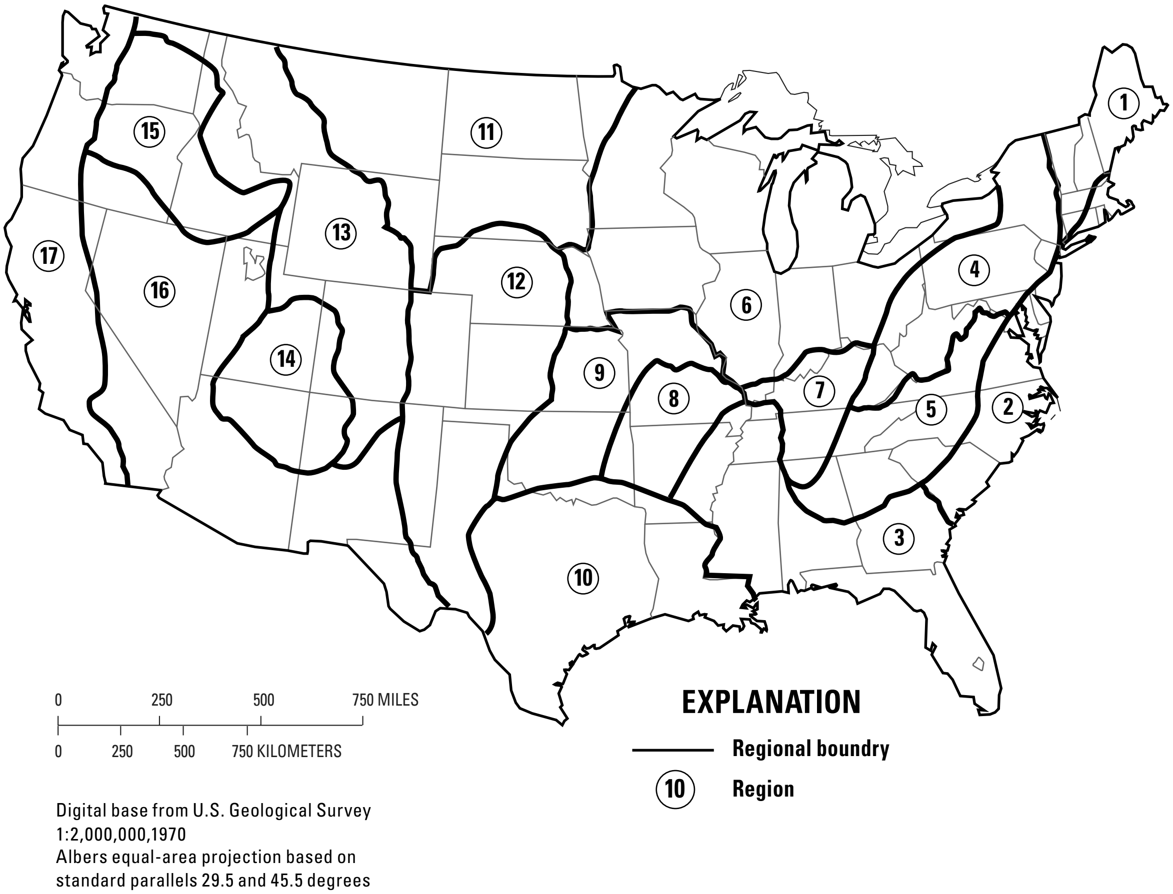

Figure 3. Map showing flood-region boundaries within the conterminous United States (modified from Crippen and Bue, 1977).

portions of Idaho, Wyoming, Montana, Washington, Nevada, California, and Arizona and are shown to not represent the drainage area and peak-flow limits for Utah. The curve for region 14, which encompasses much of Utah and parts of Colorado, New Mexico, and Arizona appears to be valid for Utah streams. Streams that drain small drainage basins (less than 20 mi^2) in Utah appear to exceed the envelope curve for maximum rainfall-runoff floods in the United States (Costa, 1987), while streams that drain larger drainage basins (greater than 20 mi^2) appear well below the limit. The reason for the differences for the smaller drainage areas is not known.

COMPUTATION OF PEAK FLOW FROM GAGED SITES

For more than 100 years, the USGS has been publishing the annual peak flow at streamflow-gaging stations. The annual peak flow at a gaging station is the largest computed streamflow that occurred during a single water year (October 1-September 30), typically computed by applying the highest recorded water-surface elevation, or gage-height, to the active stage-discharge rating for that particular streamflow-gaging station. Annual peak-flow data are available for continuous streamflow-gaging stations where daily-mean flows are computed, as well as stations that only record maximum water-surface elevations, or gage-heights, commonly referred to as crest-stage streamflow-gaging stations. For the United States, these data are stored in the USGS NWIS database and are available on the world wide web at *http://nwis.waterdata.usgs.gov/usa/nwis/peak*. Peak-flow data have proven extremely useful for a variety of engineering design, water-resource management, and hydrologic science applications.

METHODS FOR ESTIMATING FREQUENCY OF PEAK FLOWS AT GAGED SITES

Commonly, the annual peak-flow dataset for a single streamflow-gaging station is used to estimate return frequencies or recurrence intervals of specific peak streamflows for that site. By fitting the recorded annual peak flows to a probability distribution, traditionally the log-Pearson Type III (LPIII), probability-based flow recurrence intervals, such as the 100-year peak streamflow, can be estimated. Bulletin 17B (U.S. Interagency Advisory Committee on Water Data, 1982) outlines this most common method of determining the frequency of peak flows at streamflow-gaging stations. The methods outlined in Bulletin 17B are specific to natural streamflow conditions and should not be applied to watersheds affected by reservoir regulation, urbanization, or other conditions that may affect the natural runoff-streamflow relation. Recurrence-interval flows at streamflow-gaging stations provide the basis for developing regional flood-frequency regression equations.

Frequency of Peak Flows at Gaged Sites

USGS streamflow-gaging stations in Utah and nearby in surrounding states were examined to determined if they meet criteria established in Bulletin 17B (U.S. Interagency Advisory Committee on Water Data, 1982). Selected gaging-station data were not affected by regulation or urbanization and possessed a minimum of 10 annual peaks. Historic data from gaging stations currently regulated by reservoirs that possessed 10 or more annual peaks prior to reservoir construction also were selected. For any station, no more than 25 percent of the annual peaks could be reported as below the defined gage base flow or 0 ft^3/s. A total of 355 streamflow-gaging stations were selected for this analysis (fig. 1). The peak-flow data from these stations consist of a mixed population of rainfall- and snowmelt-related events.

The 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence-interval flows (appendix 1) were determined for the selected stations following the techniques outlined in Bulletin 17B. As previously mentioned, flows for specific recurrence intervals are obtained by fitting the annual peak-flow record from a station to a LPIII distribution. Recurrence intervals in years and exceedance probabilities are mathematical inverses. For example, a flow with an exceedance probability of 0.10 has a recurrence interval of 10 years (1/0.10 = 10) (Berenbrock, 2002). A 10-year peak flow has a 1 in 10 probability of occurring in a single year. The equation for fitting the LPIII distribution to a series of annual peak flows takes the form (U.S. Interagency Advisory Committee on Water Data, 1982):

$$\log Q_T = \bar{X} + KS \qquad (1)$$

where:

Q_T is T-year peak flow, in cubic feet per second, where T is recurrence interval;

$\bar{X}$ is mean of the log-transformed annual peak flow,

K is frequency factor dependent on the recurrence interval and the skew coefficient of the log-transformed annual peak flow, and

S is standard deviation of the log-transformed annual peak flow.

As shown by equation 1, the skew of the annual peak flow, contained in *K*, is a critical component in fitting the distribution. Because the skew computed from the station record is sensitive to extreme events it is recommended to weight this skew, often termed station skew, with a skew computed from nearby sites, termed generalized skew (U.S. Interagency Advisory Committee on Water Data, 1982). Perica and Stayner (2004) developed a generalized skew map for the state of Utah that used stations with at least 30 years of record (fig. 4). Site-specific skews were plotted on a map, and a gridded skew map was developed by using linear and bicubic interpolation techniques. From the gridded map, Perica and Stayner (2004) developed a generalized skew contour map. For this study, generalized skew values used in the weighted skew computations for each station were obtained by interpolating between contours contained on this map. For the purposes of this report, the contours were extended into adjoining states to obtain generalized skew values for stations not located in Utah.

For all stations, the LPIII fits to the systematic annual peak-flow record were graphically examined. Most stations fit the distribution adequately. However, 11 of the selected stations did not. For stations with poor fits, recurrence-interval flows were not determined, and these stations were dropped from the analysis. Generally, stations with poor fits to the LPIII distribution contained short periods of record and a high variability in the annual peak series. The average period of record for the sites that fit poorly was 14 years, and the average standard deviation of the logarithms of annual peak flow was 1.00. The remaining stations had an average period of record of 26 years, and an average standard deviation of 0.37. An example of a station that fit well and one that fit poorly to the LPIII distribution is shown in figure 5.

Frequency of Peak Flows at Ungaged Sites that are Near Gaged Sites on the Same Stream

Frequency of peak flows can be estimated at different locations on a stream containing a gage by using a ratio of drainage area for the ungaged and gaged sites. If the drainage-area ratio of the two locations falls between 1.5 and 0.5, there is no significant tributary inflow occurring between either site, and both basins are physically and climatically similar, then peak flows can be estimated by using the equation (Guimaraes and Bohman, 1992; Stamey and Hess, 1993):

$$Q_{T(u)} = Q_{T(g)} \, (DA_u / DA_g)^a \qquad (2)$$

where:

$Q_{T(u)}$ is T-year peak flow for ungaged site, in cubic feet per second, where T is recurrence interval,

$Q_{T(g)}$ is T-year peak flow for gaged site, in cubic feet per second,

DA_u is drainage area for the ungaged site,

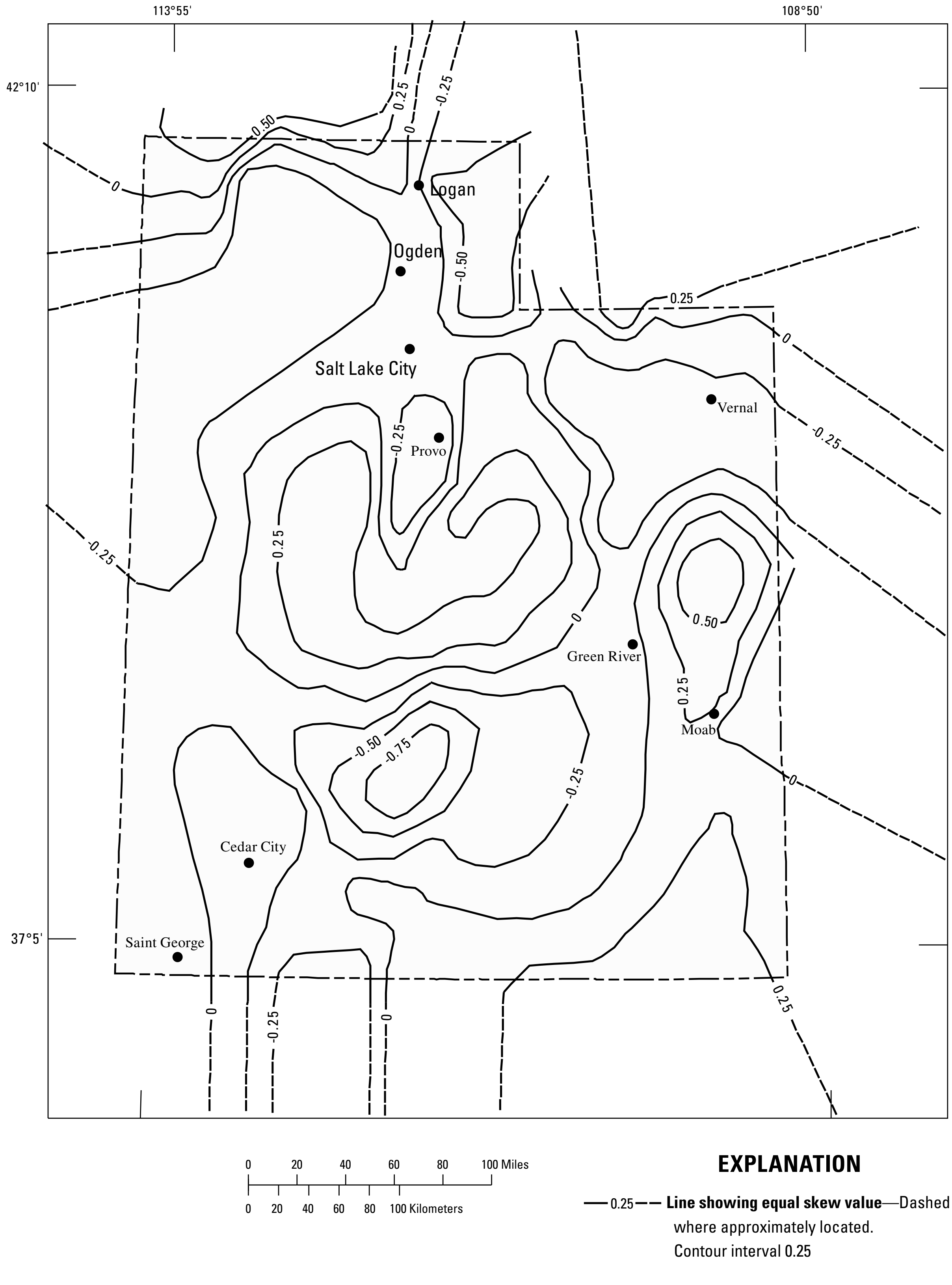

Figure 4. Generalized skew map for Utah (modified from Perica and Stayner, 2004).

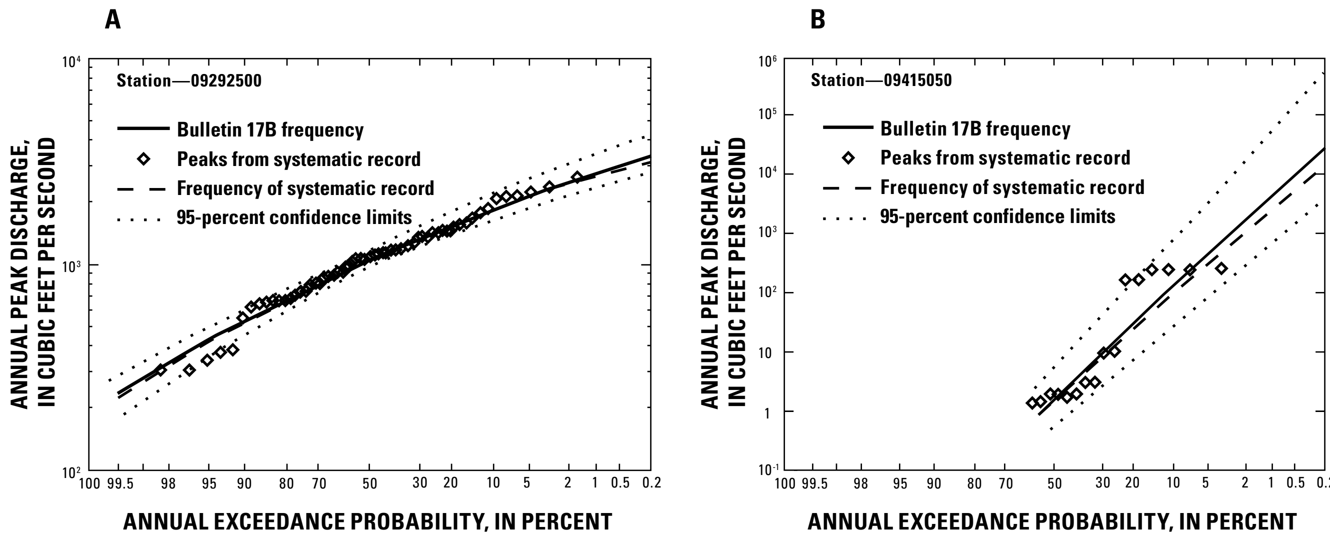

Figure 5. Example of streamflow-gaging stations with (a) an adequate fit and (b) a poor fit to the log-Pearson Type III distribution.

DA_g is drainage area for the gaged site, and

a is an exponent for the drainage area for each hydrologic region (table 2).

Table 2. Determined exponent *a* for each region.

Region	Exponent *a*
1	0.49
2	.51
3	.21
4	.84
5	.53
6	.31
7	.45

The exponent *a* was determined by regressing the logarithms of each T-year flow (T = 2, 5, 10, 25, 50, 100, 200, and 500) against the logarithms of drainage area for each region. The exponent *a* for each region is the average of the coefficients for the logarithm of drainage area for all T-year flows (table 2).

If an ungaged site is located between two gaged sites on the same stream, the following equation can be used (Berenbrock, 2002):

$$Q_{T(u)} = \left[\frac{(Q_{T(g1)} (DA_{g2}\ DA_u) + Q_{T(g2)} (DA_u\ DA_{g1}))}{(DA_{g2}\ DA_{g1})} \right] \quad (3)$$

where:

$Q_{T(u)}$ is T-year peak flow for ungaged site between gaged sites, in cubic feet per second, where T is recurrence interval,

$Q_{T(g1)}$ is T-year peak flow for upstream gaged site, in cubic feet per second,

$Q_{T(g2)}$ is T-year peak flow for downstream gaged site, in cubic feet per second,

DA_u is drainage area for the ungaged site,

DA_{g1} is drainage area for the upstream gaged site, and

DA_{g2} is drainage area for the downstream gaged site.

REGIONAL REGRESSION METHOD FOR ESTIMATING FREQUENCY OF PEAK FLOWS FOR UNGAGED SITES

Peak streamflow data, and therefore estimates of specific recurrence-interval flows, are not directly available for streams without established streamflow-gaging stations. The concept of expanding the utility of gaged-site data for use at ungaged locations with similar physiographic and climatic characteristics is not new, and several methods have been examined and tested during the past 50 years. The method of choice for the past 30 years has been statistically based regional equations that predict peak streamflow. For this method, a study area is divided into regions of similar physiographic and climatic characteristics. Multiple-linear regression techniques are applied to determine coefficients for statistically significant predictors of peak streamflow. For every region, regression models or equations are developed for each desired recurrence-interval flow such as the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year peak flow. As previously discussed, for Utah there have been a number of studies that have developed regional regression equations to predict peak flows. The previous effort that encompassed the entire state of Utah used data through water year 1986 (Thomas and others, 1997). This study used annual peak-flow data collected through water year 2005 to develop regional regression equations. Since the past statewide effort, the available dataset has been extended by 19 years, and computational techniques, including Geographic Information Systems (GIS) and statistical algorithms, have advanced considerably. GIS allows for the computation of complex basin characteristics, previously very difficult to compute, that can be statistically examined as predictors of peak flows.

Geohydrologic Regionalization of Utah

In an effort to define best-fit regression equations based upon basin physiographic and climatic characteristics, seven distinct geohydrologic regions for Utah were defined (fig. 6). The regions were determined on the basis of the following factors: (1) statistically significant groupings of basin and climatic characteristics of streamflow-gaging stations using cluster analysis techniques; (2) statewide landscape features; (3) defined climatic regions (fig. 7a); (4) defined physiographic provinces (fig. 7b); (5) previously defined flood regions (Thomas and others, 1997) (fig. 7c); and (6) scientific judgment based upon general hydrologic knowledge of the area. The seven regions were divided along hydrologic boundaries except for a portion of the divisions between regions 3 and 5, 3 and 7, and 2 and 4. These nonhydrologic divisions agreed with the general definition of the surrounding regions taking into account the factors discussed above. The location of streamflow-gaging stations used in the definition of the regions is shown on figure 1. Regions 1, 2, 4, and 5 are generally related to the two major mountain ranges in Utah, the Wasatch and Uinta Mountains. The north slope of the Uinta Mountains and most of the upper Bear River basin are contained in region 1. The northern and central parts of the Wasatch Mountains define regions 2 and 5 respectively. The south slope of the Uinta Mountains, including the Uinta Basin, makes up region 4. Region 3 includes the western part of the state, most of which is contained within the arid Basin and Range physiographic province. Region 6, the largest defined, encompasses most of the Colorado Plateau, and the Virgin River basin is mostly contained in region 7.

Basin and Climatic Characteristics

Twenty-one basin characteristics and two climatic characteristics were computed for each streamflow-gaging station by using GIS techniques. Conceptually, each of these characteristics has an influence upon the magnitude and frequency of peak streamflow. Geospatial algorithms, developed using Arc Macro Language programs written for ArcGIS (Environmental Systems Research Institute, Inc., 1999), were used in the computation of the basin characteristics. The values generated for each characteristic are directly dependent upon the algorithm, dataset, and spatial scale(s) used in their computation. As described below, the quantified uncertainties associated with the regression equations developed in this study are associated with the methods used to compute basin characteristics. For the uncertainties to be valid, the predictor variables in the equations should be computed using the same algorithms, datasets, and spatial scales. A list of the computed characteristics, the corresponding units, and the datasets they were computed from are contained in table 3. Descriptions of the datasets used are contained in table 4. Of the 23 characteristics examined for statistical significance in predicting the 8 recurrence interval flows, 5 were included in one or more of the final sets of regional equations.

Regional Regression Analysis

The regional regression method, as presented in this report, regresses basin and climatic characteristics computed for each streamflow-gaging station previously selected against the desired recurrence-interval flows for stations in each region. Stations determined to fit poorly to the LPIII distribution were not used in the analysis. For all seven regions, equations for the eight selected recurrence-interval flows were developed. Statistical outliers in the peak-flow data and the basin and climatic characteristics were screened. All peak-flow data were transformed to base-10 logarithms. Normality in the basin and climatic characteristic data was examined, and for most characteristics normality was enhanced through a transformation to base-10 logarithms. For characteristics represented as percentages, such as percent of basin defined as herbaceous upland (Vogelmann and others, 1998), a value of 1 percent was added prior to transformation to prevent null values associated with an attempt to take a logarithm of 0. Elevations were first divided by 1,000 in an effort to obtain smaller, more-convenient coefficient values.

An iterative stepwise regression approach was used in an exploratory capacity to test several combinations of basin and climatic characteristics for each region. Different combinations of basin and climatic characteristics were necessary because of the presence of multi-colinearity and (or) high correlation between some characteristics. The stepwise regressions were done using traditional weighted least-squares (WLS) technique. In an effort to mimic some of the weighting associated with the generalized least-squares (GLS) regression technique discussed below, weights for each station were computed by dividing total years of peak flow for the station by the maximum years of peak flow for a single station in that region. For each stepwise equation a variety of statistical metrics were evaluated to determine the most explanatory variables to further examine with the GLS regression technique.

GLS regression technique was applied by a program based on methods described by Stedinger and Tasker (1985) and Tasker and Stedinger (1989) to achieve the final regression models. For regional peak-flow frequency analyses, GLS regression is generally chosen over conventional least-squares regression techniques for its ability to account for cross correlation between sites, differences in station record length, and variability in peak flows at gaging stations. Traditional ordinary least-squares techniques assume independence,

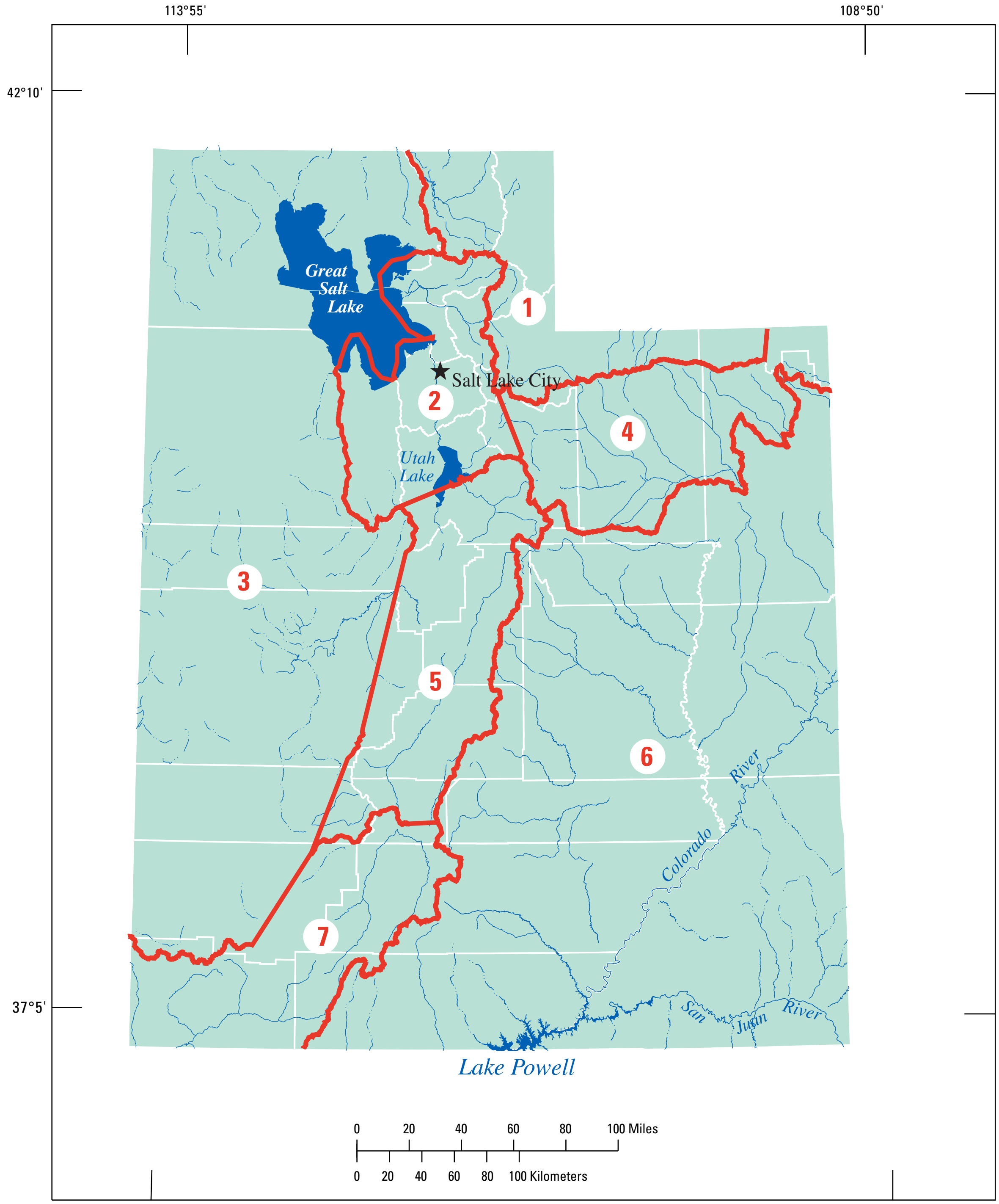

Figure 6. Geohydrologic regions of Utah used in regional regression analysis.

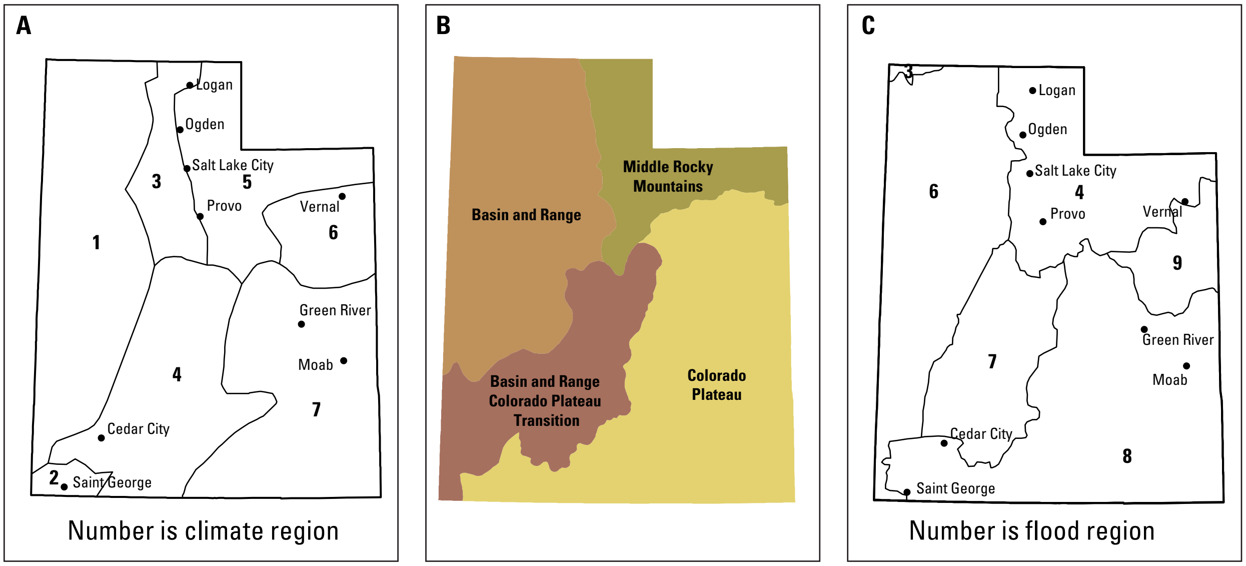

Figure 7. Other regions of Utah used to define geohydrologic regions, including (a) climatic regions of Utah (modified from National Oceanic and Atmospheric Administration, 1994), (b) physiographic regions of Utah (modified from Utah Geological Survey, 2007) and (c) flood regions of the southwestern United States (modified from Thomas and others, 1997).

Table 3. Basin physiographic and climatic characteristics.

[NED, National Elevation Dataset; NLCD, National Land Cover Dataset; PRISM, Parameter-Elevation Regressions on Independent Slopes Model; NOAA, National Oceanic and Atmospheric Administration]

Characteristic	Unit	Datasets used
Area	square miles	Watershed polygon generated by the StreamStats process
Perimeter length	miles	Watershed polygon generated by the StreamStats process
Relief	feet	10-meter NED
Relative relief	feet per mile	10-meter NED
Elevation	feet	10-meter NED
Maximum basin elevation	feet	10-meter NED
Minimum basin elevation	feet	10-meter NED
High elevation index-percent of area with elevation greater than 6,000 feet	percent	10-meter NED
Average basin slope	percent	10-meter NED
Percent of basin with slope greater than 30 percent	percent	10-meter NED
Percent of basin with slope greater than 30 percent and facing north	percent	10-meter NED
Elevation of basin at outlet	feet	10-meter NED
Percent of area covered by forest	percent	NLCD 1992
Percent of area covered by agriculture	percent	NLCD 1992
Percent of area covered by barren land	percent	NLCD 1992
Percent of area covered by developed land	percent	NLCD 1992
Percent of area covered by shrubland	percent	NLCD 1992
Percent of area covered by herbaceous upland	percent	NLCD 1992
Percent of area covered by wetland	percent	NLCD 1992
Percent of area covered by woody land	percent	NLCD 1992
Mean annual precipitation (basin wide average)	inches	PRISM
24-hour storm total with 2-year return frequency, averaged throughout basin	inches	NOAA-Atlas14[1], NOAA-Atlas 2[2]

[1] Used for Utah, Nevada, Arizona, and New Mexico

[2] Used for Idaho, Wyoming, and Colorado

Table 4. Data sources used to compute basin physiographic and climatic characteristics.

Dataset name	Source description
10-meter National Elevation Dataset (NED)	U.S. Geological Survey, 1999, National elevation dataset: U.S. Geological Survey Fact Sheet 148-99, accessed July 12, 2007, at *http://erg.usgs.gov/isb/pubs/factsheets/fs14899.html*
National Land Cover Dataset 1992 (NLCD 1992)	Vogelmann, J.E., Sohl, T.L., Campbell, P.V., and Shaw, D.M., 1998, Regional land cover characterization using Landsat Thematic Mapper data and ancillary data sources: Environmental Monitoring and Assessment, v. 51, p. 415-428, accessed July 12, 2007, at *http://landcover.usgs.gov/natllandcover.php*
Precipitation frequency atlas of the United States (National Oceanic and Atmospheric Administration Atlas 14)	Bonnin, G., Martin, D., Parzybok, T., Lin, B., Riley, D., and Yekta, M., 2006, Precipitation frequency atlas of the United States: National Weather Service, National Oceanic and Atmospheric Administration Atlas 14, vol. 1, version 4.0, accessed July 12, 2007, at *http://hdsc.nws.noaa.gov/hdsc/pfds/docs/NA14Vol1.pdf*
Precipitation frequency atlas of the United States (National Oceanic and Atmospheric Administration Atlas 2)	Miller, J.F., Frederick, R.H., and Tracy, R.J., 1973, Precipitation-frequency atlas of the Western United States: National Weather Service, National Oceanic and Atmospheric Administration Atlas 2, 11 vols., accessed July 12, 2007, at *http://nws.noaa.gov/ohd/hdsc/noaaatlas2.htm*
Parameter-elevation Regressions on Independent Slopes Model climate mapping system (PRISM) Total precipitation (30-year average, 1971-2000)	Daly, Christopher, Nielson, R.P., and Phillips, D.L., 1994, A statistical-topographic model for mapping climatological precipitation over mountainous terrain: Journal of Applied Meteorology, v. 33, no. 2, p. 140-158, accessed July 12, 2007, at *http://prism.oregonstate.edu/products*

ignoring cross correlations, between response variables. Peak flows between stations within a region often are correlated because of the widespread atmospheric conditions that they are the result of, and common years of record. Even though the response variables for the regression models developed in this study are recurrence interval flows derived from curve fitting, GLS technique examines the series of annual peaks at all stations as well as the geographic distance between stations to help determine the degree of potential correlation between sites. GLS regression technique utilizes weighting matrices that are populated from a “best fit” mathematical relation between sample cross-correlation coefficients and distance between sites for site pairs with long periods (typically 30 years) of concurrent record (Tasker and Stedinger, 1989). Sites with correlated concurrent peak flows, as estimated by using the relation between correlation and distance between sites, are given less weight. Variability in the series of annual peak flows for each station is evaluated by using the standard deviation of the population and predictor variables of the station. In GLS regression technique, the standard deviation of the annual peak series and the input predictor variables of all sites are regressed. From this regression, standard deviations are computed to obtain unbiased estimates of standard deviation for each station which is used to assign weights that account for variability. Generally speaking, unless weights are developed to account for differences in time-sampling errors and their cross correlations, traditional ordinary least-squares techniques will assume equal sampling error. Time-sampling error is assumed to be less with longer station record. GLS regression technique accounts for this by giving more weight to stations with longer periods of record.

Regional Regression Results

GLS regression equations for the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence-interval flows were developed for all seven regions (table 5). As can be seen, for each region the same set of predictor variables was used in all eight equations. This was done in an effort to provide a consistent frequency curve for any location within a specific region. The use of different variables for different recurrence-interval flows allows the potential for flow to decrease with increasing frequency, a violation in the definition of a peak streamflow frequency curve (Asquith and Thompson, 2005). In taking this approach, the variables chosen for each region were those that, on average, best predicted the eight recurrence-interval flows. Drainage area (DRNAREA) was used in all equations, mean basin elevation (ELEV) was included in three regions, and the variables mean annual precipitation (PRECIP), average basin slope (BSLDEM10M), and percent of basin defined as herbaceous upland (HERBUPLND) were each used in the equations for one region. Past peak-flow regression equations for Utah have not included the predictor variables mean basin slope or percent of basin defined as herbaceous upland. A graph of residuals for the 50-year flow regression equation for region 4 is shown in figure 8. Ideally for valid unbiased regression equations, it is desired that residuals be distributed randomly about the zero line without any discernable pattern. Graphs of the residuals were examined for all developed equations.

A measure of the average error the regression equation will yield is the average variance of prediction (Stedinger and Tasker, 1985; Tasker and Stedinger, 1989), AVP. Modified for GLS regression, AVP is given by:

Table 5. Predictive regression equations and their associated uncertainty in estimating peak flows for natural streams in Utah.

[PK, Peak flow, number following PK represents recurrence interval, in years; DRNAREA, drainage area, in square miles; ELEV, mean basin elevation, in feet; PRECIP, mean annual precipitation, in inches; BSLDEM10M, average basin slope, in percent; HERBUPLND, area covered by herbaceous upland, in percent]

Regression equation for given recurrence interval (2- to 500-year)	Average standard error of prediction, in percent	Model error, in percent	Equivalent years of record
Region 1 (equation based on data from 46 streamflow-gaging stations)			
$PK2 = 1.52\ DRNAREA^{0.677}\ 1.39^{(ELEV/1,000)}$	62	59	0.97
$PK5 = 5.49\ DRNAREA^{0.614}\ 1.30^{(ELEV/1,000)}$	54	52	1.49
$PK10 = 10.3\ DRNAREA^{0.581}1.25^{(ELEV/1,000)}$	53	51	2.00
$PK25 = 19.7\ DRNAREA^{0.547}\ 1.21^{(ELEV/1,000)}$	55	52	2.59
$PK50 = 29.4\ DRNAREA^{0.524}\ 1.19^{(ELEV/1,000)}$	57	55	2.92
$PK100 = 40.4\ DRNAREA^{0.512}\ 1.17^{(ELEV/1,000)}$	58	55	3.34
$PK200 = 58.3\ DRNAREA^{0.483}\ 1.15^{(ELEV/1,000)}$	63	60	3.35
$PK500 = 85.4\ DRNAREA^{0.457}\ 1.13^{(ELEV/1,000)}$	68	64	3.50
Region 2 (equation based on data from 32 streamflow-gaging stations)			
$PK2 = 0.585\ DRNAREA^{0.847}\ 1.07^{PRECIP}$	71	66	.91
$PK5 = 1.56\ DRNAREA^{0.747}\ 1.07^{PRECIP}$	58	54	1.62
$PK10 = 2.51\ DRNAREA^{0.703}\ 1.06^{PRECIP}$	53	50	2.46
$PK25 = 4.00\ DRNAREA^{0.661}\ 1.06^{PRECIP}$	51	47	3.70
$PK50 = 5.36\ DRNAREA^{0.635}\ 1.06^{PRECIP}$	50	46	4.59
$PK100 = 6.92\ DRNAREA^{0.613}\ 1.06^{PRECIP}$	50	46	5.38
$PK200 = 8.79\ DRNAREA^{0.592}\ 1.05^{PRECIP}$	51	47	6.06
$PK500 = 12.0\ DRNAREA^{0.555}\ 1.05^{PRECIP}$	52	48	6.84
Region 3 (equation based on data from 14 streamflow-gaging stations)			
$PK2 = 14.5\ DRNAREA^{0.328}$	357	295	.60
$PK5 = 47.6\ DRNAREA^{0.287}$	194	168	1.40
$PK10 = 83.7\ DRNAREA^{0.289}$	152	132	2.49
$PK25 = 148\ DRNAREA^{0.298}$	130	113	4.21
$PK50 = 215\ DRNAREA^{0.302}$	128	110	5.28
$PK100 = 300\ DRNAREA^{0.303}$	136	116	5.89
$PK200 = 411\ DRNAREA^{0.301}$	150	126	6.13
$PK500 = 599\ DRNAREA^{0.299}$	177	147	6.10
Region 4 (equation based on data from 42 streamflow-gaging stations)			
$PK2 = 0.083\ DRNAREA^{0.822}\ 2.72^{0.656\ (ELEV/1,000)\ -\ 0.039\ BSLDEM10M}$	49	46	1.35
$PK5 = 0.359\ DRNAREA^{0.816}\ 2.72^{0.537\ (ELEV/1,000)\ -\ 0.035\ BSLDEM10M}$	37	35	2.60
$PK10 = 0.753\ DRNAREA^{0.811}\ 2.72^{0.500\ (ELEV/1,000)\ -\ 0.032\ BSLDEM10M}$	35	32	3.84
$PK25 = 1.64\ DRNAREA^{0.804}\ 2.72^{0.414\ (ELEV/1,000)\ -\ 0.030\ BSLDEM10M}$	35	32	5.07
$PK50 = 2.68\ DRNAREA^{0.798}\ 2.72^{0.373\ (ELEV/1,000)\ -\ 0.028\ BSLDEM10M}$	37	34	5.56
$PK100 = 4.18\ DRNAREA^{0.792}\ 2.72^{0.334\ (ELEV/1,000)\ -\ 0.023\ BSLDEM10M}$	39	36	5.72
$PK200 = 6.29\ DRNAREA^{0.786}\ 2.72^{0.299\ (ELEV/1,000)\ -\ 0.021\ BSLDEM10M}$	43	39	5.69
$PK500 = 10.5\ DRNAREA^{0.778}\ 2.72^{0.256\ (ELEV/1,000)\ -\ 0.018\ BSLDEM10M}$	47	43	5.47
Region 5 (equation based on data from 35 streamflow-gaging stations)			
$PK2 = 4.32\ DRNAREA^{0.623}\ (HERBUPLND+1)^{0.503}$	99	92	1.08
$PK5 = 11.7\ DRNAREA^{0.575}\ (HERBUPLND+1)^{0.425}$	60	54	3.27
$PK10 = 18.4\ DRNAREA^{0.555}\ (HERBUPLND+1)^{0.388}$	50	45	6.11
$PK25 = 28.8\ DRNAREA^{0.538}\ (HERBUPLND+1)^{0.352}$	49	43	8.91
$PK50 = 38.4\ DRNAREA^{0.536}\ (HERBUPLND+1)^{0.331}$	53	47	9.35
$PK100 = 50.2\ DRNAREA^{0.515}\ (HERBUPLND+1)^{0.316}$	61	53	8.79
$PK200 = 64.7\ DRNAREA^{0.504}\ (HERBUPLND+1)^{0.300}$	71	62	7.99
$PK500 = 88.3\ DRNAREA^{0.489}\ (HERBUPLND+1)^{0.285}$	86	76	7.05
Region 6 (equation based on data from 99 streamflow-gaging stations)			
$PK2 = 4,150\ DRNAREA^{0.553}\ (ELEV/1,000)^{-2.45}$	108	106	1.44
$PK5 = 13,100\ DRNAREA^{0.479}\ (ELEV/1,000)^{-2.44}$	80	78	3.01
$PK10 = 24,700\ DRNAREA^{0.444}\ (ELEV/1,000)^{-2.47}$	70	68	5.06
$PK25 = 49,500\ DRNAREA^{0.411}\ (ELEV/1,000)^{-2.51}$	62	60	8.43

Table 5. Predictive regression equations and their associated uncertainty in estimating peak flows for natural streams in Utah—Continued.

Regression equation for given recurrence interval (2- to 500-year)	Average standard error of prediction, in percent	Model error, in percent	Equivalent years of record
Region 6 (equation based on data from 99 streamflow-gaging stations)—Continued			
$PK50 = 77{,}400\ DRNAREA^{0.391}\ (ELEV/1{,}000)^{-2.54}$	60	58	10.95
$PK100 = 115{,}000\ DRNAREA^{0.391}\ (ELEV/1{,}000)^{-2.58}$	61	58	12.97
$PK200 = 166{,}000\ DRNAREA^{0.361}\ (ELEV/1{,}000)^{-2.61}$	62	60	14.42
$PK500 = 258{,}000\ DRNAREA^{0.344}\ (ELEV/1{,}000)^{-2.65}$	66	63	15.40
Region 7 (equation based on data from 25 streamflow-gaging stations)			
$PK2 = 18.4\ DRNAREA^{0.630}$	76	71	2.71
$PK5 = 67.4\ DRNAREA^{0.539}$	95	88	2.46
$PK10 = 134\ DRNAREA^{0.487}$	110	102	2.62
$PK25 = 278\ DRNAREA^{0.429}$	132	121	2.85
$PK50 = 446\ DRNAREA^{0.390}$	149	136	2.99
$PK100 = 683\ DRNAREA^{0.355}$	166	151	3.13
$PK200 = 1{,}010\ DRNAREA^{0.321}$	185	167	3.23
$PK500 = 1{,}620\ DRNAREA^{0.280}$	211	189	3.35

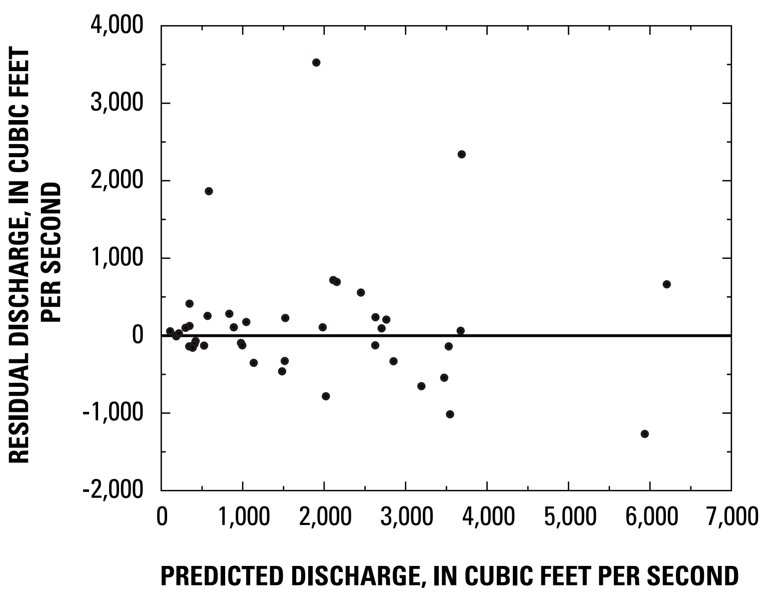

Figure 8. Residuals for 50-year recurrence-interval regression equation for region 4.

$$AVP = \sigma_\delta^2 + \left(\frac{1}{n}\right)\sum_{i=1}^{n} \mathbf{x}_i \left(\mathbf{X}^T \Lambda^{-1} \mathbf{X}\right)^{-1} \mathbf{x}_i^T \quad (4)$$

where:

AVP is the average variance of prediction,

σ_δ^2 is the model error variance,

n is the number of stations in the regression model,

$\mathbf{x}_i$ is the vector containing the basin attributes of the i^{th} station augmented by a value of one,

$\mathbf{X}$ is the matrix of all basin attributes at all stations in the regression augmented by a column of ones,

Λ is the GLS weighting matrix (Tasker and Stedinger, 1989),

T superscript indicates taking the transpose of a matrix,

and the -1 superscript indicates taking the inverse of a matrix.

The AVP is comprised of model error variance and time-sampling error. Model error variance represents the inherent error associated with the model such as the representation of non log-linear behavior with log-linear regression methods, or the inability to explain all observed variance with the selected predictor variables. Time-sampling error, computed as the difference between the AVP and model error variance, is an indication of the amount of error associated with sample size. Theoretically, time-sampling error should decrease with more data from gaging stations of similar characteristics

A more commonly used metric, the average standard error of prediction in percent, *Sp*, as computed from the AVP is given by (Aitchison and Brown (1957), modified for use of common logarithms):

$$S_p = 100\left[e^{(\ln 10)^2 AVP} - 1\right]^{0.5} \quad (5)$$

where:

S_p is the average standard error of prediction, in percent, and

AVP is the average variance of prediction.

The average standard error of prediction in percent, and the model error variance in percent for all developed equations are contained in table 5. Equations for region 4 had the smallest values, while region 3 had the largest. Generally, standard errors of prediction were lowest for equations based upon data from more than 35 gaging stations. Equations for regions 3 and 7 were based on data from 14 and 25 gaging stations, respectively. As would be expected, equations from these regions show the largest time-sampling errors, on average 19.7 percent. Equations for region 6 were based on data from 99 gaging stations and had the smallest average time-sampling error of 2.46 percent. The range and average standard error of prediction, model error, and time sampling error associated with each recurrence interval are shown in table 6.

When developing multiple-linear regression models, it is important to consider whether an observation, in this case peak-flow and basin-characteristic data from a single gaging station, potentially has a large impact on the coefficient(s) of the model. A measure of this potential impact can be obtained by using the leverage statistic (Tasker and Stedinger, 1989), which is computed for each observation independent of the model by using the equation:

$$\mathbf{h} = \mathbf{X}\left(\mathbf{X}^T \Lambda^{-1} \mathbf{X}\right)^{-1} \mathbf{X}^T \Lambda^{-1} \quad (6)$$

where:

$\mathbf{h}$ is the matrix containing leverage values for all stations,

$\mathbf{X}$ is the matrix of all basin attributes at all stations in the regression augmented by a column of ones, and

Λ is the GLS weighting matrix (Tasker and Stedinger, 1989).

Table 6. Range and average errors associated with regional regression equations for each recurrence interval.

Recurrence interval, in years	Average error, in percent	Minimum error, in percent	Maximum error, in percent
Average standard error of prediction			
2	117	48.8	357
5	82.7	37.2	194
10	74.7	34.6	152
25	73.3	35.0	132
50	76.4	36.7	149
100	81.7	39.4	166
200	89.2	42.6	185
500	101	47.4	211
Model error variance			
2	105	45.9	295
5	75.6	34.7	168
10	68.6	32.1	132
25	66.8	32.2	121
50	69.5	33.7	136
100	73.6	36.1	151
200	80.0	39.0	167
500	90.0	43.4	189
Time-sampling error			
2	12.3	2.58	62.0
5	7.02	2.15	26.3
10	6.13	2.06	19.6
25	6.49	2.15	17.4
50	6.97	2.30	18.1
100	8.04	2.48	20.2
200	9.18	2.69	23.5
500	11.1	2.98	29.9

As shown, a leverage matrix is constructed from the input predictor variables, basin climatic characteristics, and the GLS weighting matrix mentioned above. An indicator of the level at which a large impact to the model from a single observation would be expected is the leverage threshold, or limit, given by the equation:

$$h_{\text{limit}} = \frac{2\sum_{i=1}^{n} h_{ii}}{n} \quad (7)$$

where:

h_{limit} is the leverage threshold,

h_{ii} are the main diagonal components of the **h** matrix from equation 6, and

n is the number of stations in the regression model,

A graph of leverage values with the leverage limit for the 100-year peak-flow regression equation for region 2 is shown in figure 9. To assess the stability of the models by using the leverage statistic, stations with leverage values that exceeded the leverage limit were identified. These stations were then removed from the dataset and the equation was re-formulated. Equations were considered stable and the impact minimal if the coefficient(s) changed by less than 20 percent. In these cases, stations were retained in the analysis and the original equation was used. If the coefficient(s) changed by more than 20 percent, these stations were removed and the new equation was used. In order to maintain a maximum number of observations available for each regional set of equations and avoid over-tuning the calibration procedure, this leverage assessment process was iterated only once. The leverage limits for each equation, the number of stations with leverage values that exceeded the limit that were retained in the equation development, and the maximum leverage value for those stations are contained in table 7.

Weighting Peak-Flow Estimates from Gaging Stations with Regional Regression Estimates

A method for weighting flood-frequency estimates for a gaged location obtained from the annual peak flow series and regional regression equations is outlined in Bulletin 17B (U.S. Interagency Advisory Committee on Water Data, 1982). The weighting method assumes that flood-frequency estimates determined from the systematic annual peaks for a streamflow-gaging station are independent from estimates obtained for the station from regression equations (Ries and Crouse, 2002). The weighting is determined by the number of years of peak record and the equivalent years of record metric (Hardison, 1971) associated with the regression equation (table 5). The computed equivalent years of record is a representation of the number of years of record that would be required at any ungaged site in the region to achieve comparable accuracy of the given regression equation. Equivalent years of record for each regression equation were computed from the equation (modified from Hardison, 1971):

$$EQ = s_{pred}^{\,2}\,[1 + k_T g + 0.5k_T^{\,2}(1 + 0.75g^2)] \,/\, AVP^{0.5} \quad (8)$$

where:

EQ is the equivalent years of record,

s_{pred} is the average of predicted standard deviations for each station used in regional regression equation estimated from a regression between standard deviations of the annual peak series for each station and the predictor variables used in the regression equation for each station,

k_T is the log-Pearson type III deviate for T-year recurrence interval,

g is the average of weighted skew values from frequency analysis for each station used in regional regression equation, and

AVP is the average variance of prediction of the regression equation.

Weighted flood-frequency estimates can be computed as (Ries and Crouse, 2002)

$$\log Q_{T(G)w} = \frac{\left(N \log Q_{T(G)s} + EQ \log Q_{T(G)r}\right)}{N + EQ} \quad (9)$$

where:

$Q_{T(G)w}$ is the weighted T-year peak flow estimate, in cubic feet per second, where T is recurrence interval,

$Q_{T(G)s}$ is the T-year peak flow estimate derived from the systematic flood peaks,

$Q_{T(G)r}$ is the T-year peak flow estimate derived from the regression equation,

N is the number of years of peak record, and

EQ is the equivalent years of record associated with the regression equation.

Limitations of Regional Regression Equations

The applications of the regional regression equations presented in this report have certain limitations. Recurrence-interval flows estimated by using the regression equations are considered to be associated with natural atmospheric and physiographic conditions and not representative of conditions created through anthropogenic means. The annual time series of peak flows used in the development of the equations were not affected by regulation, or urbanization, and peaks associated with dam failures were not included in the analysis. The utility of the equations is related to the datasets used in their construction. The range of predictor variable values for the gaging stations used to develop the regression equations

Table 7. Leverage limits for regional regression equations, the number of streamflow-gaging stations with leverage values that exceeded the limit that were retained in the equation development, and the maximum leverage value for those stations.

Recurrence interval, in years	Leverage statistic limit	Number of sites used in analysis that exceed limit	Maximum leverage value	Recurrence interval, in years	Leverage statistic limit	Number of sites used in analysis that exceed limit	Maximum leverage value
Region 1				**Region 5**			
2	0.130	2	0.160	2	0.171	1	0.193
5	.130	3	.155	5	.171	3	.187
10	.130	3	.151	10	.171	4	.198
25	.130	3	.147	25	.171	4	.210
50	.130	3	.147	50	.171	4	.211
100	.130	3	.149	100	.171	4	.210
200	.130	3	.148	200	.171	4	.208
500	.130	3	.149	500	.171	4	.204
Region 2				**Region 6**			
2	.188	1	.210	2	.061	4	.067
5	.188	1	.213	5	.061	4	.063
10	.188	2	.215	10	.061	2	.062
25	.188	2	.218	25	.061	2	.065
50	.188	2	.219	50	.061	3	.067
100	.188	2	.220	100	.061	5	.069
200	.188	2	.221	200	.061	5	.069
500	.188	2	.222	500	.061	5	.069
Region 3				**Region 7**			
2	.286	1	.362	2	.160	1	.266
5	.286	1	.368	5	.160	1	.266
10	.286	1	.375	10	.160	1	.265
25	.286	1	.385	25	.160	1	.265
50	.286	1	.390	50	.160	1	.265
100	.286	1	.393	100	.160	1	.265
200	.286	1	.395	200	.160	1	.265
500	.286	1	.396	500	.160	1	.265
Region 4							
2	.190	3	.246				
5	.190	3	.251				
10	.190	3	.255				
25	.190	3	.258				
50	.190	4	.260				
100	.190	4	.261				
200	.190	4	.262				
500	.190	4	.262				

is contained in table 8. The equations, and associated errors, are valid for these ranges of predictor-variable values. Computation of the predictor variables was done by using specified GIS algorithms on datasets and at scales previously discussed. These same computational procedures using the same digital datasets at the same scales should be adhered to in order to stay consistent with the quantified uncertainty of the equations. It is understood that certain engineering, scientific, and management problems may require the application of the methods presented in this report outside of the prescribed ranges and with predictor-variable values computed by means other than those outlined. For these instances, the quantified errors of the equations are not valid. Consideration of the limitations presented requires proper application of hydrologic judgment by the end user of the equations of this report.

STREAMSTATS WEB-BASED COMPUTER PROGRAM

StreamStats is a web-based tool developed by the USGS that integrates published streamflow-gaging station data and regional regression equations with a web-based GIS (Ries and

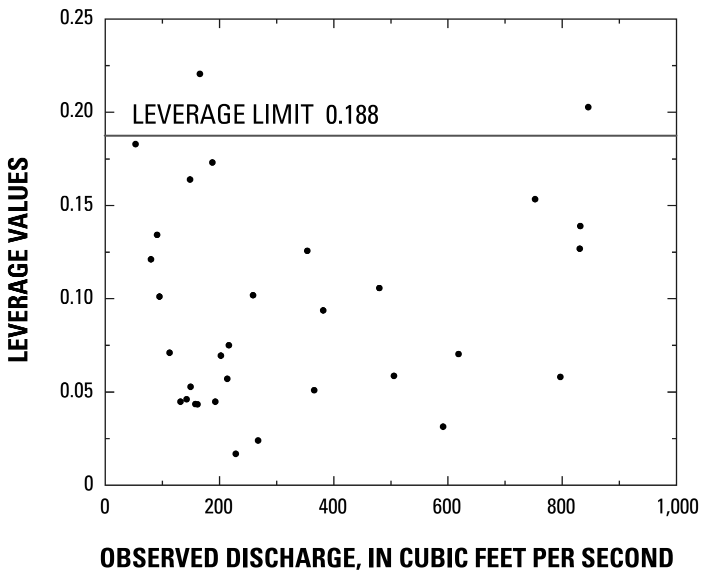

Figure 9. Leverage values and limit for 100-year recurrence-interval regression equation for region 2.

others, 2004). StreamStats allows a user to obtain a variety of streamflow statistics and basin characteristics by selecting a location on a map interface. Published data can be obtained if the user selects the location of a USGS streamflow-gaging station. If the location of interest does not have a gaging station, StreamStats will apply published regression equations for that location and estimate the associated streamflow statistics. The methods used in computing the predictor variables used in the development of the regression equations is preserved in the StreamStats application. StreamStats can be accessed on the World Wide Web at *http://water.usgs.gov/osw/streamstats/*. To use StreamStats for the application of the equations described in this report, navigate within the above StreamStats website to the state application for Utah.

SUMMARY

Engineers, planners, resource managers, and scientists use estimates of the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence-interval flows for a variety of design, planning, and management purposes. Flooding in Utah can be caused by runoff from exceptional snowpacks; widespread, slow-moving low-pressure weather systems; and high-intensity monsoonal thunderstorms of short duration. Even though these are distinct atmospheric conditions, a well-defined limit of the relation between drainage area and peak flow in Utah is evident in the Crippen and Bue (1977) region 14 envelope curve. The USGS NWIS database for Utah and surrounding states was examined for streamflow-gaging stations with 10 or more years of natural peak-flow data in order to estimate the return frequencies of specific streamflows. The 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence-interval flows were estimated for 344 unregulated USGS gaging stations in Utah and bordering states. In an effort to expand this extensive dataset to similar streams without gaging stations, regional regression equations were developed. Seven distinct geohydrologic regions were determined by using a variety of physiographic, climatic, and hydrologic characteristics. Twenty-three physiographic and climatic characteristics were computed for the 344 gaging stations. Combinations of these characteristics were statistically examined as predictors of the different recurrence-interval flows in each region. Final equations were developed by using GLS regression technique that accounts for cross correlation between sites, annual peak-flow record length, and annual peak-flow variability. Recurrence-interval flows were determined to be either solely a function of drainage area, or a function of drainage area and one or two other variables. Equations for three regions included mean basin elevation. Mean annual precipitation, average basin slope, and percent of basin defined as herbaceous upland (Vogelmann and others, 1998) were each used in the equations for one region. Equations developed from more than 35 gaging stations had standard errors of prediction that ranged from 35 to 108 percent, and errors for equations developed from less than 35 gaging stations ranged from 50 to 357 percent. On the basis of the standard error of prediction, the equations for region 4 have the least uncertainty, and the equations for regions 3 and 7 have the greatest. The limitations presented in this report should be considered for any application of the developed regression equations.

Table 8. Range of predictor variables computed for streamflow-gaging stations used in the development of the regression equations.

[—, variable not used in equations]

Region	Drainage area, in square miles	Elevation, in feet	Precipitation, in inches	Average area slope, percent	Area covered by herbaceous upland, percent
1	3.62-390	6,420-10,500	—	—	—
2	2.14-84.1	—	16.5-53.7	—	—
3	5.72-66.5	—	—	—	—
4	2.95-667	8,130-10,900	—	9.67-40.3	—
5	.91-629	—	—	—	2.14-15.6
6	.87-532	4,300-9,380	—	—	—
7	5.43-1,670	—	—	—	—

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APPENDIX

Appendix. Peak flows at selected recurrence intervals for streamflow-gaging stations in Utah and bordering states used in regional regression analysis.

[Nd, not determined, see footnote 1]

Map ID	Gaging station number	Gaging station name	Peak flow, in cubic feet per second, for given recurrence interval, in years								
			2	5	10	25	50	100	200	500	Number of annual peak flows
		Region 1									
[3]1	09217900	BLACKS FORK NEAR ROBERTSON, WYOMING	1,600	2,080	2,360	2,670	2,880	3,080	3,260	3,480	35
2	09218500	BLACKS FORK NEAR MILLBURNE, WYOMING	1,460	1,830	2,070	2,370	2,600	2,820	3,040	3,340	31
3	09220000	EAST FORK OF SMITHS FORK NEAR ROBERTSON, WYOMING	499	742	930	1,200	1,430	1,680	1,960	2,380	40
4	09220500	WEST FORK OF SMITH FORK NEAR ROBERTSON, WYOMING	438	703	911	1,210	1,470	1,750	2,060	2,510	42
5	09221680	MUD SPRING HOLLOW NEAR CHURCH BUTTE, NR LYMAN, WYOMING	56.6	190	360	713	1,110	1,660	2,390	3,740	20
6	09221700	MUD SPRING HOLLOW NEAR LYMAN, WYOMING	90.5	179	260	391	512	657	827	1,100	13
7	09223000	HAMS FORK BELOW POLE CREEK, NEAR FRONTIER, WYOMING	745	1,140	1,400	1,720	1,950	2,190	2,410	2,710	53
8	09223500	HAMS FORK NEAR FRONTIER, WYOMING	1,140	1,620	1,920	2,290	2,560	2,820	3,070	3,410	27
9	09224000	HAMS FORK AT DIAMONDVILLE, WYOMING	1,420	2,210	2,770	3,490	4,040	4,600	5,160	5,930	18
[2]10	09224800	MEADOW SPRINGS WASH TRIB NEAR GREEN RIVER, WYOMING	32.6	96.2	157	250	328	412	499	619	18
[1]11	09224810	BLACKS FORK TRIBUTARY NO 2 NEAR GREEN RIVER, WYOMING	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	17
[3]12	09224820	BLACKS FORK TRIBUTARY NO 3 NEAR GREEN RIVER, WYOMING	19	71	142	295	475	728	1,080	1,730	20
[4]13	09224840	BLACKS FORK TRIBUTARY NO 4 NEAR GREEN RIVER, WYOMING	11	24.1	36.1	55.2	72.3	92	115	149	17
[4]14	09224980	SUMMERS DRY CREEK NEAR GREEN RIVER, WYOMING	675	2,250	4,350	8,990	14,500	22,600	34,100	56,700	17
15	09225200	SQUAW HOLLOW NEAR BURNTFORK, WYOMING	104	229	349	550	739	966	1,240	1,670	20
[4]16	09225300	GREEN RIVER TRIBUTARY NO 2 NEAR BURNTFORK, WYOMING	238	746	1,340	2,480	3,680	5,230	7,190	10,500	21
17	09226000	HENRYS FORK NEAR LONETREE, WYOMING	574	894	1,150	1,540	1,880	2,250	2,680	3,340	30
[2]18	09226500	MIDDLE FORK BEAVER CREEK NEAR LONETREE, WYOMING	308	487	621	806	956	1,110	1,280	1,530	22
[2]19	09227500	WEST FORK BEAVER CREEK NEAR LONETREE, WYOMING	164	252	320	416	496	583	679	819	14
[4]20	09228500	BURNT FORK NEAR BURNTFORK, WYOMING	279	505	715	1,070	1,410	1,820	2,330	3,190	32
[1]21	09229450	HENRYS FORK TRIBUTARY NEAR MANILA, UTAH	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	10
[3]22	10010400	EAST FK BEAR RIVER NR EVANSTON, WYOMING	561	688	762	847	904	958	1,010	1,070	13
23	10011500	BEAR RIVER NEAR UTAH-WYOMING STATE LINE	1,840	2,380	2,690	3,040	3,280	3,500	3,710	3,970	63
[4]24	10012000	MILL CREEK AT UTAH-WYOMING STATE LINE	390	544	643	764	851	936	1,020	1,130	19
25	10014000	BEAR RIVER ABOVE SULPHUR CREEK, NR EVANSTON, WYOMING	1,910	2,350	2,600	2,900	3,100	3,290	3,480	3,710	10
26	10015700	SULPHUR CR.AB.RES.BL.LA CHAPELLE CR.NR EVANSTON,WY	328	543	707	936	1,120	1,320	1,530	1,830	39
27	10016000	SULPHUR CREEK NEAR EVANSTON, WYOMING	515	783	962	1,190	1,350	1,520	1,680	1,890	17
[4]28	10019000	BEAR RIVER NEAR EVANSTON, WYOMING	1,950	2,580	2,950	3,380	3,670	3,940	4,190	4,510	43
29	10019700	WHITNEY CANYON CREEK NEAR EVANSTON, WYOMING	45	84.1	115	160	196	235	277	337	17
30	10021000	WOODRUFF CREEK NEAR WOODRUFF, UTAH	242	358	426	502	553	598	640	689	27
31	10023000	BIG CREEK NEAR RANDOLPH, UTAH	57.3	110	149	198	235	271	306	350	45
32	10032000	SMITHS FORK NEAR BORDER, WYOMING	896	1,270	1,510	1,810	2,020	2,220	2,420	2,680	64
33	10040000	THOMAS FORK NEAR GENEVA, IDAHO	145	249	327	435	522	613	709	844	12
34	10040500	SALT CREEK NEAR GENEVA, IDAHO	162	293	393	529	637	748	863	1,020	12
35	10041000	THOMAS FORK NEAR WYOMING-IDAHO STATE LINE	395	805	1,140	1,620	2,020	2,440	2,880	3,510	43
36	10042500	THOMAS FORK NR RAYMOND, IDAHO	438	797	1,060	1,420	1,690	1,970	2,250	2,630	10
37	10069000	GEORGETOWN CREEK NR GEORGETOWN, IDAHO	50.4	67.2	78.6	93.2	104	116	127	143	17
38	10084500	COTTONWOOD CREEK NR CLEVELAND, IDAHO	374	562	689	851	972	1,090	1,220	1,380	48
39	10089500	MINK CREEK NR MINK CREEK IDAHO	356	400	425	452	470	486	502	521	10
[2]40	10090800	BATTLE CREEK TRIB NR TREASURETON, IDAHO	45.2	95.7	137	195	243	292	344	415	19

Appendix. Peak flows at selected recurrence intervals for streamflow-gaging stations in Utah and bordering states used in regional regression analysis—Continued.

Map ID	Gaging station number	Gaging station name	Peak flow, in cubic feet per second, for given recurrence interval, in years								
			2	5	10	25	50	100	200	500	Number of annual peak flows
		Region 1—Continued									
41	10093000	CUB RIVER NR PRESTON, IDAHO	595	718	791	875	933	988	1,040	1,110	44
42	10096000	CUB RIVER AB MAPLE CREEK NR FRANKLIN, IDAHO	558	623	661	703	731	758	783	814	13
43	10099000	HIGH CREEK NEAR RICHMOND, UTAH	214	335	418	524	603	681	760	864	22
44	10102300	SUMMIT CREEK ABV DIVERSIONS NR SMITH-FIELD, UTAH	147	212	252	300	334	366	397	435	18
45	10104700	LITTLE BEAR R BL DAVENPORT CREEK NR. AVON, UTAH	435	742	970	1,280	1,520	1,770	2,030	2,390	32
46	10104900	EAST FK LT BEAR RIV AB RES. NR AVON, UTAH	497	697	823	974	1,080	1,180	1,280	1,410	23
47	10105000	EAST FORK LITTLE BEAR R NR AVON UT	320	525	674	873	1,030	1,190	1,360	1,590	13
[4]48	10105900	LITTLE BEAR RIVER AT PARADISE, UTAH	577	1,260	1,900	2,980	3,990	5,210	6,660	8,990	13
49	10106000	LITTLE BEAR RIVER NEAR PARADISE, UTAH	717	1,100	1,390	1,800	2,140	2,500	2,890	3,460	50
50	10109001	COMBINED FLOW LOGAN R AB ST D AND LO HP AND SM C N LO UT	1,110	1,480	1,690	1,940	2,100	2,260	2,400	2,580	83
51	10111700	BLACKSMITH F B MILL CREEK NR HYRUM, UTAH	141	207	251	306	346	385	424	475	11
52	10113500	BLACKSMITH FORK AB UP & L CO.'S DAM NR HYRUM, UTAH	448	805	1,070	1,440	1,730	2,030	2,340	2,770	88
53	10128200	SOUTH FORK WEBER RIVER NEAR OAKLEY, UTAH	197	226	242	261	273	284	295	308	10
54	10128500	WEBER RIVER NEAR OAKLEY, UTAH	1,810	2,430	2,800	3,220	3,510	3,780	4,030	4,340	101
[1]55	10129350	CRANDALL CREEK NEAR PEOA, UTAH	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	10
56	10130000	SILVER CREEK NEAR WANSHIP, UTAH	122	236	326	453	556	665	779	939	14
57	10130700	EAST FORK CHALK CREEK NEAR COALVILLE, UTAH	291	369	417	474	514	552	589	637	10
58	10131000	CHALK CREEK AT COALVILLE, UTAH	512	848	1,070	1,340	1,530	1,720	1,890	2,110	80
59	10132500	LOST CREEK NEAR CROYDEN, UTAH	237	415	547	726	867	1,010	1,160	1,370	28
60	10133000	LOST CREEK AT DEVILS SLIDE, UTAH	600	1,030	1,320	1,680	1,930	2,180	2,420	2,730	13
		Region 2									
[4]61	10133700	THREEMILE CREEK NEAR PARK CITY, UTAH	10.3	14.9	18.1	22.4	25.8	29.3	33	38.1	13
62	10135000	HARDSCRABBLE CREEK NEAR PORTERVILLE, UTAH	247	364	435	515	570	619	665	721	29
[4]63	10137500	SOUTH FORK OGDEN RIVER NEAR HUNTSVILLE, UTAH	794	1,250	1,540	1,880	2,110	2,330	2,530	2,780	45
64	10137680	NORTH FORK OGDEN RIVER NEAR EDEN, UTAH	91.3	120	137	158	173	188	202	220	11
65	10137780	MIDDLE FK OGDEN RIVER AB DIV NR HUNTS-VILLE, UTAH	458	561	623	696	748	797	845	907	11
66	10139300	WHEELER CREEK NEAR HUNTSVILLE, UTAH	105	225	327	481	611	753	908	1,130	37
67	10141400	HOWARD SLOUGH AT HOOPER, UTAH	175	231	265	303	330	354	378	407	13
68	10141500	HOLMES CREEK NEAR KAYSVILLE, UTAH	18.9	34.4	46.8	64.7	79.5	95.5	113	138	18
69	10142000	FARMINGTON CR ABV DIV NR FARMINGTON, UTAH	154	253	327	428	508	592	680	804	34
70	10142500	RICKS C AB DIVERSIONS, NR CENTERVILLE, UTAH	20.1	46.3	71.8	115	155	203	261	353	18
71	10143000	PARRISH C AB DIVERSIONS NR CENTERVILLE, UTAH	13.9	24.1	31.2	40.2	46.9	53.4	59.8	68.1	20
72	10143500	CENTERVILLE CREEK ABV DIV NR CENTERVILLE, UTAH	14.3	27.4	38.8	56.7	72.7	91.1	112	145	38
[4]73	10144000	STONE CREEK ABOVE DIVERSION NEAR BOUNTI-FUL, UTAH	30	106	211	445	726	1,140	1,720	2,870	17
74	10145000	MILL C AT MUELLER PARK, NR BOUNTIFUL, UTAH	43.9	82.1	112	156	191	229	269	326	20
75	10155400	SPRING CREEK NEAR HEBER CITY, UTAH	107	182	242	328	401	480	566	693	10
76	10156000	SNAKE CREEK NEAR CHARLESTON, UTAH	86.1	108	122	138	150	162	173	188	22
77	10158500	ROUND VALLEY CREEK NEAR WALLSBURG, UTAH	116	155	180	212	235	259	282	314	12
78	10160000	DEER CREEK NEAR WILDWOOD, UTAH	61.2	87.5	104	123	137	150	163	179	11
79	10160800	NO FK PROVO RIV AT WILDWOOD UTAH	106	148	176	213	240	268	297	336	10
80	10161500	SOUTH FORK PROVO R AT VIVIAN PARK, UTAH	50.6	81.9	108	146	179	217	261	326	52
81	10164500	AMERICAN FK AB UPPER POWERPLANT NR AMERICAN FK, UTAH	330	482	575	685	761	832	900	984	69
82	10165500	DRY CREEK NEAR ALPINE, UTAH	201	279	332	401	453	506	561	635	23
[4]83	10166430	WEST CANYON CREEK NEAR CEDAR FORT, UTAH	30.2	86.1	156	304	477	725	1,070	1,760	30
[3]84	10167500	LITTLE COTTONWOOD CREEK NR SALT LAKE CITY, UTAH	387	513	594	696	771	846	921	1,020	51

Appendix. Peak flows at selected recurrence intervals for streamflow-gaging stations in Utah and bordering states used in regional regression analysis—Continued.

Map ID	Gaging station number	Gaging station name	Peak flow, in cubic feet per second, for given recurrence interval, in years								
			2	5	10	25	50	100	200	500	Number of annual peak flows
		Region 2—Continued									
85	10168500	BIG COTTONWOOD CR NR SALT LAKE CITY UTAH	377	498	578	679	755	831	908	1,010	60
86	10170000	MILL CREEK NEAR SALT LAKE CITY, UTAH	49.9	74.5	91.1	112	128	143	159	180	63
87	10171500	PARLEYS CREEK NEAR SALT LAKE CITY, UTAH	122	191	237	296	339	382	425	481	18
88	10172000	EMIGRATION CREEK NEAR SALT LAKE CITY, UTAH	25.2	45.7	62.5	87.4	109	132	159	198	57
89	10172200	RED BUTTE CREEK AT FORT DOUGLAS, NEAR SLC, UTAH	15.6	32.4	47.2	70.1	90.4	113	139	178	42
90	10172500	CITY CREEK NEAR SALT LAKE CITY, UTAH	64.4	98	121	150	171	193	214	243	72
[3]91	10172640	LEE CREEK NEAR MAGNA, UTAH	45.6	74.6	95.5	123	144	166	189	219	11
[4]92	10172700	VERNON CREEK NEAR VERNON, UTAH	20.7	71.1	142	307	515	831	1,300	2,280	46
[1]93	10172740	RUSH VALLEY TRIBUTARY NEAR FAIRFIELD, UTAH	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	11
[4]94	10172760	CLOVER CREEK NEAR CLOVER, UTAH	13.7	34.3	55.1	91	126	167	218	299	15
95	10172765	CLOVER CREEK ABOVE BIG HOLLOW, NEAR CLOVER, UTAH	16.2	29.5	40	55	67.3	80.6	94.8	115	17
96	10172790	SETTLEMENT CANYON NR TOOELE, UTAH	20.9	62.6	108	189	269	366	483	670	11
97	10172791	SETTLEMENT CREEK ABOVE RESERVOIR NEAR TOOELE, UTAH	17.9	41	62.1	95.4	125	158	196	253	10
98	10172800	SOUTH WILLOW CREEK NEAR GRANTSVILLE, UTAH	32.5	57	76.2	103	125	149	175	211	45
99	10172805	NORTH WILLOW CREEK NR GRANTSVILLE, UTAH	25.6	54	80.6	124	165	214	272	365	13
		Region 3									
[4]100	10119000	LITTLE MALAD RIVER AB ELKHORN RES NR MALAD CITY ID	108	257	431	786	1,190	1,760	2,570	4,130	15
101	10122500	DEVIL CREEK AB CAMPBELL CREEK NR MALAD CITY ID	63.9	109	146	202	250	304	365	458	15
102	10125000	DEEP CREEK BL FIRST CREEK NR MALAD CITY ID	53.9	94.9	129	182	228	281	341	433	12
103	10126180	SULPHUR CREEK NR. CORINNE, UTAH	175	235	273	320	355	389	423	468	40
[2]104	10127100	BLACK SLOUGH NEAR BRIGHAM CITY, UTAH	184	258	307	367	411	454	497	555	12
[4]105	10172835	SKULL VALLEY TRIBUTARY NR DELLE, UTAH	.1	.8	3.2	12.7	30.2	64.7	128	287	11
106	10172870	TROUT CREEK NEAR CALLAO, UTAH	47	86.8	117	157	188	219	252	295	10
[1]107	10172885	GR SALT LAKE DESERT TR NO.2 NR DUGWAY, UTAH	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	15
[4]108	10172890	GOVERNMENT CREEK NEAR DUGWAY, UTAH	10.2	116	402	1,500	3,470	7,350	14,500	33,000	10
[4]109	10172895	DEEP CREEK NEAR IBAPAH, UTAH	97.1	244	399	677	956	1,310	1,740	2,480	12
110	10172900	BAR CREEK NEAR IBAPAH, UTAH	68.9	374	860	2,010	3,400	5,390	8,120	13,100	15
[4]111	10172902	DEAD CEDAR WASH NR WENDOVER, UTAH	2.8	237	1,820	13,100	42,100	112,000	262,000	679,000	14
112	10172909	BURNT C NR SHORES, NV	1.1	7.9	23.6	80.4	183	392	801	1,950	10
[1]113	10172913	LORAY WASH TR NR COBRE, NV	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	11
114	10172920	COTTON CREEK NEAR GROUSE CREEK, UTAH	3.3	16.6	41.8	120	245	480	905	2,010	32
[1]115	10172925	GR ST LAKE DESERT TR NO 3 NR PARK VALLEY, UTAH	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	23
116	10172940	DOVE CREEK NEAR PARK VALLEY, UTAH	8.9	35.1	78.2	196	370	669	1,180	2,400	17
[4]117	10172970	ROCK CREEK NR HOLBROOK ID	170	595	1,200	2,640	4,500	7,350	11,700	20,800	18
[3]118	10172990	BLUE SPRING CREEK NR SNOWVILLE, UTAH	96.5	375	756	1,590	2,560	3,930	5,800	9,280	18
119	10240600	BIG WASH NEAR WILFORD, UTAH	159	334	486	718	920	1,150	1,400	1,770	21
120	10242440	COTTONWOOD CREEK NR ENTERPRISE, UTAH	147	395	668	1,180	1,700	2,380	3,240	4,720	18
121	10242460	ESCALANTE VALLEY TR NR PANACA, NV	20.5	120	278	636	1,050	1,610	2,340	3,590	18
122	10243240	BAKER C AT NARROWS, NR BAKER, NV	74.7	137	188	260	321	387	458	561	28
123	10243260	LEHMAN CREEK NEAR BAKER, NV	26.2	53.9	80	123	165	214	274	371	16
		Region 4									
124	09235600	POT CREEK ABOVE DIVERSIONS, NEAR VERNAL, UTAH	62.4	126	182	271	351	444	549	712	35
[3]125	09264000	ASHLEY C BELOW TROUT C NR VERNAL, UTAH	433	561	637	724	784	840	893	959	11
[2]126	09264500	SOUTH FORK ASHLEY C NR VERNAL, UTAH	313	414	474	544	592	638	682	737	12
127	09265300	ASHLEY CREEK ABOVE RED PINE CREEK NR VERNAL, UTAH	1,260	2,260	3,100	4,350	5,430	6,630	7,990	10,000	10
128	09266500	ASHLEY CREEK NEAR VERNAL, UTAH	1,110	1,690	2,060	2,510	2,830	3,130	3,430	3,800	93
129	09268000	DRY FORK ABOVE SINKS, NEAR DRY FORK, UTAH	526	745	887	1,060	1,190	1,310	1,440	1,600	37
130	09268500	NORTH FORK OF DRY FORK NEAR DRY FORK, UTAH	76.2	116	143	178	204	231	258	294	44

Appendix. Peak flows at selected recurrence intervals for streamflow-gaging stations in Utah and bordering states used in regional regression analysis—Continued.

Map ID	Gaging station number	Gaging station name	Peak flow, in cubic feet per second, for given recurrence interval, in years								Number of annual peak flows
			2	5	10	25	50	100	200	500	
		Region 4—Continued									
131	09268900	BROWNIE CANYON ABOVE SINKS, NR DRY FORK, UTAH	187	281	342	418	473	526	579	648	29
132	09269000	EAST FORK OF DRY FORK NEAR DRY FORK, UTAH	129	191	229	272	301	329	354	385	18
133	09270000	DRY FORK BELOW SPRINGS NEAR DRY FORK, UTAH	526	761	914	1,100	1,240	1,370	1,500	1,670	22
134	09270500	DRY FORK AT MOUTH NEAR DRY FORK, UTAH	487	964	1,310	1,760	2,090	2,400	2,710	3,100	35
135	09271000	ASHLEY C, SIGN OF THE MAINE, NR VERNAL, UTAH	1,390	2,030	2,460	2,990	3,390	3,780	4,180	4,700	31
136	09273000	DUCHESNE R AT PROVO R TRAIL NR HANNA, UTAH	697	882	994	1,130	1,220	1,310	1,390	1,500	21
[3]137	09273500	HADES CREEK NEAR HANNA, UTAH	74.3	108	129	156	174	193	210	233	19
138	09274000	DUCHESNE RIVER (N.FORK) NEAR HANNA, UTAH	1,220	1,430	1,540	1,670	1,750	1,830	1,900	1,980	10
139	09275000	W F DUCHESNE RIVER BL DRY HOLLOW NR HANNA, UTAH	456	678	820	994	1,120	1,240	1,350	1,500	26
140	09275500	WEST FORK DUCHESNE RIVER NEAR HANNA, UTAH	461	623	715	818	886	948	1,000	1,070	41
[4]141	09276000	WOLF CREEK ABOVE RHOADES CANYON NEAR HANNA, UTAH	49.9	73.2	88.3	107	120	133	146	163	38
142	09277500	DUCHESNE RIVER NEAR TABIONA, UTAH	1,400	1,830	2,080	2,350	2,530	2,690	2,850	3,030	35
143	09277800	ROCK CREEK ABOVE SOUTH FORK, NEAR HANNA, UTAH	1,650	2,160	2,460	2,790	3,010	3,220	3,410	3,640	19
144	09278000	SOUTH FORK ROCK CREEK NEAR HANNA,UTAH	93.1	138	167	203	228	253	277	307	38
145	09278500	ROCK CREEK NEAR HANNA, UTAH	1,720	2,180	2,430	2,700	2,870	3,030	3,170	3,330	34
146	09279000	ROCK CREEK NEAR MOUNTAIN HOME, UTAH	1,620	2,060	2,320	2,610	2,800	2,990	3,160	3,370	50
147	09279100	ROCK CREEK NEAR TALMAGE, UTAH	1,570	1,940	2,150	2,390	2,540	2,690	2,820	2,980	24
148	09279500	DUCHESNE RIVER AT DUCHESNE, UTAH	2,760	3,540	3,950	4,390	4,670	4,920	5,130	5,390	36
[3]149	09280400	HOBBLE CREEK AT DANIELS SUMMIT NEAR WALLSBURG UT	69.6	102	123	149	167	185	203	226	21
150	09286100	RED CREEK ABOVE RESERVOIR, NEAR FRUIT-LAND, UTAH	51.3	122	189	299	399	516	651	859	12
151	09287000	CURRANT C BL RED LEDGE HOLLOW NR FRUIT-LAND, UTAH	259	464	619	833	1,000	1,180	1,360	1,620	32
152	09287500	WATER HOLLOW NR FRUITLAND, UTAH	28	60	90.7	143	192	253	326	446	26
153	09288000	CURRANT CREEK NEAR FRUITLAND, UTAH	314	500	644	848	1,020	1,200	1,400	1,690	47
154	09288150	W F AVINTAQUIN CREEK NR FRUITLAND, UTAH	282	661	1,050	1,750	2,450	3,340	4,450	6,330	22
[3]155	09288900	SOWERS CREEK NEAR DUCHESNE, UTAH	54.5	161	283	517	762	1,080	1,490	2,180	22
156	09289500	LAKE FORK RIVER AB MOON LAKE, NR MOUN-TAIN HOME, UTAH	1,340	1,870	2,200	2,580	2,850	3,110	3,360	3,670	57
157	09292500	YELLOWSTONE RIVER NEAR ALTONAH, UTAH	1,050	1,550	1,870	2,250	2,520	2,770	3,010	3,320	61
158	09296000	UINTA R ABOVE CLOVER C NEAR NEOLA UTAH	1,300	1,840	2,180	2,610	2,930	3,230	3,540	3,940	10
159	09296800	UINTA R BLW POWERPLANT DIVERSION, NR NEOLA, UTAH	1,300	2,520	3,490	4,890	6,030	7,250	8,540	10,400	15
160	09297000	UINTA RIVER NEAR NEOLA, UTAH	1,400	2,090	2,580	3,230	3,740	4,280	4,840	5,610	57
161	09298000	FARM CREEK NEAR WHITEROCKS, UTAH	87.6	174	240	329	398	468	539	634	31
162	09298500	WHITEROCKS R AB PARADISE C N WHITEROCKS UTAH	1,100	1,580	1,880	2,240	2,500	2,740	2,970	3,260	10
163	09299500	WHITEROCKS RIVER NEAR WHITEROCKS, UTAH	1,100	1,730	2,130	2,620	2,970	3,310	3,630	4,030	86
164	09300500	UINTAH RIVER AT FORT DUCHESNE, UTAH	1,270	2,690	3,850	5,520	6,870	8,300	9,800	11,900	28
[4]165	09301500	UINTA RIVER AT RANDLETT, UTAH	1,090	3,270	5,480	9,060	12,200	15,800	19,700	25,400	17
166	10153500	PROVO RIVER NEAR KAMAS, UTAH	503	632	711	804	870	933	994	1,070	20
167	10153800	NORTH FORK PROVO RIVER NEAR KAMAS, UTAH	395	546	638	748	824	897	967	1,060	33
168	10154000	SHINGLE CREEK NEAR KAMAS, UTAH	178	203	218	235	247	258	269	282	10
		Region 5									
169	10145500	SALT CREEK NEAR NEPHI, UTAH	283	460	596	791	952	1,130	1,320	1,600	12
170	10146000	SALT CREEK AT NEPHI, UTAH	190	332	446	613	752	906	1,070	1,320	30
171	10146400	CURRANT CREEK NEAR MONA, UTAH	163	322	446	616	750	887	1,030	1,220	27
[4]172	10146900	UTAH LAKE TRIBUTARY NEAR ELBERTA, UTAH	180	712	1,390	2,720	4,120	5900	8,110	11,800	12
173	10147000	SUMMIT CREEK NEAR SANTAQUIN, UTAH	73.2	123	157	203	237	271	305	351	19
[2]174	10147500	PAYSON CREEK ABV DIVERSIONS, NEAR PAYSON, UTAH	140	258	351	480	585	695	811	973	15
175	10148200	TIE FORK NEAR SOLDIER SUMMIT, UTAH	23.1	80	165	379	670	1,140	1,900	3,600	33
[4]176	10148300	DAIRY FORK NEAR THISTLE, UTAH	152	393	670	1,220	1,830	2,670	3,800	5,910	14

Appendix. Peak flows at selected recurrence intervals for streamflow-gaging stations in Utah and bordering states used in regional regression analysis—Continued.

Map ID	Gaging station number	Gaging station name	Peak flow, in cubic feet per second, for given recurrence interval, in years								Number of annual peak flows
			2	5	10	25	50	100	200	500	
Region 5—Continued											
177	10148400	NEBO CREEK NEAR THISTLE, UTAH	109	208	294	430	553	695	858	1,110	10
178	10148500	SPANISH FORK AT THISTLE, UTAH	513	773	961	1,210	1,420	1,630	1,850	2,160	60
179	10150500	SPANISH FORK AT CASTILLA, UTAH	726	1,170	1,490	1,930	2,270	2,630	3,010	3,540	16
180	10152500	HOBBLE CR NR SPRINGVILLE UTAH	258	468	629	852	1,030	1,220	1,410	1,680	43
181	10187300	OTTER CREEK NEAR KOOSHAREM, UTAH	56.9	79.1	92.2	107	117	126	134	144	18
182	10194200	CLEAR CREEK ABOVE DIVERSIONS, NEAR SEVIER, UTAH	235	427	573	775	936	1,100	1,280	1520	47
183	10195000	CLEAR CREEK AT SEVIER, UTAH	202	320	405	517	604	694	786	913	32
184	10204200	MILL CREEK NEAR GLENWOOD, UTAH	1.9	18.4	56.7	180	374	708	1,260	2,490	11
185	10205030	SALINA CREEK NEAR EMERY, UTAH	152	305	433	626	791	974	1,170	1,470	42
186	10205070	COTTONWOOD CREEK NEAR SALINA, UTAH	24.9	101	220	517	912	1,540	2,510	4,590	10
[2]187	10205100	SHEEP CREEK NEAR SALINA, UTAH	4.3	8.7	12.5	18.4	23.6	29.5	36.1	46.1	12
[3]188	10205200	WEST FORK SHEEP CREEK NEAR SALINA, UTAH	3.7	8.1	11.8	17.3	21.9	26.9	32.3	39.9	12
189	10205300	SHEEP CREEK AT MOUTH NEAR SALINA, UTAH	11.7	23.4	32.9	46.6	58	70.1	83.1	102	12
190	10205700	SALINA CREEK ABOVE DIVERSION NEAR SALINA, UTAH	553	924	1,240	1,730	2,170	2,690	3,280	4,230	16
191	10206000	SALINA CREEK AT SALINA, UTAH	445	854	1,200	1,730	2,190	2,710	3,290	4,160	26
192	10208500	OAK CREEK NR. FAIRVIEW, UTAH	145	283	413	632	842	1,100	1,410	1,930	25
193	10210000	PLEASANT CREEK NEAR MOUNT PLEASANT, UTAH	150	277	391	575	746	949	1,190	1,580	21
194	10211000	TWIN CREEK NEAR MOUNT PLEASANT, UTAH	66.8	132	195	304	413	549	719	1,010	12
195	10215700	OAK CREEK NEAR SPRING CITY, UTAH	91	150	195	260	314	373	438	532	25
[3]196	10215900	MANTI CREEK BLW DUGWAY CREEK, NR MANTI, UTAH	319	466	567	698	798	900	1,000	1,140	37
197	10216400	TWELVEMILE CREEK NEAR MAYFIELD, UTAH	262	468	650	944	1,220	1,540	1,920	2,540	21
[3]198	10219200	CHICKEN CREEK NEAR LEVAN, UTAH	45.7	132	230	420	619	880	1,220	1,800	33
199	10220300	TINTIC WASH TR NEAR NEPHI, UTAH	64.3	158	254	423	589	794	1,050	1,460	14
[3]200	10224100	OAK CREEK ABOVE LITTLE CREEK, NEAR OAK CITY, UTAH	18.8	42.1	64.9	104	142	189	246	339	31
201	10232500	CHALK CREEK NEAR FILLMORE UTAH	235	424	589	852	1,090	1,370	1,700	2,230	29
202	10233000	MEADOW CREEK NEAR MEADOW UTAH	52	104	150	222	285	358	440	566	11
203	10233500	CORN CREEK NEAR KANOSH, UTAH.	134	364	615	1,080	1,550	2,160	2,920	4,220	17
204	10234500	BEAVER RIVER NEAR BEAVER, UTAH	353	611	793	1,030	1,200	1,370	1,540	1,760	92
205	10235000	SOUTH CREEK NEAR BEAVER, UTAH	32.6	79.6	126	203	275	361	461	619	12
206	10236000	NORTH FORK NORTH CREEK NEAR BEAVER, UTAH	39.8	76.6	107	150	186	225	267	328	18
[2]207	10236500	SOUTH FORK NORTH CREEK NEAR BEAVER, UTAH	176	469	767	1,280	1,760	2,330	3,010	4,080	11
208	10237500	INDIAN CREEK NEAR BEAVER, UTAH	33.1	70	104	161	213	275	349	466	13
Region 6											
209	09106200	LEWIS WASH NEAR GRAND JUNCTION, CO.	59	113	158	225	283	347	418	524	10
210	09152650	LEACH CREEK AT DURHAM, CO.	218	356	462	612	736	870	1,020	1,230	11
211	09152900	ADOBE CREEK NEAR FRUITA, CO.	131	180	212	251	279	307	335	372	11
212	09153400	WEST SALT CREEK NEAR MACK, CO.	513	1,140	1,710	2,580	3,340	4,190	5,130	6,530	10
213	09163310	EAST SALT CREEK NEAR MACK, CO.	442	1,330	2,310	4,100	5,880	8,080	10,800	15,100	9
214	09163490	SALT CREEK NEAR MACK, CO.	778	1,300	1,680	2,200	2,610	3,030	3,480	4,100	10
215	09163700	CISCO WASH NEAR CISCO, UTAH	1,670	3,210	4,470	6,300	7,830	9,490	11,300	13,900	15
216	09168100	DISAPPOINTMENT CREEK NEAR DOVE CREEK, CO.	1,180	2,570	3,890	6,110	8,210	10,700	13,800	18,600	29
217	09174500	COTTONWOOD CREEK NEAR NUCLA, CO.	123	236	328	459	568	684	808	985	10
218	09175800	DEAD HORSE CREEK NEAR NATURITA, CO.	151	546	1,040	2,010	3,050	4,390	6,090	8,990	11
[1]219	09175900	DRY CREEK NEAR NATURITA, CO.	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	12
[3]220	09177500	TAYLOR CREEK NEAR GATEWAY, CO.	111	264	408	644	859	1,110	1,400	1,840	23
221	09181000	ONION CREEK NEAR MOAB, UTAH	730	1,390	1,920	2,660	3,270	3,910	4,600	5,560	13
[2]222	09182000	CASTLE CREEK ABOVE DIVERSIONS, NEAR MOAB, UTAH	9.3	19	27.2	39	48.9	59.5	71	87.4	24
223	09182600	SALT WASH NEAR THOMPSON, UTAH	263	714	1,220	2,180	3,200	4,520	6,240	9,240	15
[2]224	09183000	COURTHOUSE WASH NEAR MOAB, UTAH	2,090	4,590	7,090	11,500	15,800	21,300	28,100	39,600	31
225	09183500	MILL CREEK AT SHELEY TUNNEL, NEAR MOAB, UTAH	185	405	622	998	1,360	1,820	2,370	3,300	23
226	09184000	MILL CREEK NEAR MOAB, UTAH	687	1,810	3,010	5,170	7,340	10,100	13,400	19,100	47
227	09185200	KANE SPRINGS CANYON NEAR MOAB, UTAH	529	842	1,070	1,370	1,610	1,850	2,110	2,460	15
228	09185500	HATCH WASH NEAR LA SAL, UTAH	493	1,210	1,970	3,340	4,720	6,470	8,660	12,400	22
229	09187000	COTTONWOOD CREEK NEAR MONTICELLO, UTAH	378	1,260	2,380	4,700	7,330	10,900	15,800	24,800	17

Appendix. Peak flows at selected recurrence intervals for streamflow-gaging stations in Utah and bordering states used in regional regression analysis—Continued.

Map ID	Gaging station number	Gaging station name	Peak flow, in cubic feet per second, for given recurrence interval, in years								Number of annual peak flows
			2	5	10	25	50	100	200	500	
		Region 6—Continued									
230	09263700	CLIFF CREEK NEAR JENSEN, UTAH	163	745	1,550	3,210	5,000	7,340	10,300	15,200	15
231	09263800	COW WASH NEAR JENSEN, UTAH	298	800	1,320	2,230	3,110	4,180	5,450	7,510	14
232	09271800	HALFWAY HOLLOW TRIB. NEAR LAPOINT, UTAH	89.8	300	538	968	1,390	1,890	2,490	3,440	15
233	09306235	CORRAL GULCH BELOW WATER GULCH, NR RANGELY, CO.	14.1	69.1	157	374	652	1,070	1,680	2,900	14
234	09306240	BOX ELDER GULCH NEAR RANGELY, CO.	14.7	57.7	118	254	418	655	987	1,630	11
235	09306242	CORRAL GULCH NEAR RANGELY, CO.	32.5	126	257	552	908	1,420	2,150	3,550	32
236	09306255	YELLOW CREEK NEAR WHITE RIVER, CO.	96.8	355	727	1,600	2,720	4,441	6,930	12,100	27
237	09306800	BITTER CREEK NEAR BONANZA, UTAH	108	443	934	2,080	3,510	5,630	8,700	14,800	19
238	09307500	WILLOW CREEK ABOVE DIVERSIONS NEAR OURAY, UTAH	231	466	704	1,130	1,570	2,130	2,860	4,130	27
[4]239	09308000	WILLOW CREEK NEAR OURAY, UTAH	629	1,850	3,200	5,650	8,100	11,100	14,900	21,000	26
[4]240	09308200	PLEASANT VALLEY WASH TRIB. NEAR MYTON, UTAH	88.2	997	3,120	9,590	18,900	33,500	55,400	98,300	11
241	09308500	MINNIE MAUD CREEK NR MYTON, UTAH	107	356	655	1,240	1,850	2,650	3,650	5,370	35
242	09309000	MINNIE MAUD C AT NUTTER RANCH NR MYTON, UTAH	481	843	1,110	1,450	1,720	1,990	2,260	2,620	23
243	09309100	GATE CANYON NEAR MYTON, UTAH	175	726	1,420	2,760	4,110	5,790	7,800	11,000	12
244	09310500	FISH CREEK ABOVE RESERVOIR, NEAR SCOFIELD, UTAH	517	826	1,040	1,300	1,500	1,700	1,890	2,140	68
245	09310700	MUD CRK BL WINTER QUARTERS CYN AT SCO-FIELD, UTAH	99.3	186	259	371	468	577	700	886	23
246	09312500	WHITE RIVER NEAR SOLDIER SUMMIT, UTAH	171	303	413	578	722	884	1,070	1,340	28
247	09312600	WHITE R BL TABBYUNE CRK NR SOLDIER SUMMIT, UTAH	193	386	552	808	1,030	1,280	1,570	2,000	38
248	09312700	BEAVER CREEK NEAR SOLDIER SUMMIT, UTAH	41.7	82.9	119	177	229	289	358	465	29
249	09312800	WILLOW CREEK NEAR CASTLE GATE, UTAH	216	387	538	779	999	1,260	1,560	2,050	27
250	09313500	PRICE RIVER NEAR HELPER, UTAH	2,270	4,300	6,160	9,230	12,100	15,600	19,900	26,800	19
251	09314200	MILLER CREEK NEAR PRICE, UTAH	1,370	3,380	5,400	8,890	12,200	16,300	21,200	29,100	13
252	09314280	DESERT SEEP WASH NEAR WELLINGTON, UTAH	501	886	1,200	1,680	2,100	2,560	3,080	3,860	15
253	09314400	COLEMAN WASH NEAR WOODSIDE, UTAH	254	607	948	1,520	2,050	2,670	3,400	4,560	10
254	09315150	SALERATUS WASH TRIB. NR WOODSIDE, UTAH	804	2,240	3,820	6,730	9,680	13,400	18,100	25,900	15
255	09315200	SALERATUS WASH TRIB NO 2 NR WOODSIDE, UTAH	974	2,530	4,030	6,480	8,700	11,200	14,100	18,400	15
256	09315400	SALERATUS WASH ABOVE C. WASH NR. GREEN RIVER, UTAH	3,040	5,960	8,640	13,000	17,100	22,100	27,900	37,400	10
257	09315500	SALERATUS WASH AT GREEN RIVER, UTAH	2,440	4,750	6,710	9,650	12,200	15,000	18,100	22,800	22
[3]258	09315900	BROWNS WASH TRIB. NR. GREEN RIVER, UTAH	206	608	1,070	1,970	2,920	4,170	5,780	8,590	15
259	09316000	BROWNS WASH NEAR GREEN RIVER, UTAH	1,780	3,750	5,480	8,160	10,500	13,200	16,100	20,600	19
260	09318000	HUNTINGTON CREEK NR HUNTINGTON, UTAH	802	1,300	1,650	2,120	2,490	2,860	3,250	3,770	71
261	09324500	COTTONWOOD CREEK NEAR ORANGEVILLE, UTAH	1,450	2,150	2,620	3,220	3,670	4,110	4,560	5,150	23
262	09326500	FERRON CREEK (UPPER STATI	784	1,310	1,750	2,410	2,980	3,620	4,350	5,460	70
[3]263	09327600	FERRON CREEK TRIB. NEAR FERRON, UTAH	106	338	623	1,210	1,860	2,750	3,940	6,100	12
264	09328300	SIDS DRAW NEAR CASTLE DAL	438	1,190	1,960	3,310	4,590	6,140	7,970	10,900	15
265	09328600	GEORGES DRAW NEAR HANKSVILLE, UTAH	216	592	998	1,730	2,470	3,400	4,530	6,430	14
266	09328700	TEMPLE WASH NEAR HANKSVILLE, UTAH	130	400	714	1,320	1,950	2,780	3,820	5,630	10
267	09328720	OLD WOMAN WASH NEAR HANKSVILLE, UTAH	263	936	1,730	3,200	4,680	6,490	8,670	12,100	10
268	09328900	CRESENT WASH NEAR CRESENT JUNCTION, UTAH	418	1,110	1,930	3,590	5,440	7,990	11,500	18,000	10
[2]269	09329050	SEVEN MILE CREEK NEAR FISH LAKE, UTAH	184	271	323	381	419	455	487	525	34
270	09329900	PINE CREEK NEAR BICKNELL, UTAH	81.9	237	390	641	865	1,120	1,400	1,810	16
271	09330120	SULPHUR CREEK NEAR FRUITA, UTAH	548	1,230	1,820	2,680	3,410	4,190	5,020	6,200	16
272	09330200	PLEASANT CREEK AT NOTOM, UTAH	270	822	1,400	2,390	3,300	4,370	5,580	7,410	14
[3]273	09330300	NEILSON WASH NEAR CAINEVILLE, UTAH	988	2,390	3,630	5,510	7,100	8,830	10,700	13,300	15
274	09330500	MUDDY CREEK NEAR EMERY, UTAH	459	976	1,480	2,360	3,230	4,300	5,630	7,860	62
275	09331500	IVIE CREEK ABOVE DIVERSIONS NR EMERY, UTAH	189	402	589	876	1,130	1,410	1,720	2,190	24
276	09333900	BUTLER CANYON NEAR HITE, UTAH	415	748	1,010	1,400	1,720	2,060	2,440	2,980	16
277	09334000	NORTH WASH NEAR HANKSVILLE (HITE), UTAH	1,190	3,080	4,980	8,250	11,400	15,100	19,500	26,500	21
[1]278	09334400	FRY CANYON NEAR HITE, UTAH	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	15
279	09334500	WHITE CANYON NEAR HANKSVILLE UTAH	2,200	4,260	5,980	8,550	10,700	13,200	15,900	19,900	20
280	09336000	BIRCH CREEK NEAR ESCALANTE, UTAH	425	1,030	1,620	2,570	3,450	4,470	5,640	7,440	17
281	09336400	UPPER VALLEY CREEK NEAR ESCALANTE, UTAH	739	1,600	2,400	3,730	4,970	6,450	8,200	1,1000	16
[3]282	09337000	PINE CREEK NEAR ESCALANTE, UTAH	177	371	536	784	994	1,230	1,480	1,850	53
283	09337500	ESCALANTE RIVER NEAR ESCALANTE, UTAH	815	1,690	2,420	3,470	4,350	5,290	6,290	7,710	50

Appendix. Peak flows at selected recurrence intervals for streamflow-gaging stations in Utah and bordering states used in regional regression analysis—Continued.

Map ID	Gaging station number	Gaging station name	Peak flow, in cubic feet per second, for given recurrence interval, in years								Number of annual peak flows
			2	5	10	25	50	100	200	500	
		Region 6—Continued									
[2]284	09338000	EAST FORK BOULDER CREEK NEAR BOULDER, UTAH	203	304	369	447	502	556	607	672	20
[2]285	09338500	EAST FORK DEER CREEK NEAR BOULDER, UTAH	21.5	65.9	117	217	321	456	628	924	20
286	09338900	DEER CREEK NEAR BOULDER, UTAH	498	1,500	2,520	4,210	5,740	7,480	9,420	12,300	20
287	09339200	TWENTYMILE WASH NR ESCALANTE, UTAH	1,680	3,010	4,030	5,440	6,570	7,760	9,020	10,800	10
288	09366500	LA PLATA RIVER AT COLORADO-NEW MEXICO STATE LINE	655	1,370	2,040	3,140	4,180	5,430	6,910	9,300	85
[3]289	09367530	LOCKE ARROYO NR. KIRTLAND, NM	105	249	395	651	902	1,210	1,590	2,220	35
290	09367550	STEVENS ARROYO NR KIRTLAND, NM	131	467	915	1,890	3,030	4,640	6,860	11,100	21
291	09367561	SHUMWAY ARROYO NEAR WATERFLOW, NM	178	776	1,710	4,040	7,110	11,900	19,100	34,200	16
292	09367980	RATTLESNAKE ARROYO NR SHIPROCK, NM	141	563	1,230	2,970	5,370	9,320	15,700	29,900	17
[3]293	09368020	MALPAIS ARROYO NR SHIPROCK, NM	109	276	460	808	1,170	1,660	2,280	3,390	19
[2]294	09371000	MANCOS RIVER NEAR TOWAOC, CO.	1,090	2,010	2,770	3,910	4,890	5,980	7,190	9,000	71
[1]295	09371300	MCELMO CREEK TRIBUTARY NEAR CORTEZ, CO.	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	11
296	09371420	MCELMO CREEK ABOVE ALKALI CANYON, NR CORTEZ, CO.	599	748	839	949	1,030	1,100	1,170	1,270	14
297	09371500	MCELMO CREEK NEAR CORTEZ, CO.	807	1,610	2,390	3,750	5,090	6,770	8,850	12,400	22
298	09371520	MCELMO CREEK ABOVE TRAIL CANYON NEAR CORTEZ, CO	473	1,110	1,770	3,010	4,280	5,940	8,060	11,800	12
299	09371700	MCELMO CREEK BELOW CORTEZ, CO.	733	1,180	1,530	2,020	2,430	2,880	3,360	4,070	11
300	09372000	MCELMO CREEK NEAR COLORADO-UTAH STATE LINE	909	1,570	2,090	2,830	3,450	4,120	4,850	5,920	55
[4]301	09372200	MCELMO CREEK NEAR BLUFF, UTAH	644	1,790	3,220	6,290	9,930	15,200	22,800	37,900	13
302	09378170	SOUTH CREEK ABOVE RESERVOIR NEAR MONTI-CELLO, UTAH	44	92.4	137	209	275	353	444	587	20
303	09378200	MONTEZUMA CREEK AT GOLF COURSE AT MONTI-CELLO, UTAH	25.1	96.7	204	465	806	1,340	2,150	3,850	13
[4]304	09378600	MONTEZUMA CREEK NEAR BLUFF, UTAH	1,220	3,640	6,860	14,200	23,400	37,300	58,100	102,000	15
[2]305	09378630	RECAPTURE CREEK NEAR BLANDING, UTAH	13.7	37.2	62.4	108	153	210	280	396	40
306	09378650	RECAPTURE CR BL JOHNSON CR NR BLANDING,UT.	114	327	564	1,000	1,460	2,030	2,750	3,970	17
307	09378700	COTTONWOOD WASH NR BLANDING UTAH	1,060	2,720	4,640	8,460	12,700	18,500	26,400	41,100	29
[4]308	09378720	COTTONWOOD WASH AT BLUFF, UTAH	1,150	4,360	9,380	22,400	40,600	70,600	119,000	230,000	10
309	09378950	COMB WASH NEAR BLANDING, UTAH	737	1,430	2,090	3,210	4,300	5,630	7,260	9,990	10
310	09379000	COMB WASH NEAR BLUFF, UTAH	1,800	3,150	4,350	6,270	8,050	10,200	12,700	16,800	10
311	09379030	BLACK MOUNTAIN WASH NEAR CHINLE, ARIZ.	722	1,670	2,580	4,110	5,530	7,240	9,240	12,400	15
[3]312	09379060	LUKACHUKAI CREEK TRIBUTARY NEAR LUKA-CHUKAI, AZ	13.1	51.5	105	221	358	552	817	1,310	14
[4]313	09379100	LONG HOUSE WASH NEAR KAYENTA, ARIZ.	177	1,160	3,000	8,080	15,200	26,500	43,800	79,900	15
314	09379300	LIME CREEK NEAR MEXICAN HAT, UTAH	1,620	4,120	6,730	11,400	16,000	21,800	28,900	40,800	15
315	09379560	EL CAPITAN WASH NEAR KAYENTA, ARIZ.	461	944	1,410	2180	2,930	3,850	4,960	6,800	14
316	09379800	COYOTE CREEK NEAR KANAB, UTAH	1,400	2,740	3,880	5,590	7,060	8,690	10,500	13,200	14
317	09379820	BUCK TANK DRAW NEAR KANAB, UTAH	9.7	70.2	207	675	1,480	3,020	5,890	13,400	10
318	09381100	HENRIEVILLE CREEK AT HENRIEVILLE, UTAH	873	2,070	3,320	5,550	7,790	10,600	14,200	20,300	16
319	09381500	PARIA RIVER NEAR CANNONVILLE, UTAH	2,710	4,780	6,430	8,860	10,900	13,100	15,600	19,200	25
[4]320	09381800	PARIA RIVER NEAR KANAB, UTAH	2,570	5,210	7,610	11,400	14,900	19,000	23,800	31,300	17
[4]321	09382000	PARIA RIVER AT LEES FERRY, AZ	3,120	6,350	9,020	12,900	16,200	19,700	23,500	28,900	82
322	09403500	KANAB C NR GLENDALE UT	623	1,430	2,140	3,180	4,060	5,000	6,010	7,430	16
323	09403600	KANAB CREEK NEAR KANAB, UTAH	368	1,010	1,630	2,640	3,520	4,520	5,620	7,220	37
324	09403700	JOHNSON WASH NEAR KANAB, UTAH	1,010	2,060	2,860	3,930	4,740	5,550	6,360	7,410	16
[4]325	09403780	KANAB CREEK NR FREDONIA, ARIZ.	893	1,790	2,570	3,770	4,810	5,980	7,300	9,280	16
[3]326	09403800	BITTER SEEPS WASH TRIB NEAR FREDONIA, ARIZ.	134	566	1,160	2,410	3,820	5,730	8,220	12,600	14
		Region 7									
327	09404450	EAST FORK VIRGIN RIVER NEAR GLENDALE, UTAH	101	232	362	586	804	1,070	1,400	1,930	38
328	09404500	MINERAL GULCH NEAR MT. CARMEL, UTAH	202	1,040	2,330	5,290	8,800	13,700	20,300	32,300	14
329	09404700	EAST FK VIRGIN RIVER NR MOUNT CARMEL JUNC-TION, UTAH	519	1,100	1,600	2,350	2,990	3,690	4,460	5,570	11
330	09404900	EAST FORK VIRGIN RIVER NEAR SPRINGDALE, UTAH	872	2,410	4,000	6,790	9,460	12,700	16,500	22,600	14
331	09405420	N FK VIRGIN R BLW BULLOCH CANYON NR GLEN-DALE, UTAH	207	410	598	910	1,200	1,560	1,980	2,670	11

Appendix. Peak flows at selected recurrence intervals for streamflow-gaging stations in Utah and bordering states used in regional regression analysis—Continued.

Map ID	Gaging station number	Gaging station name	Peak flow, in cubic feet per second, for given recurrence interval, in years								
			2	5	10	25	50	100	200	500	Number of annual peak flows
Region 7—Continued											
332	09405500	NORTH FORK VIRGIN RIVER NEAR SPRINGDALE, UTAH	1,710	3,170	4,340	6020	7,410	8,900	10,500	12,800	82
[4]333	09406000	VIRGIN RIVER AT VIRGIN, UTAH	3,690	6,870	9,550	13,600	17,200	21,200	25,700	32,400	89
334	09406300	KANARRA CREEK AT KANARRAVILLE, UTAH	141	367	608	1,040	1,480	2,030	2,720	3,880	23
335	09406700	SOUTH ASH CREEK BELOW MILL CREEK NEAR PINTURA, UTAH	199	549	926	1,610	2,280	3,120	4,160	5,860	16
336	09406800	SOUTH ASH CREEK NEAR PINTURA, UTAH	193	468	740	1,200	1,640	2,170	2,790	3,790	14
337	09407200	ASH CR BLW WEST FIELD DITCH AT TOQUERVILLE, UTAH	264	828	1,490	2,770	4,110	5,860	8,080	11,900	10
338	09408000	LEEDS CREEK NEAR LEEDS, UTAH	161	724	1,590	3,670	6,300	10,200	16,000	27,400	42
[4]339	09408150	VIRGIN RIVER NEAR HURRICANE, UTAH	6,000	11,000	14,900	20,400	25,000	29,800	35,000	42,300	19
[3]340	09408200	FORT PIERCE WASH NR ST. GEORGE, UTAH	2,240	4,650	6,740	9,950	12,700	15,900	19,400	24,600	11
341	09408400	SANTA CLARA RIVER NEAR PINE VALLEY, UTAH	68.7	156	244	395	544	727	951	1,320	46
342	09409500	MOODY WASH NEAR VEYO, UTAH	210	802	1,600	3,310	5,280	8,000	11,700	18,400	15
343	09410000	SANTA CLARA RIVER AB WINSOR DAM NR SANTA CLARA, UTAH	944	2,390	3,840	6,340	8,740	11,600	15,100	20,600	30
344	09413900	BEAVER DAM WASH NEAR ENTERPRISE, UTAH	278	1350	2,880	6,140	9,750	14,500	20,600	30,900	14
[1]345	09415050	BIG BEND WASH TRIB NEAR LITTLEFIELD, ARIZONA	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	26
346	10173450	MAMMOTH CREEK ABV WEST HATCH DITCH, NEAR HATCH, UTAH	401	562	660	773	851	925	994	1,080	40
347	10174500	SEVIER RIVER AT HATCH, UTAH	566	883	1,110	1,410	1,640	1,880	2,120	2,460	81
[4]348	10183900	EAST FORK SEVIER RIVER NEAR RUBYS INN, UTAH	101	176	240	340	430	533	653	840	34
349	10185000	ANTIMONY CREEK NEAR ANTIMONY, UTAH	239	417	527	652	733	805	870	944	21
350	10241300	FREMONT WASH NEAR PARAGONAH, UTAH	105	199	275	384	474	570	673	821	16
351	10241400	LITTLE CREEK NEAR PARAGONAH, UTAH	36.7	126	244	502	806	1,240	1,850	3,010	21
352	10241430	RED CREEK NEAR PARAGONAH, UTAH	14.4	24.9	33.1	44.7	54.2	64.5	75.5	91.4	11
353	10241470	CENTER CREEK ABV PAROWAN CREEK, NEAR PAROWAN, UTAH	57.9	142	231	392	554	759	1,020	1,460	23
354	10241600	SUMMIT CREEK NEAR SUMMIT, UTAH	69.3	218	409	820	1,300	1,990	2,970	4,850	23
355	10242000	COAL CREEK NEAR CEDAR CITY, UTAH	743	1,590	2,340	3,510	4,540	5,710	7,030	9,010	75

[1]Annual peak series plotted poorly to log Pearson Type III distribution, peak-flow recurrence intervals not determined, not used in analysis.

[2]Leverage statistic exceeded limit and removed from analysis.

[3]Leverage statistic exceeded limit but remained in analysis.

[4]Peak-flow recurrence interval discharge(s) and/or basin characteristics determined to be outliers, not used in analysis.

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