



# 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

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**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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## Conversion Factors and Datums

| 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 <sup>2</sup> )             | 2.590   | square kilometer (km <sup>2</sup> )        |
| Flow rate                                  |         |  |
| cubic foot per second (ft <sup>3</sup> /s) | 0.02832 | cubic meter per second (m <sup>3</sup> /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).

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

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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    |

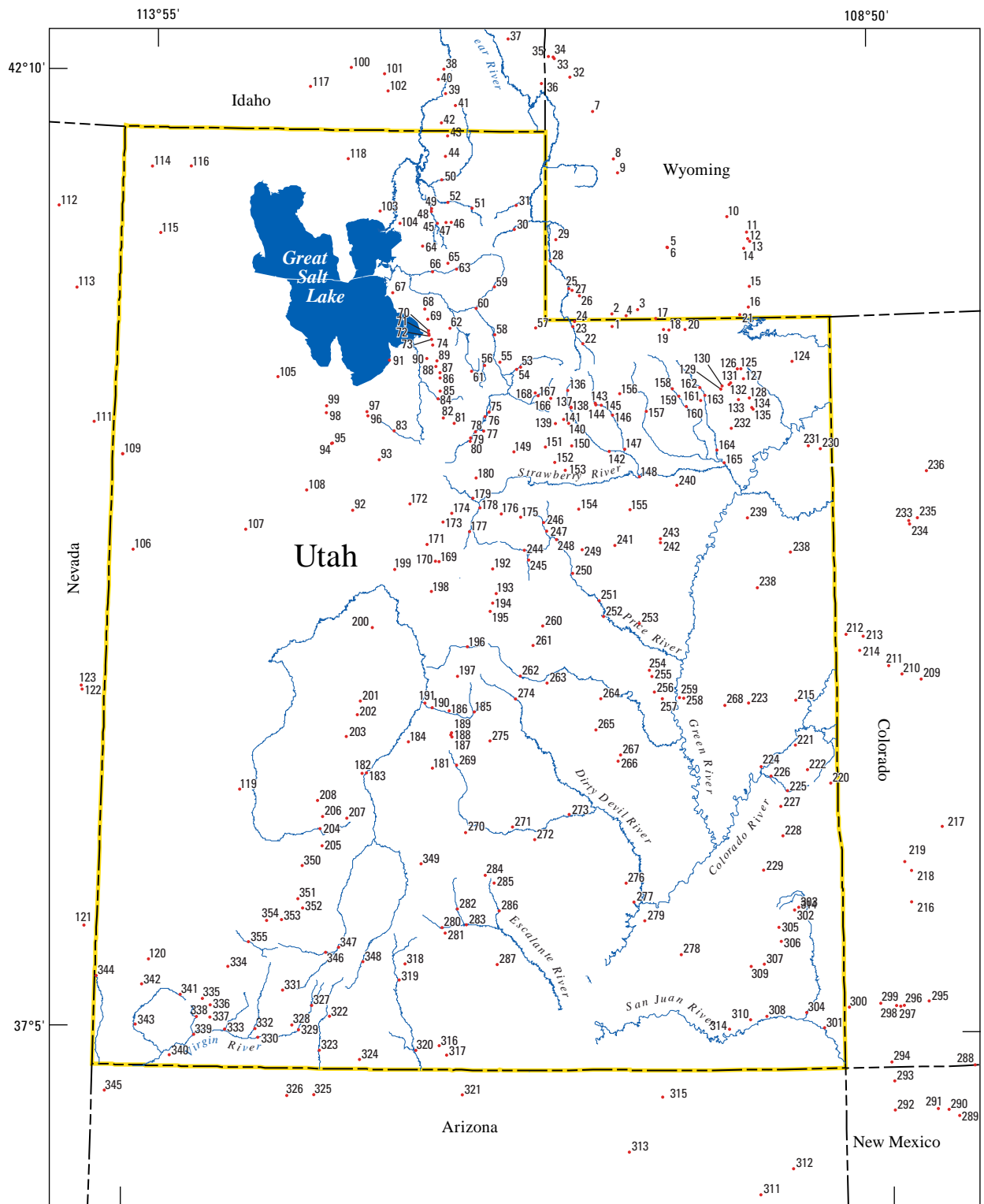


Figure 1. Location of streamflow-gaging stations in Utah and bordering states used in regional regression analysis.

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

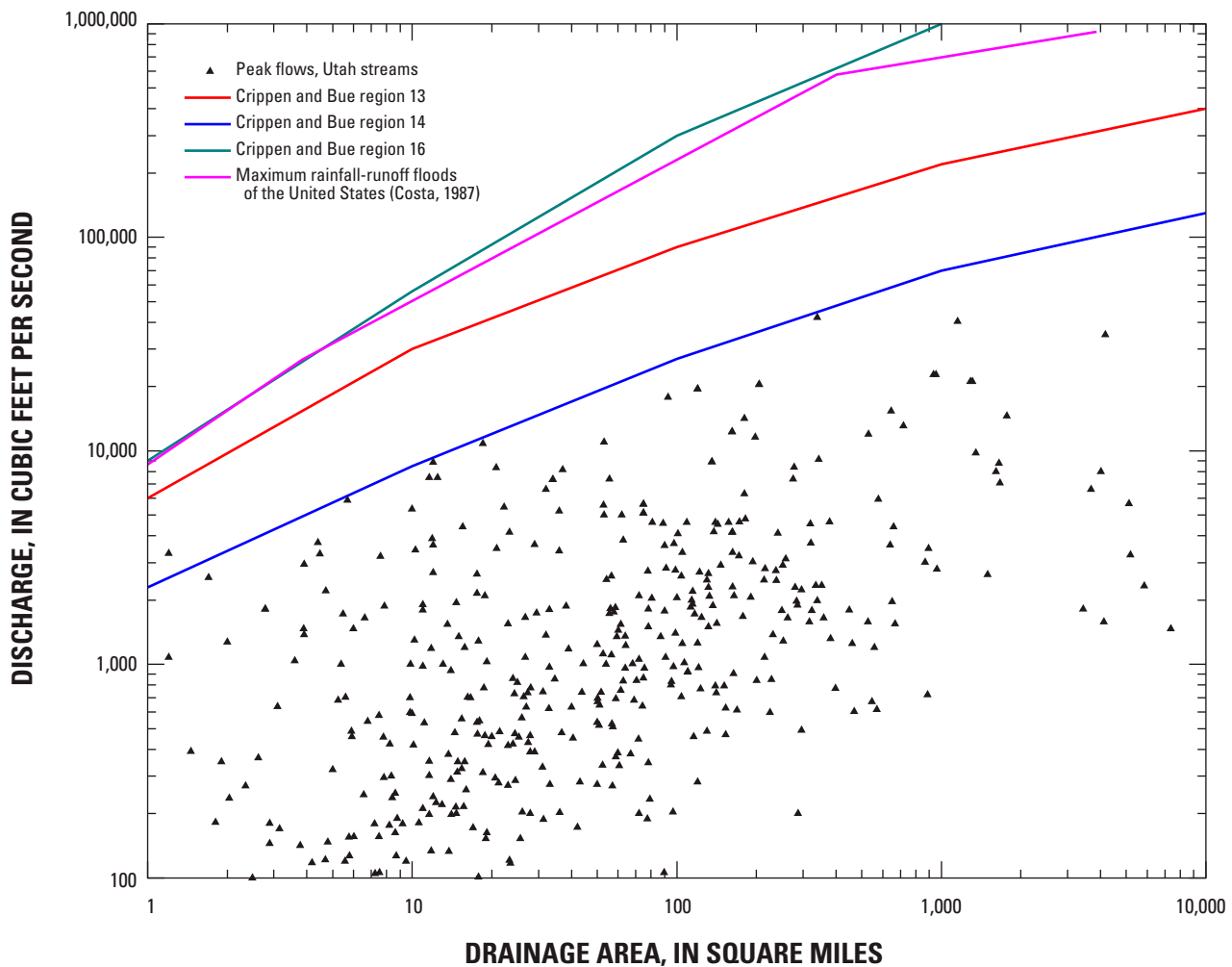
Peak streamflows for most streams in northern and eastern Utah are dominated by snowmelt runoff. The snowmelt runoff period typically is between April and late June, with peaks occurring in late May and early June. Rapid melting of exceptionally large snowpacks can lead to statewide flooding, as was 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

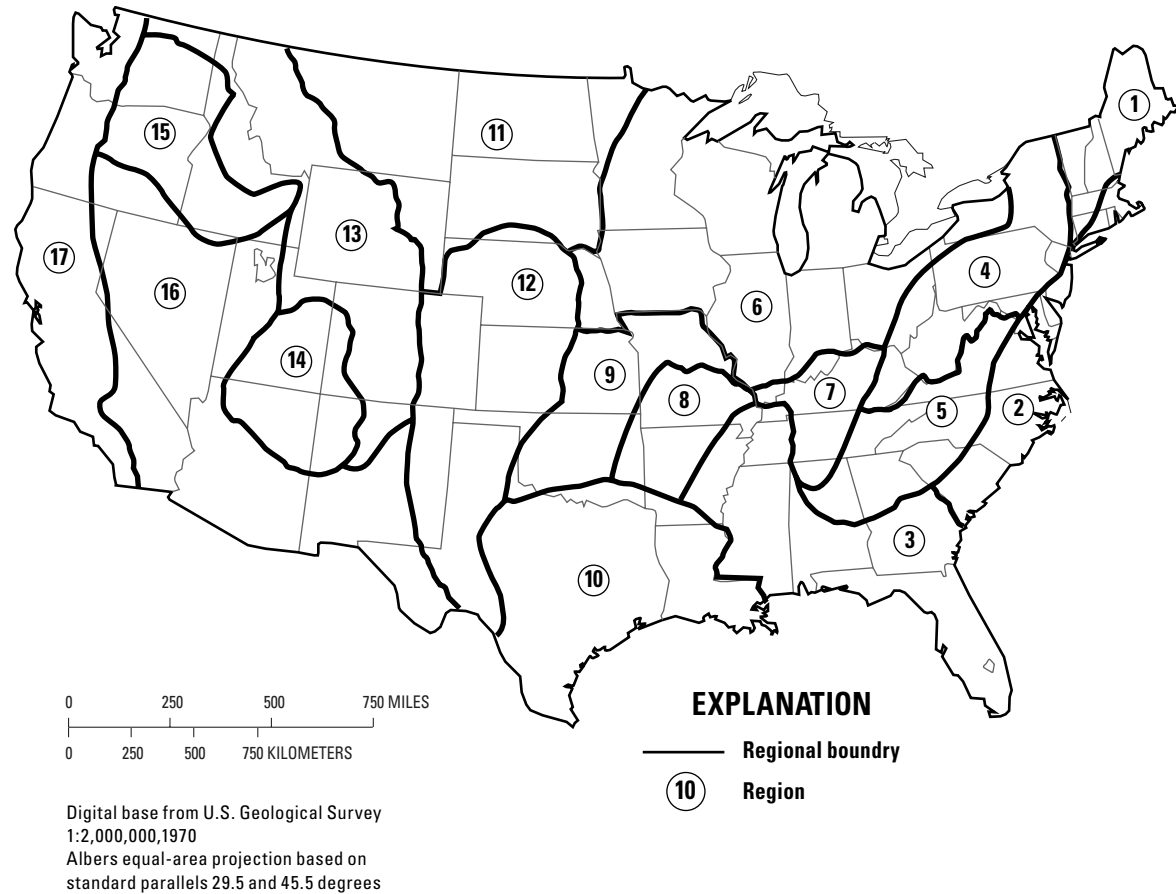
Envelope curves allow for a method of estimating potential maximum floodflows in a given geographic area. These curves are developed by plotting the largest peak flow for all gage sites against drainage area. With streamflow record length considered to be long enough to capture maximum peak flows at 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. Maximum natural peak flows for streams in Utah are well below the envelope curve of the United States (Costa, 1987).

## 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

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

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 determine 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<sup>3</sup>/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):

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

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):

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

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,

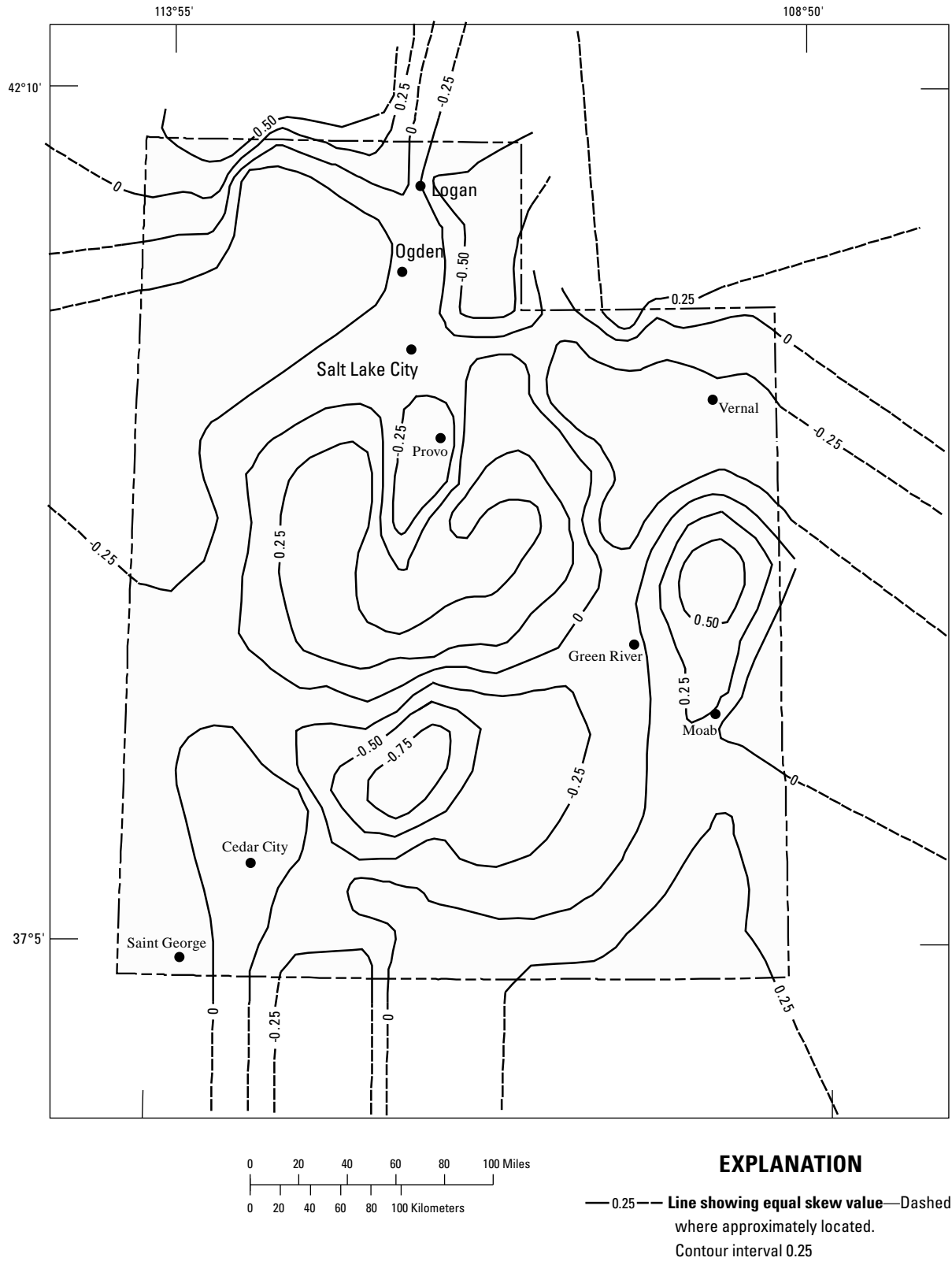


Figure 4. Generalized skew map for Utah (modified from Perica and Stayner, 2004).

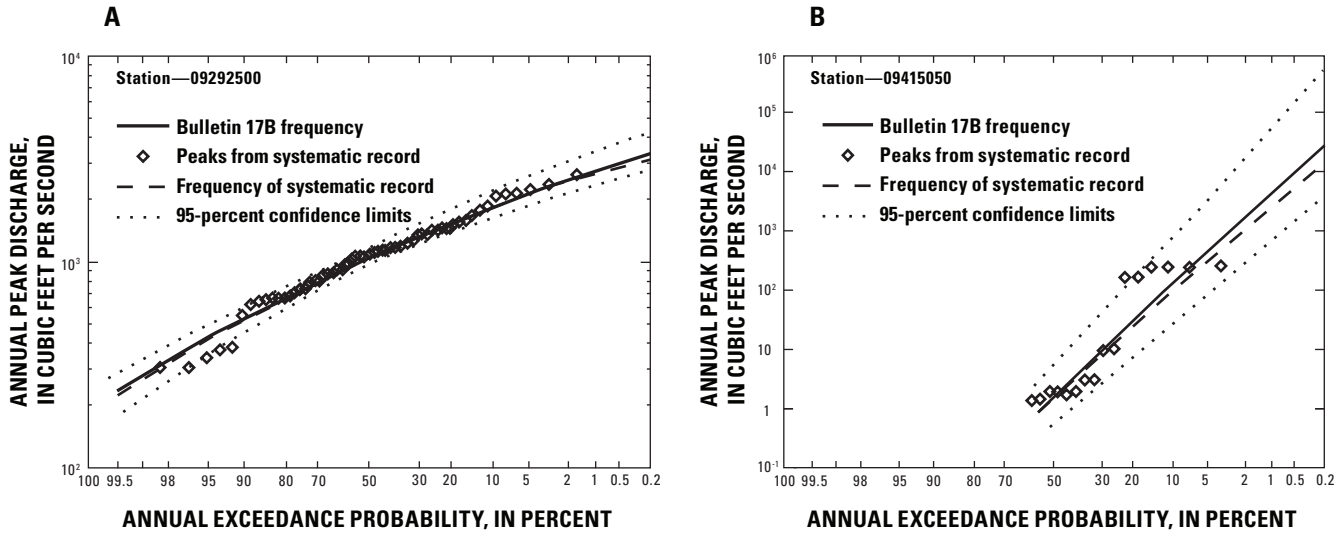


Figure 5. Example of streamflow-gaging stations with (a) an adequate fit and (b) a poor fit to the log-Pearson Type III distribution.

$DA_g$  is drainage area for the gaged site, and  $a$  is an exponent for the drainage area for each hydrologic region (table 2).

$DA_{g1}$  is drainage area for the upstream gaged site, and  $DA_{g2}$  is drainage area for the downstream gaged site.

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,

## 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-collinearity 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,

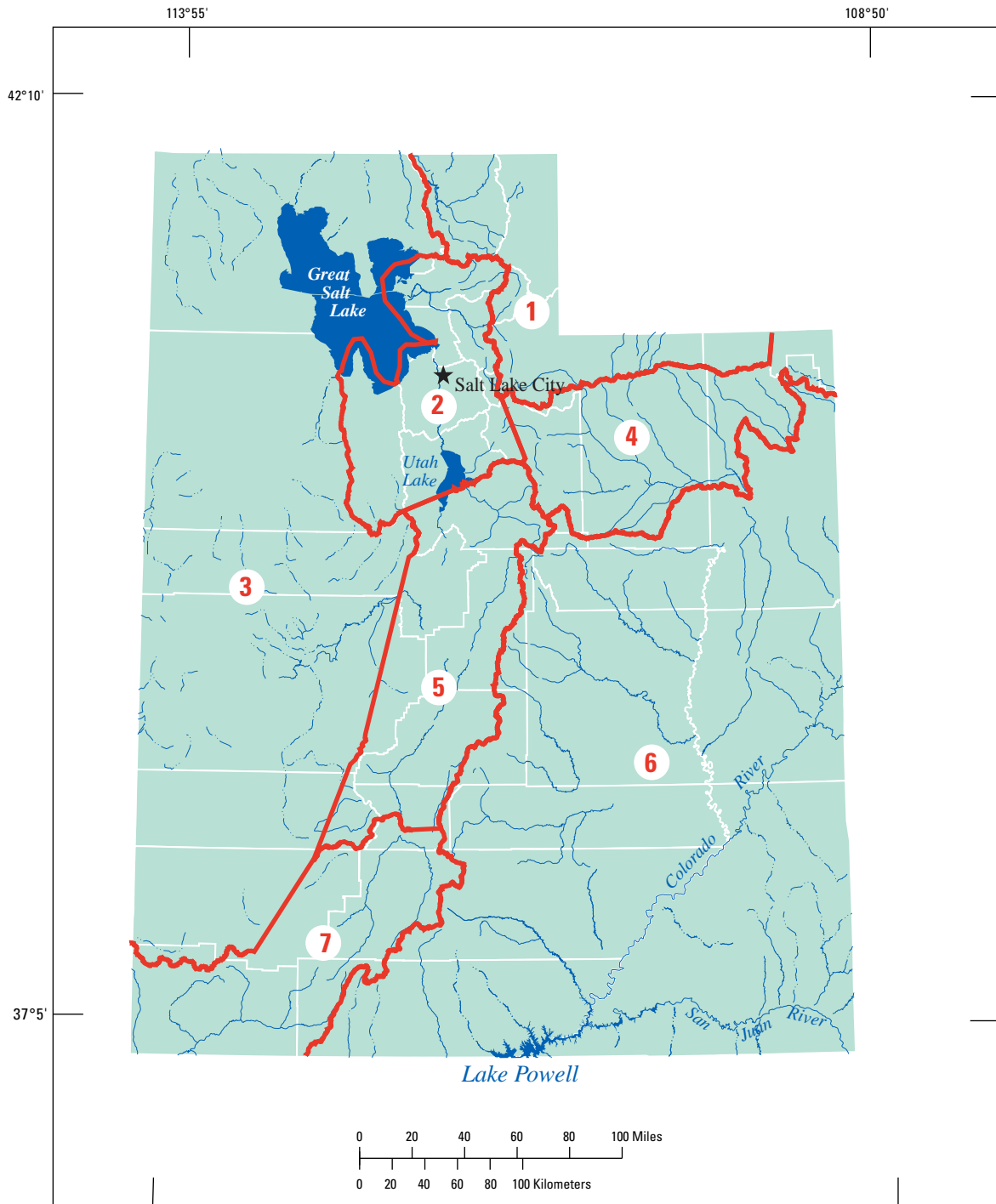
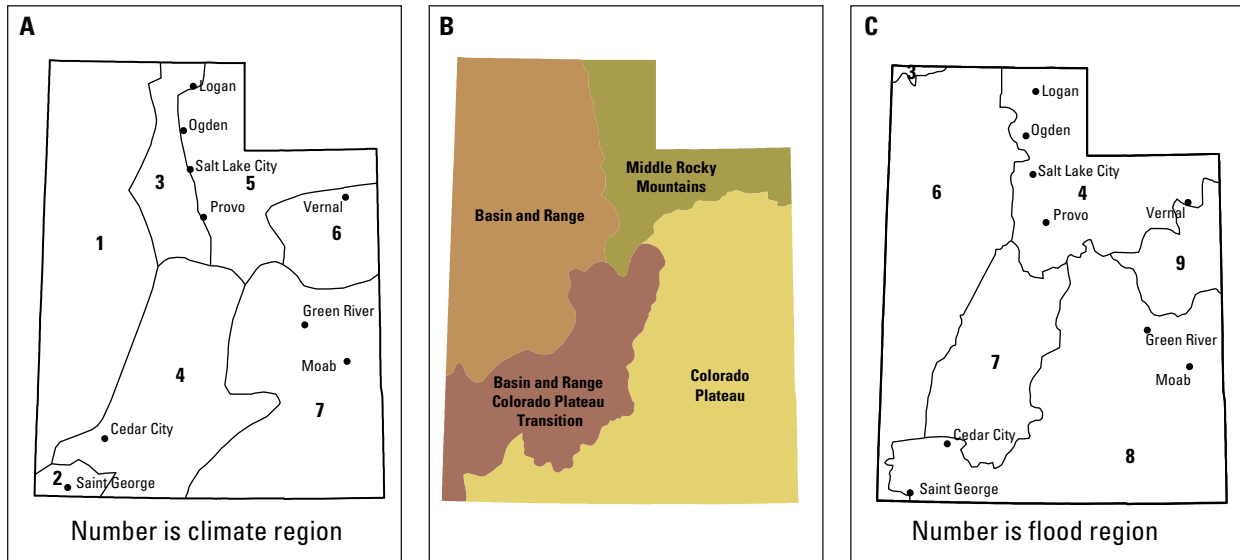


Figure 6. Geohydrologic regions of Utah used in regional regression analysis.



**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 <sup>1</sup> , NOAA-Atlas 2 <sup>2</sup>  |

<sup>1</sup> Used for Utah, Nevada, Arizona, and New Mexico

<sup>2</sup> 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 <a href="http://erg.usgs.gov/isb/pubs/factsheets/fs14899.html">http://erg.usgs.gov/isb/pubs/factsheets/fs14899.html</a>   |
| 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 <a href="http://landcover.usgs.gov/natl/landcover.php">http://landcover.usgs.gov/natl/landcover.php</a>                          |
| 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 <a href="http://hdsc.nws.noaa.gov/hdsc/pfds/docs/NA14Vol1.pdf">http://hdsc.nws.noaa.gov/hdsc/pfds/docs/NA14Vol1.pdf</a> |
| 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 <a href="http://nws.noaa.gov/ohd/hdsc/noaaatlas2.htm">http://nws.noaa.gov/ohd/hdsc/noaaatlas2.htm</a>  |
| 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 <a href="http://prism.oregonstate.edu/products">http://prism.oregonstate.edu/products</a>  |

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.

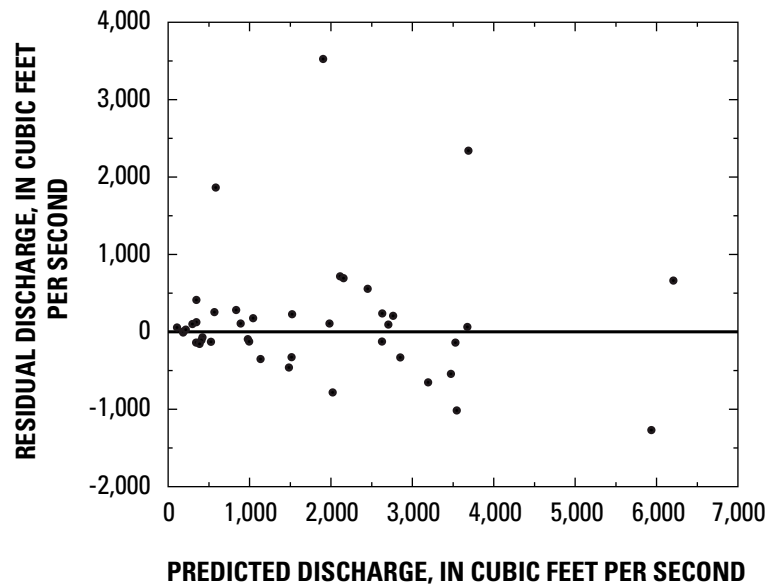
[PK, Peak flow, number following PK represents recurrence interval, in years; DRNAREA, drainage area, in square miles; ELEV, mean basin elevation, in feet; PRECIP, mean annual precipitation, in inches; BSLDEM10M, average basin slope, in percent; HERBUPLND, area covered by herbaceous upland, in percent]

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

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**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 <sup>0.391</sup> (ELEV/1,000) <sup>-2.54</sup>           | 60   | 58                      | 10.95                      |
| PK100 = 115,000 DRNAREA <sup>0.391</sup> (ELEV/1,000) <sup>-2.58</sup>         | 61   | 58                      | 12.97                      |
| PK200 = 166,000 DRNAREA <sup>0.361</sup> (ELEV/1,000) <sup>-2.61</sup>         | 62   | 60                      | 14.42                      |
| PK500 = 258,000 DRNAREA <sup>0.344</sup> (ELEV/1,000) <sup>-2.65</sup>         | 66   | 63                      | 15.40                      |
| Region 7 (equation based on data from 25 streamflow-gaging stations)           |  |                         |                            |
| PK2 = 18.4 DRNAREA <sup>0.630</sup>  | 76   | 71                      | 2.71                       |
| PK5 = 67.4 DRNAREA <sup>0.539</sup>  | 95   | 88                      | 2.46                       |
| PK10 = 134 DRNAREA <sup>0.487</sup>  | 110  | 102                     | 2.62                       |
| PK25 = 278 DRNAREA <sup>0.429</sup>  | 132  | 121                     | 2.85                       |
| PK50 = 446 DRNAREA <sup>0.390</sup>  | 149  | 136                     | 2.99                       |
| PK100 = 683 DRNAREA <sup>0.355</sup>   | 166  | 151                     | 3.13                       |
| PK200 = 1,010 DRNAREA <sup>0.321</sup>   | 185  | 167                     | 3.23                       |
| PK500 = 1,620 DRNAREA <sup>0.280</sup>   | 211  | 189                     | 3.35                       |



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

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

where:

- $AVP$  is the average variance of prediction,
- $\sigma_\delta^2$  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  $i^{\text{th}}$  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,
- $\Lambda$  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,  $S_p$ , 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:

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

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
- $\Lambda$  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:

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

where:

$h_{\text{limit}}$  is the leverage threshold,

$h_i$  are the main diagonal components of the  $\mathbf{h}$  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):

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

where:

$EQ$  is the equivalent years of record,

$s_{\text{pred}}$  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)

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

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.

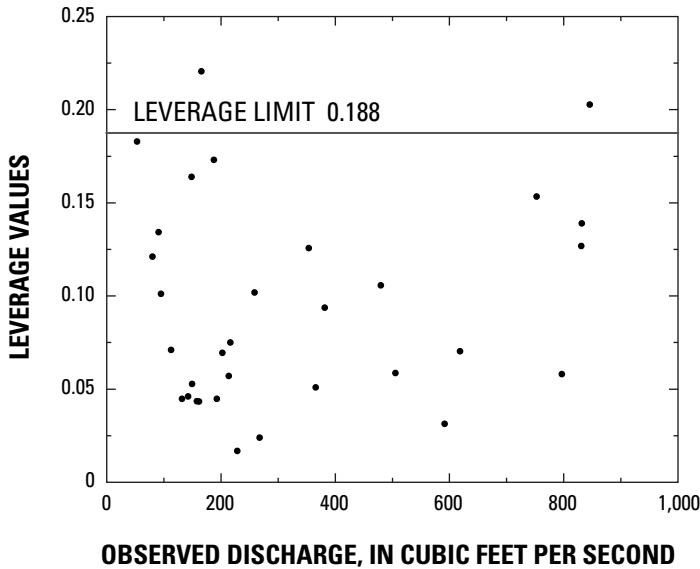
| Recurrence interval, in years | Leverage statistic limit | Number of sites used in analysis that exceed limit | Maximum leverage value | Recurrence interval, in years | Leverage statistic limit | Number of sites used in analysis that exceed limit | Maximum leverage value |
|-------------------------------|--------------------------|--|------------------------|-------------------------------|--------------------------|--|------------------------|
| <b>Region 1</b>               |                          |  |                        | <b>Region 5</b>               |                          |  |                        |
| 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                   |
| <b>Region 2</b>               |                          |  |                        | <b>Region 6</b>               |                          |  |                        |
| 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                   |
| <b>Region 3</b>               |                          |  |                        | <b>Region 7</b>               |                          |  |                        |
| 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                   |
| <b>Region 4</b>               |                          |  |                        |                               |                          |  |                        |
| 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

**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                     | —                  | —                        | —                           | —  |

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.

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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 |       |       |       |        |        |        |        | Number of annual peak flows |
|-----------------|-----------------------|--|--|-------|-------|-------|--------|--------|--------|--------|-----------------------------|
|                 |                       |  | 2  | 5     | 10    | 25    | 50     | 100    | 200    | 500    |                             |
| <b>Region 1</b> |                       |  |  |       |       |       |        |        |        |        |                             |
| <sup>3</sup> 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                          |
| <sup>2</sup> 10 | 09224800              | MEADOW SPRINGS WASH TRIB NEAR GREEN RIVER, WYOMING     | 32.6   | 96.2  | 157   | 250   | 328    | 412    | 499    | 619    | 18                          |
| <sup>1</sup> 11 | 09224810              | BLACKS FORK TRIBUTARY NO 2 NEAR GREEN RIVER, WYOMING   | Nd   | Nd    | Nd    | Nd    | Nd     | Nd     | Nd     | Nd     | 17                          |
| <sup>3</sup> 12 | 09224820              | BLACKS FORK TRIBUTARY NO 3 NEAR GREEN RIVER, WYOMING   | 19   | 71    | 142   | 295   | 475    | 728    | 1,080  | 1,730  | 20                          |
| <sup>4</sup> 13 | 09224840              | BLACKS FORK TRIBUTARY NO 4 NEAR GREEN RIVER, WYOMING   | 11   | 24.1  | 36.1  | 55.2  | 72.3   | 92     | 115    | 149    | 17                          |
| <sup>4</sup> 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                          |
| <sup>4</sup> 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                          |
| <sup>2</sup> 18 | 09226500              | MIDDLE FORK BEAVER CREEK NEAR LONETREE, WYOMING        | 308  | 487   | 621   | 806   | 956    | 1,110  | 1,280  | 1,530  | 22                          |
| <sup>3</sup> 19 | 09227500              | WEST FORK BEAVER CREEK NEAR LONETREE, WYOMING          | 164  | 252   | 320   | 416   | 496    | 583    | 679    | 819    | 14                          |
| <sup>4</sup> 20 | 09228500              | BURNT FORK NEAR BURNTFORK, WYOMING                     | 279  | 505   | 715   | 1,070 | 1,410  | 1,820  | 2,330  | 3,190  | 32                          |
| <sup>1</sup> 21 | 09229450              | HENRYS FORK TRIBUTARY NEAR MANILA, UTAH                | Nd   | Nd    | Nd    | Nd    | Nd     | Nd     | Nd     | Nd     | 10                          |
| <sup>2</sup> 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                          |
| <sup>4</sup> 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                          |
| <sup>4</sup> 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                          |
| <sup>2</sup> 40 | 10090800              | BATTLE CREEK TRIB NR TREASURETON, IDAHO                | 45.2   | 95.7  | 137   | 195   | 243    | 292    | 344    | 415    | 19                          |

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

**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   |                             |
| <b>Region 1—Continued</b> |                       |  |  |       |       |       |       |       |       |       |                             |
| 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                          |
| 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                         |
| 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                          |
| <b>Region 2</b>           |                       |  |  |       |       |       |       |       |       |       |                             |
| 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                          |
| 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 HUNTSVILLE, 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                          |
| 73                        | 10144000              | STONE CREEK ABOVE DIVERSION NEAR BOUNTIFUL, 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                          |
| 83                        | 10166430              | WEST CANYON CREEK NEAR CEDAR FORT, UTAH                  | 30.2   | 86.1  | 156   | 304   | 477   | 725   | 1,070 | 1,760 | 30                          |
| 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 |       |       |        |        |         |         |         | Number of annual peak flows |
|---------------------------|-----------------------|---|--|-------|-------|--------|--------|---------|---------|---------|-----------------------------|
|                           |                       |   | 2  | 5     | 10    | 25     | 50     | 100     | 200     | 500     |                             |
| <b>Region 2—Continued</b> |                       |   |  |       |       |        |        |         |         |         |                             |
| 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                          |
| <sup>9</sup> 91           | 10172640              | LEE CREEK NEAR MAGNA, UTAH                          | 45.6   | 74.6  | 95.5  | 123    | 144    | 166     | 189     | 219     | 11                          |
| <sup>9</sup> 92           | 10172700              | VERNON CREEK NEAR VERNON, UTAH                      | 20.7   | 71.1  | 142   | 307    | 515    | 831     | 1,300   | 2,280   | 46                          |
| <sup>9</sup> 93           | 10172740              | RUSH VALLEY TRIBUTARY NEAR FAIRFIELD, UTAH          | Nd   | Nd    | Nd    | Nd     | Nd     | Nd      | Nd      | Nd      | 11                          |
| <sup>9</sup> 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 TOOEELE, UTAH                  | 20.9   | 62.6  | 108   | 189    | 269    | 366     | 483     | 670     | 11                          |
| 97                        | 10172791              | SETTLEMENT CREEK ABOVE RESERVOIR NEAR TOOEELE, 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                          |
| <b>Region 3</b>           |                       |   |  |       |       |        |        |         |         |         |                             |
| <sup>4</sup> 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                          |
| <sup>2</sup> 104          | 10127100              | BLACK SLOUGH NEAR BRIGHAM CITY, UTAH                | 184  | 258   | 307   | 367    | 411    | 454     | 497     | 555     | 12                          |
| <sup>4</sup> 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                          |
| <sup>1</sup> 107          | 10172885              | GR SALT LAKE DESERT TR NO.2 NR DUGWAY, UTAH         | Nd   | Nd    | Nd    | Nd     | Nd     | Nd      | Nd      | Nd      | 15                          |
| <sup>4</sup> 108          | 10172890              | GOVERNMENT CREEK NEAR DUGWAY, UTAH                  | 10.2   | 116   | 402   | 1,500  | 3,470  | 7,350   | 14,500  | 33,000  | 10                          |
| <sup>4</sup> 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                          |
| <sup>4</sup> 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                          |
| <sup>1</sup> 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                          |
| <sup>1</sup> 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                          |
| <sup>4</sup> 117          | 10172970              | ROCK CREEK NR HOLBROOK ID                           | 170  | 595   | 1,200 | 2,640  | 4,500  | 7,350   | 11,700  | 20,800  | 18                          |
| <sup>3</sup> 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                          |
| <b>Region 4</b>           |                       |   |  |       |       |        |        |         |         |         |                             |
| 124                       | 09235600              | POT CREEK ABOVE DIVERSIONS, NEAR VERNAL, UTAH       | 62.4   | 126   | 182   | 271    | 351    | 444     | 549     | 712     | 35                          |
| <sup>3</sup> 125          | 09264000              | ASHLEY C BELOW TROUT C NR VERNAL, UTAH              | 433  | 561   | 637   | 724    | 784    | 840     | 893     | 959     | 11                          |
| <sup>2</sup> 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                          |

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

**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    |                             |
| <b>Region 4—Continued</b> |                       |  |  |       |       |       |        |        |        |        |                             |
| 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                          |
| <sup>3</sup> 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                          |
| <sup>4</sup> 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                          |
| <sup>3</sup> 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 FRUITLAND, UTAH      | 51.3   | 122   | 189   | 299   | 399    | 516    | 651    | 859    | 12                          |
| 151                       | 09287000              | CURRENT C BL RED LEDGE HOLLOW NR FRUITLAND, 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              | CURRENT 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                          |
| <sup>3</sup> 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 MOUNTAIN 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                          |
| <sup>4</sup> 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                          |
| <b>Region 5</b>           |                       |  |  |       |       |       |        |        |        |        |                             |
| 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              | CURRENT CREEK NEAR MONA, UTAH                        | 163  | 322   | 446   | 616   | 750    | 887    | 1,030  | 1,220  | 27                          |
| <sup>4</sup> 172          | 10146900              | UTAH LAKE TRIBUTARY NEAR ELBERTA, UTAH               | 180  | 712   | 1,390 | 2,720 | 4,120  | 5,900  | 8,110  | 11,800 | 12                          |
| 173                       | 10147000              | SUMMIT CREEK NEAR SANTAQUIN, UTAH                    | 73.2   | 123   | 157   | 203   | 237    | 271    | 305    | 351    | 19                          |
| <sup>2</sup> 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                          |
| <sup>4</sup> 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    |                             |
| <b>Region 5—Continued</b> |                       |   |  |       |       |        |        |        |        |        |                             |
| 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  | 1,520  | 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                          |
| <sup>2</sup> 187          | 10205100              | SHEEP CREEK NEAR SALINA, UTAH                     | 4.3  | 8.7   | 12.5  | 18.4   | 23.6   | 29.5   | 36.1   | 46.1   | 12                          |
| <sup>3</sup> 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                          |
| <sup>3</sup> 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                          |
| <sup>3</sup> 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                          |
| <sup>3</sup> 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                          |
| <sup>2</sup> 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                          |
| <b>Region 6</b>           |                       |   |  |       |       |        |        |        |        |        |                             |
| 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                          |
| <sup>1</sup> 219          | 09175900              | DRY CREEK NEAR NATURITA, CO.                      | Nd   | Nd    | Nd    | Nd     | Nd     | Nd     | Nd     | Nd     | 12                          |
| <sup>3</sup> 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                          |
| <sup>2</sup> 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                          |
| <sup>2</sup> 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                          |

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

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  |
| 239                | 09308000              | WILLOW CREEK NEAR OURAY, UTAH                      | 629  | 1,850 | 3,200 | 5,650  | 8,100  | 11,100 | 14,900 | 21,000                      | 26  |
| 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 SCOFIELD, 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 TABBYS 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  |
| 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  |
| 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  |
| 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  |
| 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  |
| 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  |
| 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     |                             |
| <b>Region 6—Continued</b> |                       |   |  |       |       |        |        |        |         |         |                             |
| <sup>2</sup> 284          | 09338000              | EAST FORK BOULDER CREEK NEAR BOULDER, UTAH          | 203  | 304   | 369   | 447    | 502    | 556    | 607     | 672     | 20                          |
| <sup>2</sup> 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                          |
| <sup>3</sup> 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                          |
| <sup>3</sup> 293          | 09368020              | MALPAIS ARROYO NR SHIPROCK, NM                      | 109  | 276   | 460   | 808    | 1,170  | 1,660  | 2,280   | 3,390   | 19                          |
| <sup>2</sup> 294          | 09371000              | MANCOS RIVER NEAR TOWAOC, CO.                       | 1,090  | 2,010 | 2,770 | 3,910  | 4,890  | 5,980  | 7,190   | 9,000   | 71                          |
| <sup>1</sup> 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                          |
| <sup>4</sup> 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 MONTICELLO, UTAH   | 44   | 92.4  | 137   | 209    | 275    | 353    | 444     | 587     | 20                          |
| 303                       | 09378200              | MONTEZUMA CREEK AT GOLF COURSE AT MONTICELLO, UTAH  | 25.1   | 96.7  | 204   | 465    | 806    | 1,340  | 2,150   | 3,850   | 13                          |
| <sup>4</sup> 304          | 09378600              | MONTEZUMA CREEK NEAR BLUFF, UTAH                    | 1,220  | 3,640 | 6,860 | 14,200 | 23,400 | 37,300 | 58,100  | 102,000 | 15                          |
| <sup>3</sup> 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                          |
| <sup>4</sup> 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                          |
| <sup>3</sup> 312          | 09379060              | LUKACHUKAI CREEK TRIBUTARY NEAR LUKACHUKAI, AZ      | 13.1   | 51.5  | 105   | 221    | 358    | 552    | 817     | 1,310   | 14                          |
| <sup>4</sup> 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 | 2,180  | 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                          |
| <sup>4</sup> 320          | 09381800              | PARIA RIVER NEAR KANAB, UTAH                        | 2,570  | 5,210 | 7,610 | 11,400 | 14,900 | 19,000 | 23,800  | 31,300  | 17                          |
| <sup>4</sup> 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                          |
| <sup>4</sup> 325          | 09403780              | KANAB CREEK NR FREDONIA, ARIZ.                      | 893  | 1,790 | 2,570 | 3,770  | 4,810  | 5,980  | 7,300   | 9,280   | 16                          |
| <sup>3</sup> 326          | 09403800              | BITTER SEEPS WASH TRIB NEAR FREDONIA, ARIZ.         | 134  | 566   | 1,160 | 2,410  | 3,820  | 5,730  | 8,220   | 12,600  | 14                          |
| <b>Region 7</b>           |                       |   |  |       |       |        |        |        |         |         |                             |
| 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 JUNCTION, 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 GLENDALE, UTAH  | 207  | 410   | 598   | 910    | 1,200  | 1,560  | 1,980   | 2,670   | 11                          |

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

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 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                          |
| <sup>4</sup> 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                          |
| <sup>4</sup> 339   | 09408150              | VIRGIN RIVER NEAR HURRICANE, UTAH                    | 6,000  | 11,000 | 14,900 | 20,400 | 25,000 | 29,800 | 35,000 | 42,300 | 19                          |
| <sup>3</sup> 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                          |
| <sup>1</sup> 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                          |
| <sup>4</sup> 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                          |

<sup>1</sup>Annual peak series plotted poorly to log Pearson Type III distribution, peak-flow recurrence intervals not determined, not used in analysis.

<sup>2</sup>Leverage statistic exceeded limit and removed from analysis.

<sup>3</sup>Leverage statistic exceeded limit but remained in analysis.

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



