Prepared in cooperation with the Idaho Department of Environmental Quality

Estimating Low-Flow Frequency Statistics for Unregulated Streams in Idaho

Scientific Investigations Report 2006–5035

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

Estimating Low-Flow Frequency Statistics for Unregulated Streams in Idaho

By Jon E. Hortness

Prepared in cooperation with the
Idhao Department of Environmental Quality

Scientific Investigations Report 2006-5035

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

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
P. Patrick Leahy, Acting Director

U.S. Geological Survey, Reston, Virginia: 2006

For sale by U.S. Geological Survey, Information Services
Box 25286, Denver Federal Center
Denver, CO 80225

For more information about the USGS and its products:
Telephone: 1-888-ASK-USGS
World Wide Web: http://www.usgs.gov/

Suggested citation:
Hortness, J.E., 2006, Estimating low-flow frequency statistics for unregulated streams in Idaho: U.S. Geological Survey Scientific Investigations Report 2006-5035, 31 p.

Contents

Figures

Tables

Conversion Factors, Datums, Definitions, and Abbreviations and Acronyms

Conversion Factors

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	2.54	centimeter
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometer
square mile	2.590	square kilometer

Datums

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).

Altitude, as used in this report, refers to distance above the vertical datum.

Definitions

Water year: In U.S. Geological Survey reports, a water year is the 12-month period from October 1 through September 30. The water year is designated by the calendar year in which it ends; thus, the water year ending September 30, 2001, is called the “2001 water year”.

Climatic year: In U.S. Geological Survey reports, a climatic year is the 12-month period from April 1 through March 31. The climatic year is designated by the calendar year in which it begins; thus, the climatic year beginning April 1, 2001, is called the”2001 climatic year.”

Abbreviations and Acronyms

Abbreviations and Acronyms	Meaning
GIS	Geographic Information System
GLS	Generalized Least Squares
IDEQ	Idaho Department of Environmental Quality
MSE	mean square error
NPDES	National Pollution Discharge Elimination System
OLS	Ordinary Least Squares
TMDL	Total Maximum Daily Load
USGS	U.S. Geological Survey

This page left intentionally blank

Estimating Low-Flow Frequency Statistics for Unregulated Streams in Idaho

By Jon E. Hortness

Abstract

Low-flow frequency statistics are needed by Federal, State, and local agencies for regulatory activities and water-use planning and management, as well as by commercial and hydroelectric facilities to determine the availability of water for supply and power generation. Logistic and multiple-linear regression analyses were used to develop zero-flow-probability and low-flow-estimating equations for eight separate geographic regions of Idaho and parts of adjacent States, using physical and climatic characteristics as the explanatory variables. As part of this process, the relevant statistics were updated for all gaging stations in Idaho, and some in adjacent States, that, in general, had 10 or more years of record through water year 2003 and were unaffected by regulation and(or) diversions.

Zero-flow-probability equations were developed for three of the eight geographic regions. These equations can be used to estimate the annual probability that the 1-, 7-, or 30-day low flows will equal zero. Using only data from the gaging stations used in the development process (sample data), these equations produced results with percent-correct values ranging from 74 to 100 percent. Any variability in the zero-flow characteristics within each region that was not represented by the data used to develop the equations may affect the predictive accuracy of the final equations.

Estimating equations were developed that can be used for estimating the $1Q_{10}$, $7Q_2$, $7Q_{10}$, and $30Q_5$ low-flow frequency statistics at ungaged, unregulated sites on streams in Idaho. The standard errors of prediction for these equations exhibited a minimum range of +26.9 to -21.2 percent and a maximum range of +311 to -75.7 percent. The $7Q_2$ estimating equations generally exhibited the lowest standard errors and the $1Q_{10}$ equations generally exhibited the largest standard errors. The equations may not yield reliable results for sites with basin-characteristic values that are outside of the range of values used to develop the equations. The equations also are not applicable for sites on regulated streams or on streams that are affected by significant gains and(or) losses resulting from factors including spring flow, channel seepage, diversions, and irrigation returns.

Introduction

Frequency statistics, such as the 7-day, 10-year low flow [$7Q_{10}$; annual minimum mean discharge for 7 consecutive days, which has a 0.1 (1/10; 10 percent) probability of not being exceeded in any one year], commonly are used by States when setting effluent limits and allowable pollutant loads to meet water-quality standards. These same low-flow frequency statistics also indicate the probable availability of water in streams during times when conflicts between water supply and demand are most prevalent. Because of this, low-flow statistics are needed by Federal, State, and local agencies for regulatory activities and water-use planning and management. Low-flow statistics also are used by commercial and hydroelectric facilities to determine the availability of water for supply and power generation.

In Idaho, more than 800 river reaches have been designated as impaired [exceeding water-quality and(or) biological criteria]. These reaches have or will have their load of pollutants analyzed and maximum loading rates set by Total Maximum Daily Load (TMDL) assessments. To determine the load of a constituent in a stream, streamflow-quantity information is needed. This information is especially important for low-flow periods when agencies need to determine the maximum effluent limits for National Pollution Discharge Elimination System (NPDES) discharge permits.

The U.S. Geological Survey (USGS) operates a network of streamflow-gaging stations in Idaho that provides streamflow data for a variety of purposes, and low-flow statistics can be calculated from the streamflow data collected at these locations. However, it is not feasible to operate gaging stations at all locations where low-flow statistics are needed. Because of this, methods are needed that can be used to estimate low-flow statistics at locations where no streamflow information exists. This is most often accomplished using regionalization techniques and regression analyses that relate low-flow statistics to selected physical and climatic characteristics of drainage basins.

The last Statewide evaluation of low-flow characteristics by the USGS was published in 1996 and included flow data through 1990 (Kjelstrom and others, 1996). Although this report included low-flow statistics over a wide range of flow durations and recurrence intervals, it only included low-flow statistics at gaged sites with 10 or more years of continuous record. Because methods are needed to estimate low-flow statistics at ungaged sites throughout Idaho, the USGS, in cooperation with the Idaho Department of Environmental Quality (IDEQ), began a study to develop methods for estimating the $1Q_{10}$, $7Q_2$, $7Q_{10}$, and $30Q_5$ low-flow frequency statistics at ungaged sites. In the past, estimating low-flow statistics at ungaged sites has met with only limited success because of difficulties in adequately describing the effects of geology and other factors that typically affect low flows (Riggs, 1972). The use of GIS (Geographic Information System) to obtain a larger number of basin characteristics, especially geologic characteristics, and the improved accuracy of source data may significantly improve the success of this method.

Purpose and Scope

This report presents techniques used to develop regional regression equations that can be used to estimate various low-flow statistics for ungaged sites on unregulated streams in Idaho. Multiple linear regression analyses were used to develop equations for estimating the $1Q_{10}$, $7Q_2$, $7Q_{10}$, and $30Q_5$ low-flow frequency statistics at ungaged, unregulated sites on streams in Idaho, and logistic regression analyses were used to develop equations for estimating the zero-flow probability for 1-, 7-, and 30-day low flows. The report also describes the associated reliability and limitations of the regression equations. Regression statistics, such as the standard error of estimate, were calculated to help assess the reliability and accuracy of each equation.

Relevant low-flow frequency statistics ($1Q_{10}$, $7Q_2$, $7Q_{10}$, and $30Q_5$) were updated for the gaging stations in Idaho and adjacent States used in the equation development process. These gaging stations included all those in Idaho, and some in adjacent States, with generally 10 or more years of record on streams unaffected by regulation and(or) diversions. Relevant low-flow statistics updated through water year 2003 for these gaging stations also are presented in this report.

Description of Study Area

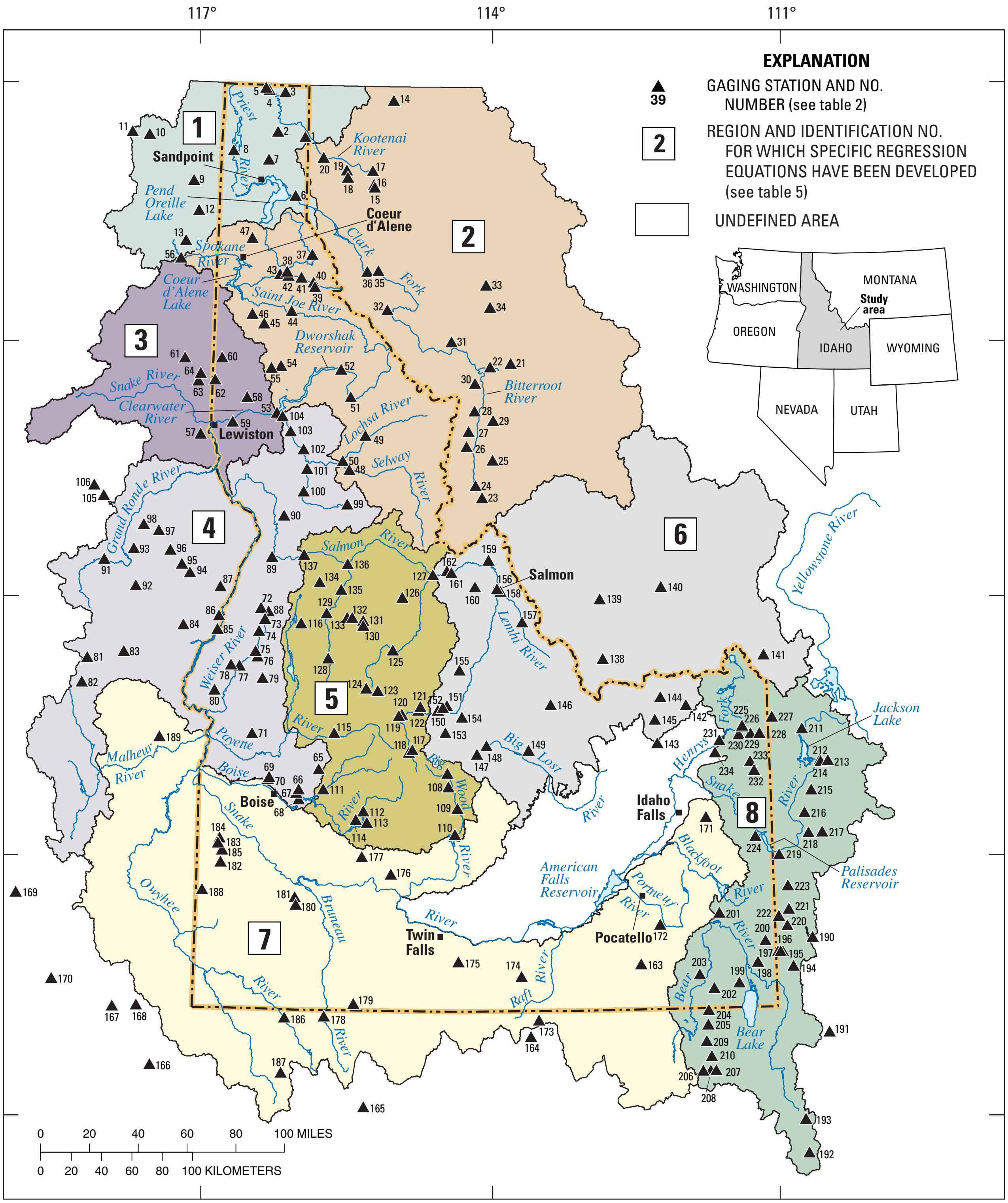
The study area (fig. 1) includes the entire State of Idaho and areas in the adjacent States of Washington, Oregon, Nevada, Utah, Wyoming, and Montana where particular drainage basins cross over State boundaries. The northern and central parts of the area are composed mainly of rugged, mountainous terrain; broad plains and mildly sloping valleys and hills predominate in the south. Geologic features across the study area consist of sedimentary, igneous, and metamorphic rocks ranging in age from Precambrian to Holocene (Bond, 1978). The granitic Idaho batholith is the major structural feature in the central part of the study area, and basalt covers much of the southern and western parts (Ross and Savage, 1967).

Most precipitation in the study area results from storms moving inland from the Pacific Ocean. The amount of precipitation varies widely throughout the area and is greatly affected by topography. Precipitation ranges from less than 10 in/yr on the Snake River Plain in south-central Idaho to 60 to 70 in/yr in the central mountains of Idaho (Molnau, 1995). The most significant amounts of precipitation are a direct result of orographic effects and occur primarily in the winter months. Spring and summer thunderstorms in the southern part of the study area sometimes produce large amounts of localized precipitation. Resulting streamflow varies geographically and seasonally and can be affected by land use and vegetation. During much of the year, typically August through March, streamflow in most unregulated streams in the study area is minimal base flow; during April, May, June, and July, streamflow is significantly greater, primarily as a result of snowmelt. Annual minimum streamflows typically occur during October through January. Occasionally during the winter months, large frontal systems carrying warmer air release moisture as rain on the snowpack and frozen ground, which results in rapid snowmelt and high runoff rates, particularly at altitudes less than 6,000 ft above sea level (National Oceanic and Atmospheric Administration, 1971).

Previous Investigations

Various low-flow statistics for selected gaging stations in Idaho with 10 or more years of record through 1990 were determined by Kjelstrom and others (1996). The statistics included the annual minimum mean discharges for periods of 1, 3, 5, 7, 14, 30, 60, 90, 120, and 183 consecutive days for recurrence intervals of 2, 5, 10, 20, 50, and 100 years. Kjelstrom and others (1995) also documented annual minimum discharges for selected gaging stations in Idaho with 5 to 9 years of record through 1990.

Although no studies have been completed that document methods for estimating low-flow statistics at ungaged sites in Idaho, several studies resulted in methods for estimating monthly-exceedance, annual-mean, and peak-flow statistics at ungaged sites. Most recently, regional regression techniques were used to develop equations that can be used to estimate various streamflow statistics at ungaged sites. These techniques resulted in equations for estimating the following statistics: monthly-exceedance and annual-mean discharges (Hortness and Berenbrock, 2001); peak-flow discharges (Berenbrock, 2002); and bankfull-flow discharges (Hortness and Berenbrock, 2003).



Base from U.S. Geological Survey digital data, 1:2,000,000, 1999; Regions based on Hydrologic Unit Boundaries, 1:2,000,000, 1999;
Transverse Mercator projection. Factor at central meridian: 0.99960. Longitude of central meridian: -114° 00'. Latitude of origin: 42° 00'
False easting (meters): 500,000.0 False northing (meters): 100,000.0

Figure 1. Location of the study area, streamflow-gaging stations, and eight regions used to estimate low-flow frequency statistics for unregulated streams in Idaho.

Quillian and Harenberg (1982) and Horn (1988) developed methods for estimating mean annual discharges in streams across Idaho. Kjelstrom (1998) developed a method for estimating the 20-, 50-, and 80-percent monthly-exceedance discharge values for the Salmon and Clearwater River Basins in central Idaho using the mean monthly discharge and a multiplication factor. This method pertains only to the approximately 1,050 subbasins identified by Lipscomb (1998), who estimated the mean monthly discharges for each subbasin by apportioning mean annual discharges into monthly increments on the basis of records from gaging stations selected as being characteristic of the subbasin. Lipscomb estimated the mean annual discharges by using the regional regression equations developed by Quillian and Harenberg (1982).

Thomas and others (1973), Kjelstrom and Moffatt (1981), and Quillian and Harenberg (1982) developed regional regression equations for estimating peak flows at ungaged sites in Idaho. Portions of Idaho also were included in regional peak-flow studies by Hedman and Osterkamp (1982) and Thomas and others (1994). Regression equations specific to bankfull flows were developed for the Salmon River Basin by Emmett (1975) and for the entire State by Harenberg (1980).

Low-Flow Frequency Statistics at Gaging Stations

Low-flow frequency statistics are determined using the annual minimum mean flows for any given number of days (N-day low flows) during an annual period. The mean flow for each N-day period throughout the annual period is computed and the minimum value is used for that period. The series of annual minimum N-day values are then fit to a log-Pearson Type III distribution to determine the recurrence intervals (Riggs, 1972). The annual period referred to as a climatic year (April 1 through March 31) is often used in low-flow analyses because the annual low-flow period in most parts of the country occurs during the late summer and autumn months. Use of the climatic year allows for inclusion of the entire low-flow period in the same year, whereas use of the traditional water year (October 1 through September 30) may artificially separate the low-flow period into two different years.

Updated relevant low-flow frequency statistics ($1Q_{10}$, $7Q_2$, $7Q_{10}$, and $30Q_5$) were computed for 234 gaging stations located throughout Idaho and portions of the adjacent States (fig. 1). This included all of those gaging stations located in Idaho and those in adjacent States within about an 80-mi buffer surrounding Idaho that, in general, had 10 or more years of record through water year 2003, exhibited little or no signs of trends, and were unaffected by regulations and/or diversions. A small number of gaging stations with fewer than 10 years of record were included in the analyses after the data were analyzed and found to contain a broad enough range of streamflow conditions that they would not bias the statistical results. Selected information for each gaging station included in the final dataset are presented in table 6 (at back of report) and the relevant low-flow frequency statistics for each gaging station are presented in table 7 (at back of report).

Streamflow data were analyzed for trends using Kendall's *tau* hypothesis test. Trends in the data could introduce an element of error into the frequency analyses, since a major assumption is that annual low flows are independent and stationary over time. The Kendall's *tau* test measures the monotonic relationship between two data sets, in this case, streamflow and time (Helsel and Hirsch, 1992). A relatively stringent P-value threshold of 2 percent ($\alpha = 0.02$) was used in this study. Data from gaging stations that exhibited trends based on this criteria were analyzed further and compared to data from nearby gaging stations to determine inclusion or exclusion from the dataset.

Streamflow data were screened to prevent data affected by regulations and/or diversions from biasing the dataset. Decisions to include or exclude data from a specific gaging station were made using hydrologic judgment based on all available information regarding the occurrence, timing, and magnitude of regulations and diversions upstream of the gaging stations. No specific criteria were used. In general, all gaging stations with data affected by upstream regulations were removed from the dataset, as well as those with data affected by upstream diversions during typical low-flow periods. The information available was not always complete and the accuracy was questionable in some cases, especially with regard to magnitudes of upstream diversions. Therefore, it is possible that data affected by regulations or diversions could have been included in the final datasets. However, the overall effects on the data are believed to be minimal.

Estimating Low-Flow Frequency Statistics at Ungaged Sites

Because gaging stations cannot be located at all sites where streamflow information is needed, other methods are used to estimate streamflow statistics for these sites. The two most commonly used methods for estimating streamflow statistics at ungaged sites are the drainage-area ratio method and regression equations (Ries and Friesz, 2000). The drainage-area ratio method can be used when the ungaged site is located near a gaging station on the same stream. Regression equations can be used to estimate streamflow statistics at most ungaged sites.

Drainage-Area Ratio

A major assumption of the drainage-area ratio method is that the streamflow at the ungaged site is the same per unit area as the streamflow at a nearby gaging station located on the same stream (index site). The method involves determining the drainage areas for both the ungaged site and the index site. The streamflow statistics are computed for the index site and then are divided by the drainage area to determine the streamflow per unit area for each statistic. The values for streamflow per unit area are then multiplied by the drainage area for the ungaged site to estimate the statistics for that site. The accuracy of this method depends on the proximity of the two sites and the similarities in drainage area and other physical and climatic (basin) characteristics of their drainage basins. The equation that represents this method is as follows:

$$Q_u = \left(\frac{DA_u}{DA_g} \right) Q_g \ , \tag{1}$$

where

Q_u is the streamflow statistic for the ungaged site,

DA_u is the drainage area for the ungaged site,

DA_g is the drainage area for the gaged site, and

Q_g is the streamflow statistic for the gaged site.

It is fairly common practice to use this method when the sites are located on the same stream and the ratio between the drainage areas of the index site and the ungaged site is between 0.5 and 1.5. On the basis of specific analyses in certain areas, some researchers have found that this range should be either reduced or expanded. Koltun and Schwartz (1986) recommended a range of 0.85 to 1.15 times the area of the index site for estimates of low-flow statistics in Ohio, and Ries and Friesz (2000) determined that a range of 0.3 to 1.5 was applicable for low-flow statistics in Massachusetts. Parrett and Johnson (2004) recommended the standard ratio of 0.5 to 1.5 for flood frequency analyses in Montana, as did Berenbrock (2002) and Kjelstrom (1998) for flood-frequency analyses in Idaho.

Regional Regression Equations

The regression analyses were completed for eight separate geographic regions of the State, as was done in the recent peak-flow and monthly exceedance studies (Hortness and Berenbrock, 2001 and 2003; Berenbrock, 2002). Basin and climatic variables (basin characteristics) for the gaging stations used in this study were obtained from previous studies or determined using GIS algorithms equivalent to those used in previous studies. Two types of regression analyses, logistic and multiple linear, were used. Logistic regression analysis was used for regions that included gaging stations at which any of the relevant N-day low flows equaled zero. Data from those stations were used to develop an equation for use in determining the probability of the annual minimum N-day flow being zero for an ungaged site. Multiple linear regression analyses were used in all regions to develop equations for estimating low-flow frequency statistics.

Determination of Regions

The regional boundaries used in this study are the same ones that were defined by Hortness and Berenbrock (2001): eight study regions and one undefined region that was not included in the analysis (fig. 1). The region boundaries were determined on the basis of the following: (1) grouping of gages with similar basin characteristics revealed during cluster analyses (statistical method for grouping data with similar characteristics), (2) location of geographic features, such as large mountain ranges or breaks between mountains and plains, and (3) use of hydrologic judgment based on general knowledge of the area. The undefined region is made up almost entirely of the area commonly referred to as the eastern Snake River Plain. This area includes several dams, major irrigation diversions, springs with extremely large discharges, and flat-land drainages and channel bottoms with very high infiltration rates. This area was not included in the analysis because flows influenced by these conditions cannot be characterized by a regional regression approach. More detailed information on how the regional boundaries were determined can be found in the previous report by Hortness and Berenbrock (2001).

Basin Characteristics

More than 30 separate basin characteristics were obtained for each of the 234 gaging stations included in this study. The basin characteristics for gaging stations included in previous studies by Hortness and Berenbrock (2001; 2003) and Berenbrock (2002) were used in this study. For gaging stations not included in those studies, the basin characteristics were derived using current GIS techniques equivalent to those used in the previous studies. In general, all basin characteristics were obtained using either custom Arc Macro Language (AML) programs written for ArcGIS or current tools (ArcHydro Tools) available in ArcGIS version 9.0 (Environmental Systems Research Institute, Inc., 2005). The sources for the values of all basin characteristics are given in table 1 and a list of all basin characteristics considered during this study are presented in table 8 (at back of report).

Several basin characteristics were removed from consideration after a review of the correlation plots of the data. Generally, if two basin characteristics correlated well with each other, the one that was the least difficult to obtain was kept and the other was removed. Other characteristics were removed because of missing data or difficulty in obtaining the data. Descriptions of the basin characteristics used in the final equations and the methods of determination are provided in table 2, and basin-characteristic values for each gaging station are listed in table 9 (at back of report).

Table 1. Sources for data used to obtain basin characteristics used to estimate low-flow frequency statistics for unregulated streams in Idaho.

Dataset	Source
National Elevation Dataset (NED)	Several basin characteristics were calculated using 30-meter-resolution digital-elevation data derived from the 1-arc-second National Elevation Dataset (NED) (URL: http://ned.usgs.gov/).
Elevation Derivatives for National Applications (EDNA)	Hydrologic derivatives of NED data were developed using procedures similar to those of EDNA Stage 1 processing, using a custom projection for Idaho (URL: http://edna.usgs.gov/Edna/methodology.asp).
National Land Cover Dataset (NLCD)	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 (URL: http://landcover.usgs.gov/natllandcover.asp).
Major lithology, Pacific Northwest	U.S. Geological Survey, 1995, Major lithology: Spokane, Washington, U.S. Geological Survey, polygon data converted to grid-cell resolution 200 meters (URL: http://www.icbemp.gov/spatial/min).
Mean annual precipitation, Idaho (used for areas within Idaho)	Molnau, M., 1995, Mean annual precipitation, 1961-1990, Idaho: Moscow, University of Idaho, Agricultural Engineering Department, State Climate Program, scale 1:1,000,000 (URL: http://snow.ag.uidaho.edu/Climate/reports.html).
Western United States average monthly or annual precipitation (PRISM; used for areas outside of Idaho)	Daly, C., and Taylor, G., 1998, Western United States average monthly or annual precipitation, 1961-90, Oregon: Portland, Water and Climate Center of the Natural Resources Conservation Service, grid-cell resolution 4 kilometers (URL: http://www.ocs.orst.edu/prism/prism_new.html).

Table 2. Description of basin characteristics used in the final equations for estimating low-flow frequency statistics for unregulated streams in Idaho.

Basin characteristic (identifier)	Description
Drainage area (*A*)	Drainage area of the basin that contributes surface runoff, in square miles; estimated using Arc/Info Grid with 30-meter-resolution digital-elevation models (DEMs).
Mean annual precipitation (*P*)	Mean annual precipitation over the entire drainage area, in inches; estimated using Arc/Info Grid with a combination of 500-meter resolution (within Idaho) and 4-kilometer resolution (outside of Idaho) precipitation grids covering the 1961-1990 period.
Developed land (*DV*)	Areas of residential, commercial, industrial, and transportation lands, in percentage of drainage area; estimated from the National Land Cover Dataset (NLCD) 1992 version.
Agricultural land (*AG*)	Areas of pasture, row crop, small grain, fallow, and urban/recreational grass lands, in percentage of drainage area; estimated from the National Land Cover Dataset (NLCD) 1992 version.
Basin slope (*BS*)	Average slope of the basin, in percent; estimated using the SLOPE function in Arc/Info Grid with 30-meter-resolution DEMs.
Water (*W*)	Areas of open water or perennial ice and snow, in percentage of drainage area; estimated from the National Land Cover Dataset (NLCD) 1992 version.
Basin relief (*R*)	Relief of the basin, in feet; estimated using Arc/Info Grid with 30-meter-resolution digital-elevation models (DEMs).
Surficial volcanic rocks (*V*)	Areas of surficial volcanic rocks, in percentage of drainage area; estimated from the Pacific Northwest Major Lithology data set.
Slopes greater than 50 percent (*S*50)	Area with slopes greater than 50 percent, in percentage of drainage area; estimated using the SLOPE function in Arc/Info Grid with 30-meter-resolution DEMs.

Logistic Regression Analysis

Logistic regression analyses were used to develop equations that relate the probability of a specific N-day low flow equaling zero to basin characteristics. The use of logistic regressions for water-resources applications is discussed in more detail by Helsel and Hirsch (1992). Applications specific to low-flow analyses can be found in a paper by Tasker (1989) and a report by Ludwig and Tasker (1993). Hosmer and Lemeshow (2000) provide a complete discussion of logistic regression.

The output variable in a logistic regression equation is dichotomous (binary), meaning that there are two possible outcomes. In this study, the possible outcomes were *flow* or *no flow*. Logistic regression is conceptually similar to multiple linear regression because the relation between one dependent variable and several independent variables is evaluated. The differences are reflected in the form of the equation and in the assumptions. Four important concepts regarding logistic regression analyses are as follows: (1) the conditional mean of the regression equation must fall between zero and 1; (2) the distribution of the errors is binomial, not normal; (3) equation coefficients are estimated using the log likelihood function, not least squares as is done in linear regression; and (4) the general principles that guide the development of linear regression equations are also relevant for logistic regression (Hosmer and Lemeshow, 2000).

The final form of the logistic regression equation results in a probability of success of one of the two possible outcomes. For this study, it was the probability that the specific N-day low flow is equal to zero. The final form of the logistic regression equation can be written as follows:

$$P_{zero} = \frac{e^{(a+c_1V_1+c_2V_2+...+c_nV_n)}}{1+e^{(a+c_1V_1+c_2V_2+...+c_nV_n)}} , \qquad (2)$$

where

P_{zero} is the probability of the N-day low flow being equal to zero,

a is the regession model constant,

e is a mathematical constant,

c_1 to c_n are the regression model coefficients, and

V_1 to V_n are the required basin characteristics.

Data from each of the gaging stations listed in table 6 were used in the logistic regression analyses. The Statit Custom QC (Statit Software, 2005) statistical software package was used to perform the logistic regression analyses. The data required to perform the analyses included the total number of years of record, total number of years that each of the specific N-day low flows equaled zero, and basin characteristics for each gaging station in the region being analyzed. In the analyses, the number of years that the specific N-day low-flow equaled zero was the dependent variable, the total number of years of record was the binomial trials variable (number of possible zero-flow years), and the basin characteristics were the independent variables. The total years of N-day zero flows and total years of record for each of the gaging stations are presented in table 10 (at back of report). Only region 2 had no gaging stations with at least 1 year where one of the N-day low flows equaled zero. Basin-characteristic data for the gaging stations were presented previously in table 9.

Several statistical parameters were used to help with the selection of the final probability equations. The overall likelihood ratio tests whether the model coefficients are significantly different from zero. This ratio follows a chi-squared distribution and computed *p*-values indicate whether model coefficients are significantly different from zero. A *p*-value threshold of 0.05 was used for this analysis. McFadden's R^2 is a transformation of the log-likelihood ratio intended to be similar to the unadjusted R^2 in linear regression. However, McFadden's R^2 tends to be smaller than R^2 in linear regression. The percentage of correct responses is calculated as the number of observed zero flows that were predicted by the model as zero flows, plus the number of non-zero flows predicted by the model as non-zero flows, divided by the total number of gaging stations used in the analysis. The odds ratio is a measure of the relative influence of an independent variable on the model.

Multiple Linear Regression Analysis

The use of multiple linear regression equations is the most common method used for estimating streamflow statistics at ungaged sites. In multiple linear regression analyses, streamflow statistics from several long-term gaging stations are statistically related to various basin characteristics for each of the gaging stations. The resulting equation can then be used with the relevant basin characteristics to estimate streamflow statistics at ungaged sites where no streamflow data are available.

The typical form of equations generated from multiple linear regression analyses is

$$Y_i = b_0 + b_1X_1 + b_2X_2 + ... + b_nX_n + \varepsilon_i , \qquad (3)$$

where

Y_i is the estimate of the dependent variable for site i,

b_0 to b_n are the $n+1$ regression model coefficients,

X_i to X_n are the n independent variables, and

ε_i is the residual error (difference between the observed and estimated values of the dependent variable) for site i.

Four assumptions are associated with the regression analyses: (1) the mean of ε_i is zero, (2) the variance of ε_i is constant and independent of the values of X_n, (3) the values for ε_i are normally distributed, and (4) the values for ε_i are independent of each other (Haan, 1977).

Streamflow statistics and basin characteristics generally are log-normally distributed. As a result, a log transformation of the variables is necessary to satisfy assumption 1 above. The use of log-transformed values results in an equation of the following linear form:

$$\log Y_i = b_0 + b_1 \log X_1 + b_2 \log X_2 + ... + b_n \log X_n + \varepsilon_i \,. \quad (4)$$

The coefficients for this equation are derived from the multiple linear regression analyses and then the equation is transformed back to original units. The retransformed equation takes on the following form:

$$Y_i = 10^{b_0} X_1{}^{b_1} X_2{}^{b_2} ... X_n{}^{b_n} 10^{\varepsilon_i} \,. \quad (5)$$

In hydrologic terms, assuming that ε_i is zero as stated in the assumptions above, the equation can be written as:

$$Q_i = a V_1{}^{c_1} V_2{}^{c_2} ... V_n{}^{c_n} \,, \quad (6)$$

where

Q_1 is the low-flow statistic,

a is the model constant transformed back to original units,

V_1 to V_n are the required basin characteristics, and

c_1 to c_n are the regression model coefficients.

Because streamflow data are essentially correlated spatially and in time, assumption 4 is not strictly satisfied when the most commonly used form of regression analysis, Ordinary Least Squares (OLS) is used. As a result, Generalized Least Squares (GLS) regression techniques were developed for use in regression analysis of peak- and low-flow frequency statistics. GLS techniques are the most appropriate for dealing with hydrologic regressions because the algorithms allow for the weighting of station data to compensate for spatial correlation and differences in record length (Tasker and Stedinger, 1989). For this study, OLS techniques were used to narrow down the list of possible explanatory variables (basin characteristics) and then GLS techniques were used to determine the final estimating equations. The Statit Custom QC (Statit Software, 2005) statistical software package was used to perform the initial regressions using OLS techniques and the USGS software package GLSNET (U.S. Geological Survey, 1998) was used to finalize the equations using GLS techniques.

Because the regression technique for low-flow statistics requires a log transformation, zero values cannot be used in the multiple linear regression analyses. All gaging stations listed in table 6 were used in the analyses except those with specific low-flow statistics equal to zero (see table 7). Depending on the values of the various low-flow statistics for a specific gaging station, it would be possible to include the gaging station in the analysis for one statistic but exclude it from the analysis for another. The basin characteristic values used in the analyses were presented previously in table 8. To ensure that zero values, which cannot be transformed, would not result for any gaging station, 1 percent was added to the values of the following basin characteristics prior to the log transformation: developed land (*DV*), agricultural land (*AG*), water (*W*), volcanic rock (*V*), and slopes greater than 50 percent (*S*50). In addition, basin relief (*R*) was divided by 1,000 prior to transformation to allow for more convenient coefficients in the final equations.

The final equations were chosen primarily, but not exclusively, on the basis of the following statistical parameters: (1) mean square error (MSE), the model error variance of the estimates for the stations included in the analysis; (2) R^2adj, the percentage of the variation in the dependent variable explained by the independent variables, adjusted for the number of stations and the number of independent variables used in the regression analysis; and (3) the PRESS statistic, an estimate of the prediction error sum of squares. In the end, simpler equations were chosen over more complex equations if the statistical parameters were similar.

Final Estimating Equations

Logistic regression analyses were performed for each of the regions with at least one gaging station with N-day low-flow data equal to zero (all the regions except region 2). The analyses in three of those regions—4, 6, and 7—resulted in equations that were statistically significant for estimating the annual probability of zero flows for 1-, 7-, and 30-day periods. Likely reasons why statistically significant equations could not be developed for regions 1, 3, 5, and 8 are that there were a relatively small number of gaging stations with N-day low-flow values equal to zero or there were a small number of zero values per gaging station.

The logistic regression equations developed for regions 4, 6, and 7 are presented in table 3 and should be used to determine the probability of the specific annual minimum N-day flows equaling zero for ungaged sites in those regions before low-flow frequency statistics are estimated. Values for some of the previously defined statistical parameters used to evaluate the quality of the equations are included in table 3. If the resulting probability is greater than the non-exceedance probability for the statistic of interest, then the expected value for that statistic would be zero and the low-flow frequency equations should not be used. If the resulting probability is less than the non-exceedance probability for the statistic of interest, then the low-flow frequency equations should be used to estimate the value of the statistic. For example, if the probability of a specific 7-day low flow equaling zero was 0.35 from the equation, the expected value for the $7Q_{10}$ statistic would be zero ($0.35 > 0.10$ or $^1/_{10}$), and the expected value for the $7Q_2$ statistic would be greater than zero ($0.35 < 0.50$ or $^1/_2$) and should be estimated using the low-flow frequency equation.

Table 3. Logistic regression equations used to estimate the probability of zero flow for unregulated streams in regions 4, 6, and 7 in Idaho.

[Locations of regions are shown in figure 1. **Zero flow annual probability equation**: $P_{\text{n-day}}$, annual probability of zero flow for *n* days; *A*, drainage area in square miles; *P*, mean annual precipitation, in inches; *DV*, developed land in percentage of drainage area; *AG*, agricultural land in percentage of drainage area; *BS*, basin slope in percent. OLR: Overall likelihood ratio. OLR-*p*: chi-square *p*-value for the overall likelihood ratio. **Percentage correctly estimated**: Based only on the sample data used to develop the equation]

Zero flow annual probability equation	McFadden's R^2	OLR	OLR-*p*	Percentage correctly estimated
Region 4				
$P_{\text{1-day}} = \dfrac{e^{(-47.5 - 0.0264A - 0.243P + 50.5(DV+1))}}{1 + e^{(-47.5 - 0.0264A - 0.243P + 50.5(DV+1))}}$	0.757	148.3	<0.0001	90
$P_{\text{7-day}} = \dfrac{e^{(-50.3 - 0.0323A - 0.224P + 52.5(DV+1))}}{1 + e^{(-50.3 - 0.0323A - 0.224P + 52.5(DV+1))}}$	.717	125.1	<.0001	95 (10-year) 100 (2-year)
$P_{\text{30-day}} = \dfrac{e^{(-57.1 - 0.0369A - 0.246P + 59.5(DV+1))}}{1 + e^{(-57.1 - 0.0369A - 0.246P + 59.5(DV+1))}}$	.772	127.4	<.0001	100
Region 6				
$P_{\text{1-day}} = \dfrac{e^{(25.5 - 0.0160A - 1.29P + 0.908(AG+1))}}{1 + e^{(25.5 - 0.0160A - 1.29P + 0.908(AG+1))}}$	0.847	353.2	<0.0001	100
$P_{\text{7-day}} = \dfrac{e^{(25.0 - 0.0156A - 1.27P + 0.899(AG+1))}}{1 + e^{(25.0 - 0.0156A - 1.27P + 0.899(AG+1))}}$	.828	338.8	<.0001	96 (10-year) 92 (2-year)
$P_{\text{30-day}} = \dfrac{e^{(26.8 - 0.0157A - 1.39P + 0.932(AG+1))}}{1 + e^{(26.8 - 0.0157A - 1.39P + 0.932(AG+1))}}$	.809	285.9	<.0001	96
Region 7				
$P_{\text{1-day}} = \dfrac{e^{(8.39 - 0.0136A - 0.442BS)}}{1 + e^{(8.39 - 0.0136A - 0.442BS)}}$	0.537	217.1	<0.0001	78
$P_{\text{7-day}} = \dfrac{e^{(8.09 - 0.0121A - 0.454BS)}}{1 + e^{(8.09 - 0.0121A - 0.454BS)}}$	.547	200.3	<.0001	74 (10-year) 96 (2-year)
$P_{\text{30-day}} = \dfrac{e^{(8.92 - 0.0141A - 0.516BS)}}{1 + e^{(8.92 - 0.0141A - 0.516BS)}}$	.607	183.4	<.0001	89

Although equations were not able to be developed for regions 1, 3, 5, and 8, the data show that it is possible, though not very common, to have occurrences of zero flow at certain locations within these regions. Thus, low-flow estimates approaching zero for ungaged sites (determined from the regression equations) may need additional analyses to determine if zero flows also are likely. Analyses could include comparisons of basin characteristics to gaging stations with known zero-flow occurrences in the same region (table 10) or field observations during expected low-flow periods.

Multiple linear regression analyses resulted in the development of four equations to estimate the low-flow frequency statistics $1Q_{10}$, $7Q_2$, $7Q_{10}$, and $30Q_5$ for unregulated streams in each of the eight regions in the State. The final equations are presented in table 4, along with the associated standard error of the model and the standard error of prediction for each equation. The standard error of the model measures how well the regression model fits the data used to develop it. The standard error of prediction includes the model error as well as an estimate of the sample error and is a better indicator of the model's overall predictive ability (Pope and others, 2001). The values presented in $\log_{10}$ format represent the errors of the log-transformed equations. The percentage values represent the range of errors for the final untransformed equations. These values were determined using error transformation equations presented in Riggs (1968).

Table 4. Regression equations for estimating low-flow frequency statistics for unregulated streams in regions 1-8 in Idaho.

[Locations of regions are shown in figure 1. **Low-flow frequency equation:** *A*, drainage area, in square miles; *BS*, basin slope, in percent; *P*, mean annual precipitation, in inches; *R*, basin relief, in feet; *S*50, slopes greater than 50 percent in percentage of drainage area; *V*, surficial volcanic rocks, in percentage of drainage area; *W*, water, in percentage of drainage area]

Low-flow frequency equation	Standard error of model		Standard error of prediction	
	$\log_{10}$	Percent	$\log_{10}$	Percent
Region 1				
$1Q_{10} = 0.794\ A^{0.420}\ (W + 1)^{1.32}$	0.078	+19.7 to –16.6	0.177	+50.3 to –33.5
$7Q_{10} = 0.804\ A^{0.453}\ (W + 1)^{1.22}$	.032	+7.55 to –7.02	.155	+43.0 to –30.1
$7Q_2 = 0.731\ A^{0.613}\ (W + 1)^{0.907}$	.032	+7.55 to –7.02	.132	+35.4 to –26.1
$30Q_5 = 0.911\ A^{0.512}\ (W + 1)^{1.05}$	.032	+7.55 to –7.02	.136	+36.7 to –26.8
Region 2				
$1Q_{10} = 0.0000497\ A^{1.05}\ P^{2.03}$	0.333	+115 to–53.5	0.346	+122 to –54.9
$7Q_{10} = 0.0000728\ A^{1.06}\ P^{1.98}$	.317	+107 to –51.8	.329	+113 to –53.1
$7Q_2 = 0.000153\ A^{1.04}\ \mathrm{P}^{1.92}$	.243	+74.9 to –42.8	.253	+78.9 to –44.1
$30Q_5 = 0.000164\ A^{1.04}\ \mathrm{P}^{1.87}$	.270	+86.3 to –46.3	.281	+91.0 to –47.6
Region 3				
$1Q_{10} = 0.00492\ A^{-0.0990}\ (R/1{,}000)^{5.15}$	0.467	+193 to –65.9	0.552	+257 to –72.0
$7Q_{10} = 0.00964\ A^{-0.0923}\ (R/1{,}000)^{4.76}$	.462	+190 to –65.5	.545	+251 to –71.5
$7Q_2 = 0.00953\ A^{0.392}\ (R/1{,}000)^{3.36}$	.298	+98.6 to –49.6	.351	+125 to –55.4
$30Q_5 = 0.0186\ A^{0.109}\ (R/1{,}000)^{3.84}$	.327	+112 to –52.9	.386	+143 to –58.9
Region 4				
$1Q_{10} = 0.00000187\ A^{1.03}\ P^{2.90}$	0.452	+183 to –64.7	0.471	+195 to –66.2
$7Q_{10} = 0.00000222\ A^{1.05}\ P^{2.88}$	.432	+170 to –63.0	.449	+181 to –64.4
$7Q_2 = 0.0000215\ A^{1.04}\ P^{2.41}$	.328	+113 to –53.0	.341	+119 to –54.4
$30Q_5 = 0.00000993\ A^{1.04}\ P^{2.58}$	.360	+129 to –56.4	.375	+137 to –57.8
Region 5				
$1Q_{10} = 0.0000497\ A^{0.968}\ (V{+}1)^{1.96}$	0.382	+141 to –58.5	0.419	+163 to –61.9
$7Q_{10} = 0.0000654\ A^{0.959}\ (V{+}1)^{1.96}$	.341	+120 to –54.4	.378	+139 to –58.1
$7Q_2 = 0.000453\ A^{1.04}\ (V{+}1)^{1.51}$	.042	+10.3 to –9.31	.103	+26.9 to –21.2
$30Q_5 = 0.000190\ A^{0.981}\ (V{+}1)^{1.74}$	.222	+66.6 to –40.0	.255	+80.0 to –44.5
Region 6				
$1Q_{10} = 0.0000324\ A^{1.06}\ P^{2.38}$	0.287	+93.8 to –48.4	0.309	+104 to –50.9
$7Q_{10} = 0.0000360\ A^{1.06}\ P^{2.38}$	0.286	+98.3 to –43.3	.307	+103 to –50.7
$7Q_2 = 0.000133\ A^{1.05}\ P^{2.10}$	0.226	+68.5 to –40.6	.243	+75.0 to –42.9
$30Q_5 = 0.000127\ A^{1.04}\ P^{2.10}$	0.264	+83.5 to –45.5	.283	+91.9 to –47.9
Region 7				
$1Q_{10} = 0.0149\ A^{0.613}\ (S50 + 1)^{0.949}$	0.544	+250 to –71.5	0.614	+311 to –75.7
$7Q_{10} = 0.0177\ A^{0.627}\ (S50 + 1)^{0.924}$	.503	+219 to –68.6	.570	+271 to –73.1
$7Q_2 = 0.0329\ A^{0.678}\ (S50 + 1)^{0.796}$	.483	+204 to –67.1	.533	+241 to –70.7
$30Q_5 = 0.0272\ A^{0.648}\ (S50{+}1)^{0.851}$	.485	+206 to –67.3	.541	+248 to –71.2
Region 8				
$1Q_{10} = 3.15\ A^{0.866}\ BS^{-0.640}$	0.201	+59.0 to –37.1	0.226	+68.3 to –40.6
$7Q_{10} = 2.27\ A^{0.903}\ BS^{-0.545}$	.124	+33.0 to –24.8	.157	+43.6 to –30.4
$7Q_2 = 3.86\ A^{0.930}\ BS^{-0.648}$	.136	+36.9 to –27.0	.157	+43.4 to –30.3
$30Q_5 = 6.17\ A^{0.940}\ BS^{-0.844}$	.119	+31.6 to –24.0	.144	+39.2 to –28.1

Accuracy and Limitations

The percentage of correct values for the zero-flow probability equations ranged from 74 to 100 percent (table 3). The values for regions 4 and 6 were all 90 percent or higher. The values for region 7 ranged from 74 to 96 percent. These values provide an indication of the accuracy of the equations based only on the data used to develop the equations. It is assumed that the data used in each region provide a good representation of the zero-flow characteristics of streams in the region. However, any variability in the zero-flow characteristics within each region that was not represented in the development of the equations may have an effect on the final predictive accuracy of the equations.

The model and prediction standard errors for the final estimating equations range significantly across the eight regions (table 4). Equations for regions 1 and 8 had relatively low standard errors, whereas those for regions 3 and 7 were quite large. The large errors associated with the region 3 equations may be the result of the low number of gaging stations (eight) available for the analysis. The large errors associated with the region 7 equations likely indicate that the available basin characteristics do not adequately represent the factors that affect low flows in this area. The natural variability of streamflow may also be an important factor. Prediction of streamflow statistics that have a high degree of variability will always have more uncertainty than prediction of statistics that are more stable. Hortness and Berenbrock (2001) noted that the natural variability of streamflow in regions 6 and 7 is generally greater than the natural variability in the other regions. It is also important to note that even a large percentage error associated with low-flow values does not necessarily result in a large-magnitude error range around the value. For example, a low-flow value of 5.0 ft^3/s with errors of +150 and -75 percent would have a resulting error range of 1.25 to 12.5 ft^3/s.

The standard errors of prediction for the equations across the eight regions had a minimum range of +26.9 to -21.2 percent for the $7Q_2$ statistic in region 5 and a maximum range of +311 to -75.7 percent for the $1Q_{10}$ statistic in region 7. These error values represent the general predictive ability of the estimating equations; however, other factors could limit the applicability of the equations. It is important to note that because of the transformation from log to back to arithmetic units, the standard error values will always have larger positive values than negative values.

Because the zero-flow probability and low-flow estimating equations are based on regression analyses, the equations might not be reliable for sites where the basin-characteristic values are outside of the range of values that were used to develop the equations (table 5). In addition, using basin characteristic values near their extremes (maximum or minimum, table 5) might result in unreliable estimates. Figure 2 shows a "cloud of common values" for two basin characteristics. In this example, if the minimum value for mean annual precipitation and the maximum value for mean basin elevation were used, the combination would plot outside of the "cloud of common values," thus the corresponding equation might result in unreliable estimates. Generating basin-characteristic values by using datasets or processes other than those described in this study also will result in estimates of unknown reliability. The standard errors for each equation are only applicable if the datasets presented in table 1 are used to obtain the required basin characteristics.

The equations are not applicable for stream reaches affected by irrigation diversions and(or) returns, or dams that regulate streamflow. The Boise River downstream from Lucky Peak Lake, the Clearwater River downstream from Dworshak Reservoir, and the entire Snake River in Idaho are examples of stream reaches within the study area for which the estimating equations are not applicable. However, the equations could be used on regulated streams to provide an estimate of natural flow statistics for comparison with the regulated statistics, given that, as previously explained, all of the basin characteristics for the site fall within the ranges of those used to develop the equations.

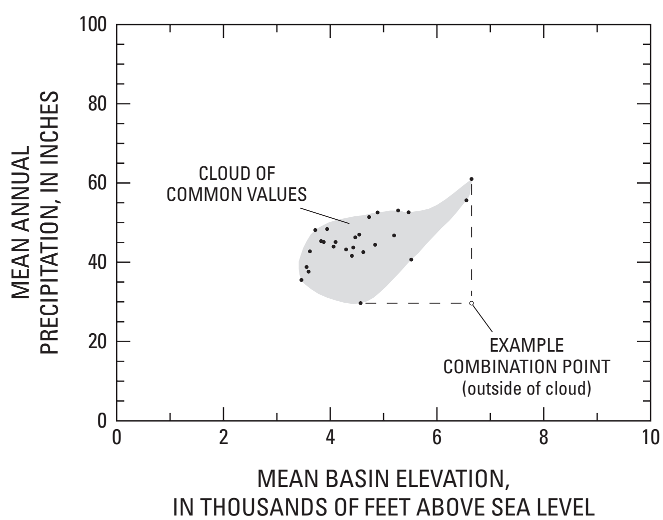


Figure 2. Joint distribution of two example basin characteristics, mean basin elevation and mean annual precipitation.

Table 5. Range of values of basin characteristics used to estimate low-flow frequency statistics for unregulated streams in regions 1-8 in Idaho.

[Location of regions are shown in figure 1. **Equation variables:** *A*, drainage area, in square miles; *P*, mean annual precipitation, in inches; *DV*, developed land, in percentage of drainage area; *AG*, agricultural land, in percentage of drainage area; *BS,* basin slope, in percent; *W*, water, in percentage of drainage area; *R*, basin relief, in feet; *V*, surficial volcanic rocks, in percentage of drainage area; *S*50, slopes greater than 50 percent, in percentage of drainage area]

	Equation variables								
	A	*P*	*DV*	*AG*	*BS*	*W*	*R*	*V*	*S50*
Region 1									
Maximum	1,011.0	54.3	3.59	23.2	46.4	6.69	5,866.9	27.9	41.4
Minimum	12.5	25.1	.000	.005	12.2	.004	2,230.6	.000	1.04
Region 2									
Maximum	2,442.5	69.4	1.83	4.43	66.8	3.98	7,789.6	99.9	67.4
Minimum	3.0	24.8	.000	.000	23.8	.000	1,643.9	.000	2.62
Region 3									
Maximum	674.9	30.1	18.6	91.6	35.4	0.258	5,098.9	92.7	27.5
Minimum	17.6	19.3	.031	7.46	10.0	.006	1,442.8	14.5	.018
Region 4									
Maximum	5,507.9	65.6	0.126	18.4	57.2	1.04	8,364.5	100.0	63.1
Minimum	4.0	15.9	.000	.000	18.7	.000	1,821.4	18.2	1.27
Region 5									
Maximum	12,228.0	44.5	2.21	2.44	46.7	4.37	10,701.3	100.0	46.1
Minimum	19.3	22.4	.000	.000	20.2	.002	2,743.5	27.1	3.47
Region 6									
Maximum	6,236.7	42.3	0.385	9.27	66.2	1.19	9,419.7	93.0	77.2
Minimum	6.4	15.3	.000	.000	8.60	.000	2,395.4	.000	1.36
Region 7									
Maximum	535.3	29.3	0.296	28.1	35.3	0.599	5,683.3	100.0	28.5
Minimum	7.4	12.3	.000	.000	10.1	.000	1,681.7	.000	.189
Region 8									
Maximum	874.8	56.0	0.176	70.7	53.2	3.83	6,232.1	90.1	60.5
Minimum	6.6	14.2	.000	.000	6.15	.000	1,100.5	.000	.002

The estimating equations may not be applicable for streams that exhibit significant gains as a result of spring flow or significant losses as a result of channel seepage. The effects of headwater springs and other small springs that are representative of many or all streams in a particular region because of similar geologic conditions likely would be reflected in the equations for that region. The effects of larger springs which significantly affect streamflows likely would not be reflected in the equations. Similarly, the effects of small losses due to channel seepage which are representative of streams in a particular region likely would be reflected in the equations, while the effects of larger losses likely would not. In specific instances, user judgment may be required to decide if the particular ungaged site of interest is affected by factors similar to those that affected the gaging station data used to develop the relevant equations. For example, results for an ungaged site on the Lemhi River near Lemhi in region 6, which has fairly significant and highly variable streamflow gains and losses (Donato, 1998), may be suspect since no mainstem Lemhi River gaging stations were used to develop the equations. However, if a gaging station from the Lemhi River or another river with similar characteristics were included, the equations likely would produce satisfactory results.

Application of Regional Regression Method

Three examples are given for using the equations to estimate low-flow frequency statistics for unregulated streams in Idaho. Example 1 addresses the basic ungaged site with the entire upstream drainage area located within the same region and no zero-flow probabilities, example 2 addresses the situation where zero-flow probability equations are used to estimate the probability of zero flows at a site (regions 4, 6, and 7, only) and example 3 addresses the situation where the drainage area of a specific site encompasses parts of two separate regions.

Example 1

An estimate of the $7Q_2$ low-flow statistic is required for a stream location in region 2. The following required basin characteristics were determined for region 2 equations: A, 2180.5 mi^2; and P, 30.2 in. Since region 2 has no zero flow annual probability equations, the user would go directly to the low-flow frequency regression equations. Based on the basin-characteristic values, the estimated $7Q_2$ statistic can be computed as follows:

$$7Q_2 = 0.000153A^{1.04}P^{1.92}$$

$$7Q_2 = 0.000153(2180.5)^{1.04}(30.2)^{1.92}$$

$$7Q_2 = 315 \text{ ft}^3/\text{s}$$

The predicted range of the actual values for this low-flow statistic, based on the range of the standard error of prediction given in table 4, is as follows:

$$7Q_2 = 176 \text{ ft}^3/\text{s to } 562 \text{ ft}^3/\text{s } (+78.9 \text{ to } -44.1 \text{ percent}) .$$

Example 2

An estimate of the $7Q_{10}$ low-flow statistic is required for a stream location in region 6. The following required basin characteristics were determined for region 6 equations: A, 8.2 mi^2; and P, 24.7 in.; and AG, 1.35 percent. Based on these values, the probability of the 7-day low-flow equaling zero at this site is computed as follows:

$$P_{7\text{-day}} = \frac{e^{(25.0 - 0.0156A - 1.27P + 0.899(AG+1))}}{1+e^{(25.0 - 0.0156A - 1.27P + 0.899(AG+1))}}$$

$$P_{7\text{-day}} = \frac{e^{(25.0 - 0.0156(8.2) - 1.27(24.7) + 0.899(1.35+1))}}{1+e^{(25.0 - 0.0156(8.2) - 1.27(24.7) + 0.899(1.35+1))}}$$

$$P_{7\text{-day}} = 0.012$$

Because the probability is less than 0.10 (1/10 for 10 year recurrence), the equation estimates that the 7-day low flow for this site is greater than zero. The estimated $7Q_{10}$ statistic can then be computed as follows:

$$7Q_{10} = 0.0000360A^{1.06}P^{2.38}$$

$$7Q_{10} = 0.0000360(8.2)^{1.06}(24.7)^{2.38} .$$

$$7Q_{10} = 0.691 \text{ ft}^3/\text{s}$$

The predicted range of the actual values for this low-flow statistic, based on the range of the standard error of prediction given in table 4, is as follows:

$$7Q_{10} = 0.341 \text{ ft}^3/\text{s to } 1.40 \text{ ft}^3/\text{s } (+103 \text{ to } -50.7 \text{ percent}) \cdot$$

Example 3

An estimate of the $30Q_5$ low-flow statistic is required for a site in region 5 on a stream with a drainage basin encompassing parts of regions 5 and 6. The recommended method for handling sites with portions of its drainage basin in two regions is as follows: (1) calculate values for the entire drainage basin by using equations from the first region, (2) calculate values for the entire drainage basin by using equations from the second region, and (3) average the two values on the basis of the proportion of drainage area in each region (Sando, 1998). The following required basin characteristics were determined for region 5 and 6 equations: A, 5,153.0 mi^2; V, 78.5 percent; and P, 39.4 in. The portion of the drainage area located in region 5 covers 1,622.0 mi^2 and the portion in region 6 covers 3,531.0 mi^2. The step to check for the probability of zero flow in region 6 was skipped because of the large portion of the drainage area in region 5. Because the region boundaries were almost exclusively drawn along hydrologic boundaries, the occurrence of zero flows at sites that have portions of the drainage area in two regions is highly unlikely, but should be verified.

Region 5 calculations:

$$30Q_5 = 0.000127A^{1.04}P^{2.10}$$

$$30Q_5 = 0.000127(5153.0)^{1.04}(39.4)^{2.10} .$$

$$30Q_5 = 2,060 \text{ ft}^3/\text{s}$$

Region 6 calculations:

$$30Q_5 = 0.000127A^{1.04}P^{2.10}$$

$$30Q_5 = 0.000127(5153.0)^{1.04}(39.4)^{2.10} .$$

$$30Q_5 = 2,060 \text{ ft}^3/\text{s}$$

Area-weighted average:

$$30Q_5 = 1,690 \text{ ft}^3/\text{s}\left(\frac{1,622.0}{5,153.0}\right) + 2,060 \text{ ft}^3/\text{s}\left(\frac{3,531.0}{5,153.0}\right).$$

$$30Q_5 = 1,940 \text{ ft}^3/\text{s}$$

Summary

The USGS, in cooperation with the Idaho Department of Environmental Quality (IDEQ), used multiple linear regression analyses to develop equations that can be used for estimating the $1Q_{10}$, $7Q_2$, $7Q_{10}$, and $30Q_5$ low-flow frequency statistics at ungaged, unregulated sites on streams in Idaho. As part of this process, the relevant statistics were updated for all gaging stations in Idaho and some in adjacent States that, in general, had 10 or more years of record through water year 2003 and were unaffected by regulation and/or diversions. In regions of the State where one or more of these statistics are sometimes equal to zero, logistic regression analyses were used to develop equations for estimating the probability that the annual N-day low flow is equal to zero. Various physical and climatic characteristics of the drainage basins (basin characteristics) were used as the explanatory variables in each of the equations.

The logistic regression analyses in regions 4, 6, and 7 resulted in equations that were statistically significant for estimating the annual probability of zero flows for 1-, 7-, and 30-day periods. The final probability equations correctly predicted zero-flow values for 74 to 100 percent of the gaging stations used to develop the equations, depending on the region and the N-day period. Although it is assumed that these gaging stations provide a good representation of zero-flow characteristics in each of the regions, any variability in the zero-flow characteristics within each region that was not represented may affect the predictive accuracy of the final equations. The zero-flow probability equations should be used for sites in regions 4, 6, and 7 before low-flow frequency statistics are estimated. If the resulting probability is greater than the non-exceedance probability for the statistic of interest, then the expected value for that statistic would be zero and the low-flow frequency equations should not be used. If the resulting probability is less than the non-exceedance probability for the statistic of interest, then the low-flow frequency equations should be used to estimate the value of the required statistic.

The equations for estimating low-flow frequency statistics had standard errors of prediction with a minimum range of +26.9 to -21.2 percent and a maximum range of +311 to -75.7 percent. In general, the $7Q_2$ estimating equations exhibited the lowest standard errors, whereas the $1Q_{10}$ equations exhibited the largest standard errors. The equations may not yield reliable results for sites with basin-characteristic values that are outside of the range of values used to develop the equations. The equations also are not applicable for sites on regulated streams or on streams that are affected by significant gains and(or) losses resulting from factors including spring flow, channel seepage, diversions, and irrigation returns. If desired, however, the equations could be used on regulated streams to provide an estimate of natural flow statistics for comparison with the regulated statistics.

References Cited

Berenbrock, Charles, 2002, Estimating the magnitude of peak flows at selected recurrence intervals for streams in Idaho: U.S. Geological Survey Water-Resources Investigations Report 02-4170, 59 p.

Bond, J.G., 1978, Geologic map of Idaho: Moscow, Idaho Bureau of Mines and Geology, 1 sheet, scale 1:500,000.

Daly, C., and Taylor, G., 1998, Western United States average monthly or annual precipitation, 1961-90, Oregon: Portland, Water and Climate Center of the Natural Resources Conservation Service, accessed DATE at URL: http://www.ocs.orst.edu/prism/prism_new.html.

Donato, M.M., 1998, Surface-water/ground-water relations in the Lemhi River Basin, East-Central Idaho: U.S. Geological Survey Water-Resources Investigations Report 98-4185, 20 p.

Emmett, W.W., 1975, The channels and waters of the upper Salmon River area, Idaho: U.S. Geological Survey Professional Paper 870-A, 115 p.

Environmental Systems Research Institute, Inc., 2005, ArcGIS desktop help: accessed June, 2005, at URL: http://webhelp.esri.com/arcgisdesktop/9.1.

Haan, C.T., 1977, Statistical methods in hydrology: Ames, Iowa State University Press, 378 p.

Harenberg, W.A., 1980, Using channel geometry to estimate flood flows at ungaged sites in Idaho: U.S. Geological Survey Water-Resources Investigations 80-32, 39 p.

Hedman, E.R., and Osterkamp, W.R., 1982, Streamflow characteristics related to channel geometry of streams in western United States: U.S. Geological Survey Water-Supply Paper 2193, 17 p.

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: New York, Elsevier Science Publishing Company, Inc., 522 p.

Horn, D.R., 1988, Annual flow statistics for ungaged streams in Idaho: American Society of Civil Engineers, Journal of Irrigation and Drainage Engineering, v. 114, no. 3, p. 463-474.

Hortness, J.E., and Berenbrock, Charles, 2001, Estimating monthly and annual streamflow statistics at ungaged sites in Idaho: U.S. Geological Survey Water-Resources Investigations Report 0-4093, 36 p.

Hortness, J.E., and Berenbrock, Charles, 2003, Estimating the magnitude of bankfull flows for streams in Idaho: U.S. Geological Survey Water-Resources Investigations Report 03-4261, 36 p.

Hosmer, D.W., and Lemeshow, S., 2000, Applied logistic regression: New York, John Wiley & Sons, Inc., 373 p.

Kjelstrom, L.C., 1998, Methods for estimating selected flow-duration and flood-frequency characteristics at ungaged sites in central Idaho: U.S. Geological Survey Water-Resources Investigations Report 94-4120, 10 p.

Kjelstrom, L.C., and Moffatt, R.L., 1981, A method of estimating flood-frequency parameters for streams in Idaho: U.S. Geological Survey Open-File Report 81-909, 99 p.

Kjelstrom, L.C., Stone, M.A.J., and Harenberg, W.A., 1995, Statistical summaries of streamflow data for selected gaging stations in Idaho and western Wyoming through September 1990—Volume 2: Gaging stations with 5 to 9 years of record or that measure discharge from springs: U.S. Geological Survey Water-Resources Investigations Report 94-4070, 94 p.

Kjelstrom, L.C., Stone, M.A.J., and Harenberg, W.A., 1996, Statistical summaries of streamflow data for selected gaging stations in Idaho and adjacent States through September 1990—Volume 1. Gaging stations with 10 or more years of record: U.S. Geological Survey Water-Resources Investigations Report 94-4069, 533 p.

Koltun, G.F., and Schwartz, R.R., 1986, Multiple-regression equations for estimating low flows at ungaged stream sites in Ohio: U.S. Geological Survey Water-Resources Investigations Report 86-4354, 39 p., 6 pls.

Lipscomb, S.W., 1998, Hydrologic classification and estimation of basin and hydrologic characteristics of subbasins in central Idaho: U.S. Geological Survey Professional Paper 1604, 49 p.

Ludwig, A.H., and Tasker, G.D., 1993, Regionalization of low-flow characteristics of Arkansas streams: U.S. Geological Survey Water-Resources Investigations Report 93-4013, 19 p.

Molnau, M., 1995, Mean annual precipitation, 1961-1990, Idaho: Moscow, University of Idaho, Agricultural Engineering Department, State Climate Program, scale 1:1,000,000. Available at URL: http://snow.ag.uidaho.edu/Climate/reports.html.

National Oceanic and Atmospheric Administration, 1971, Climates of the states, climate of Idaho, in Climatography of the United States: Silver Spring, Md., no. 60-10, 18 p.

Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p.,1 pl.

Pope, B.F., Tasker, G.D., and Robbins, J.C., 2001, Estimating the magnitude and frequency of floods in rural basins of North Carolina—revised: U.S. Geological Survey Water-Resources Investigations Report 01-4207, 44 p.

Quillian, E.W., and Harenberg, W.A., 1982, An evaluation of Idaho stream-gaging networks: U.S. Geological Survey Open-File Report 82-865, 57 p.

Ries, K.G., and Friesz, P.J., 2000, Methods for estimating low-flow statistics for Massachusetts streams: U.S. Geological Survey Water-Resources Investigations Report 00-4135, 81 p.

Riggs, H.C., 1968, Some statistical tools in hydrology: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 4, Chap. A1, 39 p.

Riggs, H.C., 1972, Low-flow investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 4, Chap. B1, 18 p.

Ross, S.H., and Savage, C.N., 1967, Idaho earth science: Moscow, Idaho Bureau of Mines and Geology, 285 p.

Sando, S.K., 1998, Techniques for estimating peak-flow magnitude and frequency relations for South Dakota streams: U.S. Geological Survey Water-Resources Investigations Report 98-4055, 48 p.

Statit Software, 2005, Statit Custom QC: accessed January 2005, at URL: http://www.statit.com/statitcustomqc/customqc_default.htm.

Tasker, G.D., 1989, Regionalization of low flow characteristics using logistic and GLS regression, *in* Kavvas, M.L., ed., New directions for surface water modeling: IAHS Publication No. 181, p. 323-331.

Tasker, G.D., and Stedinger, J.R., 1989, An operational GLS model for hydrologic regression: Journal of Hydrology, v. 3, p. 361-375.

Thomas, C.A., Harenberg, W.A., and Anderson, J.M., 1973, Magnitude and frequency of floods in small drainage basins in Idaho: U.S. Geological Survey Water-Resources Investigations Report 7-73, 61 p.

Thomas, B.E., Hjalmarson, H.W., and Waltemeyer, S.D., 1994, Methods for estimating magnitude and frequency of floods in the Southwestern United States: U.S. Geological Survey Open-File Report 93–419, 211 p.

U.S. Geological Survey, 1995, Major lithology—Spokane, Washington: accessed July 2004, at URL: http://www.icbemp.gov/spatial/min.

U.S. Geological Survey, 1998, Water Resources Applications Software, GLSNET: accessed February 2005, at URL: http://water.usgs.gov/software/glsnet.html.

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 2004, at URL: http://edcwww.cr.usgs.gov/programs/lccp.

Table 6. Selected information for gaging stations used to estimate low-flow frequency statistics for unregulated streams in regions 1-8 in Idaho.

[Location of gaging stations and regions are shown in figure 1. Gaging station name: ID, Idaho; WA, Washington; MT, Montana; OR, Oregon; UT, Utah; NV, Nevada; WY, Wyoming. Water year: The 12-month period from October 1 through September 20, designated by the calendar year in which it ends]

Map No.	Gaging station No.	Gaging station name	Periods of record (water years)
		Region 1	
1	12305500	Boulder Creek near Leonia, ID	1928–71,1973–77
2	12311000	Deep Creek at Moravia, ID	1928–71
3	12316800	Mission Creek near Copeland, ID	1958–81
4	12320500	Long Canyon Creek near Porthill, ID	1931–59
5	12321000	Smith Creek near Porthill, ID	1928–60
6	12392155	Lightning Creek at Clark Fork, ID	1989–2003
7	12392300	Pack River near Colburn, ID	1958–82
8	12393500	Priest River at Outlet of Priest Lake near Coolin, ID	1912–48
9	12396000	Calispell Creek near Dalkena, WA	1950–73
10	12408500	Mill Creek near Colville, WA	1940–72,1977–86
11	12409000	Colville River at Kettle Falls, WA	1923–2003
12	12427000	Little Spokane River at Elk, WA	1948–71
13	12431000	Little Spokane River at Dartford, WA	1929–32,1947–2003
		Region 2	
14	12301300	Tobacco River near Eureka, MT	1959–2003
15	12301999	Wolf Creek near Libby, MT	1967–77
16	12302000	Fisher River near Jennings, MT	1951–69
17	12302055	Fisher River near Libby, MT	1968–2003
18	12302500	Granite Creek near Libby, MT	1933–34,1936–44,1960–69
19	12303100	Flower Creek near Libby, MT	1960–92
20	12303500	Lake Creek at Troy, MT	1945–57,1983–96
21	12340000	Blackfoot River near Bonner, MT	1898–1901,1903–06,1940–2003
22	12341000	Rattlesnake Creek at Missoula, MT	1899–1900,1958–67
23	12343400	East Fork Bitterroot River near Conner, MT	1956–72,2001–03
24	12344000	Bitterroot River near Darby, MT	1937–2003
25	12346500	Skalkaho Creek near Hamilton, MT	1949–53,1957–79,2001–03
26	12347500	Blodgett Creek near Corvallis, MT	1947–69
27	12350000	Bear Creek near Victor, MT	1938–55,1957–59
28	12350500	Kootenai Creek near Stevensville, MT	1949–53,1957–63
29	12351000	Burnt Fork Bitterroot River near Stevensville, MT	1920–24,1938–62
30	12352000	Lolo Creek above Sleeman Creek near Lolo, MT	1951–60
31	12353280	Ninemile Creek near Huson, MT	1973–83
32	12354000	St. Regis River near St. Regis, MT	1910–17,1958–75,2002–03
33	12375900	South Crow Creek near Ronan, MT	1982–2003
34	12377150	Mission Creek above Res near St. Ignatius, MT	1982–2003
35	12389500	Thompson River near Thompson Falls, MT	1911,1956–2003
36	12390700	Prospect Creek at Thompson Falls, MT	1956–2003
37	12411000	North Fork Coeur d'Alene River above Shoshone Creek near Prichard, ID	1951–2003
38	12413000	North Fork Coeur d'Alene River at Enaville, ID	1911–13,1939–2003
39	12413140	Placer Creek at Wallace, ID	1967–97,1999–2000
40	12413150	South Fork Coeur d'Alene River at Silverton, ID	1968–88,1999–2000
41	12413210	South Fork Coeur d'Alene at Elizabeth Park near Kellogg, ID	1987–2003
42	12413470	South Fork Coeur d'Alene River near Pinehurst, ID	1987–2003
43	12413500	Coeur d'Alene River at Cataldo, ID	1911–12,1920–72,1987–2003
44	12414500	St. Joe River at Calder, ID	1911–12,1920–2003
45	12414900	St. Maries River near Santa, ID	1966–2003
46	12415000	St. Maries River at Lotus, ID	1912–13,1920–66
47	12416000	Hayden Creek below North Fork near Hayden Lake, ID	1948–54,1959,1966–97
48	13336500	Selway River near Lowell, ID	1911,1930–2003

Table 6. Selected information for gaging stations used to estimate low-flow frequency statistics for unregulated streams in regions 1-8 in Idaho.—Continued

[Location of gaging stations and regions are shown in figure 1. Gaging station name: ID, Idaho; WA, Washington; MT, Montana; OR, Oregon; UT, Utah; NV, Nevada; WY, Wyoming. Water year: The 12-month period from October 1 through September 20, designated by the calendar year in which it ends]

Map No.	Gaging station No.	Gaging station name	Periods of record (water years)
		Region 2 (Continued)	
49	13336900	Fish Creek near Lowell, ID	1958–67
50	13337000	Lochsa River near Lowell, ID	1911–12,1930–2003
51	13340500	North Fork Clearwater River at Bungalow Ranger Station, ID	1945–69
52	13340600	North Fork Clearwater River near Canyon Ranger Station, ID	1967–2003
53	13341000	North Fork Clearwater River at Ahsahka, ID	1926–68
54	13341300	Bloom Creek near Bovill, ID	1959–72
55	13341400	East Fork Potlatch River near Bovill, ID	1959–72
		Region 3	
56	12424000	Hangman Creek at Spokane, WA	1948–2003
57	13334700	Asotin Creek below Kearney Gulch near Asotin, WA	1960–82,1992
58	13341500	Potlatch River at Kendrick, ID	1946–60
59	13342450	Lapwai Creek near Lapwai, ID	1975–2003
60	13345000	Palouse River near Potlatch, ID	1915–19,1967–2003
61	13346100	Palouse River at Colfax, WA	1964–73,1976–79
62	13346800	Paradise Creek at University of Idaho at Moscow, ID	1979–2003
63	13348000	South Fork Palouse River at Pullman, WA	1934–42,1960–81,2001–2003
64	13348500	Missouri Flat Creek at Pullman, WA	1934–40,1960–79
		Region 4	
65	13196500	Bannock Creek near Idaho City, ID	1939–42,1951–72
66	13200000	Mores Creek above Robie Creek near Arrowrock Dam, ID	1951–2003
67	13200500	Robie Creek near Arrowrock Dam, ID	1951–72
68	13201000	Mores Creek near Arrowrock, ID	1916–54
69	13207000	Spring Valley Creek near Eagle, ID	1955–59,1961–72
70	13207500	Dry Creek near Eagle, ID	1954–68
71	13250600	Big Willow Creek near Emmett, ID	1962–82
72	13251300	West Branch Weiser River near Tamarack, ID	1959–77
73	13251500	Weiser River at Tamarack, ID	1937–72,1974–76
74	13253500	Weiser River at Starkey, ID	1939–49
75	13256000	Weiser River near Council, ID	1937–53
76	13257000	Middle Fork Weiser River near Mesa, ID	1911–13,1919–22,1937–49,1981–83, 1985–88
77	13258500	Weiser River near Cambridge, ID	1939–2003
78	13260000	Pine Creek near Cambridge, ID	1938–62
79	13261000	Little Weiser River near Indian Valley, ID	1920–21,1923–27,1938–71
80	13267000	Mann Creek near Weiser, ID	1911–13,1920–21,1937–62
81	13269300	North Fork Burnt River near Whitney, OR	1964–80
82	13270800	South Fork Burnt River above Barney Creek near Unity, OR	1963–81
83	13275500	Powder River near Baker, OR	1904–14,1929–68
84	13288200	Eagle Creek above Skull Creek near New Bridge, OR	1958–98
85	13289960	Wildhorse River at Brownlee Dam, ID	1979–96
86	13290190	Pine Creek near Pine, OR	1967–96
87	13291000	Imnaha River above Gunboot Creek, OR	1945–53
88	13315500	Mud Creek near Tamarack, ID	1937–38,1946–59
89	13316500	Little Salmon River at Riggins, ID	1951–55,1957–2003
90	13316800	North Fork Skookumchuck Creek near White Bird, ID	1959–71
91	13319000	Grande Ronde River at La Grande, OR	1904–15,1918–23,1926–89
92	13320000	Catherine Creek near Union, OR	1932–96

Table 6. Selected information for gaging stations used to estimate low-flow frequency statistics for unregulated streams in regions 1-8 in Idaho.—Continued

[Location of gaging stations and regions are shown in figure 1. Gaging station name: ID, Idaho; WA, Washington; MT, Montana; OR, Oregon; UT, Utah; NV, Nevada; WY, Wyoming. Water year: The 12-month period from October 1 through September 20, designated by the calendar year in which it ends]

Map No.	Gaging station No.	Gaging station name	Periods of record (water years)
		Region 4 (Continued)	
93	13323600	Indian Creek near Imbler, OR	1938–50
94	13325500	Wallowa River above Wallowa Lake near Joseph, OR	1924–33
95	13329500	Hurricane Creek near Joseph, OR	1915,1924–78
96	13330000	Lostine River near Lostine, OR	1912–15,1925–91,1995–2003
97	13330500	Bear Creek near Wallowa, OR	1915,1924–85,1995–2003
98	13331500	Minam River at Minam, OR	1912–14,1965–2003
99	13337500	South Fork Clearwater River near Elk City, ID	1945–74,2002–03
100	13338000	South Fork Clearwater River near Grangeville, ID	1911–16,1923–63
101	13338500	South Fork Clearwater River at Stites, ID	1912,1965–2003
102	13339000	Clearwater River at Kamiah, ID	1910–66
103	13339500	Lolo Creek near Greer, ID	1980–2003
104	13340000	Clearwater River at Orofino, ID	1931–38,1965–2003
105	14010000	South Fork Walla Walla River near Milton, OR	1903,1907–17,1931–91,2001
106	14011000	North Fork Walla Walla River near Milton, OR	1930–69
		Region 5	
107	13135500	Big Wood River near Ketchum, ID	1948–72
108	13136500	Warm Springs Creek at Guyer Hot Springs near Ketchum, ID	1941–58
109	13139500	Big Wood River at Hailey, ID	1889–90,1915–2003
110	13141000	Big Wood River near Bellevue, ID	1911–96
111	13185000	Boise River near Twin Springs, ID	1911–2003
112	13186000	South Fork Boise River near Featherville, ID	1945–2003
113	13186500	Lime Creek near Bennett, ID	1945–56
114	13187000	Fall Creek near Anderson Ranch Dam, ID	1945–56
115	13235000	South Fork Payette River at Lowman, ID	1941–2003
116	13240000	Lake Fork Payette River above Jumbo Creek near McCall, ID	1946–2003
117	13292500	Salmon River near Obsidian, ID	1941–53
118	13293000	Alturas Lake Creek near Obsidian, ID	1941–52
119	13295000	Valley Creek at Stanley, ID	1911–14,1921–72,1993–2003
120	13295500	Salmon River below Valley Creek at Stanley, ID	1925–61
121	13296000	Yankee Fork Salmon River near Clayton, ID	1921–49
122	13296500	Salmon River below Yankee Fork near Clayton, ID	1922–92,2000–03
123	13308500	Middle Fork Salmon River near Capehorn, ID	1929–72
124	13309000	Bear Valley Creek near Capehorn, ID	1922–60
125	13309220	Middle Fork Salmon R at Middle Fork Lodge nr Yellow Pine, ID	1973–81,1999–2003
126	13310000	Big Creek near Big Creek, ID	1945–59
127	13310199	Middle Fork Salmon R at mouth near Shoup, ID	1994–2003
128	13310500	South Fork Salmon River near Knox, ID	1929–61
129	13310700	South Fork Salmon River near Krassel Ranger Station, ID	1967–82,1985–86,1989–2003
130	13311000	East Fork South Fork Salmon River at Stibnite, ID	1928–43,1983–97
131	13311500	East Fork South Fork Salmon River near Stibnite, ID	1928–41
132	13312000	East Fork South Fork Salmon River near Yellow Pine, ID	1928–43
133	13313000	Johnson Creek at Yellow Pine, ID	1928–2003
134	13313500	Secesh River near Burgdorf, ID	1943–52
135	13314000	South Fork Salmon River near Warren, ID	1931–43
136	13314300	South Fork Salmon River at mouth nr Mackay Bar, ID	1994–2003
137	13315000	Salmon River near French Creek, ID	1945–56

Table 6. Selected information for gaging stations used to estimate low-flow frequency statistics for unregulated streams in regions 1-8 in Idaho.—Continued

[Location of gaging stations and regions are shown in figure 1. Gaging station name: ID, Idaho; WA, Washington; MT, Montana; OR, Oregon; UT, Utah; NV, Nevada; WY, Wyoming. Water year: The 12-month period from October 1 through September 20, designated by the calendar year in which it ends]

Map No.	Gaging station No.	Gaging station name	Periods of record (water years)
		Region 6	
138	06013500	Big Sheep Creek below Muddy Creek near Dell, MT	1936,1946–53,1961–79
139	06015500	Grasshopper Creek near Dillon, MT	1921–33,1946–54,1955–58,1960–61
140	06019500	Ruby River above Reservoir near Alder, MT	1938–2003
141	06037500	Madison River near West Yellowstone, MT	1913–73,1983–86,1989–2001
142	13108500	Camas Creek at 18–mile Shearing Corral near Kilgore, ID	1937–54,1969–73
143	13112000	Camas Creek at Camas, ID	1925–2003
144	13113000	Beaver Creek at Spencer, ID	1941–54,1969–82,1985–93
145	13113500	Beaver Creek at Dubois, ID	1921–73,1983,1985–87
146	13117300	Sawmill Creek near Goldburg, ID	1960–73
147	13120000	North Fork Big Lost River at Wild Horse near Chilly, ID	1944–2003
148	13120500	Big Lost River at Howell Ranch near Chilly, ID	1904–14,1920–2003
149	13128900	Lower Cedar Creek above Diversions near Mackay, ID	1966–73,1980–84
150	13297330	Thompson Creek near Clayton, ID	1973–2003
151	13297350	Bruno Creek near Clayton, ID	1971–2003
152	13297355	Squaw Creek below Bruno Creek near Clayton, ID	1973–2003
153	13297450	Little Boulder Creek near Clayton, ID	1970–86
154	13298000	East Fork Salmon River near Clayton, ID	1929–39,1973–82
155	13299000	Challis Creek near Challis, ID	1944–63
156	13302500	Salmon River at Salmon, ID	1913–16,1919–2003
157	13305000	Lemhi River near Lemhi, ID	1939,1955–63,1967–2003
158	13305500	Lemhi River at Salmon, ID	1928–43
159	13306000	North Fork Salmon River at North Fork, ID	1930–40
160	13306385	Napias Creek blw Arnett Creek nr Salmon, ID	1991–2003
161	13306500	Panther Creek near Shoup, ID	1945–78
162	13307000	Salmon River near Shoup, ID	1945–81,2003
		Region 7	
163	10119000	Little Malad River above Elkhorn Reservoir near Malad City, ID	1911–13,1932,1941–69
164	10172940	Dove Creek near Park Valley, UT	1959–68,1971–73
165	10315500	Marys River above Hot Springs Creek near Deeth, NV	1944–80,1982–2003
166	10329500	Martin Creek near Paradise Valley, NV	1922–2003
167	10352500	McDermitt Creek near McDermitt, NV	1949–84,1985–2003
168	10353000	East Fork Quinn River near McDermitt, NV	1949–82
169	10396000	Donner Und Blitzen River near Frenchglen, OR	1911–21,1938–2003
170	10406500	Trout Creek near Denio, NV	1933–91
171	13057940	Willow Creek below Tex Creek near Ririe, ID	1977–79,1986–2003
172	13075000	Marsh Creek near McCammon, ID	1954–2003
173	13077700	George Creek near Yost, UT	1959–89
174	13079100	Cassia Creek abv Stinson Creek nr Elba, ID	1965–75
175	13092000	Rock Creek near Rock Creek, ID	1910–13,1939,1944–74
176	13154000	Clover Creek below Calf Creek near Bliss, ID	1938–43,1957–62
177	13155300	Little Canyon Creek at Stout Crossing near Glenns Ferry, ID	1966–71
178	13161500	Bruneau River at Rowland, NV	1913–18,1967–2003
179	13162500	East Fork Jarbidge River near Three Creek, ID	1929–33,1954–71
180	13169500	Big Jacks Creek near Bruneau, ID	1939–50,1965–2003
181	13170000	Little Jacks Creek near Bruneau, ID	1939–50
182	13172680	Reynolds Creek at Tollgate near Reynolds, ID	1966–93
183	13172720	Macks Creek near Reynolds, ID	1964–91
184	13172735	Salmon Creek near Reynolds, ID	1964–99
185	13172740	Reynolds Creek at Outlet near Reynolds, ID	1963–93
186	13176000	Owyhee River above China Diversion Dam near Owyhee, NV	1939–84

Table 6. Selected information for gaging stations used to estimate low-flow frequency statistics for unregulated streams in regions 1-8 in Idaho.—Continued

[Location of gaging stations and regions are shown in figure 1. Gaging station name: ID, Idaho; WA, Washington; MT, Montana; OR, Oregon; UT, Utah; NV, Nevada; WY, Wyoming. Water year: The 12-month period from October 1 through September 20, designated by the calendar year in which it ends]

Map No.	Gaging station No.	Gaging station name	Periods of record (water years)
		Region 7 (Continued)	
187	13177000	Jack Creek near Tuscarora, NV	1913–25
188	13178000	Jordon Creek above Lone Tree Creek near Jordan Valley, OR	1946–53,1955–72,2003
189	13226500	Bully Creek at Warmsprings near Vale, OR	1965–85
		Region 8	
190	09208000	LaBarge Creek near LaBarge Meadows Ranger Station, WY	1951–82
191	09224000	Hams Fork at Diamondville, WY	1918–33,1945–49
192	10010400	East Fork Bear River near Evanston, WY	1974–86
193	10015700	Sulphur Creek below La Chapelle Creek near Evanston, WY (above Res)	1958–97
194	10032000	Smiths Fork near Border, WY	1942–2003
195	10040000	Thomas Fork near Geneva, ID	1940–51
196	10040500	Salt River near Geneva, ID	1940–51
197	10041000	Thomas Fork near Wyoming–Idaho State Line	1950–92
198	10047500	Montpelier Creek at weir near Montpelier, ID	1943–79
199	10058600	Bloomington Creek at Bloomington, ID	1961–86
200	10069000	Georgetown Creek near Georgetown, ID	1940–56
201	10077000	Soda Creek near Soda Springs, ID	1913–29
202	10093000	Cub River near Preston, ID	1940–52,1956–86
203	10096000	Cub River above Maple Creek near Franklin, ID	1940–52
204	10099000	High Creek near Richmond, UT	1944–52,1971–72,1979–89
205	10102300	Summit Creek above diversions near Smithfield, UT	1962–79
206	10104700	Little Bear River below Davenport Creek near Avon, UT	1961–92
207	10104900	East Fork Little Bear River above reservoir near Avon, UT	1964–86
208	10105000	East Fork Little Bear River near Avon, UT	1938–51
209	10109000	Logan River above State Dam near Logan, UT	1954–2003
210	10113500	Blacksmith Fork above UP&L Co Dam near Hyrum, UT	1914–96,2000–03
211	13010065	Snake River above Jackson Lake at Flagg Ranch, WY	1984–2003
212	13011500	Pacific Creek at Moran, WY	1917–18,1944–75,1978–2003
213	13011900	Buffalo Fork above Lava Creek near Moran, WY	1965–2003
214	13012000	Buffalo Fork near Moran, WY	1917–18,1945–60
215	13014500	Gros Ventre River at Kelly, WY	1918,1945–58
216	13018300	Cache Creek near Jackson, WY	1962–2003
217	13019438	Little Granite Creek at mouth near Bondurant, WY	1982–93
218	13019500	Hoback River near Jackson, WY	1917–18,1945–58
219	13023000	Greys River above Reservoir near Alpine, WY	1917–18,1937–39,1954–2003
220	13024500	Cottonwood Creek near Smoot, WY	1933–57
221	13025000	Swift Creek near Afton, WY	1943–80
222	13025500	Crow Creek near Fairview, WY	1946–50,1962–67
223	13027000	Strawberry Creek near Bedford, WY	1932–43
224	13032000	Bear Creek above Reservoir near Irwin, ID	1917–18,1934–37,1953–71
225	13044500	Warm River at Warm River, ID	1912–15,1918–32
226	13045500	Robinson Creek at Warm River, ID	1912–15,1918–32
227	13046680	Boundary Creek near Bechler Ranger Station Y.N.P., WY	1984–2003
228	13046995	Falls River above Yellowstone Canal near Squirrel, ID	1994–2003
229	13047500	Falls River near Squirrel, ID	1905–09,1918–2003
230	13047600	Falls River near Ashton, ID	1994–2003
231	13049500	Falls River near Chester, ID	1962–2003
232	13052200	Teton River above South Leigh Creek near Driggs, ID	1962–2003
233	13054000	Teton River near Tetonia, ID	1930–33,1934–37,1940–57
234	13055000	Teton River near St Anthony, ID	1890–93,1903–09,1920–76,1978–2003

Table 7. Low-flow frequency statistics for streamflow-gaging stations used in low-flow regression analyses for unregulated streams in regions 1-8 in Idaho.

[$1Q_{10}$, 1-day, 10-year low flow; $7Q_{10}$, 7-day, 10-year flow; $7Q_2$, 7-day, 2-year low flow; $30Q_5$, 30-day, 5-year low flow]

Gaging station No.	$1Q_{10}$	$7Q_{10}$	$7Q_2$	$30Q_5$
Region 1				
12305500	4.42	5.07	9.18	7.56
12311000	7.83	8.65	13.0	11.44
12316800	1.81	1.94	3.54	3.13
12320500	2.82	3.40	6.25	4.92
12321000	5.15	5.65	11.0	9.46
12392155	2.20	2.50	11.4	2.47
12392300	18.6	19.5	28.3	26.3
12393500	142	145	215	176
12396000	3.86	6.10	9.28	9.68
12408500	4.96	5.54	8.47	7.64
12409000	15.5	21.1	61.9	39.6
12427000	31.0	34.8	40.3	38.6
12431000	84.0	87.2	123	104
Region 2				
12301300	30.5	37.7	61.8	57.3
12301999	3.22	3.80	6.81	5.70
12302000	63.4	75.1	95.9	91.5
12302055	48.5	59.8	85.4	79.5
12302500	4.60	5.06	7.59	7.55
12303100	3.55	3.84	4.90	4.63
12303500	61.2	76.2	108	94.5
12340000	230	284	390	402
12341000	.596	.859	4.65	2.84
12343400	29.2	41.0	60.8	64.2
12344000	97.9	122	173	167
12346500	14.0	16.5	19.3	20.6
12347500	2.08	2.34	5.15	4.25
12350000	1.08	1.43	3.06	2.76
12350500	3.06	3.75	7.95	6.72
12351000	4.92	7.17	11.1	11.9
12352000	8.53	9.77	20.5	15.5
12353280	12.4	14.1	19.9	18.5
12354000	50.5	65.2	86.2	83.9
12375900	3.92	4.56	5.53	5.35
12377150	5.94	6.69	7.78	7.65
12389500	73.5	93.4	128	123
12390700	29.5	30.8	42.7	36.4
12411000	52.8	58.6	79.6	75.5
12413000	144	164	220	207
12413140	.901	1.07	3.17	2.33
12413150	26.6	31.6	42.2	41.8
12413210	40.3	48.6	60.3	56.3
12413470	61.6	70.4	90.3	82.7
12413500	215	238	317	292
12414500	185	233	333	313
12414900	28.3	32.9	45.3	42.4
12415000	24.1	28.7	45.1	39.1
12416000	2.39	2.56	3.59	3.39
13336500	255	333	496	463
13336900	22.9	23.3	29.8	28.0
13337000	199	243	358	335
13340500	328	405	587	541
13340600	330	477	629	641
13341000	525	645	1000	935
13341300	.496	.546	.729	.677
13341400	4.08	4.36	6.01	5.51
Region 3				
12424000	2.69	2.95	9.15	5.18
13334700	23.3	26.6	32.7	32.4
13341500	5.00	5.49	7.81	7.20
13342450	1.43	1.61	3.93	2.86
13345000	.956	1.81	6.20	4.26
13346100	.200	.287	3.20	1.63
13346800	.075	.116	.186	.244
13348000	.494	.627	1.77	1.06
13348500	.000	.000	.105	.012
Region 4				
13196500	0.155	0.168	0.313	0.240
13200000	9.67	10.4	25.6	17.4
13200500	.000	.045	.312	.156
13201000	12.1	12.7	26.6	19.0
13207000	.000	.000	.000	.000
13207500	.000	.000	.099	.045
13250600	1.76	2.16	2.87	2.82
13251300	.475	.572	.800	.753
13251500	1.48	3.12	4.73	4.54
13253500	10.2	10.4	14.6	12.8
13256000	28.4	33.4	44.7	47.5
13257000	.000	.000	1.054	.396
13258500	25.7	29.6	61.8	47.9
13260000	0.991	1.29	2.41	2.15
13261000	4.94	5.60	8.50	7.78
13267000	.185	.258	1.24	.874
13269300	.210	.246	.646	.494
13270800	13.0	14.6	17.6	17.6
13275500	.40	.70	4.86	2.25
13288200	44.2	53.1	69.6	67.5
13289960	9.11	9.61	18.8	13.3
13290190	18.0	18.9	33.1	25.2
13291000	21.3	31.3	48.4	47.1
13315500	1.01	1.05	1.31	1.31
13316500	97.5	111	153	135
13316800	.183	.211	.768	.547
13319000	7.58	8.95	18.2	14.6
13320000	12.6	15.9	21.4	20.7
13323600	1.50	1.58	3.06	2.37
13325500	15.3	15.6	22.6	19.7
13329500	8.37	9.34	14.4	12.5
13330000	15.1	17.5	25.9	23.2
13330500	6.03	6.54	9.83	8.54
13331500	24.9	36.8	62.7	57.0
13337500	19.3	21.9	31.7	29.9
13338000	48.6	74.8	118	112
13338500	80.3	111	152	145
13339000	481	672	1,090	992
13339500	18.9	21.1	31.8	29.0
13340000	584	768	1,120	1,040
14010000	82.2	83.5	98.7	91.1
14011000	1.18	1.47	2.45	2.16

Table 7. Low-flow frequency statistics for streamflow-gaging stations used in low-flow regression analyses for unregulated streams in regions 1-8 in Idaho.—Continued

[$1Q_{10}$, 1-day, 10-year low flow; $7Q_{10}$, 7-day, 10-year flow; $7Q_2$, 7-day, 2-year low flow; $30Q_5$, 30-day, 5-year low flow]

Gaging station No.	$1Q_{10}$	$7Q_{10}$	$7Q_2$	$30Q_5$
Region 5				
13135500	22.5	34.0	39.1	40.5
13136500	19.0	24.3	27.4	27.7
13139500	.412	.752	47.3	6.89
13141000	22.2	23.4	44.6	32.4
13185000	163	214	279	268
13186000	101	126	171	159
13186500	6.38	10.2	16.5	14.5
13187000	10.1	11.1	13.3	12.5
13235000	158	198	251	244
13240000	1.89	6.70	12.1	11.0
13292500	2.94	3.05	7.04	4.75
13293000	11.3	11.5	14.8	13.5
13295000	44.5	46.4	64.1	57.4
13295500	165	179	272	229
13296000	19.8	29.2	37.9	34.9
13296500	239	262	351	318
13308500	46.3	49.5	61.5	57.1
13309000	59.4	64.3	81.9	72.8
13309220	202	268	358	364
13310000	70.8	94.3	108	109
13310199	382	561	714	698
13310500	21.1	23.0	32.5	28.2
13310700	66.5	80.8	107	97.9
13311000	4.41	4.77	6.17	5.48
13311500	10.2	11.2	12.3	12.0
13312000	27.7	27.9	35.1	31.5
13313000	35.3	44.1	59.7	54.1
13313500	29.8	31.2	39.1	34.9
13314000	191	230	338	317
13314300	177	289	397	368
13315000	2,040	2,480	2,890	3,120
Region 6				
6013500	28.8	30.7	37.6	34.4
6015500	.000	.520	8.25	5.57
6019500	54.9	60.4	84.9	78.9
6037500	283	301	361	335
13108500	4.46	4.46	14.43	7.94
13112000	.000	.000	.000	.000
13113000	.000	.000	7.72	1.87
13113500	.000	.000	.000	.000
13117300	9.14	9.94	13.7	12.5
13120000	12.3	13.7	17.4	16.3
13120500	38.8	44.0	60.7	53.9
13128900	1.63	1.72	2.83	2.96
13297330	1.66	2.04	2.94	2.61
13297350	.000	.000	.137	.093
13297355	4.14	4.72	6.88	6.14
13297450	2.79	3.37	4.39	4.04
13298000	32.1	44.0	60.8	57.0
13299000	6.60	7.09	10.4	8.82
13302500	483	553	808	711
13305000	50.0	55.4	98.3	86.0
13305500	15.0	16.4	32.6	27.3
13306000	14.4	18.3	24.8	23.7
13306385	4.74	5.41	6.74	6.52
13306500	34.5	46.9	65.3	63.7
13307000	854	938	1,250	1,180
Region 7				
10119000	6.13	6.42	13.44	9.81
10172940	.083	.083	.140	.104
10315500	.365	.402	1.06	.701
10329500	3.64	3.80	5.23	4.64
10352500	.000	.000	1.09	.239
10353000	.484	.581	1.30	.936
10396000	14.9	20.7	30.6	28.7
10406500	.605	.695	2.44	1.49
13057940	4.86	5.30	18.1	9.57
13075000	20.3	23.9	38.3	33.1
13077700	1.17	1.27	1.65	1.54
13079100	0.251	.280	.670	.458
13092000	4.23	4.50	6.81	5.92
13154000	.000	.000	.145	.072
13155300	.016	.092	.299	.228
13161500	3.47	3.72	8.57	5.85
13162500	3.68	5.00	7.45	6.52
13169500	.000	.000	.000	.000
13170000	.000	.000	.000	.000
13172680	.000	.000	.202	.025
13172720	.000	.000	.016	.006
13172735	.000	.000	.016	.000
13172740	.079	.195	.848	.490
13176000	5.98	6.97	16.5	12.0
13177000	.958	.955	1.60	1.42
13178000	.475	.940	1.96	1.50
13226500	.145	.187	.708	.500
Region 8				
9208000	2.10	2.23	3.05	2.75
9224000	.000	1.71	13.55	8.92
10010400	5.39	5.98	7.86	6.89
10015700	.000	.000	.123	.008
10032000	39.8	42.8	55.0	50.7
10040000	1.36	1.67	2.55	2.07
10040500	1.40	1.47	3.21	2.34
10041000	6.96	7.73	11.9	9.96
10047500	3.03	4.61	6.43	5.63
10058600	12.5	12.7	14.8	13.7
10069000	18.8	18.9	22.8	20.7
10077000	39.0	39.7	46.1	43.4
10093000	14.7	15.0	18.2	16.8
10096000	0.879	1.10	2.15	1.60
10099000	4.42	4.71	6.82	5.82
10102300	2.84	3.30	4.40	3.84
10104700	10.9	14.0	20.9	17.1
10104900	4.67	5.22	6.79	6.01
10105000	6.35	6.77	9.95	8.28
10109000	14.1	15.0	56.1	26.6
10113500	39.7	46.4	66.3	55.8
13010065	176	182	265	221
13011500	22.6	25.9	35.6	32.3
13011900	74.9	86.2	100.9	98.8
13012000	91.6	103	123	115
13014500	106	118	132	133
13018300	1.79	2.11	3.30	2.82
13019438	2.86	3.23	4.60	3.94
13019500	116	149	164	167

Table 7. Low-flow frequency statistics for streamflow-gaging stations used in low-flow regression analyses for unregulated streams in regions 1-8 in Idaho.—Continued

[$1Q_{10}$, 1-day, 10-year low flow; $7Q_{10}$, 7-day, 10-year flow; $7Q_2$, 7-day, 2-year low flow; $30Q_5$, 30-day, 5-year low flow]

Gaging station No.	$1Q_{10}$	$7Q_{10}$	$7Q_2$	$30Q_5$
Region 8 (Continued)				
13023000	117	136	169	160
13024500	8.70	8.98	11.5	10.8
13025000	25.0	27.3	31.0	30.5
13025500	21.5	24.2	31.7	29.6
13027000	24.4	24.8	27.7	27.4
13032000	12.3	13.9	17.8	16.5
13044500	145	164	183	175
13045500	30.4	36.6	54.7	47.6
13046680	51.3	53.4	63.0	58.5
13046995	278	303	381	352
13047500	192	233	335	295
13047600	233	256	400	336
13049500	25.8	38.6	139	92.8
13052200	94.2	112	165	144
13054000	97.9	128	172	168
13055000	246	278	335	318

Table 8. Basin characteristics considered during the low-flow regressin analyses for unregulated streams in Idaho.

[Equation variables are shown in **bold**]

Basin characteristic	Explanation
AG	**Pasture and hay; row crops; small grains; fallow; urban or recreational grasses**
A	**Area of drainage basin**
Aluv	alluvial deposits
Barren	Bare rock, sand, or clay; quarries, mines, or pits; transitional
BS	**Average slope of drainage basin**
DV	**Residential, commercial, industrial, or transportation lands**
E	Mean drainage basin elevation
F	Deciduous, evergreen, or mixed forest land
Glacial	Glacial drift and ice
Granite	Granitic rocks
GT6000	Percentage of drainage basin area above 6,000 ft
HS Dec	Median Dec 21 hillshading
HS June	Median June 21 hillshading
Loess	Loess
Met/Sed	Metamorphic or sedimentary rocks
NF30	Percentage of drainage basin area with north-facing slopes greater than 30 percent
NF50	Percentage of drainage basin area with north-facing slopes greater than 50 percent
P	**Combination precipitation based on Molnau (1995) and PRISM (Daly and Taylor, 1998)**
P2	PRISM (Daly and Taylor, 1998) precipitation
Perim	Perimeter drainage basin, in miles
R	**Relief of drainage basin**
S30	Percentage of drainage basin area with slopes greater than 30 percent
***S*50**	**Percentage of drainage basin area with slopes greater than 50 percent**
Sand	Dune sand
Shdw Dec	Percentage of drainage basin area in shadow on Dec 21
Shdw June	Percentage of drainage basin area in shadow on June 21
Shrub	Shrubland
Slope	Average slope of drainage basin, in percent
Undefined	Unclassified lithology units
Upland	Grasslands or herbaceous lands
V	**Volcanic rocks**
W	**Open water or perennial ice and snow**
W(2)	Open water
Wetland	Woody wetlands; emergent, herbaceous wetlands
Woody	Orchards or vineyards

Table 9. Basin characteristic values used to develop the final probability and estimating equations for low-flow frequency statistics for unregulated streams in regions 1-8 in Idaho.

[Locations of regions are shown in figure 1. **Equation variables**: ***A***, drainage area, in square miles; ***P***, mean annual precipitation, in inches; ***DV***, developed land, in percentage of drainage area; ***AG***, agricultural land, in percentage of drainage area; ***BS***, basin slope, in percent; ***W***, water, in percentage of drainage area; ***R***, basin relief, in feet; ***V***, surficial volcanic rocks, in percentage of drainage area; ***S*50**, slopes greater than 50 percent, in percentage of drainage area]

Gaging station No.	Equation variables								
	A	***P***	***DV***	***AG***	***BS***	***W***	***R***	***V***	***S*50**
Region 1									
12305500	55.3	48.3	0.001	0.005	37.1	0.018	4,134.8	14.1	18.0
12311000	133.1	30.4	1.13	6.47	21.2	.721	5,376.7	12.3	4.09
12316800	12.5	29.1	.088	.042	25.4	.004	3,178.5	4.65	1.89
12320500	29.9	41.3	.000	.009	46.4	.009	5,803.1	.000	41.4
12321000	71.1	46.1	.368	.269	37.0	.343	5,866.9	.000	22.9
12392155	115.1	54.3	.081	.347	43.2	.168	4,844.3	3.78	37.7
12392300	121.4	38.1	.463	.519	32.2	.366	5,441.4	.000	12.7
12393500	596.6	38.8	.328	.141	28.9	6.69	5,124.1	21.1	14.1
12396000	68.2	36.7	.017	.972	30.1	.347	3,731.6	17.6	8.12
12408500	82.5	37.7	.119	1.30	29.6	.016	3,832.5	4.45	11.1
12409000	1,011.0	27.6	.983	9.74	22.3	.777	5,308.7	15.3	6.39
12427000	84.4	28.2	2.04	6.30	13.2	.618	2,230.6	9.75	1.80
12431000	634.9	25.1	3.59	23.2	12.2	.895	4,281.5	27.9	1.04
Region 2									
12301300	460.2	32.7	0.463	1.86	24.5	0.830	4,956.2	0.000	13.7
12301999	216.0	24.8	.205	.214	24.3	.041	3,996.5	.000	5.19
12302000	785.3	28.1	.122	1.15	26.7	.265	5,103.5	.000	10.0
12302055	843.7	28.0	.175	1.07	27.2	.249	5,413.7	.000	10.5
12302500	23.7	53.0	.033	.000	54.1	.847	5,917.3	24.5	56.1
12303100	11.3	52.6	.009	.000	48.3	1.60	4,788.9	4.35	43.6
12303500	125.0	43.9	.735	.426	38.5	.300	5,752.5	9.89	33.8
12340000	2,283.6	29.4	.006	4.43	25.7	.858	6,056.4	9.00	11.6
12341000	80.7	37.1	.935	.087	36.7	.623	5,406.1	.600	26.0
12343400	379.3	28.4	.079	.569	33.2	.164	5,278.4	82.2	16.2
12344000	1,049.7	31.9	.044	.553	37.7	.185	6,187.1	65.1	24.0
12346500	88.1	29.6	.037	.000	38.8	.071	4,576.0	15.5	26.0
12347500	26.1	60.9	.000	.000	57.0	.397	4,871.1	80.4	59.4
12350000	27.8	55.0	.000	.000	52.1	.269	4,957.9	83.6	53.0
12350500	29.0	55.6	.000	.000	58.8	.368	5,711.5	88.4	66.4
12351000	73.0	30.6	.102	.589	36.5	.123	4,390.9	2.39	20.3
12352000	250.3	46.7	.180	.669	35.4	.029	5,865.4	37.3	20.1
12353280	169.7	28.7	.046	2.31	31.2	.019	4,956.2	.000	14.1
12354000	43.6	44.5	.007	.000	47.2	.066	4,434.8	.000	44.8
12375900	7.6	55.1	.000	.000	59.7	3.98	5,273.5	.000	59.7
12377150	12.4	69.4	.000	.000	66.8	1.21	5,901.2	.000	67.4
12389500	641.5	29.6	.063	.362	30.0	.797	4,998.9	.000	14.5
12390700	181.5	43.7	.038	.036	43.5	.039	4,349.7	.000	37.9
12411000	334.0	48.2	.021	.006	40.8	.170	3,722.1	.000	30.7
12413000	893.7	45.4	.076	.177	41.9	.223	4,637.1	.151	32.7
12413140	15.0	41.5	.042	.000	49.6	.000	3,461.3	1.94	52.9
12413150	105.6	42.5	.779	.338	45.8	.130	4,133.8	2.83	43.8
12413210	181.8	43.3	1.22	.224	45.8	.127	4,438.3	1.64	43.9
12413470	287.1	45.1	1.83	.200	44.6	.220	4,605.6	1.04	41.2
12413500	1,207.4	45.0	.552	.199	42.3	.239	4,673.2	0.360	34.3
12414500	1,024.5	47.0	.036	.014	41.3	.057	5,487.6	2.96	30.2
12414900	272.6	37.7	.470	2.44	25.1	.140	3,792.4	8.60	3.45
12415000	434.5	35.6	.422	1.54	23.8	.154	4,214.6	13.9	3.13
12416000	21.5	38.8	.092	.104	41.8	.126	3,243.5	.000	28.7
13336500	1,913.1	40.6	.000	.000	44.2	.190	7,789.6	56.1	38.6

Table 9. Basin characteristic values used to develop the final probability and estimating equations for low-flow frequency statistics for unregulated streams in regions 1-8 in Idaho.—Continued

[Locations of regions are shown in figure 1. **Equation variables**: ***A***, drainage area, in square miles; ***P***, mean annual precipitation, in inches; ***DV***, developed land, in percentage of drainage area; ***AG***, agricultural land, in percentage of drainage area; ***BS***, basin slope, in percent; ***W***, water, in percentage of drainage area; ***R***, basin relief, in feet; ***V***, surficial volcanic rocks, in percentage of drainage area; ***S50***, slopes greater than 50 percent, in percentage of drainage area]

Gaging station No.	Equation variables								
	A	*P*	*DV*	*AG*	*BS*	*W*	*R*	*V*	*S50*
Region 2 (Continued)									
13336900	88.3	46.3	0.007	0.000	34.7	0.027	4,633.9	99.9	21.1
13337000	1,179.4	46.6	.051	.000	38.5	.191	7,331.2	68.5	28.0
13340500	997.5	52.5	.006	.000	39.0	.058	5,663.4	31.0	26.2
13340600	1,294.2	51.4	.004	.001	40.4	.059	6,182.5	33.0	29.5
13341000	2,442.5	47.6	.016	.157	36.5	1.04	6,894.5	25.6	23.1
13341300	3.0	48.1	.000	.000	32.0	.000	1,643.9	.000	7.74
13341400	42.7	42.7	.001	.034	26.3	.000	2,146.1	.000	2.62
Region 3									
12424000	674.9	20.8	2.55	64.8	10.5	0.186	3,187.9	17.8	0.431
13334700	170.5	23.0	.031	7.46	35.4	.006	5,098.9	92.7	27.5
13341500	453.7	29.5	.865	32.0	18.2	.258	3,849.7	35.7	2.76
13342450	268.9	19.3	.784	33.3	18.9	.248	4,100.8	68.7	7.82
13345000	316.0	30.1	.863	25.0	21.2	.165	2,859.7	16.1	2.49
13346100	491.7	26.9	1.11	48.3	17.7	.153	3,350.1	14.5	1.74
13346800	17.6	24.5	18.6	63.4	11.8	.030	1,801.2	34.4	.128
13348000	126.9	23.8	5.54	83.9	11.9	.041	2,637.5	34.4	.152
13348500	27.1	23.2	6.34	91.6	10.0	.008	1,442.8	33.8	.018
Region 4									
13196500	4.8	22.1	0.000	0.000	32.9	0.000	2,396.4	100	10.6
13200000	397.0	24.8	.008	.005	31.3	.014	5,019.7	92.9	13.2
13200500	16.0	23.3	.000	.000	39.8	.000	3,410.5	99.4	27.4
13201000	424.4	24.5	.009	.010	31.7	.132	5,068.8	92.8	14.1
13207000	19.2	19.4	.082	4.15	24.3	.025	3,094.6	71.3	3.21
13207500	59.4	20.4	.051	5.42	25.3	.011	4,310.4	50.6	6.73
13250600	55.2	15.9	.002	.006	23.6	.000	2,987.5	97.2	3.77
13251300	4.0	39.8	.000	.423	27.3	.000	1,821.4	97.6	3.98
13251500	36.6	34.6	.061	5.55	22.3	.000	1,896.9	86.4	1.53
13253500	105.4	32.3	.025	1.93	26.5	.005	4,662.7	93.5	5.94
13256000	391.9	29.6	.069	4.24	24.2	.318	5,242.5	91.9	5.22
13257000	86.1	34.0	.013	.672	27.4	.026	5,221.5	80.0	6.87
13258500	596.4	29.2	.051	3.60	23.5	.293	5,444.7	88.2	4.86
13260000	55.3	22.4	.003	.673	26.4	.034	5,035.8	97.9	8.01
13261000	79.5	28.2	.002	.011	26.9	.008	4,618.1	89.5	6.12
13267000	56.8	22.1	.001	.007	31.6	.963	4,800.2	89.9	11.4
13269300	110.8	25.1	.024	1.21	18.7	.008	3,066.8	59.3	1.27
13270800	38.9	28.6	.003	.052	28.2	.000	3,427.4	100	7.38
13275500	205.2	24.7	.111	2.42	26.5	1.04	5,393.4	28.9	10.5
13288200	155.7	47.5	.000	.007	40.5	.144	6,684.6	56.7	32.3
13289960	177.1	27.5	.001	.810	29.4	.009	6,313.8	85.3	15.4
13290190	298.5	33.7	.032	8.34	27.4	.060	7,681.4	77.3	13.2
13291000	99.9	56.2	.000	.005	37.1	.092	5,791.9	62.6	27.1
13315500	15.1	35.4	.000	.418	27.4	.000	2,183.3	98.7	1.31
13316500	576.1	29.6	.039	3.83	33.4	.228	7,591.0	66.2	20.9
13316800	15.3	30.2	.038	.000	30.6	.014	3,191.9	100	19.3
13319000	687.4	27.6	.126	.149	20.3	.061	5,095.2	83.7	3.83
13320000	104.1	39.7	.001	.001	28.6	.007	5,586.1	97.2	12.9

Table 9. Basin characteristic values used to develop the final probability and estimating equations for low-flow frequency statistics for unregulated streams in regions 1-8 in Idaho.—Continued

[Locations of regions are shown in figure 1. **Equation variables**: ***A***, drainage area, in square miles; ***P***, mean annual precipitation, in inches; ***DV***, developed land, in percentage of drainage area; ***AG***, agricultural land, in percentage of drainage area; ***BS***, basin slope, in percent; ***W***, water, in percentage of drainage area; ***R***, basin relief, in feet; ***V***, surficial volcanic rocks, in percentage of drainage area; ***S50***, slopes greater than 50 percent, in percentage of drainage area]

Gaging station No.	Equation variables								
	A	*P*	*DV*	*AG*	*BS*	*W*	*R*	*V*	*S50*
Region 4 (Continued)									
13323600	24.8	43.6	0.000	0.000	21.3	0.000	3,278.0	100	3.31
13325500	43.7	65.6	.000	.000	50.9	.887	5,390.9	80.5	53.1
13329500	29.6	64.6	.000	.000	57.2	.876	5,298.0	45.4	63.1
13330000	71.5	56.7	.064	.276	49.2	.512	5,981.8	75.6	50.5
13330500	72.1	44.7	.104	.736	45.6	.085	5,859.0	95.6	43.9
13331500	239.2	46.5	.017	.169	43.5	.472	6,598.7	98.2	41.1
13337500	260.8	35.3	.018	.001	24.1	.008	3,584.2	18.2	2.05
13338000	843.4	34.9	.007	.000	29.7	.055	7,070.0	29.7	11.1
13338500	1,168.3	31.3	.120	18.4	25.7	.068	7,553.9	48.0	9.56
13339000	4,827.4	38.3	.057	7.94	36.2	.203	8,163.1	57.4	26.2
13339500	241.4	31.5	.001	5.93	22.6	.005	4,938.4	74.8	5.75
13340000	5,507.9	37.4	.055	8.65	34.4	.208	8,364.5	58.2	23.9
14010000	61.9	46.4	.000	.000	46.3	.000	3,818.7	100	52.1
14011000	42.6	42.2	.000	.006	42.1	.006	4,263.5	96.8	40.4
Region 5									
13135500	137.5	31.4	0.044	0.009	40.6	0.041	4,932	37.3	33.3
13136500	92.6	35.8	.002	.015	42.6	.011	4,229	47.4	35.2
13139500	627.6	29.4	.273	.530	42.7	.048	6,616	27.5	39.2
13141000	786.2	26.5	.379	2.05	40.2	.079	7,120	27.1	36.1
13185000	831.6	32.4	.002	.001	44.3	.070	7,338	83.6	41.3
13186000	641.6	34.7	.007	.002	42.1	.035	6,089	91.9	35.2
13186500	133.6	22.4	.000	.000	29.3	.002	5,459	97.1	10.4
13187000	55.6	32.2	.000	.000	33.6	.007	5,094	96.4	16.0
13235000	449.3	34.5	.027	.001	46.7	.294	6,786	81.1	46.1
13240000	48.7	37.2	.000	.040	42.1	.087	3,861	86.6	36.4
13292500	93.9	34.7	.090	2.34	32.8	.022	3,434	43.0	25.1
13293000	35.6	44.5	.000	.000	37.6	4.37	3,579	70.5	34.0
13295000	148.9	23.9	.076	2.30	26.1	.627	4,478	39.8	13.0
13295500	510.4	29.6	.092	2.44	30.4	1.46	4,677	38.0	19.9
13296000	187.3	27.1	.003	.008	41.0	.048	4,201	95.2	32.9
13296500	811.1	28.0	.066	1.55	33.6	.977	4,965	59.3	23.0
13308500	133.8	28.4	.068	.002	26.6	.158	3,135	83.4	11.3
13309000	181.7	30.0	.000	.000	20.2	.086	2,987	71.7	3.47
13309220	1,037.9	29.0	.008	.009	38.4	.127	5,307	83.3	31.9
13310000	451.5	28.7	.001	.001	44.3	.050	5,385	69.1	42.1
13310199	2,871.6	26.9	.003	.009	45.4	.173	7,277	70.2	44.4
13310500	91.7	37.5	.000	.001	31.7	.030	3,717	92.4	13.5
13310700	329.3	33.6	.000	.002	38.0	.215	5,387	92.9	26.8
13311000	19.3	34.0	2.21	.068	35.3	.095	2,744	96.5	17.3
13311500	42.9	30.9	1.86	.033	40.8	.067	3,364	100.0	31.9
13312000	106.9	30.0	.759	.013	41.7	.072	4,183	99.4	34.2
13313000	216.4	34.3	.006	.008	28.2	.085	4,458	87.0	12.6
13313500	102.5	43.9	.002	.000	24.8	.078	3,005	84.9	6.41
13314000	1,164.0	33.2	.071	.004	37.4	.115	6,378	93.8	27.0
13314300	1,306.0	32.9	.065	.013	38.9	.126	7,117	92.4	29.9
13315000	12,228.0	24.4	.050	1.65	37.8	.238	10,701	53.3	30.3

Table 9. Basin characteristic values used to develop the final probability and estimating equations for low-flow frequency statistics for unregulated streams in regions 1-8 in Idaho.—Continued

[Locations of regions are shown in figure 1. **Equation variables**: ***A***, drainage area, in square miles; ***P***, mean annual precipitation, in inches; ***DV***, developed land, in percentage of drainage area; ***AG***, agricultural land, in percentage of drainage area; ***BS***, basin slope, in percent; ***W***, water, in percentage of drainage area; ***R***, basin relief, in feet; ***V***, surficial volcanic rocks, in percentage of drainage area; ***S50***, slopes greater than 50 percent, in percentage of drainage area]

Gaging station No.	Equation variables								
	A	*P*	*DV*	*AG*	*BS*	*W*	*R*	*V*	*S50*
Region 6									
6013500	277.0	18.8	0.020	0.000	24.1	0.032	4,691.8	9.77	10.0
6015500	349.0	19.2	.014	2.99	18.8	.016	5,193.8	20.5	3.70
6019500	525.5	22.9	.002	2.13	20.1	.025	5,130.4	2.32	5.36
6037500	434.9	42.3	.166	.000	11.3	.264	2,785.6	81.6	2.13
13108500	228.4	26.8	.000	9.27	12.8	.128	3,641.5	34.2	2.35
13112000	393.9	21.1	.016	9.10	8.60	.075	5,062.4	60.6	1.36
13113000	123.2	20.3	.383	3.12	19.6	.017	3,015.2	4.85	2.10
13113500	238.7	19.4	.385	2.05	16.7	.009	3,696.0	38.3	2.02
13117300	74.2	23.8	.004	.099	32.7	.008	4,280.2	35.3	16.1
13120000	114.7	29.8	.000	.000	43.1	.094	4,984.0	34.0	38.0
13120500	440.4	27.0	.005	.030	37.8	.233	5,284.1	42.3	28.6
13128900	8.4	26.6	.000	.000	66.2	.056	5,123.4	0.000	77.2
13297330	29.5	22.6	.064	.057	47.7	.035	3,963.8	61.5	46.9
13297350	6.4	21.7	.180	.090	40.8	.000	3,470.0	29.7	32.4
13297355	71.6	25.2	.018	.012	36.3	.042	4,114.3	62.0	22.4
13297450	18.3	32.0	.000	.000	41.3	1.19	5,501.5	60.5	28.0
13298000	540.2	26.0	.001	.089	38.2	.167	6,227.5	81.9	25.9
13299000	84.6	25.6	.000	.340	37.2	.175	4,996.6	93.0	25.1
13302500	3,746.1	21.6	.084	2.54	33.4	.398	8,655.9	50.9	22.7
13305000	907.1	15.6	.017	5.83	25.2	.033	6,430.2	10.3	14.4
13305500	1,258.0	15.3	.017	7.05	26.4	.028	7,370.8	12.2	14.7
13306000	210.3	22.9	.173	.440	43.6	.010	6,244.4	3.96	37.4
13306385	40.7	24.9	.001	.022	22.9	.000	2,395.4	4.28	2.58
13306500	520.7	24.0	.000	.029	38.6	.039	6,652.8	9.68	29.4
13307000	6,236.7	20.4	.070	3.23	33.3	.281	9,419.7	34.9	23.0
Region 7									
10119000	107.1	13.2	0.039	21.3	17.7	0.434	3,724.2	15.1	2.39
10172940	28.7	17.0	.000	.000	17.5	.000	2,659.9	6.02	0.19
10315500	389.8	15.2	.002	3.51	17.5	.002	5,032.4	44.9	4.76
10329500	176.2	21.9	.001	.017	21.0	.048	4,930.3	90.9	4.26
10352500	225.4	17.0	.000	6.16	17.3	.023	3,931.3	88.6	2.99
10353000	137.9	22.2	.005	.022	22.2	.017	3,436.4	87.6	4.12
10396000	204.7	29.1	.001	.002	16.2	.096	5,455.7	98.8	7.28
10406500	86.7	16.9	.011	1.64	23.1	.009	3,926.9	87.3	6.50
13057940	431.4	16.6	.001	14.5	13.3	.039	2,544.2	31.5	0.68
13075000	367.4	14.3	.296	28.1	16.8	.088	4,652.6	20.5	4.70
13077700	7.8	23.6	.000	.000	32.6	.031	2,707.3	.000	16.2
13079100	7.4	21.8	.000	.014	25.2	.000	1,681.7	11.5	2.38
13092000	81.6	14.5	.001	.174	31.6	.001	3,685.2	86.1	19.9
13154000	103.3	14.0	.000	1.64	15.1	.039	3,683.5	83.6	1.82
13155300	14.2	23.5	.033	.000	25.2	.000	2,397.6	100.0	5.26
13161500	380.8	18.3	.000	1.86	25.1	.021	4,956.4	56.5	8.87
13162500	84.9	24.8	.001	.035	35.3	.023	5,683.3	86.5	28.5
13169500	243.7	13.8	.000	.016	10.1	.006	3,447.7	96.1	3.62
13170000	103.4	14.2	.000	.002	13.2	.000	3,447.5	89.9	6.08
13172680	18.7	21.2	.000	.011	23.0	.126	2,569.4	100.0	2.53
13172720	12.5	13.6	.000	3.60	21.1	.092	2,467.9	96.9	1.13
13172735	13.1	14.7	.048	.052	26.1	.008	2,329.3	100.0	4.88
13172740	91.8	14.8	.010	4.27	20.2	.107	3,719.2	91.5	1.72
13176000	452.3	21.6	.112	1.24	20.6	.599	3,672.2	60.1	3.84

Table 9. Basin characteristic values used to develop the final probability and estimating equations for low-flow frequency statistics for unregulated streams in regions 1-8 in Idaho.—Continued

[Locations of regions are shown in figure 1. **Equation variables**: ***A***, drainage area, in square miles; ***P***, mean annual precipitation, in inches; ***DV***, developed land, in percentage of drainage area; ***AG***, agricultural land, in percentage of drainage area; ***BS***, basin slope, in percent; ***W***, water, in percentage of drainage area; ***R***, basin relief, in feet; ***V***, surficial volcanic rocks, in percentage of drainage area; ***S*50**, slopes greater than 50 percent, in percentage of drainage area]

Gaging station No.	Equation variables								
	A	***P***	***DV***	***AG***	***BS***	***W***	***R***	***V***	***S*50**
Region 7 (Continued)									
13177000	26.8	29.3	0.005	0.505	29.9	0.016	4,247.5	0.362	10.5
13178000	454.2	26.1	.258	.726	19.5	.221	3,905.0	79.3	3.69
13226500	535.3	12.3	.016	1.86	17.4	.026	3,958.2	73.5	1.47
Region 8									
9208000	6.6	40.3	0.000	0.000	29.6	0.000	1,442.8	0.000	10.6
9224000	390.1	23.6	.057	.434	15.4	.747	3,048.4	.000	1.56
10010400	34.5	40.4	.000	.101	39.5	2.15	3,997.8	.000	31.1
10015700	58.5	21.6	.000	10.8	9.65	.000	2,997.9	.000	.002
10032000	165.2	34.1	.000	.000	31.3	.500	4,033.0	.000	13.3
10040000	45.4	23.8	.000	.000	26.5	.051	2,730.5	.000	6.05
10040500	37.8	26.8	.000	.000	28.0	.046	2,443.9	.256	5.46
10041000	113.8	25.1	.000	.000	27.4	.024	2,826.5	.085	6.25
10047500	50.6	21.5	.000	.000	32.0	.390	3,225.2	.000	15.5
10058600	24.3	35.1	.000	.000	27.4	.071	3,487.4	.806	7.64
10069000	21.9	26.1	.000	.000	41.0	.044	3,534.8	.000	31.9
10077000	50.9	18.2	.000	70.7	6.15	.157	1,100.5	77.0	.639
10093000	30.4	36.0	.000	.000	31.3	.022	3,983.1	.000	19.4
10096000	23.2	14.2	.011	17.9	19.8	.000	1,695.4	.000	1.13
10099000	16.3	40.9	.000	.000	49.4	.003	4,510.9	.000	50.2
10102300	11.6	39.3	.000	.000	53.2	.182	4,577.3	.000	60.5
10104700	62.2	38.0	.000	1.05	30.1	.040	4,381.5	.000	14.5
10104900	56.8	35.4	.000	.000	28.3	.040	3,719.8	.000	16.3
10105000	69.2	35.2	.000	.000	30.1	.368	3,932.8	.000	18.9
10109000	214.4	35.6	.010	.008	33.3	.175	5,255.6	.000	20.0
10113500	264.6	28.3	.000	.153	28.5	.097	4,206.7	.000	14.9
13010065	502.5	47.4	.036	.000	15.8	3.83	3,509.4	45.0	3.12
13011500	162.7	36.3	.076	.000	20.3	1.70	3,763.2	17.8	3.75
13011900	330.1	37.1	.055	.407	27.0	.296	4,566.8	6.88	13.4
13012000	370.2	36.6	.056	.984	26.3	.264	4,619.9	6.16	12.5
13014500	608.0	31.6	.015	.516	23.3	.436	5,015.9	.127	7.14
13018300	10.7	34.7	.000	.000	40.3	.049	3,551.7	.000	27.6
13019438	82.7	31.0	.154	.182	38.6	.030	4,943.0	.585	26.3
13019500	561.3	26.7	.032	2.55	30.3	.020	5,650.1	.086	16.3
13023000	448.8	34.9	.003	.105	35.1	.059	5,632.6	.000	22.5
13024500	25.7	39.5	.000	.000	45.1	.311	3,738.3	.000	40.0
13025000	27.7	39.3	.000	.000	49.3	.000	4,223.5	.000	52.2
13025500	113.8	29.4	.000	2.83	24.9	.261	3,647.1	.000	5.63
13027000	20.1	40.8	.000	.000	49.7	.000	3,663.7	.000	50.1
13032000	78.3	26.7	.000	.000	38.8	.135	3,806.4	.000	26.3
13044500	131.1	31.8	.000	.000	9.05	.255	2,604.8	62.8	.475
13045500	123.7	35.3	.000	2.44	10.6	.582	2,516.2	61.5	1.05
13046680	85.4	56.0	.001	.000	6.94	.232	2,270.2	90.1	.656
13046995	322.3	53.5	.001	.000	10.9	1.48	3,501.7	84.2	1.75
13047500	333.6	52.9	.000	.110	11.0	.755	3,655.8	82.8	1.71
13047600	336.9	52.2	.001	2.35	10.8	1.48	3,897.7	82.0	1.68
13049500	512.9	42.6	.020	19.5	9.89	.582	4,197.5	71.3	1.52
13052200	341.4	31.7	.176	24.8	23.6	.290	5,223.4	9.11	15.4
13054000	479.2	30.3	.138	26.7	21.5	.350	5,277.0	18.7	12.9
13055000	874.8	27.7	.080	32.8	19.0	.281	6,232.1	47.7	9.69

Table 10. Total years with the *N*-day low flow equal to zero and total years of record for streamflow-gaging stations used in logistic regression analyses for unregulated streams in regions 1-8 in Idaho.

Gaging station No.	1-day zero flow	7-day zero flow	30-day zero flow	Total years of record
Region 1				
12305500	0	0	0	45
12311000	0	0	0	42
12316800	0	0	0	22
12320500	0	0	0	28
12321000	0	0	0	30
12392155	1	1	0	12
12392300	0	0	0	23
12393500	0	0	0	32
12396000	0	0	0	22
12408500	0	0	0	40
12409000	0	0	0	79
12427000	0	0	0	22
12431000	0	0	0	58
Region 2				
12301300	0	0	0	44
12301999	0	0	0	9
12302000	0	0	0	18
12302055	0	0	0	35
12302500	0	0	0	14
12303100	0	0	0	31
12303500	0	0	0	24
12340000	0	0	0	65
12341000	0	0	0	8
12343400	0	0	0	18
12344000	0	0	0	66
12346500	0	0	0	27
12347500	0	0	0	22
12350000	0	0	0	16
12350500	0	0	0	9
12351000	0	0	0	23
12352000	0	0	0	9
12353280	0	0	0	9
12354000	0	0	0	17
12375900	0	0	0	20
12377150	0	0	0	20
12389500	0	0	0	47
12390700	0	0	0	47
12411000	0	0	0	52
12413000	0	0	0	63
12413140	0	0	0	30
12413150	0	0	0	20
12413210	0	0	0	13
12413470	0	0	0	15
12413500	0	0	0	67
12414500	0	0	0	82
12414900	0	0	0	37
12415000	0	0	0	45
12416000	0	0	0	36
13336500	0	0	0	73
13336900	0	0	0	9
13337000	0	0	0	74
13340500	0	0	0	24
13340600	0	0	0	35
Region 2 (Continued)				
13341000	0	0	0	38
13341300	0	0	0	11
13341400	0	0	0	11
Region 3				
12424000	0	0	0	53
13334700	0	0	0	22
13341500	0	0	0	14
13342450	0	0	0	28
13345000	0	0	0	40
13346100	0	0	0	10
13346800	0	0	0	24
13348000	0	0	0	30
13348500	5	4	3	25
Region 4				
13196500	0	0	0	22
13200000	0	0	0	52
13200500	2	0	0	20
13201000	0	0	0	38
13207000	14	14	14	14
13207500	5	2	1	13
13250600	0	0	0	20
13251300	0	0	0	17
13251500	0	0	0	35
13253500	0	0	0	10
13256000	0	0	0	15
13257000	3	3	2	16
13258500	0	0	0	64
13260000	0	0	0	23
13261000	0	0	0	35
13267000	1	1	1	25
13269300	0	0	0	13
13270800	0	0	0	18
13275500	2	0	0	49
13288200	0	0	0	39
13289960	0	0	0	17
13290190	0	0	0	29
13291000	0	0	0	8
13315500	0	0	0	13
13316500	0	0	0	49
13316800	0	0	0	11
13319000	0	0	0	78
13320000	0	0	0	64
13323600	0	0	0	12
13325500	0	0	0	8
13329500	0	0	0	53
13330000	0	0	0	73
13330500	0	0	0	68
13331500	0	0	0	38
13337500	0	0	0	29
13338000	0	0	0	44
13338500	0	0	0	38
13339000	0	0	0	54

Table 10. Total years with the N-day low flow equal to zero and total years of record for streamflow-gaging stations used in logistic regression analyses for unregulated streams in regions 1-8 in Idaho.—Continued

Gaging station No.	1-day zero flow	7-day zero flow	30-day zero flow	Total years of record
Region 4 (Continued)				
13339500	0	0	0	23
13340000	0	0	0	45
14010000	0	0	0	68
14011000	0	0	0	39
Region 5				
13135500	0	0	0	22
13136500	0	0	0	17
13139500	7	6	2	87
13141000	0	0	0	57
13185000	0	0	0	92
13186000	0	0	0	57
13186500	0	0	0	10
13187000	0	0	0	10
13235000	0	0	0	61
13240000	0	0	0	57
13292500	0	0	0	11
13293000	0	0	0	11
13295000	0	0	0	60
13295500	0	0	0	34
13296000	0	0	0	26
13296500	0	0	0	66
13308500	0	0	0	43
13309000	0	0	0	31
13309220	0	0	0	12
13310000	0	0	0	13
13310199	0	0	0	9
13310500	0	0	0	31
13310700	0	0	0	30
13311000	0	0	0	26
13311500	0	0	0	12
13312000	0	0	0	13
13313000	0	0	0	74
13313500	0	0	0	8
13314000	0	0	0	11
13314300	0	0	0	9
13315000	0	0	0	11
Region 6				
6013500	0	0	0	24
6015500	2	1	0	20
6019500	0	0	0	64
6037500	0	0	0	69
13108500	0	0	0	10
13112000	55	54	48	69
13113000	4	3	2	20
13113500	32	32	28	46
13117300	0	0	0	12
13120000	0	0	0	59
13120500	0	0	0	55
13128900	0	0	0	10
13297330	0	0	0	30
13297350	6	5	1	31
13297355	0	0	0	30
Region 6 (Continued)				
13297450	0	0	0	14
13298000	0	0	0	17
13299000	0	0	0	19
13302500	0	0	0	86
13305000	0	0	0	42
13305500	0	0	0	14
13306000	0	0	0	9
13306385	0	0	0	11
13306500	0	0	0	32
13307000	0	0	0	36
Region 7				
10119000	0	0	0	29
10172940	0	0	0	11
10315500	0	0	0	57
10329500	0	0	0	81
10352500	12	10	4	53
10353000	0	0	0	32
10396000	0	0	0	72
10406500	0	0	0	59
13057940	0	0	0	18
13075000	0	0	0	48
13077700	0	0	0	29
13079100	0	0	0	9
13092000	0	0	0	33
13154000	3	2	0	8
13155300	0	0	0	5
13161500	0	0	0	40
13162500	0	0	0	21
13169500	43	41	35	46
13170000	10	10	10	10
13172680	7	5	4	37
13172720	9	4	1	26
13172735	15	13	9	39
13172740	1	0	0	40
13176000	0	0	0	45
13177000	0	0	0	11
13178000	0	0	0	22
13226500	1	1	0	21
Region 8				
9208000	0	0	0	30
9224000	2	1	1	17
10010400	0	0	0	12
10015700	16	11	7	39
10032000	0	0	0	60
10040000	0	0	0	11
10040500	0	0	0	11
10041000	0	0	0	42
10047500	1	0	0	36
10058600	0	0	0	25
10069000	0	0	0	16
10077000	0	0	0	13
10093000	0	0	0	42

Table 10. Total years with the N-day low flow equal to zero and total years of record for streamflow-gaging stations used in logistic regression analyses for unregulated streams in regions 1-8 in Idaho.—Continued

Gaging station No.	1-day zero flow	7-day zero flow	30-day zero flow	Total years of record	Gaging station No.	1-day zero flow	7-day zero flow	30-day zero flow	Total years of record
Region 8 (Continued)					Region 8 (Continued)				
10096000	0	0	0	12	13023000	0	0	0	51
10099000	0	0	0	17	13024500	0	0	0	24
10102300	0	0	0	17	13025000	0	0	0	28
10104700	0	0	0	31	13025500	0	0	0	8
10104900	0	0	0	22	13027000	0	0	0	10
10105000	0	0	0	11	13032000	0	0	0	17
10109000	0	0	0	49	13044500	0	0	0	14
10113500	0	0	0	83	13045500	0	0	0	17
13010065	0	0	0	19	13046680	0	0	0	17
13011500	0	0	0	54	13046995	0	0	0	18
13011900	0	0	0	37	13047500	0	0	0	9
13012000	0	0	0	15	13047600	0	0	0	87
13014500	0	0	0	13	13049500	0	0	0	9
13018300	0	0	0	40	13052200	0	0	0	42
13019438	0	0	0	10	13054000	0	0	0	41
13019500	0	0	0	13	13055000	0	0	0	76

Manuscript approved for publication, February 3, 2006

Prepared by the Enterprise Publishing Network,

Publishing Service Center, Tacoma, Washington
Bill Gibbs
Sharon Wahlstrom
Judy Wayenberg

For more information concerning the research in this report, contact the
Idaho Water Science Center Director,
U.S. Geological Survey, 230 Collins Road
Boise, Idaho 83702-4520
http://id.water.usgs.gov

USGS

Hortness

Estimating Low-Flow Frequency Statistics for Unregulated Streams in Idaho

SIR 2006–5035