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The development of regional regression equations for flood flow estimates of ungauged streams in the state of Arkansas

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**THE DEVELOPMENT OF REGIONAL REGRESSION
EQUATIONS FOR FLOOD FLOW ESTIMATES OF UNGAUGED STREAMS IN
THE STATE OF ARKANSAS**

**THE DEVELOPMENT OF REGIONAL REGRESSION
EQUATIONS FOR FLOOD FLOW ESTIMATES OF UNGAUGED RURAL
STREAMS IN THE STATE OF ARKANSAS**

**A thesis submitted in partial fulfillment of the
requirements for Honors Studies in Civil Engineering**

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December, 2007
University of Arkansas**

**This thesis is approved for
Recommendation to the
Honors College**

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INTRODUCTION

Statement of the Problem

Knowledge of the frequency and magnitude of floods on streams is crucial to the design of bridges and culverts. Estimates of the peak magnitude and frequency of flood events are also used in the design of flood control structures, the management and regulation of flood plains, the establishment of flood insurance rates, and the formulation of emergency evacuation plans for flood-prone areas (Tortorelli and McCabe, 2001). The most reliable estimates of floods of specified probability at gauged sites are based on frequency analyses of stream gauging station records (Becker, 1986). This type of specified and accurate flood stream flow analysis is not possible for every stream due to the lack of gauging stations and the many years of data required for such an analysis. It is therefore necessary to determine a mathematical relationship between peak flows and physiographic and hydrologic characteristics of the gauged watersheds so that peak runoff from an ungauged watershed can be calculated using an equation specific to the region in which that stream flows. The United States Geological Survey (USGS) has developed and published such regression equations for every state.

The Little Rock USGS office last updated these equations for Arkansas in 1995 (Hodge & Tasker, 1995). These equations have average standard errors of prediction from 35% to 45% for 100-year estimations. Although these wide margins of error are acceptable for regression equations, new methods of creating regression equations offer greater accuracy. Now an additional 10 years of data from existing and newly installed gauging stations can be used to develop more accurate equations. This is achieved by using a regionalization approach that incorporates local watershed characteristics using

geographic information systems and up-to-date spatial data in addition to gauging station data. Once developed, these more accurate equations will be used for the prediction of peak streamflow frequencies and magnitudes in ungauged streams for the design of bridges, culverts, and flood control structures throughout the state.

Objectives of Study

The objective of this project is to improve the accuracy of the peak streamflow frequency estimates in ungauged streams by using a regionalization approach and the Bulletin 17B method of flood flow analysis. The entire state will be considered one region and the final results will be compared to previous studies done in the state. The data used will be the most up-to-date available from the USGS gauging stations around the state. This includes data from gauging stations that had less than 10 years of data when the last such study was conducted by Hodge & Tasker (1995). The data from a station will be used if that site contains more than 10 years of unregulated data. The resulting data will then be processed using the Bulletin 17B method and then by using least sum of squares regression analysis, the most accurate regression equation for specific frequencies will be calculated. An evaluation of the equations will be included with the final flood flow prediction equations. An evaluation of the HEC-SSP program and how it performs the Bulletin 17B analysis will be included with the final regression equations.

LITERATURE REVIEW

Overview

Performing an accurate flood flow frequency analysis is necessary to create flood flow prediction equations that are used for the sizing of hydrologic structures such as bridges and culverts. Identifying the most accurate distribution and using the best correlating parameters for that distribution for streamflow data is sometimes esoteric and there are several analytical methods that can be used to fit the natural distribution of extreme streamflows. Several federal organizations have worked together to refine a method for determining flood flow frequencies and magnitudes which is known as the Bulletin 17B method (IACWD, 1982). A program recently released by the US Army Corps of Engineers Hydrologic Engineering Center named HEC-SSP performs the Bulletin 17B analysis. HEC-SSP is available at <http://www.hec.usace.army.mil/software/hec-ssp/>.

Estimated peak streamflows for unregulated streams are developed by using years of accumulated river gauging data. Including the most recent data in a flood flow frequency analysis allows for the most accurate hydrologic estimates. Moreover, it has long been known that annual flood series are too short for reliable estimation for extreme events. Therefore, complete data for many years, including historical events, is crucial in estimation of extreme events (Zhang and Singh, 2005). For this reason, researchers group data from similar stations together to give a better prediction on extreme events. The regionalization method is used to develop a flood frequency curve that is then compared with hydrologic or physiographic characteristics of that watershed or region. Finally, regression equations are developed that express an accurate relationship between

the peak streamflows and the statistically important characteristics of that region, as proven through statistic error analysis.

Definition of Flood Frequency Analysis

Flood frequency analysis is a procedure that is completed on floodplain analyses, construction projects, and other projects pertaining to water resources. It is done to calculate the probable magnitude of a flood and relates it to a risk tolerance level. Flood frequency analyses are completed using statistics to find a recurrence interval, in years, that is associated with a specific magnitude flood. Any water resource structure is built to accept a certain level of risk, which is called the probability of exceedance. This is expressed as the reciprocal of the return period and traditionally is classified at intervals of 2, 5, 10, 20, 50, 100, and 500 years.

Regional Flood Frequency Analysis - Regionalization

A regional flood frequency analysis, or regionalization, was the method used in this analysis. A regional flood frequency analysis is used when there is either no or insufficient gauging data from a stream to do a proper flood frequency analysis. To find flood flow magnitudes for that stream or any streams in its region, the gauging data from watersheds with similar physical characteristics are analyzed in a group as a homogeneous population. Homogeneous means that all observations in the data series originate from the same parent population. Even though stream flood flow magnitudes are different among the streams, if they have similar event frequencies, they can be grouped and analyzed together. This is done because analyzing the data samples together gives more accurate conclusions than if only one sample was used (Hosking & Wallis,

1997). A regression analysis then is used to develop equations correlating that region's physical characteristics to the estimated flood flows.

Regional frequency analysis involves five steps: 1) screening of the data 2) identification of homogeneous regions 3) choice of a frequency distribution 4) estimation of the frequency distribution, and 5) evaluation of the results (Hosking & Wallis, 1997).

Data Screening

The first step to using the regionalization method involves screening the data to eliminate unfit data. Data from a single gauging station is seen fit only if it has at least 10 years of data and is on a stream not regulated by any hydrologic structure (IACWD, 1982). Historical data, specifically, high discharge events, are used as they give good bearing to the estimation of extreme flood events. Historical data includes any event that was not recorded by the gauging station because the station was damaged, not built for a flood of that magnitude, or was not built yet, but the flood was still estimated by observation or by historic written records. Abnormally large or small data recordings should be checked with data from surrounding stations to eliminate gross errors. Applying the discordancy measure compares peak flow responses with the peak flows within the entire group. The discordancy measure compares data from one station with the data from surrounding stations to help find erroneous data. If the discordancy measure is large, then the site is said to be discordant and that peak data is not used in the study. Gauging stations that had drainage areas of 2750 square miles or greater were also left out. Almost all sites with drainage areas of 2750 square miles or greater already have gauging stations on them, meaning a more accurate single flood frequency analysis can

be completed for that one station. Therefore, these stations do not benefit from a regional flood frequency analysis.

Identification of Homogenous Regions

After establishing which stations have data that can be used, those stations are recorded and data about the physiographic, geographic, and hydrologic characteristics that influence that station are collected. This data includes: latitude, longitude, station elevation, watershed area, mean basin elevation, basin length, basin slope, basin perimeter, shape factor, max stream length, max stream slope, overland flow, north facing, south facing, and average precipitation. This data is collected and the screened stations with the accompanying data are compared to each other using a multivariate analysis. The analysis compares all variables on a one by one basis for all the stations chosen. A graphical representation allows for inspection of the relationship between the variables to see which variables are related.

A region can be determined based on the variables that show correlation among the group of stations. Regions may be delineated by several variables, including physical location or elevation. Certain variables such as longitudinal and latitudinal coordinates, elevation, and watershed perimeter share relationships with other variables. For example, at differing elevations different average annual rainfalls can be expected. Therefore, elevation might only be needed to be considered in the final regression equation since the annual rainfall average is, in a way, expressed through the elevation variable.

Fitting a Theoretical Distribution

Choosing a distribution is sometimes difficult because flood events are a succession of natural events which are not known to fit any one specific known statistical distribution (IACWD, 1982). The Bulletin 17B method is the accepted method of flood flow frequency analysis outlined by the Hydrology Subcommittee of the Interagency Advisory Committee on Water Data in 1982 (IACWD, 1982). This is a widely accepted method used by Federal agencies when performing flood flow frequency analyses. Bulletin 17B is used to plot the logarithms of annual peak discharges to a log Pearson Type III (LPIII) distribution using the method of moments to compute mean, standard deviation, and skew of the log-transformed data (Flynn & Kirby, 2006).

Estimation of a Frequency Distribution

The fourth step of estimating the frequency distribution and magnitudes is also included in the Bulletin 17B analysis. The best fitting prediction curve to the flood flow data is calculated using the method of moments within the HEC-SSP program. A relationship is found between the prediction curve and quantifiable watershed characteristics by using the method of least sum of squares. The error of this line and the prediction curve is evaluated by also using the method of least squares.

Bulletin 17B

Concept of Bulletin 17B

Bulletin 17B fits a Log Pearson III distribution to observed annual peaks by computing the base 10 logarithms of the discharge at selected exceedance probabilities (IACWD, 1982). This is expressed in the equations:

$$\text{Log}Q = \bar{X} + KS \quad (1)$$

$$K = \frac{2}{G} \left[\left[\left(K_N - \frac{G}{6} \right) \frac{G}{6} + 1 \right]^3 - 1 \right] \quad \text{For } -1.0 \leq G \leq 1.0 \quad (2)$$

where,

Q = discharge,

\bar{X} = mean of annual peak flow,

K = factor that is a function of the selected exceedance probability and the skew, coefficient, available in Appendix 3 of Bulletin 17B,

S = standard deviation of logarithms,

K_N = standard normal deviate,

G = skew coefficient of logarithms.

Bulletin 17B recommends many methods and mechanisms to account for differences between the stations within a region. The skew associated with each station, incomplete records, broken records, historical data, zero flood years, low and high outliers, plotting positions, and confidence limits are all addressed by Bulletin 17B and the HEC-SSP software, which uses Bulletin 17B analysis and are more closely examined in the following pages.

Skew

The Log Pearson Type III method assumes that the flood flow data is a normal distribution, which can be visualized as a bell curve. When graphed, the actual flood data does not fit a normal bell curve distribution but rather contains a skew. Skewness is

defined as the asymmetry in the distribution of the sample data values (Easton & McColl, 2007). A normal bell curve is symmetrical. When a skew is introduced, the distribution becomes asymmetrical, such as with the occurrence of a certain magnitude flood. This concept is represented in Figure 1.

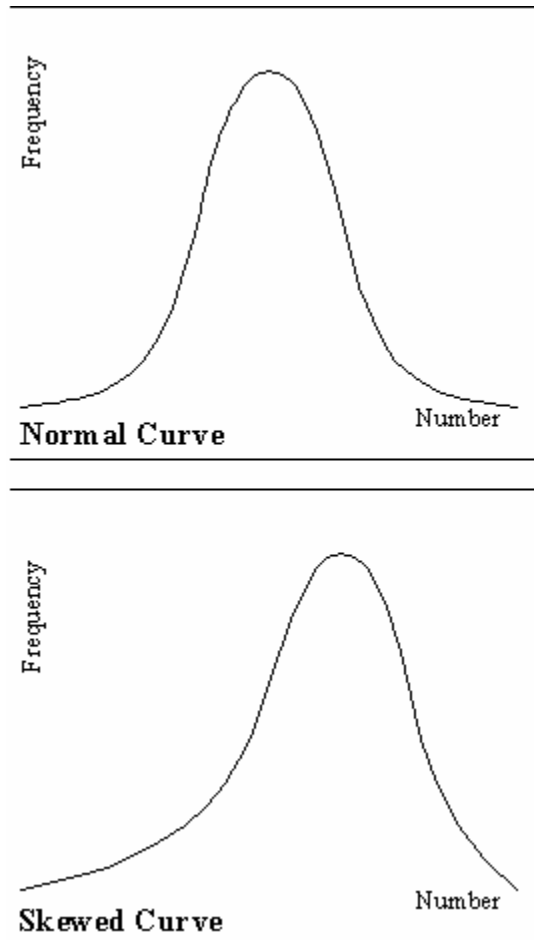


Figure 1 - Normal vs. Skewed Distribution

The skew is accounted for by introducing a coefficient to shift the apex thus making the curve asymmetrical. The station skew used in flood frequency analyses are calculated by using the following equations as outlined in Bulletin 17B:

$$\bar{X} = \frac{\Sigma X}{N} \quad (3)$$

$$S = \left[\frac{\Sigma(X - \bar{X})^2}{(N-1)} \right]^{0.5} \quad (4a)$$

$$S = \left[\frac{(\Sigma X^2) - \frac{(\Sigma X)^2}{N}}{(N-1)} \right]^{0.5} \quad (4b)$$

$$G = \frac{N \Sigma(X - \bar{X})^3}{(N-1)(N-2)S^3} \quad (5a)$$

$$G = \frac{N^2 (\Sigma X^3) - 3N(\Sigma X)(\Sigma X^2) + 2(\Sigma X)^3}{N(N-1)(N-2)S^3} \quad (5b)$$

where,

X = logarithm of annual peak flow,

N = number of items in data set,

S = standard deviation of logarithm,

\bar{X} = mean logarithm.

The skew coefficient is sensitive to extreme events; therefore it is difficult to obtain accurate skew estimates from small samples.

Skew coefficients accuracy can be improved by weighting the station skew with generalized skew estimated by pooling information from nearby sites (IACWD, 1982).

The recommended procedure for developing generalized skew coefficients requires the use of at least 40 stations, or all the stations within a 100-mile radius be used when calculating skew coefficients and the stations used should have 25 years or more of recorded data (IACWD, 1982). The actual procedure for calculating generalized skew coefficients also includes using one of three methods: 1) skew isolines drawn on a map 2) skew prediction equations and 3) the mean of the station skew values (IACWD, 1982).

Developing a skew isoline map starts with plotting each station skew value at the centroids of its drainage basin and then evaluating the plotted data to find any geographic or topographic trends. Isolines are drawn between congruent values if a pattern is evident. The average of the differences squared between the observed and the isoline values, otherwise known as the mean-square error (MSE), is computed. MSE values are used in evaluating the accuracy of the isoline map. If no pattern can be found and therefore no lines can be drawn, then this method should not be used (IACWD, 1982).

Skew prediction equations can be developed that relate the station skew coefficient or the differences from the isoline map to the predictor variables that have an effect on the skew coefficient of the station record (IACWD, 1982). These variables include watershed and climatologic variables. The developed prediction equation should preferably be used for estimating the skew coefficient at stations with variables that are within range of predetermined skew and station data that can be used to calibrate the equation. Again, the MSE will be used to evaluate the accuracy of the prediction equation (IACWD, 1982)

The mean of the station skew values requires the mean and variance of the skew coefficients for all stations. In the cases where the variability of the runoff regime is so

large as to inhibit finding 40 stations with similar hydrology, the arithmetic mean and variance of only 20 stations may be used to find the generalized skew coefficient. The only requirement of the 20 stations is that the meteorologic, topographic, and geographic characteristics of their drainage basins should be representative of the region around the station of interest (IACWD, 1982)

Station skews for the USGS stations used in this study have already been calculated using one of the three methods and that station skew value is already stored in the metadata for each individual station, along with the flood data from the gauging stations. The HEC-SSP program, which is used to run the Bulletin 17B analysis, contains three options for skew. One is to use the station skew, which has already been found from the generalized skew map which was developed when Bulletin 17B was compiled and is attached to the data that is provided by USGS. The second option is to use a weighted skew by weighing the station and generalized skew coefficient form a better estimate for skew in a given watershed (IACWD, 1982). The third option is to use a regionalized skew which can be entered manually along with a regional mean standard error.

To weigh the skew, the generalized skew coefficient is first assumed to be unbiased and independent of station skew. Then by weighing the station and generalized skew in inverse proportion to their individual MSE, the MSE of the weighed estimate is minimized (IACWD, 1982). This is expressed in the equation:

$$G_w = \frac{MSE_{\bar{G}}(G) + MSE_G(\bar{G})}{MSE_{\bar{G}} + MSE_G} \quad (6)$$

where,

- G_w = weighted skew coefficient,
- $MSE_{\bar{G}}$ = mean-square error of generalized skew,
- G = station skew,
- MSE_G = mean-square error of station skew,
- \bar{G} = generalized skew.

If the MSE of the generalized skew can be estimated, then equation 6 can be used regardless of the source of generalized skew (IACWD, 1982).

When using the weighted skew option within HEC-SSP, the following equation is used instead of equation 6 because it requires only the station skew and the record length in years and the results are sufficiently accurate:

$$MSE_G \cong 10^{[A-B[\log_{10}(N/10)]]} \quad (7)$$

where,

- MSE_G = mean-square error of station skew,
- N = record length (years),
- A = $-0.33 + 0.08|G|$ if $|G| \leq 0.90$,
- $= -0.52 + 0.30|G|$ if $|G| > 0.90$,
- B = $0.94 - 0.26|G|$ if $|G| \leq 1.50$,
- $= 0.55$ if $|G| > 1.50$,
- $|G|$ = absolute value of the station skew.

Using equation 7 with stations having absolute skew values (logs) greater than 2 and long periods of record gives little weight to the station skew value (IACWD, 1982). Using equation 6 may also improperly weigh the generalized skew if the generalized and station skews differ by more than 0.5. If this situation occurs, an examination of the data and the flood-producing characteristics of the watershed should be made and possibly greater weight given to the station skews (IACWD, 1982).

The regional skew can be found off of Plate 1 in Bulletin 17B and the MSE can be entered manually. The default MSE for the entire country is 0.302.

Outliers

Outliers are extreme values in a frequency distribution that depart significantly from the trend of the remaining data and can have a disproportionate influence on the mean (NEDARC, 2007). Simply ignoring or deleting these outliers can significantly affect the statistical parameters calculated from the data, especially for small data sets (IACWD, 1982). HEC-SSP allows for the manual identification of high and low outlier thresholds, and also for the default detection and treatment of outliers as outlined in Bulletin 17B (Brunner, 2006).

If the station skew is greater than 0.4, tests for high outliers are considered first. If the station skew is less than -0.4, then tests for low outliers are considered first. If the station skew is between 0.4 and -0.4, then tests for both high and low outliers should be applied removing outliers from the data set (IACWD, 1982).

If the logarithms of peaks in a sample are greater than X_H in equation 8, then they are considered high outliers. Flood peaks that are considered high outliers should be compared with historical data and flood information at nearby sites. If the information

available indicates that the high outlier is a maximum over an extended period of time, then that data should be treated as historic flood data. If information is not available to indicate that the high outlier should be addressed as historic flood data, then the data should be retained as part of the systematic record (IACWD, 1982). The equation to calculate the high outlier threshold is:

$$X_H = \bar{X} + K_N S \quad (8)$$

where,

X_H = high outlier threshold in log units,

\bar{X} = mean logarithm of systematic peaks (X's) excluding zero flood events, peaks below gauge base, and outliers previously detected,

K_N = K value from Appendix 4 of Bulletin 17B for sample size N,

S = standard deviation of X's.

Equation 9 calculates the low outlier threshold. Equation 10 is used to calculate the low outlier threshold for data in which an adjustment for historical flood data has previously been made. If the logarithm of any annual peaks in a sample is less than X_L in equation 9 or 10, then they are considered low outliers and are deleted from the data set and the conditional probability adjustment in Appendix 5 of Bulletin 17B is applied (IACWD, 1982). The low outlier threshold is:

$$X_{.L} = \bar{X} - K_N S \quad (9)$$

where,

X_L = low outlier threshold in log units.

The equation for data that has adjustments made for historical data:

$$X_L = \tilde{M} - K_H \tilde{S} \quad (10)$$

where,

\tilde{M} = historically adjusted mean logarithm,

K_H = K value from Appendix 4 for period used to compute \tilde{M} and \tilde{S} ,

\tilde{S} = historically adjusted standard deviation.

Bulletin 17B analysis and HEC-SSP computations require that all outliers, historical data, personal analyses, and results of data from nearby gauging stations to be well documented. Outliers that lie close to the threshold should be tested for sensitivity of the results to being treated as outliers (IACWD, 1982).

Broken Record

Certain gauging stations may be missing data due to the gauge being removed, damaged or any other reason that would cause it to not record data certain years and therefore put a break in the continuous systematic data. Bulletin 17B recommends analyzing the different record segments as a continuous record with a length equal to both the records combined. The only reason this action would not be taken is if there is a physical change in the watershed that would make the entire record not homogeneous

(IACWD, 1982). It is up to the analyst to investigate the watershed data before assuming both segments.

Incomplete Record

Incomplete records are records in which only some peak flows are missing because they were too low or too high to record or the gauge was out of operation for a short time because of flood damage. Systematic records with incomplete data require different treatment than broken records do (IACWD, 1982). For stations missing data because the flooding was too high, there is usually information available from which a discharge estimate can be made (IACWD, 1982). USGS routinely enters estimates for some gauging stations throughout the state of Arkansas. For crest gauge sites where the bottom of the gauge is not reached in some years, conditional probability adjustment is recommended as outlined in Appendix 5 of Bulletin 17B (IACWD, 1982). HEC-SSP treats incomplete records as outlined by Bulletin 17B.

Zero Flood Years

Some stations are located in arid regions that have no flow for the entire year. The Log Pearson III distribution prohibits the inclusion of zero flood values because the logarithm of zero is negative infinity. Bulletin 17B recommends the conditional probability adjustment for zero flood years as outlined in Appendix 5 of Bulletin 17B.

Historical Data

Historical data is an estimated flood event that occurred before gauging devices began the systematic record. Bulletin 17B outlines a statistical adjustment for this historic data. The underlying assumption to this adjustment is that the data from the

systematic record is representative of the interval between the historic record and the systematic record. Before historical data is used, it is important to evaluate the reliability of the data, the peak discharge magnitude, changes in the watershed conditions over an extended period of time, and the effects of these on the computed frequency curve (IACWD, 1982). HEC-SSP treats historical data in the method outlined by Bulletin 17B (Brunner, 2006).

In a historical data adjustment, the historic data is used to define the historically longer period of years, “H”. The number of events, “Z”, that are known to be the largest in the historically longer period “H” are given a weight of 1.0. The remaining events, “N”, from the systematic record are given a weight calculated by equation 11 (IACWD, 1982). Computations for the weights of the individual year’s data can be calculated directly using the equations:

$$W = \frac{(H - Z)}{(N + L)} \quad (11)$$

$$\tilde{M} = \frac{W\Sigma X + \Sigma X_z}{H - WL} \quad (12)$$

$$\tilde{S}^2 = \frac{W\Sigma(X - \tilde{M})^2 + \Sigma(X_z - \tilde{M})^2}{(H - WL - 1)} \quad (13)$$

$$\tilde{G} = \frac{H - WL}{(H - WL - 1)(H - WL - 2)} \left[\frac{W\Sigma(X - \tilde{M})^3 + \Sigma(X_z - \tilde{M})^3}{\tilde{S}^3} \right] \quad (14)$$

where,

W = systematic record weight,

H = number of years in historic period,

- Z = number of historic peaks including high outliers that have historic information,
- N = record length (years),
- L = number of low values to be excluded, such as: number of zeros, number of incomplete record years (below measurable base), and low outliers which have been identified,
- \tilde{M} = historically adjusted mean,
- X = logarithmic magnitude of systematic peaks excluding zero flood events, peaks below base and high or low outliers,
- X_z = logarithmic magnitude of a historic peak including a high outlier that has historic information,
- \tilde{S} = historically adjusted standard deviation,
- \tilde{G} = historically adjusted skew coefficient.

After adjusting the data, the historically adjusted frequency curve is plotted logarithmically through points established by equation 15.

The historically adjusted plotting positions for the individual flood events are found by using equation 18, in which the historically adjusted order number of each event, “ \tilde{m} ” is computed from equations 16 and 17 (IACWD, 1982). These equations are:

$$\text{Log}Q = \tilde{M} + K\tilde{S} \quad (15)$$

$$\tilde{m} = E \quad \text{when } 1 \leq E \leq Z \quad (16)$$

$$\tilde{m} = WE - (W - 1)(Z + 0.5) \quad \text{when } (Z+1) \leq E \leq (Z+N+L) \quad (17)$$

$$P\tilde{P} = \frac{\tilde{m} - a}{H + 1 - 2a} (100) \quad (18)$$

where,

- \tilde{m} = historically adjusted order number of each event for use in formulas to compute the plotting position on a probability graph,
- E = event number when events are ranked in order from greatest magnitude to smallest magnitude, ranging from 1 to $(Z + N)$,
- $P\tilde{P}$ = plotting position in percent,
- a = constant that is characteristic of a given plotting position formula; for Weibull formula, $a = 0$; for Median formula, $a = 0.3$; and for Hazen formula, $a = 0.5$.

Calculating the historically adjusted skew is then calculated using the method previously outlined in this paper and then weighed with the generalized skew (IACWD, 1982). This process is the same as explained in the skew section of this paper.

HEC-SSP follows this method for data years labeled as historic data in the data downloadable through the USGS website. Some stations report systematic record data that contains both usable historical and unusable regulated data. These sites require all of the usable data to be entered manually. The historical data is isolated by entering beginning and end dates between which the historical data is contained (Brunner, 2006). Bulletin 17B analysis is executed thereafter.

Confidence Limits

How well a sample will predict the total flood population depends on the sample size, its accuracy, and if the underlying distribution is known (IACWD, 1982).

Confidence limits provide a measure of the uncertainty of the estimated exceedance probability of a selected discharge or a measure of the uncertainty of the discharge at a selected exceedance probability (IACWD, 1982). It is recommended to evaluate the data for data points close to the confidence limits after the analysis is completed. Peak flows for the low probability storms sometimes contain a very high difference between the confidence limits, which needs to be evaluated by the analyst. HEC-SSP defaults to 5% and 95% confidence limits. The confidence limits can also be changed to any value and the program will run the 17B analysis with the adjustment included (Brunner, 2006).

Expected Probability

The expected probability is the average of the true probabilities of all magnitude estimates for any specified flood frequency that might be made from successive samples of a specified size (IACWD, 1982). It essentially represents a measure of the central tendency of the spread between confidence limits. Expected probability curves depart from the normal distribution in an attempt to account for uncertainty in application of the curve (IACWD, 1982). Computing the expected probability helps account for the errors in the flood flow collection, which are usually random and greatest during maximum flood flows (IACWD, 1982). Measurement errors are usually random and the variance added is therefore relatively small in comparison to the year-to-year variance in flood flows. Peak flood flows errors for historic events can be very high due to uncertainty of

the stage and stage-discharge relationships (IACWD, 1982). The expected probability of a normal distribution can be calculated using the equation:

$$P_N = \text{prob} \left[t_{N-1} > K_N \left(\frac{N}{N+1} \right)^{1/2} \right] \quad (19)$$

where,

T_{N-1} = the Student's t-statistic with N-1 degrees of freedom,

K_N = standard normal variate of the desired probability of exceedance,

N = sample size.

HEC-SSP calculates both the normal distribution and the expected distribution and labels both respectively on the final graphical and tabular output (Brunner, 2006).

Evaluation of Results

After completing a regional flood flow analysis, the results must be observed and understood. In many cases, the results are compared to previous flood flow studies. Direct comparison of the difference in flood flowrates is a common way to compare equations. Results from this study can be compared to two recently completed studies which are explained more in depth in the following section.

Previous Studies in Arkansas

Flood frequency analyses have been conducted periodically for each state by the USGS using available stream flood flow data. The last such study for Arkansas was conducted by Hodge & Tasker (1995) using the Bulletin 17B method and regression analysis was used to correlate the streams physical and flood characteristics. Their analysis resulted in four sets of regression equations for four different regions of

Arkansas, based on the physiography and drainage boundaries (Hodge & Tasker, 1995). Their analysis included the use of 204 rural stations that had 10 years or more of unregulated records and with drainage areas of less than 7,770 square kilometers and slopes less than 70.3 m/km (Hodge & Tasker, 1995). Of the 204 stations used, 189 were in Arkansas and the other 15 were stations located in Missouri, Oklahoma, and Louisiana. Large rivers such as the Red, Arkansas, White, Black, St. Francis, Mississippi, and Ouachita Rivers were all treated individually as their flood flow characteristics differ from smaller tributary streams (Hodge & Tasker, 1995).

Regions were defined by an analysis of covariance tests using dummy variables that represented subregions (Hodge & Tasker, 1995). The analysis indicated that there were significant differences in the models for the four subregions. The regions defined by Hodge & Tasker (1995) are bounded by major river basin divides. This is helpful because the drainage basin of a smaller stream will not overlap two regions (Hodge & Tasker, 1995).

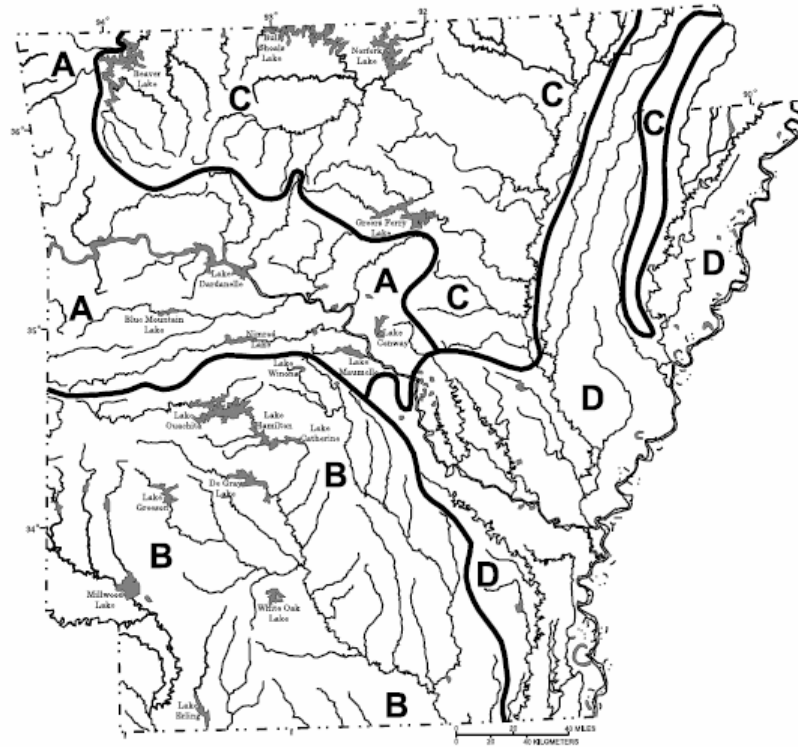


Figure 2 - Regions of Arkansas Defined by Hodge & Tasker (1995)

According to the analysis by Hodge & Tasker (1995), the variables that appeared to be the most significant were drainage area, main channel slope, mean basin elevation, and basin shape factor. The variables and range of values used in each region are reported in Table 1.

Table 1 - Range of Explanatory Variables for Regression Equations in Arkansas

| Hydrologic study region | Drainage area (sq. km) | Main channel slope (m/km) | Mean basin elevation (m) | Basin shape factor |
|-------------------------|------------------------|---------------------------|--------------------------|--------------------|
| Region A | 0.23-1,980 | 0.56-70.3 | -- | -- |
| Region B | 0.13-6,890 | -- | 43.3-381 | 0.058-0.642 |
| Region C | 0.21-5,280 | -- | -- | -- |
| Region D | 0.52-4,530 | 0.086-7.73 | -- | 0.015-0.533 |

Source: Hodge & Tasker, 1995

A region of influence method of analysis was also performed by Hodge & Tasker (1995) as an alternative to the regional flood frequency analysis. This was only used as an alternative because the region of influence method was still being improved.

A second study was performed by Chhibber (2006), who also used four regions within the state. His approach used L-Moments to compute flood flows (Chhibber, 2006).

Flood Frequency Analyses in Surrounding States

Individually conducted flood frequency analyses are available for the surrounding states of Oklahoma, Texas, Tennessee, and Missouri. A range of approaches were taken to find equations that use the physiography as a predictor of flood flows.

Oklahoma

Oklahoma used gauging data from 352 sites with at least 8 years of data in Oklahoma and 25 kilometers into the neighboring states of Arkansas, Kansas, Missouri, New Mexico, and Texas. 162 additional miscellaneous measurement sites or streamflow gauging stations with short records were also used, making a total of 671 measurements. These included gauging stations that were in unregulated basins and basins affected by regulation, urbanization, and irrigation (Tortorelli & McCabe, 2001).

The state of Oklahoma was divided into two regions; east and west. Extreme peak discharges were plotted and a major difference was apparent at roughly the 28-inch mean annual precipitation line, which divides the state into two halves at 98 degrees 15 minutes longitude (Tortorelli & McCabe, 2001). The regions were decided upon by visual inspection.

Drainage area was noted as the most influential basin characteristic. A study was done by Asquith & Slade (1995) which determined that channel length and channel slope were not as important as drainage area. A multi-linear regression analysis was conducted on the data to find regression equations for the two regions. The Bulletin 17B method was used for calculation and distribution of the data and used its guidelines for skew and outliers.

Tennessee

Tennessee used the region of influence method. Data was used from a total of 297 gauging stations within the state and 156 gauging stations in the neighboring states of Georgia, North Carolina, Virginia, Alabama, Kentucky, and Mississippi. All stations were taken from drainage basins with 1 to 30 percent total impervious cover. The drainage basins containing 30 percent total impervious cover were shown to have similar streamflow characteristics to rural drainage basins. The state was divided into four hydrologic regions as outlined by major geographical and hydrologic boundaries (Law & Tasker, 2000).

A computer program was developed for the state that compared the basin characteristics of the different gauging stations in order to find similarities among sites. The program found the most important variables were the contributing drainage area, channel slope, climate slope, and a physiographic-region factor that allows the region of influence method to capture the uniqueness in flood magnitude potential found in the four hydrologic areas (Law & Tasker, 2000).

Aside from using the region of influence method to find a relationship among gauging stations, the rest of the analysis was completed using the Bulletin 17B method.

Multivariable regression equations were used to find a best fit line that matched the distribution among site data.

Missouri

Missouri used a standard regional flood frequency analysis to analyze gauge data from a total of 278 gauging stations having at least 10 years of unregulated data. 230 stations were located in Missouri and the remaining 48 were from the neighboring states of Iowa, Kansas, and Arkansas. No stations in Illinois were used (Alexander and Wilson, 1995). The state was separated into three regions delineated by major physiographic characteristics.

The Bulletin 17B method was used to complete the flood flow frequency analysis for each region. An ordinary least squares regression analysis was used to indicate that drainage area and main channel slope were the significant factors in predicting flood flows. Generalized least square regressions were used to find a best fit curve for the discharge data. The regression was computed by using a computer program called GLSNET that was developed in conjunction with USGS (Alexander and Wilson, 1995).

Texas

Texas used data from 559 stream gauging stations in Texas and 105 stream gauging stations in the neighboring states of Arkansas, Louisiana, New Mexico, and Oklahoma to execute a regional flood flow analysis. The state was separated into 11 different regions delineated on basis of physiography and climate conditions. For 5 of the 11 regions, the relation between the peak discharge frequency and the contributing drainage area were non-linear, which required that one set of equations be made for

drainage areas less than 32 square miles and another set of equations for drainage areas greater than 32 square miles (Sumioka & Kernell, 2001).

The analysis was run using the Bulletin 17B method of analysis. The weighted standard error of prediction ranged greatly among regions.

Flood flow prediction equations were developed for the different regions of Texas using multivariate regression analysis. A computer program was also developed by Asquith and Slade (1999) that constructs a unique set of regression equations for each gauging site. Variables that were found to be significant were contributing drainage area, basin shape factor, and stream slope.

Louisiana

Louisiana used both the regionalization method and the region of influence method. In the final regression equations, the region of influence method was found to produce lower root-mean-square errors than the regionalization model. They used 227 gauging stations within Louisiana and 133 gauging stations 50 miles into the neighboring states of Texas, Arkansas, and Mississippi for a total of 360 gauging stations (Ensminger, 1998). Stations with only 10 years of annual maximum discharge data, and with drainage areas of less than 3,000 square miles were used, bringing the final number of gauging stations used to 303.

The regionalization approach used the Bulletin 17B method to complete the flood flow frequency analysis. The final regression analysis for the regionalization model showed drainage area, channel slope, and mean annual precipitation to be the best variables for prediction equations. Even though the state has four distinct regions; pine

hills, alluvial plains, prairies, and coastal marshes, significant differences were delineated between the pine hills region and the non-pine hill regions.

A summary of the the most recent flood flow frequency studies for the states surrounding Arkansas is included in Table 2.

Table 2 - Summary of Flood Flow Analysis in Surrounding States

| State | Type of Analysis Used | Parameters Used in Flood Prediction Equations | Stations Used | Hydrologic Regions |
|--------------|--|---|----------------------------------|---------------------------|
| Arkansas | Multivariable Regression (Bulletin 17B) Region of Influence Used as alternate | DA - Drainage Area S - Main Channel Slope E - Mean Basin Elevation SH - Basin Shape Factor | 189 In-State 15 Out-of-State | 4 |
| Oklahoma | Multiple Linear Regression with Adjustments (Bulletin 17B) | DA - Drainage Area | 352 In-State 162 Out-of-State | 2 |
| Texas | Regression Analysis within NFF Program (Bulletin 17B) | DA - Drainage Area SH - Basin Shape Factor S - Main-Channel Slope | 559 In-State 105 Out-of-State | 11 |
| Tennessee | Single-Variable and Multi-Variable Regression Analysis (Bulletin 17B) Region of Influence Used as alternative | DA - Drainage Area S - Main-Channel Slope CF - Climate Factor PF - Physiographic Region Factor | 297 In-State 156 Out-of-State | 4 |
| Missouri | Generalized Least Squares Regression (Bulletin 17B) | DA - Drainage Area S - Main-Channel Slope | 230 In-State 48 Out-of-State | 3 |
| Louisiana | Regionalization (Bulletin 17B) Region of Influence Used as alternative | DA - Drainage Area S - Main Channel Slope AP - Mean Annual Precipitation | 227 In-State 133 Out-of-State | 2 |

RESEARCH METHODS

Overview

Performing a regional flood frequency analysis for the state of Arkansas involves many steps. These steps include procuring and screening the data from the gauging stations within the state to eliminate data that has been affected by diversion or regulation and also to eliminate stations that have less than 10 years of recorded data. A Bulletin 17B analysis must then be completed on data from each site to find predicted flood flows and their frequencies using the beta version of HEC-SSP. Finally, a multiple regression analysis must be performed to find prediction equations for the estimated flood flows by relating them to the physiographic characteristics of the gauging station. The following pages summarize the procedures used to complete the estimation of flood flow magnitudes of ungauged streams.

Flood Flow Data

Stream gauging stations solely from Arkansas were used in this study, unlike other states that used data from gauging stations a certain distance into the surrounding states. This decision was made to simplify the study. USGS maintains gauging stations throughout the state which either measure peak flood flows or measure data continuously. Data was taken from the USGS Office of Surface Water website (<http://nwis.waterdata.usgs.gov/usa/nwis/peak>). Flood flow data recorded through the 2006 water year were used. A water year is 12-month period that spans from October 1 to September 30, which is chosen because it is a relatively dry time of year. The total number of USGS stations that were considered in this study was 372. Stations were screened and those that did not have at least 10 years of data unaffected by regulation or

diversion were left out, which brought the actual number of stations down to 258. Furthermore, after discordant sites and sites with watersheds greater than 2750 square miles were taken out, the total number was brought down to 184.

Special attention was given to the side notes posted about each data point from each station on the USGS website. Notes for years that indicated the flood flow was affected by a dam failure, regulation, or an unknown degree of diversion or regulation were noted and deleted from that systematic data set. Discordant sites or peak data were deleted. Discordant sites and data were taken from the recent study completed by Chhibber (2006). The remaining segmented data was then treated as incomplete data as outlined in Bulletin 17B earlier in this paper.

Bulletin 17B Analysis

Data may be entered into HEC-SSP software four different ways: import from another HEC-DSS file, import data from the USGS website, import from a Microsoft Excel™ spreadsheet, or manually enter the data into a table. Data from stations that were completely unregulated or not affected by dam failure were entered into HEC-SSP by downloading the entire data set from the USGS website through the HEC-SSP. Data from stations that were affected by regulation or diversion but still had at least of 10 years of data were entered into HEC-SSP by way of a Microsoft Excel™ spreadsheet or by using the manual data entry option. Any historical data included in the data set was also entered manually using the historic data option in HEC-SSP so that the program could treat it as historical peaks as outlined in Bulletin 17B.

HEC-SSP offers three options for generalized skew, as discussed in the literature review section: station skew, generalized skew, and regional skew. The station skew was used in this study.

HEC-SSP also offers several different plotting positions. The user may specify among the Weibull, Median or Hazen plotting positions. HEC-SSP also allows the user to manually enter the A & B constants. For the purpose of this study, the default Weibull position was used.

HEC-SSP by default calculates the confidence limits at 5 and 95 percent. The user may define their own confidence limits, though for this study, the default values were used.

The result of the Bulletin 17B analysis was a log Pearson III plot, from which the values from the expected probability curve, not the calculated curve, were used for the prediction of the 2, 5, 10, 20, 50, 100, and 500 year storms. A discussion of the expected probability curve is included in the expected probability section of the literature review section. The expected values were used because they are higher and therefore more conservative. These values were recorded in a spreadsheet along side the physiographic data for the same site. This study used the expected probability curve, which is higher and more conservative than the computed probability curve, therefore the default option of computing the expected probability curve was not changed.

HEC-SSP also offers an option to use a manual low outlier threshold. The default is zero, and this default was used in this study. Low and high outliers were left to be calculated using the methods outlined in Bulletin 17B.

The historic data option was used whenever there was data available that was marked as historical data. If the data were to be imported and evaluated using the USGS website data import option, HEC-SSP would not recognize this earmark. Hence, this option was utilized whenever there was historic data in the data record.

Manual recurrence intervals can be specified, though for this study, the defaults were used because they contained the recurrence intervals that were being studied.

Log Pearson III plots were calculated for all available and fit data by using the HEC-SSP software. The program output includes four flood flows for each common recurrence interval (2 year, 5 year, etc.): the lower confidence limit, computed flow, expected flow, and upper confidence limit. The flood flows for the expected flood flow were used in this study because they are a more conservative, or higher, estimate. The flood flows were recorded in a Microsoft Excel™ spreadsheet.

Watershed Data

Physical data was calculated using the Watershed Modeling System (WMS) software, which was previously performed by Chhibber (2006). This data was compared to data provided by USGS and in most cases, the WMS value was used. Precipitation data for each watershed was obtained from Dr. Steve J. Burian, Assistant Professor of Civil and Environmental Engineering, University of Utah, Salt Lake City, Utah (Burian et al. 2007).

Regression Analysis

Before performing a regression analysis on the data, a statistical method known as multivariate analysis was used to find correlations among physiographic data so that redundant variables could be left out of the final regression analysis. JMP statistical

software package was then used to compute a multiple regression analysis for each recurrence interval flow to find an equation relating the peak flow to the physiographic characteristics of the watershed. JMP software can be found at <http://www.jmp.com/>.

The underlying principle of a linear regression is to find a straight line that best fits the data set for which you wish to find a prediction equation. Both stepwise regression and the least sum of squares method were used in this study. In the stepwise regression, all of the physiographic variables were considered for the final equations. A forward stepwise regression was used, which means that the regressor that most improved the fit was brought into the equation based on a specified level of significance. After each step in the stepwise regression, a least squares regression is computed with the given variables.

In a least squares regression, the distance between each data point and the prediction line is squared and the sum of all of the distances from each point to the prediction line is minimized, thus producing a best fit line. Every regression of course also contains a residual. Linear regression analysis assumes that all the prediction variables are independent and the residuals follow a normal distribution (Draper & Smith, 1998). In an effort to compute an equation that properly depicts the mathematics of the flood flow distribution, the logarithm of all data was taken, a least squares regression was computed, and a graph of the residual was analyzed to see if the underlying mathematics were properly modeled.

Preliminary equations were calculated to study how well a regression equation fit the data when using the raw data. The raw data produced regression equations that did not fit well. A plot of the residuals versus the prediction variable should show a random

distribution. The log of the data was taken in an effort to find the correct underlying mathematics.

The residual of the final equations can be measured by several methods. The adjusted coefficient of determination, also known as the R squared statistic, was noted in the analysis. A higher adjusted R squared value indicates a better fit.

The computed error in the final equations was noted and the usability of the aforementioned methods and programs were noted and are included in the results and discussion section.

RESULTS AND DISCUSSION

Overview

Peak streamflow data provided by USGS from 372 stream gauging stations in Arkansas were considered for this study with a final 184 being used in the analysis after screening the data. All watersheds, watershed boundaries, and watershed physiographic data were found using Watershed Modeling Software (WMS). The flood flow frequency analysis for each gauging station was completed using the Bulletin 17B method within the HEC-SSP program. The regression analysis to correlate physiographic watershed characteristics to flood flow quantiles was computed using a stepwise multiple variable regression analysis within JMP statistical software package.

Watershed Modeling

Available watershed data was first obtained from USGS. Many stations did not have associated physiographic data provided by USGS and therefore the WMS values were used for all of the stations. All watershed modeling was completed using WMS by Chhibber (2006). Differences explored in Chhibber's analysis showed that the WMS values in most cases were not significantly different than those provided by USGS. Large differences between the WMS and USGS values were proven to be the error of the USGS data.

Cluster Analysis

Previous flood flow frequency studies for ungauged streams in the state of Arkansas separated the state into several regions and unique prediction equations were found for each region, often using different variables for different regions. Chhibber

(2006) explored different clusters in Arkansas and found no region to be more accurate than when using the state as a whole.

Screening the Data

Data was obtained for all 372 stations and after omitting those stations that did not have at least 10 years of unregulated data only 184 stations remained. A map of the stations used in this study is shown in Figure 3.

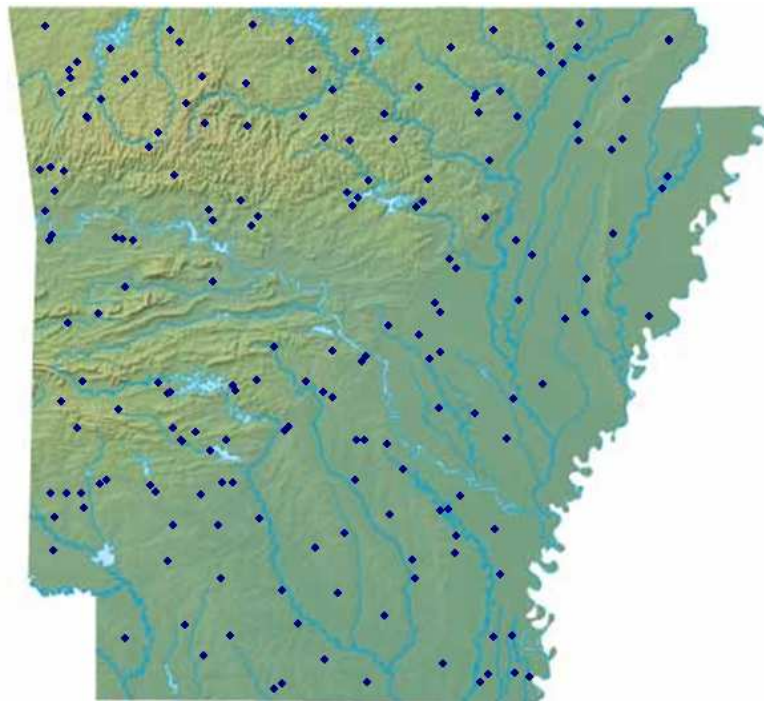


Figure 3 - Location of USGS Stations Used in Study

A previous similar study performed by Chhibber (2006) revealed the presence of several sites that were shown to be grossly discordant from the rest of the state. The extremely different values were evaluated one by one with surrounding sites. If the value

did not correlate with similar high or low events in surrounding stations, or if there was no record of localized extreme events from the National Climatic Data Center (NCDC), that data was deleted from the station and the station was tested again for discordance. Discordancy calculations were ran using a method outlined by Hosking and Wallis (1997). A table of the discordant data is provided in Table 3.

Table 3 - Discordant Sites

| Station Number | Action Taken | Comments |
|-------------------------|---------------------------|--|
| 7047860 | Station Retained | 1200 cfs for August 13, 2002 for a watershed size of 0.95 sq. mi seemed odd. But NCDC website says there was a flash flood in Jonesboro on that date at 6 a.m. Twenty homes and some businesses were flooded. Many roads throughout the city were flooded. |
| 7077680 | Station Retained | Nothing was obvious from the station dataset |
| 7078170 | 92 cfs and 30 cfs deleted | No extreme events (including draught) were reported by NCDC for Arkansas County, AR for December 1970 and July 1972 |
| 7078210 | 645 cfs deleted | No extreme events (including draught) were reported by NCDC for Arkansas County, AR for April 1973. Data point might be erroneous; it appears it could be 64.5 cfs. |
| 7249457 | Station Retained | Nothing was obvious from the station dataset |
| 7257200 | Station Retained | Nothing was obvious from the station dataset. Neighboring stations (7257100 and 7256500) have similar low flows for May 1981. NCDC does not report any extreme event for this period. |
| 7263860 | Station Retained | Neighboring stations (7264100) has similar low flow for May 1971. NCDC does not report any extreme event for this period. |
| 7360150 | 1220 cfs deleted | NCDC does not report any extreme event for this period. 1220 cfs for a watershed area of 0.42 sq. mi. seems erroneous. |
| 7364128 | 750 cfs deleted | No extreme events (including draught) were reported by NCDC for Lincoln County, AR for March 1996 |
| Source: Chhibber (2006) | | |

Bulletin 17B Analysis

After screening and importing the data into HEC-SSP, the program ran the process of fitting the flood flow data to a predictive curve on a log Pearson III plot as outlined by Bulletin 17B. An example of a log Pearson III plot is shown in Figure 4.

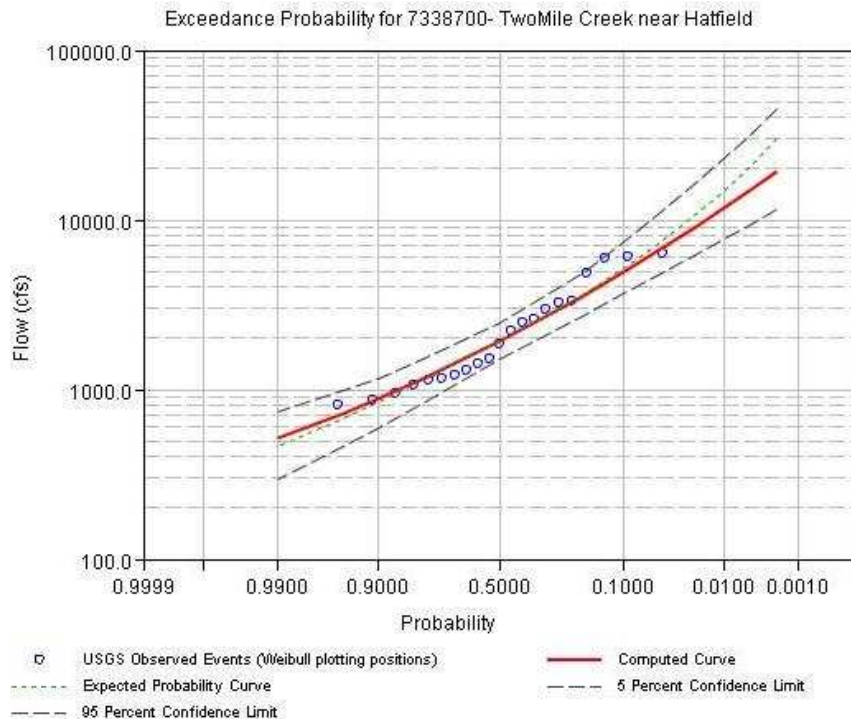


Figure 4 - Pearson Log III plot for station 7338700 from HEC-SSP

Data for stations with no historical data was imported from the USGS Surface Water Website through the HEC-SSP program. The program performed wonderfully in this aspect, although speed performance dropped significantly when 25 or more stations and their data were all stored in the same study file. This problem was avoided by splitting the entire data group into 11 study files.

Data that had regulation or historical data that needed to be analyzed differently or eliminated, respectively, had to be either entered through a Microsoft Excel™ spreadsheet or entered into the program using the manual option. Theoretically the program should have been able to import the data via Microsoft Excel™ spreadsheet, which is simplest, although when the number of data years reached around 15 or 20, the program usually froze upon import. For these larger fragmented data sets, data was entered using the manual option, which creates a metadata file. Format must be in either the dd/mm/yyyy or the ddmmyyyy format in Microsoft Excel™ and it must be in the ddmmyyyy format to be entered into HEC-SSP manually. For example, the 21st of March 1968 must be in the format 21MAR1968 for the program to read the data properly.

A significant downfall in the program was its lack of ability to use data before the year 1900. Every method and combination possible for data entry was attempted and the program read every piece of data from the 1800s as from the year 1900. The US Army Corps of Engineers was notified of the problem in May 2007.

Older data, especially from high flood magnitude events is very useful for the accurate prediction of higher flood flow storm events, so it is unfortunate that this data could not be used. At the same time, however, many of the stations that had data from the 1800s available were on large rivers such as the Mississippi and Arkansas Rivers, both of which were not used in the final analysis because their drainage areas are over 2750 square miles. Ultimately, this problem did not affect the analysis too much, though it is a problem that needs to be fixed if the program is going to be an effective tool for single site analysis.

Physiographic Data

Data for each station used were collected by Chhibber (2006) and used in this study. Table 4 lists each variable and its description. In the regression analysis, these values were regressed with the flood flows for each standard recurrence interval.

Table 4 - List of Variables

| Physical/Hydrologic watershed characteristics | Description |
|--|---|
| Latitude | The global latitude of the gauging station |
| Longitude | The global longitude of the gauging station |
| Station Elevation | The elevation of the gauging station |
| Watershed Area | A topographic area within a line drawn connecting the highest points uphill of a stream gauging station through which overland flow drains. |
| Mean Basin Elevation | Arithmetic average of elevations of all the points inside the watershed area. |
| Basin Length | Length of the basin from the outlet point to the farthest point inside the watershed |
| Basin Slope | Bed slope of the basin order channel, within two points at 10% and 85% of the channel run. |
| Basin Perimeter | Perimeter of the watershed along its boundary. |
| Shape Factor | The ratio of the square of the basin length to the basin area. |
| Max. stream length | The maximum channel flow length along the main channel. |
| Max. stream slope | Bed slope along the max. stream length |
| Overland flow | Sum of sheet flow and shallow concentrated flow (TR-55). |
| North and South facing | Percentage of basin whose aspect is directed towards the north (and south). |
| Average Precipitation | Average measured precipitation as measured at the gauging station |

Regression Analysis

A preliminary regression analysis was completed using the raw physiographic data. The residual versus predicted plot using the raw data shown in Figure 5 appears to be a cone shape that diverges from zero, meaning the underlying mathematics have not been properly identified. The best equation using the raw data computed an adjusted R squared of 0.5731.

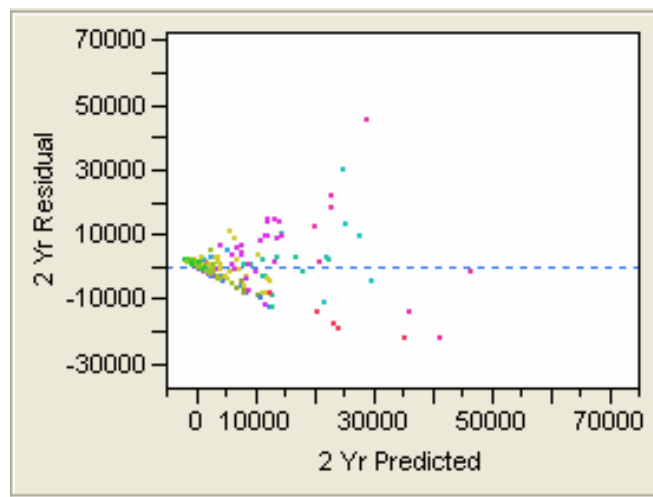


Figure 5 - Residual vs. Preliminary 2 Year Equation Using Raw Data

Figure 6 shows a random distribution of residuals after the logarithm of the data was taken. The random distribution means the equation decently represents the line created from the data computed using the Bulletin 17B method.

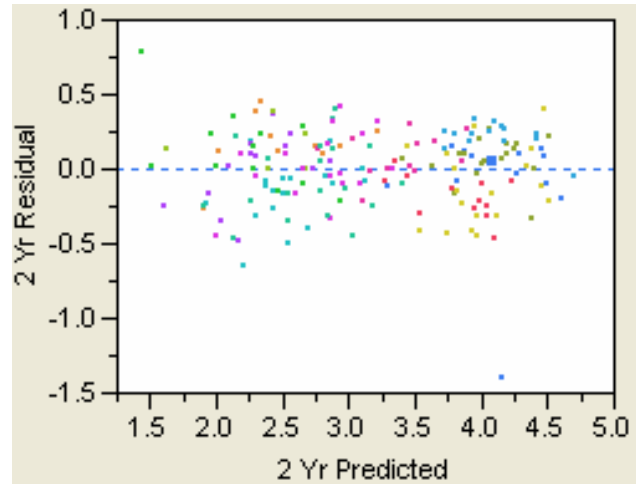


Figure 6 - Residual vs. Preliminary 2 year Equation Using Logged Data

After verifying that a linear regression equation fits well to the logarithm of the data, all of the original data was evaluated using a multivariate analysis. A multivariate analysis compares every data point of one variable with the data point of every other data point in an effort to make any one-to-one relationships among the variables apparent so redundant variables can be eliminated. Figure 7 illustrates the first multivariate analysis completed after taking the log of all of the physiographic data in an effort to identify redundant variables. A close one-to-one relationship appears as a clustering of data in a 45 degree line between the x and y axes.

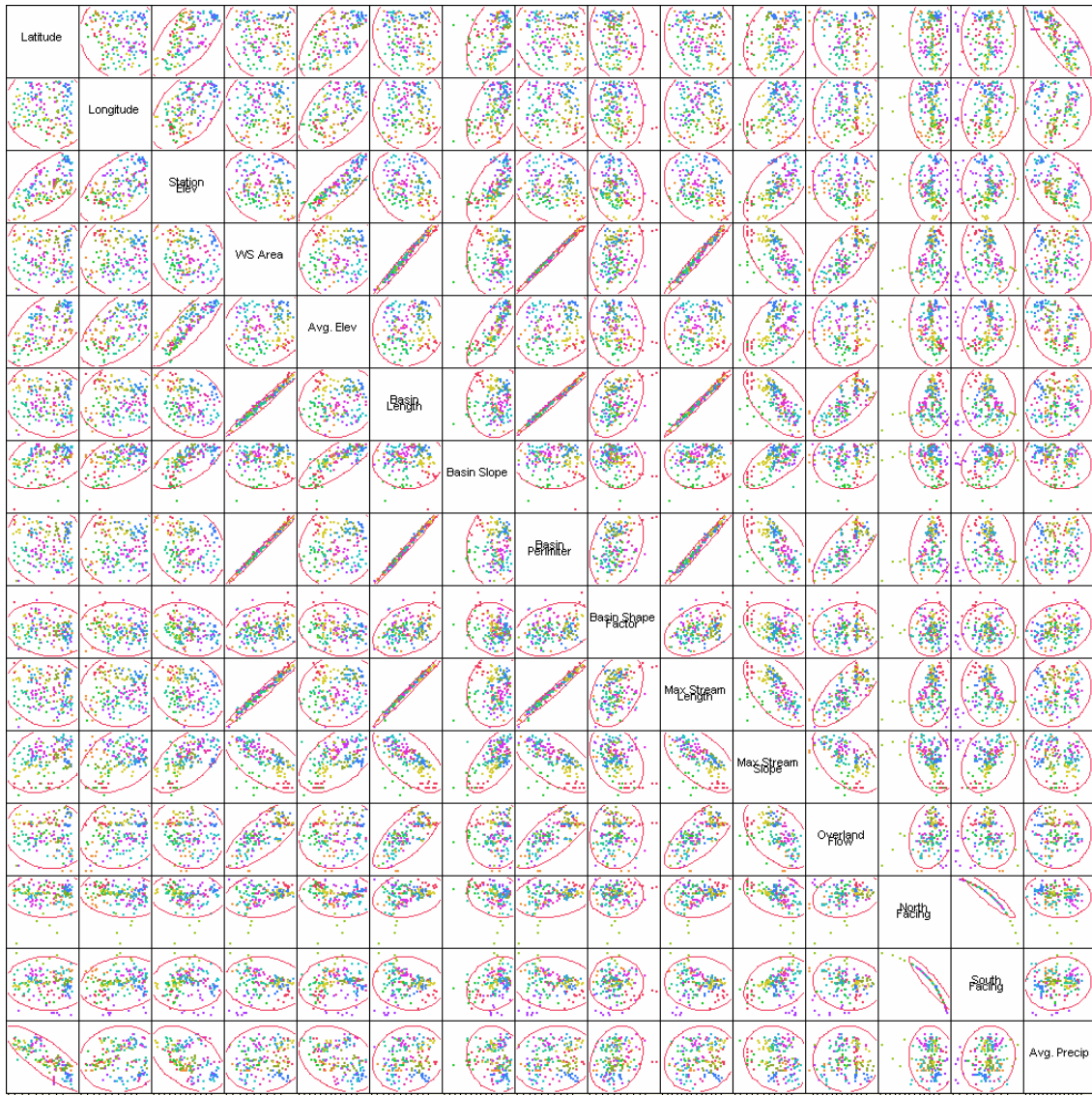


Figure 7 - Complete Multivariate Analysis

Illustrated in Figure 8 is the multivariate analysis of the variables that were determined to be redundant.

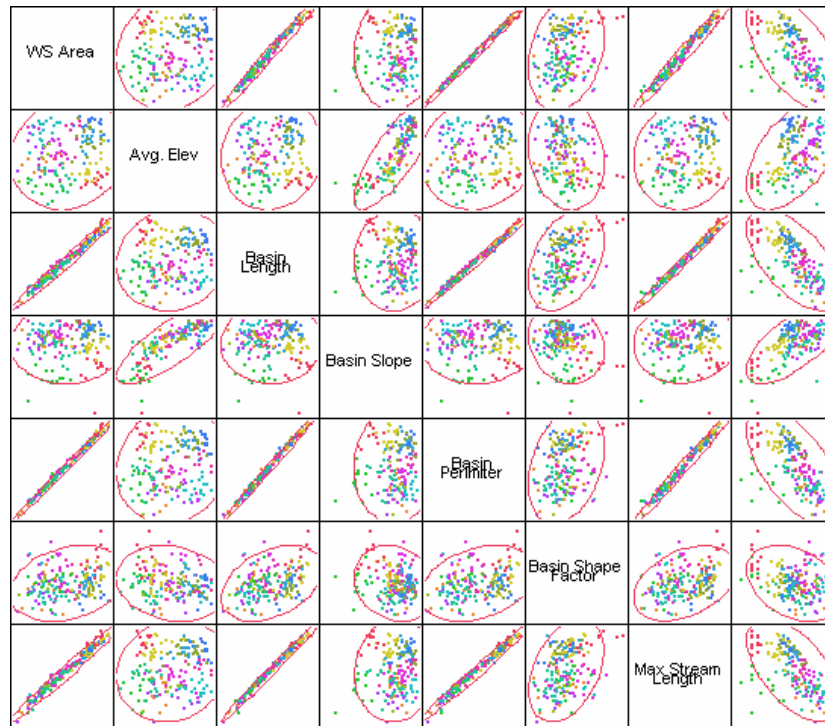


Figure 8 - Multivariate Analysis of Redundant Variables

A strong correlation between watershed area, basin length, basin perimeter, and max stream length is evident. To avoid redundancy in the final regression equation, only watershed area was taken into consideration in the final equations.

The purpose of this study was to create simple prediction equations; therefore several equations were considered comparing accuracy with number of variables to find a good median. All possible regression equations using every combination and number of variables were computed and the best equations using six or less variables are presented in Table 5.

Table 5 - Best Fitting Variables and Associated Errors for the 2 Year Regression

| Num. of variables | Adjusted R squared | Cp | Intercept | Water Shed Area | Basin Slope | Basin Shape Factor | North Facing | Avg. Elev. | Avg. Precip. |
|-------------------|--------------------|--------|-----------|-----------------|-------------|--------------------|--------------|------------|--------------|
| 6 | 0.9140 | 7.00 | 0.782 | 0.660 | 0.179 | -0.397 | -0.450 | 0.229 | 1.233 |
| 5 | 0.9127 | 5.52 | 3.169 | 0.665 | 0.201 | -0.364 | -0.489 | 0.153 | |
| 4 | 0.9141 | 5.65 | 3.614 | 0.668 | 0.270 | -0.373 | -0.450 | | |
| 3 | 0.9105 | 8.21 | 2.892 | 0.658 | 0.290 | -0.352 | | | |
| 2 | 0.9062 | 16.13 | 2.785 | 0.643 | 0.310 | | | | |
| 1 | 0.8652 | 100.33 | 2.366 | 0.651 | | | | | |

A graph of the effect of the number of variables versus the adjusted R squared is illustrated in Figure 9.

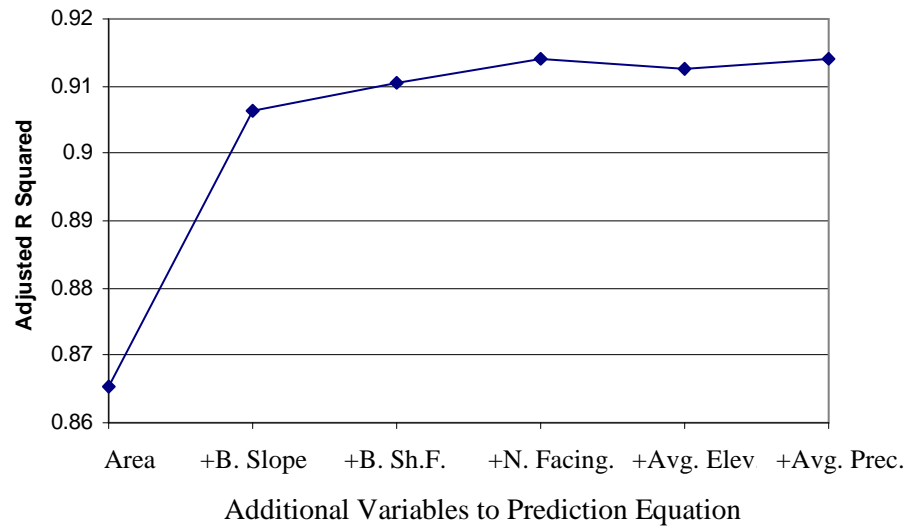


Figure 9 - Adjusted R Squared vs. Variables Used in Prediction Equation

Mallow's Cp is also a good measure of redundancy among the variables in a regression equation. Mallow's Cp value basically is a value that converges to the number of variables in the equation when an accurate regression equation for the given variables

has been reached. A Mallows' Cp value that is close to the number of variables used in the equation indicates a good fit. The final Cp of 8.21 when using three variables is not as good as a Cp of 5.52 when 5 variables, however it does indicate the equation has a fair measure of predictability and the variables share a low level of redundancy. Using five variables would create an equation that is cumbersome to use while not improving the predictive capability of the equation a significant amount. The final prediction equations had no more than three variables because the fourth variable that would have been added, north facing, is not a user-friendly variable to calculate.

Another multivariate analysis was completed using the final three variables to ensure that they were independent of each other and had little redundancy. Figure 10 illustrates that their final analysis showed no strong correlation patterns among them.

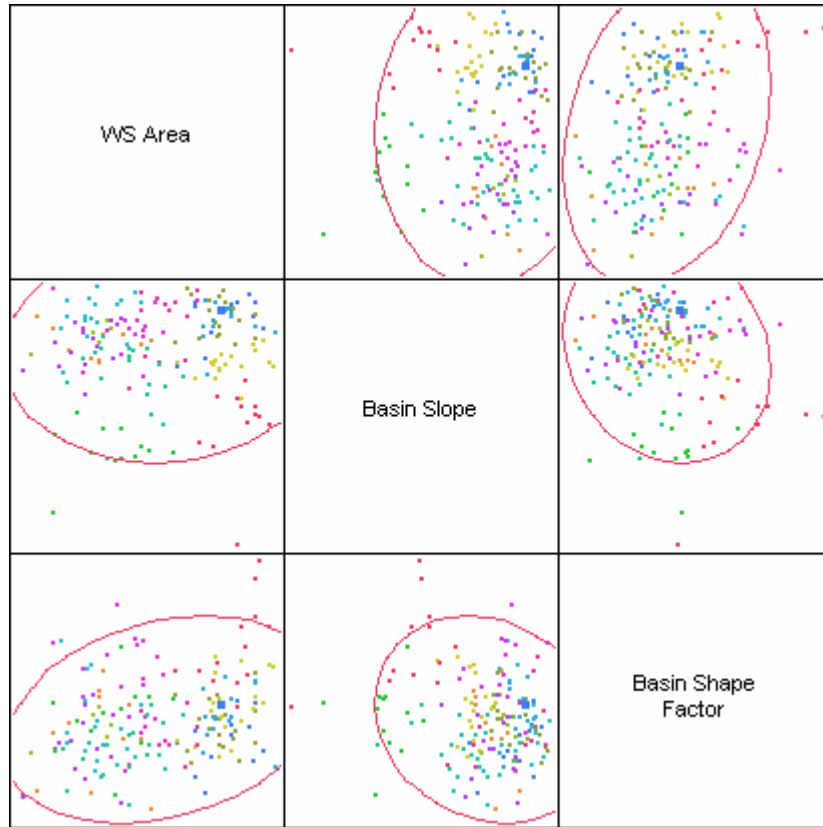


Figure 10 - Multivariate Analysis for Regression Equation Variables

The final regression equations for each of the recurrence intervals for the entire state of Arkansas are shown below. The root mean square error (RMSE) of these regression equations to the LPIII projections are reported in brackets after the equations. It is important to keep in mind that additional error was included from the estimation of the LPIII projections from the actual data, so the overall error of prediction of these equations are even more than shown below.

$$Q_2 = 779A^{0.658}BS^{0.290}SH^{-0.352} \quad [\text{RMSE} = 25.4\%] \quad (20)$$

$$Q_5 = 1676A^{0.649}BS^{0.336}SH^{-0.364} \quad [\text{RMSE} = 23.9\%] \quad (21)$$

$$Q_{10} = 2504A^{0.644}BS^{0.359}SH^{-0.370} \quad [\text{RMSE} = 23.9\%] \quad (22)$$

$$Q_{20} = 3513A^{0.640}BS^{0.378}SH^{-0.375} \quad [\text{RMSE} = 24.6\%] \quad (23)$$

$$Q_{50} = 5204A^{0.634}BS^{0.399}SH^{-0.381} \quad [\text{RMSE} = 26.4\%] \quad (24)$$

$$Q_{100} = 6834A^{0.629}BS^{0.413}SH^{-0.386} \quad [\text{RMSE} = 28.6\%] \quad (25)$$

$$Q_{500} = 12108A^{0.619}BS^{0.440}SH^{-0.394} \quad [\text{RMSE} = 35.7\%] \quad (26)$$

where,

Q = predicted flood flows for the subscripted frequency (cfs),

A = watershed area (sq. mi.),

BS = basin slope (ft/ft),

SH = shape factor (mi²/mi²).

Flood Flow Prediction Equation Comparison

A matter of interest in this study was to observe how grouping the entire state into one region affected the prediction equations. To compare the different equations, 20 stations comprising 11% of the stations used in this study, were chosen and flood flow predictions were made using the equations developed by Hodge & Tasker (1995), Chhibber (2006), and the state-wide equations developed in this study. The LPIII projections originally computed using Bulletin 17B analysis were also compared to the results from this study. Stations were chosen at random until five stations were found for each region. When these five stations had been reached, any successive stations chosen from that region were rejected and another station was chosen until all regions had five stations. This was done in an attempt to give an even cross-section of values produced by the set of four equations developed by Hodge & Tasker and Chhibber.

In order to create the comparison plots, the relative error between the two methods was evaluated. That is, difference of the two flows for the methods being compared was divided by the method being subtracted. For example, the calculated flood flow for a specific station using Chhibber's method had the same calculation using the statewide method (labeled "Q McCall") subtracted from it and then the difference was divided by Q McCall in order to "normalize" the data. A variability chart was chosen to display the data. The box plots shown at every recurrence interval show a middle box composed of three horizontal lines showing from bottom to top: 25th percentile, 50th percentile, otherwise known as the median, and 75th percentile. The "whiskers" at the top and bottom show any outliers and are no longer than 1.5 times the length of the box. The short horizontal dash indicates the cell mean. Figures 11 through 14 show the three different comparisons that were calculated using JMP software. Figure 11 and 12 are graphs of the difference of flows from the statewide equations developed in this study and the methods used by Chhibber and Hodge & Tasker versus the different recurrence intervals. Figure 13 is a graph of the difference of the results from this study and the calculated LPIII values versus the recurrence intervals. Figure 14 is the same as the Figure 13 but the Hodge & Tasker values were used instead of the statewide equations.

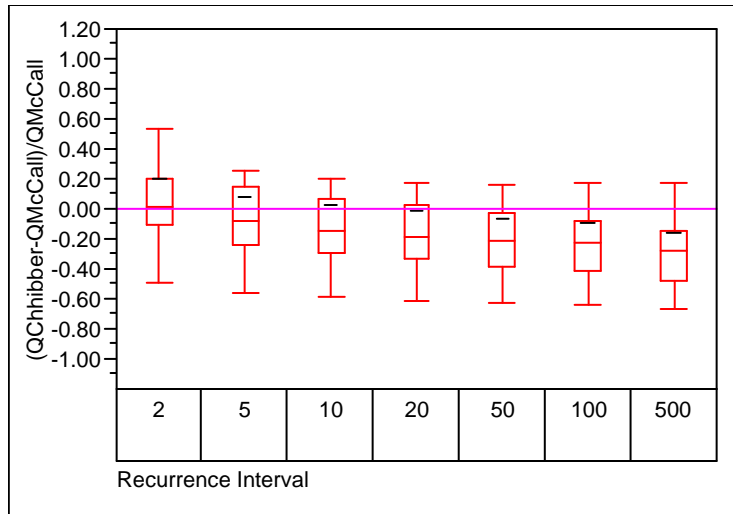


Figure 11 - $(QChhibber-QMcCall)/QMcCall$ vs. Recurrence Interval

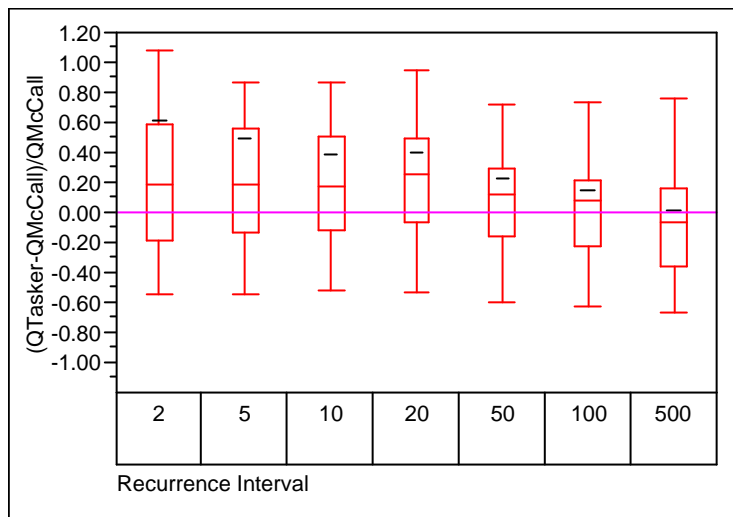


Figure 12 - $(QTASKER-QMcCall)/QMcCall$ vs. Recurrence Interval

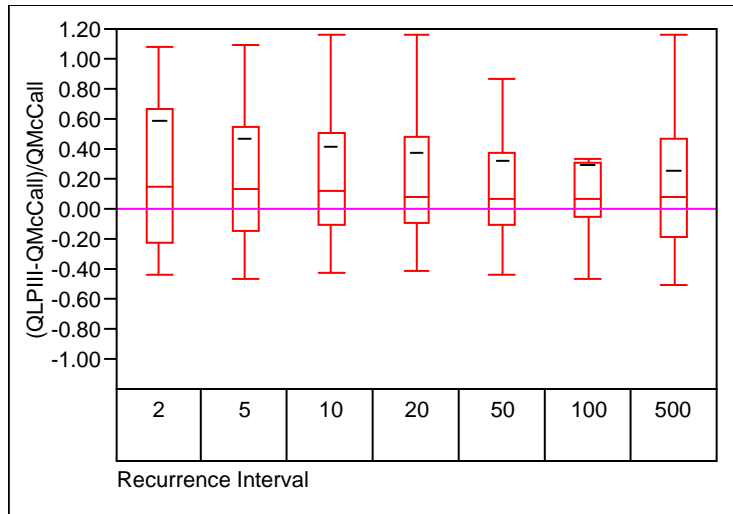


Figure 13 - $(\text{QLPIII}-\text{QMcCall})/\text{QMcCall}$ vs. Recurrence Interval

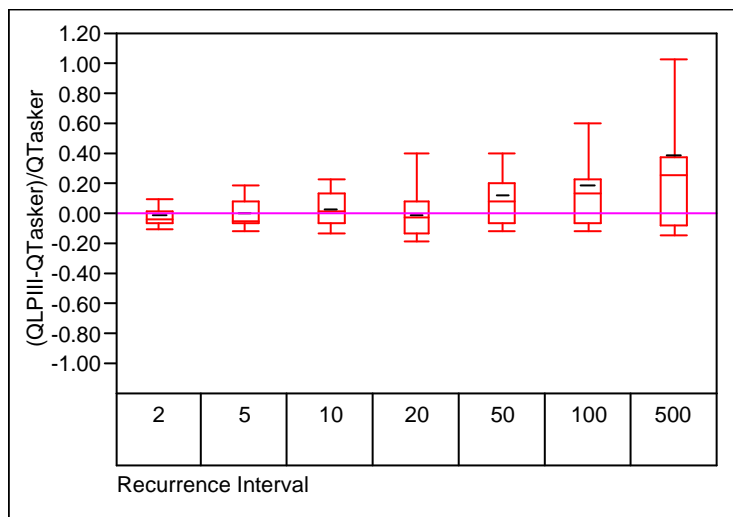


Figure 14 - $(\text{QLPIII}-\text{QHodge\&Tasker})/\text{QHodge\&Tasker}$ vs. Recurrence Interval

The most notable trend visible in the Figure 11 is the slow and linear decrease below zero of the mean. This indicates that, on average, Chhibber's method resulted in larger values than the statewide equations for the first three recurrence intervals and smaller values for the last four values. The first recurrence interval has an especially large spread of differences. Although the median is zero, meaning that the statewide values are

equally split – half more than Chhibber and half less than Chhibber; the mean is positive, meaning that on average Chhibber’s method yielded more conservative values. The median grew more negative and the 25th to 75th percentile range decreased as the recurrence interval grew, meaning that the statewide method calculated more conservative flows for the higher interval flows.

A comparison with the Hodge & Tasker method shows a much more evenly spaced distribution across the graph. The two methods differed most in the first recurrence interval, though there was a much wider spread of values for Hodge & Tasker and the statewide flows for the all of the recurrence intervals. This indicates that the behavior of the statewide equations is similar to Hodge & Tasker’s equations, regardless of the wide distribution of differences. This is probably because Hodge & Tasker used the same Bulletin 17B method. The large differences are probably due to the fact that they grouped streams that looked alike and responded alike, while the statewide equations averaged all different behaving streams within the state. As far as flow values go, Hodge & Tasker’s method yielded a higher average of results since the mean is above zero for every interval.

Comparison of the statewide equations to the LPIII values, flow values as close to actual flood flows as possible, shows a mean that is always positive – between about 25% and 60% more positive as compared to the statewide equations. While the mean is close to zero, the results show variability with the distribution lying more on the high side. This means that whenever the difference between the two methods diverges from zero, the state-wide equations more often than not underestimate the LPIII values. This is favorable because the LPIII values sometimes underestimate the higher recurrence

intervals. This is because the LPIII projection has to give equal importance to the error for the lower recurrence interval storms as to the high ones, which can pull down the projection and greatly decrease the higher projected storm flood flows, but at the very least makes them slightly less than actual.

The comparison shown in Figure 14 of the LPIII values and Hodge & Tasker's values is shown because Hodge & Tasker used similar methods as were used in this method and the effect of regionalization is the largest difference between the two methods. Comparing Figure 13 to Figure 14, the statewide method yielded a mean that, aside from the 500 year storm, was consistently higher than Hodge & Tasker's method, meaning that Hodge & Tasker's regionalization of the state into four regions resulted in more conservative answers than the statewide equations. The smaller boxes and "whiskers" for the smaller floods indicate that Hodge & Tasker also resulted in values with less variability of differences. For the 2 to 20 year storms, the mean was nearly zero and the variability low for the 2 to 10 year storms, meaning both give similar answers for those intervals. For the higher recurrence intervals, Hodge & Tasker resulted in results that were often less than the LPIII projections.

Conclusion

One of the objectives of this study was to evaluate the performance of the new program HEC-SSP released by the U.S. Corps of Engineers which uses the Bulletin 17B method on compute flood flow data. The program ran well, completing the Bulletin 17B computation on many stations without problems. The program lacks the ability to process data from before the year 1900. It also has problems with reopening a study when it already has saved several stations stations and their associated computed data.

Lastly, performance dropped off dramatically when more than 25 or so stations were in the study. Once these problems have been addressed, HEC-SSP will be a valuable tool for the hydrologic community.

Even though the more conservative values were taken from the Bulletin 17B analysis and were used for the final regression analysis, it appears that the equations built from this analysis are generally less conservative than those developed from Hodge & Tasker's study and for the first year or two of Chhibber's method. The resulting equations calculate values that will always underestimate the true behavior of the more extreme behaving streams in the state. This is because the state-wide equations averages in milder behaving streams with the extreme behaving streams since no regions were used to separate watersheds into regions of similar behaving streams. Taken as a whole, the statewide equations developed in this study more often than not underestimate the LPIII values.

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APPENDIX A: DATA

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|--------|--------|--------|--------|--------|--------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7046600 | 213.15 | 2121.92 | 287.63 | 0.0058 | 6.44 | 13,675 | 21,889 | 27,615 | 33,266 | 40,765 | 46,545 | 60,463 |
| | | | | | | 14,041 | 21,742 | 27,467 | 33,572 | 42,158 | 49,119 | 69,108 |
| 7047200 | 219.52 | 0.18 | 220.07 | 0.0005 | 3.13 | 168 | 200 | 215 | 227 | 240 | 248 | 262 |
| | | | | | | 19 | 28 | 36 | 43 | 55 | 65 | 94 |
| 7047820 | 270.27 | 1.36 | 327.59 | 0.0361 | 3.33 | 497 | 772 | 977 | 1,192 | 1,503 | 1,763 | 2,474 |
| | | | | | | 238 | 433 | 594 | 776 | 1,063 | 1,322 | 2,114 |
| 7047823 | 270.34 | 0.36 | 313.15 | 0.0474 | 2.61 | 139 | 221 | 281 | 342 | 429 | 500 | 690 |
| | | | | | | 117 | 219 | 304 | 403 | 560 | 704 | 1,152 |
| 7047860 | 289.63 | 0.9 | 325.94 | 0.0368 | 1.34 | 420 | 644 | 862 | 1,150 | 1,714 | 2,367 | 5,493 |
| | | | | | | 252 | 464 | 642 | 844 | 1,166 | 1,461 | 2,364 |
| 7047880 | 329.06 | 0.09 | 388.22 | 0.1222 | 1.35 | 44 | 83 | 129 | 197 | 346 | 528 | 1,453 |
| | | | | | | 78 | 155 | 223 | 304 | 436 | 562 | 961 |
| 7047924 | 192.78 | 0.5 | 202.03 | 0.0082 | 2.66 | 107 | 209 | 304 | 424 | 635 | 851 | 1,651 |
| | | | | | | 87 | 149 | 199 | 254 | 340 | 417 | 648 |
| 7047942 | 192.52 | 531.86 | 253.24 | 0.012 | 3.76 | 5,786 | 10,617 | 14,989 | 20,283 | 29,212 | 37,840 | 66,954 |
| | | | | | | 8,430 | 13,755 | 17,850 | 22,303 | 28,768 | 34,188 | 49,953 |
| 7047950 | 166.68 | 780.45 | 242.3 | 0.0063 | 4.07 | 8,228 | 12,933 | 16,254 | 19,574 | 24,057 | 27,572 | 36,259 |
| | | | | | | 8,753 | 13,804 | 17,608 | 21,691 | 27,526 | 32,343 | 46,235 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|--------|--------|---------|---------|---------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7047975 | 461.83 | 1.18 | 1941.34 | 0.2835 | 2.66 | 204 | 406 | 574 | 762 | 1,047 | 1,295 | 2,002 |
| | | | | | | 427 | 856 | 1,234 | 1,680 | 2,408 | 3,089 | 5,240 |
| 7047990 | 390.04 | 0.69 | 1499.41 | 0.1193 | 3.2 | 177 | 405 | 606 | 837 | 1,189 | 1,495 | 2,346 |
| | | | | | | 219 | 422 | 598 | 802 | 1,130 | 1,435 | 2,388 |
| 7048000 | 1232 | 82.84 | 1702.89 | 0.1567 | 2.41 | 8,679 | 16,783 | 23,659 | 31,475 | 43,552 | 54,262 | 85,605 |
| | | | | | | 6,110 | 11,471 | 15,983 | 21,173 | 29,225 | 36,420 | 58,315 |
| 7048600 | 1138.25 | 398.44 | 1687 | 0.1713 | 2.52 | 24,249 | 45,490 | 64,022 | 85,673 | 120,427 | 152,397 | 251,674 |
| | | | | | | 17,350 | 32,229 | 44,633 | 58,843 | 80,589 | 99,746 | 157,544 |
| 7048900 | 1279.92 | 1.11 | 1375.02 | 0.0445 | 1.63 | 144 | 278 | 419 | 612 | 988 | 1,405 | 3,150 |
| | | | | | | 285 | 527 | 731 | 964 | 1,333 | 1,671 | 2,709 |
| 7048940 | 1477.16 | 22.41 | 1913.75 | 0.1737 | 2.17 | 2,986 | 6,155 | 9,018 | 12,451 | 18,097 | 23,437 | 40,676 |
| | | | | | | 2,763 | 5,281 | 7,428 | 9,917 | 13,835 | 17,388 | 28,310 |
| 7049000 | 1168.06 | 264.68 | 1610.16 | 0.1458 | 3.08 | 13,193 | 22,093 | 28,341 | 34,507 | 42,634 | 48,856 | 63,630 |
| | | | | | | 11,788 | 21,763 | 30,052 | 39,524 | 54,016 | 66,775 | 105,270 |
| 7049500 | 1006.47 | 1026.76 | 1571.5 | 0.121 | 1.82 | 24,758 | 47,280 | 64,419 | 82,457 | 107,569 | 127,752 | 177,644 |
| | | | | | | 32,792 | 59,673 | 81,752 | 106,840 | 144,720 | 177,699 | 276,142 |
| 7050200 | 1336.31 | 2.81 | 1647.55 | 0.1721 | 1.74 | 609 | 1,350 | 2,036 | 2,868 | 4,241 | 5,539 | 9,684 |
| | | | | | | 760 | 1,483 | 2,110 | 2,843 | 4,020 | 5,110 | 8,507 |
| 7050285 | 1294.68 | 82.02 | 1883.9 | 0.1819 | 1.55 | 9,853 | 17,637 | 23,707 | 30,277 | 39,947 | 48,167 | 71,027 |
| | | | | | | 7,404 | 14,072 | 19,726 | 26,265 | 36,466 | 45,642 | 73,642 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|---------|---------|---------|---------|---------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7050400 | 1012.11 | 0.74 | 1347.68 | 0.106 | 2 | 192 | 331 | 443 | 566 | 754 | 920 | 1,411 |
| | | | | | | 261 | 504 | 713 | 956 | 1,348 | 1,713 | 2,849 |
| 7050500 | 963.1 | 527.34 | 1583.19 | 0.1768 | 3.22 | 16,513 | 29,435 | 39,944 | 51,549 | 68,980 | 84,020 | 126,407 |
| | | | | | | 19,315 | 35,737 | 49,384 | 64,993 | 88,791 | 109,658 | 172,523 |
| 7054400 | 717.34 | 3.42 | 1035.93 | 0.1919 | 2.44 | 1,109 | 2,011 | 2,897 | 4,054 | 6,233 | 8,587 | 18,376 |
| | | | | | | 792 | 1,545 | 2,197 | 2,959 | 4,181 | 5,308 | 8,822 |
| 7054450 | 455.71 | 0.85 | 1031.8 | 0.1982 | 2.13 | 269 | 434 | 541 | 639 | 759 | 844 | 1,028 |
| | | | | | | 336 | 665 | 954 | 1,293 | 1,845 | 2,362 | 3,988 |
| 7055000 | 419.66 | 6057.68 | 1272.08 | 0.1046 | 1.59 | 72,177 | 123,815 | 165,653 | 212,479 | 284,775 | 349,439 | 544,526 |
| | | | | | | 105,995 | 188,867 | 255,810 | 331,255 | 442,950 | 538,351 | 819,535 |
| 7055550 | 1158.66 | 4.23 | 1280.6 | 0.0552 | 2.03 | 582 | 1,109 | 1,641 | 2,348 | 3,698 | 5,169 | 11,292 |
| | | | | | | 677 | 1,248 | 1,724 | 2,268 | 3,121 | 3,894 | 6,253 |
| 7055608 | 1088.54 | 409.11 | 1104.63 | 0.1232 | 2.3 | 582 | 1,109 | 1,641 | 2,348 | 3,698 | 5,169 | 11,292 |
| | | | | | | 16,569 | 30,342 | 41,719 | 54,677 | 74,397 | 91,688 | 143,600 |
| 7055650 | 1132.67 | 8.32 | 1880.3 | 0.2382 | 2.88 | 1,446 | 3,451 | 5,348 | 7,662 | 11,457 | 15,012 | 26,058 |
| | | | | | | 1,428 | 2,785 | 3,958 | 5,330 | 7,517 | 9,523 | 15,757 |
| 7055800 | 832.74 | 6.1 | 1466.59 | 0.2419 | 1.86 | 1,078 | 2,331 | 3,538 | 5,062 | 7,731 | 10,406 | 19,908 |
| | | | | | | 1,364 | 2,683 | 3,832 | 5,178 | 7,338 | 9,334 | 15,553 |
| 7056000 | 560.35 | 828.62 | 1466.92 | 0.2271 | 2.49 | 38,247 | 68,992 | 92,283 | 116,441 | 150,013 | 176,883 | 244,528 |
| | | | | | | 30,611 | 57,236 | 79,493 | 105,063 | 144,121 | 178,442 | 281,949 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|---------|---------|---------|---------|---------|-----------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7057000 | 451.98 | 1096 | 1356.34 | 0.1763 | 3.12 | 36,772 | 69,371 | 97,208 | 129,116 | 179,077 | 223,954 | 358,172 |
| | | | | | | 31,581 | 58,062 | 79,951 | 104,926 | 142,736 | 175,658 | 274,393 |
| 7057300 | 721.57 | 0.76 | 846.67 | 0.071 | 4.32 | 279 | 470 | 610 | 755 | 956 | 1,119 | 1,538 |
| | | | | | | 181 | 338 | 472 | 626 | 872 | 1,096 | 1,793 |
| 7059000 | 432.67 | 1612.53 | 1001.56 | 0.0883 | 1.98 | 25,445 | 43,172 | 54,885 | 65,944 | 79,629 | 89,342 | 109,893 |
| | | | | | | 39,102 | 69,777 | 94,642 | 122,675 | 164,543 | 200,613 | 307,511 |
| 7060500 | 316.38 | 9963.82 | 1192.07 | 0.0947 | 1.39 | 119,402 | 194,814 | 252,835 | 314,981 | 406,031 | 483,228 | 697,458 |
| | | | | | | 149,803 | 264,947 | 357,435 | 461,370 | 614,312 | 744,229 | 1,125,506 |
| 7060600 | 569.94 | 1.24 | 707.49 | 0.0998 | 1.82 | 224 | 429 | 667 | 1,024 | 1,818 | 2,820 | 4,433 |
| | | | | | | 373 | 714 | 1,007 | 1,348 | 1,893 | 2,397 | 3,963 |
| 7060670 | 621.12 | 3.25 | 840.32 | 0.1143 | 1.21 | 835 | 1,323 | 1,734 | 2,214 | 3,004 | 3,758 | 6,315 |
| | | | | | | 844 | 1,621 | 2,288 | 3,063 | 4,300 | 5,441 | 8,971 |
| 7060710 | 434.99 | 58.43 | 950.17 | 0.2653 | 1.99 | 4,313 | 9,445 | 13,671 | 18,234 | 24,705 | 29,960 | 43,197 |
| | | | | | | 6,052 | 11,704 | 16,553 | 22,201 | 31,086 | 39,132 | 63,873 |
| 7060830 | 988.74 | 0.24 | 1054.55 | 0.0298 | 2.14 | 59 | 127 | 184 | 246 | 336 | 412 | 608 |
| | | | | | | 84 | 155 | 214 | 281 | 388 | 487 | 790 |
| 7061000 | 237.72 | 11056.4 | 1139.92 | 0.0595 | 2.02 | 136,013 | 216,862 | 277,985 | 342,675 | 436,300 | 514,807 | 729,413 |
| | | | | | | 122,908 | 211,631 | 281,692 | 359,583 | 472,776 | 567,688 | 844,405 |
| 7061100 | 339.33 | 3.76 | 462.03 | 0.0715 | 2.24 | 787 | 1,475 | 2,069 | 2,762 | 3,878 | 4,912 | 8,190 |
| | | | | | | 653 | 1,216 | 1,691 | 2,235 | 3,093 | 3,873 | 6,266 |

| Station Identificat- ion Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|--|--------------------------|----------------------|------------------------------------|---------------------------|---|---|---------|---------|---------|---------|---------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7068870 | 404.59 | 0.18 | 460.64 | 0.0874 | 2.34 | 136 | 202 | 257 | 319 | 420 | 515 | 830 |
| | | | | | | 92 | 178 | 253 | 339 | 480 | 612 | 1,025 |
| 7068890 | 258.66 | 229.23 | 497.65 | 0.0741 | 2.69 | 15,673 | 29,931 | 41,298 | 53,729 | 72,100 | 87,638 | 130,414 |
| | | | | | | 9,243 | 16,589 | 22,589 | 29,365 | 39,632 | 48,599 | 75,419 |
| 7069250 | 560.66 | 0.48 | 666.28 | 0.1028 | 1.66 | 239 | 418 | 583 | 783 | 1,127 | 1,465 | 2,632 |
| | | | | | | 208 | 403 | 572 | 768 | 1,087 | 1,384 | 2,314 |
| 7069290 | 609.26 | 2.28 | 767.48 | 0.1058 | 1.86 | 533 | 999 | 1,415 | 1,915 | 2,753 | 3,564 | 6,322 |
| | | | | | | 562 | 1,073 | 1,511 | 2,018 | 2,827 | 3,572 | 5,878 |
| 7069500 | 254.07 | 1161.47 | 743.98 | 0.0643 | 2.93 | 24,994 | 45,370 | 62,156 | 80,846 | 109,142 | 133,724 | 203,595 |
| | | | | | | 25,037 | 43,954 | 59,141 | 76,148 | 101,421 | 123,066 | 187,061 |
| 7072000 | 291.98 | 1117.18 | 854.86 | 0.0647 | 4.15 | 10,921 | 21,285 | 31,426 | 44,379 | 67,390 | 90,631 | 173,428 |
| | | | | | | 21,629 | 37,836 | 50,821 | 65,340 | 86,875 | 105,263 | 159,644 |
| 7072200 | 390.55 | 1.26 | 467.51 | 0.0339 | 3.52 | 601 | 836 | 993 | 1,149 | 1,358 | 1,524 | 1,944 |
| | | | | | | 218 | 395 | 541 | 707 | 967 | 1,202 | 1,919 |
| 7072500 | 229.56 | 7461.54 | 752.35 | 0.0713 | 1.74 | 39,906 | 66,359 | 86,937 | 109,097 | 141,684 | 169,367 | 246,207 |
| | | | | | | 105,390 | 183,962 | 246,590 | 316,592 | 419,197 | 506,000 | 760,221 |
| 7073000 | 406.56 | 215.31 | 730.44 | 0.071 | 3.38 | 9,045 | 14,943 | 19,515 | 24,431 | 31,656 | 37,795 | 54,854 |
| | | | | | | 8,083 | 14,449 | 19,634 | 25,481 | 34,325 | 42,031 | 65,073 |
| 7073500 | 420.62 | 99.61 | 678.03 | 0.0645 | 2.67 | 4,522 | 8,438 | 11,989 | 16,264 | 23,373 | 30,126 | 52,097 |
| | | | | | | 5,144 | 9,244 | 12,599 | 16,391 | 22,169 | 27,247 | 42,480 |

| Station Identificat- ion Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|--|--------------------------|----------------------|------------------------------------|---------------------------|---|---|---------|---------|---------|---------|---------|-----------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7074000 | 298.07 | 471.9 | 666.57 | 0.0547 | 2.42 | 14,092 | 25,422 | 35,181 | 46,471 | 64,387 | 80,669 | 130,240 |
| | | | | | | 14,127 | 24,875 | 33,535 | 43,243 | 57,777 | 70,332 | 107,567 |
| 7074200 | 560.7 | 1.19 | 639.83 | 0.0511 | 2.03 | 618 | 1,027 | 1,254 | 1,438 | 1,622 | 1,732 | 1,901 |
| | | | | | | 288 | 534 | 741 | 978 | 1,354 | 1,699 | 2,757 |
| 7074250 | 270.47 | 35.61 | 432.81 | 0.0582 | 3.36 | 2,885 | 5,895 | 8,906 | 12,867 | 20,260 | 28,169 | 59,927 |
| | | | | | | 2,340 | 4,213 | 5,750 | 7,489 | 10,155 | 12,513 | 19,619 |
| 7074500 | 194.09 | 19957.9 | 949.74 | 0.0665 | 1.44 | 106,423 | 178,117 | 238,350 | 307,344 | 416,742 | 516,470 | 824,602 |
| | | | | | | 210,915 | 364,572 | 486,060 | 621,358 | 817,625 | 982,059 | 1,460,475 |
| 7074550 | 265.78 | 5.96 | 274.03 | 0.0024 | 3.31 | 211 | 512 | 846 | 1,315 | 2,252 | 3,313 | 7,926 |
| | | | | | | 288 | 455 | 582 | 719 | 921 | 1,096 | 1,605 |
| 7074855 | 204.13 | 1.6 | 212.7 | 0.0051 | 2.85 | 310 | 492 | 640 | 806 | 1,069 | 1,311 | 2,080 |
| | | | | | | 159 | 264 | 346 | 436 | 572 | 693 | 1,051 |
| 7074865 | 388.05 | 8.37 | 553.57 | 0.0565 | 2.21 | 1,192 | 2,794 | 4,318 | 6,202 | 9,379 | 12,421 | 22,398 |
| | | | | | | 1,037 | 1,898 | 2,615 | 3,430 | 4,701 | 5,844 | 9,321 |
| 7074900 | 1083.2 | 0.32 | 1294.69 | 0.1925 | 2.35 | 94 | 167 | 218 | 267 | 331 | 379 | 485 |
| | | | | | | 169 | 337 | 485 | 660 | 946 | 1,215 | 2,069 |
| 7074950 | 1352.49 | 1.55 | 1511.98 | 0.0752 | 2.11 | 308 | 671 | 983 | 1,335 | 1,865 | 2,324 | 3,590 |
| | | | | | | 378 | 711 | 995 | 1,321 | 1,841 | 2,318 | 3,790 |
| 7075000 | 483.12 | 302.07 | 1274.87 | 0.1448 | 2.78 | 21,659 | 40,202 | 56,539 | 75,748 | 106,774 | 135,433 | 224,754 |
| | | | | | | 13,304 | 24,556 | 33,902 | 44,581 | 60,907 | 75,275 | 118,590 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|--------|--------|---------|---------|---------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7075300 | 481.11 | 148.28 | 1138.89 | 0.14 | 3.28 | 9,337 | 17,403 | 24,224 | 31,987 | 44,051 | 54,809 | 86,652 |
| | | | | | | 7,782 | 14,406 | 19,924 | 26,236 | 35,936 | 44,515 | 70,472 |
| 7075500 | 430.02 | 316.32 | 1171.73 | 0.1801 | 2.48 | 22,314 | 35,406 | 44,388 | 53,237 | 64,918 | 73,974 | 95,759 |
| | | | | | | 15,209 | 28,382 | 39,399 | 52,044 | 71,459 | 88,617 | 140,497 |
| 7075600 | 483.12 | 1.32 | 681.53 | 0.06 | 2.99 | 252 | 485 | 708 | 991 | 1,492 | 1,999 | 3,828 |
| | | | | | | 281 | 523 | 727 | 961 | 1,330 | 1,668 | 2,708 |
| 7075800 | 725.13 | 0.2 | 824.93 | 0.0589 | 2.03 | 50 | 102 | 147 | 201 | 285 | 362 | 593 |
| | | | | | | 93 | 176 | 247 | 330 | 463 | 587 | 973 |
| 7076000 | 261.78 | 1148.74 | 1061.19 | 0.1293 | 2.16 | 54,711 | 74,816 | 87,088 | 98,267 | 111,957 | 121,846 | 143,752 |
| | | | | | | 33,886 | 61,663 | 84,473 | 110,391 | 149,484 | 183,459 | 284,893 |
| 7076630 | 281.85 | 0.69 | 333.51 | 0.0322 | 1.53 | 230 | 372 | 455 | 526 | 603 | 653 | 743 |
| | | | | | | 194 | 356 | 491 | 644 | 888 | 1,111 | 1,795 |
| 7076820 | 224.4 | 4.96 | 305.21 | 0.0345 | 3.06 | 790 | 1,155 | 1,413 | 1,675 | 2,040 | 2,340 | 3,136 |
| | | | | | | 568 | 1,017 | 1,386 | 1,803 | 2,448 | 3,025 | 4,774 |
| 7076850 | 194.54 | 164.89 | 294.79 | 0.0333 | 2.9 | 6,340 | 11,281 | 14,910 | 18,647 | 23,802 | 27,873 | 38,029 |
| | | | | | | 5,747 | 9,963 | 13,334 | 17,089 | 22,714 | 27,578 | 41,996 |
| 7076870 | 209.97 | 23.05 | 257.26 | 0.0165 | 1.67 | 2,021 | 3,997 | 5,511 | 7,073 | 9,199 | 10,864 | 14,886 |
| | | | | | | 1,560 | 2,683 | 3,580 | 4,575 | 6,084 | 7,407 | 11,337 |
| 7077100 | 329.39 | 12.82 | 409.08 | 0.0633 | 1.15 | 2,898 | 4,218 | 4,989 | 5,659 | 6,426 | 6,945 | 7,974 |
| | | | | | | 1,786 | 3,299 | 4,564 | 6,010 | 8,267 | 10,306 | 16,503 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|--------|--------|--------|--------|--------|--------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7077200 | 340.09 | 1.61 | 417.82 | 0.0741 | 4.24 | 388 | 574 | 690 | 797 | 927 | 1,020 | 1,224 |
| | | | | | | 301 | 563 | 783 | 1,036 | 1,437 | 1,802 | 2,928 |
| 7077340 | 374.25 | 0.67 | 460.06 | 0.0773 | 2.57 | 276 | 456 | 587 | 721 | 907 | 1,057 | 1,442 |
| | | | | | | 204 | 388 | 544 | 725 | 1,014 | 1,282 | 2,112 |
| 7077380 | 222.99 | 697 | 301.59 | 0.0205 | 5.31 | 4,317 | 5,633 | 6,584 | 7,563 | 8,953 | 10,097 | 13,167 |
| | | | | | | 10,418 | 17,308 | 22,662 | 28,525 | 37,072 | 44,252 | 65,241 |
| 7077430 | 255.23 | 0.19 | 259.35 | 0.0043 | 1.97 | 34 | 61 | 88 | 123 | 187 | 253 | 507 |
| | | | | | | 42 | 71 | 95 | 120 | 159 | 195 | 302 |
| 7077500 | 182.96 | 1141.4 | 274.96 | 0.0079 | 10.24 | 6,060 | 8,870 | 10,984 | 13,220 | 16,462 | 19,183 | 26,636 |
| | | | | | | 8,674 | 13,624 | 17,340 | 21,322 | 26,975 | 31,589 | 44,929 |
| 7077555 | 164.17 | 1280.55 | 266.42 | 0.0074 | 12.07 | 5,473 | 8,147 | 9,643 | 10,901 | 12,258 | 13,115 | 14,628 |
| | | | | | | 8,664 | 13,527 | 17,163 | 21,052 | 26,552 | 31,022 | 43,936 |
| 7077860 | 168.19 | 11.45 | 178.21 | 0.0028 | 3.35 | 351 | 473 | 532 | 576 | 619 | 643 | 679 |
| | | | | | | 461 | 729 | 933 | 1,152 | 1,476 | 1,753 | 2,561 |
| 7077920 | 194.65 | 30.95 | 207.66 | 0.0027 | 3.24 | 524 | 748 | 864 | 955 | 1,047 | 1,102 | 1,195 |
| | | | | | | 887 | 1,389 | 1,768 | 2,174 | 2,767 | 3,269 | 4,725 |
| 7078000 | 175.14 | 177.92 | 213.11 | 0.0031 | 3.89 | 2,449 | 4,081 | 5,179 | 6,233 | 7,573 | 8,562 | 10,762 |
| | | | | | | 2,737 | 4,236 | 5,356 | 6,551 | 8,265 | 9,689 | 13,795 |
| 7078170 | 188.87 | 3.46 | 197.03 | 0.0052 | 5.34 | 186 | 216 | 236 | 256 | 284 | 306 | 366 |
| | | | | | | 213 | 348 | 454 | 568 | 741 | 890 | 1,334 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|--------|--------|--------|--------|---------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7188900 | 1000.42 | 1.14 | 1159.3 | 0.1731 | 2.5 | 109 | 306 | 486 | 692 | 990 | 1,234 | 1,828 |
| | | | | | | 370 | 725 | 1,034 | 1,396 | 1,981 | 2,525 | 4,230 |
| 7194800 | 1030.84 | 167.35 | 1301.78 | 0.0756 | 1.86 | 10,501 | 24,311 | 37,032 | 52,374 | 77,392 | 100,611 | 172,638 |
| | | | | | | 8,606 | 15,574 | 21,296 | 27,782 | 37,665 | 46,358 | 72,421 |
| 7194890 | 1119.37 | 38.56 | 1292.54 | 0.0299 | 2.15 | 1,536 | 3,517 | 5,399 | 7,723 | 11,632 | 15,393 | 27,721 |
| | | | | | | 2,379 | 4,173 | 5,622 | 7,243 | 9,706 | 11,871 | 18,332 |
| 7195000 | 1052 | 128.99 | 1277.9 | 0.0379 | 1.34 | 5,481 | 10,515 | 14,527 | 18,849 | 25,088 | 30,272 | 44,005 |
| | | | | | | 6,661 | 11,751 | 15,868 | 20,485 | 27,470 | 33,583 | 51,765 |
| 7195200 | 1076.87 | 0.38 | 1279.01 | 0.0449 | 2.2 | 50 | 124 | 200 | 297 | 470 | 643 | 1,253 |
| | | | | | | 127 | 237 | 329 | 435 | 605 | 761 | 1,245 |
| 7247000 | 569.53 | 202.72 | 871.68 | 0.1035 | 2.76 | 11,055 | 19,238 | 25,370 | 31,759 | 40,714 | 48,008 | 66,875 |
| | | | | | | 9,307 | 16,978 | 23,307 | 30,503 | 41,482 | 51,131 | 80,149 |
| 7249447 | 430.28 | 9.99 | 518.29 | 0.0405 | 2.49 | 1,679 | 2,397 | 2,814 | 3,179 | 3,598 | 3,883 | 4,447 |
| | | | | | | 1,014 | 1,823 | 2,488 | 3,239 | 4,400 | 5,437 | 8,570 |
| 7249457 | 479.88 | 1.01 | 563.98 | 0.0643 | 3.37 | 465 | 550 | 592 | 626 | 661 | 683 | 723 |
| | | | | | | 231 | 431 | 600 | 794 | 1,103 | 1,385 | 2,257 |
| 7249490 | 759.01 | 92.32 | 1509.31 | 0.1889 | 2.51 | 8,213 | 17,587 | 25,634 | 34,817 | 48,897 | 61,202 | 96,218 |
| | | | | | | 6,829 | 12,912 | 18,053 | 23,986 | 33,209 | 41,462 | 66,629 |
| 7249500 | 850.07 | 34.91 | 1395.66 | 0.1783 | 4.28 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | | | | | | 2,935 | 5,548 | 7,759 | 10,310 | 14,295 | 17,872 | 28,832 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|--------|--------|--------|--------|---------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7249650 | 864.99 | 8.35 | 1405.29 | 0.1767 | 3.06 | 1,305 | 2,539 | 3,523 | 4,590 | 6,138 | 7,436 | 10,892 |
| | | | | | | 1,285 | 2,470 | 3,485 | 4,665 | 6,535 | 8,242 | 13,521 |
| 7249950 | 843.52 | 0.33 | 992.89 | 0.1194 | 2.13 | 37 | 101 | 169 | 257 | 412 | 564 | 1,069 |
| | | | | | | 155 | 303 | 432 | 583 | 827 | 1,056 | 1,776 |
| 7250000 | 408.04 | 437.8 | 1119.63 | 0.1498 | 2.22 | 24,184 | 41,509 | 53,869 | 66,174 | 82,524 | 95,114 | 125,192 |
| | | | | | | 18,565 | 34,298 | 47,365 | 62,302 | 85,104 | 105,154 | 165,496 |
| 7251790 | 456.23 | 72.2 | 1654.47 | 0.2306 | 1.78 | 8,528 | 16,487 | 23,825 | 32,923 | 48,774 | 64,764 | 123,111 |
| | | | | | | 6,946 | 13,340 | 18,799 | 25,139 | 35,075 | 44,044 | 71,532 |
| 7255100 | 400 | 4.92 | 460.6 | 0.0158 | 1.75 | 828 | 1,577 | 2,077 | 2,539 | 3,084 | 3,442 | 4,114 |
| | | | | | | 548 | 954 | 1,281 | 1,646 | 2,206 | 2,705 | 4,198 |
| 7255500 | 379.87 | 17.56 | 533.76 | 0.0339 | 2.09 | 760 | 1,495 | 2,072 | 2,690 | 3,573 | 4,291 | 6,144 |
| | | | | | | 1,485 | 2,639 | 3,581 | 4,640 | 6,265 | 7,707 | 12,039 |
| 7256000 | 352.6 | 53.08 | 500.8 | 0.0352 | 1.72 | 3,143 | 5,151 | 6,625 | 8,163 | 10,351 | 12,154 | 16,995 |
| | | | | | | 3,329 | 5,883 | 7,953 | 10,277 | 13,812 | 16,922 | 26,211 |
| 7257000 | 487.66 | 273.22 | 1441.97 | 0.2583 | 2.06 | 19,438 | 36,917 | 51,908 | 69,136 | 96,175 | 120,506 | 193,419 |
| | | | | | | 16,369 | 31,168 | 43,707 | 58,221 | 80,708 | 100,760 | 161,789 |
| 7257100 | 446.24 | 0.25 | 553.59 | 0.0868 | 5.62 | 49 | 93 | 129 | 170 | 233 | 287 | 444 |
| | | | | | | 84 | 160 | 225 | 301 | 422 | 535 | 887 |
| 7257200 | 348 | 155.26 | 1081.23 | 0.1887 | 2.45 | 8,516 | 11,547 | 13,125 | 14,394 | 15,711 | 16,530 | 17,958 |
| | | | | | | 9,693 | 18,247 | 25,449 | 33,745 | 46,581 | 58,012 | 92,758 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|--------|--------|--------|--------|--------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7257500 | 447.54 | 241.54 | 1260.19 | 0.2109 | 2.31 | 16,755 | 29,575 | 40,209 | 52,173 | 70,588 | 86,867 | 134,536 |
| | | | | | | 13,670 | 25,780 | 35,981 | 47,740 | 65,902 | 82,046 | 131,062 |
| 7257700 | 467.38 | 7.02 | 859.18 | 0.1079 | 5.47 | 793 | 2,049 | 2,931 | 3,717 | 4,541 | 5,041 | 5,806 |
| | | | | | | 810 | 1,513 | 2,106 | 2,786 | 3,854 | 4,817 | 7,775 |
| 7258200 | 698.42 | 0.92 | 825.35 | 0.117 | 4.47 | 192 | 348 | 480 | 631 | 870 | 1,086 | 1,742 |
| | | | | | | 234 | 448 | 631 | 844 | 1,185 | 1,500 | 2,480 |
| 7258500 | 423.39 | 240.63 | 745.93 | 0.0909 | 2.12 | 12,087 | 19,445 | 24,301 | 28,871 | 34,592 | 38,758 | 47,988 |
| | | | | | | 11,010 | 19,997 | 27,390 | 35,781 | 48,554 | 59,767 | 93,395 |
| 7260630 | 381.55 | 1.84 | 536.78 | 0.1093 | 2.26 | 457 | 872 | 1,199 | 1,549 | 2,051 | 2,469 | 3,566 |
| | | | | | | 460 | 879 | 1,239 | 1,655 | 2,321 | 2,934 | 4,836 |
| 7263400 | 357.77 | 15.01 | 563.52 | 0.1849 | 2.7 | 2,064 | 4,081 | 5,823 | 7,828 | 10,965 | 13,781 | 22,158 |
| | | | | | | 2,002 | 3,840 | 5,413 | 7,239 | 10,123 | 12,745 | 20,833 |
| 7263580 | 270.52 | 20.51 | 471.6 | 0.076 | 4.08 | 3,394 | 5,532 | 7,196 | 9,009 | 11,727 | 14,095 | 20,974 |
| | | | | | | 1,643 | 3,001 | 4,128 | 5,410 | 7,394 | 9,161 | 14,526 |
| 7263590 | 351.84 | 0.97 | 480.6 | 0.0793 | 2.78 | 641 | 879 | 1,042 | 1,208 | 1,439 | 1,630 | 2,150 |
| | | | | | | 256 | 483 | 677 | 901 | 1,258 | 1,586 | 2,604 |
| 7263860 | 205.49 | 2.69 | 213.77 | 0.0021 | 1.31 | 378 | 504 | 562 | 605 | 644 | 664 | 691 |
| | | | | | | 227 | 364 | 468 | 581 | 751 | 899 | 1,332 |
| 7263910 | 257.25 | 2.4 | 322.05 | 0.0382 | 2.81 | 619 | 866 | 1,037 | 1,208 | 1,446 | 1,638 | 2,142 |
| | | | | | | 374 | 678 | 930 | 1,215 | 1,662 | 2,065 | 3,294 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|--------|---------|---------|---------|---------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7264000 | 199.11 | 199.14 | 315.72 | 0.0353 | 4.21 | 2,064 | 4,081 | 5,823 | 7,828 | 10,965 | 13,781 | 22,158 |
| | | | | | | 5,804 | 10,027 | 13,395 | 17,141 | 22,735 | 27,548 | 41,813 |
| 7264050 | 239 | 85.89 | 290.9 | 0.0218 | 2.07 | 1,320 | 2,257 | 3,153 | 4,319 | 6,515 | 8,952 | 19,559 |
| | | | | | | 3,726 | 6,398 | 8,525 | 10,884 | 14,424 | 17,496 | 26,584 |
| 7264100 | 217.67 | 8.38 | 234.14 | 0.0031 | 2.14 | 890 | 1,266 | 1,461 | 1,616 | 1,772 | 1,867 | 2,022 |
| | | | | | | 452 | 725 | 934 | 1,160 | 1,496 | 1,786 | 2,634 |
| 7265001 | 256.33 | 635.68 | 255.62 | 0.012 | 4.68 | 3,330 | 4,779 | 5,715 | 6,599 | 7,725 | 8,565 | 10,513 |
| | | | | | | 8,777 | 14,260 | 18,465 | 23,030 | 29,634 | 35,147 | 51,173 |
| 7338700 | 937.49 | 16.02 | 1294.23 | 0.2 | 4.85 | 1,933 | 3,606 | 5,207 | 7,252 | 10,970 | 14,858 | 30,042 |
| | | | | | | 1,739 | 3,323 | 4,675 | 6,241 | 8,708 | 10,940 | 17,825 |
| 7339500 | 318.24 | 187.74 | 838.04 | 0.1084 | 2.47 | 14,766 | 27,752 | 39,265 | 52,993 | 75,714 | 97,339 | 168,827 |
| | | | | | | 9,326 | 17,082 | 23,500 | 30,809 | 41,986 | 51,835 | 81,489 |
| 7339800 | 396.03 | 6.24 | 561.28 | 0.0726 | 5.79 | 655 | 1,202 | 1,658 | 2,178 | 2,988 | 3,715 | 5,938 |
| | | | | | | | | | | | | |
| 7340000 | 272.89 | 2679.39 | 828.7 | 0.077 | 1.7 | 45,197 | 69,847 | 88,507 | 108,334 | 137,272 | 161,740 | 229,655 |
| | | | | | | 55,382 | 97,939 | 132,208 | 170,705 | 227,822 | 276,739 | 421,007 |
| 7340200 | 306.67 | 10.66 | 416.1 | 0.0135 | 1.9 | 1,618 | 2,718 | 3,458 | 4,169 | 5,069 | 5,736 | 7,211 |
| | | | | | | 847 | 1,451 | 1,933 | 2,467 | 3,279 | 3,994 | 6,120 |
| 7340300 | 771.88 | 89.28 | 1318.02 | 0.2552 | 2.09 | 14,308 | 23,839 | 30,331 | 36,594 | 44,607 | 50,587 | 64,232 |
| | | | | | | 7,774 | 14,942 | 21,063 | 28,174 | 39,306 | 49,335 | 80,072 |

| Station Identificat- ion Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|--|--------------------------|----------------------|------------------------------------|---------------------------|---|---|--------|--------|--------|---------|---------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7340500 | 335.48 | 361.93 | 924.04 | 0.1505 | 2.63 | 27,840 | 47,690 | 64,343 | 83,394 | 113,545 | 141,005 | 225,845 |
| | | | | | | 15,452 | 28,544 | 39,421 | 51,853 | 70,846 | 87,551 | 137,885 |
| 7340530 | 336.34 | 0.67 | 393.96 | 0.0258 | 4.37 | 191 | 354 | 480 | 612 | 798 | 949 | 1,339 |
| | | | | | | 123 | 221 | 302 | 392 | 535 | 664 | 1,057 |
| 7341000 | 353.09 | 120.24 | 787.33 | 0.0925 | 3.56 | 9,712 | 19,298 | 28,067 | 38,681 | 56,407 | 73,337 | 128,992 |
| | | | | | | 5,841 | 10,618 | 14,554 | 19,022 | 25,849 | 31,855 | 49,941 |
| 7341100 | 389.54 | 9.31 | 598.02 | 0.0914 | 2.73 | 2,146 | 4,648 | 6,650 | 8,778 | 11,714 | 14,059 | 19,707 |
| | | | | | | 1,187 | 2,214 | 3,078 | 4,068 | 5,622 | 7,025 | 11,319 |
| 7341700 | 289.09 | 11.74 | 352.66 | 0.0175 | 2.11 | 2,026 | 3,635 | 5,168 | 7,130 | 10,723 | 14,518 | 29,664 |
| | | | | | | 937 | 1,622 | 2,171 | 2,783 | 3,715 | 4,536 | 6,988 |
| 7344320 | 259.02 | 1.4 | 294.56 | 0.021 | 1.55 | 283 | 499 | 634 | 754 | 889 | 979 | 1,144 |
| | | | | | | 272 | 485 | 661 | 858 | 1,167 | 1,446 | 2,293 |
| 7348615 | 214.57 | 226.76 | 309.85 | 0.026 | 3.26 | 4,142 | 9,347 | 14,709 | 21,986 | 36,056 | 51,806 | 120,214 |
| | | | | | | 6,330 | 10,804 | 14,345 | 18,264 | 24,087 | 29,080 | 43,808 |
| 7348630 | 308.31 | 0.05 | 324.62 | 0.0271 | 1.29 | 23 | 45 | 66 | 94 | 144 | 196 | 396 |
| | | | | | | 35 | 65 | 91 | 120 | 168 | 212 | 350 |
| 7349430 | 234.36 | 233.37 | 322.78 | 0.0284 | 1.89 | 3,256 | 6,715 | 9,742 | 13,265 | 18,828 | 23,881 | 39,121 |
| | | | | | | 8,018 | 13,827 | 18,454 | 23,597 | 31,275 | 37,903 | 57,469 |
| 7355800 | 704.15 | 0.66 | 1198.29 | 0.0862 | 3.29 | 182 | 290 | 377 | 474 | 623 | 756 | 1,154 |
| | | | | | | 192 | 364 | 512 | 682 | 955 | 1,208 | 1,992 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|---------|---------|---------|---------|---------|-----------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7355900 | 678.46 | 0.18 | 1223.95 | 0.2645 | 5.51 | 35 | 64 | 98 | 151 | 271 | 429 | 1,381 |
| | | | | | | 94 | 189 | 274 | 374 | 539 | 694 | 1,191 |
| 7356000 | 655.14 | 413.55 | 1137.21 | 0.1367 | 3.28 | 22,679 | 36,287 | 46,264 | 56,521 | 70,820 | 82,362 | 112,084 |
| | | | | | | 15,178 | 27,807 | 38,241 | 50,127 | 68,205 | 84,025 | 131,580 |
| 7356500 | 612.05 | 60.95 | 871.67 | 0.1249 | 3.11 | 6,799 | 11,771 | 15,484 | 19,344 | 24,742 | 29,131 | 40,456 |
| | | | | | | 4,274 | 7,938 | 11,002 | 14,512 | 19,942 | 24,779 | 39,474 |
| 7356700 | 602.86 | 1.85 | 747.97 | 0.0827 | 4.93 | 422 | 886 | 1,322 | 1,863 | 2,792 | 3,707 | 6,864 |
| | | | | | | 323 | 605 | 843 | 1,116 | 1,548 | 1,942 | 3,156 |
| 7357000 | 404.16 | 1095.56 | 950.16 | 0.0917 | 3.82 | 45,038 | 75,336 | 99,401 | 126,280 | 168,004 | 205,756 | 323,022 |
| | | | | | | 24,324 | 43,291 | 58,650 | 75,945 | 101,780 | 123,988 | 189,986 |
| 7357501 | 421.1 | 1100.63 | 949 | 0.0921 | 3.9 | 41,420 | 69,670 | 93,226 | 120,519 | 164,864 | 206,911 | 347,312 |
| | | | | | | 24,251 | 43,157 | 58,467 | 75,704 | 101,451 | 123,580 | 189,342 |
| 7357700 | 656.55 | 3.87 | 804.94 | 0.111 | 1.63 | 645 | 1,348 | 1,985 | 2,748 | 3,996 | 5,166 | 8,882 |
| | | | | | | 845 | 1,613 | 2,269 | 3,029 | 4,238 | 5,348 | 8,774 |
| 7359500 | 228.05 | 1581.4 | 810.36 | 0.061 | 3.12 | 74,684 | 140,116 | 211,055 | 314,859 | 545,151 | 846,858 | 2,690,061 |
| | | | | | | 29,548 | 51,566 | 69,167 | 88,830 | 117,917 | 142,713 | 215,840 |
| 7359520 | 249.97 | 2.85 | 502.46 | 0.0994 | 7.92 | 272 | 707 | 1,213 | 1,954 | 3,497 | 5,321 | 13,780 |
| | | | | | | 384 | 717 | 998 | 1,320 | 1,829 | 2,290 | 3,710 |
| 7359610 | 577.81 | 132.05 | 963.1 | 0.1912 | 2.72 | 19,168 | 36,244 | 52,536 | 73,415 | 111,522 | 151,939 | 312,941 |
| | | | | | | 8,431 | 15,883 | 22,163 | 29,399 | 40,607 | 50,597 | 80,993 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|--------|--------|---------|---------|---------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7359700 | 514.41 | 201.96 | 935.43 | 0.1817 | 2.67 | 20,952 | 38,555 | 52,598 | 67,858 | 90,269 | 109,253 | 161,245 |
| | | | | | | 11,059 | 20,711 | 28,808 | 38,115 | 52,460 | 65,187 | 103,778 |
| 7359710 | 565.92 | 8.64 | 750.75 | 0.084 | 5.68 | 2,240 | 3,952 | 5,238 | 6,590 | 8,509 | 10,076 | 14,194 |
| | | | | | | 852 | 1,570 | 2,170 | 2,854 | 3,921 | 4,878 | 7,803 |
| 7359750 | 607.24 | 2.26 | 749.55 | 0.0848 | 2.54 | 813 | 1,702 | 2,445 | 3,273 | 4,502 | 5,556 | 8,423 |
| | | | | | | 469 | 884 | 1,236 | 1,642 | 2,286 | 2,875 | 4,691 |
| 7359800 | 394.85 | 301.53 | 843.25 | 0.1489 | 4.02 | 26,034 | 40,884 | 51,514 | 62,343 | 77,316 | 89,397 | 120,563 |
| | | | | | | 11,765 | 21,648 | 29,841 | 39,189 | 53,454 | 65,969 | 103,703 |
| 7359805 | 448.77 | 7.72 | 715.97 | 0.1476 | 2.35 | 967 | 2,704 | 4,894 | 8,354 | 16,315 | 26,832 | 86,721 |
| | | | | | | 1,271 | 2,432 | 3,425 | 4,576 | 6,400 | 8,065 | 13,204 |
| 7360800 | 337.29 | 119.65 | 581.88 | 0.0678 | 1.96 | 10,792 | 18,902 | 25,632 | 33,235 | 45,034 | 55,569 | 87,004 |
| | | | | | | 6,565 | 11,848 | 16,183 | 21,091 | 28,577 | 35,169 | 54,941 |
| 7361000 | 324.28 | 381.89 | 784.03 | 0.1238 | 2.73 | 26,873 | 52,673 | 76,145 | 104,906 | 154,164 | 202,957 | 375,617 |
| | | | | | | 14,929 | 27,306 | 37,523 | 49,154 | 66,846 | 82,346 | 128,898 |
| 7361200 | 281.07 | 142.45 | 410.35 | 0.0237 | 2.31 | 7,241 | 12,813 | 17,356 | 22,407 | 30,081 | 36,796 | 56,196 |
| | | | | | | 5,123 | 8,780 | 11,684 | 14,903 | 19,712 | 23,864 | 36,126 |
| 7361500 | 229.33 | 178.83 | 540.4 | 0.0922 | 2.76 | 12,335 | 18,332 | 22,191 | 25,798 | 30,318 | 33,631 | 41,089 |
| | | | | | | 8,288 | 15,055 | 20,625 | 26,947 | 36,585 | 45,050 | 70,486 |
| 7361600 | 182.13 | 1071.17 | 553.64 | 0.0559 | 2.98 | 32,729 | 61,934 | 86,324 | 114,432 | 159,027 | 200,186 | 329,777 |
| | | | | | | 22,658 | 39,544 | 53,053 | 68,144 | 90,528 | 109,669 | 166,180 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|--------|--------|--------|--------|--------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7361680 | 290.81 | 1.46 | 359.4 | 0.0499 | 1.55 | 231 | 494 | 687 | 877 | 1,114 | 1,286 | 1,643 |
| | | | | | | 359 | 667 | 926 | 1,223 | 1,693 | 2,123 | 3,443 |
| 7361760 | 238.22 | 9.08 | 396.9 | 0.0687 | 3.7 | 713 | 1,069 | 1,355 | 1,679 | 2,197 | 2,683 | 4,296 |
| | | | | | | 966 | 1,772 | 2,443 | 3,207 | 4,397 | 5,466 | 8,720 |
| 7361780 | 249.46 | 3.46 | 319.55 | 0.0422 | 3.65 | 462 | 740 | 973 | 1,241 | 1,677 | 2,089 | 3,463 |
| | | | | | | 447 | 808 | 1,107 | 1,446 | 1,974 | 2,449 | 3,894 |
| 7361800 | 149.96 | 265.15 | 290.49 | 0.041 | 2.72 | 16,821 | 24,127 | 29,352 | 34,693 | 42,185 | 48,296 | 64,449 |
| | | | | | | 8,534 | 14,885 | 19,978 | 25,664 | 34,177 | 41,532 | 63,332 |
| 7361894 | 184.5 | 9.12 | 248.61 | 0.0224 | 3.92 | 329 | 572 | 760 | 962 | 1,259 | 1,512 | 2,220 |
| | | | | | | 686 | 1,194 | 1,604 | 2,060 | 2,758 | 3,374 | 5,220 |
| 7362050 | 129.93 | 10.4 | 205.99 | 0.0487 | 2.8 | 379 | 935 | 1,507 | 2,258 | 3,612 | 5,002 | 10,035 |
| | | | | | | 1,054 | 1,908 | 2,612 | 3,410 | 4,646 | 5,751 | 9,098 |
| 7362100 | 97.56 | 384.36 | 228.62 | 0.0402 | 1.98 | 6,398 | 13,835 | 21,160 | 30,456 | 46,679 | 62,722 | 117,575 |
| | | | | | | 12,115 | 21,121 | 28,336 | 36,392 | 48,428 | 58,817 | 89,537 |
| 7362330 | 142.4 | 12.71 | 189.25 | 0.0076 | 3.09 | 884 | 1,896 | 2,793 | 3,833 | 5,458 | 6,906 | 11,126 |
| | | | | | | 678 | 1,123 | 1,471 | 1,851 | 2,422 | 2,916 | 4,376 |
| 7362450 | 240.22 | 4.83 | 316.49 | 0.0405 | 1.69 | 676 | 1,331 | 1,841 | 2,381 | 3,139 | 3,753 | 5,295 |
| | | | | | | 721 | 1,310 | 1,798 | 2,352 | 3,217 | 3,997 | 6,367 |
| 7362587 | 781.35 | 26.97 | 1148.98 | 0.1465 | 2.1 | 5,634 | 8,946 | 11,658 | 14,769 | 19,792 | 24,544 | 40,415 |
| | | | | | | 3,006 | 5,692 | 7,969 | 10,599 | 14,720 | 18,442 | 29,840 |

| Station Identification Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|-------------------------------|--------------------|----------------|---------------------------|---------------------|--|---|--------|--------|--------|---------|---------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7362715 | 388.07 | 4.69 | 516.78 | 0.0875 | 2.77 | 1,531 | 2,673 | 3,470 | 4,255 | 5,278 | 6,043 | 7,793 |
| | | | | | | 743 | 1,391 | 1,938 | 2,566 | 3,557 | 4,457 | 7,222 |
| 7363000 | 260.91 | 549.43 | 639.75 | 0.1105 | 1.82 | 27,866 | 45,558 | 57,710 | 69,498 | 84,783 | 96,283 | 122,964 |
| | | | | | | 21,166 | 38,574 | 52,901 | 69,189 | 93,892 | 115,503 | 180,174 |
| 7363050 | 233.82 | 1.49 | 335.39 | 0.0678 | 1.58 | 159 | 387 | 699 | 1,234 | 2,624 | 4,659 | 18,806 |
| | | | | | | 395 | 744 | 1,040 | 1,381 | 1,923 | 2,422 | 3,960 |
| 7363200 | 152.86 | 1125.26 | 461.96 | 0.0466 | 3.31 | 22,505 | 38,791 | 49,728 | 60,029 | 72,821 | 82,027 | 101,946 |
| | | | | | | 21,396 | 36,966 | 49,344 | 63,117 | 83,452 | 100,762 | 151,733 |
| 7363300 | 200 | 204.01 | 337.47 | 0.0217 | 4.84 | 6,962 | 14,736 | 21,204 | 28,319 | 38,707 | 47,410 | 70,453 |
| | | | | | | 4,875 | 8,221 | 10,850 | 13,746 | 18,028 | 21,679 | 32,431 |
| 7363330 | 186.22 | 4.8 | 293.8 | 0.0345 | 2.3 | 445 | 990 | 1,479 | 2,055 | 2,967 | 3,797 | 6,269 |
| | | | | | | 615 | 1,105 | 1,509 | 1,965 | 2,673 | 3,309 | 5,235 |
| 7363430 | 309.87 | 0.67 | 355.38 | 0.0371 | 1.85 | 114 | 268 | 433 | 662 | 1,110 | 1,610 | 3,723 |
| | | | | | | 186 | 341 | 472 | 621 | 858 | 1,075 | 1,741 |
| 7363450 | 212.55 | 0.27 | 245.33 | 0.0254 | 2.01 | 45 | 110 | 171 | 243 | 357 | 461 | 762 |
| | | | | | | 89 | 162 | 223 | 292 | 402 | 503 | 812 |
| 7363500 | 97.06 | 2095.32 | 359.25 | 0.0326 | 4.49 | 21,892 | 38,705 | 51,259 | 64,164 | 81,944 | 96,071 | 131,316 |
| | | | | | | 26,084 | 43,924 | 57,865 | 73,220 | 95,555 | 114,268 | 168,951 |
| 7364000 | 86.02 | 2438.28 | 337.95 | 0.0301 | 4.38 | 19,167 | 35,491 | 49,071 | 64,437 | 88,213 | 109,462 | 172,797 |
| | | | | | | 28,408 | 47,611 | 62,569 | 79,014 | 102,865 | 122,795 | 180,930 |

| Station Identificat- ion Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|--|--------------------------|----------------------|------------------------------------|---------------------------|---|---|--------|--------|--------|--------|---------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7364030 | 143.33 | 0.33 | 169.16 | 0.0191 | 1.36 | 46 | 102 | 144 | 185 | 237 | 274 | 353 |
| | | | | | | 107 | 193 | 264 | 345 | 472 | 589 | 946 |
| 7364070 | 149.24 | 5.65 | 170.4 | 0.0476 | 2.35 | 339 | 552 | 701 | 850 | 1,051 | 1,208 | 1,593 |
| | | | | | | 746 | 1,358 | 1,866 | 2,443 | 3,343 | 4,153 | 6,615 |
| 7364110 | 229.19 | 0.74 | 268.19 | 0.0137 | 3.05 | 132 | 252 | 361 | 492 | 711 | 920 | 1,604 |
| | | | | | | 124 | 217 | 293 | 377 | 508 | 625 | 981 |
| 7364120 | 153.25 | 218.83 | 228.84 | 0.0131 | 4.6 | 1,734 | 2,446 | 2,866 | 3,237 | 3,671 | 3,971 | 4,590 |
| | | | | | | 4,490 | 7,397 | 9,650 | 12,108 | 15,712 | 18,759 | 27,674 |
| 7364125 | 217.47 | 4.89 | 306.66 | 0.0493 | 1.18 | 1,048 | 1,560 | 1,866 | 2,138 | 2,455 | 2,673 | 3,110 |
| | | | | | | 873 | 1,608 | 2,222 | 2,922 | 4,022 | 5,019 | 8,059 |
| 7364128 | 167.94 | 101.6 | 191.27 | 0.0036 | 4.24 | 1,535 | 1,748 | 1,851 | 1,933 | 2,019 | 2,072 | 2,166 |
| | | | | | | 1,918 | 3,001 | 3,816 | 4,689 | 5,951 | 7,008 | 10,068 |
| 7364140 | 191.17 | 37.27 | 289.84 | 0.0331 | 2.19 | 3,944 | 6,804 | 9,771 | 13,967 | 22,928 | 34,239 | 99,099 |
| | | | | | | 2,380 | 4,195 | 5,665 | 7,314 | 9,823 | 12,032 | 18,635 |
| 7364150 | 120.48 | 588.48 | 208.25 | 0.0095 | 6.45 | 4,460 | 11,786 | 21,969 | 39,227 | 81,828 | 140,428 | 481,153 |
| | | | | | | 6,963 | 11,158 | 14,348 | 17,793 | 22,751 | 26,862 | 38,795 |
| 7364165 | 209.11 | 18.2 | 284.41 | 0.0322 | 1.9 | 849 | 1,605 | 2,408 | 3,527 | 5,803 | 8,456 | 21,026 |
| | | | | | | 1,549 | 2,749 | 3,726 | 4,825 | 6,511 | 8,006 | 12,494 |
| 7364190 | 85.17 | 1157.77 | 190.91 | 0.0097 | 7.11 | 4,762 | 5,985 | 6,720 | 7,386 | 8,206 | 8,800 | 10,135 |
| | | | | | | 10,566 | 16,825 | 21,560 | 26,662 | 33,948 | 39,939 | 57,280 |

| Station Identificat- ion Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|--|--------------------------|----------------------|------------------------------------|---------------------------|---|---|--------|--------|--------|--------|--------|---------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7364260 | 139.81 | 20.05 | 169.94 | 0.0058 | 2.6 | 704 | 1,290 | 1,709 | 2,126 | 2,669 | 3,083 | 4,023 |
| | | | | | | 899 | 1,468 | 1,909 | 2,387 | 3,100 | 3,714 | 5,514 |
| 7364550 | 202.65 | 0.07 | 232.26 | 0.0422 | 1.95 | 57 | 100 | 155 | 243 | 450 | 727 | 2,334 |
| | | | | | | 43 | 81 | 113 | 151 | 211 | 268 | 446 |
| 7365800 | 149.74 | 180.21 | 248.26 | 0.0319 | 3.11 | 4,779 | 11,154 | 17,840 | 26,744 | 43,164 | 60,272 | 123,681 |
| | | | | | | 5,871 | 10,141 | 13,548 | 17,337 | 23,001 | 27,888 | 42,357 |
| 7365900 | 155.63 | 50.49 | 239.6 | 0.0225 | 2.82 | 2,010 | 4,883 | 8,220 | 13,125 | 23,491 | 35,892 | 95,170 |
| | | | | | | 2,377 | 4,093 | 5,462 | 6,982 | 9,271 | 11,263 | 17,176 |
| 7367658 | 158.17 | 0.93 | 162.93 | 0.0027 | 2.4 | 155 | 209 | 247 | 285 | 338 | 381 | 494 |
| | | | | | | 98 | 159 | 207 | 258 | 336 | 405 | 608 |
| 7367661 | 92.1 | 313.55 | 413.2 | 0.0315 | 2.48 | 4,526 | 6,996 | 8,726 | 10,450 | 12,776 | 14,601 | 19,132 |
| | | | | | | 9,120 | 15,709 | 20,950 | 26,774 | 35,441 | 42,893 | 64,883 |
| 7367670 | 179.19 | 3.34 | 126.46 | 0.0022 | 2.95 | 261 | 389 | 480 | 573 | 703 | 810 | 1,093 |
| | | | | | | 200 | 316 | 406 | 501 | 644 | 768 | 1,129 |
| 7367680 | 83.24 | 618.57 | 404.11 | 0.0304 | 2.66 | 8,006 | 11,819 | 14,261 | 16,538 | 19,383 | 21,464 | 26,136 |
| | | | | | | 13,771 | 23,517 | 31,219 | 39,748 | 52,341 | 63,077 | 94,625 |
| 7367740 | 164.83 | 1.83 | 114.89 | 0.0023 | 2.11 | 232 | 297 | 335 | 370 | 411 | 441 | 507 |
| | | | | | | 153 | 245 | 317 | 393 | 509 | 609 | 906 |

| Station Identificat- ion Number | Station Elev. (ft) | Area (sq. mi.) | Basin Avg. elevation (ft) | Basin Slope (ft/ft) | Basin shape factor (mi ² /mi ²) | Discharge for Recurrence Interval (years) | | | | | | |
|--|--------------------------|----------------------|------------------------------------|---------------------------|---|---|-------|-------|-------|--------|--------|--------|
| | | | | | | *Second row are calculated values using equations developed in this study | | | | | | |
| | | | | | | 2 yr | 5 yr | 10 yr | 20 yr | 50 yr | 100 yr | 500 yr |
| 7369680 | 80.92 | 508.33 | 222.43 | 0.0002 | 3.03 | 2,459 | 3,949 | 5,869 | 8,892 | 15,969 | 25,313 | 78,608 |
| | | | | | | 2,693 | 3,651 | 4,318 | 4,998 | 5,925 | 6,658 | 8,729 |

