Basic Characteristics for Regression Analysis in Arid Areas

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Multiple-regression techniques are commonly used to transfer flood characteristics from gaged to ungaged watersheds. In the arid or semiarid areas of the United States, the standard errors of these regression relations often are quite large. One way to reduce the standard error is to identify basin characteristics that are significant for predicting *T*-year flood discharges such as 50- or 100-year floods. Recent investigations have identified new characteristics that appear to be promising. Examples of these are main channel sinuosity, hydraulic radius, bank-full channel conveyance, basin shape, time-to-peak of the flood hydrograph, effective drainage area, and percent of the basin in a given hydrologic soil group. The appropriateness of their use and the application of these basin characteristics are discussed. In addition, a few new basin characteristics are suggested that have not yet been investigated. Examples include channel infiltration losses, ratio of main channel width to flood-plain width, stream-network magnitude, channel storage indices, and drainage density.

Planning and designing highway bridges and culverts requires knowledge of the magnitude and frequency of flooding so that economical and safe designs can be obtained. At most locations where drainage structures are contemplated, no gaging station records are available. Therefore, there is a need to develop techniques for transferring flood characteristics (such as the 100-year flood-peak discharge) from gaging stations to ungaged sites. A technique commonly used to estimate flood characteristics is multiple-regression analysis. In this analysis, flood characteristics at ungaged sites are estimated by regression equations that use basin and climatic characteristics as predictor variables. For arid areas in the southwestern United States, the standard errors of estimate of the regression equations often exceed 60 percent and can be as high as 100 percent. A possible way of improving this transfer technique is to identify new basin characteristics that are significant in predicting flood characteristics.

The purposes of this paper are to (1) describe basin characteristics presently being used, (2) document the need for new basin characteristics, (3) describe some new basin characteristics that have been recently evaluated and show promise, and (4) suggest some new basin characteristics that might be useful for estimating flood characteristics. Several of the new basin characteristics have been used in the more humid areas in the east, but they may have applicability in the arid west as well. Basin characteristics, as described in this paper, can be (1) channel characteristics, such as active channel width, hydraulic radius, and sinuosity ratio; (2) topological characteristics, such as stream-network magnitude, link-length distribution parameters, and drainage density; (3) hydrograph characteristics, such as time-to-peak and basin lag time; and (4) the more conventional basin characteristics, such as drainage area, channel slope, percent of forestation, and soil characteristics.

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PRESENTLY USED BASIN CHARACTERISTICS

The U.S. Geological Survey has made extensive use of regression equations based on basin and climatic characteristics to estimate flood characteristics. Since 1973, every Geological Survey District Office has published at least one report on estimating flood-peak discharges at ungaged sites. A list of these reports by state is provided in (*1*). The regression equations in these reports are based on basin and climatic characteristics that can be readily determined from topographic maps and climatic reports of the National Weather Service or state agencies. Table 1 summarizes the frequency of use of these basin and climatic characteristics in the statewide regional flood-frequency analyses. The data in table 1 are based on statewide reports that were published before December 31, 1986. Drainage area was used in regression equations in reports prepared for all 50 states and Puerto Rico; it is usually the most significant variable in accounting for variability in flood estimates. Main channel slope and some index of precipitation (such as annual precipitation or the 2-year 24-hour precipitation) were variables used in regression equations for 24 and 33 states, respectively. Basin storage and forest cover are expressed as percentages of the total drainage area covered with lakes, swamps and ponds (for basin storage), or forests. Mean basin elevation is a popular variable in the western states where flood characteristics for watersheds at higher elevations are much different from those at lower elevations. Main channel length is occasionally used in conjunction with drainage area to describe basin shape. Normally, however, channel length is highly correlated with drainage area and does not explain any additional variation in the flood characteristics. This partially explains why channel length is used in only five states. Minimum January temperature is sometimes used to help explain the difference in flood peaks caused predominantly by snowmelt and those caused by rainfall. Soil characteristics are not used very frequently, possibly because the infiltration values readily accessible for these regional flood studies are not well defined. Soil characteristics may be a variable that warrants further evaluation in future studies in arid areas. There were a few other variables, such as basin shape (basin length squared divided by drainage area) and

TABLE 1 SUMMARY OF BASIN AND CLIMATIC CHARACTERISTICS USED IN U.S. GEOLOGICAL SURVEY REGRESSION EQUATIONS

Independent variable	Number of States (including Puerto Rico)
Drainage area	51
Channel slope	24
Annual precipitation	22
Basin storage (%)	18
Mean basin elevation	12
Precipitation intensity	11
Forest cover (%)	9
Channel length	5
Minimum January temperature	5
Soils characteristics	4

seasonal snowfall, that were used in only one state each and are not shown in table 1.

Many of the basin and climatic characteristics shown in table 1 have been used frequently because of their availability, ease of computation, and no requirement for a site visit. Future research and evaluation should be oriented towards identifying new predictor variables that might provide a more accurate estimating relation even though additional effort may be needed to determine their values.

NEED FOR NEW BASIN CHARACTERISTICS

One useful aspect of using regression equations to estimate flood characteristics is that the accuracy of these equations is easily determined. Accuracy as used in this paper is defined as the standard error of estimate of the regression analysis; it is the error to expect two-thirds of the time. This standard error is a measure of the accuracy of the regression equations when compared to the gaging station data used to develop the equations. It may or may not reflect the true predictive accuracy of the regression equations.

Table 2 summarizes the distribution of standard errors of estimate for the 50- and 100-year flood discharges for the 50 states and Puerto Rico. The table is based on the maximum values for the different hydrologic regions within each state, and it shows that all 50 states and Puerto Rico have at least one hydrologic region where the standard error of estimate exceeds 30 percent. However, there are some hydrologic regions in Alabama, Georgia, Wisconsin, Pennsylvania, and Ohio where the standard error is less than 30 percent. The data in table 2 can be used to determine the number of states having standard errors in a certain range. For example, 6 states have maximum standard errors in the range of 30 to 40 percent, and 12 states have maximum standard errors in the range 50 to 60 percent. Keep in mind, however, that the standard errors often vary considerably among hydrologic regions within a given state, and the distribution of standard errors shown in table 2 is based on the maximum value for any hydrologic region in that state.

It is interesting to note the geographical distribution of the standard errors. States where the maximum standard error exceeds 60 percent are shown in figure 1. The states are predominantly in the West with the exception of Minnesota, Maryland, and Florida. Each of these three states has one or more low-lying hydrologic region where basin storage, channel storage, or non-contributing areas of the watershed are significant. The standard error tends to be higher in the western states due to the greater variability in annual flood-peak data (time-sampling errors) and the less dense gaging station network (space-sampling errors). The problem is compounded by the fact the watershed and climatic characteristics are more variable in the arid areas of the western states. In addition, the watershed and climatic characteristics frequently used (table 1) do not sufficiently account for the variation in flood characteristics among watersheds. These are some of the reasons why the states with standard errors exceeding 60 percent are mostly in the more arid West. It is possible that this high standard error could be reduced by using different basin characteristics that explain more of the variation in flood characteristics from site to site. It should be noted, however, that the standard errors for basins at higher elevations and the more humid areas in the west tend to be less than 60 percent, primarily because of the reduced variability in the annual flood-peak data. Therefore the reader should not infer from figure 1 that all hydrologic regions within the shaded states have standard errors exceeding 60 percent.

DESCRIPTION OF NEW BASIN CHARACTERISTICS

In this section, promising new basin characteristics recently used by various analysts and a few new basin characteristics that might be useful for estimating flood characteristics are discussed. The discussion of these basin characteristics will be grouped into the following categories: channel characteristics, elevation-oriented approach, topological characteristics, and hydrograph characteristics. These categories are defined below.

Channel Characteristics

In many arid or semiarid areas, T-year flood discharges decrease (attenuate) as basin size increases. This is due, in part, to

TABLE 2 DISTRIBUTION OF STANDARD ERRORS FOR 50- AND 100-YEAR FLOODS ESTIMATED FROM U.S. GEOLOGICAL SURVEY REGRESSION EQUATIONS

Standard error (in percent)	Number of States (including Puerto Rico)
>30*	51
>40	45
>50	31
>60	19
>80	10
>100	2

*Certain hydrologic regions in Alabama, Georgia, Wisconsin, Pennsylvania, and Ohio had standard errors less than 30 percent

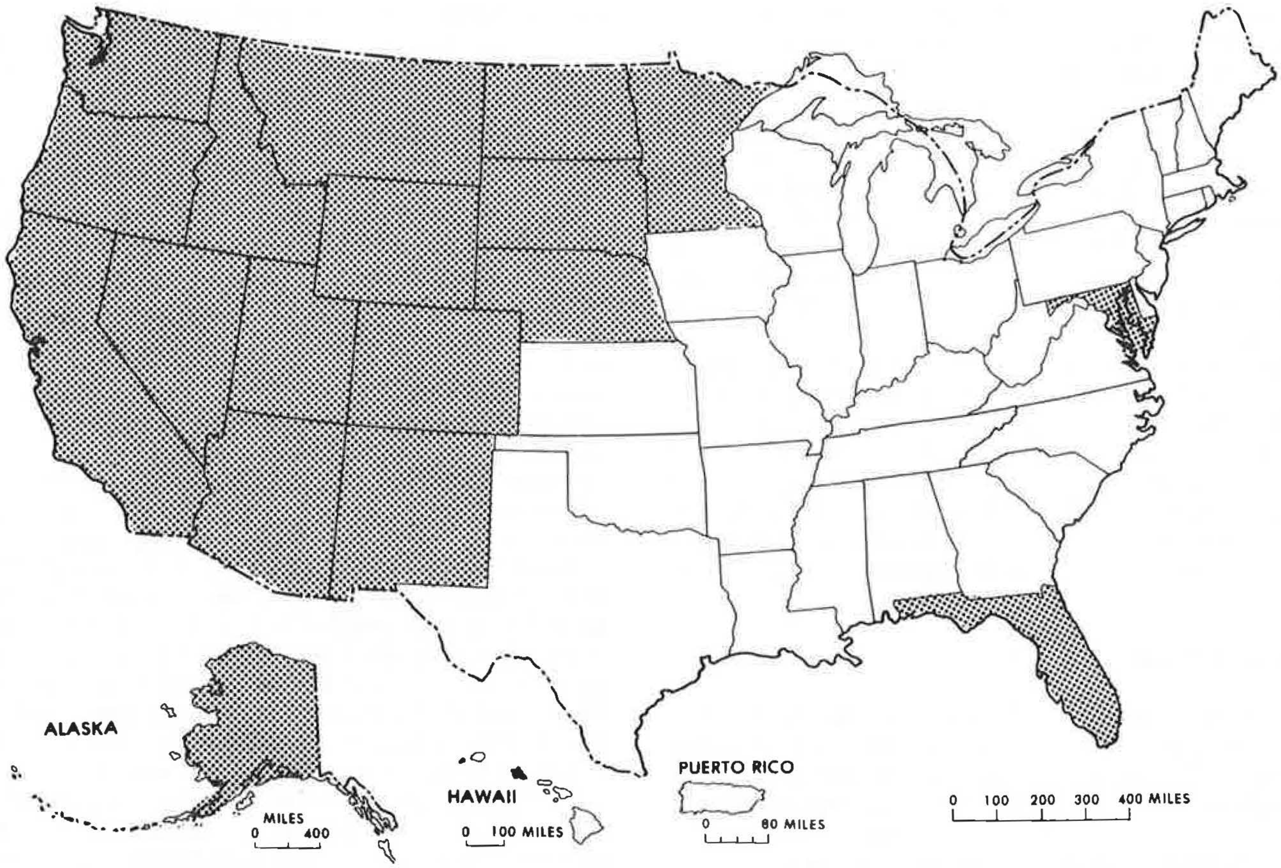

FIGURE 1 Identification of states where standard errors of estimate for the 50- and 100-year floods exceed 60 percent in at least one hydrologic region.

channel storage and channel losses. Since drainage area is usually the most important independent variable, this explains why conventional basin characteristics often do not adequately explain the variation in flood characteristics. As an alternative, many analysts (*2, 3, 4*) have used channel-geometry characteristics, primarily active channel width, to estimate flood characteristics. Active channel width is briefly defined as the width of main channel measured between the permanent vegetation on each bank. The application and accuracy of the channel-geometry technique and a more complete definition of the required channel characteristics are given in (*2, 3, 4*). The method does require a field visit to the ungaged site to measure channel width. Regression equations based on active channel width have been developed by the Geological Survey in eight western states and Ohio and are listed in (*1*). These nine states also have regression equations based on basin and climatic characteristics.

Channel storage often causes flood discharges to decrease in a downstream direction. In a recent study in southern Arizona (*5*), attenuation adjustment factors were computed by dividing at-site *T*-year flood estimates by the regional regression estimates. These adjustment factors were then multiplied by the regional regression estimates when applied to ungaged sites with significant channel storage. Another approach is to define channel characteristics that reflect these storage characteristics and use them in the regression analysis. One such study (*6*) in 1964 examined channel width, channel width/depth ratio, channel cross-sectional area, and channel cross-sectional area times length of the main channel as indices of channel storage. None of these characteristics was found to be significant in estimating flood discharges, given that drainage area and channel length were already included in the equation. However, these indices should be reevaluated in future studies. Another measure that is closely related and that might be useful as an index of channel storage, is the main channel width relative to floodplain width. This value could be measured from topographic maps at several locations throughout the basin and averaged to obtain a single index.

In arid areas in the west, floods usually occur in dry stream channels. The volume and peak discharge of the flood is reduced by infiltration into the stream bed, stream banks, and possibly the floodplain. The U.S. Soil Conservation Service (*7*) has defined ways of estimating these reductions in flood volumes and peak discharges using characteristics of the channel reach such as effective hydraulic conductivity, a decay factor, average width and length of the reach. Procedures are given for estimating the reduction in flow with and without using observed inflow-outflow data. A table is provided for relating streambed material characteristics to the above-mentioned channel characteristics so that the method is applicable to ungaged sites (i.e., no observed inflow-outflow data).

In a recent study in Kentucky (*8*), main channel sinuosity was found to be significant for estimating flood discharges. The main channel sinuosity was defined as the ratio of the main channel length divided by the basin length (straight-line distance from outlet to basin divide) and is another measure of channel storage. In the Kentucky study, the main channel sinuosity was inversely related to flood discharges.

In a recent study in Arkansas (*9*), hydraulic radius or mean channel depth was found to be a significant predictor variable. It was assumed that the hydraulic radius used in conjunction with channel slope was a better index of velocity of the flood wave than channel slope alone. A method for determining hydraulic radius without visiting the ungaged site was given in the report (*9*). The standard errors of the regression were reduced an average of 9 percent when hydraulic radius was used in conjunction with conventional watershed characteristics.

Bank-full channel conveyance was found to be a significant factor for estimating urban flood discharges in Houston, Texas (*10*). In this study, bank-full channel conveyance was defined as the conveyance at a controlling section downstream from the gage when the water-surface elevation was equal to that of the lower stream bank. The conveyance was computed using Manning's equation. Although this variable was used for urban streams, it may also be applicable to rural streams.

Elevation-Oriented Approach

In arid or semiarid areas, flood characteristics tend to vary as a function of elevation of the watershed. In the eastern foothills of the Rocky Mountains in Colorado, the drainage area below 8,000 feet was shown to be a better predictor of rainfall floods than the entire drainage area (*11*). This is because extreme rainfall events generally occur at elevations below 8,000 feet. Above 8,000 feet, precipitation generally occurs as snowfall, and unit runoff is not as great. In the Colorado study (*11*), the standard error of the 100-year rainfall-related flood was reduced significantly by using drainage area only below 8,000 feet rather than the entire drainage area of the watershed.

In Nevada, unit-flood-discharge values (discharge per square mile) were determined for each of several elevation zones (*12*). The total *T*-year flood discharge for a given watershed was determined by the sum of the products of the area of each elevation zone and its respective unit-flood-discharge values. The unit values were adjusted by trial-and-error procedures until a good agreement was reached with station data. This approach may be applicable to other areas of the southwest and deserves further evaluation.

Topological Characteristics

Topological characteristics are defined as those characteristics describing the geometry or geomorphology of the channel network and the basin. A recent report using data for small streams in Wyoming has indicated that stream-network magnitude (number of first order streams) and link-length distribution parameters are useful for estimating the shape of unit hydrographs (*13*). The link-length distribution parameters are actually the scale and shape parameters of the two-parameter gamma distribution. This distribution is fitted to the sample of internal link lengths, defined as the distance between junctions (confluences) of streams of order of 2 and 3, 3 and 4, etc. The distribution of internal link lengths essentially describes the density of the stream channel network. If the stream-network magnitude and link-length distribution parameters are important in estimating unit hydrographs, then they may have application in estimating flood discharges of a given return period.

In a study in Kentucky, basin shape, defined as the basin length squared divided by drainage area, was shown to be a significant variable for estimating *T*-year flood discharges (*8*). In this case, basin length was measured as a straight-line distance from the gage to the point on the basin divide used to determine main channel length. The shape of the basin is indicative of how fast the flood waters run off the basin. A long narrow basin tends to store water and attenuate flood peaks. On the other hand, runoff tends to be more rapid from circular basins since the travel time of the flood wave for the major tributaries tends to be more nearly equal. Occasionally, drainage area and main-channel length are used independently in the regression equations and are, in effect, a measure of basin shape (*9, 14*). In these instances, main-channel length has a negative exponent in the regression equation.

Another variable closely related to the link-length distribution parameters is drainage density. Drainage density is defined as the total length of all streams per unit of area. It is a measure of the development of the drainage system and should be an indicator of how fast the surface runoff occurs. To the author's knowledge, no one has demonstrated that this variable is significant in predicting flood discharges. This variable is affected by the scale of the maps used, the contour interval, and the extent to which streamlines are mapped. As an alternative to measuring the blue streamlines on the topographic map, perhaps the stream length should be computed as the total distance upstream until the swales disappear on the map. Now that topographic coverage at a scale of 1:24,000 is available nearly nationwide, this variable may prove to be significant in estimating *T*-year flood discharges.

Hydrograph Characteristics

Hydrograph characteristics are computed from basin characteristics combined with streamflow data. In actuality, they are streamflow characteristics, but in this paper they will be referred to as basin characteristics since they are indicative of basin response. Time-to-peak, time of concentration, and basin lag time are examples of hydrograph characteristics. These characteristics integrate the effects of soils, basin slope and shape, channel storage, land cover, and stream network configuration. In a recent study in Wisconsin, the time-to-peak was shown to decrease the standard error of prediction significantly over using the more conventional variables of drainage area and mean annual precipitation (*15*). Of course the reduction in standard error would have to be significant to make it worthwhile to collect the streamflow data needed to compute the time-to-peak. In Wisconsin, the standard error of prediction was reduced from about 35–38 percent to 23–32 percent, depending on the recurrence interval of the flood discharge. The analyst would have to make the decision as to whether the reduction in standard error warranted the collection of limited streamflow data.

Certain analysts have shown that basin lag time (time from centroid of rainfall excess to centroid of runoff) is significant in estimating flood discharges for urban areas (*16, 17*). This characteristic may also be useful in estimating flood discharges for rural areas. As noted above, the reduction in standard error would have to be significant to warrant collecting the streamflow and rainfall data needed.

The author's personal experience in using hydrograph characteristics to estimate flood discharges in Illinois was that the reduction in standard error was not sufficient to warrant collecting the needed data. In the Illinois study (unpublished report), the linear storage routing coefficient was also used as a predictor variable in addition to time of concentration. The linear storage coefficient is the slope of the recession hydrograph, which is indicative of how fast the flood waters drain from storage once inflow (precipitation excess) to the watershed has ceased. The time of concentration and the linear storage coefficient were statistically significant but they did not substantially reduce the standard error of estimate determined by using conventional basin characteristics. It is the author's opinion that the use of these hydrograph characteristics needs further evaluation relative to the estimation of *T*-year flood discharges.

Conventional Basin Characteristics

There are also possible improvements in the conventional basin characteristics given in table 1 that are worth considering. In a recent study in Colorado, effective drainage area proved to be a more significant predictor variable than total drainage area (*18*). Effective drainage area was computed by subtracting drainage areas upstream from all erosion-control or flood-retention structures in the basin from the total drainage area. Since the U.S. Soil Conservation Service has constructed these erosion-control and/or flood-retention structures in most arid basins, the use of effective drainage area should be applicable in areas outside of Colorado. These control structures are generally small, uncontrolled reservoirs designed to retain about a 25-year flood. This concept of effective drainage area is not intended for use in basins with large flood-control reservoirs with controlled outflow. Effective drainage area is most applicable for small drainage areas, since this is where the majority of the erosion-control and flood-retention structures have been constructed. It may be necessary to determine effective drainage area from field reconnaissance rather than maps if the reproducibility of computing this variable proves to be low.

Soil characteristics have occasionally proven to be significant in estimating flood discharges (see table 1). One possible reason that soils characteristics have not been used more is that the infiltration values are not well defined. The infiltration values available in the Geological Survey Streamflow and Basin Characteristics File were provided to the Geological Survey by the U.S. Soil Conservation Service during a nationwide surface-water network analysis study in 1969–70. It is the author's opinion that these infiltration values should be reviewed and possibly recomputed based on the latest soils maps.

Studies in Maryland and Delaware have indicated that the percentage of the basin in each of two (A and D) of the four hydrologic soil groups (A, B, C, D) of the U.S. Soil Conservation Service is a significant predictor variable for *T*-year flood discharges (*19, 20*). The use of these soil characteristics greatly reduced the standard error of estimate in the Coastal Plain region of Maryland and Delaware, and these characteristics should be investigated in arid areas of the western United States. The percent of the basin having a certain soil type proved to be more significant than an average infiltration value for the entire basin.

SUMMARY AND CONCLUSION

The standard errors of regression equations for estimating *T*-year flood discharges in arid areas are often quite high. A possible solution is to identify new basin characteristics that are significant in explaining the variation in flood discharges from site to site. Several types of basin characteristics that have recently been evaluated were discussed. The following basin characteristics may be useful for estimating flood discharges in the arid West.

Channel characteristics—

1. Channel-geometry characteristics, primarily active channel width, have been used by the Geological Survey in eight western states and Ohio to provide reliable estimates of *T*-year flood discharges.
2. A study in the southwestern United States in 1964 investigated four indices of channel storage and did not find any of them significant for estimating *T*-year flood discharges (*6*). However, these characteristics should be reevaluated in future studies.
3. A possible new indicator of channel storage is main channel width relative to floodplain width.
4. Channel infiltration losses as defined by the U.S. Soil Conservation Service may be useful in estimating *T*-year flood discharges (*7*).
5. Main channel sinuosity was found to be significant in estimating *T*-year floods in Kentucky and may have applicability in the arid West (*8*).
6. Hydraulic radius was found to be significant in Arkansas, where the inclusion of this characteristic reduced the standard error of estimate by an average of 9 percent for several recurrence interval floods (*9*).
7. Bank-full channel conveyance as used in an urban study in Houston should be investigated in studies of rural flood characteristics in arid areas (*10*).

Elevation-oriented approach—

1. The drainage area of basins below 8,000 feet was shown to be more significant than total drainage area when estimating rainfall related flood discharges in Colorado (*11*).
2. In Nevada, unit flood runoff per elevation zone was summed to obtain an estimate of the total flood discharge (*12*). This approach may be applicable to other areas in the Southwest.

Topological characteristics—

1. Stream-network magnitude and link-length distribution parameters were shown to be useful in Wyoming for estimating unit hydrographs (*13*) and may have applicability for estimating *T*-year flood discharges.
2. Basin shape was found to be significant in Kentucky in

estimating flood discharges (*8*) and may have applicability in the arid West.

3. Drainage density could be a useful characteristic for estimating *T*-year floods.

Hydrograph characteristics—

1. The time-to-peak hydrograph characteristic reduced standard errors of prediction 6 to 12 percent in Wisconsin over use of conventional basin characteristics (*15*).

2. Basin lag time was shown to be significant in urban areas (*16, 17*) and may have application to rural streams in arid areas if streamflow and rainfall data can be obtained in a cost-effective manner.

Conventional basin characteristics—

1. Effective drainage area was shown to be significant in estimating *T*-year flood discharges for small streams in eastern Colorado (*18*) and may have applications in other areas of the Southwest.

2. In studies in Maryland and Delaware, the percent of the basin in a given hydrologic soil group proved to be a more significant variable than the average infiltration value for the entire basin (*19, 20*). This approach needs to be evaluated in the more arid areas in the West.

The investigation and use of the basin characteristics discussed in this report may lead to development of improved regression models for streams in arid or semiarid areas of the United States. Understanding the physical processes that cause floods is necessary to develop improved predictive models.

REFERENCES

1. W. O. Thomas Jr. Techniques Used by the U.S. Geological Survey in Estimating the Magnitude and Frequency of Floods. *Proceedings of 18th Annual Geomorphology Symposium*, Oxford, Ohio, September 1987.
2. H. C. Riggs. Streamflow Characteristics from Channel Size. American Society of Civil Engineers, *Journal of Hydraulics Division*, Vol. 104, No. HYI, 1978, pp. 87–96.
3. E. R. Hedman and W. R. Osterkamp. *Streamflow Characteristics Related to Channel Geometry of Streams in Western United States*. U.S. Geological Survey Water-Supply Paper 2193, 17 p., 1982.
4. K. L. Wahl. Accuracy of Channel Measurements and the Implications in Estimating Streamflow Characteristics. *U.S. Geological Survey Journal of Research*, Vol. 5, No. 6, 1977, pp. 811–814.
5. J. H. Eychaner. *Estimation of Magnitude and Frequency of Floods in Pima County, Arizona, with Comparisons of Alternative Methods*. U.S. Geological Survey Water-Resources Investigations 84-4142, 1984.
6. M. A. Benson. *Factors Affecting the Occurrence of Floods in the Southwest*. U.S. Geological Survey Water-Supply Paper 1580-D, 72 p., 1964.
7. U.S. Soil Conservation Service. *National Engineering Handbook*, Section 4 Hydrology, Chapter 19 Transmission Losses. U.S. Department of Agriculture, Washington, D.C., 1983.
8. A. F. Choquette. *Regionalization of Peak Discharges for Streams in Kentucky*. U.S. Geological Survey Water-Resources Investigations Report 87-4209, 1987.
9. B. L. Neely, Jr. *Magnitude and Frequency of Floods in Arkansas*. U.S. Geological Survey Water-Resources Investigations Report 86-4335, 1986.
10. F. Liscum and B. C. Massey. *Technique for Estimating the Magnitude and Frequency of Floods in the Houston, Texas, Metropolitan Area*. U.S. Geological Survey Water-Resources Investigations 80-17, 1980.
11. R. D. Jarrett and J. E. Costa. *Evaluation of the Flood Hydrology in the Colorado Front Range Using Streamflow Records and Paleohydrologic Data for the Big Thompson River Basin*. U.S. Geological Survey Water-Resources Investigations Report 87-4117, 1987.
12. D. O. Moore. *Estimating Peak Discharges from Small Drainages in Nevada According to Basin Areas within Elevation Zones*. Nevada State Highway Department Hydrologic Report no. 3, 1976.
13. M. R. Karlinger, D. P. Guertin, and B. M. Troutman. Use of Topological Information in Hydrograph Estimation. *Water Resources Bulletin*, Vol. 23, No. 2, 1987, pp. 271–279.
14. B. E. Colson and J. W. Hudson. *Flood Frequency of Mississippi Streams*. Mississippi State Highway Department, 1976.
15. K. W. Potter and E. B. Faulkner. Catchment Response Time as a Predictor of Flood Quantiles. *Water Resources Bulletin* (in press).
16. L. A. Martens. *Flood Inundation and Effects of Urbanization in Metropolitan Charlotte, North Carolina*. U.S. Geological Survey Water-Supply Paper 1591-C, 60 p., 1968.
17. D. G. Anderson. *Effects of Urban Development on Floods in Northern Virginia*. U.S. Geological Survey Water-Supply Paper 2001-C, 22 p., 1970.
18. R. K. Livingston and D. R. Minges. *Techniques for Estimating Regional Flood Characteristics of Small Rural Watersheds in the Plains Region of Eastern Colorado*. U.S. Geological Survey Water-Resources Investigations Report 87-4094, 1987.
19. D. H. Carpenter. *Technique for Estimating Magnitude and Frequency of Floods in Maryland*. U.S. Geological Survey Open-File Report 80-1016, 980.
20. R. H. Simmons and D. H. Carpenter. *Technique for Estimating the Magnitude and Frequency of Floods in Delaware*. U.S. Geological Survey Open-File Report 78-93, 1978.