Weighting Gaging-Station Peak-Flow Estimates with Regression-Equation Peak-Flow Estimates

Recorded peak flows at individual gaging stations, especially those with short periods of record, may not be representative of peak flows from long periods of record. Because of this, peak-flow estimates determined by use of the methods in Bulletin 17B at each gaging station (see the section of this report titled “Peak Flows at Gaging Stations,” page 10) were combined mathematically with the peak-flow estimates at that station, computed from regression equations (table 3, page 15), to compute the best (weighted) estimate of peak flows for that station (table 1, page 33). If two independent estimates are weighted inversely proportional to their variances, the variance of the weighted average is less than the variance of either estimate (Interagency Advisory Committee on Water Data, 1982). In other words, the weighted average will produce the most accurate peak-flow estimates (number of years of record is inversely proportional to variance, and thus the weighting in equation 3 below becomes direct with years of record). The weighted-average peak flow *(Q_{tw})* was calculated by use of the equation

$$Q_{tw} = 10^{\left(\frac{\log(Q_{to})(\omega) + \log(Q_{tr})(\omega_e)}{\omega + \omega_e}\right)}, \qquad (3)$$

where

- Q_{to} is the log-Pearson Type III estimate of the *t*-year peak discharge calculated by the methods described in the section of this report titled “Estimates of Peak Flows at USGS Streamflow-Gaging Stations” (page 19);
- Q_{tr} is the regression estimate of the *t*-year peak discharge calculated with the methods described in the section of this report titled “Estimating Peak Flows for Ungaged, Unregulated Streams in Rural Drainage Basins” (page 25);
- ω_e is the equivalent years of record for the regression estimate as defined by Hardison (1971); and
- ω is either the systematic record length, in years, if no historical peak-discharge data are available for the site, or the effective record length, in years, if historical peak-discharge data are available for the site.

The effective record length is computed as

$$\omega = \omega_s + \left(D\left(0.55 - 0.1\,ln\left(\frac{P}{1-P}\right)\right)\right), \qquad (4)$$

where

- D is minimum $(200, (\omega_h - \omega_s))$;
- P is $1 - (N_p / (\omega_h + \omega_s))$;
- N_p is the number of historic peaks;
- ω_h is the historic record length, in years, and
- ω_s is the systematic record length, in years.

ESTIMATING THE MAGNITUDE OF PEAK FLOWS FOR SELECTED RECURRENCE INTERVALS

This section describes techniques for estimating the magnitude of peak flows for streams in Kentucky for recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years. A flowchart is provided as a guide to the appropriate estimates and (or) estimating techniques for a site on a specific stream. Example applications of the peak-flow estimating equations also are provided.

Choosing the Appropriate Peak-Flow Estimation Technique

Peak flows in this report refer to peak flows of a specified recurrence interval. The recurrence interval is the average period of time between peak flows that are equal to or greater than a specified peak flow. For example, the 50-year peak flow is the flow that would be exceeded, on a long-term average, once in 50 years. This does not imply, however, that flooding will happen at regular intervals; two 50-year peak flows could occur in the same year. In contrast, a 50-year peak flow might not occur in 100 years. The recurrence interval does not indicate when the estimated flood peak will occur.

The reciprocal of the recurrence interval is called the annual exceedance probability; that is, the probability that a given peak flow will be exceeded in any given year. For example, the annual exceedance probability of the 50-year peak flow would be 0.02. In other words, there is a 2-percent chance that the 50-year peak flow will be exceeded in any given year.

To obtain estimated peak flows for streams in Kentucky, information on the site (site refers to a location on a stream) of interest is needed, including whether the site is at or near (and on the same stream as) a USGS streamflow-gaging station and whether the site drains an urbanized or regulated drainage basin. The different peak-flow estimates and estimating techniques in this report are appropriate to various combinations of these site characteristics.

The flowchart in figure 5 should be used to choose the appropriate method of obtaining estimated peak flows. The boxes in the right column of the flowchart show the appropriate section of this report for obtaining the peak flows. The "Limitations and Accuracy" statements in each section should be read before applying the equations in that section. Although the discussions on limitations are intended to be comprehensive, it is possible that other specific limitations will arise in the application of the equations in these sections.

The following definitions apply to figure 5:

Site at a gaging station—the drainage area of the study site is within 3 percent of the drainage area of a USGS streamflow-gaging station and on the same stream (see plate 1 for a map of the gaging stations);

Regulated—the drainage basin above the site contains more than 4.5 million ft^3 of usable reservoir storage per mi^2 (Benson, 1962) (usable reservoir storage is the volume of water normally available for release from a reservoir, between the minimum and maximum controllable elevations) or peaks have changed significantly following the addition of a reservoir(s) to a drainage basin;

Diversion—the peak flows from a drainage basin are affected by diversion of flow into or out of the basin;

Site near a gaging station—the drainage area of the site ranges from 50 to 200 percent of the drainage area of a USGS gaging station (excluding the plus or minus 3 percent considered "at a gaging station") and on the same stream;

Urbanized—more than 15 percent of the drainage-basin area above the site is covered by some type of commercial, industrial, or residential development.

Estimates of Peak Flows at USGS Streamflow-Gaging Stations

The 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year peak flows for streamflow-gaging stations discussed in this section were calculated by use of the guidelines of the Interagency Advisory Committee on Water Data (1982) (Bulletin 17B). The calculations involved fitting the Pearson Type III probability distribution to the logarithms (base 10) of the observed annual peak flows at a gaging station. This fitting required computation of the mean, standard deviation, and skew of the logarithms of the annual peak-flow data. The peak flow for any selected recurrence interval was determined from the fitted curve.

Presentation of the Estimates

The peak flows for recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years at USGS streamflow-gaging stations in Kentucky with 10 years or more of record (with the exceptions noted in the section of this report titled "Data Used for Peak-Flow Estimates and Estimating Techniques," page 8) are listed in table 1 (page 33). Three different peak flows are given (where appropriate) for unregulated stations: the gaging-station estimate (G), the regression-equation estimate (R), and a weighted average (W) of these two estimates. As discussed in the section of this report titled "Development of Peak-flow Estimates and Estimating Techniques" (page 10), the weighted average is the most accurate peak-flow estimate for each gaging station.

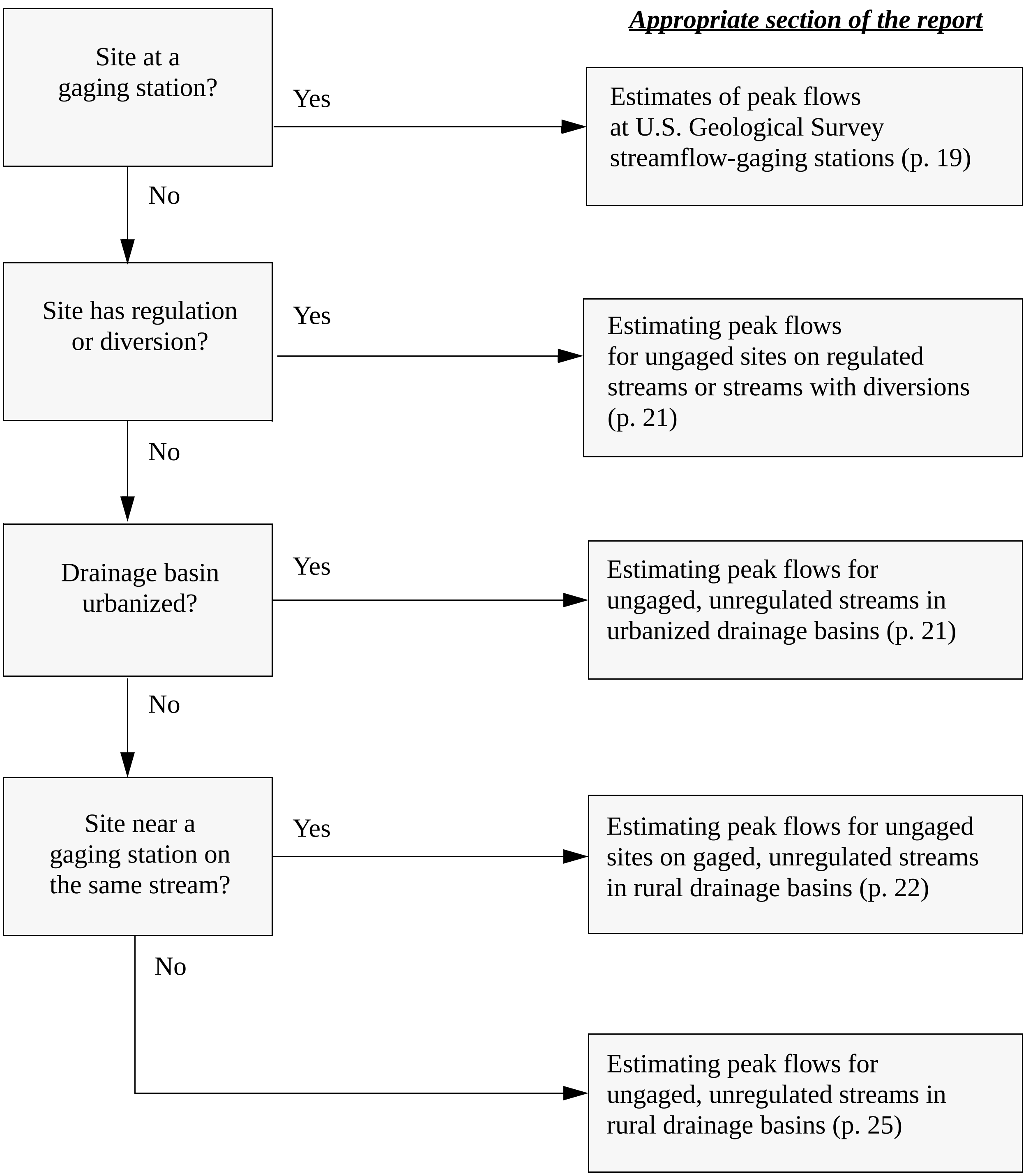

Figure 5. Flowchart for choosing the appropriate means of obtaining estimated peak flows in Kentucky.

For regulated stations, the regression-equation estimate cannot be weighted with the gaging-station estimate because the regression equations do not apply to regulated stations. For sites with drainage-basin characteristics outside the bounds of the drainage-basin characteristics of stations used to create the regression equations, only the gaging-station estimate is presented because the accuracy of the regression-equation estimate is unknown. Also included in table 1 are the USGS gaging-station number and name, the total drainage area, the period of recorded peak flows, the regulation status of the station, and the source of any regulation at a station. Station locations are shown on plate 1.

Limitations and Accuracy of the Estimates

The recorded annual peak flows used to compute the peak flows for given recurrence intervals at gaging stations in this section are assumed to be representative of recorded and unrecorded peaks. Generally, collecting additional years of data at a station provides improved estimates of peak flows. The estimated peak flows at gaging stations will not be reliable if the drainage basin of a station becomes significantly more regulated or urbanized than it was during the period used to calculate the peak flows. In addition, if the flow management at a regulated station changes, the estimated peak flows presented in this section may not apply, depending on the magnitude of the changes. The peak-flow data were analyzed in an attempt to identify significant changes in flow management; subtle or recent changes in flow management may have gone undetected.

If an extreme flood did not occur at a regulated station during the period of streamflow-data collection for that station, the estimated peak flows may underestimate appreciably the true peak flows. This underestimation could result because a large inflow to a reservoir may cause outflows to be regulated differently than at any previous time.

The estimated peak flows in this section do not consider the possibility of dam failures. If a dam failure occurs, the peak flows on streams with dams that store large quantities of water could be much greater than the given peak flows.

Estimating Peak Flows for Ungaged Sites on Regulated Streams or Streams With Diversions

Techniques for estimating peak flows for ungaged, regulated streams or for streams with diversions that will affect peak flows are beyond the scope of this report, because peak flows on these types of streams are dependent on variable human activities. A potential technique for estimating peak flows at ungaged sites on ungaged, regulated streams would be to route peak inflows through the regulated reservoir(s), taking into account regulation practices. The applicable technique of this report could be used to estimate the magnitude of the peak inflows. Physical modeling could be used for sites affected by diversion.

Estimating Peak Flows for Ungaged, Unregulated Streams in Urbanized Drainage Basins

The regression equations presented in the section of this report titled “Estimating Peak Flows for Ungaged, Unregulated Streams in Rural Drainage Basins” (page 25), are not appropriate for urban basins. Peak-flow estimates for ungaged urban basins in Jefferson County, Ky., should be made by use of the methods described in Martin and others (1997). Peak-flow estimates for other urban areas of Kentucky should use the USGS nationwide regression equations contained in Sauer and others (1983).

Martin and others (1997) found that the USGS nationwide urban-regression equations tended to overestimate peak flows for urban streams in Jefferson County. Sherwood (1986) similarly indicated there was positive bias (overestimation) for the USGS nationwide urban-estimating equations when applied in Ohio. It has not been demonstrated that peak-flow estimates from the nationwide urban-regression equations tend to overestimate flows for other urban areas in Kentucky, but such positive bias may well be present.

Sauer and others (1983) presented seven- and three-variable nationwide urban-regression equations in their report. Although the three-variable equations are easier to apply, a later study utilizing new data (Sauer, 1985) showed the three-variable equations to be biased in some areas of the country (mainly in some southeastern States). Only the seven-variable regression equations are recommended for use in Kentucky, because of the potential for biases.

Computed urban peak flows should be compared to the equivalent rural peak flows to make sure that the urban peak-flow estimate is reasonable. The urbanization of a drainage basin generally causes peak flows to increase for those basins that do not have appreciable in-channel or detention storage. The increase in peak flows is usually most dramatic for low recurrence-interval flows, which occur frequently, and less pronounced for high recurrence-interval flows, which occur infrequently (Sauer and others, 1983).

The location of urbanization in a drainage basin may have an effect on peak flows that is not accounted for in the urban-regression equations. For example, if the lower part of a basin is urbanized and the upper part is not, rapid removal of floodwaters from the lower part may occur before the upper part can contribute appreciable runoff. This pattern of urbanization potentially could decrease peak flows from a drainage basin (Sauer and others, 1983).

Estimating Peak Flows for Ungaged Sites on Gaged, Unregulated Streams in Rural Drainage Basins

If an ungaged site is near (see “Limitations of the Technique” later in this section for details) a USGS streamflow-gaging station and on the same stream, a weighted peak flow is calculated. The weights are determined as a function of the difference in drainage area between the ungaged site and the gaging station.

Application of the Technique

Equation 5 (below) provides the means for calculating a final weighted peak flow at an ungaged site on a gaged stream by weighting the peak flow from the gaging station with the peak flow from a regression equation. A different approach is given (equation 9) for sites where the explanatory variables, drainage area (Regions 2, 3, 5, 6, and 7), or drainage area and slope (Regions 1 and 4), are outside the range of the variables used in the development of the regression equations (see table 4 and fig. 6). This range is two-dimensional for Regions 1 and 4. Another approach (equation 10) is provided for ungaged sites located between two gaging stations.

Table 4. Range in values of the basin characteristics used as explanatory variables in the regional peak-flow-regression equations for Kentucky
[--, not applicable]

Region	Total drainage area (square miles)	Main-channel slope (feet per mile)
1	0.16 - 1,197	3.49 - 206
2	.09 - 1,232	--
3	.59 - 722	--
4	.26 - 960	3.60 - 343
5	.24 -1,299	--
6	.22 - 757	--
7	.10 - 706	--

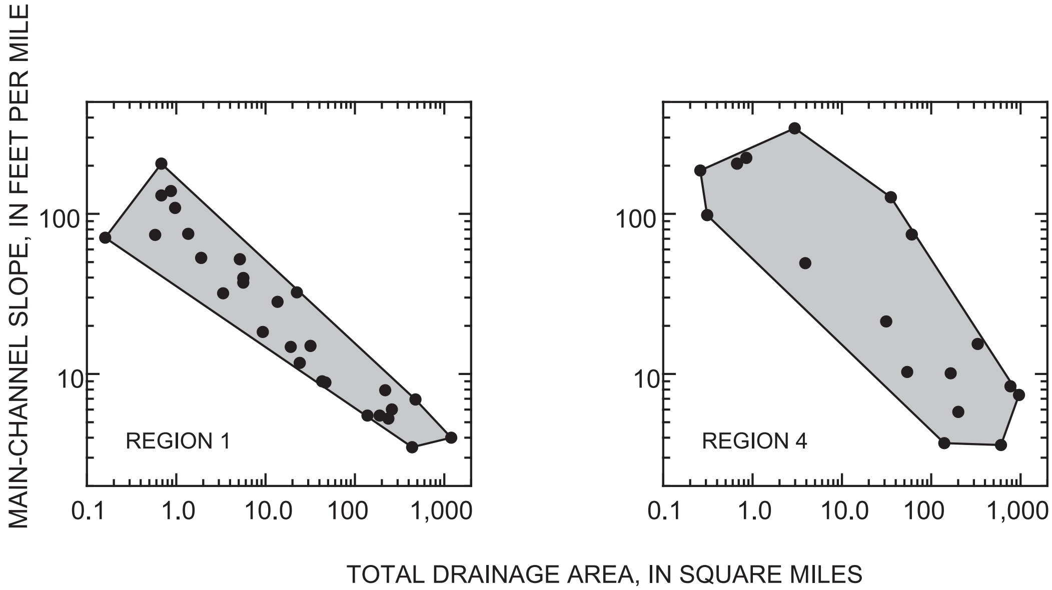

Figure 6. Total drainage area and main-channel slope sampling spaces for the peak-flow regression equations for Regions 1 and 4 in Kentucky.

Application of the equations in this section is based on the assumption that the river is contained completely in one of the seven regions of Kentucky. If a basin spans more than one region, the appropriate equations in this section should be used by computing peak flows, assuming all of the basin is in one of the regions. The peak flows then should be recomputed assuming all of the basin is in the other region (or regions, if there are more than two). Final peak flows should be computed as a weighted average of the peak flows, with weights corresponding to the fraction of the basin in each region. Peak-flow estimates for ungaged sites in basins with drainage from adjacent States can be made similarly by an area weighting of the regression estimate for Kentucky with the regression estimate for the adjacent State. Peak-flow estimating equations for West Virginia (Wiley and others, 2000), Virginia (Bisese, 1995), and Tennessee (Law and Tasker, in press) have been published by the USGS and cooperating agencies.

$$Q_{uf} = Q_r(W_r) + Q_u(1 - W_r)\,, \qquad (5)$$

where

Q_{uf} is the final weighted peak flow for a given recurrence interval (for example, the 50-year peak flow) for an ungaged site on a gaged stream, and

Q_r is the regression estimate of the peak flow, at the ungaged site, for a given recurrence interval (for example, the 50-year peak flow) from table 3 in the section of this report titled "Estimating Peak Flows for Ungaged, Unregulated Streams in Rural Drainage Basins" (page 25), for the appropriate region.

W_r is a weighting factor; for

$$A_u > A_g,\ W_r = (A_u / A_g) - 1,\ \text{and for} \qquad (6)$$

$$A_u < A_g,\ W_r = (A_g / A_u) - 1\,, \qquad (7)$$

where

A_u is the total drainage area at the ungaged site, and

A_g is the total drainage area at the gaging station.

$$Q_u = Q_w (A_u / A_g)^b , \qquad (8)$$

where

Q_w is the weighted-average peak flow for a given recurrence interval (such as the 50-year peak flow) for the gaging station from table 1 (page 33) in the section of this report titled “Estimates of Peak Flows at USGS Streamflow-Gaging Stations,” page 19 (or from possible future reports), and

b is the coefficient (exponent) for the drainage-area-only regression equation for the region and for the appropriate recurrence interval (table 5).

If explanatory variables are outside the two-dimensional range of the variables used for the regression equations (Regions 1 and 4; fig. 6), or outside the range of drainage areas (Regions 2, 3, 5, 6, and 7; table 4) then

$$Q_{uf} = Q_w (A_u / A_g)^b , \qquad (9)$$

where

Q_{uf} is the final weighted peak flow for a given recurrence interval (for example, the 50-year peak flow) for an ungaged site on a gaged stream, and

Q_w is the weighted-average peak flow for a given recurrence interval (such as the 50-year peak flow) for the gaging station from table 1 (page 33) in the section of this report titled “Estimates of Peak Flows at USGS Streamflow-Gaging Stations,” page 19, (or from possible future reports). If the weighted-average peak flow is not available, the gaging-station peak flow should be used.

A_u, A_g, and b were defined in equations 6, 7, and 8.

If the ungaged site is located between two gaging stations, then the log base-10 interpolated peak-flow estimate may be calculated using equation 10, then detransformed from logs ($Q_{ui} = 10^{\log Q_{ui}}$).

$$\log Q_{ui} = \log Q_{w1} + ((\log Q_{w2} - \log Q_{w1}) (\log A_u - \log A_{g1}) / (\log A_{g2} - \log A_{g1})) , \qquad (10)$$

where

Q_{ui} is the interpolated peak flow for a given recurrence interval (for example, the 50-year peak flow) for an ungaged site located between two gaging stations,

Q_{w1} and Q_{w2} are the weighted-average peak flows for a given recurrence interval (such as the 50-year peak flows) at the upstream and downstream gaging stations, respectively, from table 1 (page 33) discussed in the section of this report titled, “Estimates of Peak Flows at USGS Streamflow-Gaging Stations” (page 19),

A_u is the total drainage area at the ungaged stream site, and

A_{g1} and A_{g2} are the total drainage areas at the upstream and downstream gaging stations, respectively.

Table 5. Coefficients (exponents) of the drainage-area-only regional peak-flow regression equations for Kentucky

Recurrence interval (years)	Region						
	1	2	3	4	5	6	7
2	0.673	0.728	0.748	0.824	0.704	0.600	0.623
5	.651	.721	.712	.803	.692	.586	.616
10	.642	.715	.692	.794	.686	.578	.613
25	.634	.709	.670	.786	.682	.569	.610
50	.629	.704	.656	.783	.679	.564	.610
100	.625	.699	.643	.780	.677	.559	.609
200	.622	.695	.632	.778	.676	.555	.610
500	.618	.690	.620	.776	.674	.551	.610

Limitations of the Technique

This technique is applicable to ungaged sites on gaged, unregulated streams in rural drainage basins that range from 50 to 200 percent of the drainage area of the gaging station(s), except for sites that are plus or minus 3 percent of the drainage area. For ungaged sites within 3 percent of the gaging-station drainage area, the weighted-average peak-flow estimates (table 1, page 33) should be used. If the difference in drainage areas is less than 3 percent and the weighted-average peak-flow estimate is not available for the station, the gaging-station peak-flow estimate from table 1 should be used.

This method is not applicable to urbanized drainage basins, to regulated streams, or to sites affected by diversion (see "Choosing the Appropriate Peak-Flow Estimation Technique," page 18, for definitions of these terms); neither is it applicable if the area between the ungaged site and the gaging station(s) is urbanized nor contains regulation (utilizing the same definitions of urbanized and regulated recently referred to, but using drainage-area difference instead of drainage area in these definitions).

Estimating Peak Flows for Ungaged, Unregulated Streams in Rural Drainage Basins

Peak flows for ungaged drainage basins for selected recurrence intervals generally are estimated by rainfall-runoff procedures or by regression-based procedures. Newton and Herrin (1982) analyzed various procedures of both types. The rainfall-runoff models that they analyzed, including the Natural Resources Conservation Service TR-20 and TR-55 models, the USCOE HEC-1 model, and the rational method, were not calibrated to at-site flow data. Newton and Herrin (1982) concluded that certain regression-based methods (specifically, the USGS State-regression equations and index-flood methods) are the most accurate and reproducible procedures for estimating peak flows for given recurrence intervals.

Regression equations are used in this section of the report to compute peak-flow estimates for ungaged, unregulated streams in rural drainage basins in Kentucky. The response (dependent) variables used in developing the regression equations were the peak flows computed at USGS gaging stations and the explanatory (independent) variables were drainage-basin characteristics such as drainage area and stream slope.

Application of the Technique

Peak-flow regression equations for recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years are presented in table 3 (page 15). The variables used in the equations are described in the text that follows. The average standard error of prediction and other measures of error are discussed in the section of this report titled "Limitations and Accuracy of the Technique."

All of the regression equations in this report are statistical models. These models are not based directly on rainfall-runoff processes. For this reason, when applying these equations, the explanatory variables should be computed by the same techniques that were used in the development of the equations. The use of "more accurate" techniques of computing the explanatory variables will result in peak-flow estimates of unknown accuracy.

Definitions of equation variables in table 3:

Q_T – Peak flow—The calculated peak flow, in ft^3/s, for recurrence interval T (T = 2, 5, 10, 25, 50, 100, 200, or 500 years).

TDA – Total drainage area—The total area, measured in mi^2 on a horizontal plane, of a drainage basin. Total drainage area includes all enclosed subbasins characterized by internal drainage, for example, sinkholes in karst terrain. The drainage area can be determined from a number of sources. Bower and Jackson (1981) lists drainage areas measured from paper USGS topographic quadrangle maps (1:24,000 scale within Kentucky and 1:62,500 scale outside Kentucky) at selected points for many streams in Kentucky. Drainage areas can be computed by digitizing the area of a drainage basin, after delineating the drainage-basin boundaries on 1:24,000-scale topographic quadrangle maps. Drainage areas also can be computed from geographic information system (GIS) 1:24,000-scale map coverages. The drainage areas for the 238 streamflow-gaging stations used in the development of the Kentucky regression equations (table 3) were determined by use of either paper or GIS maps of the resolutions cited previously. These values are listed in table 2 (page 61).

S – Main-channel slope—The slope computed as the difference in elevation between points located at 10 and 85 percent of the main-channel length from the gage, divided by the stream length between these two points (in ft/mi), as determined from USGS 7.5-minute topographic quadrangle maps. The main-channel length is measured along the main-stream channel from the gage to the basin divide, following the longest tributary.

If the drainage basin at a site is located in two (or more) hydrologic regions (plate 1), the peak flow for a given recurrence interval is determined by (1) applying the appropriate estimating equation from table 3 as though the basin is located entirely in each region, and then (2) weighting the two (or more) estimates in proportion to the fraction of the drainage basin in each region (see example 1, page 27).

Limitations and Accuracy of the Technique

The regression equations presented in this section of the report are not applicable to regulated or urbanized drainage basins or drainage basins with diversion. The terms “regulated,” “diversion,” and “urbanized” are defined and the appropriate methodologies for assessing these conditions are described in the section of this report titled “Choosing the Appropriate Peak-Flow Estimation Technique” (page 18).

If the explanatory variables in Regions 1 and 4 (total drainage area and main-channel slope) used in the regression equations in this section are outside the two-dimensional range of the values used to develop the equations (the gray areas on fig. 6, page 23), the accuracy of predictions of peak flows from the equations is unknown and could be reduced substantially. The accuracy of predictions also will be unknown if the total drainage area in Regions 2, 3, 5, 6, and 7 is outside the respective ranges in table 4 (page 22). The further the basin characteristics are outside the sampling space (the gray areas on fig. 6 or the ranges in table 4), the greater the potential for large reductions in the accuracy of the regression equations.

The average standard error of prediction (ASEP) is a measure of how well the regression equations estimate peak flows when they are applied to ungaged drainage basins. The ASEP is the square root of the average variance of prediction at a group of sites with the same basin characteristics as the gaging stations used in development of the regression equations. The standard error of prediction varies from site to site, depending on the values of the explanatory variables (drainage area and main-channel slope for Regions 1 and 4) for each site. The standard error of prediction will be smaller for sites that have explanatory variables near the mean of their range; however, the error associated with the different values of the explanatory variables is a small part of the total standard error of prediction. For this reason, the ASEP can be used as an approximate standard error of prediction for individual sites. The probability that the true value of a peak flow at a study site is between the positive-percent ASEP and the negative-percent ASEP is approximately 68 percent. For example, there is a 68 percent probability that the true 50-year peak flow in Region 1 at an ungaged site ranges from +52.9 to -34.6 percent (table 3, page 15) of the computed peak flow.

The average equivalent years of record is another measure of the overall accuracy of the regression equations. This measure represents the average number of years of gaging-station data needed to determine estimates with accuracy equal to the regression equations. The average equivalent years of record is a function of the accuracy of the regression equations, the recurrence interval, and the average variance and skew of the annual peak flows at gaging stations (Hardison, 1971).

In GLS regression, the average variance of prediction is divided into two parts: the model-error variance and the sampling-error variance. The average standard error of prediction is the square root of the average variance of prediction. The estimated model-error variance and average sampling-error variance from the regression equations in this section of the report are given in table 3. The model-error variance is a measure of the error resulting from an incomplete model if the true values of the estimated peak flows at gaging stations were known at all streams in Kentucky (rather than the sample values that were used). In other words, the explanatory variable (total drainage area and slope for Regions 1 and 4) in the regression equation would not explain all the variation in peak flows from the complete population. The true model-error variance cannot be reduced by additional data collection, although the estimated model-error variance may change if additional data are obtained. The average sampling-error variance for the regression equations is a measure of the error associated with sampling only a subset of the total population of streams in Kentucky (space-sampling error) and sampling only a subset of the total years of data at the gaging stations (time-sampling error). The sampling error can by reduced by collecting more data at existing gaging stations, collecting data at new gaging stations, or some combination of both.

Another overall measure of how well regression equations will estimate flood peaks when applied to ungaged basins is the PRESS statistic. The PRESS statistic is a validation-type statistic. To compute the PRESS statistic, one gaging station is removed from the stations used to develop the regression equation, then the value of the one left out is predicted. The difference between the predicted value from the regression equation and the observed peak flow at that station is computed. The gaging station removed then is changed and the above process repeated until every station has been removed once. The prediction errors then are squared and summed. PRESS/n is analogous to the average variance of prediction, and the square root of PRESS/n is analogous to the average standard error of prediction. Values of the square root of PRESS/n close to the values of the average standard error of prediction provide some measure of validation of the regression equations.

Example Applications of the Estimating Equations

The regional peak-flow estimating equations presented in this report (table 3) can be applied to rural, unregulated streams by (1) determining the basin characteristics required for the appropriate equation, (2) checking to ensure that the basin characteristics are within the range of characteristics used to develop the equations (table 4 and fig. 6), and (3) use of the measured basin-characteristic values with the appropriate equation(s) to compute the estimate.

Example 1—Assume that an estimate of the 100-year peak flow, Q_{100}, is needed for an ungaged stream site in Region 3 with a total drainage area of 600 mi^2, the upper 333 mi^2 (55.5 percent of the basin) of which is located in Region 2. The peak-flow estimate for drainage basins located in two regions is determined by (1) applying the estimating equation as though the basin is located entirely in each region, and then (2) weighting the two estimates in proportion to the basin drainage area in each region, as follows:

For the Region 2 estimate,

$$\begin{aligned} Q_{100} &= 538\ TDA^{0.699}, \\ &= 538\ (600)^{0.699}, \\ &= 47{,}100\ ft^3/s. \end{aligned}$$

For the Region 3 estimate,

$$\begin{aligned} Q_{100} &= 1{,}100\ TDA^{0.643}, \\ &= 1{,}100\ (600)^{0.643}, \\ &= 67{,}300\ ft^3/s. \end{aligned}$$

The area-weighted regression estimate for the ungaged site is

$$Q_{100} = 0.555\ (47{,}100) + 0.445\ (67{,}300) = 56{,}100\ \mathrm{ft}^3/\mathrm{s}.$$

Example 2—Assume the 600 mi^2 ungaged, unregulated stream site in example 1 is located downstream from a gaging station with a total drainage area of 466 mi^2. In this case, a weighting of the regression estimate of Q_{100} at the ungaged site with the Q_{100} value at the adjacent gaging station by use of equation 5 is appropriate. The drainage area of the ungaged site is less than 200 percent of the drainage area at the gaging station ((600/466)100 = 129 percent), as required for use of equation 5. Again, when the ungaged drainage basin is located in two or more regions, the peak-flow estimate (using equation 5 in this case) is determined by (1) applying the estimating equation as though the basin is located entirely in each region, and then (2) weighting the two estimates in proportion to the basin drainage area in each region as

$$Q_{uf} = Q_r(W_r) + Q_u(1 - W_r),$$

For the Region 2 estimate,

Q_r = 47,100 ft^3/s, the regression estimate at the ungaged site, as determined in example 1, and

Q_u = $Q_w(A_u / A_g)^b$, where Q_w is the weighted 100-year peak-flow estimate at the gaging station, listed in table 1 (page 33), and b is the exponent of the drainage-area-only regression equation for Region 2 (table 5),

Assume Q_w is 50,700 ft^3/s at the upstream gaging station (table 1) and b is 0.699 for the 100-year peak flow in Region 2 (table 5). Therefore, the gaging station peak-flow estimate "translated" downstream to the ungaged site is

$Q_u = 50{,}700(600/466)^{0.699} = 60{,}500$ ft^3/s.

For $A_u > A_g$, $W_r = (A_u / A_g) - 1$, or

$W_r = (600/466) - 1 = 1.288 - 1 = 0.288$.

The gage-weighted peak-flow estimate at the ungaged site in Region 2 is computed by use of equation 5 as

$Q_{uf} = 47{,}100\ (0.288) + 60{,}500\ (1 - 0.288) = 56{,}600$ ft^3/s.

For the Region 3 estimate,

Q_r = 67,300 ft^3/s, the regression estimate at the ungaged site, as determined in example 1, and

Q_u = $Q_w(A_u / A_g)^b$, where Q_w is the weighted 100-year peak-flow estimate at the gaging station (50,700 ft^3/s), and b is the exponent of the drainage-area-only regression equation for Region 3, 0.643 (table 5),

The gage peak-flow estimate "translated" downstream to the ungaged site is

$Q_u = 50{,}700(600/466)^{0.643} = 59{,}600$ ft^3/s.

$W_r = 0.288$, as determined previously.

The gage-weighted peak-flow estimate at the ungaged site in Region 3 is computed by use of equation 5 as

$Q_{uf} = 67{,}300\ (0.288) + 59{,}600\ (1 - 0.288) = 61{,}800$ ft^3/s.

The final estimate is an area-weighted average of these Region 2 and Region 3 estimates,

$Q_{uf} = 0.555\ (56{,}600) + 0.445\ (61{,}800) = 58{,}900$ ft^3/s.

Example 3—Assume the 600 mi^2 ungaged, unregulated stream site in example 2 also is located upstream from a gaging station that has a total drainage area of 1,101 mi^2. In this case, a logarithmic interpolation is used between the peak flows at the gaging stations based on the drainage area at the ungaged site and at the two gages. The logarithmically interpolated peak-flow estimate may be calculated by use of equation 10 as

$$\log Q_{ui} = \log Q_{w1} + ((\log Q_{w2} - \log Q_{w1})(\log A_u - \log A_{g1}) / (\log A_{g2} - \log A_{g1})),$$

$\log Q_{ui}$ = log 50,700 + ((log 70,000 - log 50,700) (log 600 - log 466) / (log 1101 - log 466)),

$\log Q_{ui}$ = 4.7462

$Q_{ui} = 10^{4.7462} = 55{,}700$ ft^3/s.