LOW-FLOW CHARACTERISTICS OF KENTUCKY STREAMS

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U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 91-4097

Prepared in cooperation with the
KENTUCKY NATURAL RESOURCES AND
ENVIRONMENTAL PROTECTION CABINET

Louisville, Kentucky
1991

methods and from the regression equations are given in table 2. Also included in table 2 are the drainage area and mapped streamflow variability for each partial-record station. Figures 11 and 12 show the relation between the $7Q_2$ and $7Q_{10}$ low flows estimated from correlation techniques and estimated using the regression equations. The $7Q_2$ estimating equation tends to slightly underpredict for stations having observed discharge values above about 2 ft^3/s. Figures 11 and 12 both show considerable scatter in estimates below about 1.0 ft^3/s which becomes more pronounced the closer the estimates are to 0.1 ft^3/s.

ESTIMATING LOW-FLOW FREQUENCY VALUES AT STREAM SITES IN KENTUCKY

Stream Sites With Gage Information

Sites at Gage Locations

Estimates of low-flow values are presented for 136 continuous-record and 212 partial-record stations. When an estimate of low-flow is required at a stream site, the first step should be to scan tables 1 and 2 to determine whether low-flow frequency values have previously been estimated. This is the primary source for a low-flow estimate at a stream site.

Sites near Gage Locations

If information is available for the stream where an estimate is desired, but not at the specific location, a weighting procedure can be employed (Carpenter, 1983). The first constraint to the use of this method is that the drainage area of the ungaged site differ by no more than 50 percent from that of the gaged site (either a continuous- or partial-record station). The second constraint to the use of this method is that the entire drainage basin where the estimate is desired be within the same variability-index area (pl. 1). This second constraint is important because the method assumes a linear relation between the flow values at the gaged and ungaged sites. This is not a valid assumption if the gaged and ungaged sites are affected by different basin characteristics.

The first step in using the weighting procedure is to verify that the above two constraints are not violated. Obtain the low-flow value at the gage site from either table 1 or 2 (from column labeled "From graphical correlation") and also estimate the value at the gaged site using either equation 2 or 3, whichever is appropriate. Compute the correction factor at the gaged site (C_g) as the ratio of the observed low-flow value from table 1 or 2 to the estimated value from either equation 2 or 3. This correction factor will now be used to compute a correction factor at the ungaged site based on the difference in drainage area between the gaged and ungaged site by

$$C_u = C_g - \frac{2\Delta A}{A_g}(C_g - 1) , \qquad (4)$$

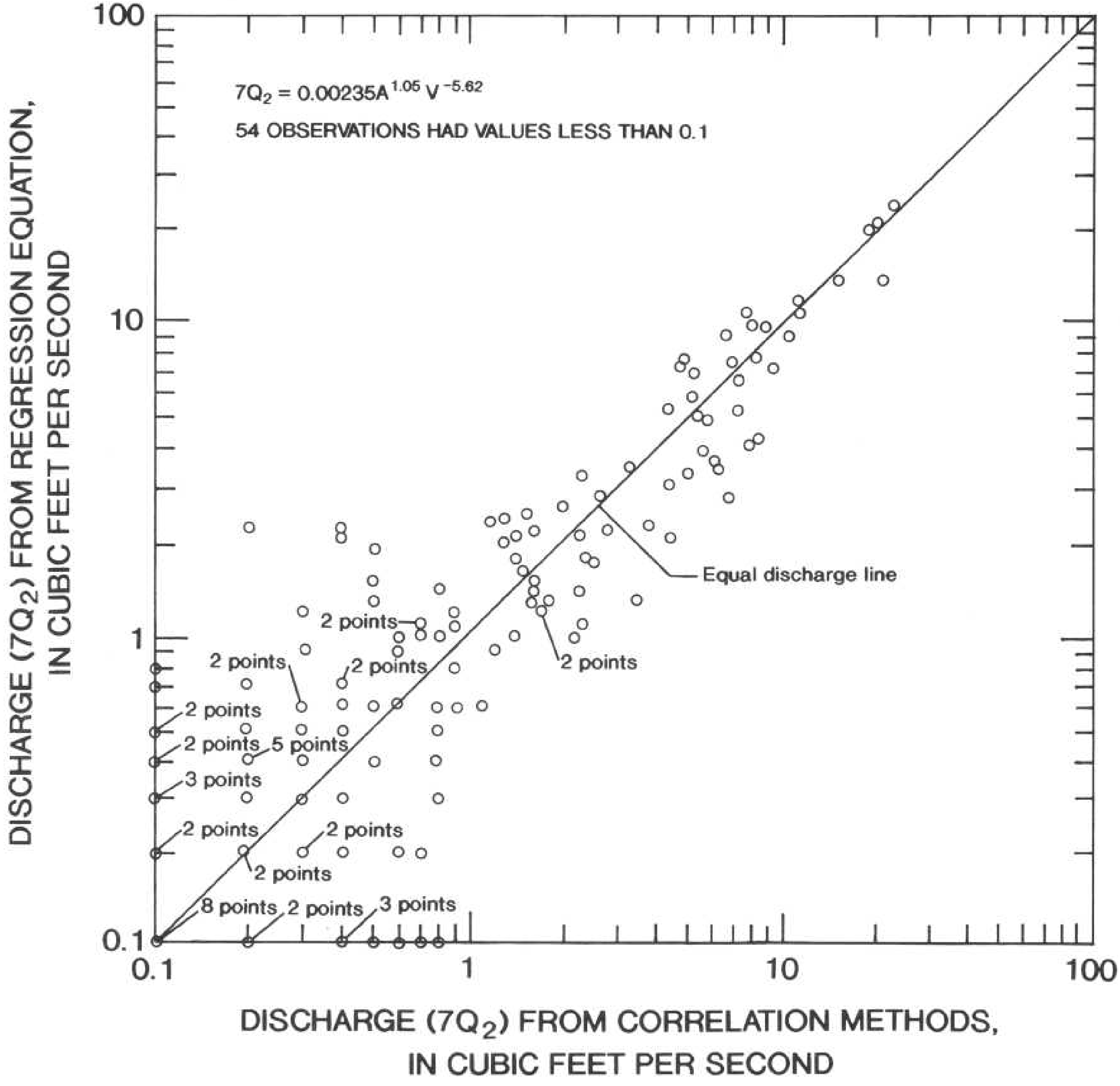

Figure 11.--Plot of 7-day 2-year low flow from correlation methods and from regression equation for selected partial-record gaging stations in Kentucky.

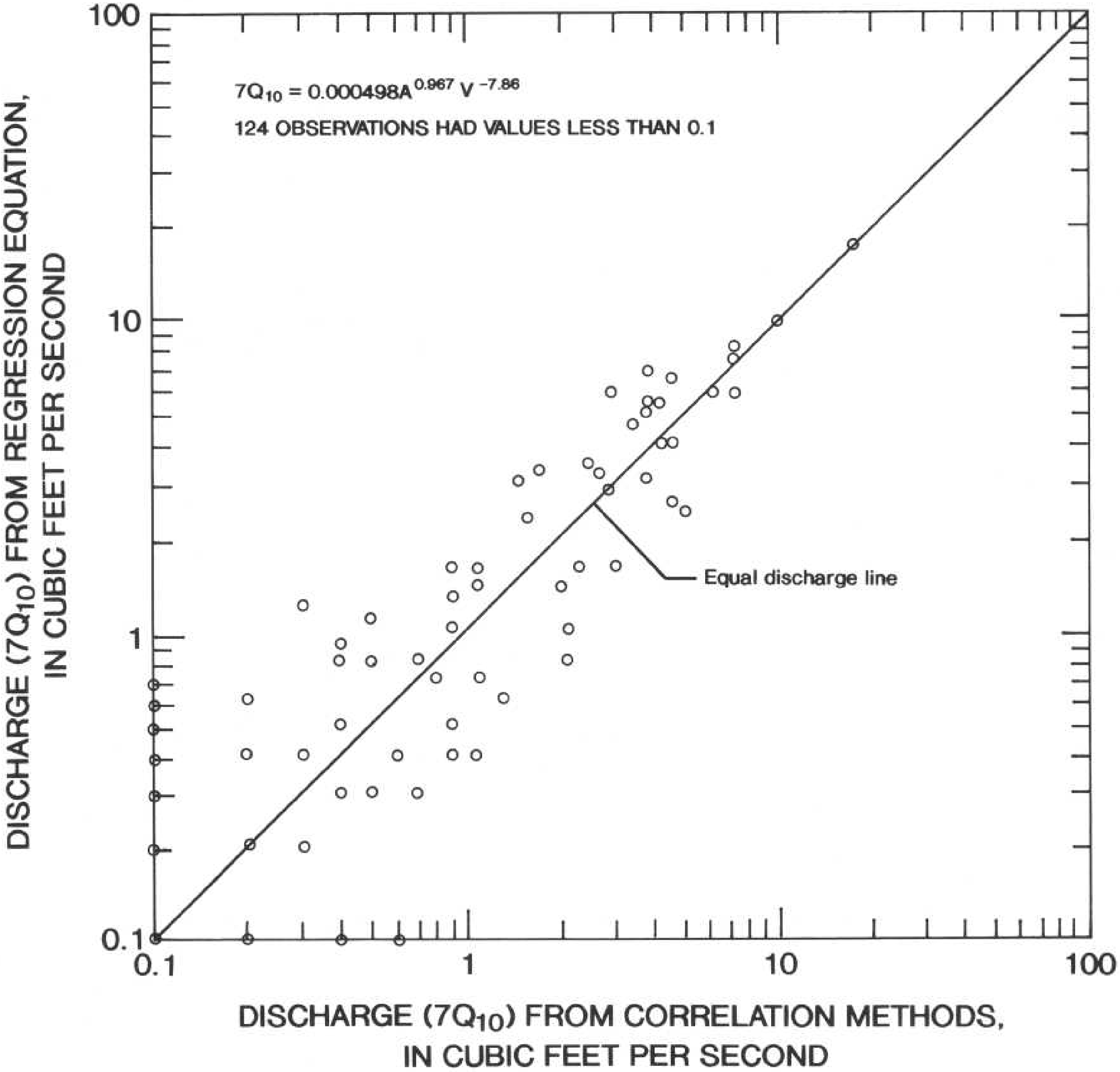

Figure 12.--Plot of 7-day 10-year low flow from correlation methods and from regression equation for selected partial-record gaging stations in Kentucky.

where

C_u is the correction factor for the ungaged site;
C_g is the correction factor for the gaged site;

A is the absolute value of the difference in drainage area between the gaged and ungaged site, in square miles; and
A_g is the drainage area of the gaged site, in square miles.

Compute the estimated discharge at the ungaged site using either equation 2 or 3 and multiply this value by the correction factor, C_u from equation 4, to obtain the weighted value of low-flow at the ungaged site. The equation is

$$Q_w = C_u Q_u , \qquad (5)$$

where

Q_w is the weighted discharge determined at the ungaged site, in cubic feet per second;
C_u is the correction factor for the ungaged site (from equation 4); and
Q_u is the regression estimate of low flow from either equation 2 or 3, in cubic feet per second.

As the difference in drainage area between the gaged and ungaged site approaches 50 percent, the value of C_u approaches 1, and no longer has an effect on the regression estimate at the ungaged site.

Sites Between Gage Locations

If a low-flow estimate is desired between two gage locations on the same stream, the value can be estimated by straight-line interpolation, using the low-flow values and corresponding drainage areas at the two gaged sites. As with the previous method, the technique should not be used where the reach extends over, or is drained by more than one variability-index boundary. When this condition exists, the relation is not linear between the two gaged sites.

Stream Sites With No Gage Information

If no streamflow information is available at the desired stream site or at a nearby stream site on the same stream so that the estimating methods in the previous section cannot be used, then equations 2 and 3 can be used directly to estimate low-flow values. These equations, or the curves shown in figures 7 and 8, can be used to estimate values of the $7Q_2$ and $7Q_{10}$ at ungaged, unregulated stream sites in Kentucky. A value of 0.05 ft^3/s or less, using either equation 2 or 3, should be considered zero.

Total drainage area of the site of interest should be obtained from USGS 7.5-minute topographic maps. The drainage areas for many sites along streams in Kentucky are listed in Bower and Jackson (1981). Streamflow variability is obtained from plate 1. The percent of total drainage area within each streamflow-variability index area will also need to be determined. Examples of numerical and graphical procedures for obtaining the estimated $7Q_2$ and $7Q_{10}$ values from basins lying entirely within one index area and those in two or more index areas are given in the following sections.

Sites With Drainage Basins in One Index Area

The numerical solution for obtaining the $7Q_2$ and $7Q_{10}$ values at an ungaged site that is entirely within the same streamflow-variability index area is computed using the following method. Determine the total drainage area of the site from USGS 7.5-minute topographic maps and the streamflow variability from plate 1. Substitute the values into equations 2 and 3 below. The example assumes the site has a total drainage area of 155 mi² and is entirely within the variability index area of 0.70.

$$7Q_2 = 0.00235\ A^{1.05}\ V^{-5.62} \quad \text{(Equation 2)}$$

$$7Q_2 = 0.00235\ (155)^{1.05}(0.70)^{-5.62}$$

$$7Q_2 = 0.00235\ (199)(7.42)$$

$$7Q_2 = 3.5\ ft^3/s$$

$$7Q_{10} = 0.000498\ A^{0.967}\ V^{-7.86} \quad \text{(Equation 3)}$$

$$7Q_{10} = 0.000498\ (155)^{0.967}(0.70)^{-7.86}$$

$$7Q_{10} = 0.000498\ (131)(16.5)$$

$$7Q_{10} = 1.1\ ft^3/s$$

A graphical solution can be obtained from the curves shown in figures 7 and 8. Enter the plot on the abscissa scale at 155 mi² and proceed upward to the 0.70 streamflow-variability index curve. From there, proceed to the ordinate scale to obtain the estimated $7Q_2$ and $7Q_{10}$ value.

Sites With Drainage Basins in More Than One Index Area

If the drainage area for a desired site location includes more than one variability index area, the following method is used to estimate the $7Q_2$ and $7Q_{10}$ values. Determine the total drainage area of the site and percent of the drainage basin located within each of the streamflow-variability index areas. For this example, assume that an estimate of the $7Q_{10}$ is desired for a 300 mi² basin having 65 percent of the drainage area within a variability index area of 0.90. The remaining 35 percent is contained in an area having a variability index of 0.70. The numerical solution is as follows. First, obtain a value for the $7Q_{10}$ as if all of the basin were contained in the 0.70 variability index area, and perform the following computation:

$$7Q_{10} = 0.000498\ A^{0.967}\ V^{-7.86} \quad \text{(Equation 3)}$$

$$7Q_{10} = 0.000498\ (300)^{0.967}(0.70)^{-7.86}$$

$$7Q_{10} = 0.000498\ (249)(16.5)$$

$$7Q_{10} = 2.0\ ft^3/s$$

Assume the entire area lies within the 0.90 variability index area and compute the flow.

$$7Q_{10} = 0.000498\ A^{0.967}\ V^{-7.86}$$

$$7Q_{10} = 0.000498\ (300)^{0.967}(0.90)^{-7.86}$$

$$7Q_{10} = 0.000498\ (249)(2.29)$$

$$7Q_{10} = 0.28\ ft^3/s$$

To obtain a solution, multiply each flow value computed above by the corresponding percent of basin drainage area and sum the resulting values to determine the weighted average low-flow estimate.

$$\begin{aligned} 2.0\ ft^3/s\ (0.65) &= 1.30 \\ 0.28\ ft^3/s\ (0.35) &= \underline{0.10} \\ \text{weighted average } 7Q_{10} &= 1.40 \quad \text{or} \quad 1.4\ ft^3/s \end{aligned}$$

A graphical solution using the curves in figures 7 and 8 can be obtained using the same method. First, obtain values of the $7Q_2$ or $7Q_{10}$ for each variability index using the entire drainage area from either figure 7 or 8, whichever is appropriate. Multiply the values obtained from the graph by the percent of total drainage area corresponding to that variability index and sum the results to obtain the weighted average low-flow estimate.

The $7Q_{10}$ for stream sites with drainage areas less than 3 mi^2 should be considered zero, unless the site is located in a variability index area of 0.45, 0.50, or 0.55 (pl. 1). Streamflow information should be collected at sites in these index areas with drainage areas less than 3 mi^2 to determine low-flow values. The $7Q_{10}$ should be considered zero for stream sites draining areas less than 600 mi^2 in variability index areas of either 1.25 or 1.35. These areas coincide with the Western Kentucky Coal Field and the Outer Bluegrass physiographic regions (fig. 1). Streamflow information should be collected at sites when the $7Q_2$ or $7Q_{10}$ estimated from equations 2 or 3 is between 0.1 and 1.0 ft^3/s. Considerable scatter was evident in figures 9 through 12 for low-flow estimates in this range.

SUMMARY

Low-flow characteristics were determined for 136 continuous- and 212 low-flow partial-record streamflow-gaging stations in Kentucky. Values of the 7-day low flow for the unregulated streamflow record of 10 years or more were used to construct frequency curves at the continuous-record stations. These curves were compared to output from the Log Pearson Type III frequency analysis and in all cases there was good agreement; therefore, the results from the Log Pearson Type III analysis were used. Because of climatic trends in the station data, the frequency values for stations with less than 25 years of record were adjusted through correlation techniques to stations having 25 or more years of record. Selected frequency values previously estimated at 212 partial-record stations were reviewed. The values were estimated using graphical correlation techniques with one or more of the continuous-record gaging stations.

Techniques to estimate the $7Q_2$ and $7Q_{10}$ low flows at ungaged stream sites in Kentucky were developed from the available data. The estimating equations use drainage area and the streamflow-variability index as the regressor variables. The streamflow variability at a station is the standard deviation of the logarithms of the daily mean flows taken at selected percentiles from the flow-duration curve. The streamflow variability reflects the influence of surficial geology observed by the spatial variation of stream base flow. The $7Q_2$ and $7Q_{10}$ estimating equations have a standard error of 71 and 90 percent, respectively. Ten of the 212 partial-record gaging stations also were used to develop the estimating equations. Data from the remaining partial-record sites were used as verification data resulting in a standard error of prediction of the $7Q_2$ and $7Q_{10}$ low flows of 76 and 91 percent, respectively.

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