# ESTIMATING SELECTED LOW-FLOW FREQUENCY STATISTICS AND HARMONIC-MEAN FLOWS FOR UNGAGED, UNREGULATED STREAMS IN INDIANA

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ABSTRACT:

Information on low-flow characteristics of streams is essential for the management of water resources. This report provides equations for estimating the 1-, 7-, and 30-day mean low flows for a recurrence interval of 10 years and the harmonic-mean flow at ungaged, unregulated stream sites in Indiana. These equations were developed using the low-flow statistics and basin characteristics for 108 continuous-record streamgages in Indiana with at least 10 years of daily mean streamflow data through the 2011 climate year (April 1 through March 31). The equations were developed in cooperation with the Indiana Department of Environmental Management.

Regression techniques were used to develop the equations for estimating low-flow frequency statistics and the harmonic-mean flows on the basis of drainage-basin characteristics. A geographic information system was used to measure basin characteristics for selected streamgages. A final set of 25 basin characteristics measured at all the streamgages were evaluated to choose the best predictors of the low-flow statistics.
Logistic-regression equations applicable statewide are presented for estimating the probability that selected low-flow frequency statistics equal zero. These equations use the explanatory variables total drainage area, average transmissivity of the full thickness of the unconsolidated deposits within 1,000 feet of the stream network, and latitude of the basin outlet. The percentage of the streamgage low-flow statistics correctly classified as zero or nonzero using the logistic-regression equations ranged from 86.1 to 88.9 percent.

Generalized-least-squares regression equations applicable statewide for estimating nonzero low-flow frequency statistics use total drainage area, the average hydraulic conductivity of the top 70 feet of unconsolidated deposits, the slope of the basin, and the index of permeability and thickness of the Quaternary surficial sediments as explanatory variables. The average standard error of prediction of these regression equations ranges from 55.7 to 61.5 percent.

Regional weighted-least-squares regression equations were developed for estimating the harmonic-mean flows by dividing the State into three low-flow regions. The Northern region uses total drainage area and the average transmissivity of the entire thickness of unconsolidated deposits as explanatory variables. The Central region uses total drainage area, the average hydraulic conductivity of the entire thickness of unconsolidated deposits, and the index of permeability and thickness of the Quaternary surficial sediments. The Southern region uses total drainage area and the percent of the basin covered by forest. The average standard error of prediction for these equations ranges from 39.3 to 66.7 percent.

The regional regression equations are applicable only to stream sites with low flows unaffected by regulation and to stream sites with drainage basin characteristic values within specified limits. Caution is advised when applying the equations for basins with characteristics near the applicable limits and for basins with karst drainage features and for urbanized basins. Extrapolations near and beyond the applicable basin characteristic limits will have unknown errors that may be large. Equations are presented for use in estimating the 90-percent prediction interval of the low-flow statistics estimated by use of the regression equations at a given stream site.

The regression equations are to be incorporated into the U.S. Geological Survey StreamStats Web-based application for Indiana. StreamStats allows users to select a stream site on a map and automatically measure the needed basin characteristics and compute the estimated low-flow statistics and associated prediction intervals.

RASTERS:

Several basin characteristics derived from characteristics in well logs from the Indiana Water-Well Record (Indiana Department of Natural Resources, 2002) were tested to evaluate their potential use to explain the variability of low-flow statistics in Indiana streams.

K1

The K1 characteristic was derived from a grid of texture-based estimates of average horizontal hydraulic conductivity for the unconsolidated deposits in each basin and can range from 1 to 100 feet per day (ft/d) (fig. 3). The K1 characteristic was computed by averaging the K1 grid values contained within each basin boundary. The statewide grid of 3,855 feet by 3,855 feet square was created by means of an inverse-distance-weighting interpolation of point values of texture-based average horizontal hydraulic conductivity. The point values are located at water wells and are based on the lithologic description recorded by the well driller at the time of well installation. Water-well records used to compute the gridded data are from the published, on-line Indiana Water-Well Record Database (Indiana Department of Natural Resources, 2002). The hydraulic-conductivity grids were created using 82,588 wells in Indiana (an average density of 2.7 wells per $mi^2$) that penetrate at least 50 percent of the unconsolidated deposits.

Well records used for this study had been processed to classify texture-based lithology according to procedures described in Arihood (2009). The descriptions of lithology for each well record consisted of phrases that describe the depth range and type of unconsolidated deposits recorded during drilling, such as “sand from 10 to 20 ft”; “clay from 20 to 30 ft”, and “sand and gravel from 20 to 23 ft”. Depth ranges were converted into thicknesses of unconsolidated deposits. The lithologic descriptions were converted into a texture-based value of horizontal hydraulic conductivity at each well by the following procedure, with one modification, as described in Arihood (2009, p. 5–10). All coarse-grained deposits (for example, sand, sand and gravel, gravel) were assumed to have a horizontal hydraulic conductivity of 100 ft/d, and all fine-grained deposits (for example, clay, silt, silty sand) were assumed to have a horizontal hydraulic conductivity of 1 ft/d. The two horizontal hydraulic conductivity values used to represent coarse-grained deposits and fine-grained deposits were considered sufficiently similar to real-world values and different from each other to represent a contrast in the aquifer and nonaquifer material. Next, using all unconsolidated lithologies for the first 70 ft below land surface at the well site, a thickness-weighted average of the two hydraulic conductivities was calculated by multiplying 100 ft/d times the thickness of the coarse-grained deposits, adding 1 ft/d multiplied by the thickness for the fine-grained deposits and dividing the total by the 70 ft thickness of the defined “top layer”; this depth was modified from the 100 ft depth used by Arihood (2009) to better approximate the upper part of coarse-grained unconsolidated deposits  that were most likely to contribute flow to and discharge into streams. If less than 70 ft of unconsolidated deposits were present, then K1 was based on the thickness of deposits that were present. A more complete description of the procedure is provided in Arihood (2009, p. 5–10).

K2

The K2 characteristic computed for each basin is the average thickness-weighted horizontal hydraulic conductivity of the entire sequence of unconsolidated deposits. K2 was calculated for each grid cell the same way that K1 is derived, except that the entire thickness of unconsolidated deposits (not just the top 70 ft) described in water well logs between land surface and bedrock was used in the computations. The K2 characteristic was also computed by averaging the K2 grid values contained within each basin boundary. Values of K2 used to represent each basin in the regression equations are listed in table 3-1 in the report.

T2

The T2 characteristic computed for each basin represents the average texture-based transmissivity of the entire thickness of unconsolidated deposits within a basin. T2 was calculated for each grid cell by multiplying the average texture-based horizontal hydraulic conductivity of the entire thickness of unconsolidated deposits (K2) by the total thickness of unconsolidated deposits. The T2 characteristic was also computed by averaging the T2 grid values contained within each basin boundary. Values of T2 used to represent each basin in the regression equations are listed in table 3-1 in the report.

ST2

The ST2 characteristic computed for each basin represents the average texture-based transmissivity of the entire thickness of unconsolidated deposits within a 1,000-ft buffer zone around the stream network. The ST2 was calculated for each grid cell by multiplying the average texture-based horizontal hydraulic conductivity of the entire thickness of unconsolidated deposits within the buffer zone around the stream network by the total thickness of unconsolidated deposits within the buffer zone.

CONTENTS:

This report consists of a report and four raster datasets. The individual metadata files pertain to each of the four rasters, K1, K2, T2, and ST2.

SIR2016-5102.pdf

00Readme.txt

SIR2016-5102 Metadata Rasters

Rasters.zip

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To access the data:

The data files can be downloaded from https://pubs.er.usgs.gov/publication/sir20165102.The main product is a Portable Document Format (.pdf) report that requires Adobe Acrobat for viewing. Acrobat software runs on a variety of systems and is available for download free of charge from Adobe at http://www.adobe.com.

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