DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared in cooperation with
THE ARKANSAS GEOLOGICAL COMMISSION

WATER-RESOURCES INVESTIGATIONS REPORT 83-4063

INTRODUCTION

This report was prepared by the U.S. Geological Survey in cooperation with the Arkansas Geological Commission to increase the low-flow information for Arkansas streams beyond that obtained through analysis of the site-specific data from continuous-record and low-flow partial-record stations. The primary purpose of this study was to identify perennial streams. The secondary purpose was to classify them by flow. This information can be useful for planning and designing water supplies, analyzing environmental and economic impacts of various projects, water-quality modeling, and the determination of optimum and maintenance flows for a variety of instream uses (Task Committee, 1980).

The map shows the extent of perennial streams classified according to the relative magnitude of their 7-day, 10-year low flows. The identification of perennial streams is complete for the entire State of Arkansas with the exception of the Mississippi Alluvial Plain (shaded area on map). Also presented are the 7-day, 10-year low flow values at continuous-record stations and low-flow partial-record stations statewide.

Low-flow investigations have been ongoing for many years in Arkansas. Hines (1975) presented flow-duration and low-flow frequency information for all continuous-record stations up to 1970, as well as all low-flow partial-record stations. That report contains references to earlier reports with low-flow information.

For those who use the International System (SI) of measurement rather than the inch-pound system, cubic feet per second may be converted to cubic meters per second by using the multiplication factor 0.02832.

DEFINING PERENNIAL AND NONPERENNIAL STREAMS

Streams are divided into three basic categories according to permanence of flow. A perennial stream flows continuously throughout the year; during dry weather its flow is sustained by ground-water discharge or controlled releases of water by man. An intermittent stream flows only during certain times of the year; during dry weather its water loss to evaporation, or to percolation through the streambed material, exceeds available inflow to the stream. An ephemeral stream flows only briefly and only in direct response to runoff from precipitation.

Although providing a broad outline, the foregoing definitions lack the precision necessary to quantitatively separate perennial streams from nonperennial streams. For the purposes of this study, perennial streams are defined in terms of the frequency at which periods of zero flow recur in the historical record. A stream, or reach of stream, is considered perennial if annual periods of zero flow, 7 consecutive days or longer, have a recurrence interval greater than 10 years. (The 7-day, 10-year low flow is greater than zero.) This definition refers to flow and not to the presence or absence of water in the streambed; it includes streams that have flows artificially maintained (regulated), as well as those with naturally sustained flow. The magnitude of perennial flow is defined as the 7-day, 10-year low flow value. Use of the 7-day, 10-year low flow value in the definition used in this study provides an objective means of classifying streams.

Figure 1 demonstrates the relation of perennial streams and perennial flow to the general definition and to the wider range of low flows in Arkansas streams. The basis for using a 10-year recurrence interval flow value to represent perennial streamflow is seen in the shape of low-flow frequency curves for continuous-record stations on perennial streams. The 7-day low-flow value decreases rapidly from small recurrence intervals to the 10-year value, then decreases less rapidly. Thus the 7-day, 10-year low flow is a better indicator of dependable flow than are flows at smaller recurrence intervals. Also it is a value that can be defined fairly reliably from the usual streamflow record.

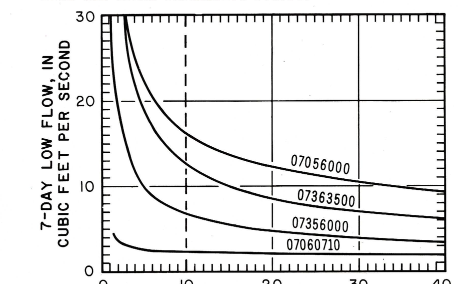


Figure 1.—Low-flow frequency curves for representative index stations on perennial streams.

The 7-day, 10-year low flow is widely used in water-quality studies and is the most widely used low-flow index in the United States. In addition, its use in defining perennial streams delineates a perennial-stream drainage that is significantly reduced from the drainage resulting from direct runoff and release of short-term storage. The drainage so defined is useful in distinguishing between geologic formations capable of sustaining streamflow through ground-water discharge and those that are not.

DATA AVAILABLE FOR ESTIMATION OF 7-DAY, 10-YEAR LOW FLOW VALUES

Strict application of the perennial-stream definition would require years of observation at many points along every stream in the State. In lieu of this, streamflow data from three types of stations were used. Flows were interpolated between station sites in order to develop the continuous perennial-stream drainage presented on the map. In the order presented, these station types represent a decreasing intensity of observation and thus a decreasing level of accuracy. Perennial-stream designations as presented are considered estimates.

The first type of station is the continuous-record gaging station. These stations are sites where a continuous record of mean-daily discharge have been computed for a period of several years. With the exception of a few recently regulated sites, for which no better estimates are available, these stations have at least 8 years of record and an average record length of 25 years. Each station record was used to develop a frequency curve that relates the magnitude of annual low flows to the frequency of occurrence (fig. 1). The graphical method of developing frequency information uses the formula:

$$\text{RECURRENCE INTERVAL} = \frac{n+1}{m},$$

where
n = total number of annual low flows, and
m = ranked order number of an annual low flow.

The annual low flow is the minimum flow averaged throughout a given number of consecutive days during a climatic year (April 1-March 31). Statistics for a variety of consecutive-day intervals are available, but this study used only 7-day annual low flows. For ranking, the annual low flows are ordered from smallest to largest.

Annual low-flow values are then plotted against their respective recurrence intervals to get the frequency curve. The curve indicates the recurrence interval of annual low flows less than or equal to a given flow. The reciprocal of the recurrence interval is the probability of occurrence of an annual low flow less than or equal to the given flow during any one climatic year.

Frequency information is most commonly obtained by using the "Daily Values Statistics" program available through the U.S. Geological Survey's WATSTORE computer-based hydrologic data system. This program fits a theoretical probability distribution (log-Pearson Type III) to the annual low flows. Agreement with the frequency curves developed by the graphical method is usually quite good and the computer method saves much time and labor. However, for some stations there are discrepancies between the computer and graphically derived results; in which case, the graphical method is preferred.

For regulated stations, the record was analyzed only for those years for which a consistent pattern of regulation had been established. Often, after the establishment of a new reservoir, several years of operation are necessary to establish a consistent pattern of regulation. On several streams below new reservoirs in the southwestern part of the State, this pattern has not yet been established. The low-flow values for stations below these reservoirs are based on the minimum release specified in each reservoir's operating rules and do not necessarily correspond to the limited record available. The degree of regulation on the Mississippi River has been slowly increasing throughout its period of recorded flows. In order to reflect current conditions, 1951 was arbitrarily selected as the beginning of the period for which record was analyzed.

The second type of station is the low-flow partial-record station. These stations are sites where several base-flow measurements have been made over a period of years. Each station's measured flows are plotted against concurrent mean-daily flows at a nearby unregulated continuous-record gaging station (index station). The plots are used to estimate low-flow characteristics (7-day, 10-year low flow, for example) at the low-flow partial-record station when they are known at the index station. This method requires that both sites be free from significant regulation. See Hines (1975) for a more detailed discussion of both continuous-record and low-flow partial-record stations.

The third type of station is the reconnaissance site. These stations are sites where one-time (occasionally more) observations of streamflow were made. All observations used in this report were made during the unusually dry summer of 1980 (fig. 2), most within the period from August 26 to September 12. The primary distinction made at each site was flow versus zero flow. Estimates of flow were made in flowing streams, however. Dry sections across the streambed or stream cross-sections with small areas and no detectable flow were necessary to qualify as a zero-flow observation.

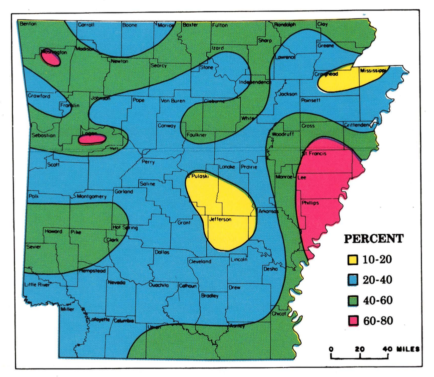


Figure 2.—Percent of normal precipitation for months of June, July and August 1980.
[Based on U.S. Department of Commerce, 1980.]

As shown in figure 3, the number of observations varied from area to area; it was dependent upon the density of flowing streams in the area. The objective was to surround flowing streams with observations of no flow. On flowing streams, estimates of the magnitude of flow form the basis for the relative magnitude of flows delineated on the perennial-stream map (in conjunction with continuous-record and low-flow partial-record station data).

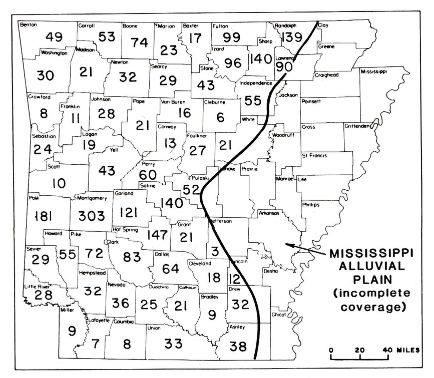
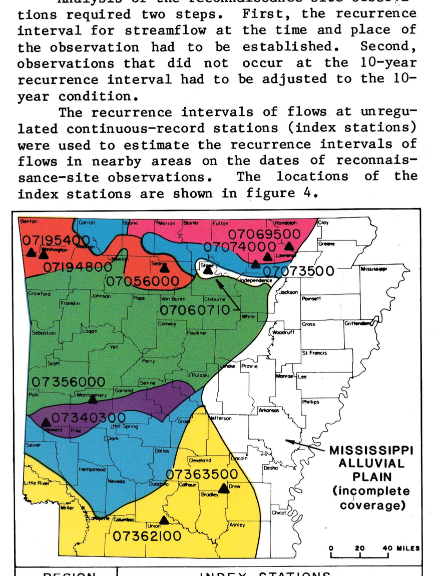


Figure 3.—Number of reconnaissance sites by county.

ANALYSIS OF RECONNAISSANCE-SITE DATA

Analysis of the reconnaissance-site observations required two steps. First, the recurrence interval for streamflow at the time and place of the observation had to be established. Second, observations that did not occur at the 10-year recurrence interval had to be adjusted to the 10-year condition.

The recurrence intervals of flows at unregulated continuous-record stations (index stations) were used to estimate the recurrence intervals of flows in nearby areas on the dates of reconnaissance-site observations. The locations of the index stations are shown in figure 4.



REGION	INDEX STATIONS		
1	07074000	07060710	07069500
2	07073500	07074000	07056000
3	07056000	07194800	07195400
4	07056000	07356000	
5	07340300	07356000	
6	07356000	07363500	
7	07356000	07362100	07363500

Figure 4.—Regions and index stations used in analysis.

The seven relatively homogeneous regions shown in figure 4 roughly define the areas for which index stations were considered representative. Several index stations were used in each region when determining the recurrence interval for flows on a specific date. They are listed in figure 4 by region. The index stations used for a given region were not necessarily located in that region.

The two major factors used in establishing the regions were 1) similarity in the low-flow frequency values at unregulated continuous-record and low-flow partial-record stations that had 7-day, 10-year low flows greater than or equal to 0.1 cubic foot per second, and 2) uniformity of geologic formations.

First, low-flow frequency values for different stations were compared by plotting the 7-day, 2-year versus the 7-day, 10-year annual low flows. Stations from regions 1 and 2 are used in figure 5 as an example. The plot separates the stations into different areas of the graph depending on the magnitude of the 10-year value relative to the 2-year value. The dashed line is placed arbitrarily to emphasize the separation. For any given 2-year value, stations plotting above the line have a higher 10-year value and have frequency curves with smaller slopes than those plotting below it. They can sustain relatively higher low flows over longer recurrence intervals. Where the stations separated in this plot corresponded to differences in their geographic location, they provided a basis for establishing the regions outlined in figure 5. Not all regions showed differences by this method, however.

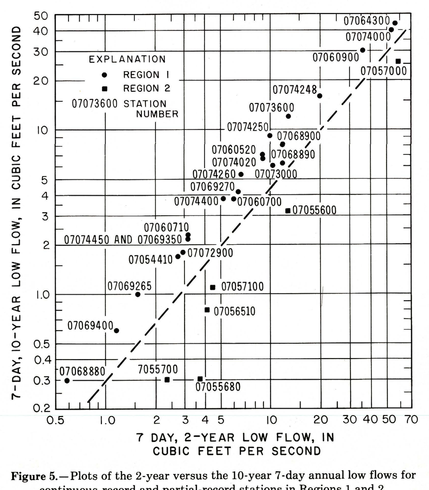


Figure 5.—Plots of the 2-year versus the 10-year 7-day annual low flows for continuous-record and partial-record stations in Regions 1 and 2.

Second, the extent of geologic formations as delineated by Haley and others (1976) established a basis for more closely defining the boundaries of regions indicated by the preceding method. The differences revealed by the preceding method usually corresponded to differences in geology.

Figure 6 shows the estimated recurrence intervals at the time of reconnaissance-site observations (late August and early September 1980). For much of the study area (regions 4 and 7 as shown in fig. 4), the fact that recurrence intervals were less than 10 years was irrelevant because most streams had already gone to zero flow and therefore are not perennial. However, on streams where flow was observed, it was necessary to adjust those flows to the 10-year recurrence interval and to distinguish between reaches of stream that would be flowing and those that would not be flowing at the 10-year recurrence interval.

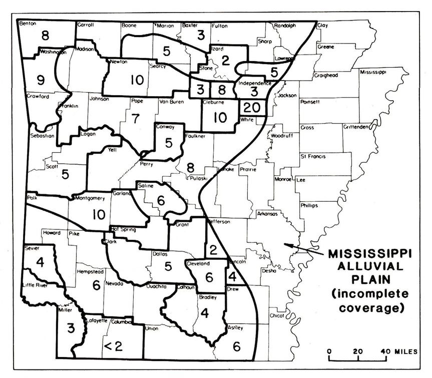


Figure 6.—Estimated recurrence intervals (in years) of low flows at time of reconnaissance-site observations based on index station records.

This adjustment was made by developing relations between flows that occur at the recurrence intervals of the reconnaissance-site observations and flows at the 10-year recurrence interval. These relations were unique to each region. Region 1 is used as an example in figure 7 to demonstrate the technique. Flow values at the recurrence interval estimated for the reconnaissance-site observations (3 years) were plotted against the 10-year recurrence-interval flow values. Flow values were used from continuous-record and low-flow partial-record stations in region 1 having the lowest flows (3-year recurrence interval flows less than 5 cubic feet per second). A regression line was calculated and used to translate flows observed in the field at the lower recurrence interval to 10-year recurrence-interval flows.

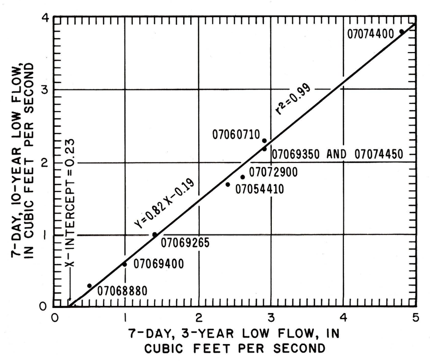


Figure 7.—Relation between low flows at 3-year and 10-year recurrence intervals in Region 1.

Most important, these relations gave a value for flows observed in the field below which the 10-year recurrence-interval flow would be zero. For example, all streams in region 1 estimated in the field to be flowing at less than 0.2 cubic foot per second and observed at a 3-year recurrence interval were considered to have a 7-day, 10-year low flow of zero.

The area maintaining flow with the lowest recurrence interval during the summer of 1980 was region 1. For the three index stations in that region, the maximum recurrence interval for the entire summer was about 4 years. It is interesting to note that other regions reached recurrence intervals greater than 20 years, with about the same rainfall deficiency. Apparently the geology of region 1 can store and release water throughout longer periods of time. A longer period of deficient rainfall would be necessary to reach the higher recurrence intervals in region 1.

LIMITS OF STUDY

The accuracy of the perennial-stream designations diminishes as the estimated recurrence interval of low flows at the time of reconnaissance-site observations deviates from the 10-year recurrence interval. Figure 6 can be used as a guide in assessing the relative accuracy of the perennial-stream identification beyond the confirmation of continuous-record or low-flow partial-record stations.

The use of estimated flow at reconnaissance sites (as opposed to actual measurements) also limits the accuracy of the results. However, the primary goal of the study was to identify the perennial-stream drainage; magnitude of flow was considered secondary. The short time span and the large area to be covered prohibited measurements. For this reason, broad flow categories were used on the map and the exact point of breaks between the categories should be considered approximate.

Because of the use of one-time observations at the reconnaissance sites, it is possible that sites were included in the perennial-stream drainage that had flow only because of temporary regulation. Sites where some identifiable form of regulated flow was judged to be nonperennial were identified as nonperennial. These sites were most common in areas near cities and irrigated farmland.

Where observed, the limits of disappearing streams were delineated. However, reconnaissance sites were located only at points accessible to vehicles and at a limited number of points along each stream. It is possible that the perennial-stream drainage as shown includes small sections where flow has disappeared and reappeared. Conversely, it is possible that small segments of flowing streams were overlooked outside the perennial-stream drainage.

It was necessary to limit coverage of perennial streams in the Mississippi Alluvial Plain because of the extensive degree of regulation during the natural low-flow months. The regulation is caused by ground water used for irrigation that eventually reaches the streams. The techniques used in delineating perennial streams require the absence of significant regulation. Where data from continuous-record and low-flow partial-record stations in the area were sufficient, they were used to delineate some perennial streams. On the map, a dashed line and question mark are used at the termination of the known perennial part of these streams to emphasize that the identification of perennial streams in the Mississippi Alluvial Plain is not complete.

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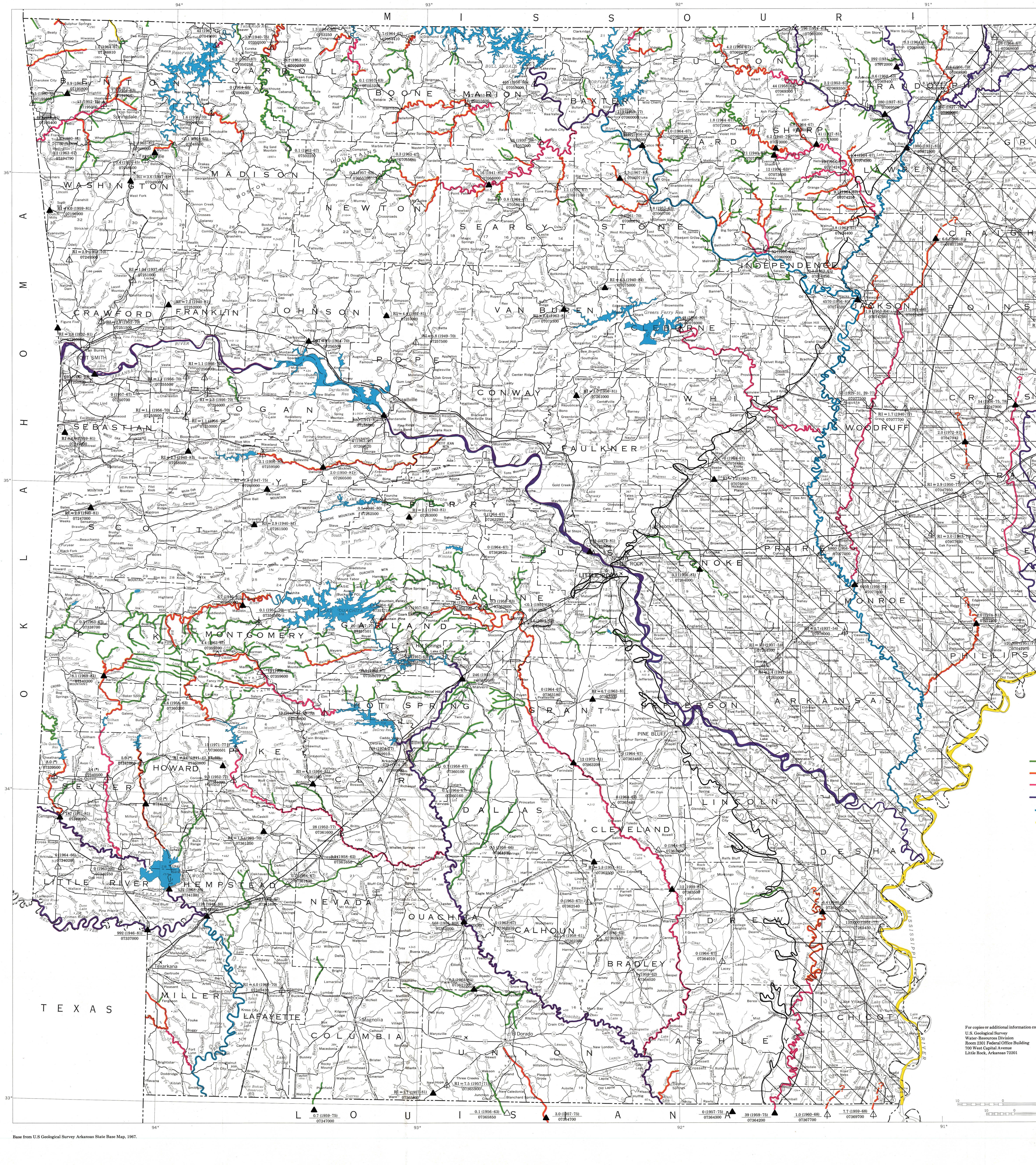

EXPLANATION

Mississippi Alluvial Plain (Incomplete coverage in this area; not all perennial streams are delineated)

7-Day, 10-Year Low Flow in Cubic Feet per Second -- Dashed and queried where not determined beyond gage

- 0<Flow<1.0
- 1.0-10
- 10-100
- 100-1000
- 1000-10,000
- 100,000-150,000

Reservoir Immediately Upstream or Downstream of a Perennial Stream

Continuous-Record Gaging Station

Discontinued Continuous-Record Gaging Station

Low-Flow Partial-Record Station

Accompanying each station is the following information:

$$\frac{48\ (1966\text{-}80)}{07076000} = \frac{\text{7-Day, 10-Year Low Flow (Period of Record in Climatic Years)}}{\text{Station Number}}$$

If the 7-day, 10-year low flow is zero at a continuous-record station, the recurrence interval, in years, of 7-day zero flow is substituted as follows:

$$\frac{\text{RI}=2.2\ (1963\text{-}81)}{07075300}$$

No estimates of zero-flow recurrence intervals are available at partial-record stations

* Low-Flow Value is Based on Reservoir Operating Rules at Recently Regulated Station

‡ Estimated Leakage

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Scale 1:500,000
1 inch equals approximately 8 miles

IDENTIFICATION AND CLASSIFICATION OF PERENNIAL STREAMS OF ARKANSAS

By
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1983

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