EFFECTIVENESS OF THE STREAMFLOW-GAGING NETWORK IN KENTUCKY IN PROVIDING REGIONAL STREAMFLOW INFORMATION

By Kevin J. Ruhl

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Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.59	square kilometer
cubic foot (ft^3)	0.02832	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

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ABSTRACT

This report describes the results of an analysis of the effectiveness of the streamflow-gaging network in Kentucky in providing regional streamflow information. The data available for analysis included streamflow-gaging stations in Kentucky and selected stations in adjacent States. One phase of the analysis determined the increased effectiveness of the network if hypothetical new stations were added. The analysis was based on the principles of generalized least squares regression. Regional regression equations were developed and the regression coefficients were estimated by considering the time-sampling error in streamflow characteristics and the cross-correlation between stations. The average variance of prediction consists of model error and sampling error. Each gaging station in the network was then evaluated on the basis of how much the data from that station affected the sampling-error component of the regression equations. The potential effects of data from proposed new gaging stations on the sampling-error component of the regression equations also was evaluated.

Data from streamflow-gaging stations in Kentucky and selected stations in adjoining States were used to develop regression equations for selected mean-flow, low-flow, and high-flow statistics. The unregulated periods of record for all active and discontinued gaging stations with 5 or more years of unregulated record were used to develop the regression equations. Physical and climatic basin characteristics used to develop the regression equations were selected on the basis of regionalization equations previously developed for Kentucky streams. Gaging station records for development of the regression equations included records for currently regulated streams prior to regulation and records from discontinued stations. Only active gaging stations on unregulated streams were included in the network analysis because only these stations can be used in regionalizing streamflow statistics.

Regression analyses were done to determine the average mean-square error, or error variance, associated with each regional estimating equation for the three flow statistics for current (1989) conditions. This condition would be as if the entire network were discontinued, therefore, no further data would be collected. The error can be divided into a model-error component and a sampling-error component. In network analysis routines, the sampling-error component is the means of evaluating which gaging station records are contributing most to a regional estimating equation. The network analysis was then done to evaluate the effect of each gaging station record on the average sampling-error variance associated with each regional estimating equation if 5 years and 20 years of additional data, beyond current conditions, were collected. As the stations are operated for a longer period, the sampling-error variance decreases relative to current conditions.

If the current network were continued and if no new stations were added, the greatest reduction in average sampling-error variance for the regional estimating equations with the addition of 5 years and 20 years of new data was found for the mean-flow and low-flow statistics. Without the addition of new gages, there was little improvement in regional information for peak flows. With the addition of the hypothetical new gages, the greatest improvement in the effectiveness of the network was for mean flows and peak flows. The results indicated that the addition of new stations whose drainage areas are less than 100 square miles would produce the greatest reduction in average sampling-error variance from current conditions in the mean-flow analysis. New stations having small drainage areas (less than 100 square miles) and fairly steep slopes (greater than 25 feet per mile) would make the greatest improvements in peak-flow information. Only new stations with drainage areas ranging from 200 to 450 square miles produced a significant reduction in average sampling-error variance on the low-flow analysis.

INTRODUCTION

The U.S. Geological Survey (USGS) has operated continuous-record streamflow-gaging stations in Kentucky since 1907. Since that time, many stations have been operated and subsequently discontinued after data were collected for various lengths of time. Several agencies have cooperated with the USGS in collecting surface-water data. In 1988, the Kentucky Natural Resources and Environmental Protection Cabinet, Division of Water (DOW) and the USGS began a cooperative study to improve the use of available resources in the collection of streamflow data.

Many streamflow-gaging stations in a surface-water-data network are established primarily to provide information on current streamflow conditions at particular locations. This information is useful for water-management decisions concerning water supply or waste-disposal monitoring. However, data from these "project operation" gaging stations may have limited transfer value and, therefore, are not usable in regional analyses if the streamflow is regulated by human activities.

The statistical characteristics of streamflow have become increasingly important to designers and planners of water-related facilities and to the permitting of discharges from those facilities. Consequently, streamflow-gaging stations for "regional hydrology" have been established primarily to estimate a probability of occurrence (exceedance or non-exceedance) of certain flow in any year, rather than to collect data on specific hydrologic events. Data from such stations can be used in the design of water-treatment facilities and highway structures and in water-supply planning. Data collected at these stations on natural-flow streams are transferable to other streams in the region through an empirical functional relation (usually a regression model) developed between streamflow characteristics and selected basin characteristics. This procedure is commonly referred to as "regionalization."

Placement of streamflow-gaging stations used in regionalization should provide spatial coverage of a region or area and should provide information for a range of basin and streamflow characteristics. Considered together, the group of stations and their characteristics make up a data-collection "network" suitable for providing regional information.

The agencies that operate data-collection networks need to know which streamflow-gaging stations in a regional network are providing cost-effective information and at what point in time additional data collection can be stopped. The network analysis technique described by Tasker (1987) and Moss and Tasker (1990) was used in this study to obtain answers to these questions for the streamflow-gaging network in Kentucky.

Purpose and Scope

This report identifies the contribution of each active streamflow-gaging station in Kentucky to the knowledge of regional streamflow characteristics. This contribution is expressed in terms of a reduction of the average sampling-error variance associated with a regional regression equation. The analysis is done assuming that the network will continue to be operated for a specific number of years. The analysis can be extended to estimate the contribution of proposed new gaging stations in reducing this sampling error.

Specifically, this report (1) identifies the streamflow-gaging stations in Kentucky, and selected stations in adjacent States, whose periods of unregulated streamflow record are 5 or more years; (2) describes the development of regional regression equations--derived from generalized least squares regression--for estimation of selected mean-flow, low-flow, and high-flow statistics; (3) identifies which active stations will provide the most cost-effective regional streamflow information for selected future times (termed planning horizons); and (4) identifies proposed new stations whose basin characteristics would improve regional streamflow information for selected future times.

Previous Studies

Certain components of the surface-water data-collection program in Kentucky are described in reports by Beaber (1970) and Ruhl (1989). Beaber defined the purpose(s) each active gaging station (in 1970) served, and proposed general locations for new gaging stations throughout the State. Most of the proposed stations were distributed throughout Kentucky on streams draining small areas (less than 200 mi^2). The stations were recommended for operation for approximately 25 years to provide temporal and spatial data for regional analyses, and to function as index stations for correlation with nearby ungaged streams. Many of the stations proposed by Beaber (1970) were established within several years after publication of that report. More recently, Ruhl (1989) presented the results of a cost-effectiveness assessment of the operation of the streamflow-gaging network (in 1987) in Kentucky and described the purpose(s) of each active gaging station in the network.

NETWORK-ANALYSIS TECHNIQUE

The network-analysis technique used in this study is based on generalized least squares (GLS) regression (Tasker, 1986; Tasker, 1987). This method, Network Analysis Using Generalized Least Squares (NAUGLS), evolved from Network Analysis for Regional Information (NARI) described by Moss and others (1982). NARI is based on the regional regression approach (Benson and Matalas, 1967) and is an evaluation of the likelihood of improving the regression relation by the collection of additional data. The NARI methodology, in which ordinary least squares (OLS) is used to calibrate the regression model, is based on results of simulations by means of stochastic hydrology. In the NAUGLS methodology, GLS regression is used. GLS regression (Stedinger and Tasker, 1985 and 1986) allows adjustments to be made for the cross correlation in concurrent record (where the values of a streamflow statistic are not independently distributed) and for various lengths of record among stations. In a comparison of the two methodologies, Moss and Tasker (1990) found that, for the design experiments, the NAUGLS method provided a better estimate of the value of additional streamflow data than did the NARI method.

Description of Technique

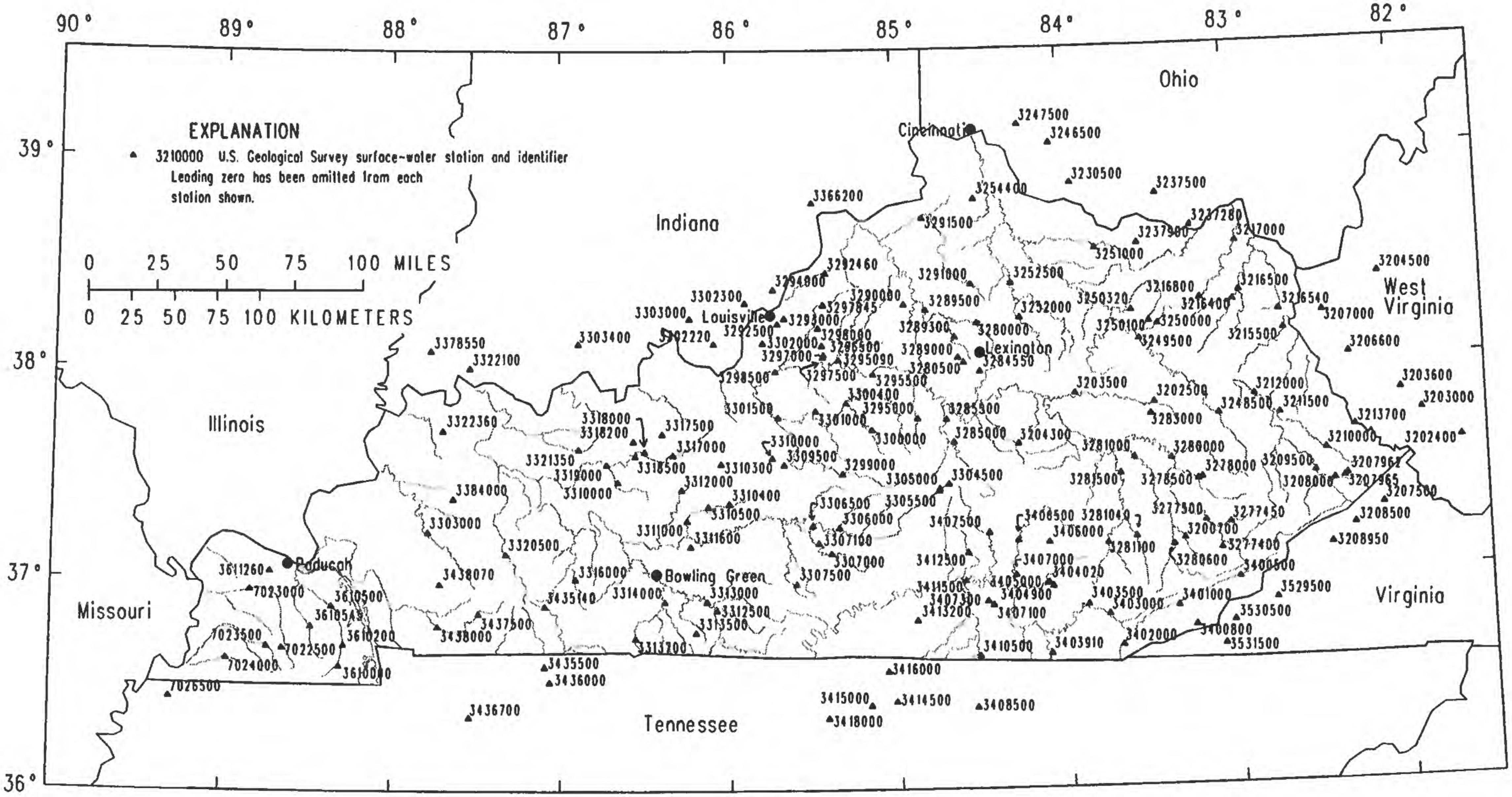
Continued operation of active gaging stations is likely to enhance the predictive ability of a regional regression model by reducing the sampling errors in the flow statistics at the gaging station. The addition of new stations to a network is likely to enhance the predictive ability of a regional regression model by increasing the number of observation points. In either case, the additional data collected would increase the accuracy of the estimated regression coefficients. The network-analysis problem is whether to spend the limited resources available on collecting additional data at active sites, adding new sites, or doing both. One objective method of determining the best "trade off" between extending records at existing stations and establishing additional stations is to maximize the regional regression model's predictive capability, expressed as the inverse of the average variance of prediction of the model. The average variance of prediction is the variances of prediction averaged over a representative set of streamflow sites in a region. In this case, the representative set of sites is taken to be a set of streamflow sites with the same basin characteristics as the active gaged sites. The variance of prediction at a site is made up of two independent parts--the part due to model error, which can be improved only by choosing a better form of the model, and the part due to sampling error, which can be improved by collecting additional data. If the model error is assumed to be constant, then the network-analysis problem can be addressed as one of minimizing average sampling-error variance. Tasker and Stedinger (1989), and Tasker (1986) present a mathematical formulation of the network-analysis problem. The average sampling-error variance is a measure of the error in the average regression prediction in a region due to estimating with sample estimates of the regression coefficients. It is a function of not only how long the streamflow-gaging stations used in estimating regression coefficients have been operated, but also where the gages are in relation to each other and what values of basin characteristics are used in the regression. These properties make the average sampling-error variance a good criterion by which to evaluate the trade off between extended records and additional stations in a network analysis. The method has previously been applied in evaluating the streamflow-gaging network in Kansas (Medina, 1987).

Application of Technique to Kentucky's Streamflow-Gaging Network

Selected statistical parameters related to mean flow, low flow, and high flow were chosen for evaluation of the streamflow-gaging network in Kentucky. Use of regression equations previously developed for Kentucky streams also was desirable because the network would be evaluated on the basis of information currently in use. The statistics chosen were the mean annual flow (Q_a); the 7-day, 2-year, low flow ($7Q_2$); and the 100-year peak flow (Q_{100}). The flow statistics were chosen to represent a broad range in flow and to allow the inclusion of as many stations as possible in the analysis. Available regression equations for these flow statistics include basin characteristics as the explanatory variables needed to produce an estimate. The equation for Q_a is given by Beaber (1970), the equation for $7Q_2$ is given by Ruhl and Martin (1991), and the equation for Q_{100} is given by Choquette (1988).

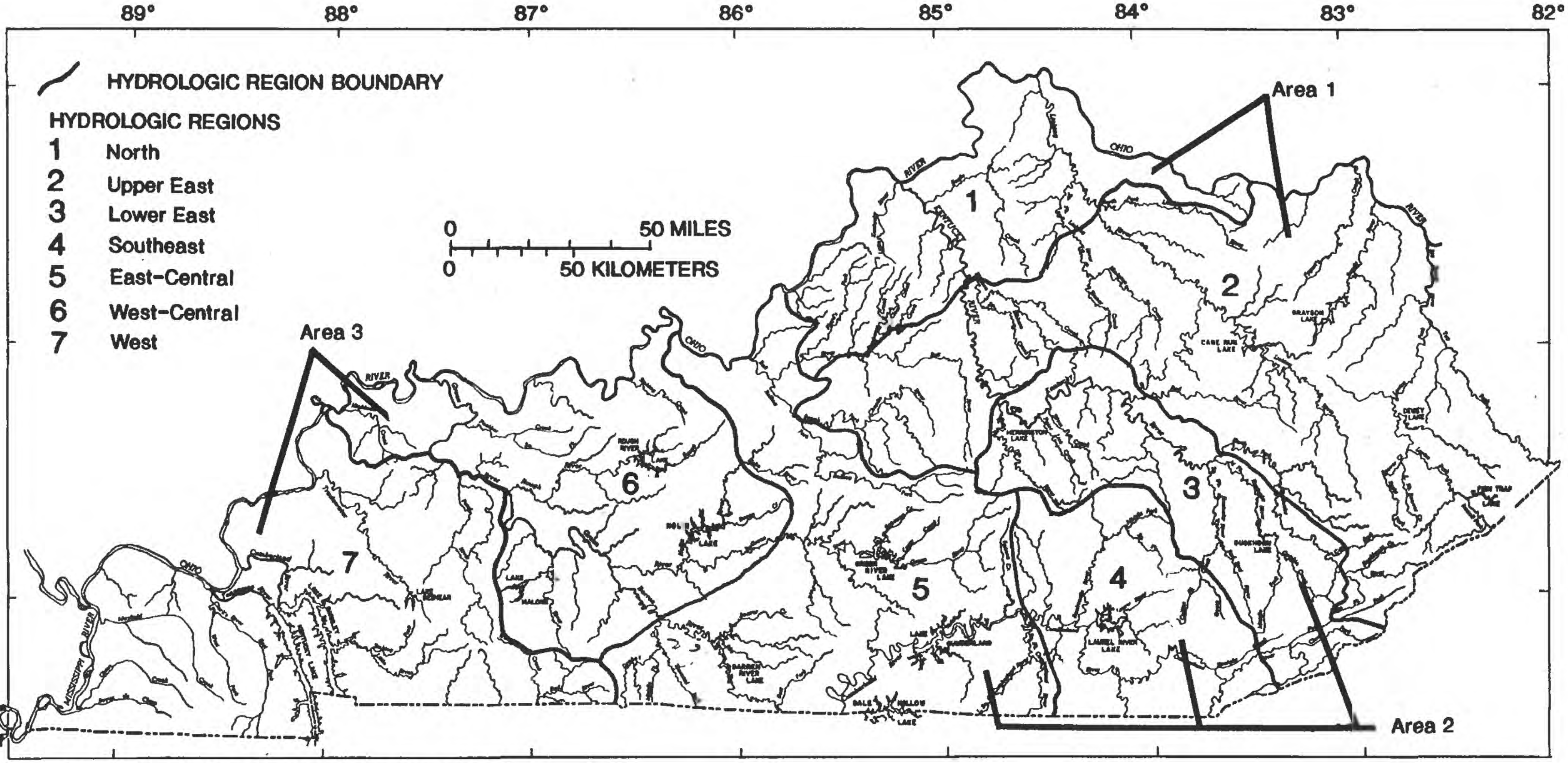
Streamflow-gaging stations with 5 or more years of continuous, unregulated record were considered appropriate for use in the analysis. These stations are listed in table 1 (at the back of the report) and the locations are shown in figure 1. For the Q_a regression equation, all stations (178) were considered to be usable. For the $7Q_2$ regression equation, stations whose drainage areas were greater than 1,500 mi^2, $7Q_2$'s were zero, or flows were subject to local diversion were excluded from the analysis resulting in 113 stations being used. For the Q_{100} analysis, stations whose drainage areas were greater than 1,000 mi^2 were excluded from the analysis resulting in 169 stations being used. These guidelines were consistent with guidelines used to develop the regional regression equations.

Mean- and low-flow regional regression equations for Kentucky were developed for use on streams statewide; however, the peak-flow regression consists of separate equations for each of seven hydrologic regions within Kentucky (fig. 2). These seven regions represent areas whose flood response characteristics are homogeneous. Initially, separate regression and network-analysis runs were made for each of the seven regions. The results from these analyses did not fully identify which stations were providing the most cost-effective information because each of the seven regions contained too few stations. Therefore, regions were combined, and the original seven regions were reduced to three areas. These areas consisted of (1) regions 1 and 2, (2) regions 3, 4, and 5, and (3) regions 6 and 7. Area 1 had 65 stations, area 2 had 54 stations, and area 3 had 50 stations available for analysis. Explanatory variables in the regression equations for each of the regions that were combined may have differed; therefore, the explanatory variables used to develop the regression equations for each of the new areas consisted of the combination of the variables used in the individual equations. In area 1, therefore, all explanatory variables in the regional regression equations for regions 1 and 2 (Choquette, 1988) were used to



Base from U.S. Geological Survey digital data, 1:250,000, 1983

Figure 1.--Locations of continuous-record streamflow-gaging stations used in the study.



Base from Kentucky Department of Commerce, 1964,
Map series B, Frankfort, Kentucky

Figure 2.--Hydrologic regions for estimating peak discharges in Kentucky and how they were combined to form three areas used in the study (From Choquette, 1988).

develop the regression equation for area 1. If the regression analysis indicated that certain variables were insignificant, they were excluded, and the regression was rerun. This procedure was repeated for areas 2 and 3.

The GLS regression equation for estimating mean annual flow was of the same form (logarithmic, base 10) as the OLS regression equation presented by Beaber (1970). Both the GLS and OLS equations contained total drainage area, mean basin elevation, and the maximum 24-hour, 2-year rainfall intensity. Area of lakes and ponds was excluded as a variable from the GLS equation because Beaber stated that excluding area of lakes and ponds increased the standard error by only 0.2 percent. The respective variable-exponent values for the two equations were within 15 percent. The GLS regression equation for estimating $7Q_2$ was of the same form (logarithmic, base 10) as that given by Ruhl and Martin (1991), and the respective variable-exponent values were within 3 percent. The three GLS regression equations developed for estimating Q_{100} were the result of combining information from the seven regions presented by Choquette (1988) and are of the same form (logarithmic, base 10). Information from regions 1 and 2 (fig. 2) was combined, and all explanatory variables in equations for regions 1 and 2 were used to generate the GLS regression equation. Explanatory variables that were not significant at the 10-percent level in the initial regression run were omitted, and the regression was rerun. The insignificant variables were basin-shape index (B_s) and main-channel sinuosity (S_s). The variables used in the final GLS regression equation were contributing-drainage area (A_c) and main-channel slope (S_c). The resulting linear regression equation fit the observed data closely. Equations for regions 3, 4, and 5 each contained A_c, and the equation for region 3 also contained S_s. In the initial regression analysis, S_s was not significant at the 10-percent level and was omitted from the final analysis leaving A_c as the only variable. The exponent for A_c in the GLS equation differed by less than 10 percent from the exponents for A_c in the equations for the three regions given by Choquette (1988). The area 3 analysis for regions 6 and 7 was similar to that for area 1. B_s and S_s were determined to be insignificant at the 10-percent significance level, and only A_c and S_c were included in the final regression equation. The resulting linear regression equation fit the observed data closely.

After an appropriate GLS regression model was developed for the mean- and low-flow statistics and for each of the three high-flow areas, the network analysis was then undertaken. The first step was to select appropriate future times for which the effects of network-management strategies could be determined; these future times are referred to as "planning horizons". The network was evaluated with reference to each flow statistic for (1) a zero-year planning horizon, (2) a 5-year planning horizon, and (3) a 20-year planning horizon. An 'x'-year planning horizon refers to conditions at the end of that year. Therefore, a zero-year planning horizon represents current conditions (1989 in this analysis), a 5-year horizon represents operation of the network for short-term information needs, and a 20-year horizon represents operation of the network for long-term information needs. An operation and maintenance cost also was assigned to each gaging station included in the analysis. A cost equal to one unit was used for each gage because all gages operated as part of the network are assigned the same base cost of operation even though certain gages may cost slightly more or less than the base or average cost. Regulated stations, discontinued stations, or stations subject to local diversion that would affect a particular flow statistic were omitted from the network analysis because only active, unregulated stations can contribute additional regional information. The network analysis consisted of two parts; one for active stations and one for active stations plus a set of hypothetical new stations.

EFFECTIVENESS OF THE STREAMFLOW-GAGING NETWORK

The network analysis, as stated previously, is based on the effect that each active unregulated-gaging station has on reducing the average sampling-error variance associated with a regional regression equation. GLS regression was used to develop the models, the form of which was based on previous studies. The resulting regression equations were also similar to those given in the previous studies. Average sampling-error variance is expressed in base 10 logarithmic units squared.

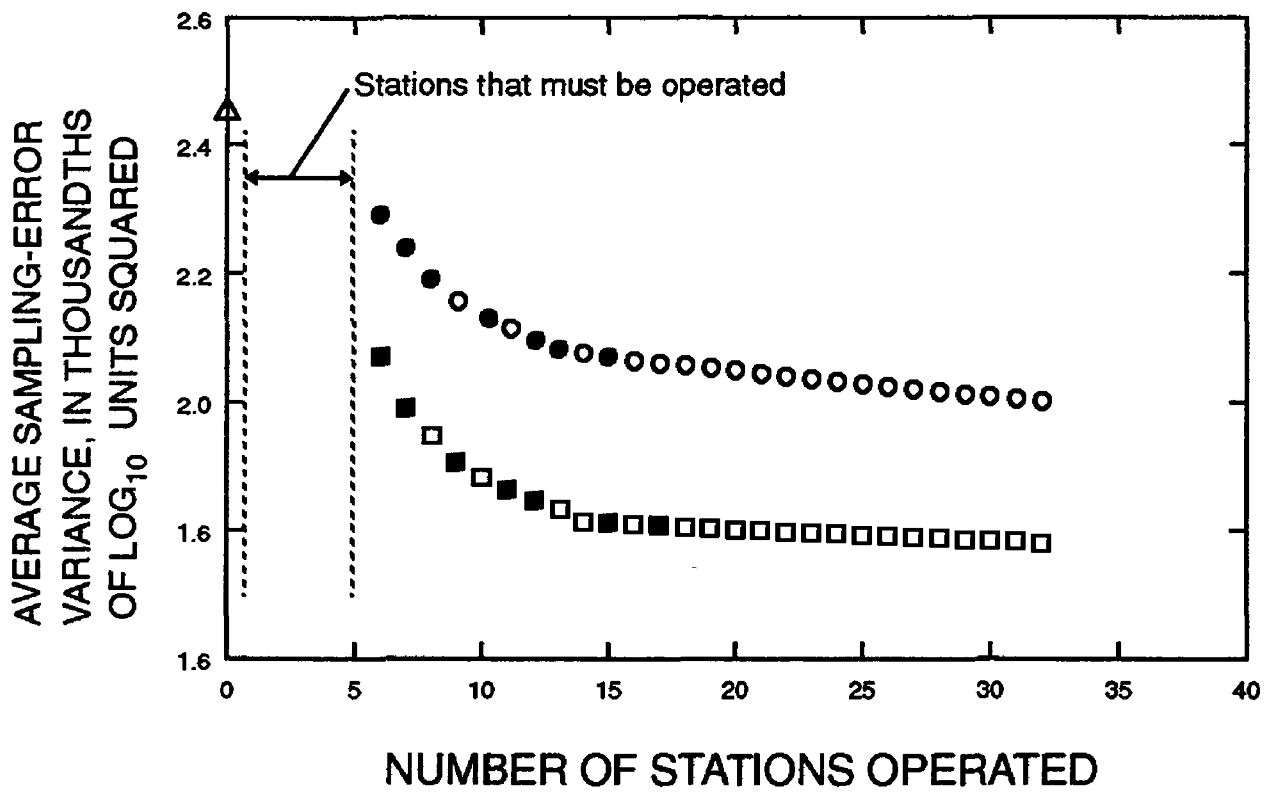
Results are presented in table 2 and in a series of graphs for each flow statistic analyzed. The table and each graph show the average sampling-error variances associated with (1) the current (1989) condition of the network, (2) the 5-year planning horizon, and (3) the 20-year planning horizon. The pair of graphs in each figure represents conditions excluding and including proposed new stations. The graphical presentation is similar to that shown in figure 3. The triangle on the ordinate represents current conditions (zero-year planning horizon), or the average sampling-error variance if no stations were continued and no new stations were added. This is the average sampling-error variance associated with the GLS regression equation. Each circle or square represents an estimate of the smallest average sampling-error variance that can be achieved for the indicated network operation cost. The circles represent the reduction in sampling-error variance associated with stations operated for a 5-year planning horizon, whereas the squares show an even greater reduction in sampling-error variance for a 20-year planning horizon because of the increased record length. The marginal decrease in sampling-error variance for a particular station is indicated by the slope of the graph at that point. The gap shown by the arrows represents the gaging stations that are considered mandatory in operating the network. The cost and sampling-error variance associated with these mandatory stations is not shown directly in the graph so as to give emphasis to them. This category could include any station usable for regionalization (unregulated and not affected by local diversion) that must necessarily be operated indefinitely. Examples are gaging stations operated to fulfill a legal requirement (such as monitoring for water supply), for project operation (monitoring inflow to a reservoir), or to define long-term flow trends. In this report, only three stations are classified as mandatory (table 1). The data from these stations are primarily used by the U.S. Army Corps of Engineers (COE) to monitor unregulated streams that affect the operation of COE flood control projects in the State. As previously stated, all stations were assigned the same cost because, except in rare cases, an average cost per gage is used by USGS offices in Kentucky.

Table 2. Average sampling-error variance for selected network strategies used in the study

[$\log_{10}$ units^2, base 10 logarithmic units squared; variances shown for the 5- and 20-year planning horizons are the lowest obtained for that analysis]

Type of analysis	Planning horizon (years)	Average sampling-error variance ($\log_{10}$ units)^2	
		Excluding new stations	Including new stations
Mean flow	0	0.00050	0.00050
	5	.00045	.00041
	20	.00039	.00032
Low flow	0	.00385	.00385
	5	.00364	.00330
	20	.00325	.00279
High flow (Area 1)	0	.00250	.00250
	5	.00232	.00205
	20	.00208	.00167
High flow (Area 2)	0	.00230	.00230
	5	.00220	.00186
	20	.00205	.00154
High flow (Area 3)	0	.00274	.00274
	5	.00263	.00219
	20	.00247	.00183

The results from the mean-flow analysis are given in table 2 and in figure 4. If no new stations are added to the network, the average sampling-error variance from current conditions is reduced by about 10 percent (from 0.00050 to 0.00045) for the 5-year planning horizon and by about 22 percent (from 0.00050 to 0.00039) for the 20-year planning horizon. The addition of selected new stations to the network would reduce the sampling-error variance by almost twofold--18 and 36 percent (from 0.00050 to 0.00041 and from 0.00050 to 0.00032), respectively, for the two planning horizons. The 'new' stations used in the analysis consisted of recently installed stations (1990-91) and discontinued stations. The effect of data provided by the hypothetical stations was most pronounced for the stations whose drainage areas were less than 100 mi^2. The effect of data provided by the new stations decreased as the size of drainage area increased.



EXPLANATION

ZERO-YEAR PLANNING HORIZON

△ No active stations continued, no new stations

5-YEAR PLANNING HORIZON

○ Active stations

● New stations

20-YEAR PLANNING HORIZON

□ Active stations

■ New stations

Figure 3.--Pertinent features of graphs of average sampling-error variance and number of stations operated (Modified from Medina, 1987).

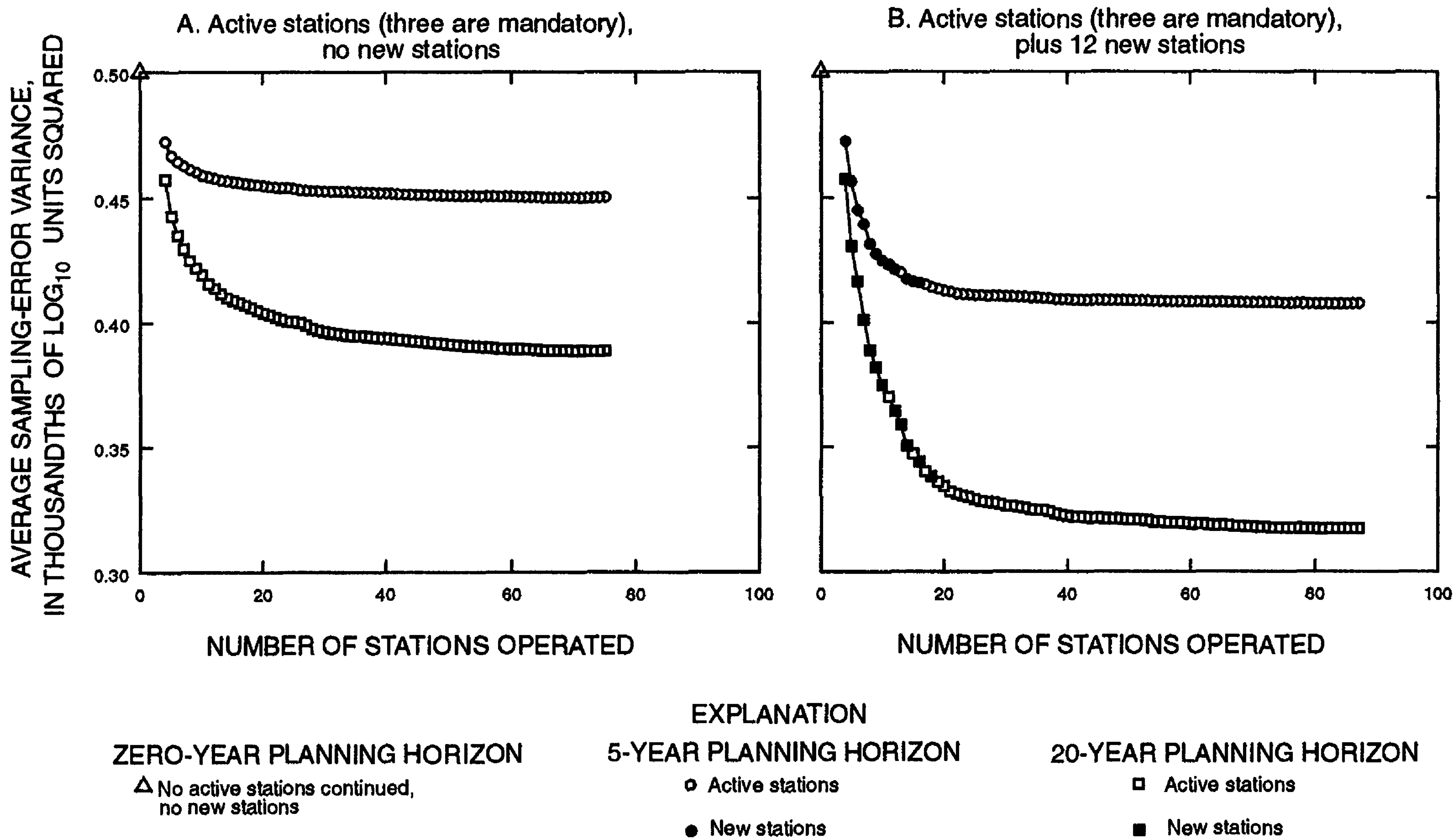


Figure 4.--Results of two network strategies to provide regional information on mean flow in Kentucky.

The results from the low-flow analysis are given in table 2 and in figure 5. If no new stations are added to the network, average sampling-error variance from current conditions is reduced by about 6 and 16 percent (from 0.00385 to 0.00364 and from 0.00385 to 0.00325) for the 5-year and 20-year planning horizons, respectively. The addition of selected new stations would reduce the variance by 14 and 28 percent (from 0.00385 to 0.00330 and from 0.00385 to 0.00279) from current conditions, respectively, for the two planning horizons. Unlike the mean-flow analysis, where almost all reduction in sampling-error variance was associated with the addition of new stations, the results from the low-flow analysis indicate that only certain stations produced a significant reduction in sampling-error variance from current conditions. The two best stations had drainage areas of 196 and 437 mi^2 and were in the central part of the State. Drainage areas of two of the next three new stations providing the greatest reduction in sampling-error variance were less than 150 mi^2, and that of the third was greater than 500 mi^2. All three hypothetical stations were in eastern Kentucky. Overall, the new stations contributed more to the reduction of average sampling-error variance from current conditions for the 5-year planning horizon than for the 20-year horizon. This finding indicates that many active stations should be continued long-term. For both planning horizons, the new stations would supplement the network of active stations in contrast to the general overhaul indicated by the mean-flow analysis.

Results from the high-flow analysis are given in table 2 and in figures 6 through 8. For all three areas, the percentage reduction in average sampling-error variance from current conditions without the addition of new stations was less than that for the mean-flow and low-flow analyses. The reduction in average sampling-error variance from current conditions for areas 1, 2, and 3 was approximately 7 and 17 percent (from 0.00250 to 0.00232 and from 0.00250 to 0.00208), 4 and 11 percent (from 0.00230 to 0.00220 and from 0.00230 to 0.00205), and 4 and 10 percent (from 0.00274 to 0.00263 and from 0.00274 to 0.00247) for the 5-year and 20-year planning horizons, respectively. The reduction in average sampling-error variance from current conditions for the three areas when new stations were added was 18 and 33 percent (from 0.00250 to 0.00205 and from 0.00250 to 0.00167), 19 and 33 percent (from 0.00230 to 0.00186 and from 0.00230 to 0.00154), and 20 and 33 percent (from 0.00274 to 0.00219 and from 0.00274 to 0.00183) respectively, for the 5-year and 20-year planning horizons. As indicated in the graphs, the reduction was greatest when new stations were added to the network, especially for areas 2 and 3. Similar to the low-flow analysis, the reduction in error in area 1 is largely associated with four of the new stations, particularly for the 20-year planning horizon (fig. 6). Area 1, which consists of hydrologic regions 1 and 2 (fig. 2) extends from southeastern to north-central Kentucky. Drainage basins of these proposed stations all have small areas (less than 100 mi^2) and slopes greater than 25 ft/mi. The stations are spread throughout area 1. Results of the analysis indicate that emphasis should be on adding stations at stream locations having basins with small drainage areas and moderately steep slopes. The analysis for the other two areas indicated a need for stations at stream locations having basins with a variable range in drainage area and slope.

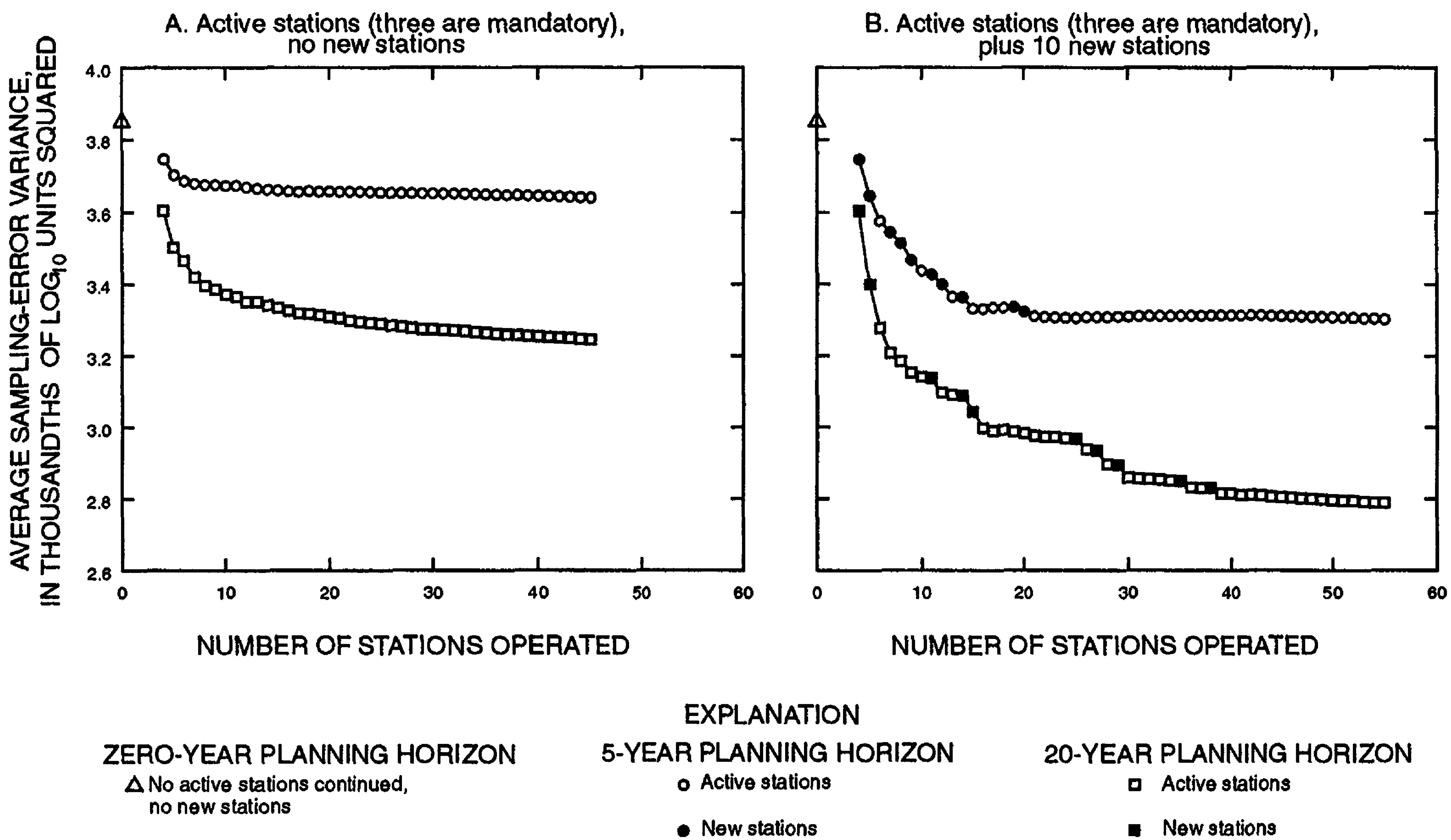


Figure 5.--Results of two network strategies to provide regional information on low flow in Kentucky.

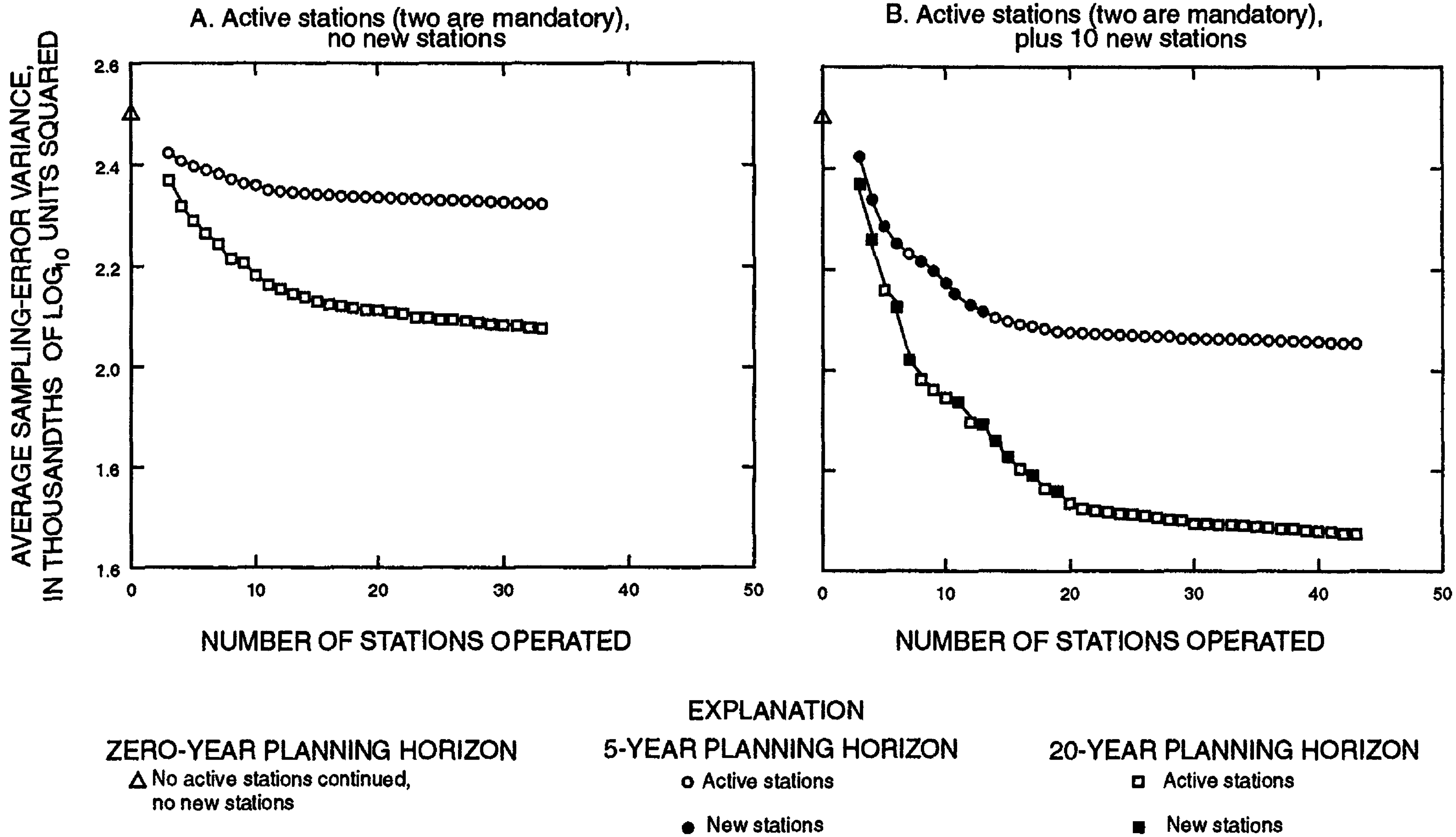


Figure 6.--Results of two network strategies to provide regional information on high flow in area 1 (hydrologic regions 1 and 2) in Kentucky.

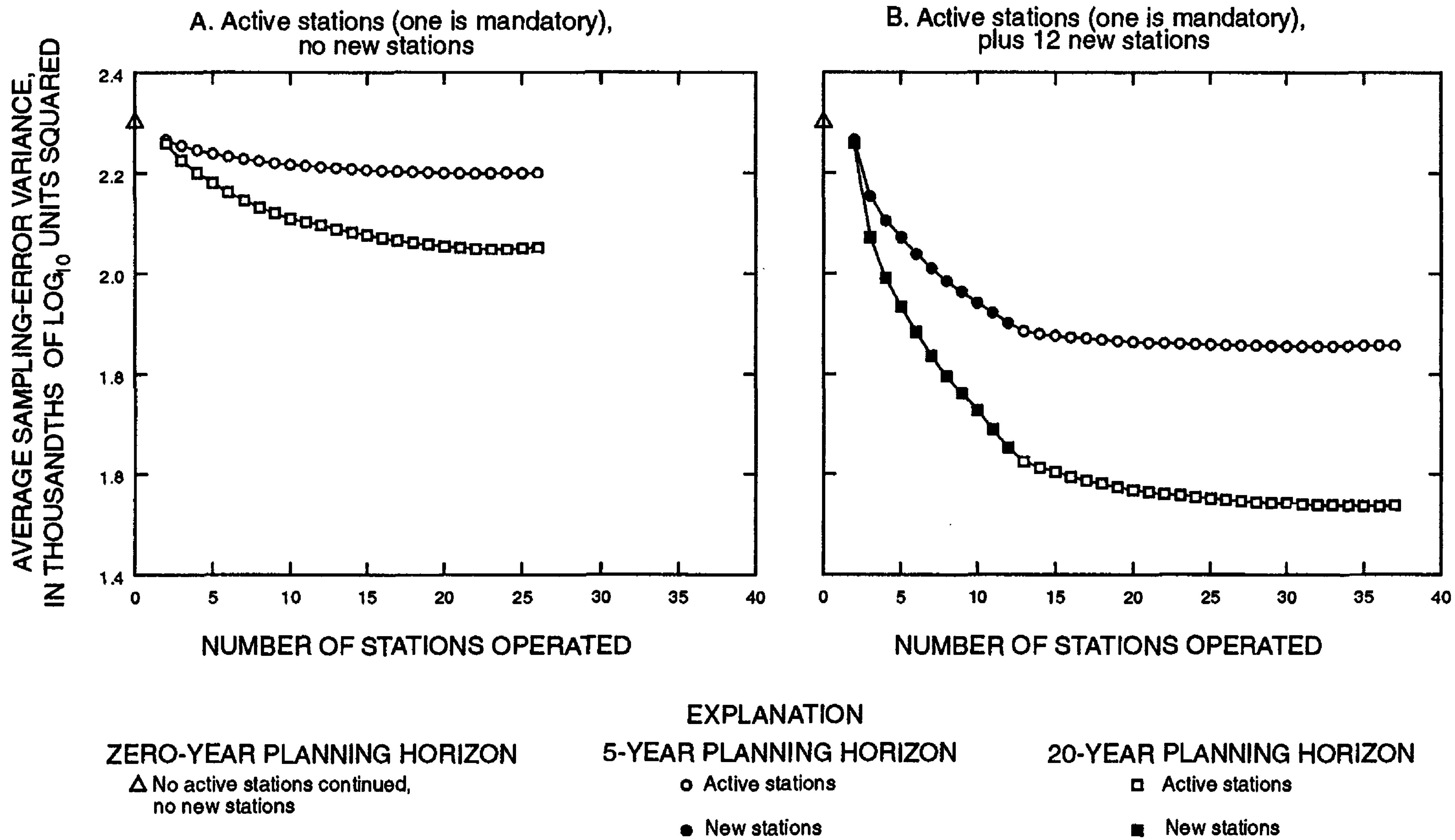


Figure 7.--Results of two network strategies to provide regional information on high flow in area 2 (hydrologic regions 3, 4, and 5) in Kentucky.

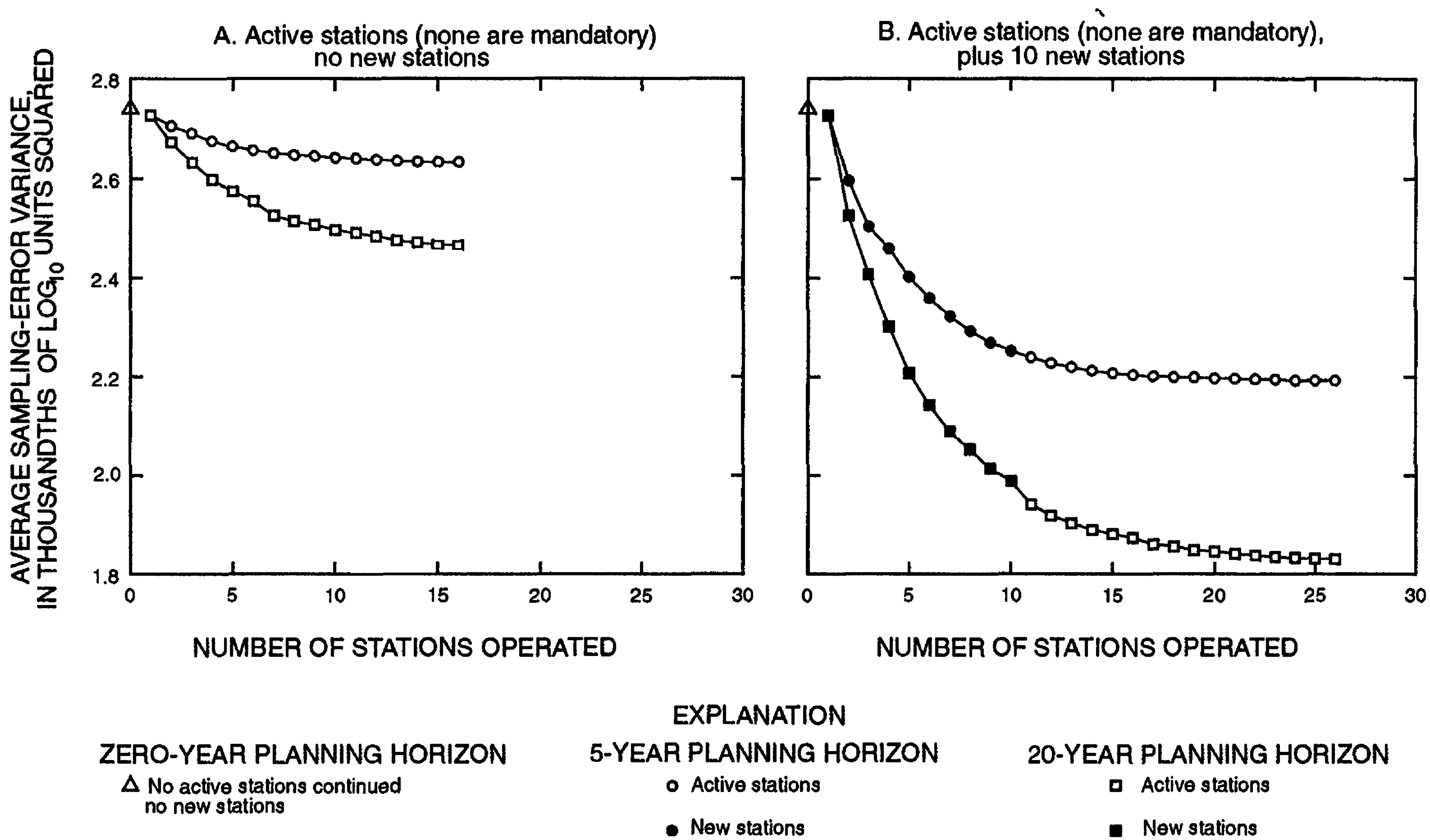


Figure 8.--Results of two network strategies to provide regional information on high flow in area 3 (hydrologic regions 6 and 7) in Kentucky.

Information resulting from the mean-flow, low-flow, and high-flow analyses is listed in table 3. An attempt has been made to rank the stations by the contribution they make in reducing the average sampling-error variance from current conditions associated with the regional regression relations (Medina, 1987). As many as three stations in the high-flow rankings may have identical values because of the three different areas used in the analysis. These identical markings will not affect the composite ranking of the stations made for the 20-year planning horizon shown in the extreme right-hand column of table 3. Overall, new stations will provide the greatest reduction in average sampling-error variance from current conditions for the regression relations developed; however, continuation of many active stations will improve regional information. The fact that certain active stations provide better information for selected types of analysis than do others should be recognized. This is also true of the new stations (see ranking for the different flow types shown in table 3).

APPLICATIONS AND LIMITATIONS OF THE ANALYSIS

A method was needed to facilitate continuous review of the streamflow-gaging station network in Kentucky. By use of the results from NAUGLS, specific stream-basin types and locations where additional information is needed can be identified. Conversely, gaging stations that provide little new information to a regional analysis can be considered for discontinuation so that resources available for data collection can be used more efficiently.

Other considerations also are involved in decisions to add or discontinue stations. A station needed for project operations or for legal reasons (mandatory stations) cannot be discontinued. Stations being operated as long-term index or trend sites or that are useful in correlating streamflow information with partial-record stations would be given greater consideration for continuation than might be indicated by the network analysis alone. Even though other factors are involved, the network analysis is a valuable tool for evaluating active and potential new stations for regional information.

Other factors concerning the location and selected basin characteristics represented by new stations also must be taken into consideration. Even though the analysis may indicate that a new site having specific basin characteristics is desirable, such a site may be difficult to locate. Factors that must be considered in locating a gaging station are the hydraulic conditions at the site, including approach flow conditions and the stability of the natural control that creates the pool where stage information is collected, accessibility to the stream, and human activities in the basin that may influence streamflow characteristics.

Table 3. Station ranking in order of importance in providing regional streamflow information for selected mean-flow, low-flow, and high-flow statistics in Kentucky

[--, station record not used in analysis; Fk, Fork; IN, Indiana; all stations are in Kentucky unless otherwise noted]

Station number	Station name	Station ranking for streamflow characteristic indicated: 5-year planning horizon, Mean flow	5-year, Low flow	5-year, High flow	20-year planning horizon, Mean flow	20-year, Low flow	20-year, High flow	Composite station ranking 20-year
03213500	New station[a]	3	--	9	1	--	7	1
03309500	New station[a]	2	11	2	4	6	2	2
03288000	Naw station[a]	6	4	7	6	8	9	3
03295500	New station[a]	12	2	9	5	2	17	4
03291500	New station[a]	9	1	11	7	1	13	5
03277400	New station[a]	8	5	8	13	12	8	6
03405000	New station[a]	11	--	9	11	--	11	7
03316000	New station[a]	7	8	10	2	22	9	8
03281000	New station[a]	13	6	11	15	11	9	9
03322360	New station[a]	14	--	11	12	--	11	10
03207965	New station[a]	4	9	3	10	24	1	11
03435140	Whippoorwill Creek near Claymoor	17	3	16	18	3	15	12
03237900	Cabin Creek near Tollasboro	21	--	13	21	--	7	13
03216540	East Fk Little Sandy River near Fallsburg	18	--	15	17	--	14	14
03413200	New station[a]	5	16	7	9	32	7	15
03610545	New station[a]	1	17	5	3	35	10	16
03292460	Harrods Creek near LaGrange	26	7	16	26	5	18	17
03303400	Crooked Creak near Santa Claus, IN	20	--	15	19	--	14	18
03611260	Massac Creek near Paducah	15	27	14	14	28	13	19
03250100	North Fk Triplett Creek near Morehead	38	18	17	30	13	16	20
03383000	Tradewater River near Olney	40	9	22	38	6	17	21
03610200	Clarks River at Almo	10	31	12	8	38	16	22
03297845	Floyds Fork near Crestwood	16	--	26	16	--	27	23
03320500	Pond River near Apex	47	13	20	48	7	20	24
03311600	Beaverdam Creek at Rhoda	19	47	13	20	48	12	25
03300400	Beech Fork at Maud	75	4	39	35	4	34	26
07024000	Bayou De Chien near Clinton	22	46	18	24	46	19	27
03251000	North Fk Licking River neer Lewisburg	54	14	33	58	9	36	28
03298000	Floyds Fork at Fisherville	67	15	40	65	10	40	29

[a]Indicates a proposed station having basin characteristics similar to those of station number given.

SUMMARY AND CONCLUSION

The effectiveness of the streamflow-gaging network in Kentucky in providing regional-streamflow information was analyzed by the use of the Network Analysis Using Generalized Least Squares (NAUGLS) technique. Streamflow-gaging stations for which 5 or more years of unregulated record was available, in Kentucky and nearby in adjacent States, were used to develop regional regression equations by means of Generalized Least Squares (GLS) regression. For the mean-flow and low-flow analysis, 178 and 113 stations, respectively, were used. For the high-flow analysis, 65 stations were used for area 1, 54 stations were used for area 2, and 50 stations were used for area 3. GLS regression allows for the adjustment of the cross correlation in concurrent record and for different record lengths between gaging stations. Regional regression equations were developed for mean flow, $7Q_2$, and Q_{100} on the basis of attributes from previously published equations for Kentucky streams. Certain limitations, which corresponded to the development of the previously published equations, were also placed on the data sets used in this report.

The network analysis was then done for each of the three flow statistics. Two network-management strategies were selected--one in which new stations were excluded and one in which hypothetical new stations were included. For each strategy, the network was analyzed under current (a zero-year planning horizon) conditions, a 5-year planning horizon, and a 20-year planning horizon. Results are presented in tabular form and as a series of graphs of average sampling-error variance of a regional regression equation plotted against network-operation cost for each of the flow statistics and for each strategy. The slope of the graphs at a point represent the marginal decrease in average sampling-error variance associated with the operation of a particular station (including new stations) used in the network analysis.

Without the addition of new stations, the greatest reduction in average sampling-error variance for the 5-year and 20-year planning horizons was found in the mean-flow and low-flow analyses. Improvement in the regional information for the peak flows was slight without the addition of new gages. When new gages were added in the analysis, however, the greatest improvement in the effectiveness of the network was found for mean flows and peak flows. The results indicate that new stations having small drainage areas (less than 100 mi^2) produced the greatest reduction in average sampling-error variance from current conditions in the mean-flow analysis. Only certain stations produced a significant effect for the low-flow analysis. These were stations for which drainage areas range from 200 to 450 mi^2. The results indicated that new stations having small drainage areas (less than 100 mi^2) and fairly steep slopes (greater than 25 ft/mi) would provide the greatest peak-flow information.

Evaluation of the effectiveness of Kentucky's streamflow-gaging network in providing regional streamflow information should be a dynamic process. If additional funding is available for the network, the results from the analysis will be used in deciding where to locate new stations. Conversely, if funding declines, the results from the analysis will be used in deciding which stations to discontinue. Even though many factors are involved in network evaluation, the NAUGLS technique is a means for deciding how best to use network resources for short- and long-term planning.

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Table 1. Selected information for the continuous-record streamflow-gaging stations used in the study

[U, unregulated; R, regulated; E, eest; Fk, fork; LD, local diversion; S, south; M, middle; Mun, municipal; N, north]

Station number	Station name	Status	Regulation	Period of daily record (water year)	Period of unregulated daily record (water year)	Years of record in analysis	Drainage area (square miles) Total	Drainage area (square miles) Contributing
03202400	Guyandotte River near Beileysville, WV	Active	U	1968-89	1968-89	21	306	306
03203000	Guyandotte River at Man, WV	Discontinued	R	1929-62	1929-62	33	758	758
03203600	Guyandotte River at Logan, WV	Discontinued	R	1963-89	1963-77	15	833	833
03204500	Mud River near Milton, WV	Discontinued	U	1938-80	1938-80	42	256	256
03206600	East Fork Twelvepole Creek near Dunlow, WV	Active	U	1965-89	1965-89	25	38.5	38.5
03207000	Twelvepole Creek at Wayne, WV	Discontinued	R	1916-22, 1928-31, 1939, 1947-66	1916-22, 1928-31, 1939, 1947-66	24	291	291
03207500	Levisa Fork neer Grundy, VA	Discontinued	U	1942-74, 1986-87	1942-74, 1986-87	35	235	235
03207962	Dicks Fork at Phyllis, KY	Discontinued	U	1975-84	1975-84	9	.82	.82
03207965	Grapevine Creek near Phyllis, KY	Discontinued	U	1974-82	1974-82	9	6.20	6.20
03208000	Levisa Fork Below Fishtrap Dam, KY	Active	R	1938-89	1938-68	30	392	392
03208500	Russell Fork at Haysi, VA	Active	U	1926-89	1926-89	63	286	286
03208950	Cranes Nest River near Clintwood, VA	Active	U	1964-89	1964-89	26	66.5	66.5
03209500	Levisa Fork et Pikeville, KY	Active	R	1938-89	1938-64	27	1,232	1,232
03210000	Johns Creek near Meta, KY	Mandatory	U	1941-89	1941-89	48	56.3	56.3
03211500	Johns Creek near Van Lear, KY	Active	R	1940-89	1940-49	10	206	206
03212000	Paint Creek at Staffordsville, KY	Discontinued	U	1950-75	1950-75	25	103	103
03213700	Tug Fork at Williamson, WV	Active	U	1968-89	1968-89	22	936	936
03215500	Blaine Creek et Yatesville, KY	Discontinued	U	1915-18, 1938-75	1915-18, 1938-75	40	217	217
03216400	Little Sendy River at Leon, KY	Discontinued	R	1962-80	1962-67	6	255	255
03216500	Little Sandy River at Greyson, KY	Active	R	1938-89	1938-67	30	400	400
03216540	E Fk Little Sandy River neer Fallsburg, KY	Active	U	1973-89	1973-89	17	12.2	12.2
03216800	Tygarts Creek at Dlive Hill, KY	Active	U	1957-89	1957-89	32	59.6	59.6
03217000	Tygarts Creek near Greenup, KY	Active	LD	1940-89	1940-89	49	242	242
03237280	Upper Twin Creek at McGaw, OH	Active	U	1963-89	1963-89	26	12.2	12.2
03237500	Ohio Brush Creek near West Union, OH	Active	U	1926-35, 1940-89	1926-35, 1940-89	58	387	387
03237900	Cabin Creek neer Tollesboro, KY	Active	U	1972-89	1972-89	17	22.4	22.4
03238500	Whiteoak Creek near Georgetown, OH	Active	LD	1924-35, 1940-89	1924-35, 1940-89	62	218	218
03246500	E Fk Little Miami River et Williamsburg, OH	Discontinued		1950-53, 1961-74	1950-53, 1961-74	18	237	237
03247500	E Fk Little Miami River neer Perrintown, OH	Active	R	1915-17, 1925-89	1915-17, 1925-77	54	476	476

Table 1. Selected information for the continuous-record streamflow-gaging stations used in the study--Continued

[U, unregulated; R, regulated; E, east; Fk, fork; LD, local diversion; S, south; M, middle; Mun, municipal; N, north]

Station number	Station name	Status	Regulation	Period of daily record (water year)	Period of unregulated daily record (water year)	Years of record in analysis	Drainage area (square miles) Total	Drainage area (square miles) Contributing
03248500	Licking River near Salyersville, KY	Active	U	1939-89	1939-89	51	140	140
03249500	Licking River at Farmers, KY	Active	R	1938-89	1938-73	35	827	827
03250000	Triplett Creek at Morehead, KY	Discontinued	LD	1941-80	1941-80	39	47.5	47.5
03250100	North Fork Triplett Creek near Morehead, KY	Active	U	1967-89	1967-89	22	84.7	84.7
03250320	Rock Lick Creek near Sharkey, KY	Discontinued	U	1973-82	1973-82	9	4.01	4.01
03251000	North Fork Licking River near Lewisburg, KY	Active	U	1946-89	1946-89	43	119	119
03252000	Stoner Creek at Paris, KY	Active	LD	1953-89	1953-89	36	239	239
03252500	South Fork Licking River at Cynthiana, KY	Active	LD	1938-89	1938-89	51	621	615
03254400	North Fork Grassy Creek near Piner, KY	Discontinued	U	1968-83	1968-83	16	13.6	13.6
03277400	Leatherwood Creek at Daisy, KY	Discontinued	U	1965-74	1965-74	10	40.9	40.9
03277450	Carr Fork near Sassafras, KY	Active	R	1964-89	1964-75	12	60.6	60.6
03277500	North Fork Kentucky River at Hazard , KY	Active	R	1940-89	1940-75	35	466	466
03278000	Bear Branch near Noble, KY	Discontinued	U	1955-73	1955-73	18	2.21	2.21
03278500	Troublesome Creek near Noble, KY	Discontinued	U	1950-81	1950-81	31	177	177
03280000	North Fork Kentucky River at Jackson, KY	Active	R	1928-31, 1938-89	1928-31, 1938-75	40	1,101	1,101
03280600	Middle Fork Kentucky River near Hyden, KY	Active	LD	1958-89	1958-89	32	202	202
03280700	Cutshin Creek at Wooton, KY	Active	U	1958-89	1958-89	32	61.3	61.3
03281000	Middle Fork Kentucky River at Tallega, KY	Active	R	1931-32, 1940-89	1931-32, 1940-60	22	537	537
03281040	Red Bird River near Big Creek, KY	Active	U	1972-89	1972-89	17	155	155
03281100	Goose Creek at Manchester, KY	Active	U	1965-89	1965-89	25	163	163
03281500	South Fork Kentucky at Booneville, KY	Active	U	1925-31, 1940-89	1925-31, 1940-89	56	722	722
03282500	Red River near Hazel Green, KY	Active	U	1954-89	1954-89	35	65.8	65.8
03283000	Stillwater Creek at Stillwater, KY	Discontinued	U	1954-73	1954-73	19	24.0	24.0
03283500	Red River at Clay City, KY	Active	LD	1931-32, 1938-89	1931-32, 1938-89	52	362	362
03284300	Silver Creek near Kingston, KY	Discontinued	LD	1968-83	1968-83	16	28.6	28.6
03284550	West Hickman Creek at Jonestown, KY	Discontinued	LD	1974-84	1974-84	10	11.0	10.9
03285000	Dix River at Danville, KY	Active	U	1943-89	1943-89	47	318	318
03285500	Dix River near Burgin, KY	Discontinued	U	1909-22	1909-22	13	395	379
03288000	North Elkhorn Creek near Georgetown, KY	Discontinued	U	1950-83	1950-83	34	119	111
03288500	Cave Creek near Fort Spring, KY	Discontinued	U	1953-72	1953-72	20	2.53	1.93
03289000	South Elkhorn Creek at Fort Spring, KY	Active	U	1950-89	1950-89	39	24.0	21.0
03289300	South Elkhorn Creek near Midway, KY	Active	LD	1982-89	1982-89	7	105	84

Table 1. Selected information for the continuous-record streamflow-gaging stations used in the study--Continued

[U, unregulated; R, regulated; E, east; Fk, fork; LD, local diversion; S, south; M, middle; Mun, municipal; N, north]

Station number	Station name	Status	Regulation	Period of daily record (water year)	Period of unregulated daily record (water year)	Years of record in analysis	Drainage area (square miles) Total	Drainage area (square miles) Contributing
03289500	Elkhorn Creek near Frankfort, KY	Active	LD	1915-18, 1940-83, 1988-89	1915-18, 1940-83, 1988-89	48	473	403
03290000	Flat Creek near Frankfort, KY	Discontinued	U	1952-71	1952-71	20	5.63	5.63
03291000	Eagle Creek at Sadieville, KY	Discontinued	U	1941-75	1941-75	34	42.9	42.9
03291500	Eagle Creek at Glencoe, KY	Discontinued	U	1915-18, 1928-31, 1938-77	1915-18, 1928-31, 1938-77	45	437	437
03292460	Harrods Creek near LaGrange, KY	Active	U	1968-89	1968-89	21	24.1	24.1
03292500	S Fork Beargrass Creek at Louisville, KY	Active	LD	1939-40, 1944-53, 1955-62, 1970-83, 1988-89	1939-40, 1944-53, 1955-62, 1970-83, 1988-89	32	17.2	17.2
03293000	M Fork Beargrass Creek at Louisville, KY	Active	LD	1944-89	1944-89	45	18.9	18.4
03294000	Silver Creek near Sellersburg, IN	Active	U	1955-89	1955-89	35	189	189
03295000	Salt River near Harrodsburg, KY	Discontinued	U	1952-73	1952-73	21	41.4	39.7
03295500	Salt River near Van Buren, KY	Discontinued	U	1939-82	1939-82	44	196	192
03295890	Brashears Creek at Taylorsville, KY	Mandatory	U	1981-89	1981-89	8	259	259
03296500	Plum Creek near Wilsonville, KY	Discontinued	U	1954-61	1954-61	7	19.1	19.1
03297000	Little Plum Creek near Waterford, KY	Discontinued	U	1954-61	1954-61	7	5.15	5.15
03297500	Plum Creek at Waterford, KY	Discontinued	U	1954-74	1954-74	20	31.8	31.8
03297845	Floyds Fork at Crestwood, KY	Active	U	1980-89	1980-89	10	46.7	46.7
03298000	Floyds Fork at Fisherville, KY	Active	U	1944-89	1944-89	45	138	138
03298500	Salt River at Shepherdsville, KY	Active	R	1938-89	1938-82	44	1,197	1,197
03299000	Rolling Fork near Lebanon, KY	Active	U	1938-89	1938-89	51	239	239
03300000	Beech Fork near Springfield, KY	Discontinued	U	1952-72	1952-72	20	85.9	85.9
03300400	Beech Fork at Maud, KY	Active	U	1972-89	1972-89	17	436	436
03301000	Beech Fork at Bardstown, KY	Discontinued	U	1940-74	1940-74	35	669	669
03301500	Rolling Fork near Boston, KY	Active	U	1938-89	1938-89	51	1,299	1,299
03302000	Pond Creek near Louisville, KY	Active	LD	1944-89	1944-89	45	64.0	64.0
03302220	Buck Creek near New Middletown, IN	Active	U	1970-89	1970-89	20	65.2	37.1
03302300	Little Indian Creek near Galena, IN	Active	U	1969-89	1969-89	21	16.1	16.1
03303000	Blue River near White Cloud, IN	Active	U	1931-89	1931-89	59	476	284
03303400	Crooked Creek near Santa Claus, IN	Active	U	1969-89	1969-89	20	7.86	7.86
03304500	McGills Creek near McKinney, KY	Discontinued	U	1951-71	1951-71	20	2.14	2.14
03305000	Green River near McKinney, KY	Discontinued	U	1951-73	1951-73	22	22.4	22.4

Table 1. Selected information for the continuous-record streamflow-gaging stations used in the study--Continued

[U, unregulated; R, regulated; E, east; Fk, fork; LD, locel diversion; S, south; M, middle; Mun, municipal; N, north]

Station number	Station name	Status	Regulation	Period of daily record (water year)	Period of unregulated daily record (water year)	Years of record in analysis	Dreinage area (square miles) Totel	Contributing
03305500	Green River neer Mount Salem, KY	Discontinued	U	1954-61	1954-61	8	36.3	36.3
03306000	Green River near Campbellsville, KY	Active	R	1931-32, 1964-89	1931-32, 1964-68	6	682	682
03306500	Green River et Greensburg, KY	Discontinued	R	1939-75	1939-68	29	736	729
03307000	Russell Creek near Columbie, KY	Mandetory	U	1940-89	1940-89	50	188	173
03307100	Russell Creek neer Gresham, KY	Discontinued	U	1965-75	1965-75	11	265	246
03307500	S Fork Little Barren River at Edmonton, KY	Discontinued	U	1941-72	1941-72	31	18.3	18.3
03309500	McDougal Creek near Hodgenville, KY	Discontinued	U	1953-71	1953-71	18	5.34	5.34
03310000	North Fork Nolin River at Hodgenville, KY	Discontinued	U	1941-73	1941-73	32	36.4	35.6
03310300	Nolin River at White Mills, KY	Active	U	1960-89	1960-89	30	357	237
03310400	Bacon Creek near Priceville, KY	Active	U	1960-89	1960-89	30	85.4	54.4
03310500	Nolin River at Wax, KY	Discontinued	U	1937-62	1937-62	26	600	378
03311000	Nolin River et Kyrock, KY	Active	R	1931-32, 1939-50, 1961-89	1931-32, 1939-50, 1961-63	14	703	480
03311600	Beaverdam Creek at Rhode, KY	Active	U	1973-89	1973-89	17	10.9	10.9
03312000	Beer Branch near Leitchfield, KY	Discontinued	U	1950-71	1950-71	22	30.8	30.8
03312500	Barren River near Pageville, KY	Discontinued	U	1939-63	1939-63	24	531	514
03313000	Barren River near Finney, KY	Active	R	1942-50, 1961-89	1942-50, 1961-64	12	942	865
03313500	West Beys Fork at Scottsville, KY	Discontinued	U	1951-72	1951-72	22	7.47	7.47
03313700	West Fork Drekes Creek near Franklin, KY	Active	LD	1968-89	1968-89	21	110	91.0
03314000	Drekes Creek near Alvaton, KY	Discontinued	U	1940-71	1940-71	32	478	358
03316000	Mud River near Lewisburg, KY	Discontinued	U	1940-72	1940-72	33	90.5	80.8
03317000	Rough River near Madrid, KY	Discontinued	U	1938-59	1938-59	20	225	158
03317500	North Fork Rough River neer Westview, KY	Discontinued	U	1954-73	1954-73	19	42.0	22.6
03318000	Rough River near Falls of Rough, KY	Discontinued	LD	1940-56	1940-56	11	454	344
03318200	Rock Lick Creek near Glenn Dean, KY	Discontinued	U	1957-71	1957-71	15	20.1	20.1
03318500	Rough River at Falls of Rough, KY	Active	R	1949-89	1949-59	11	504	394
03318800	Caney Creek neer Horse Branch, KY	Active	U	1957-89	1957-89	33	124	124
03319000	Rough River neer Dundee, KY	Active	R	1940-89	1940-59	20	757	637
03320500	Pond River near Apex, KY	Active	U	1940-89	1940-89	49	194	194
03321350	S Fork Penther Creek neer Whitesville, KY	Discontinued	U	1968-83	1968-83	15	58.2	58.2
03322100	Pigeon Creek et Evansville, IN	Discontinued	U	1961-82	1961-82	22	323	323
03322360	Beeverdam Creek neer Corydon, KY	Active	U	1972-82, 1984-86, 1989	1972-82, 1984-86, 1989	14	14.3	14.3
03366200	Herberts Creek near Madison, IN	Discontinued	U	1969-84	1969-84		9.31	9.31

Table 1. Selected information for the continuous-record streamflow-geging stations used in the study--Continued

[U, unregulated; R, regulated; E, east; Fk, fork; LD, local diversion; S, south; M, middle; Mun, municipal; N, north]

Station number	Station name	Status	Regu-lation	Period of daily record (water year)	Period of unreg-ulated daily record (water year)	Years of record in analysis	Dreinage area (square miles) Total	Contributing
03378550	Big Creek near Wadesville, IN	Discontinued	U	1966-84	1966-84		104	104
03383000	Tradewater River at Olney, KY	Active	U	1940-83, 1985-89	1940-83, 1984-89	47	255	246
03384000	Rose Creek at Nebo, KY	Discontinued	U	1952-70	1952-70	18	2.10	2.10
03400500	Poor Fork at Cumberlend, KY	Active	U	1940-89	1940-89	49	82.3	82.3
03400800	Martins Fork near Smith, KY	Active	R	1971-89	1971-78	7	55.8	55.8
03401000	Cumberland River near Harlen, KY	Active	LD	1940-89	1940-89	49	374	374
03402000	Yellow Creek neer Middlesboro, KY	Active	LD	1940-89	1940-89	49	60.6	60.6
03403000	Cumberland River near Pineville, KY	Active	LD	1938-75, 1980-89	1938-75, 1980-89	47	809	809
03403500	Cumberland River at Barbourville, KY	Active	LD	1923-31, 1948-89	1923-31, 1948-89	50	960	960
03404000	Cumberland River at Williamsburg, KY	Active	U	1951-89	1951-89	39	1,607	1,607
03404500	Cumberland River at Cumberland Falls, KY	Active	U	1907-12, 1915-89	1907-12 1915-89	79	1,977	1,977
03403910	Clear Fork at Sexton, KY	Active	U	1968-89	1968-89	21	331	331
03404820	Laurel River at Mun Dam at Corbin, KY	Active	LD	1974-89	1974-89	16	140	140
03404900	Lynn Camp Creek at Corbin, KY	Active	U	1974-89	1974-89	16	53.8	53.8
03405000	Laurel River at Corbin, KY	Discontinued	LD	1923-24, 1942-73	1922-24, 1942-73	33	201	201
03406000	Wood Creek near London, KY	Discontinued	U	1953-71	1954-71	18	3.89	3.89
03406500	Rockcestle at Billows, KY	Active	U	1936-89	1936-89	53	604	604
03407000	Rockcastle River at Rockcastle Springs, KY	Discontinued	U	1922-31	1922-31	9	745	745
03407100	Cane Branch near Parkers Lake, KY	Discontinued	U	1956-66, 1974	1956-66, 1974	11	.67	.67
03407300	Helton Br near Greenwood, KY	Discontinued	U	1956-74	1956-74	18	.85	.85
03407500	Buck Creek near Shopville, KY	Active	U	1953-89	1953-89	37	165	165
03408500	New River et New River, TN	Active	U	1934-89	1934-89	55	382	382
03410500	Cumberland River at Sterns, KY	Active	U	1943-89	1943-89	47	954	954
03411500	Cumberland River et Burnside, KY	Discontinued	R	1914-50	1914-50	37	4,865	4,865
03412500	Pitman Creek at Somerset, KY	Discontinued	U	1954-72	1954-72	19	31.3	31.3
03413200	Beaver Creek near Monticello, KY	Discontinued	U	1969-83	1969-83	15	43.4	43.4
03414500	East Fork Obey River near Jemestown, TN	Active	U	1943-89	1943-89	47	202	196
03415000	West Fork Obey River near Alpine, TN	Discontinued	U	1942-71, 1980-81	1942-71, 1980-81	31	115	81
03416000	Wolf River near Byrdstown, TN	Active	U	1943-89	1943-89	47	106	106
03418000	Roering River near Hilham, TN	Discontinued	U	1933-75	1933-75	43	78.7	51.6
03435140	Whippoorwill Creek neer Claymour, KY	Active	U	1973-89	1973-89	16	20.8	20.8

Teble 1. Selected information for the continuous-record streamflow-gaging stations used in the study--Continued

[U, unregulated; R, regulated; E, east; Fk, fork; LD, local diversion; S, south; M, middle; Mun, municipal; N, north]

Stetion number	Station name	Status	Regu-lation	Period of daily record (weter yeer)	Period of unreg-ulated daily record (water yeer)	Years of record in enalysis	Drainage erea (squere miles) Total	Contributing
03435500	Red River near Adams, TN	Discontinued	U	1921-69	1921-69	49	706	309
03436000	Sulphur Fork Red River near Adams, TN	Active	U	1939-89	1939-89	51	186	165
03436700	Yellow Creek near Shiloh, TN	Discontinued	U	1958-80	1958-80	23	124	124
03437500	South Fork Little River at Hopkinsville, KY	Discontinued	U	1950-73	1950-73	24	46.5	35.3
03438000	Little River near Cadiz, KY	Active	U	1940-89	1940-89	49	244	150
03438070	Muddy Fork Little River near Ceruleen, KY	Discontinued	U	1968-83	1968-83	15	30.5	30.5
03529500	Powell River et Big Stone Gap, VA	Discontinued	U	1945-59, 1979-81	1945-59, 1979-81	18	112	112
03530500	N Fork at Powell River at Pennington, VA	Discontinued	U	1945-51, 1979-81	1945-51, 1979-81	10	70.0	70.0
03531500	Powell River neer Jonesville, VA	Active	U	1932-89	1932-89	58	319	319
03610000	Clarks River et Murray, KY	Discontinued	U	1952-71	1952-71	20	89.7	89.7
03610200	Clarks River at Almo, KY	Active	U	1983-89	1983-89	7	134	134
03610500	Clarks River near Benton, KY	Discontinued	U	1938-73	1938-73	35	227	227
03610545	West Fork Clarks River neer Brewers, KY	Discontinued	U	1969-83	1969-83	15	68.7	68.7
03611260	Massac Creek near Paduceh, KY	Active	U	1972-89	1972-89	18	14.6	14.6
07022500	Perry Creek near Mayfield, KY	Discontinued	U	1953-65, 1968-72	1953-65, 1968-72	18	1.72	1.72
07023000	Mayfield Creek at Lovelaceville, KY	Discontinued	U	1938-72	1938-72	34	212	212
07023500	Obion Creek at Pryorsburg, KY	Discontinued	U	1951-73	1951-73	21	36.8	36.8
07024000	Bayon De Chien near Clinton, KY	Active	U	1940-78, 1984-89	1940-78, 1984-89	44	68.7	68.7
07026500	Reelfoot Creek near Samburg, TN	Discontinued	U	1951-72	1951-72	22	110	110