COST-EFFECTIVENESS OF THE U.S. GEOLOGICAL SURVEY STREAM-GAGING PROGRAM IN INDIANA

By James A. Stewart, Robert L. Miller, and Gerard K. Butch

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FACTORS FOR CONVERTING INCH-POUND UNITS TO METRIC (INTERNATIONAL SYSTEM) UNITS

Multiply inch-pound units	by	To obtain Metric units
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

COST-EFFECTIVENESS OF THE U.S. GEOLOGICAL SURVEY STREAM-GAGING PROGRAM IN INDIANA

By J. A. Stewart, R. L. Miller, and G. K. Butch

ABSTRACT

Analysis of the stream-gaging program in Indiana was divided into three phases. The first phase involved collecting information concerning the data need and the funding source for each of the 173 surface-water stations in Indiana. The second phase used alternate methods to produce streamflow records at selected sites. Statistical models were used to generate streamflow data for three gaging stations. In addition, flow-routing models were used at two of the sites. Daily discharges produced from models did not meet the established accuracy criteria and, therefore, these methods should not replace stream-gaging procedures at those gaging stations. The third phase of the study determined the uncertainty of the rating and the error at individual gaging stations, and optimized travel routes and frequency of visits to gaging stations.

The annual budget, in 1983 dollars, for operating the stream-gaging program in Indiana is $823,000. The average standard error of instantaneous discharge for all continuous-record gaging stations is 25.3 percent. A budget of $800,000 could maintain this level of accuracy if stream-gaging stations were visited according to phase III results. A minimum budget of $790,000 is required to operate the gaging network. At this budget, the average standard error of instantaneous discharge would be 27.7 percent. A maximum budget of $1,000,000 was simulated in the analysis and the average standard error of instantaneous discharge was reduced to 16.8 percent.

INTRODUCTION

The U.S. Geological Survey (USGS) is the principal Federal agency collecting surface-water data in the Nation. The collection of these data is a major activity of the Water Resources Division of the USGS. The data are collected in cooperation with State and local governments and other Federal agencies. In 1983 the USGS operating approximately 8,000 continuous-record gaging stations throughout the Nation. Some of these records extend back to the turn of the century. Any activity of long standing, such as the collection of surface-water data, should be reexamined at intervals, if not continuously, because of changes in objectives, technology, or external constraints. The last systematic nationwide evaluation of the streamflow information program was completed in 1970 and is documented by Benson and Carter (1973). The USGS is presently (1983) undertaking another nationwide analysis of the stream-gaging program that will be completed over a 5-year period with 20 percent of the program being analyzed each year.

Purpose and Scope

The objective of this analysis is to define and document the cost-effective means of furnishing streamflow information. The stream-gaging program is analyzed in three phases. In the first phase, the analysis identifies the principal uses of the data for every continuous-record gaging station and relates these uses to funding sources. Gaging stations are categorized as to whether the data are available to users in real-time, on a provisional basis, or at the end of the water year.

The second phase of the analysis examines less costly alternate methods of furnishing the needed information; among these are flow-routing models and statistical models. The stream-gaging activity no longer is considered a network of observation points, but rather an integrated information system in which data are provided both by observation and synthesis.

The final phase of the analysis involves the use of Kalman-filtering and mathematical-programing techniques to define strategies for operation of the gaging stations and minimize the uncertainty in the streamflow records for given operating budgets. Kalman-filtering techniques are used to compute uncertainty functions for each station in the network. The uncertainty function relates the standard errors of computed or estimated streamflow records to the frequency of visits to a gaging station. A steepest descent optimization program uses these uncertainty functions, information on practical stream-gaging routes, the various costs associated with stream gaging, and the total operating budget to identify the visit frequency for each station that minimizes the overall uncertainty in the streamflow records. The stream-gaging program that results from this analysis will meet the expressed water-data needs in a cost-effective manner.

The standard errors of estimate given in the report are those that would occur if daily discharges were computed through the use of methods described in this study. No attempt has been made to estimate standard errors for discharges that are computed by other means. Such errors could differ from the errors computed in the report. The magnitude and direction of the differences would be a function of methods used to account for shifting controls and for estimating discharges during periods of missing record.

History of the Stream-Gaging Program in Indiana

The earliest discharge measurement recorded in Indiana was made by Captain Howard Stanburg at the outlet of Hamilton Lake in Steuben County in August, 1830 (Follansbee, 1939). The USGS collected daily discharge records in

Indiana for short periods at several sites from 1903-22. In 1928, the USGS began collecting daily discharges at 13 stations (Corbett, 1959) in a statewide cooperative program with the U.S. Corps of Engineers. In 1930, the State of Indiana and the USGS began a cooperative agreement. A district office was established in Indianapolis on August 18, 1930, and an attempt was made to establish a meaningful hydrologic network. This led to a gradual increase in the streamflow-gaging network as cooperation with the State and the U.S. Corps of Engineers continued. A histogram of continuous-record stream gages operated by the Indiana District is shown in figure 1. Currently (1983) there are 173 gaging stations operated in Indiana.

In 1960, a statewide network of low-flow partial-record sites was established. Data were collected at sites other than continuous-record gaging stations for the purpose of obtaining low-flow characteristics within the State, at a minimum cost. Two reports titled "Low-Flow Characteristics of Indiana Streams," (P. B. Rohne, Jr., 1972, and J. A. Stewart, 1982) were published using data obtained from these partial-record stations. This program was discontinued in 1980 as a cost reducing measure.

In 1972, a study of peak flows on streams of less than 20 mi^2 (square miles) was started. One hundred crest-stage partial-record stations were installed for this program. Of these, 20 were also equipped with recording gages to measure streamflow and precipitation. Data obtained from these small-stream stations were combined with data from continuous-record and partial-record stations to develop equations for estimating flood magnitude and frequency. The results of this study are presented in the report "Techniques for Estimating Magnitude and Frequency of Floods on Streams in Indiana" (Glatfelter, 1984).

The development of Indiana's surface-water program was described and a program to meet the future needs of water-data users was proposed in the report, "Evaluation of and Recommendations for the Surface-Water Data Program in Indiana" (Marie and Swisshelm, 1970). At the time of Marie and Swisshelm's study, the Indiana program had 204 continuous-record stations. There has been a decline in the number of continuous-record stations in recent years (fig. 1).

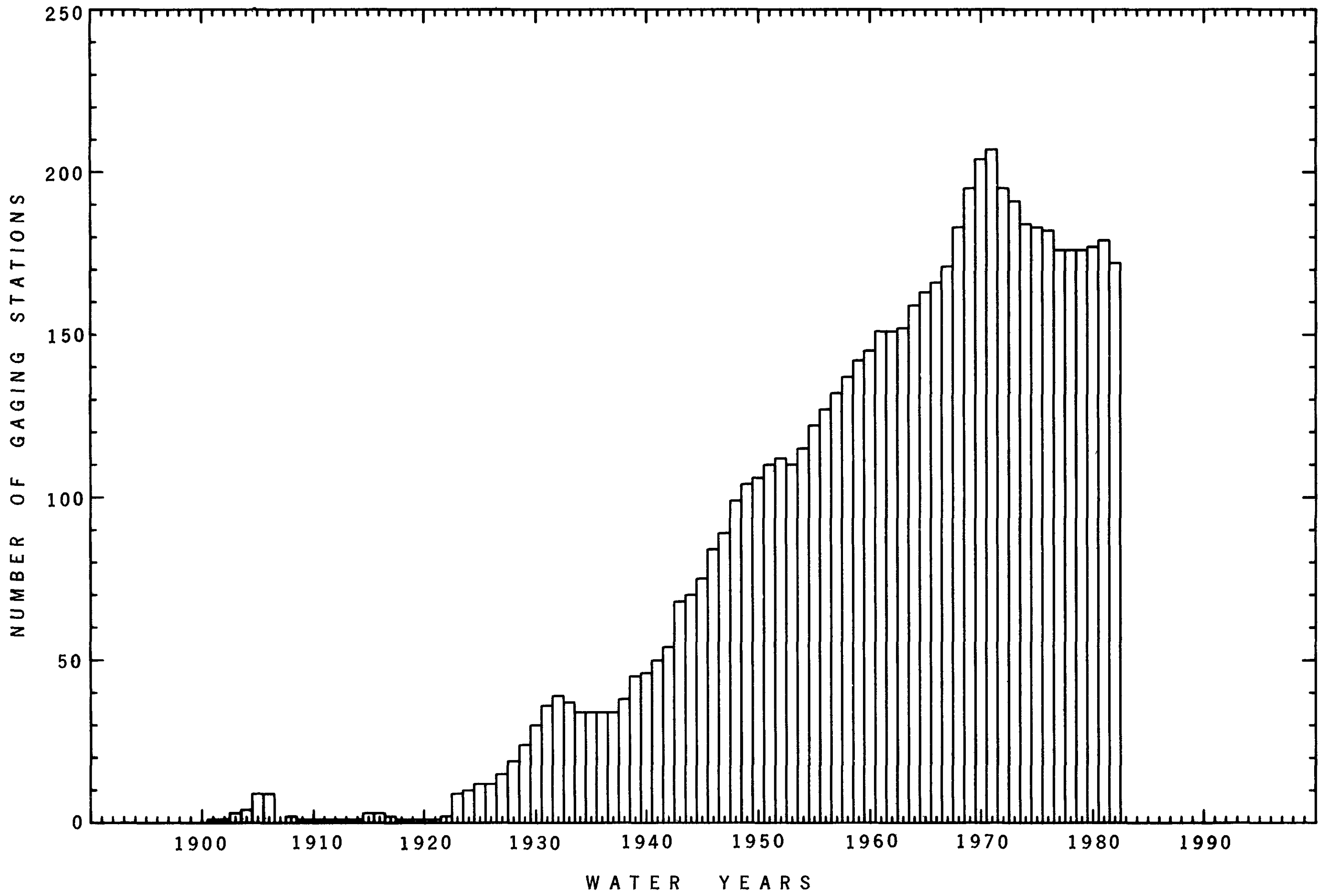

Figure 1.-- Number of continuous-record streamflow stations in Indiana.

Current Indiana Stream-Gaging Program

The 1983 stream-gaging program in Indiana consists of 173 stations. Selected hydrologic data, including drainage area, period of record, and mean annual flow for these 173 stations are shown in table 1 (after references). These gages are distributed throughout the three major physiographic regions in Indiana: the Northern Zone, the Central Zone, and the Southern Zone (fig. 2). The diverse terrain of Indiana allows for collection of data from a variety of hydrologic settings. The northern zone is the most recently glaciated portion of Indiana. Large outwash and morainal features dominate this region (Schneider, 1966). The northern zone contains 44 streamflow stations. The central zone is a broad till plain of low relief which has been modified by postglacial streams. The central zone has 69 streamflow stations. The southern zone differs from the other two zones in that the physiography is bedrock controlled. Glaciation has had much less effect in this zone which allows for the bedrock control. The various bedrock types have created seven diverse physiographic sub-areas in this zone. There are 60 streamflow stations in the southern zone.

Acknowledgments

The authors acknowledge the following agencies for their cooperation in identifying the uses of data collected at gaging stations in the Indiana stream-gaging program:

U.S. Army, Corp of Engineers, Chicago District
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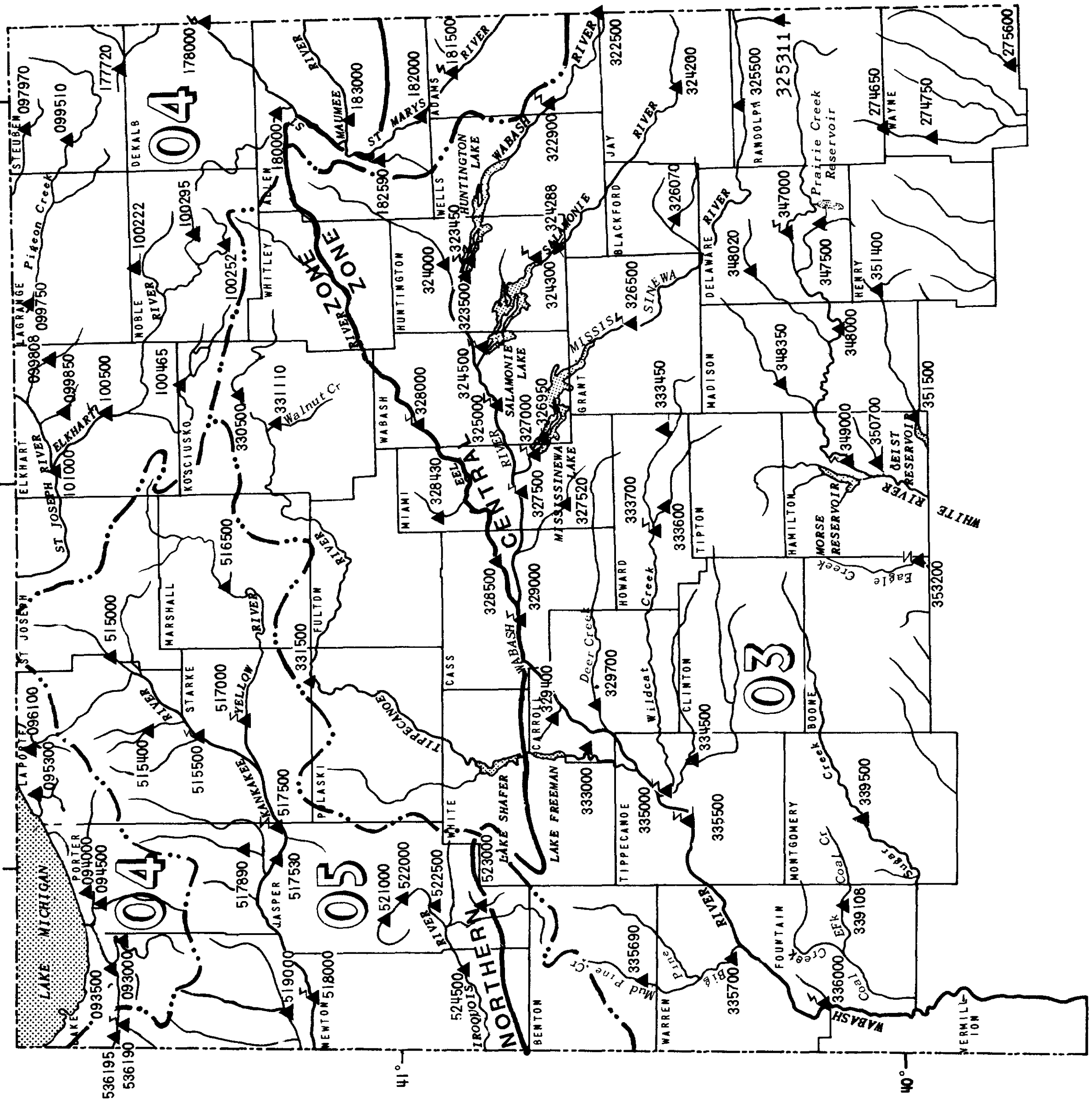
U.S. Army, Corp of Engineers, Louisville District
U.S. Army, Corp of Engineers, Rock Island District
U.S. Department of Agriculture, Soil Conservation Service
U.S. Office of Surface Mining, Indiana Office
U.S. Department of Agriculture, Forestry Service
City of Fort Wayne, Department of Transportation
National Weather Service, Cincinnati River Forecast Center
National Weather Service, Minneapolis River Forecast Center
National Weather Service, Indianapolis office
Indiana Department of Highways
Indiana Department of Natural Resources, Division of Reclamation
Indiana Department of Natural Resources, Division of Water
Indiana State Board of Health
Indianapolis Department of Public Works



85°
86°
87°
41°
40°
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05
03
NORTHERN
CENTRAL ZONE
RIVER ZONE
LAKE MICHIGAN
STEUBEN
LAGRANGE
ELKHART
ST JOSEPH
LAPORTE
PORTER
LAKE
DEKALB
NOBLE
KOSCIUSKO
MARSHALL
STARKE
JASPER
NEWTON
WHITLEY
ALLEN
ADAMS
WELLS
HUNTINGTON
WABASH
MIAMI
FULTON
PULASKI
CASS
WHITE
CARROLL
BENTON
WARREN
TIPPECANOE
FOUNTAIN
MONTGOMERY
BOONE
CLINTON
HOWARD
TIPTON
HAMILTON
MADISON
GRANT
BLACKFORD
JAY
DELAWARE
RANDOLPH
HENRY
WAYNE
VERMILLION
Pigeon Creek
ELKHART
ST JOSEPH RIVER
Walnut Cr
KANKAKEE
YELLOW RIVER
TIPPECANOE
LAKE SHAFER
LAKE FREEMAN
IROQUOIS RIVER
Mud Pine Cr
Big Pine
WABASH RIVER
Coal Creek
Sugar Creek
Wildcat Creek
Deer Creek
EEL RIVER
MISSISSINEWA LAKE
SALAMONIE LAKE
HUNTINGTON LAKE
MAUMEE
ST MARYS
MISSISSINEWA
SALAMONIE
WHITE RIVER
MORSE RESERVOIR
GEIST RESERVOIR
Prairie Creek Reservoir
Eagle Creek
097970
099510
177720
178000
099750
099808
099850
100500
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100222
100295
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096100
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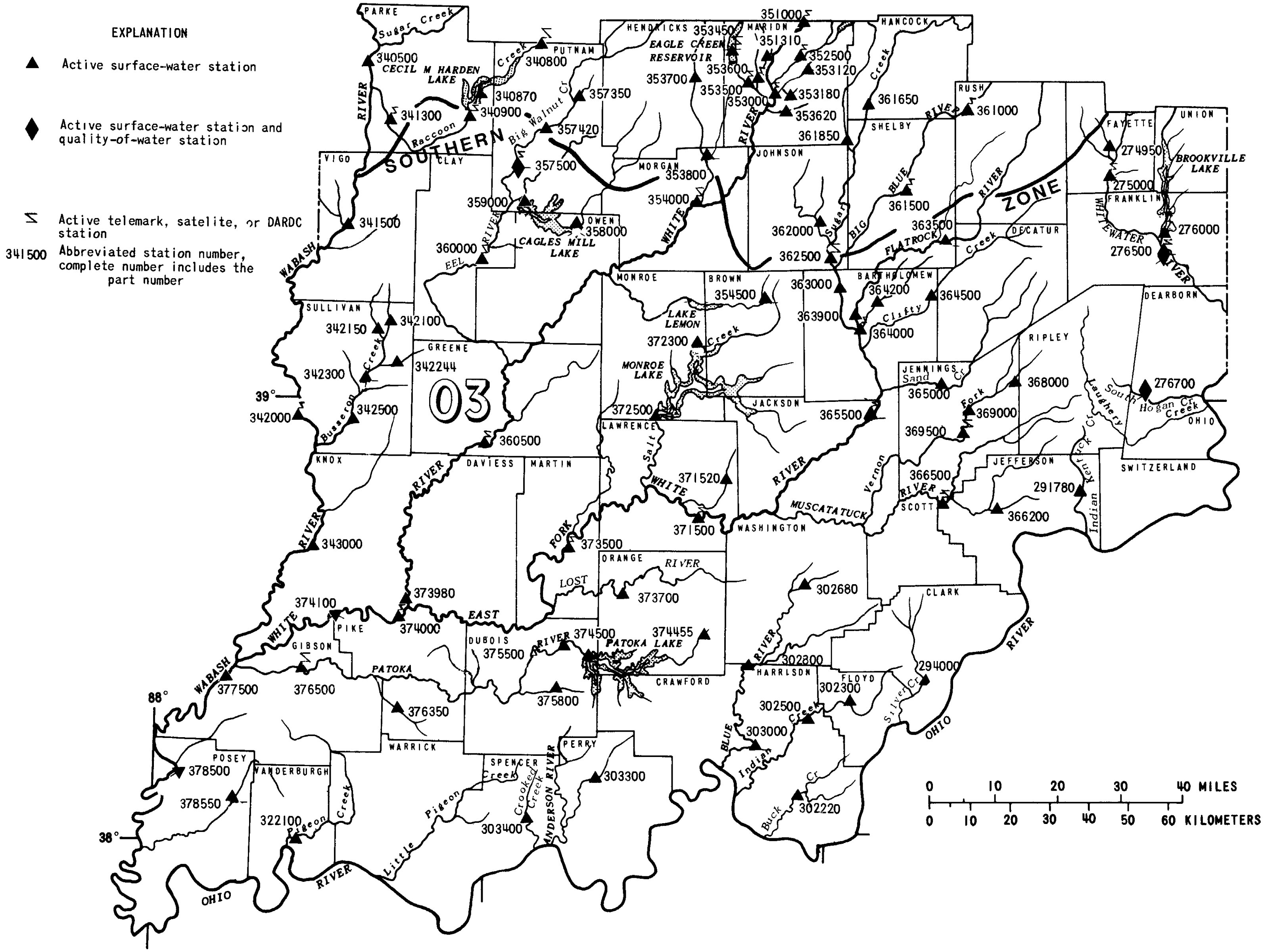

Figure 2.-- Locations of continuous-record streamflow stations in Indiana.

USES, FUNDING, AND AVAILABILITY OF CONTINUOUS STREAMFLOW DATA

The purpose of a gaging station is defined by the uses that are made of the data that are produced from the station. The uses of the data from each of the 173 gaging stations in the Indiana stream-gaging program in 1983 were identified by a survey of known data users (table 2, after references).

Data uses identified by the survey were categorized into the nine classes defined in this section. The sources of funding for each gaging station and the frequency at which data are provided to the users were also compiled (table 2, after references).

Data-Use Classes

Regional Hydrology

For data to be useful in defining regional hydrology, the streamflow at a gaging station must be largely unaffected by manmade storage or diversion. In this class, the effects of man on streamflow are not necessarily small in the basin, but the effects are limited to those caused primarily by land use. Large amounts of manmade storage may exist in the basin providing the outflow is uncontrolled. These stations are useful in developing relationships between streamflow and basin characteristics that are regionally transferable.

One hundred twenty three stations in the Indiana network are classified in the regional hydrology data-use category. One hydrologic bench-mark station in the network serves as an indicator of hydrologic conditions in watersheds relatively free of manmade alterations, and three index stations are used to indicate the current hydrologic conditions across the State, on a monthly basis.

Hydrologic Systems

Stations that can be used for accounting, that is, to define current and long-term hydrologic conditions are designated as hydrologic systems stations. Hydrologic systems stations are affected by diversions and return flows and/or are useful for defining the interaction of water systems.

The bench-mark and index stations are included in both the hydrologic systems and regional hydrology categories because they indicate current and long-term conditions of the hydrologic systems. Fourteen stations in southwestern Indiana assist in identifying the effects of strip mining on the hydrologic systems and are identified as "Coal field hydrology stations." Twenty stations are used by the Indiana Department of Natural Resources to monitor interstate flow, inter-basin flow, and the effects of irrigation. Seven stations in northern Indiana assist in identifying the effects of lakes on the hydrologic systems and are identified as "Lake hydrologic stations."

Legal Obligations

Some stations provide records of flow for the verification or enforcement of existing treaties, compacts and decrees. There are no stations in the Indiana program that exist to fulfill a legal responsibility of the USGS. Fifteen stations are operated to provide data to the Indiana Department of Natural Resources and the Indiana State Board of Health for fulfilling legal obligations.

Planning and Design

Gaging stations in this category of data use are for the planning and design of a specific project (for example, a dam, levee, floodwall, navigation system, water supply diversion, hydropower plant, or waste-treatment facility) or group of structures. The planning and design category is limited to those stations that were instituted for such purposes and where this purpose is still valid. No stations are being operated solely for planning and design. However, 45 stations are providing data that are being used for this purpose.

Project Operation

Gaging stations in this category are used on an ongoing basis to assist water managers in making operational decisions such as reservoir releases, hydropower operations, or diversions. The project operation use generally implies that data are routinely available to the operators on a real time basis. For projects on large streams, data may only be needed every few days.

There are 71 stations in the Indiana program that are used in project operation. The Indiana Department of Natural Resources and the U.S. Army Corps of Engineers use data from these stations to monitor high streamflow and manage reservoirs designed for water supply, flood control, recreation, and low-flow augmentation.

Hydrologic Forecasts

Gaging stations in this category are regularly used to provide information for hydrologic forecasting. This information might be used to forecast floods for a specific river reach, or periodic (daily, weekly, monthly, or seasonal) flow-volume forecasts for a specific site or region. The hydrologic forecasts use generally implies that the data are routinely available to the forecasters on a real-time basis. On large streams, data may only be needed every few days.

Data from 108 stations are used by the National Weather Service at Indianapolis, Cincinnati, and Minneapolis, the Indiana Department of Natural Resources, the Indiana State Board of Health, and the U.S. Army Corps of Engineers for hydrologic forecasts. The City of Fort Wayne and the National Weather Service are using an early flood-warning system for Fort Wayne. The system collects precipitation and streamflow data and transmits the information to a central receiving station. Five streamflow stations in the Indiana network are part of this system.

Water-Quality Monitoring

Gaging stations where water quality or sediment transport is monitored and/or where streamflow data contributes to the interpretation of the water-quality or sediment data are designated as water-quality monitoring sites.

Sixty-four stations are used by the Indiana State Board of Health under this category. One station in the Indiana program is a designated bench-mark station. Water-quality samples from bench-mark stations are used to indicate water-quality characteristics of streams that have been and probably will continue to be relatively free of manmade influence. Three stations in the Indiana stream-gaging program are used to supply discharge data for NASQAN (National Stream Quality Accounting Network) stations. NASQAN stations are part of a nationwide network designed to assess water-quality trends in streams.

Research

Gaging stations in this category are operated for a particular research or water-investigations study. Typically, these are only operated for a few years. Currently, no stations in the Indiana program are being operated for research.

Other

In addition to the eight data-use classes described above, four stations are used to provide streamflow information in the Indiana Water Bulletin as trend stations.

Funding

The four possible sources of funding for the streamflow-data program are:

1. Federal program.--Funds that have been directly allocated to the U.S. Geological Survey.

2. Other Federal Agency (OFA) program.--Funds that have been transferred to the U.S. Geological Survey by OFA's.

3. Cooperative (Co-op) program.--Funds that come jointly from U.S. Geological Survey cooperative-designated funding and from a non-Federal cooperating agency.

4. Other non-Federal.--Funds that are provided entirely by a non-Federal agency or a private concern under the auspices of a Federal agency. Funds in this category are not matched by U.S. Geological Survey cooperative funds.

In all four categories, the identified sources of funding pertain only to the collection of streamflow data. Sources of funding for other activities, particularly collection of water-quality samples, that might be carried out at a gaging station may not necessarily be the same as those identified herein.

There are 15 sources of funds for the Indiana stream-gaging program. One gaging station is maintained solely by Army Engineers Replacement (AER) funds directly allocated to the U.S. Geological Survey. Four stations are funded under the Federal program. The OFA program consists of four Corps Districts that fund 25 gaging stations. The Indiana Department of Natural Resources, Division of Water contributes funds to the Co-op program for 141 gaging stations, and the Indiana State Board of Health supports one station. The City of Indianapolis supports seven stations and Fort Wayne supports two. There are no "other non-Federal" sources of funds for the Indiana stream-gaging program.

Data Availability

Data availability refers to the method used to furnish streamflow data to the users. The three methods by which data are furnished are by direct-access telemetry for real-time use, by periodic release of provisional data, and by publication in the annual report, "Water Resources Data, Indiana". Streamflow data for all 173 stations are published in the annual report; data from 37 stations are available by telemetry on a real-time basis; and data from five stations are released on a provisional basis.

Presentation and Summary of Data Use

Information regarding data use, funding source, and data availability for each continuous-record gaging station is shown in table 2 (after references). An asterisk or footnote in the "Regional hydrology" column indicates the streamflow data can be used to define relations between basin characteristics and streamflow. An asterisk in the "Federal program" column indicates the station is operated from Federal funds appropriated directly to the USGS.

Conclusions Pertaining to Data Uses

A review of the data-use and funding information in table 2 (after references) indicates the Indiana Department of Natural Resources and the Corps of Engineers fund or partially fund 165 of the 173 streamflow-gaging stations. The predominate data uses are regional hydrology, project operation, and hydrologic forecasts. The streamflow data collected at many gaging stations are used by several agencies for different purposes. An example is Kankakee River at Shelby, Indiana (05518000), which is funded by the U.S. Army Corps of Engineers. Streamflow data at this gaging station are used by five agencies for planning and design, hydrologic forecasting, project operation, and water-quality monitoring.

Table 2 (after references) indicates a data need for all stations in the network. Discussions with cooperators indicate future needs of flow data from natural streams without lake effect in northern Indiana; dredged channels in northern and central Indiana; streams below reservoirs to establish releases and flow patterns reflecting mans influence; water-quality sampling points to calculate loading; urban streams reflecting mans influence; streams reflecting the effects of surface-mining operations; and streams defining low-flow patterns for areas dependent on surface resources for water supply. Remote sensing to furnish data on a real-time basis was also indicated as a future need, particularly by those agencies involved with project operation and hydrologic forecasts.

Examples of streams in Indiana with data needs that have not been met are the Grand Calumet and Little Calumet Rivers in the extreme northwestern part of the State. The Grand Calumet River flows from the heavily industrialized area of Gary to the Indiana Harbor Canal where it separates into two separate streams; part of the flow going to Lake Michigan through the canal and part going to the west. The Little Calumet River in Indiana flows east and west from the Hammond area. The outlet to the east is through Burns ditch and into Lake Michigan. The flow to the west joins the Grand Calumet River which eventually flows into the Illinois River. Streamflow data are needed on this system to determine water-quality loadings. Conventional stream gaging methods have not been successful due to the change in slope of the energy grade line as a result of industrial pumpage.

ALTERNATE METHODS OF DEVELOPING STREAMFLOW INFORMATION

The second step in the analysis of the Indiana stream-gaging program is to investigate alternate methods of providing daily streamflow information instead of operating continuous-record gaging stations. The objective of the analysis is to identify gaging stations where alternative technology, such as flow-routing or statistical models, will provide information about daily mean streamflow in a more cost-effective manner than operating a continuous-record stream gage. No guidelines exist concerning acceptable accuracies for particular uses of the data; therefore, judgment is required in deciding if the accuracy of the estimated daily flows is acceptable for the intended purpose. A criteria of acceptability of the model results was that 90 percent of the estimated daily discharge values are within 10 percent of the actual daily discharge values. The data uses at a station will influence whether a site has potential for alternate methods. For example, those stations where flood hydrographs are required in real-time, such as for hydrologic forecasts and project operation, are not candidates for the alternate methods. The primary candidates for alternate methods are stations that are operated upstream or downstream of another station on the same stream. Similar watersheds, located in the same physiographic or climatic area, may also have potential for alternate methods. Since none of Indiana's streamflow stations meet the criteria for alternate methods, an attempt was made to model those streams that had the best chance to be modeled accurately. The advantage of being able to model stations would be to use the model as a tool for estimating periods of missing streamflow record.

Three stations were selected to be modeled to determine potential for alternate means in Indiana.

Criteria of an alternate method are (1) the method should be computer oriented and easy to apply, (2) the method should have an available interface with the USGS WATSTORE Daily Values File (Hutchinson, 1975), (3) the method should be technically sound and generally acceptable to the hydrologic community, and (4) the method should permit easy evaluation of the accuracy of the simulated streamflow records. The use of a computer is mandatory to make such methods feasible. An interface with the WATSTORE Daily Values File is needed to easily calibrate the proposed alternate method. The alternate method selected for analysis must be technically sound or it will not be able to provide data of suitable accuracy. The alternate method should also provide an estimate of the accuracy of the streamflow data to judge the adequacy of the simulated data. The above criteria were used to select two methods--a flow-routing model and a statistical model.

Alternate methods were applied at three sites, Wabash River at Terre Haute Ind. (03341500), Wabash River at Covington, Ind. (03336000), and Wabash River at Vincennes, Ind. (03343000). Flow-routing techniques were used to synthesize data at Covington and Terre Haute. Regression methods were used to synthesize data at all three sites.

Description of Flow-Routing Model

Hydrologic flow-routing models use the law of conservation of mass and the relationship between storage in a reach and outflow from the reach. The hydraulics of the system are not considered. This method usually requires only a few parameters and analyzes the reach without subdivision. The input is usually a discharge hydrograph at the upstream end of the reach and the output a discharge hydrograph at the downstream end. Several different types of hydrologic routing are available such as Muskingum, modified Puls, kinematic wave, and the unit-response flow-routing method.

The unit-response method was selected because it met the criteria previously stated. This method uses two techniques--storage continuity (Sauer, 1973) and diffusion analogy (Keefer, 1974, and Keffer and McQuivey, 1974). Computer programs (Doyle and others, 1983) for the unit-response method route streamflow from one or more upstream locations to a downstream location. Downstream hydrographs are produced by the convolution (multiplication) of upstream hydrographs with appropriate unit-response functions. This method can only be applied if two stations exist on the same stream. Reservoir-routing techniques are included in the model so flows can be routed through reservoirs if the operating rules are known. Calibration and verification of the flow-routing model is achieved using observed upstream and downstream hydrographs and estimated tributary inflows. The convolution model treats a stream reach as a linear one-dimensional system in which the system output (downstream hydrograph) is computed by multiplying (convoluting) the ordinates of the upstream hydrograph by the unit-response function and lagging them appropriately. The model has the capability of combining hydrographs, multiplying a hydrograph by a drainage-area ratio, and changing the timing of a hydrograph. Routing can be accomplished using hourly data, but only daily data were used in this analysis.

Two methods are available for determining the unit (system) response function. Selection of the appropriate method depends primarily upon the variability of wave celerity (traveltime) and dispersion (channel storage) throughout the range of discharges to be routed. Adequate routing of mean daily flows can usually be accomplished using a single unit-response function (linearization about a single discharge) to represent the system response. However, if the routing coefficients vary significently with discharge, linearization about a low-range discharge results in overestimated high flows that arrive late at the downstream site; whereas, linearization about a high-range discharge results in low-range flows that are underestimated and arrive too soon. A single unit-response function may not provide acceptable results in such cases. Therefore, the option of multiple linearization (Keefer and McQuivey, 1974), which uses a family of unit-response functions to represent the system response, is available.

The objective in either the storage-continuity or diffusion-analogy flow-routing method is to calibrate two parameters that describe the storage-discharge relationship in a given reach and the traveltime of streamflow passing through the reach. In the storage-continuity method (Sauer, 1973), a response function is derived by modifying a translation hydrograph technique developed by Mitchell (1962) and applied to open channels. A triangular pulse (Sauer, 1973) is routed through reservoir-type storage and then transformed by a summation-curve technique to a unit response of desired duration. The two parameters that describe the routing reach are K_s, a storage coefficient which is the slope of the storage-discharge relation, and W_s, the translation hydrograph time base. These two parameters determine the shape of the resulting unit-response function.

In the diffusion-analogy method, two parameters require calibration, K_o, a wave dispersion or damping coefficient, and C_o, the floodwave celerity. K_o controls the spreading of the wave (analogous to K_s in the storage-continuity method) and C_o controls the traveltime (analogous to W_s in the storage-continuity method). In the single linearization method, only one K_o and C_o value are used. In the multiple linearization method, C_o and K_o are varied with discharge, so a table of wave celerity (C_o) versus discharge (Q) and a table of dispersion coefficient (K_o) versus discharge (Q) are used.

In both the storage-continuity and diffusion-analogy methods, the two parameters are calibrated by trial and error. The analyst must decide if acceptable parameters have been derived by comparing the simulated discharge to the observed discharge.

Description of Regression Analysis

Simple- and multiple-regression techniques can be used to estimate daily flow records. Regression equations can be computed that relate daily flow at a single station to daily flows at a combination of upstream, downstream, and (or) tributary stations. This statistical method is not limited, like the flow-routing method, to stations where an upstream station exists on the same stream. The explanatory (independent) variables in the regression analysis can be data from stations from different watersheds, or stations downstream or on tributary streams. The regression method has many of the same attributes as the flow-routing method in that it is easy to apply, provides indices of accuracy, and is generally accepted. The theory and assumptions of regression analysis are described in several textbooks such as Draper and Smith (1966) and Kleinbaum and Kupper (1978). The application of regression analysis to hydrologic problems is described and illustrated by Riggs (1973) and Thomas and Benson (1970). Only a brief description of regression analysis is provided in this report.

A linear regression model of the following form was developed for estimating daily mean discharges of Indiana streams:

$$y_i = B_o + \sum_{j=1}^{p} B_j x_j + e_i \quad (1)$$

where

y_i = daily mean discharge at station i (dependent variable),

x_j = daily mean discharges at nearby stations (independent variables),

B_o and B_j = regression constant and coefficients, and

e_i = the random error term.

The above equation is calibrated (B_o and B_j are estimated) using observed values of y_i and x_j. These observed daily mean discharges can be retrieved from the WATSTORE Daily Values File. The values of x_j may be discharges observed on the same day as discharges at station i or may be for previous or future days, depending on whether station j is upstream or downstream of station i. Once the equation is calibrated and verified, future values of y_i are estimated using observed values of x_j. The regression constant and coefficients (B_o and B_j) are tested to determine if they are significantly different from zero. A given station j should only be retained in the regression equation if its regression coefficient (B_j) is significantly different from zero. The regression equation should be calibrated using one period of time and then verified or tested on a different period of time to obtain a measure of the true predictive accuracy. Both the calibration and verification period should be representative of the range of flows that could occur at station i. The equation should be verified by (1) plotting the residuals e_i (difference between simulated and observed discharges) against the dependent and all independent variables in the equation, and (2) plotting the simulated and observed discharges versus time. These tests are intended to identify if (1) the linear model is appropriate or whether some transformation of the variables is needed, and (2) there is any bias in the equation such as overestimating low flows. These tests might indicate, for example, that a logarithmic transformation is desirable, that a nonlinear regression equation is appropriate, or that the regression equation is biased in some way. In this report these tests indicated that a log-linear model with y_i and x_j, in cubic feet per second, was appropriate. The application of linear-regression techniques to three watersheds in Indiana is described in a subsequent section of this report.

It should be noted that use of a regression relation to synthesize data at a discontinued gaging station entails a reduction in the variance of the streamflow record relative to that which would be computed from an actual record of streamflow at the site. The reduction in variance expressed as a fraction is approximately equal to one minus the square of the correlation coefficient that results from the regression analysis.

Wabash River at Covington, Indiana, Flow-Routing Analysis

The purpose of this flow-routing analysis is to investigate the potential use of the single-linearization diffusion-analogy model, described by Doyle and others (1983), to simulate daily mean discharges at the Wabash River at Covington, Ind. (03336000). A sketch of the reach of the Wabash River in this study area is presented in figure 3. In this application, as with the other systems that were modeled, the best model for the entire flow range is the desired product. Streamflow data available for this analysis are summarized in table 3.

The distance between the Wabash River at Lafayette, Ind. (03335500), and the Covington gage is 40.8 river miles. Big Pine Creek, which is the only major tributary in this reach, enters the Wabash River 16.7 river miles upstream from the Covington gage. The drainage area of Big Pine Creek at the mouth is 327 mi^2. Of the 951 mi^2 intervening area between the Lafayette and Covington stations, 628 mi^2 are ungaged. Major reservoirs, well upstream of Lafayette, control 2,077 mi^2 of the basin. However, releases are attenuated by the time they enter the study reach.

To simulate daily mean flows, the approach was to route the observed discharge hydrograph of the Wabash River at Lafayette, increased by a drainage area ratio (7682 mi^2/7267 mi^2 = 1.057), to the confluence of the Wabash River and Big Pine Creek. The hydrograph of Big Pine Creek near Williamsport, Ind. (03335700), was added to the mainstem flow and this combined hydrograph was then routed to Covington and increased by a drainage area ratio (8218 mi^2/8009 mi^2 = 1.026).

Table 3.--Gaging stations used in the Wabash River at Covington, Ind., flow-routing study

Station Number	Station Name	Drainage area (mi^2)	Period of record
03335500	Wabash River at Lafayette	7,267	October 1923 - present
03335700	Big Pine Creek near Williamsport	323	October 1955 - present
03336000	Wabash River at Covington	8,218	October 1939 - present

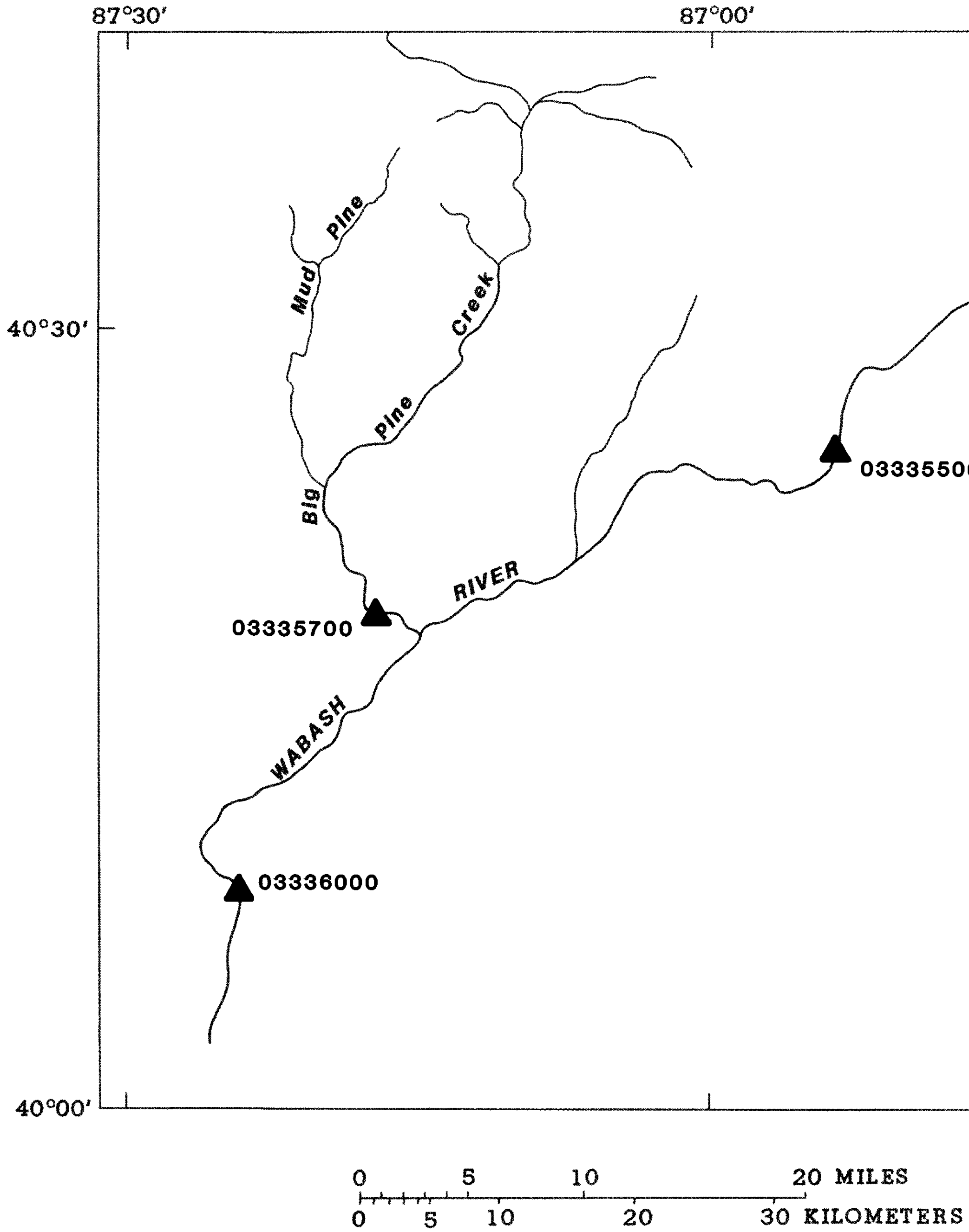

Figure 3.– Flow-routing model-study area, Wabash River at Covington, Ind., (03336000).

To route flow in this reach of the Wabash River, it was necessary to determine the model parameters C (floodwave celerity) and K (wave dispersion coefficient). The initial values for the coefficients C and K are functions of channel width, W (ft); channel slope, S (ft/ft); the slope of the stage-discharge relation, dQ/dY (ft^2/s); and the discharge, Q (ft^3/s). The coeffiecients are determined as follows:

$$C = \frac{1}{W} \frac{dQ}{dY} \tag{2}$$

$$K = \frac{Q}{2SW} \tag{3}$$

Values of C and K were computed from information obtained at the Lafayette and the Covington stations. The discharge, Q, for which initial values of C and K were linearized was the long-term mean daily discharge at each station. Channel width, W, was obtained from width-discharge relationships; channel slope, S, was determined from gage-elevation information; and the slope of the stage-discharge relation, dQ/dY, was determined from the rating curve by bracketing the mean discharge and computing the incremental change in gage height to the associated change in discharge. Initial values of C and K for the reach were computed by averaging the values computed at the two stations.

Observed flows at Lafayette and Covington for the 1980-81 water years were used to calibrate the model. During calibration C and K were varied from initial values of 2.89 and 14,554 and a best-fit single-linearization model was determined. Table 4 identifies the reach and the final calibrated values of C and K used for routing flow through the reach.

Table 4.--Calibrated model parameters for the Wabash River at Covington, Ind.

Reach	Length (mi)	C (ft/s)	K (ft^2/s)
Wabash River at Lafayette to Wabash River at Covington	40.8	2.80	15,920

A summary of the simulated daily mean discharge at Wabash River at Covington is given in table 5. Simulated daily flows are within 10 percent of the observed flows for only 70 percent of the period. Therefore, Wabash River at Covington is not a candidate for discontinuance on the basis of flow-routing.

Table 5.--Results of flow-routing model for Wabash River at Covington, Ind.

Mean absolute error (%) for 731 days	= 8.89
Mean - error (%) for 352 days	= -9.47
Mean + error (%) for 379 days	= 8.35
Total volume error (%)	= -0.72

37	Percent of total observations had errors <= 5 Percent
70	Percent of total observations had errors <= 10 Percent
83	Percent of total observations had errors <= 15 Percent
91	Percent of total observations had errors <= 20 Percent
95	Percent of total observations had errors <= 25 Percent
5	Percent of total observations had errors >= 25 Percent

Wabash River at Terre Haute, Indiana, Flow-Routing Analysis

A flow-routing analysis was used to investigate use of the single-linearization diffusion-analogy model to simulate daily mean discharges at the Wabash River at Terre Haute, Ind. (03341500). A sketch of the reach of the Wabash River in this study area is presented in figure 4. Streamflow data available for this analysis are summarized in table 6.

The distance between the Wabash River at Montezuma, Ind. (03340500), and the Terre Haute gage is 26.0 river miles. Big Raccoon Creek at Coxville, Ind. (03341300), accounts for 448 mi^2 of the 1147 mi^2 intervening area between the Montezuma and Terre Haute stations. The best flow-routing model used only the mainstem Wabash River stations.

Daily mean discharges of the Wabash River at Montezuma, increased by a drainage area ratio (12,265 mi^2/11,118 mi^2 = 1.10), were routed to Terre Haute using the single-linearization diffusion-analogy model.

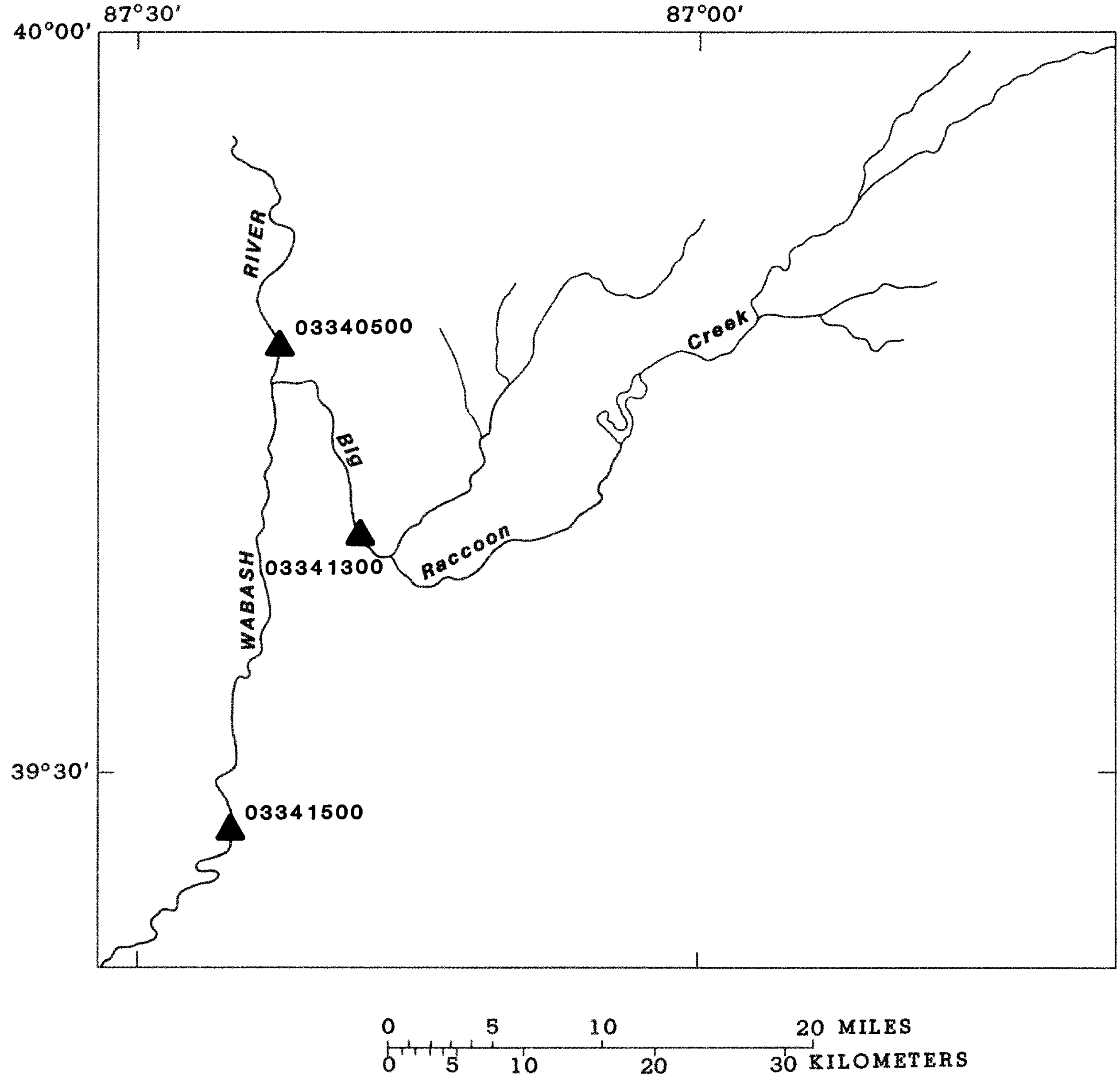

Figure 4.– Flow-routing model-study area, Wabash River at Terre Haute (03341500).

Table 6.--Gaging stations used in the Wabash River at Terre Haute, Ind., flow-routing study

Station Number	Station Name	Drainage area (mi^2)	Period of record
03340500	Wabash River at Montezuma	11,118	October 1927 - present
03341300	Big Raccoon Creek at Coxville	448	October 1956 - present
03341500	Wabash River at Terre Haute	12,265	October 1927 - present

The model parameters, C and K, as previously defined, were computed for the reach, linearizing about the long-term daily mean discharge. The same procedure outlined in the Wabash River at Covington section was used to compute average model parameter values.

Observed flows at Montezuma and Terre Haute for the 1980-81 water years were used to calibrate the model. During calibration C and K were varied from initial values of 4.43 and 14,100 and a best-fit single-linearization model was determined. Table 7 identifies the reach and the final calibrated values of C and K used for routing flow through the reach.

A summary of the simulation of daily mean discharge at Wabash River at Terre Haute is given in table 8. Simulated daily flows are within 10 percent of the observed flows for only 64 percent of the period. Therefore, Wabash River at Terre Haute is not a candidate for discontinuance on the basis of flow-routing.

Table 7.--Calibrated model parameters for the Wabash River at Terre Haute, Ind.

Reach	Length (mi)	C (ft/s)	K (ft^2/s)
Wabash River at Montezuma to Wabash River at Terre Haute	26.0	4.65	5,558

Table 8.--Results of flow-routing model for Wabash River at Terre Haute, Ind.

Mean absolute error (%) for 731 days =	8.94
Mean - error (%) for 117 days =	-4.13
Mean + error (%) for 614 days =	9.85
Total volume error (%) =	5.52
37 Percent of total observations had errors <= 5 Percent	
64 Percent of total observations had errors <= 10 Percent	
81 Percent of total observations had errors <= 15 Percent	
90 Percent of total observations had errors <= 20 Percent	
96 Percent of total observations had errors <= 25 Percent	
4 Percent of total observations had errors >= 25 Percent	

Wabash River at Covington, Indiana, Regression Analysis

A map showing the Wabash River in the reach near Covington is shown in figure 3 and data pertaining to stations in the reach are given in table 3. Streamflow data used for this analysis were from the 1979-81 water years.

Streamflow data of the Wabash River at Lafayette, Ind. (03335500), and of Big Pine Creek near Williamsport, Ind. (03335700), were used in the regression analysis to develop equations for simulating flow of the Wabash River at Covington, Ind. (03336000). The log-linear regression model for Covington includes two independent variables (flow from the Lafayette and the Williamsport gages), and two equations based on discharge (table 9). The model simulated 58 percent of the daily flows within 10 percent of actual discharge, and was judged to be an unsatisfactory replacement of data collected from the gaging station.

Wabash River at Terre Haute, Indiana, Regression Analysis

A map showing the Wabash River in the reach near Terre Haute is shown in figure 4 and data pertaining to stations in the reach are given in table 6. Streamflow data used for this analysis were from the 1979-81 water years.

Streamflow data of the Wabash River at Montezuma, Ind. (03340500), were used in the log-linear regression model to estimate streamflow at the Wabash River at Terre Haute, Ind. (03341500). Best results were obtained using one independent variable and three separate equations based on flow separation (table 9). Simulated data for Terre Haute were within 10 percent of the actual record 78 percent of the time. This accuracy was not acceptable to replace conventional streamflow record collected at this site.

Table 9.--Summary of calibration for regression modeling of mean daily streamflow at selected gage sites in Indiana

Station	Model	Percentage of simulated flow within indicated percent of actual discharge: 5%	10%	15%	20%	Calibration period (water years)
03336000 Wabash River at Covington, Ind.	For $Q_{335500} <= 6{,}459$ ft^3/s $Q_{336000} = 5.277\ Q_{335500}^{0.743}\ Q_{335700}^{0.136}$ For $Q_{335500} > 6{,}459$ ft^3/s $Q_{336000} = 3.209\ Q_{335500}^{0.851}\ Q_{335700}^{0.061}$	33	58	74	83	1979-81
03341500 Wabash River at Terre Haute, Ind.	For $Q_{340500} > 24{,}000$ ft^3/s $Q_{341500} = Q_{340500}^{1.004}$ For 11,850 ft^3/s $< Q_{340500} <= 24{,}000$ ft^3/s $Q_{341500} = Q_{340500}^{1.009}$ For $Q_{340500} <= 11{,}850$ ft^3/s $Q_{341500} = Q_{340500}^{1.007}$	45	78	90	95	1979-81
03343000 Wabash River at Vincennes, Ind.	For $Q_{342000} > 28{,}600$ ft^3/s $Q_{343000} = Q_{342000}^{.996}$ For 14,000 ft^3/s $< Q_{342000} <= 28{,}600$ ft^3/s $Q_{343000} = Q_{342000}^{1.005}$ For 6,520 ft^3/s $< Q_{342000} <= 14{,}000$ ft^3/s $Q_{343000} = Q_{342000}^{1.009}$ For $Q_{342000} <= 6{,}520$ ft^3/s $Q_{343000} = Q_{342000}^{1.004}$	52	84	93	97	1979-81

Wabash River at Vincennes, Indiana, Regression Analysis

A map showing the Wabash River in the reach near Vincennes is shown in figure 5. The gage on the Wabash River at Riverton, Ind. (03342000), has a drainage area of 13,161 mi^2, and the gage on the Wabash River at Vincennes, Ind. (03343000), has a drainage area of 13,706 mi^2. Streamflow data used for this analysis were from the 1979-81 water years.

The log-linear regression model for simulating the flow of the Wabash River at Vincennes includes one independent variable and four equations based on flow separation (table 9). The simulated data for Vincennes were within 10 percent of the actual record 84 percent of the time. This was the best regression model determined in the analysis, but it also does not meet the criteria for discontinuance of a station.

Regression Analysis Results

Linear regression techniques were applied to three selected sites in Indiana. The streamflow record for each station (dependent variable) was regressed against streamflow records at other stations (independent variables) during a given period of record (calibration period). "Best fit" linear regression models were developed and simulated a daily streamflow record that was compared to the observed streamflow record. The percent difference between the simulated and actual record for each day was calculated. Results of the regression analyses are summarized in table 9.

Modeling Summary

Several stations were analyzed but only the Wabash River at Vincennes, Ind. (03343000), model showed potential to replace gaged data. However, since real time data are needed at this gage by the National Weather Service for flood forecasting, further modeling was discontinued.

Despite the fact that regression models and flow-routing models cannot replace gaged data with sufficient accuracy, the use of hydrologic streamflow models in Indiana should be continued. Emphasis should shift from total synthesis of streamflow data to using the models as a method of replacing missing record at a station.

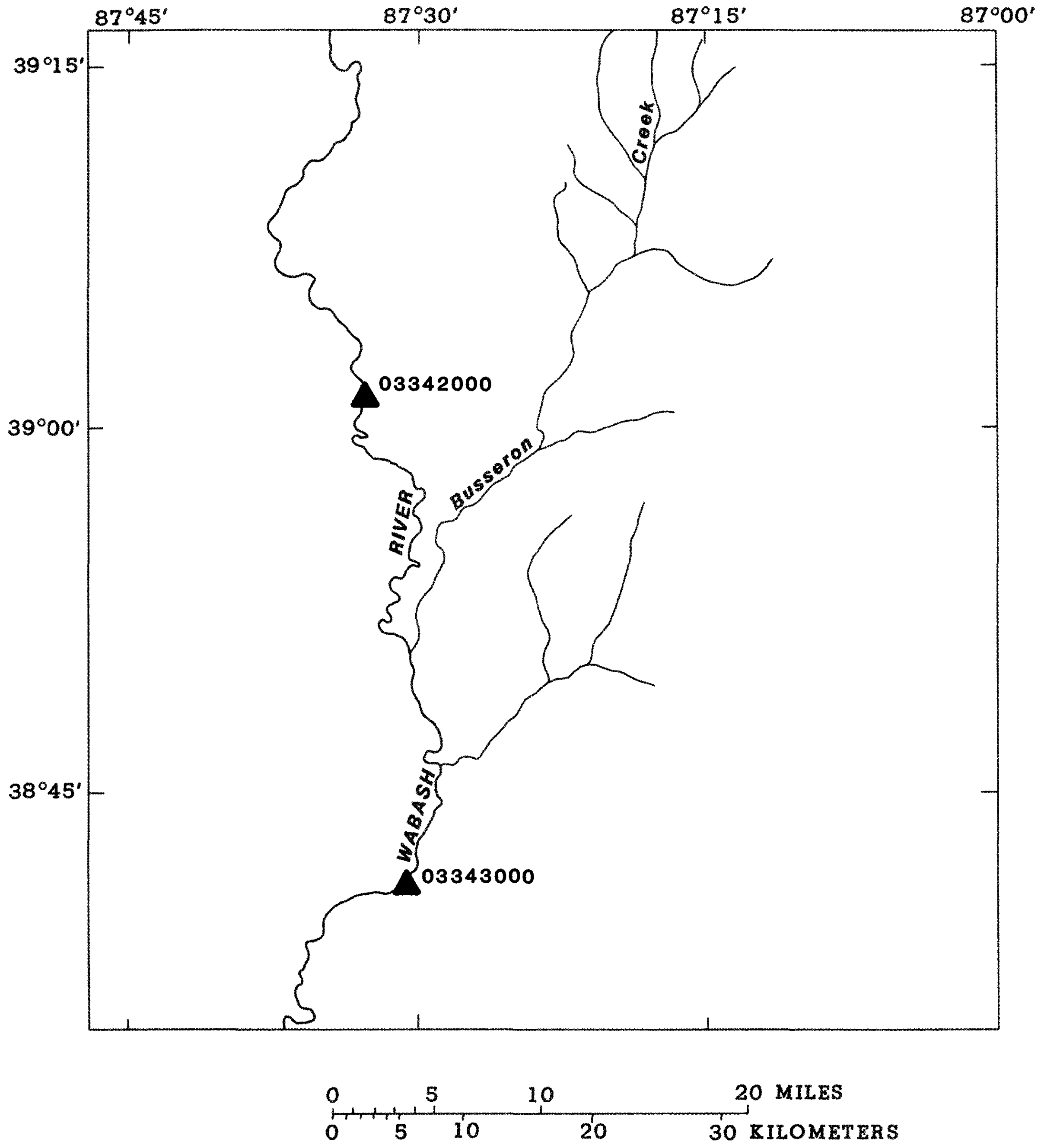

Figure 5.– Regression-analysis model-study area, Wabash River at Vincennes, Ind., (03343000).

COST-EFFECTIVE RESOURCE ALLOCATION

Introduction to Kalman-Filtering for Cost-Effective Resource Allocation (K-CERA)

In a study of the cost-effectiveness of a network of stream gages operated to determined water consumption in the Lower Colorado River Basin, a set of techniques called K-CERA were developed (Moss and Gilroy, 1980). Because of the water-balance nature of that study, the measure of effectiveness of the network was chosen to be the minimization of the sum of variances of errors of estimation of annual mean discharges at each site in the network. This measure of effectiveness tends to concentrate stream-gaging resources on the larger streams where potential errors are greatest. While such a tendency is appropriate for a water-balance network, in the broader context of the multitude of uses of the streamflow data collected by the USGS, this tendency causes undue concentration on larger streams. Therefore, the original version of K-CERA was extended to include as optional measures of effectiveness the sums of the variances of errors of estimation of the following streamflow variables: annual mean discharge in cubic feet per second, annual mean discharge in percent, average instantaneous discharge in cubic feet per second, or average instantaneous discharge in percent. The use of percentage errors does not unduly weight activities at large streams to the detriment of records on small streams. In addition, the instantaneous discharge is the basic variable from which all other streamflow data are derived. For these reasons, this study used the K-CERA techniques with the sums of the variances of the percentage errors of the instantaneous discharges at all continuously gaged sites as the measure of the effectiveness of the data-collection activity.

The original version of K-CERA also did not account for error contributed by missing stage or other correlative data that are used to compute streamflow data. The probabilities of missing correlative data increase as the period between service visits to a stream gage increases. A procedure for dealing with the missing record has been developed and was incorporated into this study.

Brief descriptions of the mathematical program used to optimize the cost-effectiveness of the data-collection activity and of the application of Kalman filtering (Gelb, 1974) to determine the accuracy of a stream-gaging record are presented below. For more detail on either the theory or the applications of K-CERA, see Moss and Gilroy (1980) and Gilroy and Moss (1981).

Description of Mathematical Program

The program, called "The Traveling Hydrographer," attempts to allocate among stream gages a predefined budget for the collection of streamflow data in such a manner that the field operation is cost-effective. The set of decisions available to a manager is the combination and frequency (number of times per year) of routes used to service the stream gages and make discharge measurements. The range of options within the program is from zero usage to daily usage for each route. A route is defined as a set of one or more stream gages and the least costly travel that takes the hydrographer from his base of operations to each of the gages and back to the base. A route will include the average cost of travel and average cost of servicing each stream gage visited along the way.

The first step in this part of the analysis is to define a set of practical routes. This set of routes will frequently contain a lone stop at an individual stream gage followed by return to the base so that individual needs of a stream gage can be considered apart from the other gages. The next step in the analysis is to account for any special requirements at each of the gages such as maintenance, equipment repair, or water-quality sampling. Such special requirements are fixed constraints and determine the minimum number of visits to each gage. The final step is to use all the available information to determine the number of times, N_i, that the i^{th} route for $i = 1,2,\ldots,$ NR, where NR is the number of practical routes, is used during a year such that (1) the budget for the network is not exceeded, (2) the minimum number of visits to each station is made, and (3) the total uncertainty in the network is minimized. Figure 6 represents this step in the form of a mathematical program. Figure 7 presents a tabular layout of the problem. Each of the NR routes is represented by a row and each of the stations is represented by a column. The zero-one matrix, (ω_{ij}), defines the routes in terms of the stations that comprise it. A value of one in row i column j indicates that gaging station j will be visited on route i; a value of zero indicates that it will not. The unit travel costs, B_i, are the pre-trip costs of the hydrographer's traveltime and any related per diem, operation, maintenance,and rental costs of vehicles. The sum of the products of B_i and N_i for $i = 1, 2, \ldots,$ NR is the total travel cost associated with the set of decisions $\underline{N} = (N_1, N_2, \ldots, N_{NR})$.

The unit-visit cost, α_j, is comprised of the average service and maintenance costs incurred on a visit to the station plus the average cost of making a discharge measurement. The set of minimum visit constraints is denoted by the row λ_j, $j = 1, 2, \ldots,$ MG, where MG is the number of stream gages. The row of integers M_j, $j = 1, 2, \ldots,$ MG specifies the number of visits to each station. M_j is the sum of the products of ω_{ij} and N_i for all i and must equal or exceed λ_j for all j if $\underline{N}$ is to be a feasible solution to the decision problem.

$$\underset{\underline{N}}{\text{Minimize}}\ V = \sum_{j=1}^{MG} \phi_j\ (M_j)$$

$V \equiv$ total uncertainty in the network

$\underline{N} \equiv$ vector of annual number times each route was used

$MG \equiv$ number of gages in the network

$M_j \equiv$ annual number of visits to station j

$\phi_j \equiv$ function relating number of visits to uncertainty at station j

Such that

Budget $\geq T_c \equiv$ total cost of operating the network

$$T_c = F_c + \sum_{j=1}^{MG} \alpha_j M_j + \sum_{i=1}^{NR} \beta_i N_i$$

$F_c \equiv$ fixed cost

$\alpha_j \equiv$ unit cost of visit to station j

$NR \equiv$ number of practical routes chosen

$\beta_i \equiv$ travel cost for route i

$N_i \equiv$ annual number times route i is used (an element of $\underline{N}$)

and such that

$$M_j \geq \lambda_j$$

$\lambda_j \equiv$ minimum number of annual visits to station j

Figure 6.--Mathematical formulation for the optimization of the routing of hydrographers.

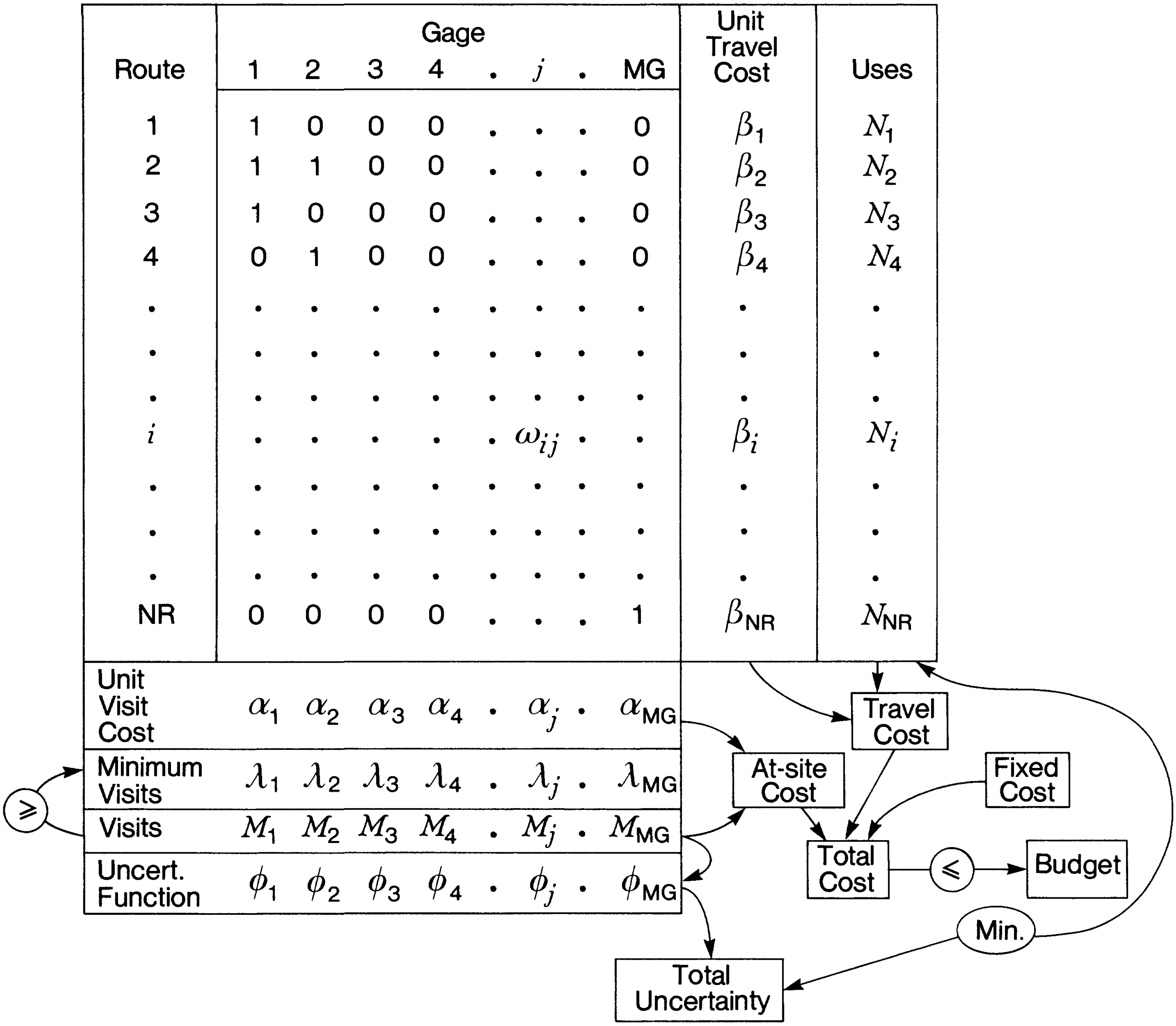

Figure 7.--Schematic of the mathematical formulation for the optimization of the routing of hydrographers.

The total cost expended at the stations is equal to the sum of the products of α_j and M_j for all j. The cost of record computation, documentation, and publication is assumed to be influenced negligibly by the number of visits to a station and is included along with overhead in the fixed cost of operating the network. The total cost of operating the network equals the sum of the travel costs, the at-site costs, and the fixed cost, and must be less than or equal to the available budget.

The total uncertainty in the estimates of discharges at the MG stations is determined by summing the uncertainty functions, ϕ_j, evaluated at the value of M_j from the row above it, for j = 1, 2, ..., MG.

As pointed out in Moss and Gilroy (1980), the steepest descent search used to solve this mathematical program does not guarantee a true optimum solution. However, the locally optimum set of values for $\underline{N}$ obtained with this technique specify an efficient strategy for operating the network, which may be the true optimum strategy. The true optimum cannot be guaranteed without testing all undominated, feasible strategies.

Description of Uncertainty Functions

As noted earlier, uncertainty in streamflow records is measured in this study as the average relative variance of estimation of instantaneous discharges. The accuracy of a streamflow estimate depends on how that estimate was obtained. Three situations are considered in this study: (1) streamflow is estimated from measured discharge and correlative data using a stage-discharge relation (rating curve), (2) the streamflow record is reconstructed using secondary data at nearby stations because primary correlative data are missing, and (3) primary and secondary data are unavailable for estimating streamflow. The variances of the errors of the estimates of flow that would be employed in each situation were weighted by the fraction of time each situation is expected to occur. Thus the average relative variance would be:

$$\overline{V} = \varepsilon_f V_f + \varepsilon_r V_r + \varepsilon_e V_e \qquad (4)$$

with

$$1 = \varepsilon_f + \varepsilon_r = \varepsilon_e$$

where

$\overline{V}$ is the average relative variance of the errors of streamflow estimates,

ε_f is the fraction of time that the primary recorders are functioning,

V_f is the relative variance of the errors of flow estimated from primary recorders,

ε_r is the fraction of time that secondary data are available to reconstruct streamflow records given that the primary data are missing,

V_r is the relative variance of the errors of estimation of flows reconstructed from secondary data,

ε_e is the fraction of time that primary and secondary data are not available to compute streamflow records, and

V_e is the relative error variance of the third situation.

The fractions of time that each source of error is relevant are functions of the frequencies at which the recording equipment is serviced.

The time τ since the last service visit until failure of the recorder or recorders at the primary site is assumed to have a negative-exponential probability distribution truncated at the next service time; the distribution's probability density function is:

$$f(\tau) = ke^{-k\tau}/(1-e^{-ks}) \tag{5}$$

where

k is the failure rate in units of $(\text{day})^{-1}$,

e is the base of natural logarithms, and

s is the interval between visits to the site in days.

It is assumed that if a recorder fails it continues to malfunction until the next service visit. As a result,

$$\varepsilon_f = (1-e^{-ks})/(ks) \tag{6}$$

(Fontaine and others, 1983, eq. 21).

The fraction of time ε_e that no records exist at either the primary or secondary sites can also be derived assuming that the time between failures at both sites are independent and have negative exponential distributions with the same rate constant. It then follows that

$$\varepsilon_e = 1 - [2(1-e^{-ks}) - 0.5(1-e^{-2ks})]/(ks)$$

(Fontaine and others, 1983, eqs. 23 and 25).

Finally, the fraction of time ε_r that records are reconstructed based on data from a secondary site is determined by the equation

$$\begin{aligned} \varepsilon_r &= 1 - \varepsilon_f - \varepsilon_e \\ &= [(1-e^{-ks}) - 0.5(1-e^{-2ks})]/(ks). \end{aligned} \tag{7}$$

The relative variance, V_f, of the error derived from primary record computation is determined by analyzing a time series of residuals that are the differences between the logarithms of measured discharge and the rating curve discharge. The rating curve discharge is determined from a relationship between discharge and some correlative data, such as water-surface elevation at the gaging station. The measured discharge is the discharge determined by field observations of depths, widths, and velocities. Let $q_T(t)$ be the true instantaneous discharge at time t and let $q_R(t)$ be the value that would be estimated using the rating curve. Then

$$x(t) = \ln q_T(t) - \ln q_R(t) = \ln [q_T(t)/q_R(t)] \quad (8)$$

is the instantaneous difference between the logarithms of the true discharge and the rating curve discharge.

In computing estimates of streamflow, the rating curve may be continually adjusted on the basis of periodic measurements of discharge. This adjustment process results in an estimate, $q_c(t)$, that is a better estimate of the stream's discharge at time t. The difference between the variable $\hat{x}(t)$, which is defined

$$\hat{x}(t) = \ln q_c(t) - \ln q_R(t), \quad (9)$$

and x(t) is the error in the streamflow record at time t. The variance of this difference over time is the desired estimate of V_f.

Unfortunately, the true instantaneous discharge, $q_T(t)$, cannot be determined and thus x(t) and the difference, $\hat{x}(t) - x(t)$, cannot be determined as well. However, the statistical properties of $\hat{x}(t) - x(t)$, particularly its variance, can be inferred from the available discharge measurements. Let the observed residuals of measured discharge from the rating curve be z(t), so that

$$z(t) = x(t) + v(t) = \ln q_m(t) - \ln q_R(t) \quad (10)$$

where

v(t) is the measurement error, and

$\ln q_m(t)$ is the logarithm of the measured discharge, equal to $\ln q_T(t)$ plus v(t).

In the Kalman-filter analysis, the z(t) time series was analyzed to determine three site-specific parameters. The Kalman filter used in this study assumes that the time residuals, x(t), arise from a continuous first-order Markovian process that has a Gaussian (normal) probability distribution with zero mean and variance (subsequently referred to as process variance) equal to p. A second important parameter is β, the reciprocal of the correlation time of the Markovian process giving rise to x(t); the correlation between $x(t_1)$ and $x(t_2)$ is $\exp[-\beta|t_1-t_2|]$. Fontaine and others (1983) also define q, the constant value of the spectral density function of the white noise which drives the Gauss-Markov x-process. The parameters p, q, and β are related by

$$\mathrm{Var}[x(t)] = p = q/(2\beta). \quad (11)$$

The variance of the observed residuals z(t) is

$$\mathrm{Var}[z(t)] = p + r \tag{12}$$

where r is the variance of the measurement error v(t). The three parameters, p, β, and r, are computed by analyzing the statistical properties of the z(t) time series. These three site-specific parameters are needed to define this component of the uncertainty relationship. The Kalman filter utilized these three parameters to determine the average relative variance of the errors of estimation of discharges as a function of the number of discharge measurements per year (Moss and Gilroy, 1980).

If the recorder at the primary site fails and there are no concurrent data at other sites that can be used to reconstruct the missing record at the primary site, there are at least two ways of estimating discharges at the primary site. A recession curve could be applied from the time of recorder stoppage until the gage was once again functioning or the expected value of discharge for the period of missing data could be used as an estimate. The expected-value approach is used in this study to estimate V_e, the relative error variance during periods of no concurrent data at nearby stastions. If the expected value is used to estimate discharge, the value that is used should be the expected value of discharge at the time of the year of the missing record because of the seasonality of the streamflow processes. The variance of streamflow, which also is a seasonally varying parameter, is an estimate of the error variance that results from using the expected value as an estimate. Thus, the coefficient variation squared $(C_v)^2$ is an estimate of the required relative error variance V_e. Because C_v varies seasonally and the times of failures cannot be anticipated, a seasonally averaged value of C_v is used:

$$\overline{C}_v = \left(100 \frac{1}{365} \sum_{i=1}^{365} \left(\frac{\sigma_i}{\mu i}\right)^2 \right)^{1/2} \tag{13}$$

where

$\overline{C}_v$ is the seasonally averaged coefficient of variation (in percent),

σ_i is the standard deviation of daily discharges for the i^{th} day of the year,

μ_i is the expected value of discharge on the i^{th} day of the year, and

$(\overline{C}_v)^2$ is used as an estimate of V_e.

The variance, V_r, of the error during periods of reconstructed streamflow records is estimated on the basis of correlation between records at the primary site and records from other gaged sites. The correlation coefficient, ρ_c, between the streamflows with seasonal trends removed (detrended) at the site of interest and detrended streamflows at the other sites is a measure of the goodness of their linear relationship. The fraction of the variance of streamflow at the primary site that is explained by data from the other sites is equal to ρ_c^2. Thus, the relative error of variance of flow estimates at the primary site obtained from secondary information will be

$$V_r = (1 - \rho_c^2)\ \bar{C}_V^2 \tag{14}$$

Because errors in streamflow estimates arise from three different sources with widely varying precisions, the resultant distribution of those errors may differ significantly from a normal or log-normal distribution. This lack of normality causes difficulty in interpretation of the resulting average estimation variance. When primary and secondary data are unavailable, the relative error variance V_e may be very large. This could yield correspondingly large values of $\overline{V}$ in equation 4 even if the probability that primary and secondary information are not available, ε_e, is quite small.

A new parameter, the equivalent Gaussian spread (EGS), is introduced here to assist in interpreting the results of the analyses. If it is assumed that the various errors arising from the three situations represented in equation 4 are log-normally distributed, the value of EGS is determined by the probability statement that

$$\text{Probability } [e^{-EGS} \leq (q_c(t)\ /\ q_T(t)) \leq e^{+EGS}] = 0.683. \tag{15}$$

Thus, if the residuals $\ln q_c(t) - \ln q_T(t)$ were normally distributed, $(EGS)^2$ would be their variance. Here EGS is reported in units of percent because EGS is defined so that nearly two-thirds of the errors in instantaneous streamflow data will be within plus or minus EGS percent of the reported values.

Application of K-CERA in Indiana

As a result of the first two parts of this analysis, 173 of the currently existing stream gages in the State of Indiana should continue in operation. Ten stations that were included in the first two phases of this network analysis do not lend themselves to the K-CERA analysis. Therefore, data from 163 stations were analyzed by K-CERA techniques.

Probability of Missing Record

As was described earlier, the statistical characteristics of missing stage or other correlative data for computation of streamflow records can be defined by a single parameter, the value of k in the truncated negative exponential probability distribution of times to failure of the equipment. In the representation of $f(\tau)$ as given in equation 5, the average time to failure is 1/k. The value of 1/k will vary from site to site depending upon the type of equipment at the site and upon its exposure to natural elements and vandalism. The value of 1/k can be influenced by advances in the technology of data collection. To estimate 1/k in Indiana, five years (1977-1981) of data were analyzed during which time, little change in equipment occurred. During this time period stations were generally visited every 6 weeks.

Missing stage record is caused by a number of reasons; timing devices, stage recorders, power sources, frozen stilling wells, intake systems, and float assemblies. In this analysis, timing devices appeared to be the primary cause of lost record. During the analysis it was discovered that stage record was being lost at stations due to ice in the stilling well. This problem occurred most often in the southern part of the State. For this reason, stations were divided into two groups; northern and southern. The two groups were further broken down into subgroups as follows: (1) stations having some type of stage recorder backup, and (2) stations with no backup unit. Recorder backup systems include an auxiliary recorder, telemetry equipment that is routinely called once a day, and local residents (observers) hired to read stage data once or twice a day.

Values of 1/k were varied depending on the location and the type of gage. This value was then used to determine ε_f, ε_e, and ε_r for each of the 163 stream gages.

There are several reasons for lost gage-height record to be more common in southern Indiana than in northern Indiana. The State is quite diverse in geology (Stewart, 1983). Ample ground cover is available for stilling well installations in the northern half of the State, while bedrock is often at or near streambed level along small streams in southern Indiana. Therefore, stilling-well installations at small stream sites in southern Indiana lack sufficient ground cover, and the water in the stilling wells often freezes during cold periods, causing lost gage-height record. A program to insulate this type of well has been implemented and a reduction in lost record caused by frozen wells is expected at these sites. Stilling wells at some stations are attached to bridge piers. These stations are also subject to freezing and sedimentation. Since pier gages cannot be economically insulated or protected from sediment, a way to decrease lost record at these sites would be to relocate them on an embankment.

Another reason for lost gage-height record, especially in southern Indiana, is that winter rainfall is frequently followed by sub-freezing weather. This often leads to periods of high flow with the float in the stilling well rising above surrounding ground cover. A frozen well during this time causes the float to be bound in ice as the water level in the well recedes. Gravity or warmer weather eventually causes the ice layer to break and the float to fall back to the lower water surface. The falling float often causes the float stem or float tape to break, or the float tape to jump the recorder spline. While these conditions may occur throughout the State they are most prevalent in southern Indiana.

Stations in northern Indiana with some type of backup-system lost records on the average 2.7 percent of the time. Northern stations without any backup-system lost 6.4 percent of the gage-height record. During the same five year period, stations in southern Indiana with a backup-system lost 5.3 percent of the gage-height record. Southern Indiana stations without a backup-system lost 8.3 percent of the gage-height record.

Cross-Correlation Coefficient and Coefficient of Variation

To compute the values of V_e and V_r of the needed uncertainty functions, daily streamflow records for each of the 163 stations for the last 30 years or the part of the last 30 years for which daily streamflow values are stored in WATSTORE (Hutchinson, 1975) were retrieved. For each of the stream gages that had three or more complete water years of data, the value of C_v was computed and various options, based on combinations of other stream gages, were explored to determine the maximum ρ_c. For the stations that had less than three water years of data, values of $\overline{C}_v$ and ρ_c were estimated subjectively. The values of $\overline{C}_v$ and ρ_c used in the analysis and the stations used for record reconstruction are shown in table 10 (after references).

Kalman-Filter Definition of Variance

To determine the variance V_f for each of the 163 stream gages, the execution of three distinct steps were required: (1) long-term rating analysis and computation of residuals of measured discharges from the long-term rating, (2) time-series analysis of the residuals to determine the input parameters of the Kalman-filter streamflow records, and (3) computation of the error variance, V_f, as a function of the time-series parameters, the discharge-measurement error variance, and the frequency of discharge measurement.

Rating Analysis

Long-term rating analysis of 163 stream-gaging stations in Indiana began with the identification of a representative period for which each station should be analyzed. At this time measurement variance for the entire period of record were studied. An attempt was made to use as many discharge measurements as possible to ensure a representative rating throughout time. Ice measurements were excluded from rating analysis because of the backwater condition ice creates. Ice affects many streams in Indiana for brief periods in a winter. During record computations, ice periods are analyzed by hydrographic comparison, and streamflow is estimated for periods showing backwater. Because ice periods are brief, standard error of instantaneous discharge for stations was determined based on yearly record. While this method probably overestimates the standard error, it is felt to be the best method available.

High water downstream of three stations, Pigeon Creek at Evansville (03322100), Hart Ditch at Munster (05536190), and Little Calumet River at Munster (05336195), can produce variable backwater at these locations. Therefore, the upper portion of each rating was excluded from the analysis and rating definition at high stages was assigned a fixed cost. Stations where a rating change occurred because of a major flood, bridge construction, or channel dredging were analyzed using measurements made subsequent to the event and prior to the occurrence of another event. Stations were analyzed using 70 to 180 recent measurements, depending on the frequency of control changes.

Following the selection of a representative series of discharge measurements for each station, the next step was to define the rating curve and compute the time-series of residuals that represent the difference between the rating curve and the measured discharges. Present rating curves do not adequately define the long-term rating function required in the analysis because of the unstable low-water controls common in Indiana streams. Therefore, ratings were computed using a logarithmic curve-fitting procedure. The rating function is of the form:

$$LQM = B1 + B3 * \log_{10} (GHT-B2) \tag{15}$$

in which

LQM is the base 10 logarithm of the measured discharge,

GHT is the recorded gage height corresponding to the measured discharge,

B1 is the base 10 logarithm of discharge for a flow depth of one foot,

B2 is the gage height of zero flow,

B3 is the slope of the rating curve ($\frac{\Delta Q}{\Delta GHT}$), and

$\log_{10}$ is the common logarithmic function.

An example of the computer output for the rating at the gaging station White River at Indianapolis (03353000), is shown in table 11 (after references).

An alternate curve-fitting technique was used for several stations because the above procedure did not adequately describe the rating due to a change in slope of the rating curve. Rating curves for these stations utilized a general linear model to solve for measured discharge as a function of gage height.

The general linear rating function is of the form:

$$LQM = a + b(LGHT) + c(LGHT)^2 + d(LGHT)^3 + e(LGHT)^4 + f(LGHT)^5 \quad (16)$$

in which

LQM is the base 10 logarithm of the measured discharge,

LGHT is the base 10 logarithm of the recorded gage height corresponding to the measured discharge, and

a, b, c, d, e, and f are regression coefficients.

Generally, the "best fit" model did not contain all combinations of LGHT or have the highest coefficient of determination (R^2). Computer output from the general linear rating function is similar to output from the logarithmic curve-fitting procedure.

After the ratings were computed, residuals were analyzed with respect to time and gage height to ensure the selected measurements represent a stable period during which no physical changes were occuring in the channel and to verify that the ratings adequately represent the discharge measurements. The residuals for 38 stations indicated a time trend due to aggrading or degrading of control or vegatative growth. Since these physical changes are occurring and seemingly will continue to occur at these sites, the time trend in the residuals was removed prior to inclusion in the uncertainty function analysis. The residuals for three gaging stations, Wabash River at Montezuma (03340500), Mud Creek near Cass[1] (03342244), and West Fork White Lick Creek at Danville (03353700), indicated a highly correlated time-series due to shifting sand. No attempt was made to remove these trends.

The time series of residuals is used to compute sample estimates of q and β, two of the three parameters required to compute V_f, by determining a best fit autocovariance function to the time series of residuals. Measurement variance, the third parameter, is determined from an assumed constant percentage standard error. For the Indiana program, open-water measurements are assumed to have a measurement error of 2 to 8 percent, with the majority having an error of 5 percent.

As discussed earlier, q and β can be expressed as the process variance of the shifts from the rating curve. The 1-day autocorrelation coefficient (RHO) of these shifts is a function of β. Table 12 (after references) presents a summary of the autocovariance analysis expressed in terms of process variance and 1-day autocorrelation. Typical fits of the covariance functions for selected stations in Indiana are given in figure 8.

[1]Prior to October 1981 station was located 1.2 miles downstream and known as Mud Creek near Dugger (03342250). Records are assumed comparable.

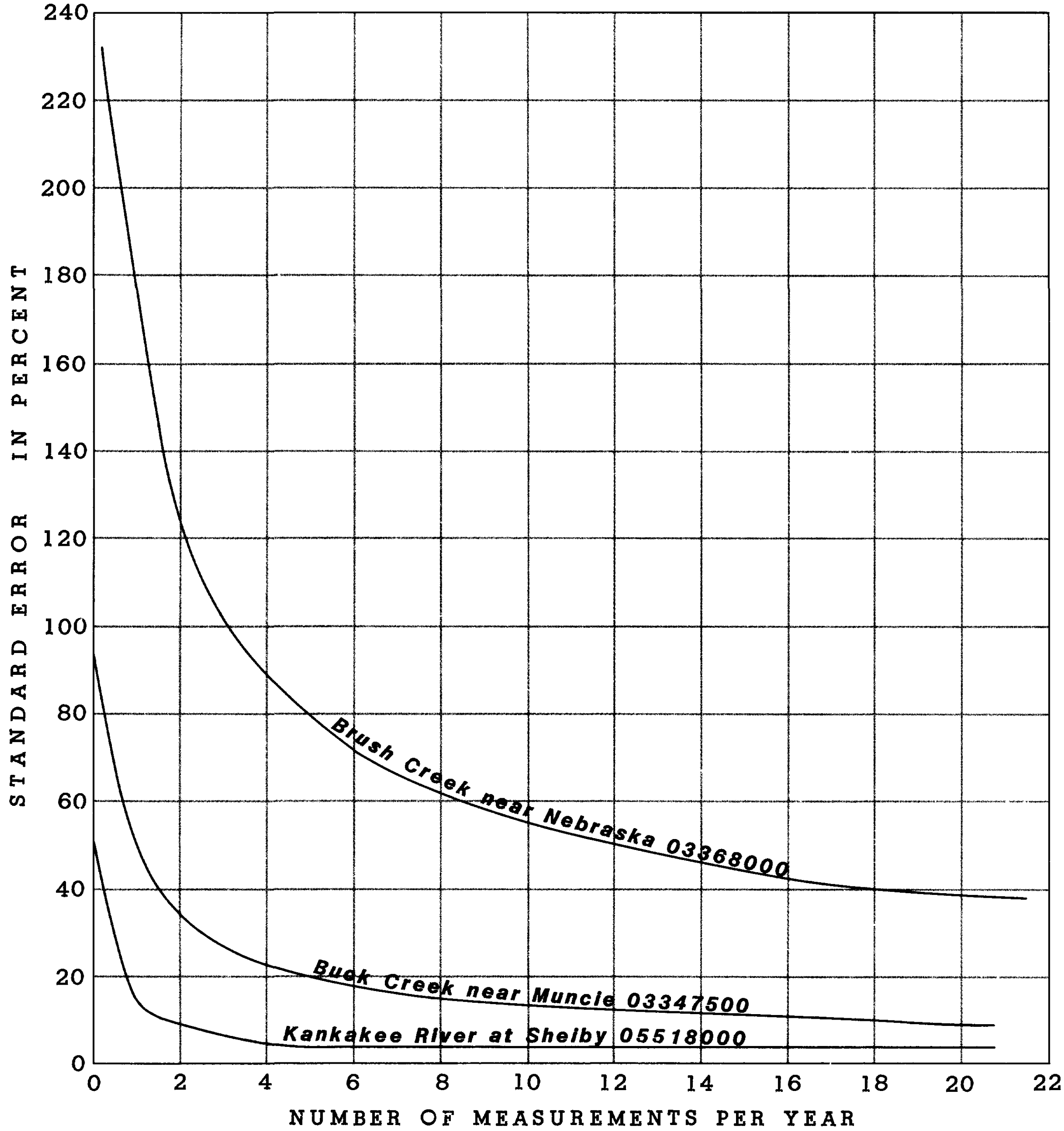

Figure 8.-- Uncertainty functions for three gaging stations in Indiana.

Determination of Routes

Indiana field personnel service 173 streamflow-gaging stations and 206 stations which consist of groundwater wells, water quality sites, special measurements, and stage-only surface-water sites. These 206 stations put a large constraint on field route planning since many of the stations must be visted a minimum of eight times per year. The larger portion of these 206 stations are located in northern Indiana. Because of location and manpower limitations separate field trips were planned for these northern Indiana non-measurement stations. Another constraint to route planning was that all gages must be serviced from the Indianapolis office making overnight travel mandatory for the majority of Indiana gages. Remote routes should be made into five day units, however, manpower restrictions limit the number of five day trips.

To determine field routes, stream-gaging stations were divided into groups based on location and the uncertainty of the stage-discharge rating of the gage. Stations within a one day travel range of Indianapolis were given individual routes or grouped into one day work units with like uncertainties. Routes to the other portions of the State were planned in average work units of 3 to 5 days with most trips being 4-day units. Planning time units of work at stream-gaging stations is somewhat subjective due to variable conditions such as preventive gage maintainance, emergency gage maintainance, road conditions, and streamflow conditions.

The cost, in 1983 dollars, associated with stream gaging was then determined. The cost was categorized as annual fixed, visit, and route costs. The annual fixed cost to operate a gage typically included equipment rental, batteries, electricity, data processing and storage, computer charges, maintenance and miscellaneous supplies, analysis, and supervisory charges. At some stations special measurements are needed. These include highwater measurements where the stage-discharge relation is variable, and ice measurements that are needed during some winter periods. Costs for station analysis and supervisory costs were determined by multiplying the estimated time that individual stations required for analysis by the hydrographers average hourly wage. These costs were then added in as a portion of the fixed cost.

Visit costs are those associated with paying the hydrographer for the time actually spent at a station servicing the equipment and making a discharge measurement. These costs vary from station to station and are a function of the difficulty and time required to make the discharge measurement. Average visit times were calculated for each station based on an analysis of discharge measurement data available. This time was them multiplied by the average hourly salary of hydrographers in the Indiana office to determine total visit costs.

Route costs include the vehicle cost associated with driving the number of miles it takes to cover the route, the cost of the hydrographer's time while in transit, and any per diem associated with the time it takes to complete the trip.

K-CERA Results

The "Traveling Hydrographer Program" utilizes uncertainty functions, appropriate cost data, and route definitions to compute the most cost-effective way to operate the Indiana streamflow-gaging program. In this application, the first step was to simulate the current practice of the Indiana District Office and determine the total uncertainty associated with the operation. To accomplish this, the specific routes and number of visits made to each streamflow gage were fixed and the associated uncertainty of the total District program was computed. The resulting average error of daily mean flow estimation for the current practice of the Indiana District is shown as a point (25.3 percent) on figure 9.

The solid line on figure 9 represents the minimum level of uncertainty with the existing equipment and technology. The dashed line represents the uncertainty of the Indiana program if no record were lost. The instrumentation and technology of the streamgaging program have remained constant for several years, however, some changes are presently occurring. For example, the application of satellite data collection platforms should reduce lost record and enable the District to bypass the minimum constraint for those stations in optimizing certain Indiana field vistation routes.

The results of the Indiana District K-CERA analysis are summarized in table 13, (after references) and are shown in figure 9. A minimum budget of $790,000 is required to operate the 173 streamflow-gages and 206 non-measurement gages. This budget results in a 27.7 percent average standard error of estimate. The current policy requires a budget of $823,000 to operate the field network and results in an average standard error of estimate of 25.3 percent. The results of the "Traveling Hydrographer Program" indicate that a 25.0 percent average standard error of estimate could be achieved with a budget of $800,000 using new routes and optimized frequencies of visitation. The standard error could be reduced to 22.9 percent by utilizing the current budget and restructuring the field routes to the optimized version. The equivelent Gaussian spread (EGS) was 10.3 percent for the entire network for the optimization at present budget. The maximum budget tested was $1,000,000 and produced an average standard error of estimate of 16.8 percent. A dashed line in figure 9 depicts Indiana standard error of estimate with the effect of zero lost record, a hypothetical situation. There are many ways that gage-height record may be lost. As discussed perviously, equipment failure, ice, and sedimentation may contribute to lost record. Better technology, such as data collection platforms (DCP), solid state timers, shaft encoders, and existing preventative measures such as insulation of the stilling well from sub-freezing temperatures can all reduce the missing record problem.

Errors at some small-stream stations are severe enough (over 20 percent in table 13, after references) that the cause should be ascertained and it's source corrected. Missing gage-height record tends to be a problem at small-stream stations, as discussed earlier. However, the data collected at some small-stream gages may also be affected by the physical setting of the stream which can cause unstable gage-height controls and streamflow measurements of poor accuracy due to physical conditions of the streambed. The rating

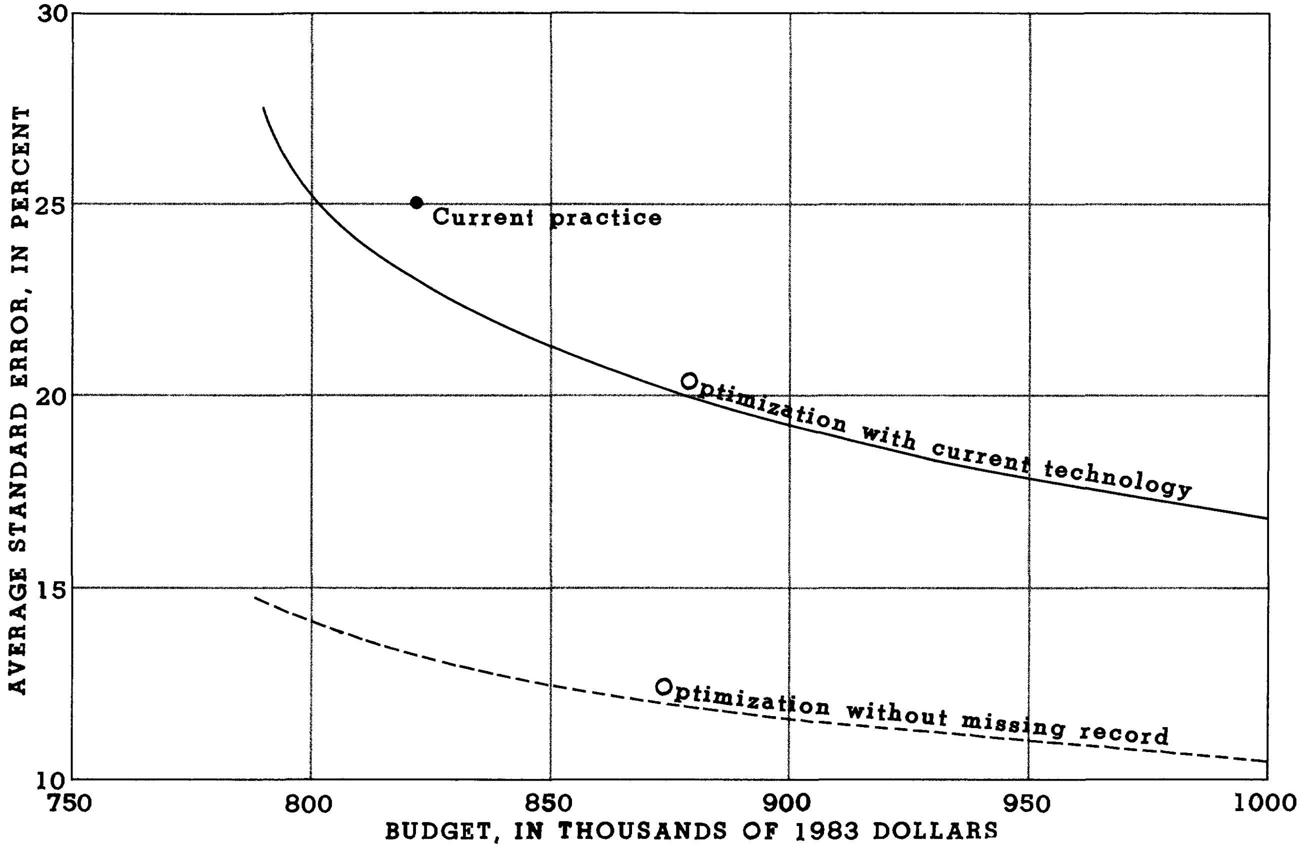

Figure 9.-- Temporal-average standard error per station.

analysis used predominately low-flow measurements since medium and high-flow measurements are too widely spaced to be an accurate predictor of control stability.

To look at these possible problems in detail would be beyond the scope of this report but a general discussion is necessary. The physiography of southern Indiana (Stewart 1982) is largely knob and valley. The knobs are made up of shale, sandstone, and limestone and are an erosional feature of some geologic age. The resultant stream beds are often incised with loose shale and gravel controls. At low flow, a pool and riffle system make measurements difficult for two reasons: (1) a measurement made at the pool may not be accurate because of the low-velocity; and (2) a measurement made close to the riffle control will have increased velocity but may loose a significent percentage of flow via the permiable shale and gravel. The loose rock controls are subject to change during any high water event. Rating curves for these streams are largely compiled of low-water measurements due to rapid rainfall runoff and minimal groundwater storage in this area (Stewart 1982). High flow events are very flashy and often do not lend themselves well to indirect measurement methods. Other streams are located in wide valleys with flat sandy flood plains and channels. These streams are very sluggish at low flow, making them difficult to measure accurately. The controls on these shallow slope streams are poorly defined, even at lowflow.

Conclusions Pertaining to the K-CERA Analysis

1. As a result of the K-CERA analysis field operations have been modified in Indiana. Frequency of measurements at gaging stations where the uncertainties are low has been reduced, and frequency of measurements at sites with high uncertainties has been increased.

2. There is no need to adopt the complete route system of the optimized version of the "Traveling Hydrographer Program". The 2-percent reduction in error predicted by the model is not significantly different then the existing error.

3. Review of table 13 shows that some small stream gages have an excessive EGS (over 20 percent) and the data may not have the accuracy for the intended use. The long-term stage-discharge ratings and periods of missing record should be studied and methods to increase the accuracy of the data and reduce missing record should be implemented.

4. New gaging stations should be designed for sub-freezing temperatures and the primary recorders should be supplemented with auxillary recording units and/or telemetry equipment.

5. Lost record should be monitored and inventoried on a computer storage system. The program should offer a wide range of options to cover the various problems encountered when dealing with missing stage record. Time periods should be documented to give detail concerning the type of equipment in place.

6. As gages are reconditioned or retrofitted to improve the stage-discharge ratings and missing record, a new analysis of the uncertainty should be made using K-CERA. Trips could be modified based on these analyses.

SUMMARY

The USGS first collected surface-water data in Indiana in 1903. In 1928 the USGS began collecting daily discharge data at 13 stations. In 1930, a district office was established in Indianapolis. The program expanded through the years and reached a maximum of 204 stations in 1970. The present program (1983) has 173 gaging stations.

An earlier analysis of the surface-water network was done in 1970 by Marie and Swisshelm. The current analysis was completed in three phases. The first phase established the data use, station funding, and data availability for all of the 173 gaging stations in Indiana. The second phase attempted to use less costly alternate means to determine the daily-mean discharge at gaging stations in lieu of stream gaging.

Alternate methods were attempted at three gaging stations, but was not successful in replacing conventional stream gaging. The attempts at alternate methods were made at those gaging stations that were the most likely candidates for modeling. The methods did produce a tool for replacement of missing stage record computations at gaging stations.

A third phase of this analysis used the USGS-developed Kalman-Filtering for Cost-Effective Resource Allocation (K-CERA) methodology to aid in evaluating the stream-gaging program. The uncertainty (error) of the instantaneous discharge is identified and is a result of (1) the variability of streamflow, (2) the methods used by the USGS to determine discharge and (3) the financial and operational constraints. The standard errors in this report may not represent a full range of discharges. At small stream stations the vast majority of discharge measurements are made at a low to medium stage. Discharge measurements affected by ice were not considered during the rating analysis portion of the study.

Missing stage record is a major contributer to error in streamflow records. A program to decrease the amount of missing record has been implemented in Indiana. A computer data storage program to monitor and inventory missing record, and to identify future missing record problems has been proposed.

The current practice for operating the stream-gaging program uses an annual budget of $823,000 (in 1983 dollars). The present (1983) average standard error of the instantaneous discharge is 25.3 percent. The optimized "Traveling Hydrographer Program" indicates that the 25 percent error could be maintained with a budget of $800,000. The standard error could be reduced to 22.9 percent by utilizing the present budget and restructuring the field routes to the optimized version.

A synopsis of the three-step evaluation in Indiana is as follows:

1. All stations have a data need at this time and should be continued.

2. No gaging stations should be replaced by alternate means, but a alternate means could be used as a method to replace missing discharge record.

3. A review of gaging station needs should be done every 10 years.

4. Stations with an EGS of 20 percent or greater should be investigated to determine the reason for the poor accuracy and these problems should be corrected or the gaging station should be moved to a more suitable location.

5. A program to obtain more accurate low-flow data at small stream stations should be implemented.

6. The current stream-gaging program should be kept intact, but gradually modified as manpower changes and new data recording and telemetry equipment are installed.

Another analysis should be done in 10 years to determine the cost effectiveness of the stream-gaging program in Indiana at that time.

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Tables 1 - 2,

and

Tables 10 - 13.

Table 1.--Selected hydrologic data for stations in the Indiana surface-water program.

Station number	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
03274650	Whitewater River near Economy, Ind.	10.4	October 1970-	11.2
03274750	Whitewater River near Hagerstown, Ind.	58.7	October 1970-	70.2
03274950	Little Williams Creek at Connersville, Ind.	9.16	September 1968-	10.5
03275000	Whitewater River near Alpine, Ind.[1]	529	October 1928-	554
03275600	East Fork Whitewater River at Abington, Ind.	200	October 1965-	235
03276000	East Fork Whitewater River at Brookville, Ind.	380	March 1954-	[2]392
03276500	Whitewater River at Brookville, Ind.	1,224	June 1915-September 1917; July 1923-	[3,4]1,278
03276700	South Hogan Creek near Dillsboro, Ind.	38.1	July 1961-	42.0
03291780	Indian-Kentuck Creek near Canaan, Ind.	27.5	October 1969-	33.6
03294000	Silver Creek near Sellerburg, Ind.	189	October 1954-	[4]221
03302220	Buck Creek near New Middletown, Ind.	[5]65.2	October 1969-	80.4
03302300	Little Indian Creek near Galena, Ind.	16.1	October 1968-	24.2
03302500	Indian Creek near Corydon, Ind.[6]	129	October 1943-	171
03302680	West Fork Blue River at Salem, Ind.	19	July 1970-	23.3
03302800	Blue River at Fredericksburg, Ind.	[7]283	June 1968-	332
03303000	Blue River near White Cloud, Ind.	[8]476	October 1930-	[3]628
03303300	Middle Fork Anderson River at Bristow, Ind.	39.8	August 1961-	[4]58.4
03303400	Crooked Creek near Santa Claus, Ind.	7.86	October 1969-	11.2
03322100	Pigeon Creek at Evansville, Ind.	323	October 1960-	352
03322500	Wabash River at New Corydon, Ind.	262	April 1951-	[4,9]202
03322900	Wabash River at Linn Grove, Ind.	453	September 1964-	[4]379
03323500	Wabash River at Huntington, Ind.	721	January 1951-	[10]602
03324000	Little River near Huntington, Ind.[11]	263	October 1943-	[3]225
03324200	Salamonie River at Portland, Ind.	85.6	September 1959-	74.3
03324300	Salamonie River near Warren, Ind.	425	March 1957-	389

Table 1.--Selected hydrologic data for stations in the Indiana surface-water program.--Continued

Station number	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
03324500	Salamonie River at Dora, Ind.	557	November 1923-	[12] 511
03325000	Wabash River at Wabash, Ind.	1,768	August 1923-	[3,4] 1,495
03325311	Little Mississinewa River at Union City, Ind.	9.67	October 1982-	[13] --
03325500	Mississinewa River near Ridgeville, Ind.	133	August 1946-	127
03326070	Big Lick Creek near Hartford City, Ind.	29.20	July 1971-	28.8
03326500	Mississinewa River at Marion, Ind.	682	September 1923-	[3,4] 630
03327000	Mississinewa River at Peoria, Ind.	808	October 1952-	[14] 711
03327500	Wabash River at Peru, Ind.	2,686	August 1943-	[4] 2,368
03327520	Pipe Creek near Bunker Hill, Ind.	159	May 1968-	148
03328000	Eel River at North Manchester, Ind.	417	October 1929-	[3] 359
03328430	Weesau Creek near Deedsville, Ind.	8.87	October 1970-	9.11
03328500	Eel River near Logansport, Ind.	789	July 1943-	[3] 738
03329000	Wabash River at Logansport, Ind.	3,779	May 1923-	[4] 4,819
03329400	Rattlesnake Creek near Patton, Ind.	6.83	October 1968-	7.00
03329700	Deer Creek near Delphi, Ind.	274	October 1943-	[3] 241
03330500	Tippecanoe River at Oswego, Ind.	113	October 1949-	[4] 101
03331110	Walnut Creek near Warsaw, Ind.	19.6	October 1969-	[4] 17.4
03331500	Tippecanoe River near Ora, Ind.	856	September 1943-	[3] 828
03333000	Tippecanoe River near Delphi, Ind.	1,865	July 1939-	[4] 1,656
03333450	Wildcat Creek near Jerome, Ind.	146	July 1961-	131
03333600	Kokomo Creek near Kokomo, Ind.	24.7	July 1959-	[4] 21.6
03333700	Wildcat Creek at Kokomo, Ind.	242	October 1955-	[4] 230
03334500	South Fork Wildcat Creek near Lafayette, Ind.	243	October 1943-	[3] 240
03335000	Wildcat Creek near Lafayette, Ind.	794	May 1954-	[4] 763
03335500	Wabash River at Lafayette, Ind.	7,267	October 1923-	[3] 6,459

Table 1.--Selected hydrologic data for stations in the Indiana surface-water program.--Continued

Station number	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
03335690	Mud Pine Creek near Oxford, Ind.	39.4	June 1971-	40.9
03335700	Big Pine Creek near Williamsport, Ind.	323	October 1955-	269
03336000	Wabash River at Covington, Ind.	8,218	October 1939-	[4]7,365
03339108	East Fork Coal Creek near Hillsboro, Ind.	33.4	September 1968-	38.8
03339500	Sugar Creek at Crawfordsville, Ind.	509	June 1938-	489
03340500	Wabash River at Montezuma, Ind.	11,118	October 1927-	[4]9,774
03340800	Big Raccoon Creek near Fincastle, Ind.[15]	139	August 1957-	142
03340900	Big Raccoon Creek at Ferndale, Ind.	222	October 1956-	[16,17]229
03341300	Big Raccoon Creek at Coxville, Ind.[18]	448	October 1956-	487
03341500	Wabash River at Terre Haute, Ind.	12,265	October 1927-	[4]10,784
03342000	Wabash River at Riverton, Ind.	13,161	October 1938-	[3,4]11,780
03342100	Busseron Creek near Hymera, Ind.	16.7	June 1966-	[4]18.9
03342150	West Fork Busseron Creek near Hymera, Ind.	14.4	October 1966-	13.9
03342244	Mud Creek near Cass, Ind.	9.16	October 1981-	[13,19]--
03342300	Busseron Creek near Sullivan, Ind.	138	June 1966-	[4,19]147
03342500	Busseron Creek near Carlisle, Ind.	228	October 1943-	[4,19]225
03343000	Wabash River at Vincennes, Ind.	13,706	October 1929-	[3,4]11,940
03347000	White River at Muncie, Ind.[20]	241	November 1930-	[4]209
03347500	Buck Creek near Muncie, Ind.	35.5	October 1954-	36.0
03348000	White River at Anderson, Ind.[21]	406.	October 1931-	[3,4]381
03348020	Killbuck Creek near Gaston, Ind.	25.5	June 1968-	25.7
03348350	Pipe Creek at Frankton, Ind.	113	May 1968-	106
03349000	White River at Noblesville, Ind.[22]	858	October 1946-	[4]841
03350700	Stony Creek near Noblesville, Ind.	50.8	July 1967-	48.6
03351000	White River near Nora, Ind.[23]	1,219	October 1929-	[3,4]1,101

Table 1.--Selected hydrologic data for stations in the Indiana surface-water program.--Continued

Station number	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
03351310	Crooked Creek at Indianapolis, Ind.	17.9	June 1969-	18.8
03351400	Sugar Creek Near Middletown, Ind.	5.80	October 1968-	6.03
03351500	Fall Creek near Fortville, Ind.	169	July 1941-	167
03352500	Fall Creek at Millersville, Ind.	298	October 1929-	[3,4]284
03353000	White River at Indianapolis, Ind.[24]	1,635	March 1904-July 1906; April 1930-	[4]1,399
03353120	Pleasant Run at Arlington Ave at Indianapolis, Ind.	7.58	December 1959-	7.67
03353180	Bean Creek at Indianapolis, Ind.	4.40	October 1970-	5.26
03353200	Eagle Creek at Zionsville, Ind.	103	October 1957-	100
03353500	Eagle Creek at Indianapolis, Ind.	174	November 1938-	156
03353600	Little Eagle Creek at Speedway, Ind.	23.9	October 1959-	20.7
03353620	Lick Creek at Indianapolis, Ind.	15.6	October 1970-	19.4
03353700	West Fork White Lick Creek at Danville, Ind.	28.8	May 1958-	29.5
03353800	White Lick Creek near Mooresville, Ind.	212	August 1957-	222
03354000	White River near Centerton, Ind.[25]	2,444	October 1930-March 1932; October 1946-	[3,4]2,418
03354500	Beanblossom Creek at Beanblossom, Ind.[26]	14.6	October 1951-	15.8
03357350	Plum Creek near Bainbridge, Ind.	3.00	July 1969-	3.77
03357500	Big Walnut Creek near Reelsville, Ind.[27]	326	July 1949-	[4]348
03358000	Mill Creek near Cataract, Ind.	245	July 1949-	263
03359000	Mill Creek near Manhatten, Ind.	294	October 1938-	[28]306
03360000	Eel River at Bowling Green, Ind.[29]	830	January 1931-	[4]874
03360500	White River at Newberry, Ind.[30]	4,688	September 1928-	[4]4,716
03361000	Big Blue River at Carthage, Ind.[31]	184	October 1950-	[4]199
03361500	Big Blue River at Shelbyville, Ind.[32]	421	September 1943-	465
03361650	Sugar Creek at New Palestine,Ind.	93.9	October 1967-	103
03361850	Buck Creek at Acton, Ind.	78.8	October 1967-	93.0

Table 1.--Selected hydrologic data for stations in the Indiana surface-water program.--Continued

Station number	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
03362000	Youngs Creek near Edinburgh, Ind.[33]	107	October 1942-	[3]107
03362500	Sugar Creek near Edinburgh, Ind.[34]	474	October 1942-	[3]491
03363000	Driftwood River near Edinburgh, Ind.[35]	1,060	October 1940-	[3]1,153
03363500	Flatrock River at St. Paul, Ind.[36]	303	October 1930-	319
03363900	Flatrock River at Columbus, Ind.	534	October 1967-	602
03364000	East Fork White River at Columbus,Ind.	1,707	October 1947-	[3]1,850
03364200	Haw Creek near Clifford, Ind.	47.5	August 1967-	50.3
03364500	Clifty Creek at Hartsville, Ind.	91.4	February 1948-	96.8
03365000	Sand Creek near Brewersville,Ind.	155	February 1948-	173
03365500	East Fork White River at Seymour, Ind.	2,341	October 1927-	2,449
03366200	Harberts Creek near Madison, Ind.	9.31	August 1968-	12.9
03366500	Muscatatuck River near Deputy, Ind.	293	November 1947-	346
03368000	Brush Creek near Nebraska, Ind.	11.4	May 1955-	13.1
03369000	Vernon Fork Muscatatuck River near Butlerville, Ind.[37]	85.9	February 1942-	[4]94.3
03369500	Vernon Fork Muscatatuck River at Vernon, Ind.[38]	198	October 1939-	[3,4]221
03371500	East Fork White River near Bedford, Ind.	3,861	[39]May 1939-	3,888
03371520	Back Creek at Leesville, Ind.	24.1	October 1970-	34.4
03372300	Stephens Creek near Bloomington, Ind.	10.9	October 1970-	13.9
03372500	Salt Creek near Harrodsburg, Ind.	432	May 1955-	[40]494
03373500	East Fork White River at Shoals, Ind.[41]	4,927	June 1903-July 1906; October 1908-September 1916; June 1923-	[3,4]5,429
03373700	Lost River near West Baden Springs, Ind.[42]	287	December 1964-	365
03374000	White River at Petersburg, Ind.[43]	11,125	October 1927-	[3,4]11,720
03374455	Patoka River near Hardinsburg, Ind.	12.8	October 1968-	25.6
03374500	Patoka River near Cuzco, Ind.	171	June 1961-	[44,45]228

Table 1.--Selected hydrologic data for stations in the Indiana surface-water program.--Continued

Station number	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
03375500	Patoka River at Jasper, Ind.	262	November 1947-	[4] 361
03375800	Hall Creek near St. Anthony, Ind.	21.8	October 1970-	33.4
03376350	South Fork Patoka River near Spurgeon, Ind.	42.8	October 1964-	[19] 50.0
03376500	Patoka River near Princeton, Ind.[46]	822	August 1934-	[3,4] 1,013
03377500	Wabash River at Mt. Carmel, Ill.	28,635	October 1927-	[4] 27,350
03378550	Big Creek near Wadesville, Ind.	104	July 1965-	112
04093000	Deep River at Lake George Outlet at Hobart, Ind.	124	April 1947-	[4] 106
04093500	Burns ditch at Gary, Ind.	160	October 1943-	[4,47] 140
04094000	Little Calumet River at Porter, Ind.	66.2	May 1945-	73.7
04094500	Salt Creek near McCool, Ind.	74.6	May 1945-	73.6
04095300	Trail Creek at Michigan City, Ind.	54.1	June 1969-	71.3
04096100	Galena River near LaPorte, Ind.	[48] 17.2	October 1969-	25.2
04097970	Lime Lake Outlet at Panama, Ind.	[49] 17.5	October 1969-	[4] 7.44
04099510	Pigeon Creek near Angola, Ind.[50]	[51] 106	October 1945-	77.9
04099750	Pigeon River near Scott, Ind.	[52] 361	June 1968-	358
04099808	Little Elkhart River at Middlebury, Ind.	[53] 97.6	October 1979-	[13] --
04099850	Pine Creek near Elkhart, Ind.	[54] 31.0	October 1979-	[13] --
04100222	North Branch Elkhart River at Cosperville, Ind.	142	October 1971-	[4] 136
04100252	Forker Creek near Burr Oak, Ind.	19.2	June 1969-	[4] 17.5
04100295	Rimmell Branch Near Albion, Ind.	10.7	November 1979-	[13] --
04100465	Turkey Creek at Syracuse, Ind.	43.8	October 1969-	[4] 36.6
04100500	Elkhart River at Goshen, Ind.	594	April 1931	511
04101000	St. Joseph River at Elkhart, Ind.	3,370	August 1947-	[4] 3,160
04177720	Fish Creek at Hamilton, Ind.	37.5	October 1969-	31.9
04178000	St. Joseph River near Newville, Ind.	610	October 1946-	[3] 519
04180000	Cedar Creek near Cedarville, Ind.	270	October 1946-	240

Table 1.--Selected hydrologic data for stations in the Indiana surface-water program.--Continued

Station number	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
04180500	St. Joseph River near Fort Wayne, Ind.	1,060	1905-06, July 1941-55, 1983-	967
04181500	St. Marys River at Decatur, Ind.	621	October 1946-	[3,4] 495
04182000	St. Marys River near Fort Wayne, Ind.	762	October 1930-	[3,4] 576
04182810	Spy Run at Fort Wayne, Ind.	14.0	September 1983-	[13] --
04182590	Harber ditch at Fort Wayne, Ind.	21.9	May 1964-	18.0
04183000	Maumee River at New Haven, Ind.	1,967	[55] October 1956-	[4] 1,639
05515000	Kankakee River near North Liberty, Ind.	174	January 1951-	150
05515400	Kingsbury Creek near LaPorte, Ind.	7.08	October 1970-	4.15
05515500	Kankakee River at Davis, Ind.	537	July 1905-July 1906; October 1924-	[3] 500
05516500	Yellow River at Plymouth, Ind.	[56] 294	July 1948-	257
05517000	Yellow River at Knox, Ind.	[57] 435	August 1905-July 1906; August 1943-	393
05517500	Kankakee River at Dunns Bridge, Ind.	[58] 1,352	July 1948-	1,313
05517530	Kankakee River near Kouts, Ind.	[59] 1,376	October 1974-	1,460
05517890	Cobbs ditch near Kouts, Ind.[60]	30.3	July 1968-	32.7
05518000	Kankakee River at Shelby, Ind.	[61] 1,779	October 1922-	[3] 1,609
05519000	Singleton ditch at Schneider, Ind.	123	July 1948-	107
05521000	Iroquois River at Rosebud, Ind.	35.6	July 1948-	26.9
05522000	Iroquois River near North Marion, Ind.	144	December 1948-	[4] 132
05522500	Iroquois River at Rensselaer, Ind.	203	July 1948-	168
05523000	Bice ditch near South Marion, Ind.	21.8	December 1948-	17.1
05524500	Iroquois River near Foresman, Ind.	449	December 1948-	380
05536190	Hart ditch at Munster, Ind.	70.7	September 1942-	60.3
05536195	Little Calumet River at Munster, Ind.	90.0	June 1958-	[3] 73.4

[1]Prior to October 1936, published as West Fork Whitewater River near Alpine.
[2]Flow regulated by Brookville Lake since January 1974. Records of daily discharge compiled from head and gate openings beginning October 1, 1981.
[3]Monthly discharge only for some periods, published in Water-Supply Paper 1305, 1307, or 1308.
[4]Some known regulation or diversion.
[5]28.1 mi^2 drainage area does not contribute directly to surface runoff.
[6]Prior to October 1961, published as Big Indian Creek near Corydon. 10.6 mi^2 of drainage area does does not contribute directly to surface runoff.
[7]76.9 mi^2 drainage area does not contribute directly to surface runoff.
[8]192 mi^2 drainage area does not contribute directly to surface runoff. Also, flow from Indian Creek, downstream of Corydon, enters Blue River via solution channel through Harrison Spring.
[9]Occasional regulation by Grand Lake, diversion from or into St. Marys River basin, and into Miami and Erie Canal.
[10]Flow regulated by Huntington Lake since January 1969. Records of daily discharge computed from head and gate opening beginning October 1, 1974.
[11]January 1944 to September 1948 published as Little River at Huntington, October 1948 to September 1956 published as Little River near Huntington, October 1956 to September 1961 published as Little Wabash River near Huntington.
[12]Flow regulated by Salamonie Lake since April 1967. Records of daily discharge computed from head and gate opening beginning October 1, 1974.
[13]No mean annual flow published, less than 5 years of streamflow record.
[14]Flow regulated by Mississinewa Lake since April 1968. Records of daily discharge compiled from head and gate openings since October 1, 1974.
[15]Prior to October 1963, published as Raccoon Creek near Fincastle.
[16]Prior to October 1963, published as Raccoon Creek at Ferndale.
[17]Flow regulated by Cecil M. Harden Lake since December 1960. Records of daily discharge compiled from head and gate opening since October 1, 1974.
[18]Prior to October 1963, published as Raccoon Creek at Coxville.
[19]Flow affected by suface-mined area.
[20]Prior to October 1948, published as West Fork White River at Muncie.
[21]Prior to October 1948, published as West Fork White River at Anderson.
[22]Prior to October 1948, Published as West Fork White River at Noblesville.
[23]Prior to October 1948, published as West Fork White River near Nora.
[24]Prior to October 1948, published as West Fork White River at Indianapolis.
[25]Published as West Fork White River at Martinsville prior to March 1932, and as West Fork White River near Centerton, October 1946 to September 1948.
[26]Prior to October 1965, published as Bean Blossom Creek at Bean Blossom.
[27]Published as Eel River near Reelsville, October 1952 to September 1956
[28]Flow regulated by Cagles Mill Lake since July 1953. Records of daily discharge compiled from head and gate opening since October 1, 1974.

[29]Prior to October 1934, published as Eel River near Centerpoint.
[30]Prior to October 1948, published as West Fork White River at Newberry.
[31]Prior to October 1961, published as Blue River at Carthage.
[32]Prior to October 1961, published as Blue River at Shelbyville.
[33]Prior to October 1977, published as Youngs Creek near Edinburg.
[34]Prior to October 1977, published as Sugar Creek near Edinburg.
[35]Prior to October 1977, published as Driftwood River near Edinburg
[36]Prior to October 1958, published as Flatrock Creek at St. Paul.
[37]Prior to October 1960, published as North Fork of Vernon Fork near Butlerville and as Vernon Fork near Butlerville, October 1960 to September 1979.
[38]Prior to October 1979, published as Vernon Fork at Vernon.
[39]High-water records only October 1943 to September 1957.
[40]Flow regulated by Monroe Lake since April 1966. Records of daily discharge compiled from head and gate openings since October 1974.
[41]Published as East Branch White River at Shoals 1903-1906 and 1908-1916.
[42]Prior to October 1965, published as Lost River near West Baden.
[43]Prior to October 1938, published as White River at Hazelton.
[44]Prior to October 1979, published as Patoka River near Ellsworth.
[45]Flow regulated by Patoka Lake since February 1978. Records of daily discharge compiled from head and gate opening since October 1981.
[46]Prior to October 1940, published as Patoka River at Patoka.
[47]Some years during high levels on Lake Michigan, only periods free from backwater are shown.
[48]2.30 mi^2 drainage area does not contribute directly to surface runoff.
[49]3.68 mi^2 drainage area does not contribute directly to surface runoff.
[50]Prior to October 1947, published as Pigeon Creek near Flint. Published as Pigeon Creek at Hogback Lake Outlet near Angola, October 1947 to September 1971, and Pigeon Creek at Hogback Lake near Angola, October 1971 to September 1974.
[51]22.5 mi^2 drainage area does not contribute directly to surface runoff.
[52]53.9 mi^2 drainage area does not contribute directly to surface runoff.
[53]5.89 mi^2 drainage area does not contribute directly to surface runoff.
[54]8.75 mi^2 drainage area does not contribute directly to surface runoff.
[55]December 1946 to September 1956 high-water records are available.
[56]22 mi^2 drainage area does not contribute directly to surface runoff.
[57]51 mi^2 drainage area does not contribute directly to surface runoff.
[58]192 mi^2 drainage area does not contribute directly to surface runoff.
[59]194 mi^2 drainage area does not contribute directly to surface runoff.
[60]Prior to October 1971, published as State ditch near Kouts.
[61]201 mi^2 drainage area does not contribute directly to surface runoff.

Table 2.--Data use, station funding, and data availability for continuous-record stations operated in 1983

[Asterisk (*) indicates explanation of data use or funding is given in text; footnotes are at end of table]

Station number	Regional hydrology	Hydrologic systems	Legal obligations	Planning and design	Project operation	Hydrologic forecasts	Water-quality monitoring	Other	Federal program	OFA program	Co-op program	Data availability
03274650	*						1				2	A
03274750	*						1				2	A
03274950	*						1				2	A
03275000	*				2,3	2,4	1				2	A,T
03275600					2,3	2	1			3		A
03276000					2,3	2				3		A
03276500					2,3	2,4	1,5			3		A,P,T
03276700	6	6					6		*			A
03291780	*										2	A
03294000	*			7	2	2					2	A
03302220	*										2	A
03302300	*										2	A
03302500	*					2,4					2	A
03302680	*			7			1				2	A
03302800	*			7		4	1				2	A
03303000	*			7		2					2	A
03303300			2		2	2					2	A
03303400	*	8									2	A
03322100	*	8			3	2,3,4					2	A,P
03322500	*	2			2	2,4					2	A,P
03322900	*				2,3	2,4				3		A
03323500			1		2,3	2,4				3		A
03324000	*	2			3	2					2	A
03324200	*		1								2	A
03324300	*		1		2,3	2,4					2	A,T
03324500			1		2,3	2				3		A,T
03325000			1		3	2,4	1			3		A,P,T
03325311	*		2		2		1				2	A,P
03325500	*		1		2	2					2	A
03326070	*										2	A
03326500	9	9	1		2 3	2,4					2	A,T

Table 2.--Data use, station funding, and data availability for continuous-record stations operated in 1983--Continued

Station number	Regional hydro-logy	Hydro-logic systems	Legal obliga-tions	Planning and design	Project opera-tion	Hydro-logic forecasts	Water-quality monitoring	Other	Federal program	OFA pro-gram	Co-op program	Data availa-bility
03327000			1		2,3	2				3		A,T,
03327500			1		3	2,4	1		*	3		A,P,T
03327520	*										2	A
03328000	*					4					2	A,T
03328430	*						1				2	A
03328500	*				3	2,4					2	A
03329000			1		3	2,4					2	A,P,T
03329400	*						1				2	A
03329700	*										2	A
03330500	*				2						2	A
03331110	*						1				2	A
03331500	*					2,4					2	A,T
03333000					3	2,4	1				2	A
03333450	*										2	A
03333600	*					2	1				2	A
03333700		2				2,4	1				2	A,P,T
03334500	*	2				2					2	A,P
03335000	*			1		2,4	1				2	A,P,T
03335500				1	3	2,4	1				2	A,P,T
03335690	*										2	A
03335700	*					4					2	A,P
03336000				1	3	2,4	1				2	A,P,T
03339108	*	8									2	A
03339500	*	8				2,4	1				2	A,T
03340500				1	3	2,4	1				2	A,P
03340800	*				2,3	4					2	A,T
03340900					2,3	2				3		A,T
03341300				1	2,3	2				3		A,P,T
03341500				1	3	2,4	1				2	A,P
03342000				1	3	2,4					2	A,T
03342100		8					1				2	A
03342150	*	8					1				2	A

Table 2.--Data use, station funding, and data availability for continuous-record stations operated in 1983--Continued

Station number	Regional hydro-logy	Hydro-logic systems	Legal obliga-tions	Planning and design	Project opera-tion	Hydro-logic forecasts	Water-quality monitoring	Other	Federal program	OFA pro-gram	Co-op program	Data availa-bility
03342244		8		1							2	A
03342300		8									2	A,T
03342500		8									2	A
03343000					3	2,4					2	A,P
03347000				1	3	2,4	1				2	A,P,T
03347500	*					2					2	A
03348000	*					2,4	1				2	A,T
03348020	*						1				2	A
03348350	*										2	A
03349000	*			1	2	2,4		10			2	A,P,T
03350700	*										2	A
03351000				1	2	2,4	1				11,12	A,T
03351310	*						1				2	A
03351400	*						1				2	A
03351500	*				2	2					2,11	A
03352500				1	2	2,4	1				11,12	A,P,T
03353000				1	2,3	2,4	1				2,11,12	A,P,T
03353120	*					2	1				11	A
03353180	*						1				2	A
03353200	*					2,4					2	A,T
03353500				1		2,4					11	A,T
03353600	*					2,4	1				2,11	A,T
03353620	*						1				2	A
03353700	*						1				2	A
03353800	*					4					2	A
03354000			2		2,3	2,4	1				2	A,P,T
03354500	*						1				2	A
03357350	*						1				2	A
03357500	*				3	4					2	A
03358000	*				2,3	2				3		A
03359000					2,3	2				3		A
03360000					2,3	2,4				3		A,P,T

Table 2.--Data use, station funding, and data availability for continuous-record stations operated in 1983--Continued

Station number	Regional hydro-logy	Hydro-logic systems	Legal obliga-tions	Planning and design	Project opera-tion	Hydro-logic forecasts	Water-quality monitoring	Other	Federal program	OFA pro-gram	Co-op program	Data availa-bility
03360500	*			1	3	1,2,4				3	2	A,P,T
03361000	*			7	2	1,2,4					2	A,P,T
03361500	*					2,4					2	A,P,T
03361650	*										2	A
03361850	*										2	A
03362000	*										2	A
03362500	*					4					2	A,P,T
03363000	*					2,4					2	A,P
03363500	*										2	A,P
03363900	*					4					2	A
03364000	*					1,2,4					2	A,P,T
03364200	*										2	A
03364500	*										2	A,P
03365000	*					4					2	A
03365500	*		2		3	1,2,4					2	A,P,T
03366200	*					1,2					2	A
03366500	*					2,4					2	A,T
03368000	*						1				2	A
03369000						2					2	A
03369500	*					2,4	1				2	A,T
03371500	*			1	3	2,4	1				2	A,P,T
03371520	*						1				2	A
03372300	*						1				2	A,P
03372500					2,3	2				3		A
03373500		9		1	2,3	2,4	1	10		3		A,P,T
03373700	*			7		4			*			A
03374000	*		2		2,3	2,4	1,5				2	A,P,T
03374455	*						1				2	A
03374500					2,3	2						A
03375500		8			2,3	2,4	1			3		A,P,T
03375800	*	8					1				2	A
03376350		8									2	A

Table 2.--Data use, station funding, and data availability for continuous-record stations operated in 1983--Continued

Station number	Regional hydro-logy	Hydro-logic systems	Legal obliga-tions	Planning and design	Project opera-tion	Hydro-logic forecasts	Water-quality monitoring	Other	Federal program	OFA pro-gram	Co-op program	Data availa-bility
03376500		8			3	2,4	1			3	2	A,T
03377500		9		1	3	2,4	5	10	*			A,P,T
03378550	*	8									2	A
04093000		2,13				2					2	A
04093500		2		3		2					2	A
04094000	*	2				2					2	A
04094500	*	2				2					2	A
04095300	*						1				1	A
04096100	*						1				2	A
04097970		13					1				2	A
04099510	*			7		2					2	A
04099750	*										2	A
04099808	*										2	A
04099850	*										2	A
04100222		13				2					2	A
04100252		13					1				2	A
04100295	*						1				2	A
04100465		13									2	A
04100500		13			3	2,4					2	A,T
04101000				1	3	2,4					2	A
04177720		13									2	A
04178000	*				3	2,4,14				3		A,P,T
04180000	*				3	2,14				3		A,P
04180500		2		3	3	2,4,14	1				14	A
04181500	*				3	2,4,14	1				2	A,P,T
04182000	*	2		3	3	2,4	1				2	A,P
04182590	*	2				2	1				2	A
04182810	*	2				2,4,14	1				14	A
04183000	*	2		3		1,2					2	A,P
05515000	*			7	3	2	1				2	A
05515400	*			7	2	1					2	A
05515500	*			7	3	1,2					2	A,T

Table 2.--Data use, station funding, and data availability for continuous-record stations operated in 1983--Continued

Station number	Regional hydro-logy	Hydro-logic systems	Legal obliga-tions	Planning and design	Project opera-tion	Hydro-logic forecasts	Water-quality monitoring	Other	Federal program	OFA pro-gram	Co-op program	Data availa-bility
05516500	*			7	3	2,4					2	A
05517000	*			7	3	2,3,4				3	2	A,T
05517500	*			7	2,3	2,4		10			2	A,T
05517530	*			7	2,3	2,4					2	A,T
05517890	*			7							2	A
05518000	*			7	3	2,34	1			3		A,T
05519000	*			7							2	A
05521000	*	2		7							2	A
05522000		2		7							2	A
05522500	*	2		7		4					2	A
05523000	*	2		7							2	A
05524500	*	2		7							2	A
05536190	*	2			3	2				3	2	A,T
05536195		2			3	2				3		A

[1] Indiana State Board of Health
[2] Indiana Department of Natural Resources, Division of Water
[3] Corps of Engineers
[4] National Weather Service
[5] Supplies discharge for a NASQAN station
[6] Hydrologic Benchmark station
[7] Soil Conservation Service
[8] Coal field hydrology station
[9] Long term index station
[10] Published in the Indiana Water Bulletin as a trend station
[11] Indianapolis Flood Board
[12] Indianapolis Sanitation Board
[13] Lake hydrology station
[14] City of Fort Wayne
A Published in the annual report
T Data available on a real-time basis
P Information released on a provisional basis

Table 10.--Statistics of record reconstruction

Branch(Br), Creek(Cr), Fork(Fk), Middle(M), Near(nr), River(R), Saint(St.), North (N), South(S), East(E), West(W),

Station number	Station name	$\overline{C}_v$	ρ_c	Station used for record reconstruction
03274650	Whitewater R nr Economy	1.52	0.92	03274750
03274750	Whitewater R nr Hagerstown	1.16	.92	03274650, 03275000
03274950	Little Williams Cr at Connersville	1.27	.786	03275600, 03275000, 03274750
03275000	Whitewater R nr Alpine	1.37	.904	03276500, 03274750
03275600	E Fk Whitewater R at Abington	1.28	.856	03275000, 03274950, 03274750
03276500	Whitewater R at Brookville	1.33	.926	03275000, 03276500
03276700	South Hogan Cr nr Dillsboro	2.23	.781	03291780, 03368000, 03366200
03291780	Indian-Kentuck Cr nr Canaan	1.74	.82	03366200, 03276700
03294000	Silver Cr nr Sellersburg	2.12	.78	03302800, 03302300
03302220	Buck Cr nr New Middleton	1.42	.733	03302800, 03302500
03302300	Little Indian Cr nr Galena	1.72	.806	03302500, 03294000
03302500	Indian Cr nr Corydon	2.12	.806	03302300, 03302800
03302680	W Fk Blue R at Salem	1.53	.820	03302800
03302800	Blue R at Fredericksburg	1.42	.844	03303000, 03302680
03303000	Blue R nr White Cloud	1.57	.850	03302500, 03302800
03303300	M Fk Anderson R at Bristow	1.96	.687	03373700, 03376750, 03374455, 03376260, 03303400
03303400	Crooked Cr nr Santa Claus	1.96	.782	03375800, 03303300, 03374455, 03376350
03322100	Pigeon Cr at Evansville	1.83	.659	03378550, 03303300, 03376350
03322500	Wabash R nr New Corydon	1.94	.791	03325500, 03325000, 03329000
03322900	Wabash R at Linn Grove	1.77	.841	03322500
03324000	Little R nr Huntington	1.83	.855	03328000, 04182590, 03324300
03324200	Salamonie R at Portland	2.26	.840	03325500, 03328000, 03325500, 03324300
03324300	Salamonie R nr Warren	1.96	.766	04181500, 03324000, 03328000, 03324200
03325000	Wabash R at Wabash	1.40	.951	03327500, 03324500, 03323500, 03324000
03325311	Little Mississinewa R at Union City	1.74	.80	e
03325500	Mississinewa R nr Ridgeville	1.40	.951	03324200, 03324300, 03326500
03326070	Big Lick Cr nr Hartford City	1.59	.761	03348020, 03325500,
03326500	Mississinewa R at Marion	1.78	.763	03325500, 03328000,
03327500	Wabash River at Peru	1.29	.951	03325000, 03324500, 03323500
03327520	Pipe Cr nr Bunker Hill	1.48	.853	03333450, 03326500, 03329700
03328000	Eel R at North Manchester	1.25	.920	03328500, 03326500,
03328430	Weesau Cr nr Deedsville	1.25	.718	03329400, 03327520, 03328000, 03331110
03328500	Eel R nr Logansport	1.16	.931	03328430
03329000	Wabash R at Logansport	1.20	.970	03327500, 03335500,
03329400	Rattlesnake Cr nr Patton	1.40	.728	03335700
03329700	Deer Cr nr Delphi	1.56	0.856	03335000, 03334500, 03333600
03330500	Tippecanoe R at Oswego	.93	.678	04100465, 04100252,
03331110	Walnut Cr nr Warsaw	1.06	.730	03328000, 03328430,
03331500	Tippecanoe R nr Ora	.82	.896	03330500, 03328500, 05517000
03333000	Tippecanoe R nr Delphi	1.10	.95	03335500, Oakdale Dam

Table 10.--Statistics of record reconstruction--Continued

Station number	Station name	$\overline{C}_v$	ρ_c	Station used for record reconstruction
03333450	Wildcat Cr nr Jerome	1.75	.918	03333700, 03327520, 03333600
03333600	Kokomo Cr nr Kokomo	1.77	.886	03333700, 03327520
03333700	Wildcat Cr nr Kokomo	1.61	.918	03333450, 03335000, 03333450
03334500	S Fk Wildcat Cr nr Lafayette	1.51	.945	03335000, 03333450, 03329700
03335000	Wildcat Cr nr Lafayette	1.43	.945	03334500, 03333700
03335500	Wabash R at Lafayette	1.01	.956	03336000
03335690	Mud Pine Cr nr Oxford	1.48	.842	03335700, 03329400, 03329700
03335700	Big Pine Cr nr Williamsport	1.56	.842	03335690, 03329400, 03329700
03336000	Wabash R at Covington	.96	.957	03340500, 03341500, 03335500
03339108	E Fk Coal Cr nr Hillsboro	1.26	.764	03339500, 03334500, 03340800
03339500	Sugar Cr at Crawfordsville	1.80	.841	03340800, 03339108, 03357420, 03358000
03340500	Wabash R at Montezuma	0.99	.983	03341500, 03335500, 03336000
03340800	Big Raccoon Cr nr Fincastle	1.73	.841	03339500, 03357350, 03357420, 03339108
03341300	Big Raccoon Cr at Coxville	1.24	.740	03340900, 03357500, 03340800, 03339500
03341500	Wabash R at Terre Haute	0.95	.983	03340500, 03342000
03342000	Wabash R at Riverton	0.94	.985	03343000, 03340500, 03341500
03342100	Busseron Cr nr Hymera	1.99	.848	03342150, 03342500, 03342300
03342150	W Fk Busseron Cr nr Hymera	2.06	.848	03342100, 03342300
03342244	Mud Cr nr Cass	1.32	.722	03342300. 03342150, 03342100 e
03342300	Busseron Cr nr Sullivan	1.67	.883	03342500, 03342150, 03342100
03342500	Busseron Cr nr Carlisle	2.02	.883	03342300, 03342100
03343000	Wabash R at Vincennes	0.88	.980	03377500, 03342000
03347000	White R at Muncie	1.82	.946	03348000, 03347500
03347500	Buck Cr nr Muncie	1.08	.848	03351500, 03347000, 03348020
03348000	White R at Anderson	1.38	.946	03347000, 03345700, 03349000
03348020	Killbuck Cr nr Gaston	1.26	.857	03348350, 03347500, 03348350, 03326070
03348350	Pipe Cr at Frankton	1.41	.857	03348020, 03351400, 03347500, 03351500
03349000	White R at Noblesville	1.34	.974	03351000
03350700	Stony Cr nr Noblesville	1.25	.807	03353200, 03351310
03351000	White R nr Nora	1.31	.975	03353000
03351310	Crooked Cr at Indianapolis	1.37	.839	03353600, 03353120
03351400	Sugar Cr nr Middletown	1.74	.798	03347500, 03361000, 03351500
03351500	Fall Cr nr Fortville	1.30	.927	03352500, 03349000
03352500	Fall Cr at Millersville	1.30	.927	03351500, 03349000
03353000	White R at Indianapolis	1.36	.975	03351000, 03353500, 03354000
03353120	Pleasant Run Cr at Indianapolis	2.06	0.761	03353600, 03351310
03353180	Bean Cr at Indianapolis	1.13	.862	03353620, 03353120
03353200	Eagle Cr at Zionsville	2.00	.806	03353800, 03348350, 03351310, 03351500
03353500	Eagle Cr at Indianapolis	1.93	.817	03353200, 03354000
03353600	Little Eagle Cr at Speedway	1.80	.839	03351310, 03353200
03353620	Lick Cr at Indianapolis	1.34	.790	03351010, 03361650, 03353600, 03353120
03353700	W Fk Whitelick Cr at Danville	2.08	.892	03353800, 03353200, 03357350
03353800	White Lick Cr at Mooresville	1.69	.899	03357500, 03358000, 03353700
03354000	White R nr Centerton	1.20	.856	03357000, 03360500, 03347000
03354500	Beanblossom Cr at Beanblossom	2.28	.719	03372300, 03371520, 03353800

Table 10.--Statistics of record reconstruction--Continued

Station number	Station name	$\overline{C}_v$	ρ_c	Station used for record reconstruction
03357350	Plum Cr nr Bainbridge	1.76	.798	03353700, 03357500, 03339108
03357500	Big Walnut Cr nr Reelsville	1.68	.856	03340800, 03358000, 03339500, 03357420
03358000	Mill Cr nr Cataract	2.07	.846	03353800, 03357500
03360000	Eel R at Bowling Green	1.42	.784	03357500, 03360500, 03359000, 03358000
03360500	White R at Newberry	1.10	.855	03354000, 03360000, 03373500
03361000	Big Blue R at Carthage	1.22	.911	03361500,
03361500	Big Blue R at Shelbyville	1.33	.927	03363000, 03362500, 03361000
03361650	Sugar Cr at New Palestine	1.30	.866	03361850, 03361000, 03362500
03361850	Buck Cr at Acton	1.55	.866	03361650, 03362500,
03362000	Youngs Cr nr Edinburgh	1.87	.853	03362500, 03364200, 03361850
03362500	Sugar Cr nr Edinburgh	1.55	.954	03363000, 03361650
03363000	Driftwood R nr Edinburgh	1.29	.978	03363000, 03361650
03363500	Flatrock R at St. Paul	1.55	.913	03361500, 03361000, 03363900
03363900	Flatrock R at Columbus	1.14	.885	03364000, 03363500
03364000	E Fk White R at Columbus	1.28	.978	03363000, 03363900, 03365500
03364200	Haw Cr nr Clifford	1.54	.821	03365000, 03364500
03364500	Clifty Cr at Hartsville	1.99	.861	03365000, 03364000, 03363500, 03364200
03365000	Sand Cr nr Brewersville	2.07	.885	03369000, 03364500, 03364200, 03369500
03365500	E Fk White R at Seymour	1.27	.956	03364000, 03371500
03366200	Harberts Cr nr Madison	1.88	.686	03366500, 03369500
03366500	Muscatatuck R nr Deputy	2.29	.826	03369500, 03366200
03368000	Brush Cr nr Nebraska	2.59	.763	03276700, 03291780
03369000	Vernon Fork nr Butlerville	2.34	.926	03369500, 03368000
03369500	Vernon Fork at Vernon	2.28	.926	03369000, 03365500
03371500	E Fk White R nr Bedford	1.11	.957	03373500, 03365500, 03373500
03371520	Back Cr at Leesville	1.52	.728	03372300, 03302680, 03374455, 03354500
03372300	Stephens Cr nr Bloomington	1.54	.728	03371520, 03302680, 03374455, 03354500
03373500	E Fk White R at Shoals	1.11	.957	03371500, 03374000
03373700	Lost R nr W Baden Springs	1.39	.792	03302800, 03302680, 03376500
03374000	White R at Petersburg	0.98	.943	03373500, 03360500, 03343000, 03377500
03374455	Patoka R nr Hardinsburg	1.72	0.790	03302800, 03302680
03375500	Patoka R at Jasper	1.81	.776	03374500, 03376500, 03374455
03375800	Hall Cr nr St. Anthony	1.74	.782	03303400, 03376350, 03374455, 03303300
03376350	S Fk Patoka nr Spurgeon	1.36	.762	03375800, 03374455, 03303300
03376500	Patoka R nr Princeton	1.39	.704	03374000, 03375500, 03373700
03377500	Wabash R at Mount Carmel,Ill.	0.87	.919	03343000, 03342000, 03374000
03378550	Big Cr nr Wadesville	2.23	.710	03376350, 03303300, 03303400
04093000	Deep R at Hobart	1.53	.968	04093500, 05536195, 05536190
04093500	Burns Ditch at Gary	1.36	.968	04093000, 05536195
04094000	Little Calument at Porter	1.04	.796	04093000, 05515400, 05536195
04094500	Salt Cr nr McCool	1.06	.910	04094000, 04095300, 04096100
04095300	Trail Cr at Michigan City	0.66	.882	04096100, 04094500
04096100	Galena R nr LaPorte	0.52	.736	04094000, 05515400
04097970	Lime Lake Outlet nr Panama	0.55	.800	04177720
04099510	Pigeon Cr nr Angola	0.68	.816	04099750, 04100222, 04100252, 04177720, 04100500

Table 10.--Statistics of record reconstruction--Continued

Station number	Station name	$\overline{C}_v$	ρ_c	Station used for record reconstruction
04099750	Pigeon R nr Scott	0.54	.816	04099510, 04100500
04099808	Little Elkhart R at Middlebury	0.60	.80	04100222, 04099850
04099850	Pine Cr at Elkhart	0.54	.82	04100222, 04099808
04100222	N Br Elkhart R at Cosperville	0.78	.860	04100500, 04177720, 04100252, 04099750, 04099510
04100252	Forker Cr nr Burr Oak	1.36	.755	03331110, 04100222, 03330500
04100295	Rimmel Br nr Abion	1.36	.755 [e]	
04100465	Turkey Cr at Syracuse	0.96	.678	03330500, 04097970, 04177720, 04100252
04100500	Elkhart R at Goshen	0.77	.860	04100222, 04099510, 04101000
04101000	St. Joseph R at Elkhart	0.47	.964	04101500, 04100500, 04099000
04177720	Fish Cr at Hamilton	1.19	.766	04180000, 04100252, 04099000
04178000	St. Joseph R nr Newville	1.42	.800	04179000, 04183000, 04178000
04180000	Cedar Cr nr Cedarville	1.42	.800	04179000, 04183000, 04178000
04181500	St. Marys R at Decatur	1.82	.984	04182000, 04183000
04182000	St. Marys R nr Fort Wayne	1.83	.984	04181500, 04183000
04182590	Harber ditch at Fort Wayne	1.85	.772	03324000, 04182000, 03324000
04183000	Maumee R at New Haven	1.29	.960	04183500, 04182000
05515000	Kankakee R nr North Liberty	0.45	.899	05515500, 04095300, 05516500
05515400	Kingsbury Cr nr LaPorte	0.57	.672	05517890, 04095300, 04096100
05515500	Kankakee R at Davis	0.41	.940	05517500, 05515000, 05518000
05516500	Yellow R at Plymouth	1.37	.918	05517000
05517000	Yellow R at Knox	0.96	0.918	05516500, 03328500, 03331500
05517500	Kankakee R at Dunns Bridge	0.56	.977	05518000, 05515000, 05515500
05517530	Kankakee R nr Kouts	0.46	.823	05517500, 05515500, 05515000
05517890	Cobb Ditch nr Kouts	0.83	.759	05519000, 04094500, 05515400
05518000	Kankakee R at Shelby	0.55	.977	05517500, 05517530, 05520500
05519000	Singleton ditch at Schneider	1.28	.759	05517890
05521000	Iroquois R at Rosebud	1.00	.903	05522500, 05523000, 05522000
05522000	Iroquois R nr North Marion	1.22	.987	05522500, 05524500, 05521000
05522500	Iroquois R at Rennsselaer	1.27	.987	05522000, 05524500, 05521000
05523000	Bice ditch nr South Marion	1.98	.746	05521000, 03335690
05524500	Iroquois R nr Foresman	1.31	.926	05522500, 05522000
05536190	Hart ditch at Munster	1.81	.936	05536290, 04093000, 05536195
05536195	Little Calumet R at Munster	1.39	.940	05536290, 05536190

[e] denotes estimated value

Table 11.--Residual Data for White River at Indianapolis, Ind.

Measurement	Gage height (ft) log	Measured discharge ft^3/s log	Time[1] (days)	Residual[2] log
853	0.77159	3.42488	17	0.03673
854	.66464	3.10037	13	-.00029
855	.59770	2.91593	13	.02154
856	.62118	3.00432	16	.03458
857	.89098	3.68753	14	.01635
858	.63144	3.02531	12	.02370
859	.61700	2.98046	20	.02386
860	.83506	3.54654	16	.00412
861	.70415	3.26245	13	.05067
862	.83251	3.61805	14	.08163
863	.55991	2.84261	20	.07804
864	.60853	2.96190	16	.03230
865	.53782	2.68574	12	.00298
866	.52763	2.63849	10	-.00478
867	.46240	2.36736	20	.01206
868	.48714	2.41330	13	-.05955
869	.46240	2.36922	21	.01392
870	.65418	3.11059	29	.04055
871	.63949	2.82217	28	-.20397
872	.97313	3.74429	1	-.10664
873	.01199	3.95182	1	.01897
874	.01828	3.94939	14	.00344
875	.67210	3.08279	18	-.03936
876	.91803	3.75051	10	.01903
877	.68574	3.19033	25	.02950
878	.63246	2.90309	9	-.10163
879	.74819	3.27416	14	-.05445
880	.67578	3.13672	14	.00406
881	.64246	3.01703	18	-.01810
882	.98046	3.89209	14	.02557
883	.84572	3.56110	16	-.00634
884	.79657	3.48714	14	.03708
885	.92117	3.76492	7	.02653
886	.60853	2.95521	20	.02561
888	.67669	3.11394	11	-.02133
889	.63548	3.00860	20	-.00537
890	.50920	2.55751	12	-.01110
891	.54283	2.64640	17	-.05534
892	.62634	3.02531	18	.03946

Table 11.--Residual Data for White River at Indianapolis, Ind.--Continued

Measurement	Gage height (ft) log	Measured discharge ft^3/s log	Time[1] (days)	Residual[2] log
893	0.48996	2.45484	15	-0.03067
894	.51322	2.55145	13	-.03380
895	.47857	2.45484	13	.02138
896	.49136	2.46835	17	-.02343
897	.51188	2.55871	13	-.02104
898	.92840	3.75587	26	.00160
899	.73719	3.30103	9	.00098
900	.59770	2.93298	14	.03860
901	.69197	3.23045	19	.05224
902	.12450	4.16732	14	.00601
903	.68034	3.23045	22	.08485
904	.73078	3.30963	15	.02641
905	.69984	3.26007	20	.06010
906	.91169	3.73400	15	.01655
907	.64542	3.07918	21	.03517
908	.58659	2.91855	13	.06115
909	.75282	3.42325	23	.08273
910	.63649	3.04922	15	.03219
911	.75511	3.37475	19	.02835
912	.53656	2.68034	19	.00240
913	.46538	2.38739	11	.01725
914	.48144	2.47857	12	.03174
915	.71265	3.12710	15	-.10776
916	.52114	2.64640	19	.02894
917	.43775	2.33041	20	.10604
918	.48001	2.47857	10	.03839
919	.62531	2.86332	19	-.11933
920	.54654	2.66558	15	-.05008
921	.53656	2.60853	13	-.06941
922	.73799	3.33244	16	.03031
923	.78533	3.43297	15	.01056
924	.70927	3.24551	13	.01980
925	.76716	3.39794	19	.02094
926	.16316	4.25527	21	.01791
927	.72835	3.33445	7	.05764
928	.80209	3.48430	29	.02079
929	.85794	3.62941	30	.03359
930	.69723	3.22531	33	.03252
931	.54777	2.70070	28	-.01954

Table 11.--Residual Data for White River at Indianapolis, Ind.--Continued

Measurement	Gage height (ft) log	Measured discharge ft^3/s log	Time[1] (days)	Residual[2] log
932	0.54407	2.59660	35	-0.10981
933	.52504	2.53908	30	-.09398
936	.77815	3.39270	28	-.01188
937	.56820	2.80550	38	.01142
938	.60423	2.95617	25	.04046
939	1.07078	4.10380	9	.05014
940	.67210	3.15836	19	.03621
941	.62634	3.02119	31	.03534
942	.50651	2.53529	33	-.02200
943	.79727	3.48430	28	.03254
944	.75891	3.39794	30	.04184
945	.45637	2.30103	33	-.02365
946	.42488	2.13988	28	-.00913
947	.46538	2.15534	35	-.21480
952	.75740	3.32634	31	-.02590
953	.74819	3.35793	33	.02933
954	.55871	2.73957	27	-.02068
955	.49136	2.38739	31	-.10439
956	.39794	2.01284	32	.04256
957	.37107	1.80618	27	.05515
958	.44091	2.30963	31	.06756
959	.63949	3.02531	35	-.00083
960	.44560	2.36361	27	.09577
961	.72428	3.23553	30	-.03047
962	.61278	2.95665	34	.01343
963	.52114	2.61700	32	-.00046
964	.50651	2.56348	25	.00619
965	.88874	3.72754	37	.06141
966	.70927	3.21748	30	-.00823
967	.59770	2.97359	30	.07921
968	1.09691	3.85914	18	-.24718
969	.96332	3.63347	0	-.19649
970	.82672	3.46835	1	-.05436
971	.69810	3.24797	9	.05279
972	.57519	2.75891	28	-.05956
973	.58433	2.82151	35	-.02827
974	.46835	2.28780	26	-.09689
975	.48572	2.39094	31	-.07549
976	.84073	3.55509	32	-.00068

Table 11.--Residual Data for White River at Indianapolis, Ind.--Continued

Measurement	Gage height (ft) log	Measured discharge ft^3/s log	Time[1] (days)	Residual[2] log
977	0.93651	3.83378	29	0.06176
978	.53656	2.56467	33	-.11327
979	.90849	3.74663	25	.03630
980	.75128	3.33041	31	-.00615
981	.61278	2.96895	30	.02573
982	.81954	3.56229	37	.05669
983	.53782	2.70243	24	.01967
984	1.06108	3.89597	11	-.13798
985	1.10687	4.04336	16	-.08288
986	.81690	3.53908	8	.03980
987	.62325	2.98408	31	.00785
988	.49554	2.50786	25	-.00237
989	.53782	2.69108	29	.00832
990	.70329	3.23805	36	.02861
991	.63043	3.01284	34	.01436
992	.55023	2.76268	31	.03335
993	.86153	3.56820	14	-.03592
994	.81757	3.50651	41	.00564
995	.61278	2.98632	29	.04310
996	.75511	3.34242	31	-.00397
997	1.18013	4.30320	3	.03279
998	.64738	3.12057	27	.07069
999	.52244	2.57171	33	-.05099
1000	.56703	2.82413	30	.03419
1001	.47129	2.42813	30	.02918
1002	.46835	2.44404	33	.05935
1003	.48572	2.47422	26	.00779
1005	.46687	2.37658	29	-.00087
1006	.58433	2.83251	29	-.01727
1007	.49693	2.50786	29	-.00842
1008	.68395	3.13354	33	-.02225
1009	.82866	3.56467	27	.03736
1010	.56110	2.75891	30	-.00994
1011	.58995	2.86034	33	-.00835
1012	.74507	3.28330	30	-.03726
1013	.71181	3.20683	1	-.02576
1014	.50515	2.49415	26	-.05742
1015	.50651	2.51983	52	-.03747
1016	.53403	2.59770	12	-.07050

Table 11.--Residual Data for White River at Indianapolis, Ind.--Continued

Measurement	Gage height (ft) log	Measured discharge ft^3/s log	Time[1] (days)	Residual[2] log
1017	1.00346	3.93802	34	0.02300
1018	.83187	3.58546	55	.05056
1019	.84572	3.61909	31	.05166
1020	.59218	2.94300	32	.06687
1022	.60423	2.91062	29	-.00509
1023	.46090	2.37475	34	.02699
1024	.47276	2.39620	30	-.00979

[1] The time elapsed since previous discharge measurement.

[2] Residual = observed discharge (log) - predicted discharge (log).

Table 12.--Summary of the autocovariance analysis

Branch(Br), Creek(Cr), Saint(St.) Fork(Fk), Middle(M), Near(nr), River(R), North(N), South(S), East(E), West(W)

Station number	Station name	RHO[a]	Measurement variance (log base 10)^2	Process variance (log base 10)^2	Period analyzed (days)[d]
03274650	Whitewater R nr Economy	0.987	0.00047	0.0778	4,786
03274750	Whitewater R nr Hagerstown	.982	.00047	.0271	4,203
03274950	Little Williams Cr at Connersville	.984	.00047	.0660	1,999
03275000	Whitewater R nr Alpine	.985	.00047	.0058	1,821
03275600	E Fk Whitewater R at Abington	.998	.00047	.0058	2,029
03276500	Whitewater R at Brookville	.981	.00047	.0009	2,725
03276700	South Hogan Cr nr Dillsboro	.960	.00047	.0111	3,848
03291780	Indian-Kentuck Cr nr Canaan	.990	.00047	.0198	3,142
03294000	Silver Cr nr Sellersburg	.938	.00047	.0062	5,263
03302220	Buck Cr nr New Middleton	.988	.00047	.0208	2,471
03302300	Little Indian Ck Galena	.992	.00047	.0355	2,345
03302500	Indian Cr nr Corydon	.969	.00047	.0050	2,968
03302680	W Fk Blue R at Salem	.987	.00047	.0235	3,235
03302800	Blue R at Fredericksburg	.984	.00047	.0018	2,576
03303000	Blue R nr White Cloud	.978	.00047	.0011	3,247
03303300	Middle Fk Anderson R at Bristow	.980	.00047	.0169	2,575
03303400	Crooked Cr nr Santa Claus	.993	.00047	.0715	3,535
03322100	Pigeon Cr at Evansville	.964	.00047	.0032	4,513
03322500	Wabash R nr New Corydon	.985	.00047	.0025	6,204
03322900	Wabash R at Linn Grove	.967	.00047	.0041	6,067
03324000	Little R nr Huntington	.968	.00047	.0005	2,255
03324200	Salamonie R at Portland	.949	.00047	.0117	3,826
03324300	Salamonie R nr Warren	.976	.00047	.0266	4,389
03325000	Wabash R at Wabash	.946	.00047	.0004	11,244
03325311	Little Mississinewa R at Union City	.983[b]	.00047	.0317	
03325500	Mississinewa R nr Ridgeville	.973	.00047	.0095	6,495
03326070	Big Lick Cr nr Hartford City	.942	.00047	.0507	4,058
03326500	Mississinewa R at Marion	.976	.00047	.0022	6,756
03327500	Wabash River at Peru	.971	.00017	.0007	14,271
03327520	Pipe Cr nr Bunker Hill	.995	.00047	.0091	4,871
03328000	Eel R at North Manchester	.991	.00047	.0023	4,319
03328430	Weesau Cr nr Deedsville	.991	.00047	.0331	2,975
03328500	Eel R nr Logansport	.978	.00017	.0014	14,386
03329000	Wabash R at Logansport	.971	.00017	.0004	7,366
03329400	Rattlesnake Cr nr Patton	.989	.00047	.0482	5,146
03329700	Deer Cr nr Delphi	.992	.00047	.0051	8,928
03330500	Tippecanoe R at Oswego	.959	.00047	.0115	6,533
03331110	Walnut Cr nr Warsaw	.980	.00047	.0070	4,111
03331500	Tippecanoe R nr Ora	.679	.00047	.0014	7,993
03333000	Tippecanoe R nr Delphi	.977	.00031	.0004	9,080

Table 12.--Summary of the autocovariance analysis--Continued

Station number	Station name	RHO[a]	Measurement variance (log base 10)^2	Process variance (log base 10)^2	Period analyzed (days)[d]
03333450	Wildcat Cr nr Jerome	0.981	0.00047	0.0379	4,340
03333600	Kokomo Cr nr Kokomo	.985	.00068	.0638	4,757
03333700	Wildcat Cr nr Kokomo	.980	.00068	.0013	5,248
03334500	S Fk Wildcat Cr nr Lafayette	.994	.00047	.0256	10,309
03335000	Wildcat Cr nr Lafayette	.994	.00017	.0047	5,867
03335500	Wabash R at Lafayette	.963	.00047	.0003	8,243
03335690	Mud Pine Cr nr Oxford	.979	.00068	.0148	4,186
03335700	Big Pine Cr nr Williamsport	.989	.00047	.0281	5,349
03336000	Wabash R at Covington	.985	.00047	.0005	8,246
03339108	E Fk Coal Cr nr Hillsboro	.971	.00047	.0100	4,278
03339500	Sugar Cr at Crawfordsville	.959	.00047	.0010	8,545
03340500	Wabash R at Montezuma	.987	.00047	.0012	8,249
03340800	Big Raccoon Cr nr Fincastle	.986	.00047	.0182	4,302
03341300	Big Raccoon Cr at Coxville	.975	.00047	.0032	8,289
03341500	Wabash R at Terre Haute	.991	.00047	.0011	8,252
03342000	Wabash R at Riverton	.970	.00047	.0002	8,268
03342100	Busseron Cr nr Hymera	.441	.00047	.0399	2,039
03342150	West Fk Busseron Ck nr Hymera	.988	.00047	.1103	1,750
03342244	Mud Ck nr Cass	.985[b]	.00047	.0654	
03342300	Busseron Cr nr Sullivan	.989	.00047	.0143	2,855
03342500	Busseron Cr nr Carlisle	.981	.00047	.0025	4,298
03343000	Wabash R at Vincennes	.973	.00047	.0004	5,108
03347000	White R at Muncie	.976	.00047	.0101	6,477
03347500	Buck Cr nr Muncie	.982	.00047	.0033	5,911
03348000	White R at Anderson	.550	.00047	.0025	3,209
03348020	Killbuck Cr nr Gaston	.979	.00047	.0246	4,568
03348350	Pipe Cr at Frankton	.969	.00047	.0046	5,307
03349000	White R at Noblesville	.942	.00047	.0017	3,670
03350700	Stony Cr nr Noblesville	.968	.00047	.0063	1,850 - 5789[c]
03351000	White R nr Nora	.957	.00047	.0007	5,180
03351310	Crooked Cr at Indianapolis	.979	.00047	.0368	1,988
03351400	Sugar Cr nr Middletown	.983	.00047	.0317	5,022
03351500	Fall Cr nr Fortville	.979	.00047	.0009	5,752
03352500	Fall Cr at Millersville	.981	.00047	.0011	4,111
03353000	White R at Indianapolis	.956	.00047	.0039	3,892
03353120	Pleasant Run at Indianapolis	.961	.00047	.0127	2,276
03353180	Bean Cr at Indianapolis	.966	.00047	.0159	1,390
03353200	Eagle Cr at Zionsville	.981	.00047	.0428	3,299
03353500	Eagle Cr at Indianapolis	.980[b]	.00047	.0239	
03353600	Little Eagle Cr at Speedway	.965	.00047	.0172	1,387
03353620	Lick Cr at Indianapolis	.983	.00047	.0164	2,695
03353700	W Fk Whitelick Cr at Danville	.984	.00047	.0229	3,127

Table 12.--Summary of the autocovariance analysis--Continued

Station number	Station name	RHO[a]	Measurement variance (log base 10)^2	Process variance (log base 10)^2	Period analyzed (days)[d]
03353800	White Lick Cr at Mooresville	0.988	0.00047	0.0193	4,934
03354000	White R nr Centerton	.965	.00047	.0016	8,195
03354500	Beanblossom Cr at Beanblossom	.958	.00047	.0179	1,874
03357350	Plum Cr nr Bainbridge	.556	.00047	.0270	2,106
03357500	Big Walnut Cr nr Reelsville	.992	.00047	.0107	4,171
03358000	Mill Cr nr Cataract	.986	.00047	.0142	5,038
03360000	Eel R at Bowling Green	.976	.00047	.0023	6,144
03360500	White R at Newberry	.977	.00047	.0005	5,810
03361000	Big Blue R at Carthage	.967	.00047	.0009	11,554
03361500	Big Blue R at Shelbyville	.971	.00047	.0021	3,271
03361650	Sugar Cr at New Palestine	.982	.00047	.0036	5,001
03361850	Buck Cr at Acton	.966	.00047	.0135	1,965
03362000	Youngs Cr nr Edinburgh	.981	.00047	.0069	2,757
03362500	Sugar Cr nr Edinburgh	.971	.00047	.0031	4,998
03363000	Driftwood R nr Edinburgh	.989	.00047	.0025	4,783
03363500	Flatrock R at St. Paul	.968	.00047	.0014	8,248
03363900	Flatrock R at Columbus	.991	.00047	.0089	3,593
03364000	E Fk White R at Columbus	.963	.00047	.0010	7,293
03364200	Haw Cr nr Clifford	.977	.00047	.0167	2,235
03364500	Clifty Cr at Hartsville	.976	.00047	.0218	3,757
03365000	Sand Cr nr Brewersville	.995	.00047	.0099	4,258
03365500	E Fk White R at Seymour	.981	.00047	.0015	6,939
03366200	Harberts Cr nr Madison	.447	.00047	.0184	4,231
03366500	Muscatatuck R nr Deputy	.977	.00047	.0053	3,008
03368000	Brush Cr nr Nebraska	.990	.00047	.0854	3,634
03369000	Vernon Fk Muscatatuck nr Butlerville	.965	.00047	.0173	2,009
03369500	Vernon Fk Muscatatuck at Vernon	.994	.00047	.0203	3,564
03371500	E Fk White R nr Bedford	.979	.00047	.0013	8,626
03371520	Back Cr at Leesville	.989	.00047	.0079	2,022
03372300	Stephens Cr nr Bloomington	.984	.00047	.0212	4,284
03373500	E Fk White R at Shoals	.969	.00047	.0002	8,498
03373700	Lost R nr W Baden Springs	.975	.00047	.0049	5,203
03374000	White R at Petersburg	.989	.00047	.0013	7,533
03374455	Patoka R nr Hardinsburg	.992	.00047	.0367	5,433
03375500	Patoka R at Jasper	.375	.00047	.0119	5,140
03375800	Hall Cr nr St. Anthony	.981	.00047	.0305	2,439
03376350	S Fk Patoka nr Spurgeon	.987	.00047	.0104	5,319
03376500	Patoka R nr Princeton	.967	.00047	.0029	8,272
03377500	Wabash R at Mount Carmel, Ill.	.964	.00047	.0009	8,282
03378550	Big Cr nr Wadesville	.985	.00047	.0517	5,403
04093000	Deep R at Hobart	.980	.00047	.0049	4,883
04093500	Burns Ditch at Gary	.993	.00047	.0163	8,732

Table 12.--Summary of the autocovariance analysis--Continued

Station number	Station name	RHO[a]	Measurement variance (log base 10)^2	Process variance (log base 10)^2	Period analyzed (days)[d]
04094000	Little Calument R at Porter	0.983	0.00047	0.0029	6,222
04094500	Salt Cr nr McCool	.991	.00047	.0082	3,678
04095300	Trail Cr at Michigan City	.976	.00047	.0008	3,444
04096100	Galena R nr LaPorte	.967	.00047	.0023	4,786
04097970	Lime Lake Outlet at Panama	.993	.00047	.0115	2,122
04099510	Pigeon Cr nr Angola	.968	.00047	.0097	2,812
04099750	Pigeon R nr Scott	.984	.00047	.0005	5,249
04099808	Little Elkhart R at Middlebury	.980[b]	.00047	.0013	
04099850	Pine Cr nr Elkhart	.940[b]	.00047	.0013	
04100222	N Br Elkhart R at Cosperville	.992	.00047	.0047	3,983
04100252	Forker Cr nr Burr Oak	.983	.00047	.0361	4,915
04100295	Rimmel Br nr Albion	.540[b]	.00047	.0164	
04100465	Turkey Cr at Syracuse	.978	.00047	.0097	2,732
04100500	Elkhart R at Goshen	.966	.00047	.0011	6,581
04101000	St. Joseph R at Elkhart	.974	.00047	.0007	9,374
04177720	Fish Cr at Hamilton	.966	.00047	.0071	3,936
04178000	St. Joseph R nr Newville	.975	.00047	.0019	6,993
04180000	Cedar Cr nr Cedarville	.972	.00047	.0021	8,611
04181500	St. Marys R at Decatur	.970	.00047	.0008	7,827
04182000	St. Marys R nr Fort Wayne	.620	.00047	.0030	3,647
04182590	Harber Ditch at Fort Wayne	.955	.00047	.0606	2,696
04183000	Maumee R at New Haven	.964	.00047	.0001	5,370
05515000	Kankakee R nr North Liberty	.969	.00047	.0009	5,285
05515400	Kingsbury Cr nr LaPorte	.961	.00047	.0018	1,672
05515500	Kankakee R at Davis	.971	.00047	.0001	4,479
05516500	Yellow R at Plymouth	.981	.00047	.0032	5,436
05517000	Yellow R at Knox	.972	.00047	.0007	10,141
05517500	Kankakee R at Dunns Bridge	.991	.00030	.0009	12,446
05517530	Kankakee R nr Kouts	.972	.00047	.0002	2,832
05517890	Cobb Ditch nr Kouts	.975[b]	.00070	.0147	
05518000	Kankakee R at Shelby	.982	.00007	.0004	6,250
05519000	Singleton ditch at Schneider	.965	.00067	.0041	2,417
05521000	Iroquois R at Rosebud	.996	.00067	.0208	6,630
05522000	Iroquois R nr North Marion	.985	.00067	.0045	6,726
05522500	Iroquois R at Rennsselaer	.985	.00047	.0073	7,238
05523000	Bice ditch nr South Marion	.978	.00067	.0152	6,089
05524500	Iroquois R nr Foresman	.980	.00047	.0078	9,823
05536190	Hart ditch at Munster	.975	.00067	.0056	14,600
05536195	Little Calumet R at Munster	.989	.00067	.0104	4,760

[a] one-day autocorrelation coefficient
[b] denotes estimated values
[c] denotes highwater measurements only
[d] total number of days between first and last measurements used in rating curve analysis

Table 13.--Selected results of K-CERA analysis

Indentification	790	Current operation	810	823	850	900	1000
	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
			Budget in thousands of 1983 dollars				
Average per station	27.7	25.3	24.0	22.9	21.4	19.4	16.8
03274650	39.1 [31.4] (9)	39.1 [31.4] (9)	33.3 [26.8] (12)	29.4 [23.6] (15)	27.4 [22.0] (17)	24.4 [19.6] (21)	20.1 [16.2] (30)
03274750	16.7 [7.0] (9)	16.7 [7.0] (9)	14.0 [6.1] (12)	12.3 [5.4] (15)	11.4 [5.1] (17)	10.1 [4.6] (21)	8.3 [3.8] (30)
03274950	40.9 [32.6] (9)	40.9 [32.6] (9)	35.4 [27.7] (12)	31.7 [24.5] (15)	29.7 [22.8] (17)	26.7 [20.2] (21)	22.3 [16.6] (30)
03275000	12.9 [8.8] (9)	12.9 [8.8] (9)	12.9 [8.8] (9)	12.2 [8.4] (10)	12.9 [8.8] (9)	12.2 [8.4] (10)	11.2 [7.7] (12)
03275600	21.5 [4.0] (8)	20.1 [3.7] (9)	21.5 [4.0] (8)	21.5 [4.0] (8)	21.5 [4.0] (8)	20.1 [3.7] (9)	18.0 [3.3] (11)
03276500	17.6 [5.6] (4)	10.9 [4.0] (9)	17.6 [5.6] (4)	17.6 [5.6] (4)	17.6 [5.6] (4)	15.4 [5.1] (5)	12.6 [4.4] (7)
03276700	28.8 [15.6] (13)	28.1 [17.9] (9)	21.7 [14.3] (16)	20.0 [13.2] (19)	19.0 [12.6] (21)	17.5 [11.6] (25)	15.0 [10.0] (34)
03291780	34.9 [9.5] (21)	56.4 [17.1] (9)	33.2 [9.0] (23)	31.7 [8.5] (25)	30.4 [8.2] (27)	27.3 [7.3] (33)	24.2 [6.5] (41)
03294000	21.8 [13.5] (13)	25.6 [15.1] (9)	20.5 [12.9] (15)	19.4 [12.3] (17)	18.5 [11.8] (19)	16.2 [10.5] (25)	14.2 [9.3] (33)
03302220	41.9 [14.8] (13)	50.7 [19.2] (9)	38.9 [13.4] (15)	36.4 [12.4] (17)	34.4 [11.5] (19)	29.8 [9.8] (25)	25.8 [8.3] (33)

Table 13.--Selected results of K-CERA analysis--Continued

		Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)					
			Budget in thousands of 1983 dollars				
Indentification	790	Current operation	810	823	850	900	1000
03302300	30.5 [13.4] (13)	37.2 [16.7] (9)	28.3 [12.3] (15)	26.5 [11.5] (17)	25.0 [10.9] (19)	21.7 [9.3] (25)	18.8 [8.0] (33)
03302500	37.1 [10.1] (13)	45.2 [12.1] (9)	34.3 [9.3] (15)	32.1 [8.7] (17)	30.3 [8.3] (19)	26.2 [7.2] (25)	22.7 [6.2] (33)
03302680	22.1 [13.8] (13)	26.6 [16.8] (9)	20.5 [12.8] (15)	19.2 [12.0] (17)	18.2 [11.3] (19)	15.8 [9.7] (25)	13.7 [8.4] (33)
03302800	19.0 [4.1] (16)	26.1 [5.6] (9)	19.0 [4.1] (16)	19.0 [4.1] (16)	19.0 [4.1] (16)	17.3 [3.8] (19)	14.6 [3.2] (26)
03303000	25.3 [6.9] (3)	14.2 [4.6] (9)	31.7 [7.8] (2)	25.3 [6.9] (3)	19.2 [5.8] (5)	16.1 [5.1] (7)	12.8 [4.3] (11)
03303300	28 [12.9] (16)	37.2 [17.4] (9)	28.0 [12.9] (16)	28.0 [12.9] (16)	28.0 [12.9] (16)	25.7 [11.9] (19)	22.0 [10.1] (26)
03303400	40.9 [16.9] (16)	55.5 [24.4] (9)	40.8 [16.9] (16)	40.8 [16.9] (16)	40.8 [16.9] (16)	37.3 [15.2] (19)	31.6 [12.7] (26)
03322100	29.1 [23.1] (16)	37.4 [29.6] (9)	29.0 [23.1] (16)	29.0 [23.1] (16)	29.0 [23.1] (16)	29.0 [23.1] (16)	25.0 [19.9] (22)
03322500	32.9 [19.2] (8)	31.0 [18.1] (9)	31.0 [18.1] (9)	28.0 [16.3] (11)	24.8 [14.3] (14)	21.8 [12.6] (18)	18.5 [10.6] (25)
03322900	20.7 [10.7] (8)	19.5 [10.2] (9)	19.5 [10.2] (9)	17.7 [9.4] (11)	15.8 [8.5] (14)	13.9 [7.6] (18)	11.8 [6.5] (25)
03324000	18.1 [3.8] (8)	17.0 [3.7] (9)	18.1 [3.8] (8)	18.1 [3.8] (8)	18.1 [3.8] (8)	16.1 [3.6] (10)	14.6 [3.3] (12)

Table 13.--Selected results of K-CERA analysis--Continued

		Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)					
			Budget in thousands of 1983 dollars				
Indentification	790	Current operation	810	823	850	900	1000
03324200	35.1 [21.0] (8)	33.2 [20.2] (9)	33.3 [20.2] (9)	30.4 [18.9] (11)	27.2 [17.2] (14)	24.1 [15.5] (18)	20.6 [13.4] (25)
03324300	32.5 [24.2] (8)	30.8 [22.9] (9)	30.8 [22.9] (9)	28.0 [20.8] (11)	25.0 [18.5] (14)	22.1 [16.4] (18)	18.7 [13.8] (25)
03325000	24.2 [5.4] (2)	9.3 [3.9] (9)	15.2 [4.7] (4)	13.2 [4.5] (5)	13.2 [4.5] (5)	11.8 [4.3] (6)	10.0 [4.0] (8)
03325311	29.0 [22.7] (8)	27.4 [21.4] (9)	27.4 [21.4] (9)	24.8 [19.3] (11)	22.0 [17.1] (14)	19.4 [15.0] (18)	16.5 [12.7] (25)
03325500	27.6 [15.1] (8)	26.1 [14.4] (9)	26.1 [14.4] (9)	23.6 [13.2] (11)	21.0 [11.8] (14)	18.5 [10.4] (18)	15.7 [8.9] (25)
03326070	49.0 [45.5] (8)	47.3 [44.0] (9)	47.3 [44.0] (9)	44.4 [41.4] (11)	40.7 [38.0] (14)	36.8 [34.4] (18)	31.9 [29.7] (25)
03326500	22.3 [7.0] (8)	21.0 [6.7] (9)	22.3 [7.0] (8)	22.3 [7.0] (8)	22.3 [7.0] (8)	20.0 [6.3] (10)	18.2 [5.9] (12)
03327500	17.1 [5.8] (3)	8.8 [4.0] (9)	12.4 [5.0] (5)	12.4 [5.0] (5)	14.2 [5.4] (4)	12.4 [5.0] (5)	10.2 [4.5] (7)
03327520	16.1 [6.9] (8)	15.1 [6.5] (9)	16.1 [6.9] (8)	16.1 [6.9] (8)	16.1 [6.9] (8)	14.3 [6.1] (10)	12.5 [5.3] (13)
03328000	24.4 [9.2] (2)	10.0 [4.5] (9)	16.0 [6.6] (4)	16.0 [6.6] (4)	12.6 [5.4] (6)	11.6 [5.1] (7)	10.0 [4.5] (9)
03328430	25.6 [17.4] (8)	24.1 [16.3] (9)	25.6 [17.4] (8)	25.6 [17.4] (8)	25.6 [17.4] (8)	22.9 [15.4] (10)	20.0 [13.4] (13)

Table 13.--Selected results of K-CERA analysis--Continued

	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
			Budget in thousands of 1983 dollars				
Indentification	790	Current operation	810	823	850	900	1000
03328500	9.4 [5.5] (8)	8.8 [5.2] (9)	9.4 [5.5] (8)	9.4 [5.5] (8)	9.4 [5.5] (8)	8.3 [5.0] (10)	7.3 [4.5] (13)
03329000	7.9 [3.4] (7.5)	6.2 [3.0] (9)	10.3 [3.9] (4)	8.9 [3.7] (5)	8.9 [3.6] (5)	7.9 [3.4] (6)	7.2 [3.3] (7)
03329400	25.4 [21.3] (9)	25.4 [21.2] (9)	23.0 [19.2] (11)	21.2 [17.6] (13)	19.6 [16.2] (15)	17.4 [14.3] (19)	15.2 [12.5] (25)
03329700	43.6 [11.2] (4)	27.0 [6.6] (9)	34.2 [8.5] (6)	28.9 [7.1] (8)	23.0 [5.6] (12)	20.3 [5.0] (15)	17.8 [4.4] (19)
03330500	23.8 [19.4] (8)	22.7 [18.6] (9)	23.8 [19.4] (8)	23.8 [19.4] (8)	23.8 [19.4] (8)	21.8 [17.9] (10)	20.3 [16.7] (12)
03331110	19.9 [11.7] (8)	18.7 [11.1] (9)	19.8 [11.7] (8)	19.8 [11.7] (8)	19.8 [11.7] (8)	17.8 [10.5] (10)	16.3 [9.6] (12)
03331500	7.9 [5.1] (8)	7.5 [4.8] (9)	7.9 [5.1] (8)	7.9 [5.1] (8)	7.9 [5.1] (8)	7.1 [4.6] (10)	6.3 [4.1] (13)
03333000	17.6 [4.7] (3)	8.6 [3.0] (9)	17.6 [4.7] (3)	14.5 [4.2] (4)	10.0 [3.4] (7)	11.1 [3.6] (6)	8.6 [3.0] (9)
03333450	27.9 [25.9] (8)	26.4 [24.6] (9)	25.1 [23.3] (10)	24.0 [22.3] (11)	21.3 [19.8] (14)	18.8 [17.4] (18)	16.2 [15.0] (24)
03333600	32.5 [30.2] (8)	30.7 [28.4] (9)	29.2 [27.0] (10)	27.8 [25.7] (11)	24.6 [22.6] (14)	21.7 [19.9] (18)	18.8 [17.1] (24)
03333700	31.6 [5.9] (8)	29.7 [5.5] (9)	27.3 [5.2] (10)	25.7 [4.9] (11)	22.0 [4.3] (14)	18.8 [3.8] (18)	15.8 [3.2] (24)

Table 13.--Selected results of K-CERA analysis--Continued

	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
			Budget in thousands of 1983 dollars				
Indentification	790	Current operation	810	823	850	900	1000
03334500	22.7 [11.7] (9)	22.6 [11.7] (9)	20.0 [10.4] (11)	18.0 [9.6] (13)	16.5 [8.8] (15)	14.4 [7.8] (19)	12.2 [6.7] (25)
03335000	18.9 [8.0] (4)	11.5 [5.2] (9)	14.7 [6.4] (6)	12.3 [5.5] (8)	9.8 [4.5] (12)	8.6 [4.0] (15)	7.6 [3.6] (19)
03335500	8.1 [3.3] (5)	5.8 [2.7] (9)	8.1 [3.3] (5)	8.1 [3.3] (5)	11.3 [3.7] (3)	9.3 [3.4] (4)	7.3 [3.1] (6)
03335690	30.0 [16.9] (9)	30.0 [16.9] (9)	27.0 [15.2] (11)	24.7 [14.0] (13)	23.0 [12.9] (15)	20.3 [11.4] (19)	17.6 [9.9] (25)
03335700	34.1 [23.0] (9)	34.1 [23.0] (9)	30.8 [20.7] (11)	28.3 [19.0] (13)	26.3 [17.5] (15)	23.3 [15.5] (19)	20.2 [13.3] (25)
03336000	8.0 [2.9] (8)	7.4 [2.7] (9)	8.0 [2.9] (8)	8.0 [2.9] (8)	7.4 [2.7] (9)	5.9 [2.3] (13)	4.6 [1.9] (20)
03339108	19.1 [11.9] (16)	25.2 [15.6] (9)	19.1 [11.9] (16)	19.1 [11.9] (16)	18.6 [11.5] (17)	16.7 [10.4] (21)	14.5 [9.0] (28)
03339500	36.8 [6.5] (8)	34.5 [6.1] (9)	36.8 [6.5] (8)	36.8 [6.5] (8)	34.5 [6.1] (9)	28.0 [5.2] (13)	22.2 [4.3] (20)
03340500	39.5 [11.4] (1)	7.9 [3.9] (9)	17.7 [6.5] (3)	17.7 [6.5] (3)	14.2 [5.7] (4)	12.0 [5.2] (5)	10.5 [4.8] (6)
03340800	16.8 [11.3] (16)	22.5 [15.1] (9)	16.8 [11.2] (16)	16.8 [11.2] (16)	16.3 [10.9] (17)	14.7 [9.8] (21)	12.7 [8.5] (28)
03341300	12.8 [6.3] (16)	16.9 [8.1] (9)	12.8 [6.3] (16)	12.8 [6.3] (16)	12.4 [6.1] (17)	11.2 [5.5] (21)	9.7 [4.8] (28)

Table 13.--Selected results of K-CERA analysis--Continued

	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
			Budget in thousands of 1983 dollars				
Indentification	790	Current operation	810	823	850	900	1000
03341500	55.9 [22.7] (1)	11.8 [3.5] (9)	27.6 [6.8] (3)	27.6 [6.8] (3)	22.2 [5.6] (4)	18.7 [4.9] (5)	16.2 [4.4] (6)
03342000	35.0 [5.0] (1)	6.5 [2.0] (9)	15.1 [2.9] (3)	15.1 [2.9] (3)	12.0 [2.6] (4)	10.1 [2.4] (5)	8.8 [2.3] (6)
03342100	52.6 [49.5] (8)	52.0 [49.5] (9)	52.6 [49.5] (8)	51.4 [48.9] (10)	50.6 [48.6] (12)	49.7 [48.1] (15)	48.4 [47.3] (21)
03342150	42.4 [36.6] (8)	40.0 [34.3] (9)	42.4 [36.6] (8)	37.9 [32.4] (10)	34.5 [29.4] (12)	30.7 [26.0] (15)	25.8 [21.7] (21)
03342244	35.8 [31.6] (8)	33.9 [29.6] (9)	35.8 [31.6] (8)	32.2 [28.1] (10)	29.4 [25.6] (12)	26.3 [22.7] (15)	22.2 [19.0] (21)
03342300	23.6 [12.8] (8)	22.1 [12.0] (9)	23.6 [12.8] (8)	20.9 [11.4] (10)	19.0 [10.3] (12)	16.9 [9.2] (15)	14.1 [7.7] (21)
03342500	23.5 [6.9] (8)	22.0 [6.5] (9)	23.5 [6.9] (8)	20.8 [6.2] (10)	18.8 [5.7] (12)	16.7 [5.1] (15)	14.0 [4.4] (21)
03343000	49.5 [18.0] (1)	10.2 [3.2] (9)	24.0 [5.4] (3)	24.0 [5.4] (3)	19.2 [4.7] (4)	16.2 [4.2] (5)	14.0 [3.9] (6)
03347000	19.2 [14.8] (8)	17.9 [14.0] (9)	18.0 [14.0] (9)	16.3 [12.8] (11)	14.4 [11.4] (14)	12.7 [10.1] (18)	10.8 [8.6] (25)
03347500	15.4 [7.8] (8)	14.5 [7.4] (9)	14.5 [7.4] (9)	13.1 [6.7] (11)	11.6 [5.9] (14)	10.2 [5.3] (18)	8.6 [4.5] (25)
03348000	18.1 [12.2] (4)	14.0 [11.6] (9)	15.6 [11.9] (6)	14.9 [11.8] (7)	14.0 [11.6] (9)	13.0 [11.4] (13)	12.2 [11.2] (19)

Table 13.--Selected results of K-CERA analysis--Continued

Indentification	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
			Budget in thousands of 1983 dollars				
	790	Current operation	810	823	850	900	1000
03348020	24.1 [21.8] (8)	22.9 [20.6] (9)	22.9 [20.6] (9)	20.9 [18.8] (11)	18.5 [16.6] (14)	16.4 [14.7] (18)	14.0 [12.5] (25)
03348350	23.6 [13.9] (4)	16.3 [10.5] (9)	19.6 [12.2] (6)	18.3 [11.6] (7)	16.3 [10.6] (9)	13.7 [9.0] (13)	11.4 [7.6] (19)
03349000	8.5 [7.1] (12)	8.5 [7.1] (12)	8.5 [7.1] (12)	8.5 [7.1] (12)	8.5 [7.1] (12)	8.5 [7.1] (12)	8.0 [6.8] (14)
03350700	21.9 [12.9] (9)	21.9 [12.9] (9)	21.9 [12.9] (9)	23.2 [13.5] (8)	19.9 [11.8] (11)	17.7 [10.5] (14)	15.2 [9.1] (19)
03351000	15.8 [4.6] (12)	15.8 [4.6] (12)	15.8 [4.6] (12)	15.8 [4.6] (12)	15.8 [4.6] (12)	15.8 [4.6] (12)	14.0 [4.3] (14)
03351310	42.9 [34.8] (5)	32.6 [26.4] (9)	28.4 [22.8] (12)	25.4 [20.3] (15)	22.5 [17.9] (19)	19.2 [15.2] (26)	15.8 [12.4] (38)
03351400	39.7 [30.1] (4)	27.4 [21.4] (9)	33.2 [26.0] (6)	30.9 [24.2] (7)	27.4 [21.4] (9)	22.9 [17.8] (13)	18.9 [14.6] (19)
03351500	14.8 [4.3] (9)	14.8 [4.3] (9)	14.8 [4.3] (9)	15.9 [4.5] (8)	13.1 [3.9] (11)	11.3 [3.5] (14)	9.5 [3.0] (19)
03352500	8.0 [3.8] (12)	8.0 [3.8] (12)	8.0 [3.8] (12)	8.0 [3.8] (12)	8.0 [3.8] (12)	8.0 [3.8] (12)	7.4 [3.6] (14)
03353000	10.8 [9.8] (12)	10.8 [9.8] (12)	10.8 [9.8] (12)	10.8 [9.8] (12)	10.8 [9.8] (12)	10.8 [9.8] (12)	10.1 [9.2] (14)
03353120	49.8 [24.4] (5)	37.8 [19.7] (9)	34.3 [18.2] (11)	32.9 [17.5] (12)	27.8 [15.0] (17)	23.9 [12.9] (23)	19.7 [10.6] (34)

Table 13.--Selected results of K-CERA analysis--Continued

Indentification	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
			Budget in thousands of 1983 dollars				
	790	Current operation	810	823	850	900	1000
03353180	35.2 [26.7] (5)	27.1 [21.2] (9)	24.6 [19.4] (11)	23.7 [18.6] (12)	20.0 [15.7] (17)	17.2 [13.5] (23)	14.2 [11.1] (34)
03353200	59.2 [36.7] (5)	43.8 [26.7] (9)	37.7 [22.7] (12)	33.6 [20.1] (15)	29.8 [17.6] (19)	25.3 [14.8] (26)	20.9 [12.2] (38)
03353500	26.2 [19.9] (9)	22.6 [14.3] (9)	27.7 [21.0] (8)	27.7 [21.0] (8)	23.8 [18.1] (11)	22.0 [16.6] (13)	17.3 [13.1] (21)
03353600	42.4 [27.3] (5)	32.3 [21.9] (9)	28.2 [19.3] (12)	25.3 [17.4] (15)	22.5 [15.6] (19)	19.3 [13.3] (26)	16.0 [11.0] (38)
03353620	37.6 [22.4] (5)	28.0 [16.5] (9)	25.3 [14.8] (11)	24.2 [14.1] (12)	20.2 [11.7] (17)	17.4 [10.0] (23)	14.3 [8.2] (34)
03353700	23.8 [11.2] (24)	41.7 [19.6] (9)	23.8 [11.2] (24)	23.8 [11.2] (24)	23.8 [11.2] (24)	23.2 [10.9] (25)	18.5 [8.8] (38)
03353800	15.7 [10.6] (16)	21.3 [14.3] (9)	15.7 [10.6] (16)	15.7 [10.6] (16)	15.7 [10.6] (16)	15.7 [10.6] (16)	13.3 [9.0] (22)
03354000	28 [10.1] (2)	13.0 [6.6] (9)	19.4 [8.5] (4)	19.4 [8.5] (4)	15.8 [7.5] (6)	14.7 [7.2] (7)	13.0 [6.6] (9)
03354500	34.4 [18.8] (16)	45.2 [24.1] (9)	34.4 [18.8] (16)	34.4 [18.8] (16)	33.4 [18.3] (17)	30.2 [16.6] (21)	26.2 [14.4] (28)
03357350	39.0 [37.4] (24)	43.7 [39.7] (9)	39.0 [37.4] (24)	39.0 [37.4] (24)	39.0 [37.4] (24)	38.8 [37.2] (25)	36.0 [35.0] (44)
03357500	24.4 [6.8] (16)	33.9 [9.6] (9)	24.4 [6.8] (16)	24.4 [6.8] (16)	23.6 [6.6] (17)	21.0 [5.9] (21)	17.9 [5.0] (28)

Table 13.--Selected results of K-CERA analysis--Continued

Indentification	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
			Budget in thousands of 1983 dollars				
	790	Current operation	810	823	850	900	1000
03358000	24.8 [10.0] (16)	33.8 [13.7] (9)	24.8 [10.0] (16)	24.8 [10.0] (16)	24.8 [10.0] (16)	24.8 [10.0] (16)	20.9 [8.4] (22)
03360000	18.8 [6.6] (10)	19.8 [6.9] (9)	17.1 [6.1] (12)	17.1 [6.1] (12)	15.8 [5.7] (14)	15.3 [5.5] (15)	14.4 [5.2] (17)
03360500	27.8 [5.7] (2)	12.0 [3.2] (9)	18.7 [4.4] (4)	18.7 [4.4] (4)	15.0 [4.0] (6)	13.8 [3.6] (7)	12.0 [3.2] (9)
03361000	10.2 [5.1] (8)	9.6 [4.9] (9)	10.2 [5.1] (8)	10.2 [5.1] (8)	10.2 [5.1] (8)	9.6 [4.9] (9)	8.7 [4.5] (11)
03361500	12.9 [7.4] (8)	12.1 [7.1] (9)	12.9 [7.4] (8)	12.9 [7.4] (8)	12.9 [7.4] (8)	12.1 [7.1] (9)	10.9 [6.5] (11)
03361650	17.0 [6.1] (16)	23.5 [8.2] (9)	17.0 [6.1] (16)	17.0 [6.1] (16)	16.4 [5.9] (17)	14.7 [5.3] (21)	12.8 [4.6] (27)
03361850	28.8 [20.2] (8)	27.3 [19.2] (9)	28.8 [20.2] (8)	28.8 [20.2] (8)	27.3 [19.2] (9)	22.9 [16.3] (13)	19.0 [13.6] (19)
03362000	21.6 [8.1] (17)	30.5 [11.3] (9)	19.8 [7.4] (20)	18.4 [6.9] (23)	17.6 [6.6] (25)	16.3 [6.2] (29)	14.2 [5.4] (38)
03362500	12.8 [8.9] (8)	12.1 [8.4] (9)	12.8 [8.8] (8)	12.8 [8.8] (8)	12.8 [8.8] (8)	12.1 [8.4] (9)	10.9 [7.8] (11)
03363000	59 [18.4] (1)	11.9 [5.3] (9)	21.8 [8.0] (4)	14.3 [6.0] (7)	11.9 [5.3] (9)	9.2 [4.4] (13)	6.5 [3.4] (22)
03363500	12.8 [6.2] (8)	12.0 [5.9] (9)	12.8 [6.2] (8)	12.8 [6.2] (8)	12.8 [6.2] (8)	12.0 [5.9] (9)	10.9 [5.5] (11)

Table 13.--Selected results of K-CERA analysis--Continued

Indentification	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
			Budget in thousands of 1983 dollars				
	790	Current operation	810	823	850	900	1000
03363900	13.2	12.4	13.2	13.2	13.2	12.4	11.8
	[8.8]	[8.3]	[8.8]	[8.8]	[8.8]	[8.3]	[7.9]
	(8)	(9)	(8)	(8)	(8)	(9)	(10)
03364000	8.6	8.0	8.6	8.6	8.6	8.6	9.2
	[5.6]	[5.3]	[5.6]	[5.6]	[5.6]	[5.6]	[5.9
	(8)	(9)	(8)	(8)	(8)	(8)	(7)
03364200	22.0	22.0	19.3	17.3	16.3	14.3	11.7
	[17.5]	[17.5]	[15.4]	[13.8]	[12.9]	[11.4]	[9.3]
	(9)	(9)	(12)	(15)	(17)	(22)	(33)
03364500	16.4	22.2	15.2	14.2	13.5	12.6	11.1
	[15.2]	[20.5]	[14.0]	[13.1]	[12.5]	[11.6]	[10.3]
	(17)	(9)	(20)	(23)	(25)	(29)	(37)
03365000	42.2	42.2	35.4	31.0	28.8	25.4	21.2
	[7.6]	[7.6]	[6.3]	[5.5]	[5.2]	[4.6]	[3.9]
	(9)	(9)	(12)	(15)	(17)	(21)	(29)
03365500	25.3	9.7	15.9	15.9	12.4	11.3	9.7
	[9.4]	[5.2]	[7.3]	[7.3]	[6.2]	[5.8]	[5.2]
	(2)	(9)	(4)	(4)	(6)	(7)	(9)
03366200	41.1	52.4	40.2	39.4	38.7	37.0	35.4
	[32.2]	[34.8]	[31.9]	[31.7]	[31.5]	[30.9]	[30.3]
	(21)	(9)	(23)	(25)	(27)	(33)	(41)
03366500	38	46.5	35.2	32.8	30.9	26.7	23.1
	[9.3]	[11.2]	[8.6]	[8.1]	[7.6]	[6.6]	[5.7]
	(13)	(9)	(15)	(17)	(19)	(25)	(33)
03368000	58.0	58.0	50.0	44.5	41.8	37.4	31.8
	[29.7]	[29.7]	[25.0]	[22.0]	[20.4]	[18.2]	[15.2]
	(9)	(9)	(12)	(15)	(17)	(21)	(29)
03369000	25.4	25.4	22.3	20.1	19.0	17.2	14.7
	[21.2]	[21.1]	[18.8]	[17.0]	[16.1]	[14.6]	[12.4]
	(9)	(9)	(12)	(15)	(17)	(21)	(29)
03369500	19.5	27.4	18.8	17.7	17.2	15.9	14.9
	[7.9]	[10.8]	[7.6]	[7.2]	[7.0]	[6.5]	[6.1]
	(16)	(9)	(17)	(19)	(20)	(23)	(26)

Table 13.--Selected results of K-CERA analysis--Continued

Indentification	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
			Budget in thousands of 1983 dollars				
	790	Current operation	810	823	850	900	1000
03371500	47.5 [13.5] (2)	16.5 [5.2] (9)	29.6 [8.1] (4)	29.6 [8.1] (4)	22.1 [6.4] (6)	19.8 [6.0] (7)	16.5 [5.2] (9)
03371520	48.5 [31.4] (8)	45.7 [29.1] (9)	48.5 [31.4] (8)	43.3 [27.4] (10)	39.5 [24.5] (12)	35.2 [21.4] (15)	29.7 [17.7] (21)
03372300	32.4 [13.7] (16)	43.5 [19.4] (9)	32.4 [13.7] (16)	32.4 [13.7] (16)	31.4 [13.3] (17)	28.2 [11.7] (21)	24.4 [10.0] (28)
03373500	32.6 [4.5] (2)	10.9 [2.3] (9)	19.6 [3.2] (4)	19.6 [3.2] (4)	14.6 [2.7] (6)	13.0 [2.6] (7)	10.9 [2.3] (9)
03373700	15.3 [7.8] (16)	20.4 [10.2] (9)	15.3 [7.8] (16)	15.3 [7.8] (16)	15.3 [7.8] (16)	14.0 [7.2] (19)	12.0 [6.2] (26)
03374000	30.3 [10.1] (1)	7.6 [3.7] (9)	14.7 [6.2] (3)	14.7 [6.2] (3)	12.3 [5.5] (4)	10.7 [4.9] (5)	9.6 [4.5] (6)
03374455	25.2 [12.4] (16)	34.0 [17.2] (9)	25.2 [12.4] (16)	25.2 [12.4] (16)	25.2 [12.4] (16)	23.1 [11.3] (19)	19.6 [9.6] (26)
03375500	31.4 [25.7] (16)	36.0 [26.6] (9)	31.4 [25.7] (16)	31.4 [25.7] (16)	31.4 [25.7] (16)	30.3 [25.5] (19)	28.7 [25.0] (26)
03375800	23.9 [16.8] (16)	31.8 [22.6] (9)	23.9 [16.8] (16)	23.9 [16.8] (16)	23.9 [16.8] (16)	22.0 [15.4] (19)	18.8 [13.1] (26)
03376350	15.8 [8.0] (16)	21.1 [10.8] (9)	15.8 [8.0] (16)	15.8 [8.0] (16)	15.8 [8.0] (16)	14.5 [7.4] (19)	12.4 [6.3] (26)
03376500	16.7 [6.8] (16)	22.1 [8.7] (9)	16.7 [6.8] (16)	16.7 [6.8] (16)	16.7 [6.8] (16)	16.7 [6.8] (16)	14.3 [5.9] (22)

Table 13.--Selected results of K-CERA analysis--Continued

	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
			Budget in thousands of 1983 dollars				
Indentification	790	Current operation	810	823	850	900	1000
03377500	35.8	8.7	17.4	17.4	14.4	12.5	11.1
	[4.9]	[1.6]	[2.4]	[2.4]	[2.2]	[2.0]	[1.9]
	(1)	(9)	(3)	(3)	(4)	(5)	(6)
03378550	30.6	40.8	30.6	30.6	30.6	30.6	26.0
	[19.2]	[26.2]	[19.2]	[19.2]	[19.2]	[19.2]	[16.2]
	(16)	(9)	(16)	(16)	(16)	(16)	(22)
04093000	19.8	19.8	19.8	19.8	17.3	15.4	12.5
	[9.8]	[9.7]	[9.8]	[9.8]	[8.9]	[8.2]	[6.9]
	(9)	(9)	(9)	(9)	(11)	(13)	(18)
04093500	18.4	18.4	18.4	18.4	16.1	14.4	11.7
	[10.6]	[10.6]	[10.6]	[10.6]	[9.5]	[8.7]	[7.3]
	(9)	(9)	(9)	(9)	11)	(13)	(18)
04094000	22.0	20.7	22.0	22.0	22.0	19.6	17.0
	[7.6]	[7.1]	[7.6]	[7.6]	[7.6]	[6.7]	[5.9]
	(8)	(9)	(8)	(8)	(8)	(10)	(13)
04094500	19.3	18.0	19.2	19.2	19.2	16.9	14.5
	[9.5]	[8.9]	[9.5]	[9.5]	[9.5]	[8.4]	[7.2]
	(8)	(9)	(8)	(8)	(8)	(10)	(13)
04095300	12.1	11.3	12.1	12.1	12.1	10.7	9.2
	[4.6]	[4.4]	[4.6]	[4.6]	[4.6]	[4.2]	[3.7]
	(8)	(9)	(8)	(8)	(8)	(10)	(13)
04096100	13.7	13.0	13.7	13.7	13.7	12.4	11.0
	[8.7]	[8.3]	[8.7]	[8.7]	[8.7]	[7.9]	[7.0]
	(8)	(9)	(8)	(8)	(8)	(10)	(13)
04097970	10.8	10.8	10.8	10.8	10.8	10.8	9.0
	[8.6]	[8.6]	[8.6]	[8.6]	[8.6]	[8.6]	[7.1]
	(9)	(9)	(9)	(9)	(9)	(9)	(13)
04099510	16.2	16.2	16.2	16.2	16.2	16.2	14.0
	[15.3]	[15.3]	[15.3]	[15.3]	[15.3]	[15.3]	[13.1]
	(9)	(9)	(9)	(9)	(9)	(9)	(13)
04099750	12.4	5.8	8.7	8.7	7.1	6.6	5.8
	[4.9]	[2.8]	[3.8]	[3.8]	[3.3]	[3.1]	[2.8]
	(2)	(9)	(4)	(4)	(6)	(7)	(9)

Table 13.--Selected results of K-CERA analysis--Continued

	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
			Budget in thousands of 1983 dollars				
Indentification	790	Current operation	810	823	850	900	1000
04099808	19.2 [9.1] (2)	9.1 [4.9] (9)	13.6 [6.9] (4)	13.6 [6.9] (4)	11.2 [5.8] (6)	10.3 [5.5] (7)	9.1 [4.9] (9)
04099850	17.4 [9.8] (2)	9.5 [7.0] (9)	12.9 [8.4] (4)	12.9 [8.4] (4)	11.0 [7.7] (6)	10.4 [7.5] (7)	9.5 [7.0] (9)
04100222	19.5 [12.3] (2)	9.0 [5.9] (9)	13.6 [8.8] (4)	13.6 [8.8] (4)	11.1 [7.2] (6)	10.3 [6.7] (7)	9.0 [5.9] (9)
04100252	29.0 [23.2] (9)	29.0 [23.2] (9)	29.0 [23.2] (9)	29.0 [23.2] (9)	29.0 [23.2] (9)	23.3 [18.4] (14)	20.0 [15.7] (19)
04100295	44.8 [33.8] (3)	34.9 [30.7] (9)	39.1 [32.0] (5)	39.1 [32.0] (5)	36.4 [31.2] (7)	33.8 [30.4] (11)	32.1 [29.7] (16)
04100465	37.4 [24.5] (2)	19.7 [13.6] (9)	28.3 [19.3] (4)	28.3 [19.3] (4)	23.7 [16.4] (6)	22.2 [15.3] (7)	19.7 [13.6] (9)
04100500	25.7 [10.0] (1)	8.7 [5.3] (9)	14.4 [7.5] (3)	14.4 [7.5] (3)	12.6 [6.9] (4)	11.4 [6.5] (5)	9.7 [5.9] (7)
04101000	13.9 [7.1] (1)	4.6 [3.8] (9)	13.9 [7.1] (1)	13.9 [7.1] (1)	9.3 [6.1] (2)	9.3 [6.1] (2)	9.3 [6.1] (2)
04177720	18.5 [13.5] (9)	18.4 [13.5] (9)	18.5 [13.5] (9)	18.5 [13.5] (9)	18.5 [13.5] (9)	18.5 [13.5] (9)	15.7 [11.6] (13)
04178000	12.2 [6.3] (9)	12.2 [6.3] (9)	12.2 [6.3] (9)	12.2 [6.3] (9)	12.2 [6.3] (9)	12.2 [6.3] (9)	10.1 [5.4] (13)
04180000	16.3 [6.9] (9)	16.3 [6.9] (9)	16.3 [6.9] (9)	16.3 [6.9] (9)	16.3 [6.9] (9)	16.3 [6.9] (9)	13.6 [5.9] (13)

Table 13.--Selected results of K-CERA analysis--Continued

Indentification	790	Current operation	Budget in thousands of 1983 dollars: 810	823	850	900	1000
	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
04181500	10.3 [4.8] (8)	9.5 [4.6] (9)	10.3 [4.8] (8)	10.3 [4.8] (8)	10.3 [4.8] (8)	14.2 [5.6] (5)	12.5 [5.3] (6)
04182000	14.9 [12.7] (9)	14.9 [12.7] (9)	14.9 [12.7] (9)	14.9 [12.7] (9)	14.9 [12.7] (9)	14.9 [12.7] (9)	13.7 [12.4] (13)
04182590	47.4 [44.5] (9)	47.4 [44.4] (9)	47.4 [44.5] (9)	47.4 [44.5] (9)	47.4 [44.5] (9)	40.0 [37.5] (14)	35.0 [32.7] (19)
04183000	10.7 [1.4] (8)	9.9 [1.3] (9)	10.7 [1.4] (8)	10.7 [1.4] (8)	10.7 [1.4] (8)	15.0 [1.6] (5)	13.1 [1.5] (6)
05515000	8.6 [5.1] (8)	8.1 [4.9] (9)	8.6 [5.1] (8)	8.6 [5.1] (8)	8.6 [5.1] (8)	7.7 [4.7] (10)	6.7 [4.2] (13)
05515400	15.3 [8.2] (8)	14.5 [7.8] (9)	15.3 [8.2] (8)	15.3 [8.2] (8)	15.3 [8.2] (8)	13.8 [7.5] (10)	12.2 [6.7] (13)
05515500	8.5 [2.5] (5)	5.7 [1.9] (9)	12.0 [3.2] (3)	12.0 [3.2] (3)	9.9 [2.8] (4)	8.5 [2.5] (5)	7.5 [2.3] (6)
05516500	14.5 [9.1] (8)	13.7 [8.7] (9)	14.5 [9.1] (8)	14.5 [9.1] (8)	14.5 [9.1] (8)	13.0 [8.3] (10)	11.4 [7.4] (13)
05517000	13.2 [5.8] (3)	7.4 [4.1] (9)	10.0 [5.0] (5)	10.0 [5.0] (5)	11.3 [5.4] (4)	10.0 [5.0] (5)	8.4 [4.5] (7)
05517500	5.6 [4.1] (4)	3.5 [2.8] (9)	5.6 [4.1] (4)	5.6 [4.1] (4)	4.9 [3.7] (5)	4.9 [3.7] (5)	4.1 [3.2] (7)
05517530	12.4 [3.7] (4)	8.0 [2.6] (9)	12.4 [3.7] (4)	12.4 [3.7] (4)	11.0 [3.3] (5)	11.0 [3.3] (5)	9.2 [2.9] (7)

Table 13.--Selected results of K-CERA analysis--Continued

Indentification	790	Current operation	810	823	850	900	1000
	Standard error of instantaneous discharge, in percent [Equivalent Gaussian spread] (Number of visits per year)						
			Budget in thousands of 1983 dollars				
05517890	18.4 [17.0] (9)	18.4 [17.0] (9)	18.4 [17.0] (9)	18.4 [17.0] (9)	16.8 [15.6] (11)	15.6 [14.4] (13)	13.4 [12.4] (18)
05518000	4.5 [3.1] (5)	3.2 [2.5] (9)	4.5 [3.1] (5)	4.5 [3.1] (5)	4.1 [2.9] (6)	3.5 [2.6] (8)	2.9 [2.3] (11)
05519000	27.6 [11.3] (9)	27.6 [11.3] (9)	27.6 [11.3] (9)	27.6 [11.3] (9)	25.0 [10.3] (11)	23.0 [9.6] (13)	19.5 [8.2] (18)
05521000	11.8 [8.9] (9)	11.8 [8.9] (9)	11.8 [8.9] (9)	11.8 [8.9] (9)	10.7 [8.1] (11)	9.8 [7.4] (13)	8.4 [6.4] (18)
05522000	14.6 [8.1] (9)	14.6 [8.0] (9)	14.6 [8.1] (9)	14.6 [8.1] (9)	12.5 [7.3] (11)	11.1 [6.7] (13)	8.8 [5.7] (18)
05522500	10.4 [9.7] (9)	10.4 [9.7] (9)	10.4 [9.7] (9)	10.4 [9.7] (9)	9.4 [8.8] (11)	8.6 [8.1] (13)	7.3 [6.9] (18)
05523000	43.7 [18.1] (9)	43.7 [18.1] (9)	43.7 [18.8] (9)	43.7 [18.1] (9)	39.5 [16.2] (11)	36.3 [14.9] (13)	30.7 [12.5] (18)
05524500	17.9 [14.6] (5)	13.7 [11.4] (9)	17.9 [14.6] (5)	17.9 [14.6] (5)	16.5 [13.6] (6)	14.5 [12.0] (8)	12.4 [10.4 (11)
06636190	12.9 [10.6] (9)	12.9 [10.6] (9)	12.9 [10.6] (9)	12.9 [10.6] (9)	11.8 [9.7] (1)	10.9 [9.0] (13)	9.4 [7.8] (18)
05536195	20.8 [10.5] (9)	20.8 [10.5] (9)	20.8 [10.5] (9)	20.8 [10.5] (9)	18.3 [9.4] (11)	16.5 [8.6] (13)	13.6 [7.3] (18)

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