Channel and Dynamic Flow Characteristics of the Chattahoochee River, Buford Dam to Georgia Highway 141

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2063

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By R. E. FAYE *and* R. N. CHERRY

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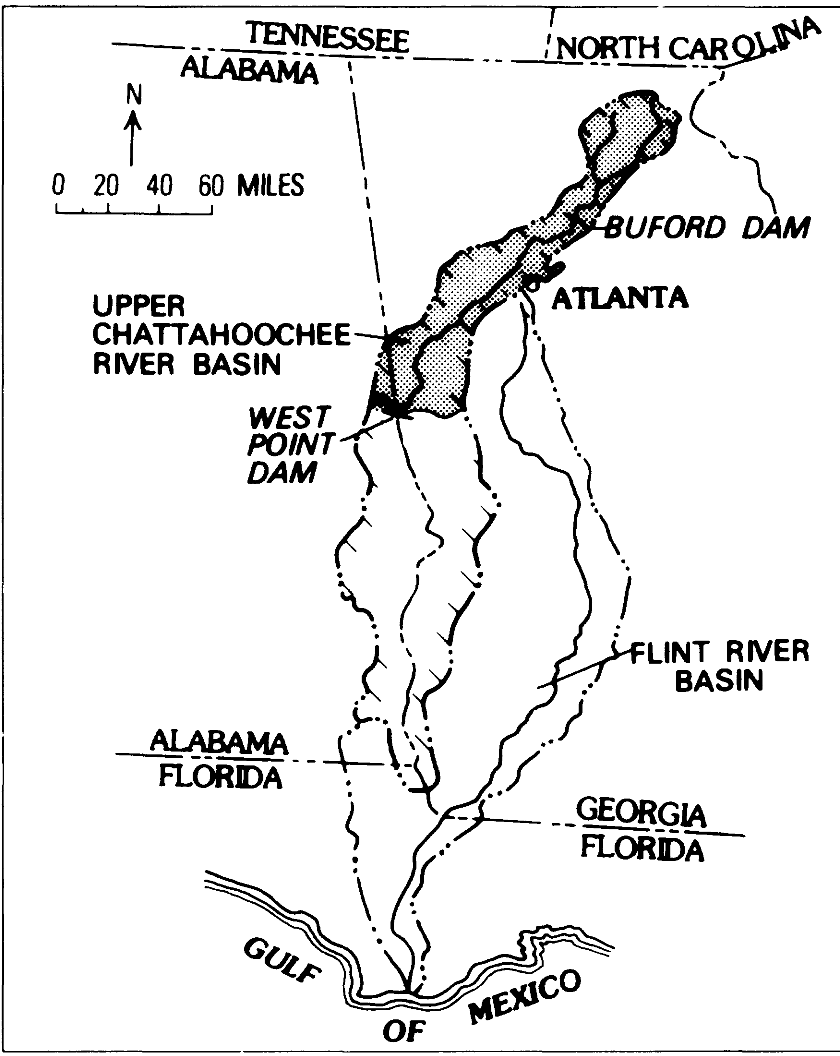
UNITS OF MEASUREMENT/CONVERSION FACTORS

Data listed in this report are defined in inch-pound units. A list of these units and the factors for their conversion to metric units is provided below.

Abbreviations of units are defined in the conversion table below or where they first appear in the text. Symbols are defined where they first appear in the text.

Multiply inch-pound unit	*by*	*to obtain metric unit*
ft (foot)	3.048×10^{-1}	m (meter)
ft (foot)	3.048×10^{2}	mm (millimeter)
ft/s (foot per second)	3.048×10^{-1}	m/s (meter per second)
ft^3/s (cubic foot per second)	2.832×10^{-2}	m^3/s (cubic meter per second)
in. (inch)	2.540×10^{-2}	m (meter)
in. (inch)	2.540×10^{1}	mm (millimeter)
mi (mile)	1.609	km (kilometer)
mi^2 (square mile)	2.590	km^2 (square kilometer)
tons (tons, short)	9.072×10^{-1}	t (metric tons)
tons/d (tons per day)	9.072×10^{-1}	t/d (metric tons per day)
$tons/ft^3$ (tons per cubic foot)	3.204×10^{1}	t/m^3 (metric tons per cubic meter)
tons/yr (tons per year)	9.072×10^{-1}	t/yr (metric tons per year)

$°F = 9/5\ (°C) + 32$ $°C = 5/9\ (°F - 32)$



Map showing location of the Chattahoochee River.

CHANNEL AND DYNAMIC FLOW CHARACTERISTICS OF THE CHATTAHOOCHEE RIVER, BUFORD DAM TO GEORGIA HIGHWAY 141

By R. E. FAYE and R. N. CHERRY

ABSTRACT

Detailed flow and cross-section data for a 17-mile reach of the Chattahoochee River in northeast Georgia are described and summarized. Flow data include measurements of highly dynamic stage and discharge at five stations during the period March 21–23, 1976. Flow data were collected at 5-minute intervals and are listed accordingly. Coordinate data for 39 cross sections in the study reach are also listed. A mathematical model is developed and applied whereby stage data collected at a single station can be used to compute highly dynamic discharge at the station. The model is based on the continuity and momentum equations that describe unsteady, one-dimensional flow in open channels. Both equations are transformed to a single quadratic equation which describes mean flow velocity at a single station. Flow-geometry parameters used by the model are computed using cross-section coordinates and the equation which describes the area of an irregular polygon. Use of the model in conjunction with highly dynamic stage data collected on March 23, 1976, provided close agreement between measured and computed discharges. The model was also used to investigate the sensitivity of highly dynamic discharge to channel and flow parameters. Computed discharge was most sensitive to changes in channel roughness and slope.

INTRODUCTION

This study is one part of the U.S. Geological Survey's Intensive River Quality Assessment of the Upper Chattahoochee River Basin (Cherry and others, 1976). The upper part of the basin (fig. 1, index map) encompasses an area of 3,550 square miles and includes the entire reach of the Chattahoochee River from its headwaters to West Point Dam, a distance of about 250 river miles. The reach of interest specific to this study is about 17 miles long and is bounded upstream and downstream by Buford Dam and Georgia Highway 141 respectively (fig. 1, table 1). River flow in this reach is influenced predominantly by regulation at Buford Dam and, to a lesser extent, by inflows from several tributaries (fig. 1). Flow regulation is mostly a function of the demand for hydroelectric power and the occurrence of downstream flooding.

Generation of hydroelectric power at Buford Dam is accompanied by the release of water downstream in the form of a pulse or wave. The flow characteristics of these waves are highly dynamic and are a direct function of the quantity of power produced and the length of the power production period. Downstream of Buford Dam, these waves significantly affect the flow and quality regimes of the Chattahoochee River. An evaluation of river flow and quality was a major objective of the River Quality Assessment and, as a first step, required the development of a transient, flow-routing model. In order to assess the flow-routing model's ability to simulate highly dynamic flows; it was first applied to the study reach (Buford Dam to Georgia Highway 141) in conjunction with a comprehensive, accurate, and detailed data base. The collection and interpretation of data for such a base were the general objectives of this study. Specific

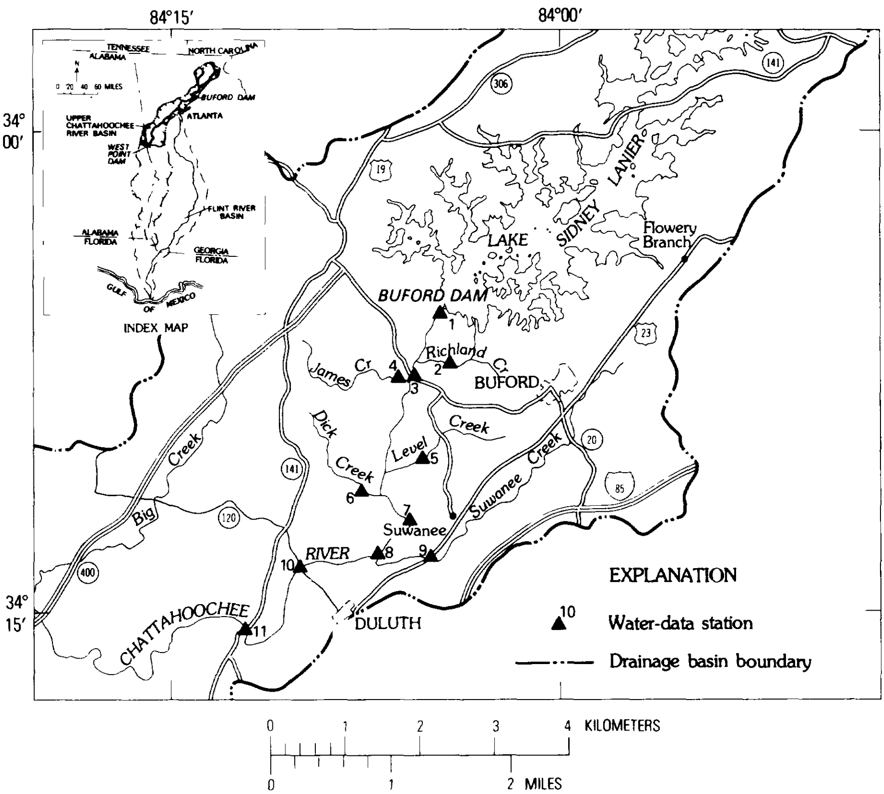


FIGURE 1.—Locations of study reach and data-collection stations.

TABLE 1.—*Name and river-mile location of stage and discharge data-collection stations*

Map key No. (fig. 1)	Station or tributary name	USGS station No.	RM of station or tributary confluence
1	Chattahoochee River at Buford Dam	02334430	348.10
2	Richland Creek	02334480	346.61
3	Chattahoochee River near Buford (Georgia Highway 20)	02334500	345.80
4	James Creek	02334520	345.48
5	Level Creek	02334580	342.20
6	Dick Creek	02334620	341.38
7	Chattahoochee River at Littles Ferry Bridge	02334655	339.86
8	Chattahoochee River at Gwinnett County water intake	02334695	338.19
9	Suwanee Creek	02335000	338.14
10	Chattahoochee River near Duluth (Georgia Highway 120)	02334950	335.26
11	Chattahoochee River near Norcross (Georgia Highway 141)	02335000	330.77

objectives included (1) a description of dynamic flow characteristics in the study reach, (2) a description of channel geometry and roughness, and (3) the presentation of a method to compute highly dynamic discharge at a gaging station using channel characteristics and stage data measured at the station. This computation method (objective 3) is presented in the form of a mathematical model but should not be confused with the flow-routing model mentioned previously. The development and application of the flow-routing model is described by Jobson and Keefer (1978).

On occasion in this text points on the Chattahoochee River will be designated by river mile (RM). Zero river mile (RM 000.00) is defined as the confluence of the Flint and Chattahoochee Rivers near the Georgia-Florida border (fig. 1, index map).

The scope of this study included (1) the collection of detailed stage and discharge data at selected stations and (2) the collection of detailed cross-section data at approximately half-mile intervals throughout the study reach. All cross-section altitudes were based on the NGVD (National Geodetic Vertical Datum) of 1929. Stations where flow data were collected are listed in downstream order in table 1 and are keyed to the numbered locations shown on figure 1. The river mile listed for tributary streams (table 1) is the location of each stream's confluence with the Chattahoochee River.

DESCRIPTION OF THE REACH

Throughout the study reach, the channel of the Chattahoochee River is oriented to the southwest and is contained mostly within the zone of cataclasis of the Brevard Fault (Georgia Department of Natural Resources, 1976). Major tributaries along the reach include Richland Creek, James Creek, Level Creek, Dick Creek and Suwanee Creek (fig. 1, table 1). Channel cross sections are rectangular to trapezoidal in shape and are characterized by high, steep banks and sand beds. Shoals and rock beds do occur, however, and are most prominent downstream of Buford Dam, upstream of the confluence with Level Creek, and upstream of Georgia Highway 141. Commercial sand dredges are located on the river upstream of the confluence with James Creek, at Littles Ferry Bridge and just downstream of Georgia Highway 120. The Gwinnett County water-supply intake is located in the reach just upstream of the Suwanee Creek confluence. Stream bank erosion through the reach is severe and is caused, for the most part, by the rapidly changing flow conditions resulting from hydropower production at Buford Dam. The root systems of mature trees that lined formerly stable river banks have been undermined by erosion and thousands of large trees have fallen into the channel. These undermined trees are a prominent feature of the channel, especially at low flow, and probably affect channel roughness characteristics at higher flows.

U.S. Geological Survey gaging stations (fig. 1, table 1) are located just downstream of Buford Dam (1), at Georgia Highway 20 (3), and at Georgia Highway 141 (11).

DATA COLLECTION AND REDUCTION

STAGE AND DISCHARGE DATA

Collection of stage and discharge data occurred intensively over a 3-day period beginning March 21, 1976. Initial flow conditions in the river were steady and low. Commencing early in the morning of March 22 regulated discharge at Buford Dam increased to approximately 4,000 ft^3/s (cubic feet per second) and was maintained at that rate for about 20 hours before returning to low flow. On March 23, regulated discharge at Buford Dam resembled a typical hydropower wave or pulse; peaking at about 8,000 ft^3/s just downstream of the dam. Stage measurements during the 3-day, data-collection period were made continuously, at 5-minute intervals, using automatic digital recorders at gaging stations just downstream of Buford Dam and at Georgia Highway 20. At Georgia Highway 141, stage was continuously measured by analog recorder and frequently by wire weight. Stage measurements were made at Littles Ferry Bridge and at Georgia Highway 120 by measuring the vertical distance between the water surface and an established reference point. Such measurements were made continuously at Littles Ferry Bridge at 10-minute intervals. Measurements at Georgia Highway 120 were made at 5-minute intervals but only in conjunction with discharge measurements. The stage record collected at each station is listed in the summary of data (table 10) and shown graphically in figures 2 to 6.

Discharge measurements during the period March 21–23, 1976 were made at Georgia Highway 20, at Littles Ferry Bridge, at Georgia Highway 120, and at Georgia Highway 141. Continuous discharge measurements were obtained at each of these stations during the periods of rise and peak discharge on March 22 and during most of the period of unsteady discharge on March 23. In general, measurements of discharge followed procedures outlined by Buchanan and Somers (1969) for data collected during rapidly changing stage. Prior to the collection of discharge data, a minimum of seventeen (17) vertical positions were established across the river section at each station. During measurement, each position was occupied sequentially and the flow depth, mean velocity, and time were recorded. Because the distance between verticals was known, each measurement defined an instantaneous partial area and mean velocity. The product of these areas and velocities provided a series of partial discharges relative to each vertical over the total period of measurement. Plotting the partial discharge against time and connecting the points with a smooth curve provided a continuous record of instantaneous discharge at each vertical. The sum of each partial discharge at a given time was considered equivalent to the instantaneous river discharge at the station at that time. Instantaneous discharges were computed in this manner at each station and are listed, at 5-minute intervals, in the summary of data (table 11). The discharge data are presented graphically in figures 7 to 10.

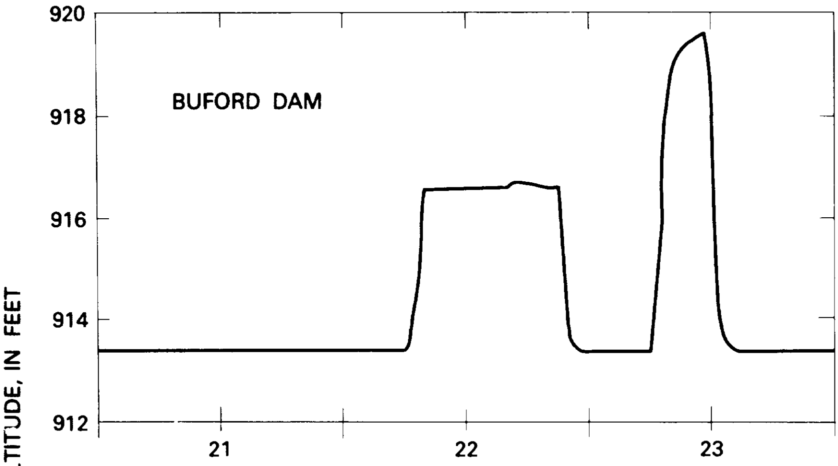
Measurements of instantaneous tributary discharge were made infrequently during the data-collection period. Stage measurements at tributary stations were made frequently, however, and were used in conjunction with established rating curves to estimate tributary flow. Tributary discharges during the period of interest are listed in the summary of data (table 12).

Withdrawals at the Gwinnett County Water intake averaged 16 ft^3/s during March 21–23, 1976.

CROSS-SECTION DATA

Cross-section data at a total of 30 locations were obtained by leveling cross country from a known bench mark to the cross-

FIGURE 2.—Measured stage of the Chattahoochee River at Buford Dam, March 21–23, 1976.



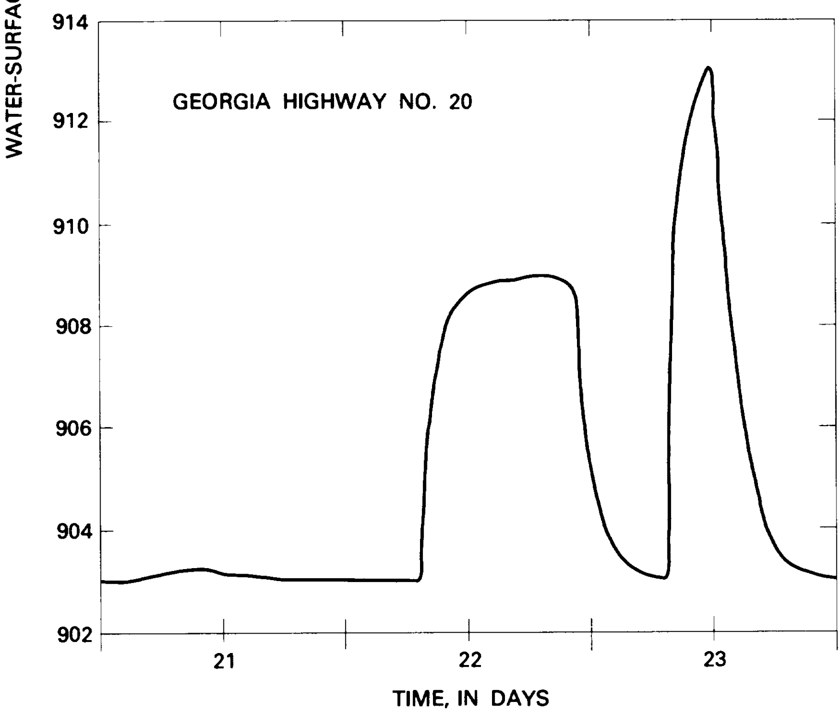
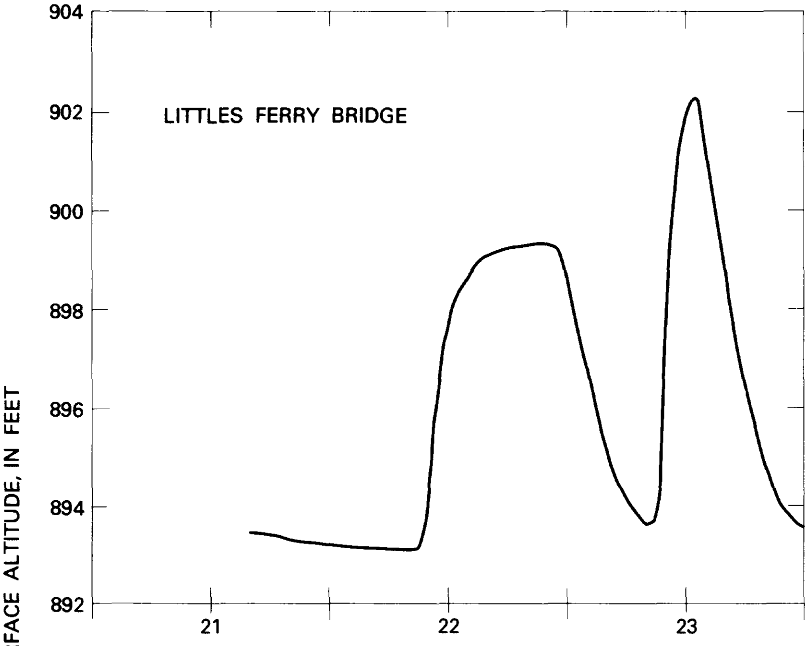


FIGURE 3.—Measured stage of the Chattahoochee River at Georgia Highway 20, March 21–23, 1976.

FIGURE 4.—Measured stage of the Chattahoochee River at Littles Ferry Bridge, March 21–23, 1976.



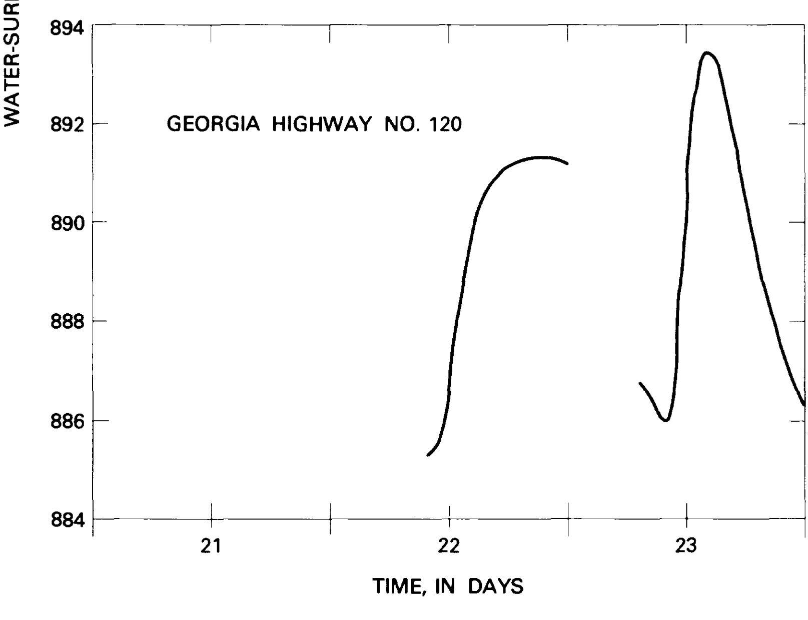


FIGURE 5.—Measured stage of the Chattahoochee River at Georgia Highway 120, March 21–23, 1976.

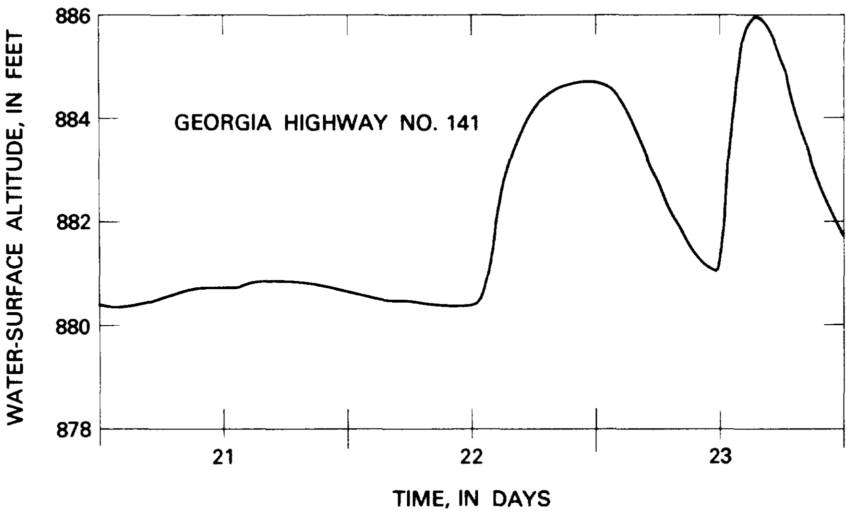


FIGURE 6.—Measured stage of the Chattahoochee River at Georgia Highway 141, March 21–23, 1976.

section location. The altitude of the water surface with respect to datum was then determined and the depth of flow across the section was measured by sounding or with a Fathometer. Measurements of the section above the water surface were made using standard leveling and stadia techniques. Cross-section coordinates at nine locations were obtained from the U.S. Army Corps of Engineers (1973). All cross-section data used in this study are listed in the summary of data (table 13).

CHANNEL CHARACTERISTICS

GEOMETRY

Typical river cross sections are shown on figure 11. The general shape of each section is rectangular with an irregular bed and high steep banks. Channel widths range from about 150 to 300 feet. No trends in width or shape were observed with distance down the reach.

A longitudinal profile of the thalweg altitude at each cross section is shown in figure 12. Several discontinuities occur in the profile most notably near the confluence with James Creek, at Littles Ferry Bridge, and upstream of the Gwinnett County water-supply intake. At each location, the low point of the discontinuity is proximate to large-scale dredging or pumping operations which have probably scoured the channel bottom.

FIGURE 7 (*left*).—Measured discharge in the Chattahoochee River at Georgia Highway 20, March 21–23, 1976.

FIGURE 8 (*right*).—Measured discharge in the Chattahoochee River at Littles Ferry Bridge, March 21–23, 1976.

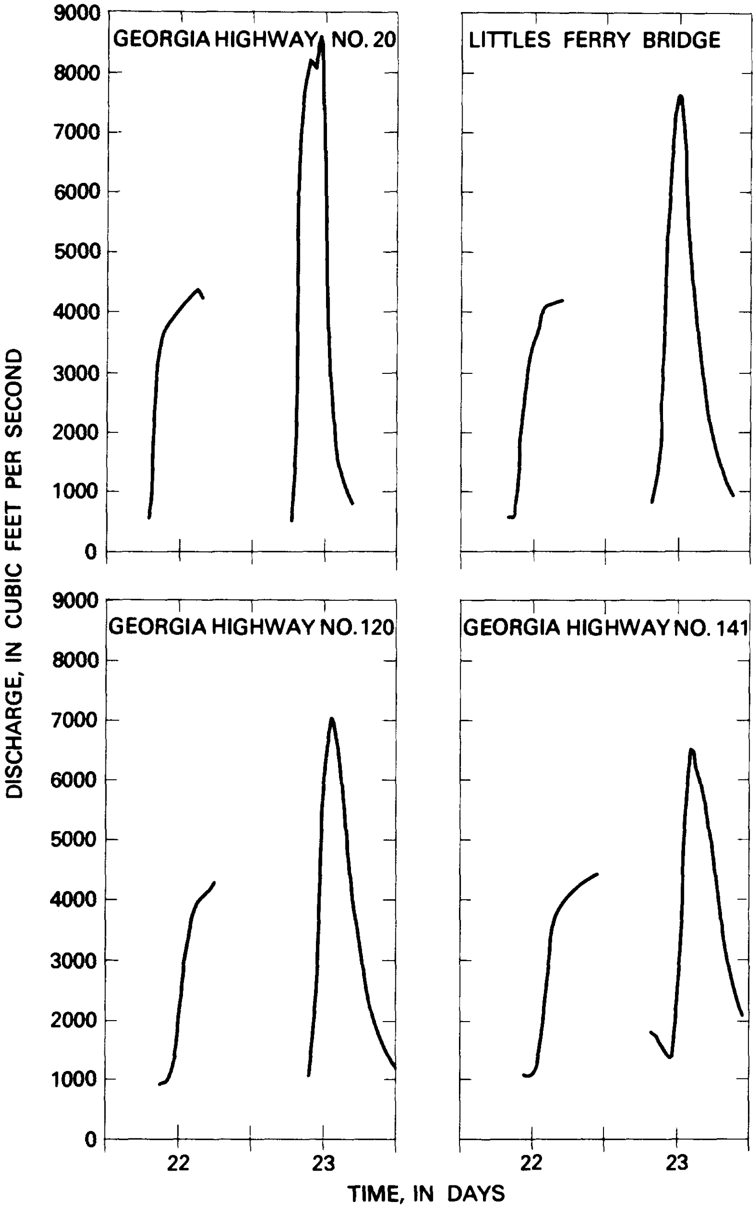


FIGURE 9 (*left*).—Measured discharge in the Chattahoochee River at Georgia Highway 120, March 21–23, 1976.

FIGURE 10 (*right*).—Measured discharge in the Chattahoochee River at Georgia Highway 141, March 21–23, 1976.

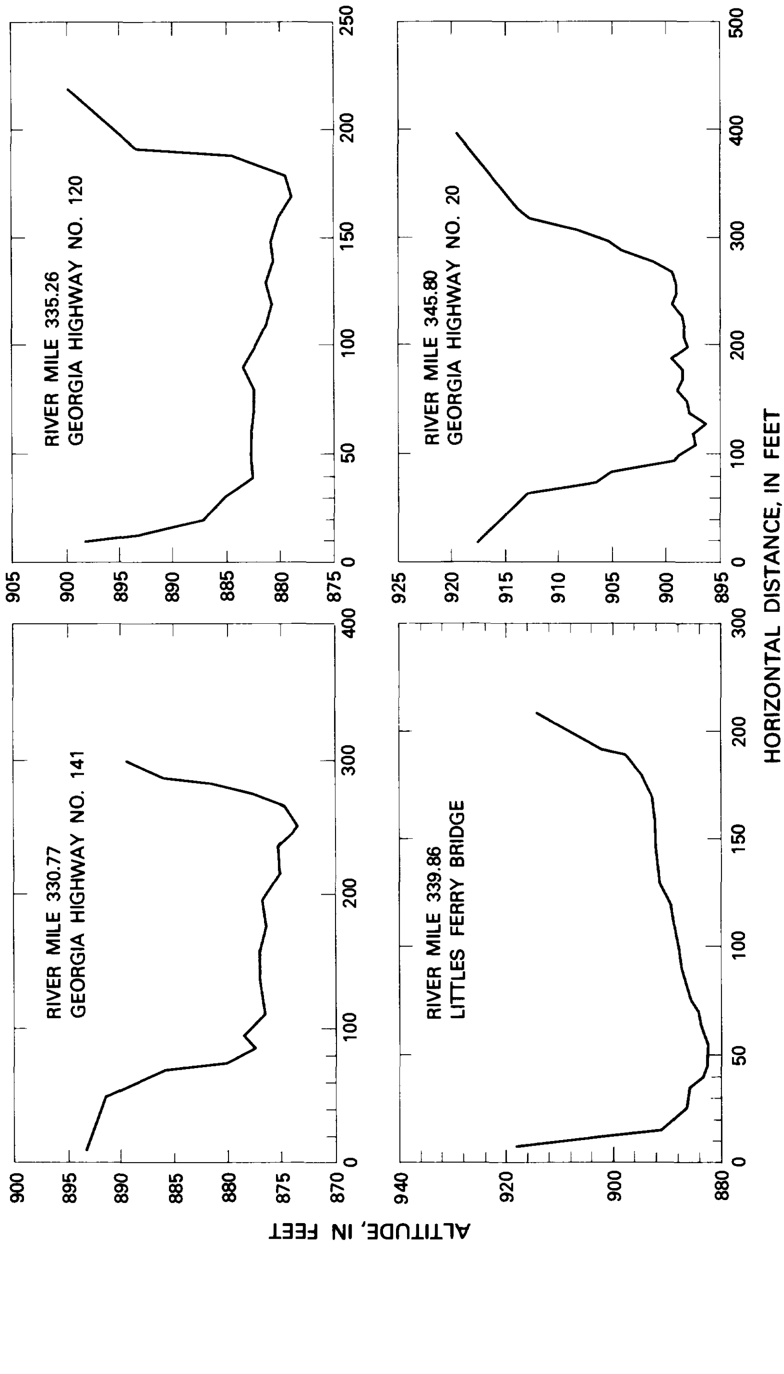


FIGURE 11 A.—Selected channel cross sections—at RM 330.77, at RM 335.26, at RM 339.86, and at RM 345.80.

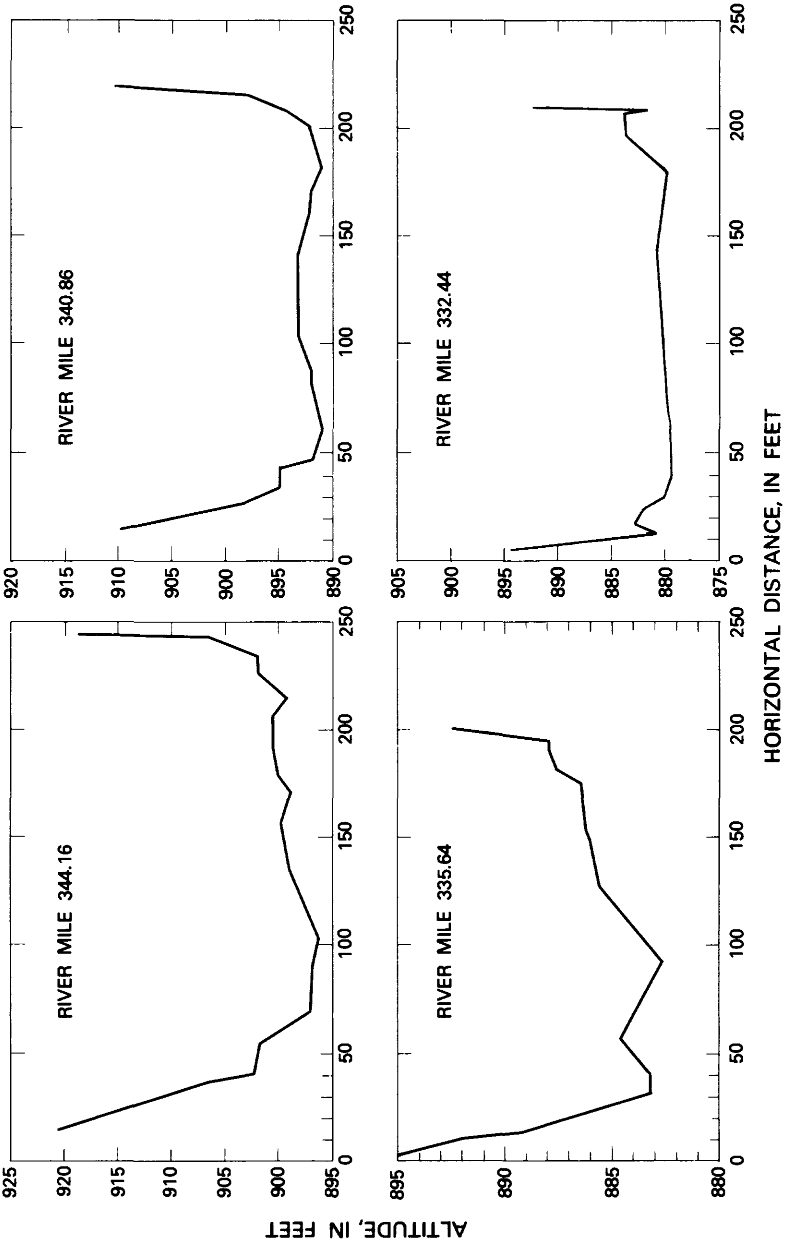


FIGURE 11*B*.—Selected channel cross sections—at RM 344.16, at RM 340.86, at RM 335.64, and at RM 332.44.

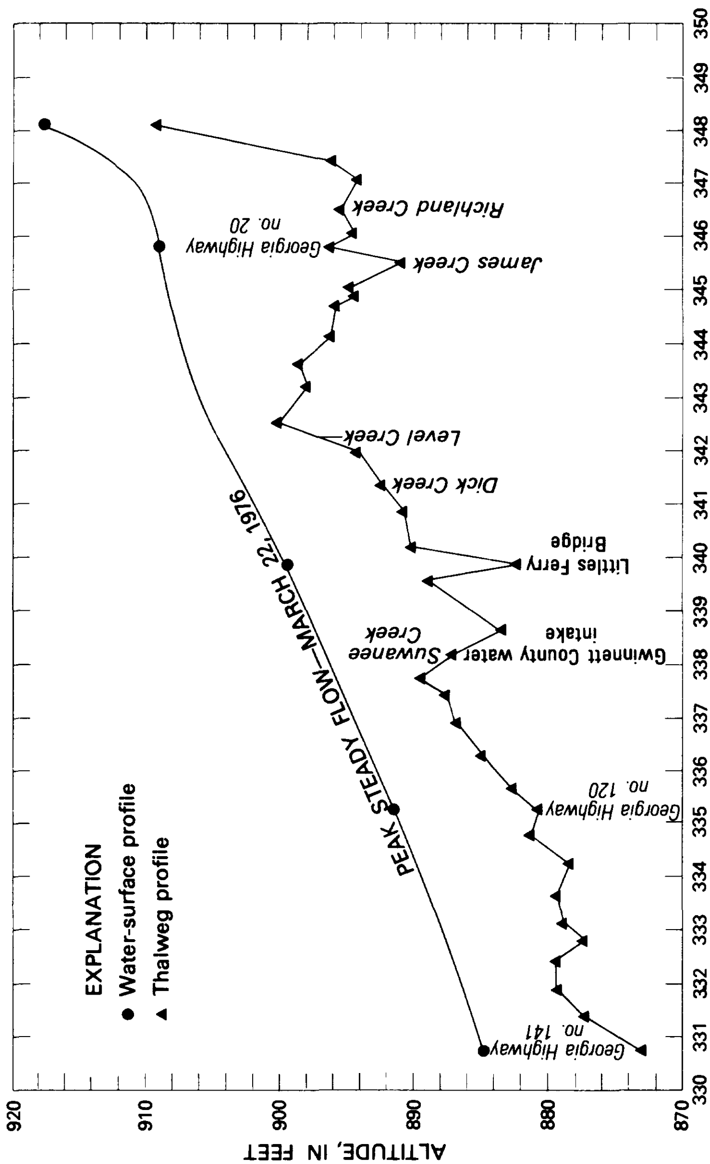


FIGURE 12.—Water-surface and thalweg profiles.

ROUGHNESS

Channel roughness is represented by Manning's roughness coefficient (n) and was computed using the relation

$$n = \frac{1.49}{V} S_o^{1/2} R^{2/3}, \qquad (1)$$

in which n=Manning's roughness coefficient, in $TL^{-1/3}$; S_o=effective channel slope, in LL^{-1}; V=mean flow velocity, in LT^{-1}; and R=hydraulic radius, in L. L and T respectively indicate units of length and time. The constant 1.49, in inch-pound units, becomes 1.0 in metric units. The computation of channel roughness using equation (1) is only valid when flow conditions are steady or nearly steady. The discharge hydrographs (figs. 7–10) indicate such conditions occurred three times during the period of measurement, during most of March 21 and during the peak discharges of March 22 and 23. Roughness coefficients computed at these times at each discharge measuring station are listed in table 2. With the exception of values at Georgia Highway 120, computed roughness coefficients are highly sensitive to depth of flow. The range of n values at individual stations is greatest at Georgia Highway 20 (0.044–0.089) and least at Georgia Highway 120 (0.036–0.039). Effective channel slopes used in the roughness computations were computed from the water-surface profile developed for peak steady flow on March 22 (fig. 12).

FLOW CHARACTERISTICS

Dynamic flow in the study reach is typified by the data collected on March 22 and 23. Stage and discharge data (tables 10 and 11) indicate that the flow at each station is most dynamic on the rising limb of the hydrograph and becomes increasingly less dynamic with increasing distance from Buford Dam. Maximum observed rates of change for both stage and discharge noted on March 23 are listed in table 3 and are shown to range, respectively, from 12.5 ft/h (feet per hour) and 10,400 $ft^3/s/h$ (cubic feet per second per hour) at Georgia Highway 20 to 2.3 ft/h and 2,620 $ft^3/s/h$ at Georgia Highway 141.

STAGE-DISCHARGE RELATIONS

The stage hydrographs shown in figures 2 to 5 indicate that hydropower flows are essentially waves translating through the reach. Peak wave discharge and wave attenuation are shown to

TABLE 2.—*Summary of channel-roughness data*

Station name	Date in 1976	Time	Discharge (ft^3/s)	Hydraulic radius (ft)	Effective channel slope (ft/ft)	Mean flow velocity (ft/s)	Manning's n ($s/ft^{1/3}$)	Maximum flow depth (ft)
Georgia Highway 20	March 22	0700	577	4.26	0.00024	0.68	0.089	6.59
	March 22	1500	4,370	8.80	.00024	2.02	.049	12.42
	March 23	1135	8,660	11.60	.00024	2.71	.044	16.63
Littles Ferry Bridge	March 20	1505	774	5.13	.00036	.96	.088	10.61
	March 22	1700	4,180	9.66	.00036	2.31	.056	16.48
	March 23	1240	7,450	12.20	.00036	3.10	.048	19.59
Georgia Highway 120	March 22	0920	940	3.45	.00036	1.65	.039	4.64
	March 22	1805	4,320	8.42	.00036	2.97	.039	10.46
	March 23	1330	7,000	10.10	.00036	3.63	.036	12.49
Georgia Highway 141	March 22	1055	1,080	3.92	.00031	1.34	.049	6.92
	March 22	1620	3,880	6.80	.00031	2.62	.036	10.18
	March 23	1440	6,550	8.62	.00031	3.39	.033	12.29

decrease and increase respectively with increasing distance from Buford Dam. Such waves, for the most part, resemble flood waves as described by Chow (1959), Fread (1975), and other investigators (see Selected References) and are characterized by hysteretic stage-discharge relations. Hysteretic relations were also noted for data collected during this study and are shown for the wave of March 23 on figures 13 to 16. The single-value discharge based on the current (1976) rating curve at Georgia Highway 141 is also shown on figure 16. The maximum width and area of each loop are listed in table 4 and are shown to progressively decrease in the downstream direction. At Georgia Highway 20, for example, the maximum loop width is equivalent to 3,200 ft^3/s while the corresponding value at Georgia Highway 141 is only 1,150 ft^3/s. Loop areas for the four stations range from about 15,000 ft^4/s at Georgia Highway 20 to about 4,200 ft^4/s at Georgia Highway 141.

The stage-discharge hysteresis relation is a direct function of the dynamic nature of the wave or pulse which, in turn, depends upon the spatial rates of change of flow velocity and depth and the time rate of change of velocity. The greater these rates of change the more dynamic is the flow and the greater the hysteresis. Where the spatial and time rates of change of flow velocity are small or negligible compared to the spacial rate of change of depth, discharge is mostly a function of storage changes in the channel and can be described by considering the conservation of mass.

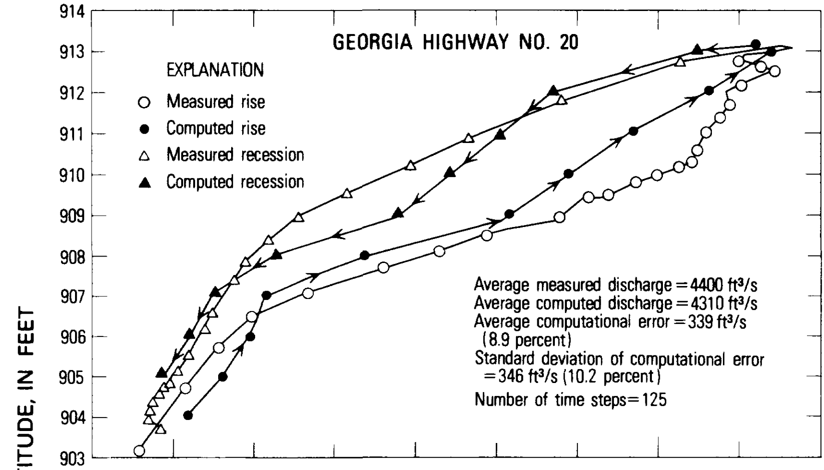
TABLE 3.—*Maximum rates of change of stage and discharge on March 23, 1976*

Station name	Maximum rate of stage change (ft/h)	Maximum rate of discharge change (ft^3/s/h)
Buford Dam	22.8	------
Georgia Highway 20	12.5	10,400
Littles Ferry Bridge	5.5	5,580
Georgia Highway 120	4.1	3,860
Georgia Highway 141	2.3	2,620

TABLE 4.—*Maximum widths and areas of hysteretic stage-discharge relations on March 23, 1976*

Station name	Loop area (ft^4/s)	Maximum loop width (ft^3/s)
Georgia Highway 20	15,000	3,200
Littles Ferry Bridge	12,000	1,900
Georgia Highway 120	7,750	1,800
Georgia Highway 141	4,200	1,150

FIGURE 13.—Hysteretic stage-discharge relation at Georgia Highway 20 on March 23, 1976—0705 to 1720 hours.



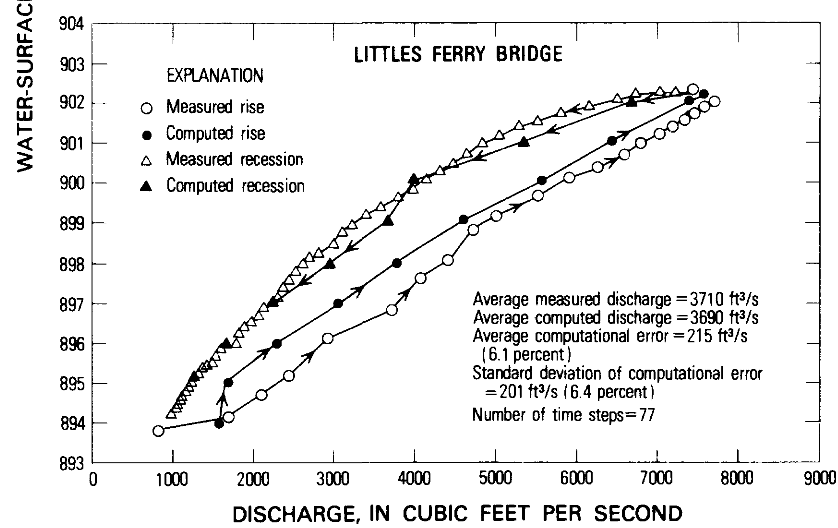
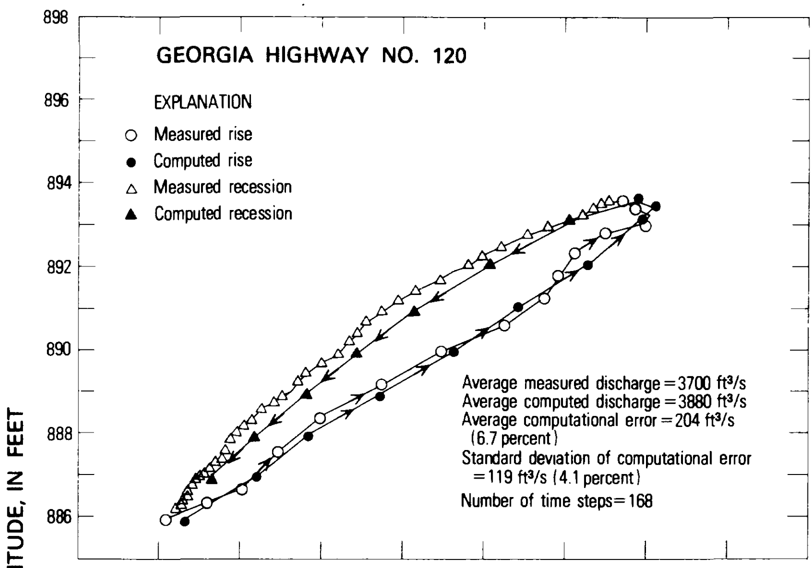


FIGURE 14.—Hysteretic stage-discharge relation at Littles Ferry Bridge on March 23, 1976—0850 to 2110 hours.

FIGURE 15.—Hysteretic stage-discharge relation at Georgia Highway 120 on March 23, 1976—1005 to 2355 hours.



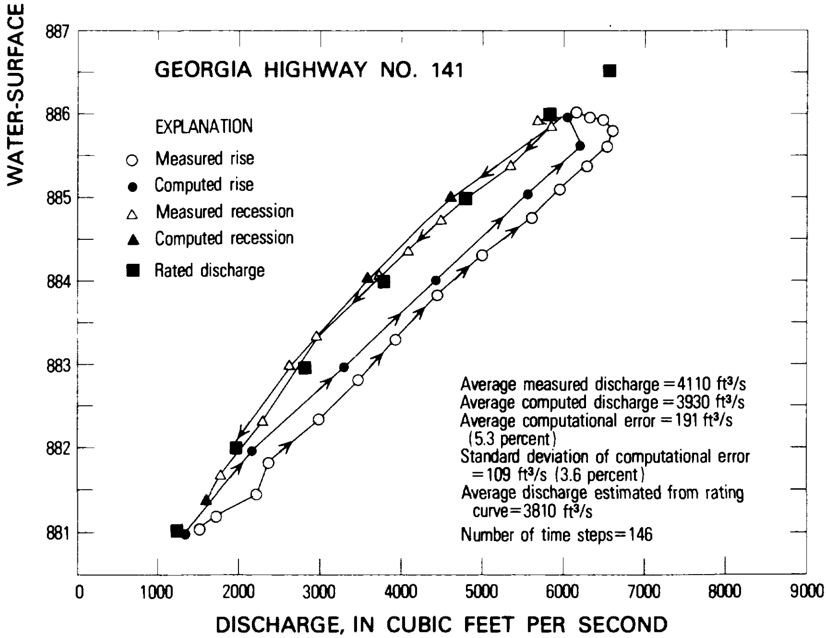


FIGURE 16.—Hysteretic stage-discharge relation at Georgia Highway 141 on March 23, 1976—1105 to 2310 hours.

WAVE VELOCITY

The computed absolute velocities of waves translating through the study reach on March 22 and 23 are listed in table 5. Absolute velocities are defined by Chow (1959) as

$$V_w = V + c, \tag{2}$$

in which V_w=absolute wave velocity, in L/T; V= the undisturbed velocity of the water through which the wave is propagated, in L/T; and c=wave celerity, in L/T. All wave-velocity measurements were determined by (1) dividing the distance between the gaging station at Buford Dam and each respective downstream station by (2) the time difference between the beginning of stage rise at Buford Dam and the corresponding rise at each station. Absolute velocities through the reach are shown to range from about 11 ft/s to Georgia Highway 20 to about 5 ft/s to Georgia Highway 141. Small day-to-day differences in wave velocity are probably due to variations in initial flow velocities (V).

TABLE 5.—*Summary of absolute wave-velocity data*

Station name	Wave velocity, in ft/s	
	March 22, 1976	March 23, 1976
Georgia Highway 20	10.12	11.24
Littles Ferry Bridge	5.49	5.90
Georgia Highway 120	5.38	5.74
Georgia Highway 141	5.43	5.75

VELOCITY DISTRIBUTIONS

The lateral distribution of mean velocity during the peak discharge of March 23, is shown for 4 stations on figures 17 to 20. A nonuniform velocity distribution occurs at each station and is caused, for the most part, by cross-section geometry, channel roughness, and bridge characteristics—in particular, the number and spacing of bridge piers. Because discharge could only be measured at bridge sites, the velocity distributions shown are considered representative of only a short reach of the channel in the vicinity of the designated station.

Estimates of kinetic energy and momentum based on mean flow velocity in rough, natural channels are generally biased low because of nonuniform velocity distributions. To compensate for this bias, in one dimensional problems, the term describing the convective acceleration of unsteady flow (see eq. 5, p. 23) is multiplied by an energy or momentum coefficient. The theoretical development of these coefficients is summarized by Chow (1959, p. 29) and is based on a logarithmic distribution of velocity with

TABLE 6.—*Energy and momentum coefficients*

Station name	α	β
Georgia Highway 20	1.67	1.38
Littles Ferry Bridge	1.02	1.01
Georgia Highway 120	1.21	1.09
Georgia Highway 141	1.17	1.07

depth during turbulent flow. Approximate energy and momentum coefficients can be computed using the formulas

$$\alpha = 1 + 3\epsilon^2 - 2\epsilon^3 \qquad (3)$$

$$\beta = 1 + \epsilon^2, \qquad (4)$$

in which α = the energy coefficient, β = the momentum coefficient and ϵ = the ratio of maximum to mean channel velocity minus one. Values of α and β equal to unity indicate a uniform velocity distribution. Energy and momentum coefficients computed using these formulas and the data shown on figures 17 to 20 are listed in table 6. Both coefficients are greatest at Georgia Highway 20.

METHOD OF COMPUTING HIGHLY DYNAMIC FLOW AT A GAGED STATION

Although the dynamic flows described in the previous section were caused by structural regulation, they are nevertheless similar to flows observed by hydrologists and engineers during floods in natural rivers and during rapid rainfall runoff from urban areas. Frequently, only a stage record of such flows is available and estimates of instantaneous and mean dynamic discharge are based on a rating curve or other single-value relation; that is, a relation based on a unique, one-to-one correspondence between depth and discharge. The hysteretic relation of stage to discharge indicates that estimates of *instantaneous* dynamic discharge based on rating curves can be significantly in error (fig. 16). On the other hand, estimates of *mean* dynamic discharge based on rating curves may not be so severely affected by hysteresis because integration of the underestimated flow during rising stages is frequently compensated for by a corresponding overestimate during falling stages.

Accurate definition of instantaneous stream discharge is critical to many hydrologic investigations. At many stations, for example, the water quality of a stream is fundamentally related to discharge. However, during periods of highly dynamic flow, stream discharge measurements made in conjunction with the collection of water-quality data are generally not representative of the discharge at the time of sampling. Such situations occur frequently

FIGURE 17.—Lateral velocity distribution at Georgia Highway 20 during peak discharge, March 23, 1976.

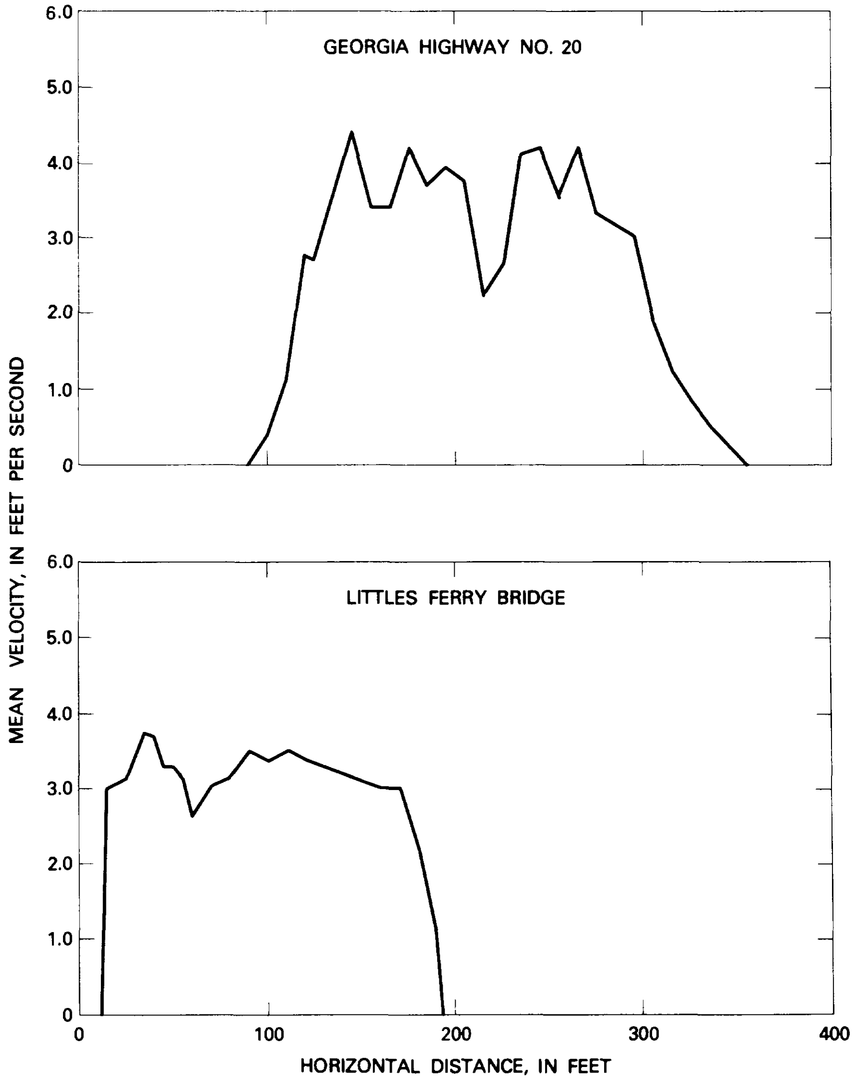


FIGURE 18.—Lateral velocity distribution at Littles Ferry Bridge during peak discharge, March 23, 1976.

on "flashy" urban streams. Thus, the interpretive value of expensive and generally accurate chemical analyses is either biased or distorted because of nonrepresentative discharge data. Similar bias occurs at gaging stations where stage hydrographs of dynamic flows are used in conjunction with rating curves to estimate

FIGURE 19.—Lateral velocity distribution at Georgia Highway 120 during peak discharge, March 23, 1976.

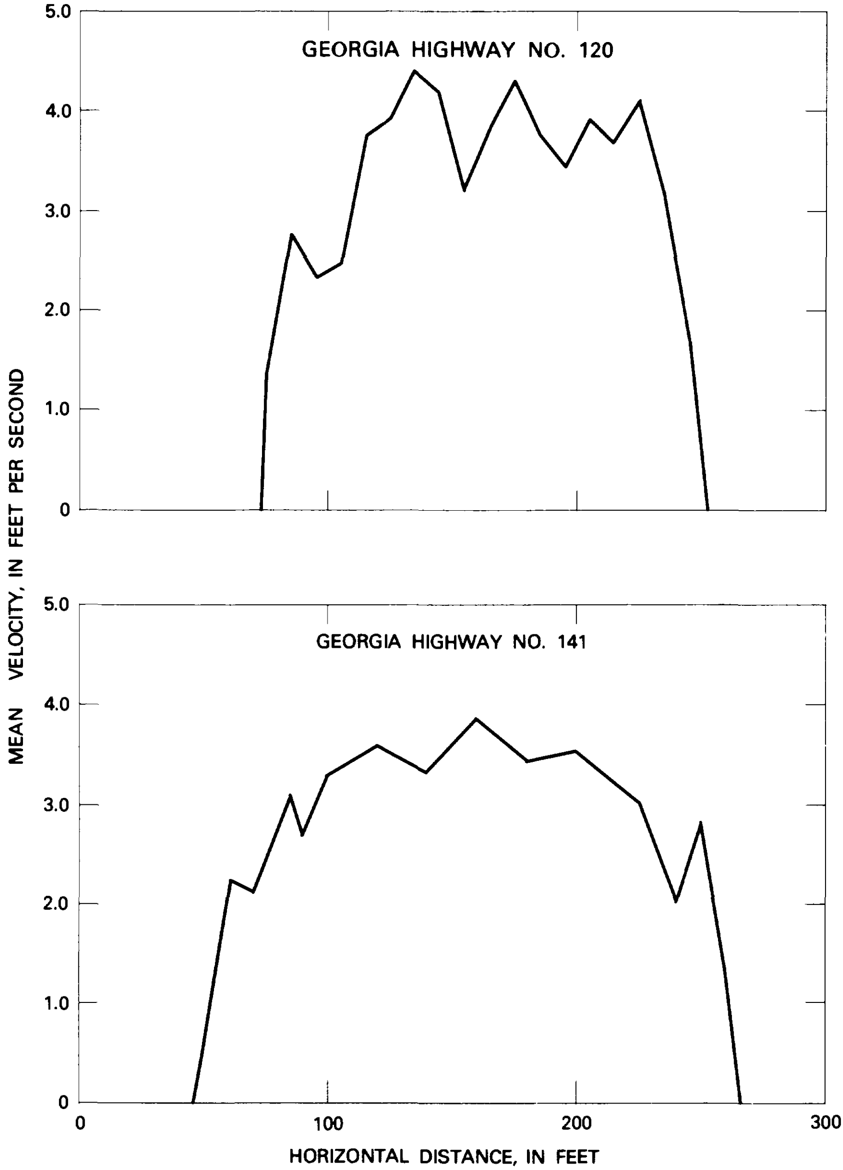


FIGURE 20.—Lateral velocity distribution at Georgia Highway 141 during peak discharge, March 23, 1976.

the storm load of water-quality constituents.

Clearly, then, a method which utilizes stage data, to accurately compute instantaneous dynamic discharge at a gaging station can be applied to a variety of hydrologic studies. One such method was developed by Fread (1975) and demonstrated for large, relatively "sluggish" streams such as the Mississippi and Atchafalaya Rivers in Louisiana. The root mean square error between observed instantaneous flood discharges in these rivers and corresponding discharges computed by Fread's model ranged from about 3 to 7 percent. The application of Fread's model, however, is limited to large rivers with generally prismatic channels and small channel slopes where the bulk of the flood wave moves approximately as a kinematic wave. Discharge produced by a kinematic wave is characterized by nearly parallel energy and channel slopes and can be reasonably described by considering the conservation of mass (Lighthill and Whitham, 1955). Such relations do not characterize flow conditions in the study reach of the Chattahoochee River nor do they apply to flow conditions in many urban streams which are subject to rapid and extensive runoff from streets and other impermeable surfaces.

The remainder of this paper discusses the development and application of a mathematical model which accurately computes highly dynamic discharge at a river station using only the stage record and channel characteristics pertaining to that station. Development of the model is based on a direct solution of the equations describing gradually varied, unsteady flow in open-channels as described by Chow (1959). These equations are transformed to describe mean flow velocity in a short reach of the channel proximate to the gaging station. Assumptions used to develop the model include:

1. the channel geometry of the short reach is permanent;
2. lateral flow to or from the stream is negligible in the vicinity of the station;
3. Manning's equation describes energy losses in the short reach due to turbulence and channel roughness; and
4. the shape of the wave profile remains stable as it translates downstream.

The final form of the model is similar to Fread's but is more general and more applicable to highly dynamic flows.

Application of the model utilizes the stage and discharge data collected on March 23, 1976 at 4 stations on the Chattahoochee River (table 1). Statistical comparisons of observed and computed discharge provide mean computation error and standard deviation of this error at each station. Sensitivity analyses of various model parameters provides some insight into the relation between channel and flow parameters and highly dynamic discharge.

MODEL DEVELOPMENT

Chow (1959) lists the equations describing gradually varied, one-dimensional, unsteady flow in open channels as

$$\frac{\partial y}{\partial x}+\frac{\alpha V}{g}\frac{\partial V}{\partial x}+\frac{1}{g}\frac{\partial V}{\partial t}=S_o-S_f \qquad (5)$$

$$D\frac{\partial V}{\partial x}+V\frac{\partial y}{\partial x}+\frac{\partial y}{\partial t}=O \qquad (6)$$

in which x = the distance along the channel, in L; y = the water-surface altitude, in L; t = time, in T; g = the acceleration due to gravity, in LT^{-2}; V = the mean flow velocity, in LT^{-1}; α = the energy coefficient; D = the hydraulic depth, in L; S_o = the effective channel slope, in LL^{-1}; and S_f = the energy slope, in LL^{-1}. Equations (5) and (6) are commonly known as the momentum and continuity equations, respectively. Terms of the momentum equation are dimensionless and include, from left to right, the gradients of pressure, convective acceleration, temporal acceleration, gravity and total stream energy. Terms of the continuity equation are dimensioned in LT^{-1} and collectively define the conservation of mass in the channel. Note that two of the partial derivatives are spatial and thus depend on a description of flow conditions along the channel. The remaining derivatives are temporal and depend only on a characterization of flow at a particular stream station.

Simultaneous addition of equations (5) and (6) removes $\frac{\partial V}{\partial x}$ from consideration and provides one equation of the form.

$$\left(D-\frac{\alpha V^2}{g}\right)\frac{\partial y}{\partial x}-\frac{\alpha V}{g}\frac{\partial y}{\partial t}+\frac{D}{g}\frac{\partial V}{\partial t}=D(S_o-S_f). \qquad (7)$$

Stage measurements (figs. 2 to 6) indicate that the general form of the wave profile remains generally stable while translating through the study reach. Under such conditions, the pressure gradient $\partial y/\partial x$ can be approximated by a function of the absolute wave velocity and the rate of change of water-surface altitude. That is

$$\frac{\partial y}{\partial x}=\frac{-1}{V_w}\frac{\partial y}{\partial t}. \qquad (8)$$

Substitution of (8) into (7) leads to

$$-\frac{D}{V_w}\frac{\partial y}{\partial t}+\frac{\alpha V^2}{V_w g}\frac{\partial y}{\partial t}-\frac{\alpha V}{g}\frac{\partial y}{\partial t}+\frac{D}{g}\frac{\partial V}{\partial t}=D(S_o-S_f). \qquad (9)$$

Consider that energy losses from channel roughness and turbulence are described by Manning's equation. The energy slope can then be defined as

$$S_f = \frac{V^2 n^2}{2.22\, R^{4/3}}, \tag{10}$$

which is a rearrangement of equation (1).

Substituting (10) into (9) and rearranging terms yields

$$\frac{g}{V_w} - \frac{\alpha V^2}{V_w D} + \frac{\alpha V}{D} \frac{\partial y}{\partial t} - \frac{V^2 n^2 g}{2.22\, R^{4/3}} + g S_o = \frac{\partial V}{\partial t}. \tag{11}$$

Note that the spatial derivatives have now been removed and all remaining derivatives are with respect to time only. Thus equation (11) can be rewritten as

$$\left(\frac{g}{V_w} - \frac{\alpha V^2}{V_w D} + \frac{\alpha V}{D}\right) \frac{dy}{dt} - \frac{V^2 n^2 g}{2.22\, R^{4/3}} + g S_o = \frac{dV}{dt}. \tag{12}$$

NUMERICAL ANALYSIS

Evaluation of equation (12) by finite-difference approximations leads to the following quadratic equation:

$$\left[\frac{-\alpha (y_{i+1} - y_{i-1})}{2\, V_w D_i} - \frac{n^2 g\, (t_i - t_{i-1})}{2.22\, R_i^{4/3}}\right] V_i^2 + \left[\frac{\alpha (y_{i+1} - y_{i-1})}{2\, D_i} - 1\right] V_i$$
$$+ (t_i - t_{i-1})\, g S_o + V_{i-1} + \frac{(y_{i+1} - y_{i-1})\, g}{2\, V_w} = 0. \tag{13}$$

In equation (13), dV and dt are evaluated by backward-difference approximations and dy is evaluated by a central-difference approximation. The subscript i is a time-step index that varies with given values of y and is never less than 2.

For convenience the coefficient terms of equation (13) are symbolized as shown below

$$a_i = \frac{-\alpha (y_{i+1} - y_{i-1})}{2\, V_w D_i} - \frac{n^2 g\, (t_i - t_{i-1})}{2.22\, R_i^{4/3}}$$

$$b_i = \frac{\alpha (y_{i+1} - y_{i-1})}{2\, D_i} - 1$$

$$c_i = (t_i - t_{i-1})\, g S_o + V_{i-1} + \frac{(y_{i+1} - y_{i-1})\, g.}{2\, V_w}.$$

COMPUTATION SCHEME

Computation of dynamic discharge at a gaginig station using equation (13) is accomplished in two steps using a digital computer. Required stream channel data include values of Manning's n and effective channel slope along with cross-section coordinates at the gage site. Data required relative to a particular flow event include a temporal distribution of water-surface altitude (stage record) and the mean flow velocity just prior to the beginning of stage rise. This velocity can either be measured or estimated from a stage-discharge rating and a stage-area relation for the gage site. Wave velocity must also be known and can be computed from concurrent stage records collected at two or more stations along the reach of interest or as the sum of initial velocity and celerity (eq. 2).

Step one of the computation scheme computes values of cross-sectional area, top width, and wetted perimeter at each given water-surface altitude. These computations are based on the given cross-section coordinates which mathematically define an irregular polygon when part of the section is occupied by flow. The value of each flow-geometry parameter (area, top width, or wetted perimeter), therefore, can be computed directly from the following equation, which describes the area of an irregular polygon with any number of sides:

$$2A = l_1(h_2 - h_m) + l_2(h_3 - h_1) + \text{--------} + l_{m-1}(h_m - h_{m-2}) + l_m(h_1 - h_{m-1}). \qquad (14)$$

In equation (14), A = the cross-sectional area of flow, in L^2; h = the vertical component of a cross-section coordinate, in L; l = the horizontal component of a cross-section coordinate, in L; and m = the number of polygon sides or the number of coordinate pairs. Values of both h and l can be measured from any convenient datum and are easily obtained from standard discharge-measurement notes. Subscripts for h and l are numbered consecutively from the leftmost or rightmost cross-section coordinate.

The solution of equation (14) utilizes a "floating coordinate" technique at the left and right boundaries of the section (polygon). These coordinates adjust with given values of water-surface altitude such that the upper side of the polygon always represents the water surface. Thus the h component of the "floating" coordinates equals the water-surface altitude and the difference between corresponding l components equals the top width. Direct solution of equation (14) provides the cross sectional area of flow at the given stage. The total distance between all coordinate points at or below the water surface equals the wetted perimeter. The velocity at the previous time step is always known. Thus coefficients a_i, b_i, and c_i, can now be computed and, with equation (12), form a second-degree polynomial equation in V_i.

$$a_iV_i^2\ b_iV_i+c_i=0 \qquad (15)$$

Step two of the computation scheme solves equation (15) by applying a Newton-Raphson iteration technique. The mean flow velocity and initial water-surface altitude at time step one must be given and are the only flow boundaries required. Where sufficient data are available, changes in Manning's n with depth must also be accounted for in the computation scheme. The instantaneous discharge at each time step is the product of the computed velocity (eq. 15) and the computed area (eq. 14).

A digital computer program written to solve equations (14) and (15) using the computation scheme discussed above is listed in table 7.

APPLICATION

The stage and discharge data collected at Georgia Highways 20, 120, 141, and at Littles Ferry Bridge on March 23, 1976 were applied to the program listed in table 7 (p. 27–32). Initial mean flow velocities were obtained by direct measurement. Effective channel slopes at each station were computed from the water-surface profile generated during the sustained peak flow on March 22 (fig. 12, table 2). Manning's n values used in the program are listed for each station in table 2. Changes in channel roughness with depth at Georgia Highways 20 and 141 and at Littles Ferry Bridge were accounted for by linear interpolation between known values (table 2). At Georgia Highway 120, Manning's n was held constant with depth at .039. Absolute wave velocities used in the program are those listed in table 5 for March 23, 1976. Energy coefficients used in the computation scheme are listed in table 6.

Observed and computed hysteresis loops are shown on figures 13 to 16. At each station the computed discharge closely approximates the measured discharge at most stages. Statistics indicating average error in units of flow and in percent are also listed. The average computation error was determined by summing the absolute difference between measured and computed discharges at each time step and dividing by the number of time steps. Values of average percentage error were similarly computed. For the three most downstream stations the average computation error was less than 6.7 percent; standard deviation of this error was 6.4 percent or less. At Georgia Highway 20 computed discharges were considerably less accurate, with an average computation error and standard deviation of 8.9 and 10.2 percent respectively.

TABLE 7.—*Digital program list*

```
C*****************************************************************************
C
C     PROGRAM TO COMPUTE DYNAMIC RIVER DISCHARGE USING "AT-A-STATION" CHANNEL
C     AND FLOW DATA. SOLUTION SCHEME UTILIZES THE CONTINUITY AND MOMENTUM
C     EQUATIONS FOR OPEN-CHANNEL FLOW TRANSFORMED TO ELIMINATE THE SPATIAL
C     DISTRIBUTION OF FLOW VELOCITY AND DEPTH. FLOW PARAMETERS (AREA, WETTED
C     PERIMETER, AND HYDRAULIC RADIUS) ARE DERIVED FROM X-Y CROSS SECTION
C     COORDINATES FOR THE PARTICULAR STATION AND ARE COMPUTED AT EACH GIVEN
C     GAGE HEIGHT. THE BASIC SOLUTION SCHEME FOR THESE PARAMETERS UTILIZES
C     THE EQUATION FOR AREA OF AN IRREGULAR POLYGON.
C
C                                ROBERT E. FAYE
C                                 15SEPT77
C
C
C
C                              VARIABLE DEFINITION
C
C     AA, BB, CC = COEFFICIENTS OF QUADRATIC EQUATION
C     AERINT = INITIAL STREAM CROSS SECTIONAL AREA
C     ALPHA = VELOCITY COEFFICIENT
C     AMN = COMPUTED MANNING'S N AT CONTROL ALTITUDE
C     BOELEV, BOELEV1, BOELEV2 = BOTTOM ELEVATION OF CHANNEL THALWEG
C     CODE = VARIABLE DESIGNATOR FOR SENSITIVITY ANALYSIS
C     DATE = BEGINNING DATE OF DATA COLLECTION
C     DELT = TIME DIFFERENCE BETWEEN STAGE MEASUREMENTS
C     DEP = CONTROL ALTITUDE FOR MANNING'S N INTERPOLATION
C     DISCH = COMPUTED DISCHARGE
C     E = WATER-SURFACE ALTITUDE(STAGE)
C     EINT = INITIAL WATER-SURFACE ALTITUDE
C     EMARK = STAGE AT WHICH CROSS-SECTION GEOMETRY CHANGES SIGNIFICANTLY
C     EPS = CLOSURE ERROR FOR NEWTON-RAPHSON ITERATION
C     ERRQ = ABSOLUTE DIFFERENCE BETWEEN COMPUTED AND MEASURED DISCHARGE
C     ETA    = MANNINGS' N VALUE
C     ETACPT = INTERCEPT FOR MANNING'S N COMPUTATION WITH DEPTH
C     ETASL = SLOPE FOR MANNING'S N COMPUTATION WITH DEPTH
C     GRAV = ACCELERATION OF GRAVITY(32.2 FT/SEC**2)
C     HYDRAD = HYDRAULIC RADIUS
C     HYDEPT = HYDRAULIC DEPTH
C     NORUN = NUMBER OF RUNS FOR SENSITIVITY ANALYSIS: EQUALS ZERO IF
C     SENSITIVITY ANALYSIS NOT REQUIRED
C     NQUEST = EQUALS 1 IF MANNINGS N IS CONSTANT; OTHERWISE EQUALS ZERO
C     NOTMSP = NUMBER OF STAGE MEASUREMENTS(IE. NUMBER OF TIME STEPS)
C     NUMGN = NUMBER OF COMPUTED MANNING'S N VALUES
C     NXY,NXY1,NXY2 = NUMBER OF X,Y COORDINATE PAIRS FOR CROSS SECTION
C     PNCTER = COMPUTATION ERROR IN PERCENT
C     QMEAS = MEASURED DISCHARGE AT STATION
C     RIVMIL = RIVER MILE OF STATION
C     RMS = STANDARD DEVIATION OF COMPUTATION ERROR
C     RMS1 = STANDARD DEVIATION OF PERCENT ERROR
C     SENSDF = INCREMENTAL ADJUSTMENT FOR SENSITIVITY ANALYSIS; EQUALS ZERO IF
C     SENSITIVITY ANALYSIS NOT REQUIRED
C     SLOPE = EFFECTIVE CHANNEL SLOPE
C     SLOPEL = SLOPE OF CHANNEL PERIMETER AT LEFT BOUNDARY OF CHANNEL
C     SLOPER = SLOPE OF CHANNEL PERIMETER AT RIGHT BOUNDARY OF CHANNEL
C     STANUM = STATION NUMBER
C     TIME = TIME OF STAGE AND DISCHARGE MEASUREMENT
C     TIMINT = INITIAL TIME
C     VARY = VARIABLE UNDERGOING SENSITIVITY ANALYSIS
C     VEL = COMPUTED MEAN FLOW VELOCITY
C     VELINT = INITIAL STREAM VELOCITY
C     WETPER = WETTED PERIMETER
C     WAVEL = ABSOLUTE WAVE VELOCITY
C     X = HORIZONTAL CROSS SECTION COORDINATE
C     Y = VERTICAL CROSS SECTION COORDINATE
C*****************************************************************************
```

```
      DIMENSION X(100),Y(100),ABC(100),ORD(100),STANAM(100),TIME(999),
     1F(999),QMEAS(999),CRA(100),DRO(100),TVEL(999),VEL(999),DELT(999),
     2 DISCH(999),ERRO(200),PNCTER(200),ETASL(10),ETACPT(10),DEP(10),
     3 AMN(10),X1(50),Y1(50),X2(50),Y2(50),DISCHD(1000),QMEASD(1000),
     4DATE(20)
      READ(5,5) STANUM,NQUEST,NUMGN,NORUN,ALPHA,SENSDF
    5 FORMAT(4I8,2F8.4)
      READ(5,7) NOTMSP,NXY,ENDVEL,EMARK,(DATE(N),N=1,10)
    7 FORMAT(2I8,2F8.4,10A2)
      READ(5,8) EINT,VELINT,AERINT,BOELEV,RIVMIL,GRAV,ETA,SLOPE,TIMINT
      ETAM = ETA
      SLOPEM = SLOPE
      ALPHAM = ALPHA
    8 FORMAT(9F8.0)
      READ(5,6) WAVEL,VARY,CODE
      WAVELM = WAVEL
    6 FORMAT (F10.5,A4,F3.1)
      IF(NQUEST.EQ.1) GO TO 49
      DO 59 I=1,NUMGN
      READ(5,51) DEP(I),ETASL(I),ETACPT(I),AMN(I)
   51 FORMAT(4F10.4)
   59 CONTINUE
   49 IF(EMARK.EQ.0.0) GO TO 23
      READ(5,55) BELEV1,BELEV2,NXY1,NXY2
      READ(5,10)(X1(I),Y1(I),I=1,NXY1)
      READ(5,10)(X2(I),Y2(I),I=1,NXY2)
   55 FORMAT(2F8.3,2I8)
      GO TO 24
   23 READ(5,10)  (X(I),Y(I),I=1,NXY)
   10 FORMAT(10F8.0)
   24 DO 11 I=1,NOTMSP
      READ(5,9) TIME(I),F(I),QMEAS(I)
    9 FORMAT (3F8.0)
   11 CONTINUE
      DO 90 I=2,NOTMSP
      DUMTM3 = TIME(I)
      QUO1 = DUMTM3/100.
      DUMTM4 = AINT(QUO1)
      IF(DUMTM4.NE.QUO1) GO TO 92
      DELT(I) = ABS(TIME(I) - TIME(I-1))*60. - 40.*60.
      IF(TIME(I-1).NE.2400.) GO TO 90
      DELT(I) = ABS(TIME(I)-0000.)*60. - 40.*60.
      GO TO 90
   92 DELT(I) = ABS(TIME(I) - TIME(I-1))*60.
   90 CONTINUE
      TIME(1) = TIMINT
      VEL(1) = VELINT
      QINT=VELINT*AERINT
      KOUNT = NOTMSP - 1
      NRUN = 0
   99 TRACK = 1.0
      KDY=0
      COUNT = 0.0
      IF(CODE.EQ.1.0) SLOPE = SLOPEM*SENSDF
      IF(CODE.EQ.2.0) WAVEL = WAVELM*SENSDF


      IF(CODE.EQ.4.0) ALPHA = ALPHAM*SENSDF
```

```
C*************************************************************************************
C     COMPUTATION OF CROSS SECTION CHARACTERISTICS BASED ON EQUATION FOR AREA
C     OF AN IRREGULAR POLYGON OF N SIDES       2*A = X(1)*(Y(2)-Y(N)) +
C     X(2)*(Y(3)-Y(1)) +.........+ X(N-1)*(Y(N)-Y(N-2)) + X(N)*(Y(1)-Y(N-1))
C*************************************************************************************
      DO 50 M=2,KOUNT
      COUNT = COUNT + 1.0
      IF(EMARK.EQ.0.0) GO TO 104
      DY = (E(M+1)-E(M-1))/2.
      IF(DY.GE.0.0.AND.E(M).GT.EMARK) GO TO 112
      IF(DY.LT.0.0.AND.E(M).GT.EMARK) GO TO 112
      DO 21 I=1,NXY1
      X(I) = X1(I)
      Y(I) = Y1(I)
   21 CONTINUE
      BOELEV = BELEV1
      NXY = NXY1
      GO TO 109
  112 DO 22 I=1,NXY2
      X(I) = X2(I)
      Y(I) = Y2(I)
   22 CONTINUE
      BOELEV = BELEV2
      NXY = NXY2
  109 Z = E(M)
      DO 100J=1,NXY
      IF (Z-Y(J)) 120,120,110
  110 ABC(J) = X(J)
      ORD(J) = Y(J)
      CBA(J) = X(J)
      DRO(J) = Y(J)
      GO TO 100
  120 ABC(J) = 0.0
      ORD(J) = 0.0
      CBA(J) = 0.0
      DRO(J) = 0.0
      TW=0.0
  100 CONTINUE
      DO 200 K=1,NXY
      IF(CBA(K).EQ.0.0) GO TO 200
      IF(CBA(K-1).EQ.0.0) GO TO 201
      IF(CBA(K+1).EQ.0.0) GO TO 202
      GO TO 200
  201 SLOPEL = (Y(K-1)-DRO(K))/(X(K-1)-CBA(K))
      YINTL = DRO(K) - SLOPEL*CBA(K)
      ABC(K-1) = (Z-YINTL)/SLOPEL
      BNDL = ABC(K-1)
      ORD(K-1) = Z
      IF(CBA(K+1).EQ.0.0) GO TO 206
      GO TO 200
  202 IF(DRO(K).EQ.Z) GO TO 200
  206 SLOPER = (Y(K+1)-DRO(K))/(X(K+1)-CBA(K))
      YINTR = DRO(K) - SLOPER*CBA(K)
      ABC(K+1) = (Z-YINTR)/SLOPER
      BNDR = ABC(K+1)
      ORD(K+1) = Z
      TW = TW + BNDR-BNDL
  200 CONTINUE


      TWW = ABS(TW)
```

```
C***********************************************************************************
C     REARRANGE SUBSCRIPT NUMBERS OF ABCISSA AND ORDINATE VALUES TO PROVIDE
C     FOR SEQUENTIAL COMPUTATION OF WETTED PERIMETER AND AREA VALUES
C***********************************************************************************
C
      JN = 0
      DO 400 KN=1,NXY
      IF(ABC(KN).EQ.0.0) GO TO 400
      JN = JN + 1
      ABC(JN) = ABC(KN)
      ORD(JN) = ORD(KN)
      NJ = JN
  400 CONTINUE
C
C***********************************************************************************
C     COMPUTE WETTED PERIMETER OF CROSS SECTION AT GIVEN STAGE
C***********************************************************************************
C
      WETPER = 0.0
      DO 800 KW=2,NJ
      TANA = (ORD(KW) - ORD(KW-1))/(ABC(KW) - ABC(KW-1))
      ABTANA = ABS(TANA)
      PHI = ATAN(ABTANA)
      WP = (ABC(KW) - ABC(KW-1))/COS(PHI)
      WETPER = WETPER + WP
  800 CONTINUE
      WPP = ABS(WETPER)
C
C***********************************************************************************
C     COMPUTE CROSS SECTIONAL AREA OF CHANNEL AT GIVEN STAGE
C***********************************************************************************
C
      AREA1 = ABC(1)*(ORD(2)-ORD(NJ))
      AREA2 = ABC(NJ)*(ORD(1)-ORD(NJ-1))
      NNJ = NJ-1
      SUMARE = 0.0
      DO 500 J=2,NNJ
      SUBARE = ABC(J)*(ORD(J+1)-ORD(J-1))
      SUMARE = SUMARE + SUBARE
  500 CONTINUE
      DBLARE = AREA1 + AREA2 + SUMARE
      AREA = ABS(DBLARE/2.0)
      HYDRAD = AREA/WPP
      HYDEPT = AREA/TWW
      DY = (E(M+1) - E(M-1))/2.
C
C***********************************************************************************
C     COMPUTATION OF MANNING'S N USING A LINEAR RELATION BETWEEN
C     DEPTH AND ROUGHNESS
C***********************************************************************************
C
      IF(NQUEST.EQ.1) GO TO 226
      DO 69 I=2,NUMGN
      IF(E(M).GT.DEP(I-1).AND.E(M).LE.DEP(I)) GO TO 68
      GO TO 69
   68 ETA = ETASL(I-1)*(E(M)-BOFLEV) + ETACPT(I-1)
      GO TO 227
   69 CONTINUE
C
C***********************************************************************************
C     NEWTON-RAPHSON SOLUTION OF POLYNOMIAL TO DETERMINE EXPLICIT VELOCITY
C***********************************************************************************
C
  226 IF(CODE.EQ.3.0) ETA = ETA**SENSDF
  227 AA = ((-DY*ALPHA)/(WAVEL*HYDEPT))-(((ETA**2)*GRAV*DELT(M))/
     1 (2.22*(HYDRAD**1.3333)))
      BB = ((DY*ALPHA)/HYDEPT - 1.)
      CC = DELT(M)*GRAV*SLOPE + VEL(M-1) + (DY*GRAV)/WAVEL
```

```
      TVEL(1) = VEL(M-1)
      EPS = .001
      MAX = 30
      DO 900 N=2,MAX
      PVEL = TVEL(N-1)
      FUNCT = AA*(PVEL**2) + BB*PVEL+ CC
      DERIV = 2.*AA*PVEL + BB
      TVEL(N) = PVEL - FUNCT/DERIV
      IF(ABS(TVEL(N)-TVEL(N-1)).LT.EPS) GO TO 901
  900 CONTINUE
  901 VEL(M) = ABS(TVEL(N))
      DISCH(M) = VEL(M)*AREA
      IF(COUNT.GT.1.0) GO TO 666
      WRITE(6,902) STANUM
  902 FORMAT(1H1,52X,'STATION NUMBER = ',I8)
      IF(RIVMIL.EQ.0.0) GO TO 906
      WRITE(6,904) RIVMIL
  904 FORMAT(53X,'RIVER MILE = ',F8.2)
  906 WRITE(6,905) BOELEV
  905 FORMAT (53X,'BOTTOM ELEVATION = ',F8.2)
      WRITE(6,907) SLOPE
  907 FORMAT (53X,'EFFECTIVE SLOPE = ',F8.7)
      WRITE(6,620) ALPHA
  620 FORMAT(53X,'VELOCITY COEFFICIENT = ',F8.3)
      WRITE(6,640) WAVEL
  640 FORMAT(53X,'ABSOLUTE WAVE VELOCITY = ',F8.3)
      WRITE(6,610) ENDVEL
  610 FORMAT(53X,'FINAL VELOCITY = ',F8.2)
      IF(NQUEST.NE.1) GO TO 778
      WRITE(6,775) ETA
  775 FORMAT(53X,'MANNINGS N = ',F5.4)
  778 WRITE(6,908)(DATE(N),N=1,10)
  908 FORMAT(53X,'BEGIN DATE = ',10A2)
      IF(NQUEST.EQ.1) GO TO 779
      WRITE(6,569)
  569 FORMAT(1H0,50X,'MANNINGS N CONFIGURATION')
      WRITE(6,578)
  578 FORMAT(54X,'STAGE',12X,'N')
      DO 53 I=1,NUMGN
      WRITE(6,579) DEP(I),AMN(I)
  579 FORMAT(51X,F10.2,2X,F10.5)
   53 CONTINUE
  666 IF(KDY.GT.0) GO TO 667
  779 WRITE(6,909)
      WRITE(6,392)
  909 FORMAT(1H0,'TIME',10X,'STAGE',9X,'VELOCITY',9X,'DISCHARGE',10X,
     1 'DISCHARGE')
      WRITE(6,910)
  910 FORMAT(12X,'FEET ABOVE MSL',5X,'FT/SEC',12X,'CFS',17X,'CFS')
      WRITE(6,911)
  911 FORMAT(46X,'COMPUTED',10X,'MEASURED')
      IF(TRACK.GT.1.0) GO TO 667




      WRITE(6,912) TIMINT,EINT,VELINT,QINT
  912 FORMAT(F6.0,10X,F6.2,10X,F5.2,27X,F7.2)
  667 IF(QMEAS(M).GT.0.0) GO TO 777
      WRITE(6,520) TIME(M),E(M),VEL(M),DISCH(M)
  520 FORMAT(F6.0,10X,F6.2,10X,F5.2,10X,F8.2)
      GO TO 701
  777 WRITE(6,510) TIME(M),E(M),VEL(M),DISCH(M),QMEAS(M)
  510 FORMAT(F6.0,10X,F6.2,10X,F5.2,10X,F8.2,10X,F8.2)
  701 KDY = KDY + 1
      DISCHD(KDY) = DISCH(M)
      QMEASD(KDY) = QMEAS(M)
      IF(TIME(M).LE.TIME(M+1)) GO TO 50
```

```
C*************************************************************************
C      STATISTICAL ANALYSIS OF COMPUTED DISCHARGE DATA
C*************************************************************************
C
      SUMERQ = 0.0
      SUMQ2 = 0.0
      SMPNTE = 0.0
      SUMQ1 = 0.0
      QTRACK = 0.0
      DO 411 J=2,KDY
      SUMQ2 = SUMQ2 + DISCHD(J)
      IF(QMEASD(J).EQ.0.0) GO TO 411
      SUMQ1 = SUMQ1 + QMEASD(J)
      QTRACK = QTRACK + 1.0
      ERRQ(J) = ABS(QMEASD(J)-DISCHD(J))
      SUMERQ = SUMERQ + ERRQ(J)
      PNCTER(J) = (ERRQ(J)/QMEASD(J))*100.
      SMPNTE = SMPNTE + PNCTER(J)
  411 CONTINUE
      AVGQC = SUMQ2/KDY
      IF(QTRACK.EQ.0.0) GO TO 903
      AVGQM = SUMQ1/QTRACK
      AVGER = SUMERQ/QTRACK
      AVGPNT = SMPNTE/QTRACK
      DIFSQ = 0.0
      DIFSQ1 = 0.0
      DO 421 J=2,KDY
      IF(QMEASD(J).EQ.0.0) GO TO 421
      DIFSQ1 = (ERRQ(J)-AVGER)**2 + DIFSQ1
      DIFSQ = (PNCTER(J) - AVGPNT)**2 + DIFSQ
  421 CONTINUE
      RMS1 = SQRT(DIFSQ1/QTRACK)
      RMS = SQRT(DIFSQ/QTRACK)
  903 WRITE(6,392)
  392 FORMAT(1H0)
      WRITE(6,441) AVGQC
  441 FORMAT(53X,'AVERAGE COMPUTED DISCHARGE = ',F9.0)
      IF(QTRACK.EQ.0.0) GO TO 769
      WRITE(6,431) AVGQM
  431 FORMAT(53X,'AVERAGE MEASURED DISCHARGE = ',F9.0)
      WRITE(6,471) AVGER
  471 FORMAT(53X,'AVERAGE COMPUTATIONAL ERROR = ',F9.2)
      WRITE(6,392)
      WRITE(6,451) AVGPNT
  451 FORMAT(53X,'AVERAGE COMPUTATION ERROR IN PERCENT = ',F7.2)
      WRITE(6,481) RMS1
  481 FORMAT(53X,'STANDARD DEVIATION OF COMPUTATIONAL ERROR = ',F9.2)
      WRITE(6,461) RMS


  461 FORMAT(53X,'STANDARD DEVIATION OF PERCENT ERROR = ',F7.2)
  769 KDY = 0
      TRACK = TRACK + 1
      WRITE(6,393)
  393 FORMAT(1H1)
      WRITE(6,565)TRACK
  565 FORMAT(50X,'DAY',F4.0)
   50 CONTINUE
      IF(SENSDF.EQ.0.0) GO TO 969
      SENFAC = SENSDF*100.
      WRITE(6,679) VARY
  679 FORMAT(53X,'VARIABLE UNDERGOING SENSITIVITY ANALYSIS = ',A4)
      WRITE(6,699) SENFAC
  699 FORMAT(53X,'VALUE OF SENSITIVITY FACTOR,IN PERCENT = ',F7.3)
      IF(NORUN.EQ.0) GO TO 969
      IF(NRUN.EQ.NORUN) GO TO 969
      NRUN = NRUN + 1
      SENSDF = SENSDF + .2
      GO TO 99
  969 STOP
      END
```

Such statistics indicate that average station discharge and average stream velocity for a particular dynamic flow event can be accurately computed using the method described in this paper.

The accuracy of computed instantaneous dynamic discharges is indicated in tables 8 and 9 as well as on figures 13 to 16. Measured and computed rise and recession discharges at water-surface altitudes representing 10, 25, 50, 75, and 90 percent of total stage change are compared at Littles Ferry Bridge (table 8) and at Georgia Highway 141 (table 9). With the exception of two discharges computed at Littles Ferry Bridge the error between measured and computed instantaneous discharge is less than 15 percent for every stage value at both stations.

An interesting comparison can be made between rated and computed discharges at Georgia Highway 141. Measured, computed, and rating-curve values of instantaneous station discharge at various stages are listed in table 9. Use of the rating curve to estimate discharge on the rising limb of the hydrograph is shown to be unsatisfactory with errors ranging from 17 to 25 percent. Errors for corresponding computed discharges, on the other hand, ranged from 4 to 14 percent. Both computed and rating-curve estimates of recession discharge at Georgia Highway 141 are shown to be satisfactory.

The data presented in figures 13 to 16 and in tables 8 and 9 indicate that the mathematical model presented in this paper can, with few exceptions, compute highly dynamic discharge within acceptable limits of error. In particular the model extends the utility of gaging station records; computing mean daily and instantaneous dynamic discharges with far greater accuracy than could otherwise be obtained from single value rating curves. In addition, data utilized in the computation scheme are, for the most part, routinely collected during station operation.

SENSITIVITY ANALYSES

The sensitivity of highly dynamic discharge to various flow and channel parameters was determined by using the model computations in conjunction with adjusted values of selected parameters. Parameters investigated include Manning's n, effective channel slope (S_o), absolute wave velocity (V_w), and the velocity coefficient (α). Flow data used in the sensitivity analyses were those collected on March 23, 1976 at Georgia Highway 120. For each analysis, the parameter being investigated was varied from 10 to 200 percent of its observed value while other model parameters remained at observed values. Model sensitivity is illustrated in figure 21 where values of mean computation error in percent are

TABLE 8.—*Measured and computed discharges at Littles Ferry Bridge, 0850 to 2120 hours—March 23, 1976*

	Rise			Recession		
Total stage change percent	Measured discharge (ft^3/s)	Computed discharge (ft^3/s)	Error percent	Measured discharge (ft^3/s)	Computed discharge (ft^3/s)	Error percent
10	1,950	1,350	31	5,370	5,670	5.6
25	2,700	2,130	21	4,160	4,060	2.4
50	4,380	3,770	14	2,800	3,020	7.9
75	5,890	5,650	4.1	1,860	1,830	1.6
90	7,220	6,780	6.1	1,330	1,330	0.0

TABLE 9.—*Measured, computed, and rating-curve discharges at Georgia Highway 141—1105 to 2310 hours—March 23, 1976*

	Rise				
Total stage change percent	Measured discharge (ft^3/s)	Computed discharge (ft^3/s)	Rated discharge (ft^3/s)	Error percent	
				Equation (12)	Rating curve
10	2,060	1,780	1,580	14.0	23
25	2,890	2,500	2,160	14.0	25
50	4,080	3,920	3,270	3.9	20
75	5,610	5,260	4,490	6.2	20
90	6,410	6,000	5,290	6.3	17
	Recession				
Total stage change percent	Measured discharge (ft^3/s)	Computed discharge (ft^3/s)	Rated discharge (ft^3/s)	Error percent	
				Equation (12)	Rating curve
10	5,620	5,340	5,400	5.0	3.9
25	4,870	4,620	4,760	5.1	2.3
50	3,720	3,620	3,780	2.7	1.6
75	2,740	2,690	2,860	1.8	4.4
90	2,360	2,190	2,330	7.2	1.3

plotted against the percent of observed value of the given parameter.

Model results were most sensitive to changes in Manning's *n* and least sensitive to changes in velocity coefficient. Sensitivity to changes in effective channel slope and sensitivity to low percentage values of absolute wave velocity was also noted. Model computations were much more sensitive to gross underestimates of parameter values than to corresponding overestimates.

OTHER COMPARISONS

On November 15, 1956, the U.S. Army Corps of Engineers made a series of 7 discharge measurements at Georgia Highway 20 in

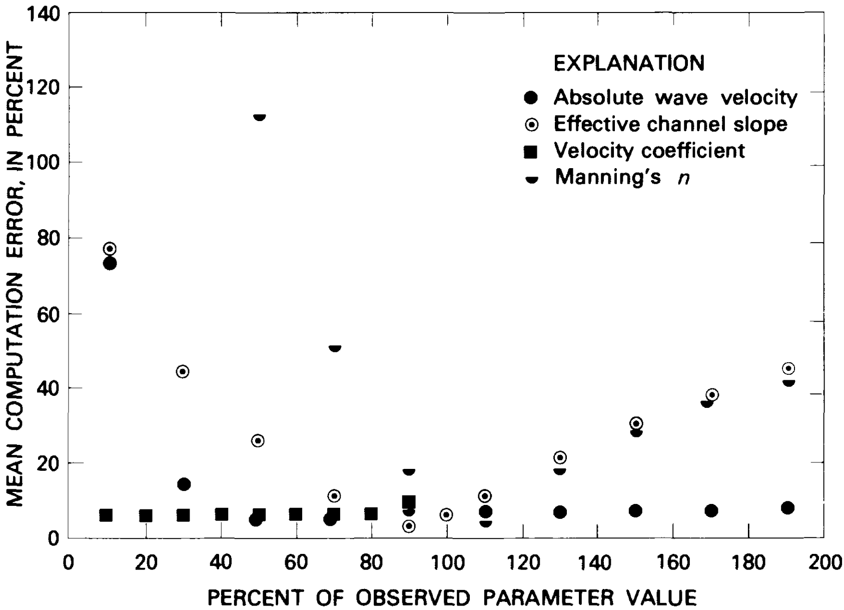


FIGURE 21.—Sensitivity of highly dynamic discharge to channel and flow parameters.

conjunction with a power generation cycle at Buford Dam. In order to apply those measurements to the mathematical model described in this report the effective channel slope and wave velocity observed at Georgia Highway 20 in March 1976 were assumed to have remained unchanged with time. However, observed streambank erosion and bottom scour have significantly changed channel roughness and geometry along the study reach since 1956. Thus, required cross-section coordinates and Manning's n values were computed, using data from the 1956 discharge notes. Computed Manning's n was nearly constant at 0.031, based on one high and two low-flow measurements. Continuous stage data were also obtained from the discharge notes and from linear interpolation between direct measurements. The results of applying the 1956 measurements to the mathematical model are shown in figure 22. Where data are available for comparison, computed and measured discharges are nearly coincident (fig. 22).

Jobson and Keefer (1979) used an implicit, finite difference, flow-routing model, in conjunction with the flow and channel geometry data listed in this report (tables 10 to 13), to compute the four hysteretic, stage-discharge relations described previously (figs. 13 to 16). Comparison of the relations computed with the

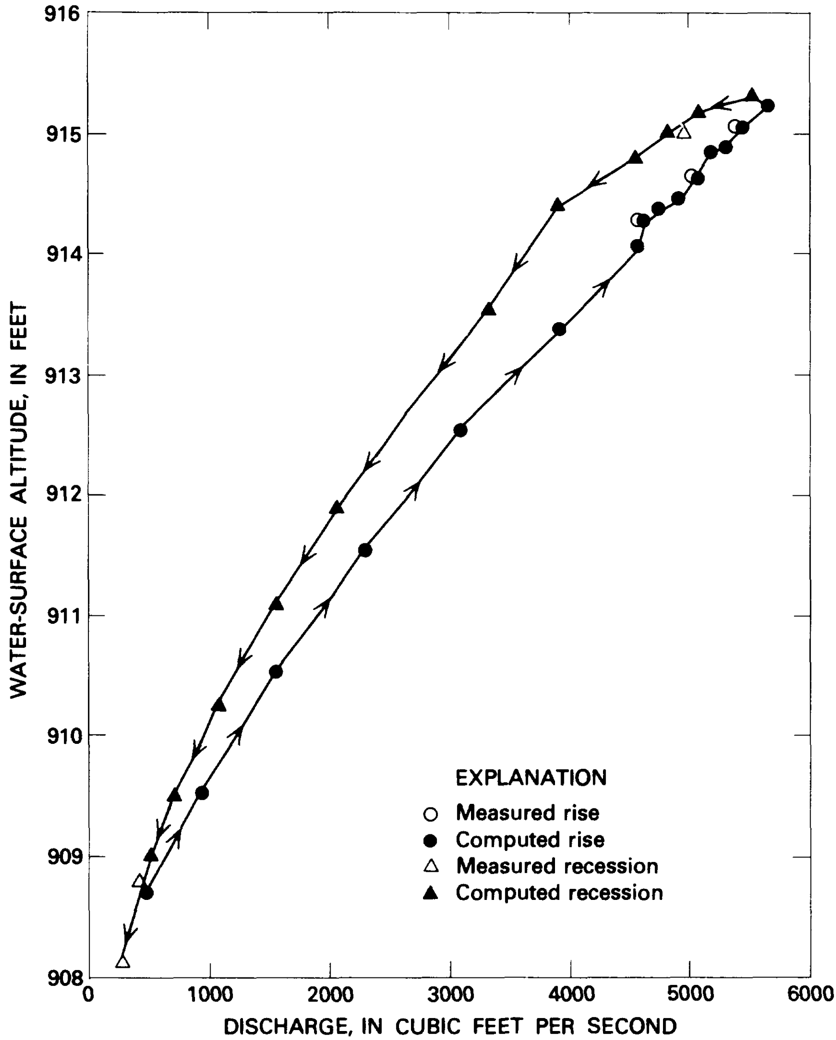


FIGURE 22.—Computed hysteretic stage-discharge relation at Georgia Highway 20—0732 to 1733 hours—November 15, 1956.

flow-routing model to those computed by the model described in this paper indicates that the flow-routing model tended to underestimate peak discharges and exaggerate hysteresis at intermediate stages.

CONCLUSIONS

The mathematical model presented in this paper and the model presented by Fread (1975) indicate that the equations describing one-dimensional, unsteady flow in open channels can mathematically describe, with reasonable accuracy, highly dynamic flow at a stream station. Fread's model was applied to large rivers where rates of stage rise were about 1 ft/day and channel slopes are on the order of 10^{-5} ft/ft. Comparison of observed discharges with those computed by Fread (1975) provided root mean square errors of 7 percent or less. The similar but more general model presented in this paper was applied to a short reach of the Chattahoochee River in northeast Georgia. Top widths in this reach range from about 150 to 300 feet and channel slopes are on the order of 10^{-4} ft/ft. Observed rates of stage change were in excess of 5 ft/hr. Simulation of hysteretic stage-discharge relations at four stations provided average computation errors of 9 percent or less.

Thus the same general methodology, applied to both large and small rivers as well as to relatively "sluggish" to highly dynamic flow conditions, mathematically computed unsteady discharge with a high degree of accuracy. Mathematical models which apply this methodology are particularly useful at gaging stations where stage records of dynamic flow are to be converted to instantaneous or mean daily discharges.

Data used to test the model presented in this paper are part of a detailed, comprehensive base of flow and channel data collected for an earlier study. These data are discussed and listed in this paper and can be used to test the computational accuracy of flow-routing or other models that simulate highly dynamic, open-channel flow.

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TABLE 10.—*Summary of river stage data*

Date and Time	Water-surface altitude, in feet				
	Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 21, 1976:					
0000	913.38	903.03	-----	-----	880.37
0005	913.38	903.03	-----	-----	-----
0010	913.38	903.03	-----	-----	-----
0015	913.38	903.03	-----	-----	-----
0020	913.38	903.03	-----	-----	-----
0025	913.38	903.03	-----	-----	-----
0030	913.38	903.03	-----	-----	880.36
0035	913.38	903.03	-----	-----	-----
0040	913.38	903.03	-----	-----	-----
0045	913.38	903.03	-----	-----	-----
0050	913.38	903.03	-----	-----	-----
0055	913.38	903.03	-----	-----	-----
0100	913.38	903.03	-----	-----	-----
0105	913.38	903.03	-----	-----	-----
0110	913.38	903.03	-----	-----	-----
0115	913.38	903.03	-----	-----	-----
0120	913.38	903.03	-----	-----	-----
0125	913.38	903.03	-----	-----	-----
0130	913.38	903.03	-----	-----	880.35
0135	913.38	903.03	-----	-----	-----
0140	913.38	903.03	-----	-----	-----
0145	913.38	903.03	-----	-----	-----
0150	913.38	903.03	-----	-----	-----
0155	913.38	903.03	-----	-----	-----
0200	913.38	903.03	-----	-----	-----
0205	913.38	903.03	-----	-----	-----
0210	913.38	903.03	-----	-----	-----
0215	913.38	903.04	-----	-----	-----
0220	913.38	903.04	-----	-----	-----
0225	913.38	903.04	-----	-----	-----
0230	913.38	903.04	-----	-----	880.35
0235	913.38	903.04	-----	-----	-----
0240	913.38	903.04	-----	-----	-----
0245	913.38	903.04	-----	-----	-----
0250	913.38	903.04	-----	-----	-----
0255	913.38	903.05	-----	-----	-----
0300	913.38	903.05	-----	-----	-----
0305	913.38	903.05	-----	-----	-----
0310	913.38	903.05	-----	-----	-----
0315	913.38	903.05	-----	-----	-----
0320	913.38	903.05	-----	-----	-----
0325	913.38	903.05	-----	-----	-----
0330	913.38	903.06	-----	-----	880.36
0335	913.38	903.06	-----	-----	-----
0340	913.38	903.06	-----	-----	-----
0345	913.38	903.06	-----	-----	-----
0350	913.38	903.07	-----	-----	-----
0355	913.38	903.07	-----	-----	-----
0400	913.38	903.07	-----	-----	-----
0405	913.38	903.07	-----	-----	-----
0410	913.38	903.07	-----	-----	-----
0415	913.38	903.08	-----	-----	-----
0420	913.38	903.08	-----	-----	-----
0425	913.38	903.09	-----	-----	-----
0430	913.38	903.09	-----	-----	880.40
0435	913.38	903.09	-----	-----	-----
0440	913.38	903.10	-----	-----	-----

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet				
	Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 21, 1976:					
0445	913.38	903.10	-----	-----	-----
0450	913.38	903.11	-----	-----	-----
0455	913.38	903.11	-----	-----	-----
0500	913.38	903.11	-----	-----	-----
0505	913.38	903.11	-----	-----	-----
0510	913.38	903.11	-----	-----	-----
0515	913.38	903.12	-----	-----	-----
0520	913.38	903.12	-----	-----	-----
0525	913.38	903.12	-----	-----	-----
0530	913.38	903.13	-----	-----	880.44
0535	913.38	903.13	-----	-----	-----
0540	913.38	903.13	-----	-----	-----
0545	913.38	903.14	-----	-----	-----
0550	913.38	903.14	-----	-----	-----
0555	913.38	903.14	-----	-----	-----
0600	913.38	903.14	-----	-----	-----
0605	913.38	903.14	-----	-----	-----
0610	913.38	903.15	-----	-----	-----
0615	913.38	903.15	-----	-----	-----
0620	913.38	903.16	-----	-----	-----
0625	913.38	903.16	-----	-----	-----
0630	913.38	903.16	-----	-----	880.52
0635	913.38	903.16	-----	-----	-----
0640	913.38	903.17	-----	-----	-----
0645	913.38	903.17	-----	-----	-----
0650	913.38	903.18	-----	-----	-----
0655	913.38	903.19	-----	-----	-----
0700	913.38	903.19	-----	-----	-----
0705	913.38	903.20	-----	-----	-----
0710	913.38	903.21	-----	-----	-----
0715	913.38	903.21	-----	-----	-----
0720	913.38	903.22	-----	-----	-----
0725	913.38	903.22	-----	-----	-----
0730	913.38	903.23	-----	-----	880.58
0735	913.38	903.24	-----	-----	-----
0740	913.38	903.25	-----	-----	-----
0745	913.38	903.25	-----	-----	-----
0750	913.38	903.26	-----	-----	-----
0755	913.38	903.26	-----	-----	-----
0800	913.38	903.26	-----	-----	-----
0805	913.38	903.27	-----	-----	-----
0810	913.38	903.27	-----	-----	-----
0815	913.38	903.28	-----	-----	-----
0820	913.38	903.28	-----	-----	-----
0825	913.38	903.28	-----	-----	-----
0830	913.38	903.28	-----	-----	880.65
0835	913.38	903.29	-----	-----	-----
0840	913.38	903.29	-----	-----	-----
0845	913.38	903.30	-----	-----	-----
0850	913.38	903.28	-----	-----	-----
0855	913.38	903.29	-----	-----	-----
0900	913.38	903.29	-----	-----	-----
0905	913.38	903.28	-----	-----	-----
0910	913.38	903.29	-----	-----	-----
0915	913.38	903.28	-----	-----	-----
0920	913.38	903.29	-----	-----	-----
0925	913.38	903.29	-----	-----	-----

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 21, 1976:					
0930	913.38	903.28	-----	-----	880.70
0935	913.38	903.29	-----	-----	-----
0940	913.38	903.28	-----	-----	-----
0945	913.38	903.28	-----	-----	-----
0950	913.38	903.27	-----	-----	-----
0955	913.38	903.27	-----	-----	-----
1000	913.38	903.27	-----	-----	-----
1005	913.38	903.26	-----	-----	-----
1010	913.38	903.26	-----	-----	-----
1015	913.38	903.27	-----	-----	-----
1020	913.38	903.26	-----	-----	-----
1025	913.38	903.25	-----	-----	-----
1030	913.38	903.24	-----	-----	880.72
1035	913.38	903.24	-----	-----	-----
1040	913.38	903.25	-----	-----	-----
1045	913.38	903.23	-----	-----	-----
1050	913.38	903.23	-----	-----	-----
1055	913.38	903.23	-----	-----	-----
1100	913.38	903.24	-----	-----	-----
1105	913.38	903.23	-----	-----	-----
1110	913.38	903.21	-----	-----	-----
1115	913.38	903.22	-----	-----	-----
1120	913.38	903.23	-----	-----	-----
1125	913.38	903.22	-----	-----	-----
1130	913.38	903.22	-----	-----	880.73
1135	913.38	903.21	-----	-----	-----
1140	913.38	903.21	-----	-----	-----
1145	913.38	903.20	-----	-----	-----
1150	913.38	903.20	-----	-----	-----
1155	913.38	903.21	-----	-----	-----
1200	913.39	903.18	-----	-----	880.73
1205	913.39	903.18	-----	-----	-----
1210	913.39	903.17	-----	-----	-----
1215	913.39	903.17	-----	-----	-----
1220	913.39	903.19	-----	-----	-----
1225	913.39	903.17	-----	-----	-----
1230	913.39	903.17	-----	-----	880.74
1235	913.39	903.18	-----	-----	-----
1240	913.39	903.16	-----	-----	-----
1245	913.39	903.17	-----	-----	-----
1250	913.39	903.15	-----	-----	-----
1255	913.39	903.15	-----	-----	-----
1300	913.39	903.16	-----	-----	-----
1305	913.39	903.16	-----	-----	-----
1310	913.39	903.16	-----	-----	-----
1315	913.39	903.15	-----	-----	-----
1320	913.39	903.15	-----	-----	-----
1325	913.39	903.16	-----	-----	-----
1330	913.39	903.14	-----	-----	880.76
1335	913.39	903.14	-----	-----	-----
1340	913.39	903.13	-----	-----	-----
1345	913.39	903.13	-----	-----	-----
1350	913.39	903.14	-----	-----	-----
1355	913.39	903.13	-----	-----	-----
1400	913.38	903.12	-----	-----	-----
1405	913.38	903.13	-----	-----	-----
1410	913.38	903.13	-----	-----	-----

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet				
	Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 21, 1976:					
1415	913.38	903.12	-----	-----	-----
1420	913.38	903.12	-----	-----	-----
1425	913.38	903.11	-----	-----	-----
1430	913.38	903.12	-----	-----	880.81
1435	913.38	903.12	-----	-----	-----
1440	913.38	903.12	-----	-----	-----
1445	913.38	903.12	-----	-----	-----
1450	913.38	903.12	-----	-----	-----
1455	913.38	903.11	-----	-----	-----
1500	913.38	903.11	-----	-----	-----
1505	913.38	903.10	893.50	-----	-----
1510	913.38	903.10	893.50	-----	-----
1515	913.38	903.10	893.50	-----	-----
1520	913.38	903.10	893.50	-----	-----
1525	913.38	903.10	------	----	-----
1530	913.38	903.10	893.49	-----	880.84
1535	913.38	903.11	-----	-----	-----
1540	913.38	903.09	893.48	-----	-----
1545	913.38	903.10	-----	-----	-----
1550	913.38	903.09	893.47	-----	-----
1555	913.38	903.10	-----	-----	-----
1600	913.38	903.10	893.45	-----	-----
1605	913.38	903.09	-----	-----	-----
1610	913.38	903.09	893.45	-----	-----
1615	913.38	903.09	-----	-----	-----
1620	913.38	903.09	893.41	-----	-----
1625	913.38	903.09	-----	-----	-----
1630	913.38	903.09	893.41	-----	880.85
1635	913.38	903.08	-----	-----	-----
1640	913.38	903.09	893.41	-----	-----
1645	913.38	903.08	-----	-----	-----
1650	913.38	903.08	893.42	-----	-----
1655	913.38	903.08	-----	-----	-----
1700	913.38	903.08	893.41	-----	-----
1705	913.38	903.08	-----	-----	-----
1710	913.38	903.08	893.39	-----	-----
1715	913.38	903.08	-----	-----	-----
1720	913.38	903.07	893.39	-----	-----
1725	913.38	903.08	-----	-----	-----
1730	913.38	903.07	893.38	-----	880.84
1735	913.38	903.07	-----	-----	-----
1740	913.38	903.07	893.37	-----	-----
1745	913.38	903.07	-----	-----	-----
1750	913.38	903.07	893.36	-----	-----
1755	913.38	903.07	-----	-----	-----
1800	913.38	903.07	893.36	-----	-----
1805	913.38	903.07	-----	-----	-----
1810	913.38	903.07	893.36	-----	-----
1815	913.38	903.07	-----	-----	-----
1820	913.38	903.07	893.36	-----	-----
1825	913.38	903.07	-----	-----	-----
1830	913.38	903.07	893.33	-----	880.83
1835	913.38	903.07	-----	-----	-----
1840	913.38	903.07	893.33	-----	-----
1845	913.38	903.07	-----	-----	-----
1850	913.38	903.07	893.32	-----	-----
1855	913.38	903.07	-----	-----	-----

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet				
	Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 21, 1976:					
1900	913.38	903.07	893.33	-----	-----
1905	913.38	903.07	-----	-----	-----
1910	913.38	903.07	-----	-----	-----
1915	913.38	903.07	-----	-----	-----
1920	913.38	903.07	893.30	-----	-----
1925	913.38	903.06	-----	-----	-----
1930	913.38	903.06	893.29	-----	880.81
1935	913.38	903.06	-----	-----	-----
1940	913.38	903.06	893.29	-----	-----
1945	913.38	903.06	-----	-----	-----
1950	913.38	903.06	893.29	-----	-----
1955	913.38	903.06	-----	-----	-----
2000	913.38	903.06	893.28	-----	-----
2005	913.38	903.06	-----	-----	-----
2010	913.38	903.06	893.27	-----	-----
2015	913.38	903.06	-----	-----	-----
2020	913.38	903.06	893.26	-----	-----
2025	913.38	903.06	-----	-----	-----
2030	913.38	903.06	893.26	-----	880.77
2035	913.38	903.06	-----	-----	-----
2040	913.38	903.06	893.25	-----	-----
2045	913.38	903.06	-----	-----	-----
2050	913.38	903.06	893.25	-----	-----
2055	913.38	903.06	-----	-----	-----
2100	913.38	903.06	893.25	-----	-----
2105	913.38	903.06	-----	-----	-----
2110	913.38	903.06	893.25	-----	-----
2115	913.38	903.05	-----	-----	-----
2120	913.38	903.05	893.24	-----	-----
2125	913.38	903.05	-----	-----	-----
2130	913.38	903.05	893.23	-----	880.74
2135	913.38	903.05	-----	-----	-----
2140	913.38	903.05	893.23	-----	-----
2145	913.38	903.05	-----	-----	-----
2150	913.38	903.05	893.22	-----	-----
2155	913.38	903.05	-----	-----	-----
2200	913.38	903.05	-----	-----	-----
2205	913.38	903.05	-----	-----	-----
2210	913.38	903.05	893.22	-----	-----
2215	913.38	903.05	-----	-----	-----
2220	913.38	903.05	893.22	-----	-----
2225	913.38	903.05	-----	-----	-----
2230	913.38	903.05	893.22	-----	880.69
2235	913.38	903.05	-----	-----	-----
2240	913.38	903.05	893.22	-----	-----
2245	913.38	903.05	-----	-----	-----
2250	913.38	903.05	893.21	-----	-----
2255	913.38	903.05	-----	-----	-----
2300	913.38	903.05	893.21	-----	-----
2305	913.38	903.05	-----	-----	-----
2310	913.38	903.05	893.21	-----	-----
2315	913.38	903.04	-----	-----	-----
2320	913.38	903.04	893.21	-----	-----
2325	913.38	903.04	-----	-----	-----
2330	913.38	903.04	893.21	-----	880.65
2335	913.38	903.04	-----	-----	-----
2340	913.38	903.04	893.20	-----	-----

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet				
	Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 21, 1976:					
2345	913.38	903.04	-----	-----	-----
2350	913.38	903.04	893.20	-----	-----
2355	913.38	903.04	-----	-----	-----
2400	913.38	903.04	893.19	-----	-----
March 22, 1976:					
0005	913.38	903.04	-----	-----	-----
0010	913.38	903.04	893.19	-----	-----
0015	913.38	903.04	-----	-----	-----
0020	913.38	903.04	893.19	-----	-----
0025	913.38	903.04	-----	-----	-----
0030	913.38	903.03	893.18	-----	880.61
0035	913.38	903.03	-----	-----	-----
0040	913.38	903.03	893.18	-----	-----
0045	913.38	903.03	-----	-----	-----
0050	913.38	903.03	893.18	-----	-----
0055	913.38	903.03	-----	-----	-----
0100	913.38	903.03	893.18	-----	-----
0105	913.38	903.03	-----	-----	-----
0110	913.38	903.03	893.17	-----	-----
0115	913.38	903.03	-----	-----	-----
0120	913.38	903.03	893.17	-----	-----
0125	913.38	903.03	-----	-----	-----
0130	913.38	903.03	893.17	-----	880.56
0135	913.38	903.03	-----	-----	-----
0140	913.38	903.03	893.17	-----	-----
0145	913.38	903.03	-----	-----	-----
0150	913.38	903.03	893.17	-----	-----
0155	913.38	903.03	-----	-----	-----
0200	913.38	903.03	893.17	-----	-----
0205	913.38	903.03	-----	-----	-----
0210	913.38	903.03	893.17	-----	-----
0215	913.38	903.03	-----	-----	-----
0220	913.38	903.03	893.17	-----	-----
0225	913.38	903.03	-----	-----	-----
0230	913.38	903.03	893.17	-----	880.52
0235	913.38	903.03	-----	-----	-----
0240	913.38	903.03	893.16	-----	-----
0245	913.38	903.03	-----	-----	-----
0250	913.38	903.03	893.16	-----	-----
0255	913.38	903.03	-----	-----	-----
0300	913.38	903.03	893.15	-----	-----
0305	913.38	903.03	-----	-----	-----
0310	913.38	903.03	893.15	-----	-----
0315	913.38	903.03	-----	-----	-----
0320	913.38	903.03	893.16	-----	-----
0325	913.38	903.03	-----	-----	-----
0330	913.38	903.03	893.16	-----	880.48
0335	913.38	903.03	-----	-----	-----
0340	913.38	903.03	893.15	-----	-----
0345	910.38	903.03	-----	-----	-----
0350	913.38	903.03	893.15	-----	-----
0355	913.38	903.03	-----	-----	-----
0400	913.38	903.03	893.15	-----	-----
0405	913.38	903.03	-----	-----	-----
0410	913.38	903.03	893.14	-----	-----
0415	913.38	903.03	-----	-----	-----

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet: Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 22, 1976:					
0420	913.38	903.03	893.14	-----	-----
0425	913.38	903.03	-----	-----	-----
0430	913.38	903.03	893.15	-----	880.46
0435	913.38	903.03	-----	-----	-----
0440	913.38	903.03	893.15	-----	-----
0445	913.38	903.03	-----	-----	-----
0450	913.38	903.03	893.12	-----	-----
0455	913.38	903.03	-----	-----	-----
0500	913.38	903.03	893.12	-----	-----
0505	913.38	903.03	-----	-----	-----
0510	913.38	903.03	893.12	-----	-----
0515	913.38	903.03	-----	-----	-----
0520	913.38	903.03	893.12	-----	-----
0525	913.38	903.03	-----	-----	-----
0530	913.38	903.03	893.11	-----	880.44
0535	913.38	903.03	-----	-----	-----
0540	913.38	903.03	893.10	-----	-----
0545	913.38	903.03	-----	-----	-----
0550	913.38	903.03	893.11	-----	-----
0555	913.38	903.03	-----	-----	-----
0600	913.38	903.09	893.11	-----	-----
0605	913.38	903.03	-----	-----	-----
0610	913.38	903.03	893.11	-----	-----
0615	913.38	903.03	-----	-----	-----
0620	913.38	903.03	893.11	-----	-----
0625	913.38	903.03	-----	-----	-----
0630	913.38	903.03	893.11	-----	880.41
0635	913.38	903.02	-----	-----	-----
0640	913.38	903.02	893.11	-----	-----
0645	913.38	903.02	-----	-----	-----
0650	913.38	903.02	893.11	-----	-----
0655	913.51	903.02	-----	-----	-----
0700	914.57	903.02	893.11	-----	-----
0705	915.60	903.02	-----	-----	-----
0710	916.10	903.02	893.11	-----	-----
0715	916.29	903.05	-----	-----	-----
0720	916.39	903.23	893.11	-----	-----
0725	916.45	903.62	-----	-----	-----
0730	916.48	904.10	893.11	-----	880.39
0735	916.50	904.57	-----	-----	-----
0740	916.52	904.97	893.11	-----	-----
0745	916.52	905.32	-----	-----	-----
0750	916.52	905.62	893.11	-----	-----
0755	916.52	905.86	-----	-----	-----
0800	916.54	906.09	893.11	-----	-----
0805	916.54	906.29	-----	-----	-----
0810	916.55	906.47	893.11	-----	-----
0815	916.54	906.63	-----	-----	-----
0820	916.55	906.77	893.11	-----	-----
0825	916.54	906.89	-----	-----	-----
0830	916.54	907.01	893.11	-----	880.37
0835	916.55	907.12	-----	-----	-----
0840	916.55	907.21	893.11	-----	-----
0845	916.55	907.30	-----	-----	-----
0850	916.56	907.38	893.12	-----	-----
0855	916.56	907.45	-----	-----	-----
0900	916.56	907.50	893.13	-----	-----

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet				
	Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 22, 1976:					
0905	916.56	907.62	-----	-----	-----
0910	916.56	907.68	893.16	-----	-----
0915	916.56	907.74	-----	-----	-----
0920	916.56	907.80	893.28	-----	-----
0925	916.56	907.86	-----	-----	-----
0930	916.57	907.91	893.39	-----	880.36
0935	916.56	907.96	-----	-----	-----
0940	916.57	908.00	893.59	885.32	-----
0945	916.57	908.04	-----	885.32	-----
0950	916.57	908.08	893.84	885.31	-----
0955	916.57	908.13	-----	885.31	-----
1000	916.58	908.16	894.23	885.31	-----
1005	916.58	908.20	-----	885.31	-----
1010	916.58	908.24	894.53	885.31	-----
1015	916.58	908.26	-----	885.31	-----
1020	916.58	908.30	894.92	885.31	-----
1025	916.58	908.32	-----	885.32	-----
1030	916.58	908.36	895.32	885.34	880.35
1035	916.57	908.39	-----	885.36	-----
1040	916.58	908.40	895.72	885.39	-----
1045	916.58	908.42	-----	885.41	-----
1050	916.58	908.44	896.03	885.43	-----
1055	916.58	908.47	-----	885.48	880.34
1100	916.58	908.49	896.22	885.53	-----
1105	916.59	908.51	-----	885.59	-----
1110	916.58	908.53	895.56	885.66	-----
1115	916.58	908.55	-----	885.73	-----
1120	916.58	908.56	896.80	885.80	-----
1125	916.58	908.57	-----	885.89	-----
1130	916.58	908.59	897.01	885.97	880.34
1135	916.58	908.61	-----	886.08	-----
1140	916.58	908.62	897.19	886.20	-----
1145	916.58	908.62	-----	886.32	-----
1150	916.58	908.65	897.37	886.43	-----
1155	916.58	908.66	-----	886.56	-----
1200	916.58	908.67	897.53	886.71	880.39
1205	916.58	908.68	-----	886.82	-----
1210	916.58	908.68	897.68	886.94	-----
1215	916.58	908.70	-----	887.11	-----
1220	916.58	908.71	897.89	887.29	-----
1225	916.58	908.72	-----	887.40	-----
1230	916.58	908.72	897.98	887.51	880.50
1235	916.58	908.73	-----	887.65	-----
1240	916.59	908.74	898.13	887.79	-----
1245	916.58	908.75	-----	887.91	-----
1250	916.59	908.76	898.14	888.04	-----
1255	916.58	908.76	-----	888.19	-----
1300	916.58	908.77	898.28	888.30	-----
1305	916.59	908.78	-----	888.41	-----
1310	916.59	908.78	898.31	888.51	-----
1315	916.59	908.78	-----	888.61	-----
1320	916.59	908.79	898.46	888.71	-----
1325	916.58	908.79	-----	888.81	-----
1330	916.58	908.80	898.51	888.90	880.94
1335	916.58	908.81	-----	889.00	-----
1340	916.58	908.81	898.53	889.09	-----
1345	916.59	908.81	-----	889.18	-----

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
	Water-surface altitude, in feet				
March 22, 1976:					
1350	916.59	908.81	898.62	889.28	-----
1355	916.59	908.82	-----	889.36	-----
1400	916.59	908.83	898.64	889.44	-----
1405	916.59	908.83	-----	889.51	-----
1410	916.58	908.83	898.66	889.58	-----
1415	916.59	908.83	-----	889.64	-----
1420	916.59	908.83	898.76	889.70	881.96
1425	916.59	908.84	-----	889.75	882.04
1430	916.59	908.84	898.81	889.94	882.13
1435	916.59	908.84	-----	889.90	882.21
1440	916.59	908.85	898.85	889.96	882.29
1445	916.59	908.84	-----	890.03	882.38
1450	916.59	908.85	898.88	890.09	882.46
1455	916.59	908.85	-----	890.14	882.54
1500	916.59	908.85	898.96	890.19	882.63
1505	916.59	908.87	-----	890.24	882.70
1510	916.59	908.85	898.95	890.29	882.78
1515	916.58	908.86	-----	890.33	882.96
1520	916.59	908.86	898.97	890.37	882.93
1525	916.59	908.86	-----	890.41	882.99
1530	916.59	908.87	899.00	890.45	883.06
1535	916.59	908.87	-----	890.50	883.12
1540	916.58	908.87	899.02	890.54	883.18
1545	916.59	908.87	-----	890.57	883.24
1550	916.59	908.88	899.03	890.61	883.29
1555	916.58	908.88	-----	890.64	883.34
1600	916.59	908.88	899.08	890.68	883.40
1605	916.59	908.88	-----	890.71	883.46
1610	916.60	908.88	899.10	890.74	883.51
1615	916.60	908.88	-----	890.76	883.55
1620	916.60	908.89	899.09	890.78	883.60
1625	916.60	908.89	-----	890.81	883.63
1630	916.61	908.89	899.11	890.83	883.67
1635	916.60	908.89	-----	890.85	883.72
1640	916.61	908.89	899.14	890.88	883.75
1645	916.61	908.89	-----	890.90	883.80
1650	916.61	908.90	899.15	890.92	883.83
1655	916.64	908.90	-----	890.93	883.86
1700	916.66	908.91	899.15	890.95	883.89
1705	916.67	908.92	-----	890.97	883.93
1710	916.68	908.92	899.17	890.99	883.95
1715	916.68	908.93	-----	891.01	883.98
1720	916.69	908.95	899.18	891.03	884.00
1725	916.69	908.95	-----	891.04	884.04
1730	916.69	908.95	899.18	891.06	884.06
1735	916.70	908.96	-----	891.07	884.09
1740	916.69	908.97	899.19	891.08	884.11
1745	916.70	908.97	-----	891.09	884.14
1750	916.69	908.98	899.19	891.11	884.16
1755	916.68	908.99	-----	891.11	884.17
1800	916.67	908.99	899.20	891.12	884.19
1805	916.66	909.00	-----	891.13	884.21
1810	916.66	909.00	899.15	891.14	884.22
1815	916.66	908.99	-----	891.15	884.24
1820	916.66	909.00	899.22	981.16	884.26
1825	916.66	909.00	-----	891.17	884.27
1830	916.66	908.99	899.23	891.18	884.29

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet				
	Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 22, 1976:					
1835	916.66	909.00	-----	891.19	884.30
1840	916.66	909.00	899.24	891.20	884.31
1845	916.66	909.00	-----	891.20	884.33
1850	916.66	908.99	899.25	891.21	884.34
1855	916.65	909.00	-----	-----	884.35
1900	916.62	909.00	899.26	-----	884.37
1905	916.61	909.00	-----	-----	884.38
1910	916.60	909.00	899.27	-----	884.40
1915	916.60	908.99	-----	-----	884.41
1920	916.59	908.98	899.29	-----	-----
1925	916.59	908.98	-----	-----	-----
1930	916.59	908.97	899.29	-----	884.48
1935	916.59	908.97	-----	-----	-----
1940	916.59	908.96	899.31	-----	-----
1945	916.59	908.95	-----	-----	-----
1950	916.58	908.96	899.31	-----	-----
1955	916.59	908.95	-----	-----	-----
2000	916.58	908.94	899.31	-----	-----
2005	916.59	908.95	-----	-----	-----
2010	916.59	908.94	899.30	-----	-----
2015	916.59	908.94	-----	891.34	-----
2020	916.58	908.94	899.31	-----	-----
2025	916.59	908.93	-----	-----	-----
2030	916.59	908.93	899.31	-----	884.57
2035	916.59	908.93	-----	-----	-----
2040	916.58	908.92	899.32	-----	-----
2045	916.58	908.92	-----	-----	-----
2050	916.58	908.92	899.32	-----	-----
2055	916.58	908.92	-----	-----	-----
2100	916.59	908.91	899.31	891.34	-----
2105	916.59	908.92	-----	-----	-----
2110	916.59	908.92	899.31	-----	-----
2115	916.59	908.91	-----	-----	-----
2120	916.58	908.91	899.31	-----	-----
2125	916.58	908.91	-----	-----	-----
2130	916.59	908.91	899.31	-----	884.64
2135	916.58	908.90	-----	-----	-----
2140	916.58	908.90	899.30	-----	-----
2145	916.58	908.90	-----	-----	-----
2150	916.41	908.90	899.30	-----	-----
2155	915.60	908.89	-----	-----	-----
2200	914.92	908.78	899.29	-----	-----
2205	914.44	908.61	-----	-----	-----
2210	914.15	908.43	899.29	-----	-----
2215	913.94	908.26	-----	-----	-----
2220	913.75	908.08	899.29	-----	-----
2225	913.63	907.90	-----	-----	-----
2230	913.54	907.72	899.29	-----	884.68
2235	913.49	907.54	-----	-----	-----
2240	913.45	907.37	899.29	-----	-----
2245	913.42	907.20	-----	-----	-----
2250	913.40	907.04	899.26	-----	-----
2255	913.39	906.88	-----	-----	-----
2300	913.38	906.73	899.22	-----	-----
2305	913.38	906.59	-----	-----	-----
2310	913.38	906.45	899.16	-----	-----
2315	913.38	906.32	-----	-----	-----

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet				
	Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 22, 1976:					
2320	913.38	906.19	899.11	-----	-----
2325	913.38	906.07	-----	-----	-----
2330	913.38	905.94	899.01	-----	884.70
2335	913.38	905.82	-----	-----	-----
2340	913.38	905.71	898.88	-----	-----
2345	913.38	905.60	-----	-----	-----
2350	913.38	905.50	898.75	-----	-----
2355	913.38	905.39	-----	-----	-----
March 23, 1976:					
0000	913.38	905.29	898.63	891.20	-----
0005	913.38	905.19	-----	-----	-----
0010	913.38	905.10	898.48	-----	-----
0015	913.38	905.01	-----	-----	-----
0020	913.38	904.93	898.34	-----	-----
0025	913.38	904.84	-----	-----	-----
0030	913.38	904.76	898.20	-----	884.67
0035	913.38	904.69	-----	-----	-----
0040	913.38	904.61	898.03	-----	-----
0045	913.38	904.54	-----	-----	-----
0050	913.38	904.47	897.88	-----	-----
0055	913.38	904.41	-----	-----	-----
0100	913.38	904.34	897.72	-----	-----
0105	913.38	904.28	-----	-----	-----
0110	913.38	904.22	897.56	-----	-----
0115	913.38	904.17	-----	-----	-----
0120	913.38	904.11	897.41	-----	-----
0125	913.38	904.06	-----	-----	-----
0130	913.38	904.01	897.26	-----	884.56
0135	913.38	903.96	-----	-----	-----
0140	913.38	903.91	897.10	-----	-----
0145	913.38	903.87	-----	-----	-----
0150	913.38	903.83	896.95	-----	-----
0155	913.38	903.79	-----	-----	-----
0200	913.38	903.75	896.80	-----	-----
0205	913.38	903.72	-----	-----	-----
0210	913.38	903.69	896.64	-----	-----
0215	913.38	903.65	-----	-----	-----
0220	913.38	903.62	896.51	-----	-----
0225	913.38	903.59	-----	-----	-----
0230	913.38	903.56	896.36	-----	884.29
0235	913.38	903.54	-----	-----	-----
0240	913.38	903.52	896.22	-----	-----
0245	913.38	903.49	-----	-----	-----
0250	913.38	903.47	896.10	-----	-----
0255	913.38	903.45	-----	-----	-----
0300	913.38	903.43	895.96	-----	-----
0305	913.38	903.41	-----	-----	-----
0310	913.38	903.39	895.88	-----	-----
0315	913.38	903.37	-----	-----	-----
0320	913.38	903.36	895.81	-----	-----
0325	913.38	903.34	-----	-----	-----
0330	913.38	903.33	895.61	-----	883.88
0335	913.38	903.31	-----	-----	-----
0340	913.38	903.30	895.34	-----	-----
0345	913.38	903.29	-----	-----	-----
0350	913.38	903.27	895.21	-----	-----

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 23, 1976:					
0355	913.38	903.26	-----	-----	-----
0400	913.38	903.25	-----	-----	-----
0405	913.38	903.24	-----	-----	-----
0410	913.38	903.23	895.07	-----	-----
0415	913.38	903.22	-----	-----	-----
0420	913.38	903.21	895.07	-----	-----
0425	913.38	903.20	-----	-----	-----
0430	913.38	903.20	894.81	-----	883.43
0435	913.38	903.19	-----	-----	-----
0440	913.38	903.18	894.66	-----	-----
0445	913.38	903.17	-----	-----	-----
0450	913.38	903.17	894.61	-----	-----
0455	913.38	903.16	-----	-----	-----
0500	913.38	903.15	894.59	-----	-----
0505	913.38	903.15	-----	-----	-----
0510	913.38	903.14	894.56	-----	-----
0515	913.38	903.14	-----	-----	-----
0520	913.38	903.13	894.57	-----	-----
0525	913.38	903.13	-----	-----	-----
0530	913.38	903.12	894.41	-----	882.97
0535	913.38	903.12	-----	-----	-----
0540	913.38	903.11	894.32	-----	-----
0545	913.38	903.11	-----	-----	-----
0550	913.38	903.11	894.20	-----	-----
0555	913.38	903.10	-----	-----	-----
0600	913.38	903.10	894.17	-----	-----
0605	913.38	903.09	-----	-----	-----
0610	913.38	903.09	-----	-----	-----
0615	913.38	903.09	-----	-----	-----
0620	913.38	903.08	894.06	-----	-----
0625	913.38	903.08	-----	-----	-----
0630	913.38	903.08	894.00	-----	882.51
0635	913.38	903.08	-----	-----	-----
0640	913.38	903.07	893.96	-----	-----
0645	913.38	903.07	-----	-----	-----
0650	913.38	903.07	893.87	-----	-----
0655	914.03	903.07	-----	-----	-----
0700	915.93	903.06	893.88	-----	-----
0705	917.36	903.06	-----	-----	-----
0710	918.17	903.11	893.81	-----	-----
0715	918.51	903.69	-----	-----	-----
0720	918.66	904.69	893.80	-----	-----
0725	918.76	905.73	-----	-----	-----
0730	918.83	906.50	893.76	886.75	882.09
0735	918.87	907.12	-----	-----	-----
0740	918.91	907.70	893.69	-----	-----
0745	918.94	908.60	-----	-----	-----
0750	918.96	908.60	893.66	-----	-----
0755	918.99	908.92	-----	-----	-----
0800	919.01	909.22	-----	-----	-----
0805	919.03	909.51	-----	-----	-----
0810	919.05	909.79	893.61	-----	-----
0815	919.08	910.01	-----	-----	-----
0820	919.09	910.19	893.57	-----	-----
0825	919.12	910.38	-----	-----	-----
0830	919.14	910.55	-----	-----	881.71

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet: Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 23, 1976:					
0835	919.15	910.74	-----	-----	-----
0840	919.17	910.90	893.57	-----	-----
0845	919.19	911.01	-----	-----	-----
0850	919.20	911.09	893.56	-----	-----
0855	919.23	911.26	-----	-----	-----
0900	919.24	911.38	893.71	-----	-----
0905	919.25	911.49	-----	-----	-----
0910	919.28	911.60	894.09	-----	-----
0915	919.29	911.70	-----	-----	-----
0920	919.30	911.77	894.61	-----	-----
0925	919.32	911.87	-----	-----	-----
0930	919.34	911.97	895.23	-----	881.38
0935	919.35	912.04	-----	886.01	-----
0940	919.37	912.12	896.15	885.99	-----
0945	919.38	912.17	-----	885.97	-----
0950	919.40	912.22	896.82	885.96	-----
0955	919.42	912.30	-----	885.95	-----
1000	919.43	912.37	897.63	885.95	-----
1005	919.44	912.43	-----	885.91	-----
1010	919.45	912.48	898.01	885.87	-----
1015	919.46	912.51	-----	885.99	-----
1020	919.47	912.58	898.79	886.11	-----
1025	919.49	912.63	-----	886.23	-----
1030	919.51	912.67	899.17	886.35	881.14
1035	919.50	912.71	-----	886.51	-----
1040	919.52	912.74	899.60	886.67	880.97
1045	919.53	912.79	-----	887.01	880.98
1050	919.54	912.80	900.10	887.34	881.00
1055	919.55	912.86	-----	887.47	881.01
1100	919.57	912.90	900.33	887.60	881.02
1105	919.57	912.92	-----	887.87	881.01
1110	919.59	912.94	900.69	888.15	881.01
1115	919.57	912.98	-----	888.42	881.01
1120	919.55	912.99	900.94	888.70	881.02
1125	919.55	913.03	-----	888.96	881.04
1130	919.54	913.04	901.20	889.22	881.07
1135	919.55	913.06	-----	889.48	881.09
1140	919.55	913.07	901.38	889.74	881.15
1145	919.55	913.08	-----	890.00	881.21
1150	919.25	913.09	901.56	890.26	881.27
1155	918.40	913.02	-----	890.45	881.36
1200	917.32	912.75	901.77	890.65	881.46
1205	916.50	912.41	-----	890.87	881.58
1210	915.91	912.09	901.93	981.10	881.71
1215	915.46	911.80	-----	891.25	881.85
1220	915.10	911.50	902.03	891.41	882.00
1225	914.80	911.23	-----	891.59	882.15
1230	914.55	911.97	902.20	891.77	882.32
1235	914.34	910.71	-----	891.95	882.49
1240	914.15	910.47	902.26	892.13	882.66
1245	913.99	910.23	-----	892.25	882.82
1250	913.86	910.00	902.26	892.37	882.99
1255	913.74	909.78	-----	892.51	883.17
1300	913.65	909.57	902.21	892.65	883.32
1305	913.58	909.36	-----	892.75	883.51
1310	913.53	909.16	902.15	892.85	883.68
1315	913.49	908.97	-----	892.93	883.83

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet				
	Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 23, 1976:					
1320	913.46	908.77	902.01	893.02	884.00
1325	913.43	908.59	-----	893.09	884.14
1330	913.42	908.40	901.87	893.17	884.31
1335	913.41	908.22	-----	893.24	884.43
1340	913.40	908.05	901.72	893.31	884.57
1345	913.40	907.89	-----	893.35	884.71
1350	913.40	907.72	901.53	893.39	884.83
1355	913.39	907.56	-----	893.42	884.96
1400	913.39	907.41	901.36	893.45	885.06
1405	913.39	907.26	-----	893.46	885.16
1410	913.38	907.11	901.11	893.48	885.27
1415	913.38	906.97	-----	893.48	885.35
1420	913.38	906.83	900.91	893.49	885.44
1425	913.38	906.70	-----	893.47	885.52
1430	913.38	906.56	900.68	893.45	885.60
1435	913.38	906.44	-----	893.41	885.66
1440	913.38	906.32	900.48	893.38	885.71
1445	913.38	906.20	-----	893.35	885.76
1450	913.38	906.08	900.27	893.32	885.81
1455	913.38	905.98	-----	893.27	885.84
1500	913.38	905.86	900.07	893.23	885.87
1505	913.38	905.76	-----	893.19	885.90
1510	913.38	905.65	899.73	893.15	885.92
1515	913.38	905.55	-----	893.09	885.93
1520	913.38	905.45	899.55	893.03	885.95
1525	913.38	905.37	-----	892.96	885.96
1530	913.38	905.27	899.32	892.90	885.96
1535	913.38	905.18	-----	892.84	885.95
1540	913.38	905.08	899.15	892.79	885.95
1545	913.38	905.00	-----	892.71	885.94
1550	913.38	904.90	898.93	892.64	885.92
1555	913.38	904.84	-----	892.55	885.91
1600	913.38	904.74	898.75	892.47	885.89
1605	913.38	904.70	-----	892.39	885.87
1610	913.38	904.60	898.46	892.32	885.84
1615	913.38	904.58	-----	892.24	885.84
1620	913.38	904.50	898.25	892.15	885.83
1625	913.38	904.44	-----	892.07	885.83
1630	913.38	904.38	898.07	891.99	885.82
1635	913.38	904.32	-----	891.91	885.78
1640	913.38	904.26	897.90	891.83	885.74
1645	913.38	904.20	-----	891.75	885.70
1650	913.38	904.16	897.81	891.65	885.66
1655	913.38	904.10	-----	891.57	885.62
1700	913.38	904.05	897.52	891.50	885.57
1705	913.38	904.00	-----	891.42	885.53
1710	913.38	903.96	897.35	891.34	885.49
1715	913.38	903.92	-----	891.24	885.45
1720	913.38	903.86	897.13	891.15	885.41
1725	913.38	903.83	-----	891.07	885.37
1730	913.38	903.79	897.00	890.98	885.34
1735	913.38	903.74	-----	890.90	885.29
1740	913.38	903.71	896.84	890.81	885.24
1745	913.38	903.68	-----	890.73	885.19
1750	913.38	903.65	896.65	890.64	885.14
1755	913.38	903.61	-----	890.56	885.09
1800	913.38	903.59	896.50	890.45	885.03

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet				
	Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 23, 1976:					
1805	913.38	903.56	-----	890.38	884.98
1810	913.38	903.53	896.34	890.30	884.93
1815	913.38	903.51	-----	890.23	884.88
1820	913.38	903.49	896.21	890.13	884.83
1825	913.38	903.46	-----	890.03	884.78
1830	913.38	903.44	895.94	889.94	884.73
1835	913.38	903.42	-----	889.87	884.67
1840	913.38	903.41	895.91	889.80	884.61
1845	913.38	903.39	-----	889.72	884.55
1850	913.38	903.37	895.76	889.65	884.49
1855	913.38	903.36	-----	889.56	884.43
1900	913.38	903.34	895.64	889.47	884.37
1905	913.38	903.33	-----	889.40	884.31
1910	913.38	903.31	895.49	889.34	884.25
1915	913.38	903.30	-----	889.27	884.19
1920	913.38	903.29	895.39	889.18	884.13
1925	913.38	903.28	-----	889.11	884.08
1930	913.38	903.27	895.26	889.04	884.03
1935	913.38	903.26	-----	888.97	883.97
1940	913.38	903.25	895.13	888.89	883.92
1945	913.38	903.24	-----	888.81	883.86
1950	913.38	902.23	895.02	888.74	883.81
1955	913.38	903.22	-----	888.67	883.76
2000	913.38	903.21	894.93	888.60	883.70
2005	913.38	903.20	-----	888.53	883.64
2010	913.38	903.20	894.83	888.46	883.59
2015	913.38	903.19	-----	888.39	883.54
2020	913.38	903.18	894.73	888.34	883.49
2025	913.38	903.18	-----	888.26	883.43
2030	913.38	903.17	894.63	888.22	883.36
2035	913.38	903.17	-----	888.16	883.31
2040	913.38	903.16	894.56	888.10	883.26
2045	913.38	903.16	-----	888.03	883.21
2050	913.38	903.15	894.48	887.96	883.16
2055	913.38	903.15	-----	887.90	883.11
2100	913.38	903.14	894.39	887.84	883.06
2105	913.38	903.14	-----	887.79	883.01
2110	913.38	903.13	894.31	887.74	882.96
2115	913.38	903.13	-----	887.66	882.91
2120	913.38	903.13	894.24	887.59	882.86
2125	913.38	903.12	-----	887.53	882.83
2130	913.38	902.12	894.17	887.48	882.79
2135	913.38	902.12	-----	887.42	882.75
2140	913.38	903.11	894.11	887.36	882.71
2145	913.38	903.11	-----	887.32	882.67
2150	913.38	903.11	894.05	887.28	882.63
2155	913.38	903.10	-----	887.23	882.59
2200	913.38	903.10	893.99	887.17	882.55
2205	913.38	903.10	-----	887.12	882.51
2210	913.38	903.10	893.93	887.07	882.47
2215	913.38	903.09	-----	887.02	882.43
2220	913.38	903.09	893.99	886.98	882.39
2225	913.38	903.09	-----	886.92	882.35
2230	913.38	903.09	893.83	886.87	882.29
2235	913.38	903.08	-----	886.85	882.26
2240	913.38	903.08	893.79	886.83	882.23
2245	913.38	903.08	-----	886.78	882.20

TABLE 10.—*Summary of river stage data*—Continued

Date and Time	Water-surface altitude, in feet				
	Buford Dam	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Highway 141 Georgia
March 23, 1976:					
2250	913.38	903.08	893.74	886.73	882.17
2255	913.38	903.07	-----	886.70	882.14
2300	913.38	903.07	893.70	886.67	882.11
2305	913.38	903.07	-----	886.61	882.08
2310	913.38	903.07	893.66	886.56	882.06
2315	913.38	903.07	-----	886.53	882.03
2320	913.38	903.06	893.62	886.51	881.98
2325	913.38	903.06	-----	886.48	881.92
2330	913.38	903.06	893.60	886.43	881.86
2335	913.38	903.06	-----	886.39	881.83
2340	913.38	903.06	893.56	886.36	881.81
2345	913.38	903.06	-----	886.33	881.78
2350	913.38	903.06	893.53	886.30	881.75
2355	913.38	903.06	-----	886.28	881.72

TABLE 11.—*Summary of river discharge data*

Date and Time	Discharge, in ft³/s			
	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 22, 1976:				
0655	577	----	----	----
0700	577	----	----	----
0705	577	----	----	----
0710	577	----	----	----
0715	610	----	----	----
0720	610	----	----	----
0725	780	----	----	----
0730	1030	----	----	----
0735	1280	----	----	----
0740	1550	----	----	----
0745	1820	----	----	----
0750	2070	----	----	----
0755	2360	600	----	----
0800	2620	600	----	----
0805	2830	600	----	----
0810	2980	600	----	----
0815	3110	600	----	----
0820	3200	600	----	----
0825	3290	600	----	----
0830	3370	600	----	----
0835	3450	600	----	----
0840	3490	600	----	----
0845	3530	600	----	----
0850	3560	600	----	----
0855	3590	610	----	----
0900	3630	620	----	----
0905	3670	730	931	----
0910	3700	810	933	----
0915	3740	860	933	----
0920	3770	940	934	----
0925	3810	1080	936	----
0930	3830	1160	938	----

TABLE 11.—*Summary of river discharge data*—Continued

Date and Time	Discharge, in ft³/s			
	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 22, 1976:				
0935	3840	1250	939	----
0940	3830	1340	940	----
0945	3760	1440	943	----
0950	3780	1520	945	----
0955	3760	1610	947	----
1000	3780	1700	949	----
1005	3810	1800	952	----
1010	3850	1910	954	----
1015	3880	2000	957	----
1020	3910	2120	966	----
1025	3950	2220	974	----
1030	3970	2300	982	----
1035	3990	2390	991	----
1040	3970	2470	1000	----
1045	3960	2560	1030	----
1050	3940	2640	1050	----
1055	3920	2720	1080	1080
1100	3920	2800	1120	----
1105	3940	2870	1160	----
1110	3970	2920	1210	----
1115	4000	2990	1250	----
1120	4020	3070	1300	----
1125	4050	3140	1350	----
1130	4080	3200	1420	----
1135	4090	3250	1490	----
1140	4080	3290	1560	----
1145	4060	3340	1640	----
1150	4060	3400	1720	----
1155	4060	3440	1800	----
1200	4050	3480	1890	----
1205	4040	3500	1980	----
1210	4040	3540	2060	----
1215	4070	3570	2130	----
1220	4050	3600	2200	----
1225	4060	3630	2260	----
1230	4070	3650	2330	----
1235	4080	3670	2410	----
1240	4100	3680	2510	----
1245	4100	3700	2600	----
1250	4110	3710	2690	1170
1255	4130	3720	2790	1180
1300	4140	3730	2880	1320
1305	4160	3740	2950	1420
1310	4170	3760	3010	1460
1315	4180	3780	3060	1510
1320	4190	3810	3120	1560
1325	4200	3830	3170	1610
1330	4210	3920	3200	1660
1335	4220	3950	3260	1700
1340	4230	3980	3310	1760
1345	4240	4000	3350	1840
1350	4250	4030	3400	1910
1355	4260	4060	3430	2020
1400	4270	4070	3470	2090
1405	4280	4020	3510	2150
1410	4290	4070	3560	2220
1415	4300	4080	3600	2300
1420	4310	4080	3640	2400

TABLE 11.—*Summary of river discharge data*—Continued

Date and Time	Discharge, in ft³/s			
	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 22, 1976:				
1425	4320	4080	3680	2500
1430	4330	4080	3710	2590
1435	4340	4080	3740	2700
1440	4350	4080	3780	2810
1445	4360	4090	3800	2920
1450	4370	4100	3830	3050
1455	4370	4110	3860	3170
1500	4370	4100	3890	3260
1505	4370	4100	3900	3330
1510	4360	4100	3910	3410
1515	4340	4100	3930	3480
1520	4330	4110	3950	3540
1525	4320	4110	3960	3620
1530	4310	4110	3980	3760
1535	4290	4110	3990	3700
1540	4280	4120	4000	3720
1545	4270	4120	4020	3740
1550	4250	4130	4030	3740
1555	4240	4130	4040	3740
1600	4230	4140	4040	3740
1605	4220	4140	4050	3760
1610	4240	4150	4060	3780
1615	4250	4170	4070	3820
1620	4280	4170	4080	3880
1625	4310	4170	4080	3840
1630	4340	4170	4090	----
1635	----	4170	4100	----
1640	----	4180	4100	----
1645	----	4180	4110	----
1650	----	4180	4120	----
1655	----	4180	4130	----
1700	----	4180	4140	----
1705	----	4180	4150	----
1710	----	4180	4160	----
1715	----	4170	4170	----
1720	----	4150	4180	----
1725	----	4140	4200	----
1730	----	4130	4210	----
1735	----	4110	4220	----
1740	----	4100	4240	----
1745	----	4180	4260	----
1750	----	4160	4280	----
1755	----	4140	4310	----
1800	----	4120	4300	----
1805	----	----	4320	----
1810	----	----	4330	----
1815	----	----	4310	----
1820	----	----	4290	----
1825	----	----	4270	----
1830	----	----	----	----
1835	----	----	----	----
1840	----	----	----	----
1845	----	----	----	----
1850	----	----	----	----
1855	----	----	----	----
1900	----	----	----	----
1905	----	----	----	----
1910	----	----	----	----

TABLE 11.—*Summary of river discharge data*—Continued

Date and Time	Discharge, in ft³/s			
	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 22, 1976:				
1915	----	----	----	----
1920	----	----	----	----
1925	----	----	----	----
1930	----	----	----	----
1935	----	----	----	----
1940	----	----	----	----
1945	----	----	----	----
March 23, 1976:				
0610	----	----	----	----
0615	----	----	----	----
0620	----	----	----	----
0625	----	----	----	----
0630	----	----	----	----
0635	----	----	----	----
0640	----	----	----	----
0645	----	----	----	----
0650	----	----	----	----
0655	----	----	----	----
0700	540	----	----	----
0705	540	----	----	----
0710	----	----	----	----
0715	----	----	----	----
0720	1140	----	----	----
0725	1550	----	----	----
0730	2000	----	----	----
0735	2610	----	----	----
0740	3550	----	----	----
0745	4250	----	----	----
0750	4880	----	----	----
0755	5750	830	----	----
0800	6050	830	----	----
0805	6360	830	----	1860
0810	6680	830	----	1850
0815	6970	830	----	1840
0820	7220	830	----	1820
0825	7400	830	----	1810
0830	7450	830	----	1800
0835	7500	830	----	1780
0840	7540	830	----	1770
0845	7590	830	----	1750
0850	7630	830	----	1740
0855	7710	1020	----	1730
0900	7770	1200	----	1710
0905	7820	1440	----	1700
0910	7850	1650	----	1690
0915	7860	1890	----	1680
0920	7870	2100	----	1660
0925	7860	2270	----	1650
0930	7840	2440	----	1640
0935	7850	2650	----	1620
0940	7900	2910	----	1610
0945	7970	3260	----	1600
0950	8060	3730	----	1580
0955	8150	4000	----	1570
1000	8220	4180	----	1560
1005	8320	4330	1100	1550
1010	8420	4440	1100	1540

TABLE 11.—*Summary of river discharge data*—Continued

Date and Time	Discharge, in ft³/s			
	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 23, 1976:				
1015	8420	4610	1110	1520
1020	8360	4740	1380	1510
1025	8310	4850	1500	1500
1030	8240	5030	1610	1500
1035	8160	5190	1720	1490
1040	8090	5550	1840	1490
1045	8020	5720	2020	1490
1050	8030	5900	2190	1490
1055	8060	6110	2330	1490
1100	8080	6310	2480	1490
1105	8160	6490	2620	1490
1110	8260	6620	2780	1490
1115	8360	6730	3020	1490
1120	8450	6840	3230	1490
1125	8540	6940	3470	1500
1130	8610	7040	3750	1540
1135	8660	7140	3990	1590
1140	8600	7220	4220	1640
1145	8480	7300	4460	1720
1150	8250	7370	4700	1810
1155	7860	7440	5020	1900
1200	7320	7500	5290	2020
1205	6860	7550	5480	2120
1210	6320	7610	5600	2250
1215	5810	7650	5720	2390
1220	5340	7670	5840	2560
1225	4940	7660	5870	2780
1230	4640	7610	5900	2970
1235	4380	7540	5950	3170
1240	4130	7450	6020	3300
1245	3900	7350	6100	3480
1250	3650	7240	6180	3640
1255	3390	7140	6260	3760
1300	3150	7040	6400	3950
1305	2930	6890	6570	4110
1310	2730	6750	6740	4290
1315	2550	6630	6900	4490
1320	2420	6500	7010	4686
1325	2290	6350	7060	4800
1330	2180	6180	7000	5000
1335	2080	5990	6920	5190
1340	2000	5810	6860	5390
1345	1920	5650	6790	5590
1350	1860	5510	6740	5780
1355	1810	5390	6750	5880
1400	1760	5270	6740	5920
1405	1720	5150	6740	6020
1410	1760	5060	6750	6130
1415	1620	4940	6710	6260
1420	1570	4840	6620	6380
1425	1530	4750	6550	6460
1430	1490	4660	6490	6520
1435	1440	4570	6412	6540
1440	1400	4480	6350	6550
1445	1360	4390	6330	6550
1450	1340	4310	6320	6540
1455	1310	4230	6300	6520
1500	1280	4150	6290	6480

TABLE 11.—*Summary of river discharge data*—Continued

Date and Time	Discharge, in ft³/s			
	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 23, 1976:				
1505	1240	4050	6260	6440
1510	1210	3960	6200	6380
1515	1170	3860	6100	6330
1520	1130	3790	6000	6270
1525	1100	3680	5890	6220
1530	1060	3580	5780	6180
1535	1040	3490	5690	6140
1540	1010	3380	5600	6100
1545	980	3280	5520	6070
1550	960	3210	5480	6030
1555	940	3160	5320	6000
1600	920	3100	5180	5970
1605	900	3040	5070	5940
1610	880	2990	5010	5920
1615	870	2850	4950	5890
1620	850	2800	4900	5870
1625	840	2760	4840	5850
1630	830	2700	4790	5830
1635	820	2660	4630	5800
1640	810	2610	4530	5780
1645	790	2560	4420	5760
1650	780	2510	4280	5710
1655	770	2480	4190	5670
1700	770	2440	4150	5620
1705	760	2410	4070	5560
1710	760	2370	4000	5510
1715	750	2340	3930	5460
1720	750	2300	3870	5410
1725	740	2250	3790	5370
1730	----	2210	3720	5320
1735	----	2180	3660	5270
1740	----	2140	3620	5210
1745	----	2100	3570	5160
1750	----	2060	3530	5110
1755	----	2000	3480	5020
1800	----	1950	3430	4950
1805	----	1910	3390	4870
1810	----	1880	3340	4790
1815	----	1840	3310	4700
1820	----	1820	3280	4620
1825	----	1790	3250	4540
1830	----	1760	3210	4490
1835	----	1720	3140	4430
1840	----	1690	3070	4370
1845	----	1650	2980	4300
1850	----	1620	2910	4230
1855	----	1580	2850	4160
1900	----	1540	2810	4100
1905	----	1510	2780	4050
1910	----	1470	2750	4000
1915	----	1450	2720	3930
1920	----	1430	2690	3870
1925	----	1410	2660	3800
1930	----	1380	2630	3740
1935	----	1360	2600	3670
1940	----	1340	2550	3610
1945	----	1310	2490	3570
1950	----	1280	2420	3510
1955	----	1250	2350	3470

TABLE 11.—*Summary of river discharge data*—Continued

Date and Time	Discharge, in ft³/s			
	Georgia Highway 20	Littles Ferry Bridge	Georgia Highway 120	Georgia Highway 141
March 23, 1976:				
2000	----	1230	2270	3430
2005	----	1210	2240	3350
2010	----	1190	2200	3260
2015	----	1170	2170	3190
2020	----	1150	2140	3110
2025	----	1130	2110	3040
2030	----	1120	2080	2980
2035	----	1100	2010	2930
2040	----	1090	2000	2880
2045	----	1080	1970	2840
2050	----	1060	1940	2800
2055	----	1050	1910	2770
2100	----	1040	1880	2750
2105	----	1020	1850	2730
2110	----	1010	1830	2700
2115	----	1000	1820	2670
2120	----	980	1810	2640
2125	----	970	1800	2610
2130	----	960	1780	2580
2135	----	----	1770	2550
2140	----	----	1750	2530
2145	----	----	1720	2500
2150	----	----	1690	2470
2155	----	----	1670	2450
2200	----	----	1650	2420
2205	----	----	1620	2400
2210	----	----	1610	2380
2215	----	----	1590	2350
2220	----	----	1570	2320
2225	----	----	1540	2300
2230	----	----	1530	2270
2235	----	----	1500	2240
2240	----	----	1470	2220
2245	----	----	1460	2190
2250	----	----	1440	2150
2255	----	----	1430	2120
2300	----	----	1410	2090
2305	----	----	1400	2050
2310	----	----	1380	2000
2315	----	----	1380	1950
2320	----	----	1360	----
2325	----	----	1360	----
2330	----	----	1350	----
2335	----	----	1340	----
2340	----	----	1330	----
2345	----	----	1320	----
2350	----	----	1300	----
2355	----	----	1280	----

TABLE 12.—*Summary of tributary discharge data*

Date and Time	Discharge, in ft³/s				
	Richland Creek	James Creek	Level Creek	Dick Creek	Suwannee Creek
March 21, 1976:					
1023	--	69	--	--	---
1035	51	--	--	--	---
1123	--	69	--	--	---
1230	--	--	--	29	---
1317	--	--	39	--	---
1840	--	--	--	--	250
March 22, 1976:					
1010	--	--	--	--	165
1030	--	--	22	--	---
1051	21	--	--	--	---
1150	--	60	--	--	---
1220	--	--	--	22	---
1245	--	--	--	--	163
1315	--	--	24	--	---
1330	29	--	--	--	---
1415	--	60	--	--	---
1430	--	--	--	22	---
1445	--	--	--	--	170
1550	--	--	25	--	---
1520	29	--	--	--	---
1600	--	--	--	22	---
1625	--	--	--	--	168
1640	--	--	25	--	---
1700	29	--	--	--	---
1720	--	60	--	--	---
March 23, 1976:					
1225	--	--	--	22	---
1240	--	35	--	--	---
1315	22	--	--	--	---
1410	--	--	--	--	130
March 24, 1976:					
0840	--	--	--	--	120
0920	--	--	9	--	---
1000	21	--	--	--	---
1038	--	30	--	--	---
1052	--	--	--	12	---

TABLE 13.—*Summary of cross-section data*

River mile 330.77		River mile 331.41		River mile 331 90		River mile 332.44	
Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)
90.0	893.20	15.0	897.6	49.0	895.0	75.0	896.0
130.0	891.40	43.0	886.7	50.0	892.0	79.5	894.0
150.0	885.92	45.0	882.4	51.0	887.4	87.5	881.9
156.0	880.22	54.0	882.3	51.5	883.3	89.5	882.7
166.0	877.42	70.0	877.3	68.0	879.6	97.5	882.0
176.0	878.62	79.0	878.4	76.0	879.7	103.0	880.0
191.0	876.62	123.5	879.8	110.0	880.3	112.0	879.4
216.0	877.02	151.0	879.8	137.5	879.5	139.0	879.5
236.0	877.02	166.0	879.6	140.0	879.5	149.0	879.8
256.0	876.52	173.0	879.8	155.0	880.3	190.0	880.3
276.0	876.92	211.5	879.8	178.5	880.1	219.0	880.8
296.0	875.12	224.0	879.6	236.0	882.5	255.5	879.7
316.0	875.42	233.0	879.3	243.0	882.7	267.0	880.1
326.0	873.92	250.0	880.7	243.5	887.4	257.0	882.0
331.0	873.42	252.0	886.7	245.0	890.2	274.0	883.6
346.0	874.72	255.0	894.0	246.0	895.0	283.0	883.6
355.0	877.62	----	----	----	----	284.0	881.9
364.0	881.62	----	----	----	----	285.5	892.2
368.0	885.92	----	----	----	----	286.0	896.0
380.0	889.40	----	----				

River mile 332.81		River mile 333.13		River mile 333.65		River mile 334.25	
Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)
−12.0	895.0	15.0	902.0	20.0	899.0	1.0	898.0
2.0	892.0	22.5	889.0	40.0	898.5	20.0	884.5
15.5	882.2	24.0	883.0	60.0	884.4	50.0	878.4
30.0	877.3	29.5	883.1	88.0	879.4	100.0	878.4
52.0	878.2	35.5	882.9	199.0	879.5	150.0	880.3
100.0	878.6	43.0	882.1	224.0	884.5	176.0	884.5
150.5	878.0	46.0	878.9	240.0	897.3	190.0	897.5
174.0	882.2	64.0	880.5	----	----	----	----
194.0	894.5	94.0	881.3	----	----	----	----
----	----	108.5	881.7	----	----	----	----
----	----	155.0	882.2	----	----	----	----
----	----	175.0	882.0	----	----	----	----
----	----	180.0	881.7	----	----	----	----
----	----	186.0	883.7	----	----	----	----
----	----	190.0	884.1	----	----	----	----
----	----	192.0	889.0	----	----	----	----
----	----	193.0	893.3	----	----	----	----

TABLE 13.—*Summary of cross-section data*—Continued

River mile 334.78		**River mile 335.26**		**River mile 335.64**		**River mile 336.31**	
Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)
15.0	898.0	97.0	898.20	15.0	895.0	15.0	903.5
17.0	891.2	100.0	893.48	23.5	892.4	15.5	893.5
18.5	887.9	108.0	887.18	26.0	889.3	18.0	890.7
25.0	887.7	118.0	885.38	45.0	883.2	29.5	890.3
46.5	884.4	128.0	882.68	51.5	883.2	31.5	889.2
47.5	883.9	138.0	882.88	69.5	884.6	93.0	884.9
54.5	882.1	148.0	882.68	106.0	882.7	100.0	884.9
61.5	882.2	158.0	882.48	141.0	885.6	143.0	886.4
127.5	883.1	168.0	882.58	162.0	886.0	180.5	886.4
164.0	881.3	178.0	883.48	164.5	886.2	195.0	890.7
108.0	881.6	188.0	882.48	189.0	886.4	213.0	893.5
175.5	885.7	198.0	881.48	196.0	887.6	218.5	901.5
176.0	891.2	208.0	880.98	205.0	887.9	----	----
177.0	896.0	218.0	881.48	208.5	887.9	----	----
----	----	228.0	880.68	215.0	892.4	----	----
----	----	238.0	880.88	217.5	899.7	----	----
----	----	248.0	880.38	----	----	----	----
----	----	258.0	879.08	----	----	----	----
----	----	268.0	879.58	----	----	----	----
----	----	278.0	884.48	----	----	----	----
----	----	281.0	893.48	----	----	----	----
----	----	308.0	899.80	----	----	----	----

River mile 336.93		**River mile 337.46**		**River mile 337.77**		**River mile 338.19**	
Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)
2.0	905.0	15.0	903.0	1.0	906.3	0.1	902.0
51.2	899.2	27.0	896.1	20.0	893.5	1.0	894.2
68.0	888.9	29.0	892.0	50.0	891.2	10.0	893.4
97.5	887.0	47.5	889.5	98.0	889.5	20.0	891.0
130.0	888.0	61.0	888.0	149.0	889.5	35.0	889.5
158.0	887.0	73.5	888.0	180.0	890.5	50.0	889.4
188.0	888.0	92.0	888.4	196.0	893.3	100.0	889.6
208.0	887.0	125.5	888.5	220.0	907.3	120.0	888.5
248.0	888.0	154.5	888.9	----	----	140.0	887.8
280.0	898.5	175.0	888.7	----	----	160.0	887.2
304.0	903.4	185.5	887.9	----	----	176.0	887.9
----	----	209.5	887.8	----	----	190.0	896.0
----	----	216.0	890.1	----	----	195.0	903.7
----	----	219.0	896.1	----	----	----	----
----	----	230.0	903.0	----	----	----	----

TABLE 13.—*Summary of cross-section data*—Continued

River mile 338.63		River mile 338.98		River mile 339.58		River mile 339.86	
Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)
3.0	905.0	15.5	910.5	25.0	908.0	8.0	918.00
8.0	893.0	17.0	898.5	28.0	898.7	12.0	901.55
12.0	888.8	24.0	895.1	30.0	896.1	15.0	891.57
26.5	887.8	43.5	890.8	40.0	895.7	25.0	887.40
30.0	885.4	130.5	892.6	47.0	894.5	35.0	885.40
41.5	886.0	143.0	892.0	55.5	894.4	40.0	883.85
113.0	886.0	164.0	892.0	62.0	890.9	45.0	882.71
152.5	885.4	174.5	890.9	85.5	889.1	50.0	882.74
173.0	883.5	185.0	891.5	120.0	891.0	55.0	882.67
184.0	884.2	202.0	891.3	154.0	891.0	60.0	883.31
190.5	888.6	206.5	891.5	184.0	893.1	65.0	883.85
204.0	893.0	212.0	893.9	212.0	894.7	70.0	884.35
225.0	904.0	218.0	898.5	213.0	898.7	80.0	885.98
----	----	----	----	222.0	905.8	90.0	887.51
----	----	----	----	----	----	100.0	888.03
----	----	----	----	----	----	110.0	888.86
----	----	----	----	----	----	120.0	889.29
----	----	----	----	----	----	130.0	891.62
----	----	----	----	----	----	145.0	892.15
----	----	----	----	----	----	160.0	892.67
----	----	----	----	----	----	170.0	892.70
----	----	----	----	----	----	180.0	894.90
----	----	----	----	----	----	190.0	897.70
----	----	----	----	----	----	193.0	902.21
				----	----	209.0	914.00

River mile 340.18		River mile 340.86		River mile 341.37		River mile 342.00	
Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)
15.0	912.6	15.0	909.5	15.0	910.5	2.5	912.0
33.0	903.1	27.0	898.3	27.0	901.2	23.0	895.4
36.0	895.7	35.0	894.9	33.0	896.8	50.0	894.4
44.0	891.9	44.0	894.9	45.0	895.4	100.0	895.1
51.5	891.7	47.5	891.7	70.0	896.4	150.0	895.5
68.0	892.1	61.5	891.0	114.0	896.4	200.0	896.3
112.5	892.1	82.5	892.0	142.0	895.4	222.0	909.4
136.0	890.5	89.0	892.1	165.0	895.2	----	----
148.0	890.6	105.0	893.3	183.5	894.7	----	----
160.0	891.2	143.0	893.3	195.0	893.5	----	----
169.5	891.3	163.0	892.2	211.0	892.6	----	----
174.0	890.5	172.0	892.1	235.0	894.4	----	----
191.0	890.3	184.5	891.2	246.0	896.7	----	----
207.0	889.6	201.0	892.2	264.0	897.9	----	----
220.5	890.3	208.0	894.5	270.0	901.2	----	----
228.5	895.7	215.5	898.2	272.0	908.0	----	----
231.0	907.0	219.0	910.2	----	----	----	----

Table 13.—*Summary of cross-section data*—Continued

River mile 342.54		River mile 343.21		River mile 343.60		River mile 344.16	
Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)
94.0	914.9	1.0	913.0	150.0	922.0	15.0	920.6
94.5	908.7	14.5	900.7	205.0	921.0	37.0	906.5
100.5	904.5	18.0	899.0	230.0	907.5	41.0	902.3
121.0	904.0	58.0	898.1	239.0	906.1	55.5	901.7
121.5	900.9	79.0	898.3	248.0	909.9	70.5	896.9
133.5	900.3	93.0	898.3	280.0	904.2	91.5	896.9
142.5	900.9	110.0	898.3	340.0	901.3	103.5	896.4
163.5	901.4	121.0	898.5	356.0	902.5	136.0	899.1
172.5	901.9	137.0	898.4	400.0	901.0	157.5	899.7
190.0	902.1	206.0	899.0	440.0	901.0	172.5	898.9
208.0	902.7	211.0	900.7	460.0	898.8	180.5	900.0
224.5	902.8	236.0	913.0	485.0	902.3	192.0	900.5
235.5	902.1	----	----	520.0	914.0	207.0	900.5
247.5	902.6	----	----	540.0	918.4	216.0	899.3
264.5	901.7	----	----	----	----	226.5	901.9
280.5	904.1	----	----	----	----	240.5	902.0
283.5	908.5	----	----	----	----	245.5	906.5
285.0	913.0	----	----	----	----	246.0	918.6

River mile 344.69		River mile 344.87		River mile 345.02		River mile 345.52	
Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)
1.0	920.5	2.5	922.0	1.0	916.1	1.0	917.5
47.0	896.9	20.0	910.0	11.0	913.0	20.0	907.6
56.0	896.3	31.0	901.3	27.0	902.3	36.0	902.5
78.0	898.2	50.0	897.2	72.0	895.0	69.0	891.0
100.0	896.0	100.0	894.5	103.0	897.0	107.0	899.5
122.0	897.0	150.0	895.4	141.0	899.3	142.0	901.0
137.0	898.2	200.0	902.5	167.0	900.5	197.0	902.5
177.0	898.4	214.0	913.5	207.0	902.3	206.0	906.1
204.0	904.7	231.0	918.5	232.0	904.8	207.0	913.7
209.0	910.6	272.0	923.4	267.0	906.2	----	----
215.0	915.6	----	----	268.0	918.2	----	----

TABLE 13.—*Summary of cross-section data*—Continued

River mile 345.80		River mile 346.06		River mile 346.52		River mile 347.07	
Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)
45.0	917.80	2.5	921.0	15.0	909.0	15.0	922.0
90.0	912.98	49.9	900.1	16.5	902.7	24.0	904.1
100.0	906.57	100.0	895.4	18.0	899.5	25.5	900.7
110.0	905.20	150.0	894.6	45.5	898.1	32.0	900.0
120.0	899.31	200.0	895.2	63.5	896.4	45.0	897.3
125.0	898.82	240.0	899.2	68.0	896.4	53.0	896.4
135.0	897.32	280.0	924.4	75.5	896.9	73.0	896.0
145.0	897.53	----	----	88.0	896.9	83.5	894.3
155.0	896.43	----	----	100.0	895.8	95.0	894.7
165.0	897.94	----	----	125.0	895.6	105.0	894.3
175.0	898.04	----	----	175.5	896.0	123.5	895.6
185.0	898.74	----	----	182.0	896.7	148.0	896.6
195.0	898.55	----	----	189.0	896.1	176.5	899.6
205.0	898.55	----	----	200.5	896.0	194.5	900.2
215.0	899.46	----	----	210.0	897.1	208.5	902.8
225.0	898.06	----	----	211.5	902.7	218.0	902.9
235.0	898.26	----	----	213.0	911.8	219.5	904.1
245.0	898.46	----	----	----	----	220.5	922.0
255.0	898.57	----	----	----	----	----	----
265.0	899.47	----	----	----	----	----	----
275.0	899.07	----	----	----	----	----	----
285.0	899.08	----	----	----	----	----	----
295.0	899.48	----	----	----	----	----	----
305.0	901.38	----	----	----	----	----	----
315.0	904.08	----	----	----	----	----	----
325.0	905.28	----	----	----	----	----	----
335.0	907.39	----	----	----	----	----	----
345.0	912.09	----	----	----	----	----	----
355.0	913.09	----	----	----	----	----	----
425.0	919.60	----	----				

River mile 347.42				River mile 347.97		River mile 348.10	
Channel 1		Channel 2					
Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)	Horizontal distance (ft)	Altitude (ft)
15.0	916.0	345.0	920.0	39.0	925.0	2.0	925.1
16.0	907.0	360.0	906.0	51.0	911.5	32.0	907.7
16.5	906.2	361.5	902.2	92.0	909.3	50.0	906.5
18.0	902.6	363.3	902.2	144.0	909.8	100.0	909.6
29.1	901.2	364.8	900.6	201.0	910.2	200.0	905.5
45.0	898.2	387.0	898.4	233.0	910.6	250.0	906.5
56.2	898.2	394.0	896.3	254.0	910.2	300.0	906.5
70.8	898.6	401.5	896.3	260.0	909.2	332.0	926.6
108.0	898.6	404.5	897.5	306.0	909.3	----	----
116.3	898.3	412.8	897.5	322.0	911.5	----	----
137.6	899.0	417.8	898.1	326.0	925.0	----	----
170.6	899.2	430.8	898.3	----	----	----	----
185.0	901.4	434.8	900.8	----	----	----	----
186.0	902.0	443.5	901.8	----	----	----	----
191.0	902.4	447.5	903.2	----	----	----	----
192.0	906.2	457.5	918.0	----	----	----	----
193.0	918.0	----	----	----	----	----	----

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