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Models for a Preliminary Flood Warning System for the Black Creek Drainage Basin, Northeast Florida

by
C. Price Robison, P.E.

St. Johns River Water Management District
Palatka, Florida

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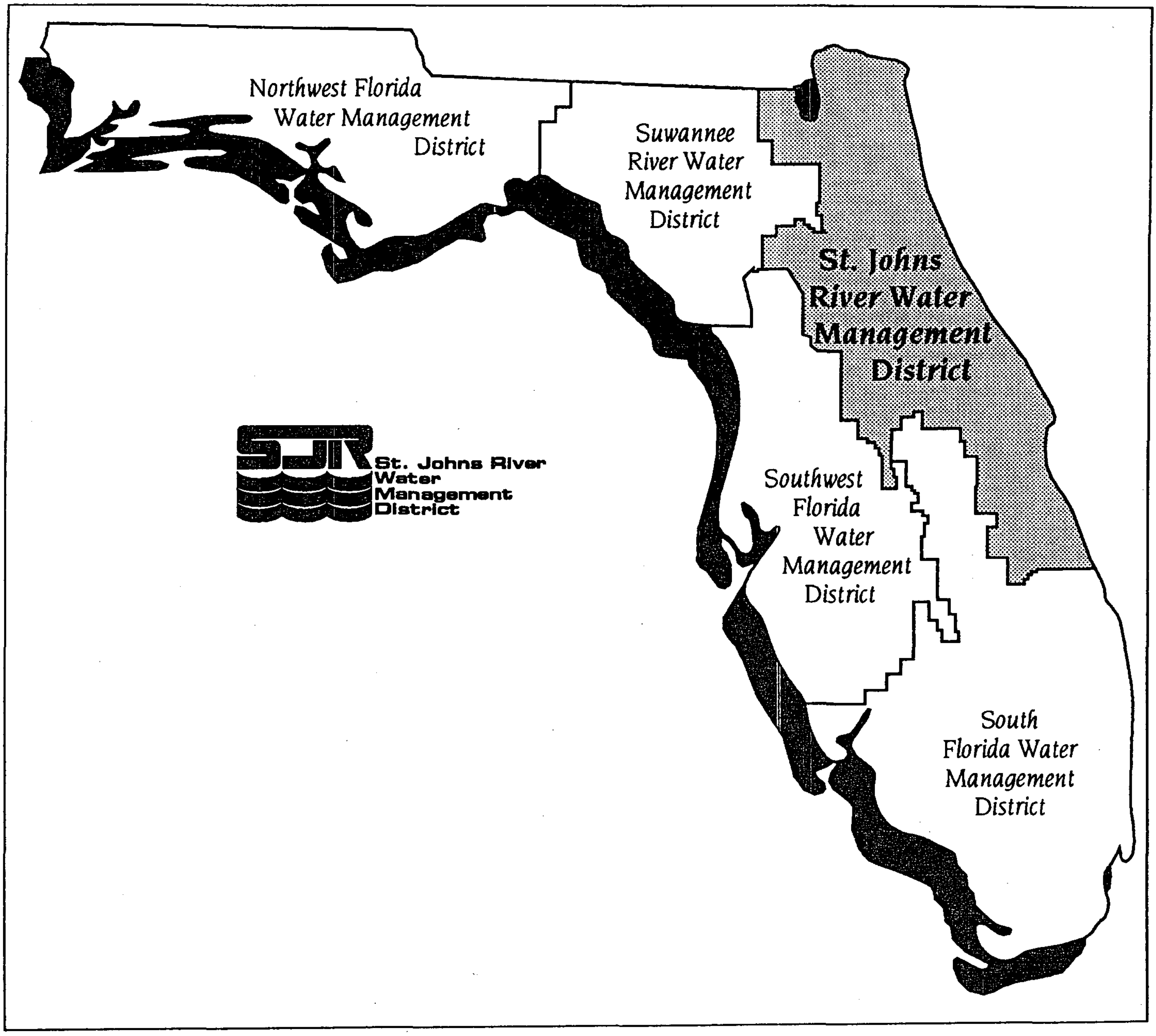

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EXECUTIVE SUMMARY

This technical report describes preliminary flood warning models for the Black Creek drainage basin developed by the St. Johns River Water Management District at the request of the Clay County Department of Public Safety. As demonstrated by a flood in September 1988, a potential for damaging floods existed along Black Creek in and around Middleburg. The best way to provide area residents with early warning of an impending flood, such as the 1988 flood, would be to install some type of a flood warning system. A comprehensive system would include both a hydrologic model and a hydraulic model. The hydrologic model used in this study was Streamflow Synthesis and Reservoir Regulation (SSARR). SSARR systematically transforms rainfall into runoff while accounting for evapotranspiration losses. The hydraulic model used was Dynamic Wave Operational Model (DWOPER). DWOPER uses runoff calculated using SSARR to project water surface elevations (stages) in the basin. These models, with periodic input of rainfall data, can be used to assess the potential for flooding in the Black Creek drainage basin at any given time.

Although SSARR and DWOPER can simulate the flooding potential for Black Creek at a given time, the models in their present form cannot provide real-time warning of impending flooding. Three tasks need to be accomplished before these models can be used in real-time simulation and warning. First, a real-time flood warning system needs an automated network of rain and stream gages. Second, SSARR and DWOPER need to be converted to use hourly data (as opposed to daily data). Finally, the entire system must be assessed periodically and as necessary to ensure that these gages are accurate, sufficient in number, and in the right location.

The real-time flood warning system should include an upgraded data collection network consisting of at least 11 rain gages and 3 stream gages. Rain gages should be located so that five are on the South Fork, five are on the North Fork, and one is on Black

Creek just downstream of the confluence of the North and South forks. Stream gages should be located so that one is on each of the following stretches: South Fork, North Fork, and Black Creek just downstream of the confluence. Cost estimates for this upgrade are included in a separate report.

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INTRODUCTION

This technical report describes preliminary flood warning models for the Black Creek drainage basin developed by the St. Johns River Water Management District (SJRWMD) at the request of the Clay County Department of Public Safety. This report deals principally with the models themselves, as opposed to the warning system of which the models are a part. These mathematical models were developed with a very sparse rain gage network that provided only daily data (as opposed to hourly data). These models, therefore, are insufficient to provide real-time warning to those likely to be affected by a given storm event. The manner in which a more comprehensive and real-time system can be developed is discussed at the end of this report.

SJRWMD is composed of ten hydrologic units, which in turn are divided into smaller drainage basins. Black Creek is the primary tributary of the Black Creek drainage basin of the Lower St. Johns River hydrologic unit (Figure 1). The North Fork and South Fork join east of Middleburg to form Black Creek (Figure 2). Black Creek flows into the St. Johns River, which in turn flows north to the Atlantic Ocean.

As demonstrated by a flood in September 1988, a potential for damaging floods existed along Black Creek in and around Middleburg. The potential for property damage and loss of life caused by flooding can only increase as population increases and the area is further developed.

The best way to provide area residents with early warning of an impending flood is to install some type of a flood warning system. The simplest system might be composed of a hydrologic model that indirectly monitors soil moisture (and, therefore, the potential for rainfall to become runoff) to provide a general idea of the flooding potential in the area at any given time. A more comprehensive system would integrate this hydrologic model with a hydraulic model. The hydraulic model, using input from

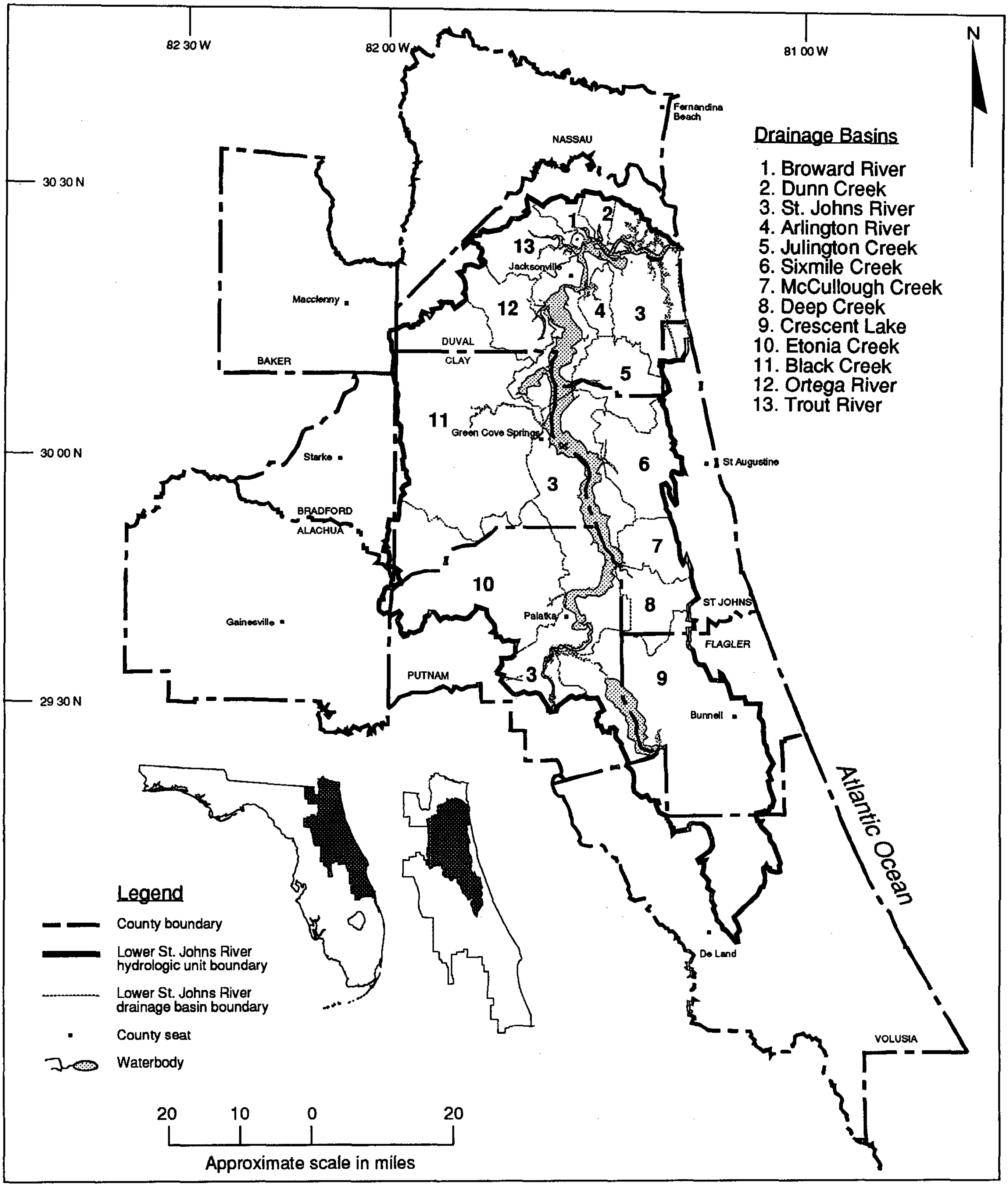

Figure 1. Lower St. Johns River surface water drainage basins

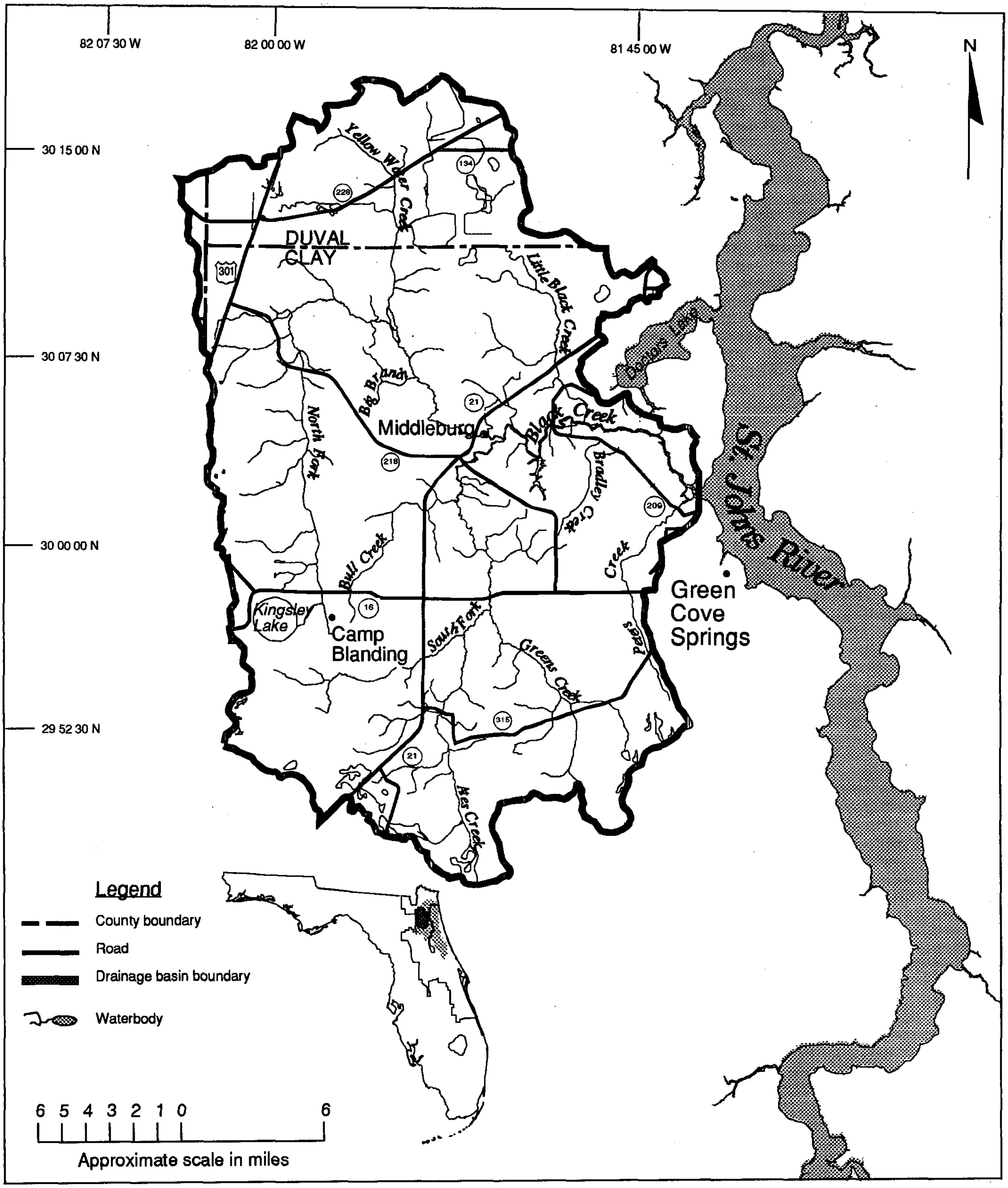

Figure 2. Black Creek drainage basin

the hydrologic model, calculates water surface levels (stages) along a creek given a hypothetical or predicted storm event. The information necessary to run these mathematical models is collected by a network of rain and stream gages.

A flood warning system goes beyond these scientific components of data collection and assessment. The other components are emergency management and public response (Osburn 1993). The complete system for the Black Creek drainage basin is addressed in greater detail in Osburn (1993). The report presented here covers the hydrologic and hydraulic modeling that could be used to predict flooding in the Black Creek drainage basin.

The hydrologic model used in this study was Streamflow Synthesis and Reservoir Regulation (SSARR). SSARR systematically transforms rainfall into runoff while accounting for evapotranspiration losses. By continuously simulating basin soil moisture, this model can predict flooding potential in the Black Creek drainage basin at any given time.

The hydraulic model used was Dynamic Wave Operational Model (DWOPER). DWOPER uses runoff calculated using SSARR to project water surface elevations (stages) throughout the basin. Factors such as tides in the St. Johns River and lateral inflows produced by SSARR are used in DWOPER.

Observed Data

Observed data for the Black Creek drainage basin include rainfall and discharge rates (collected using stream gages).

Rainfall Data

Daily rainfall data were used in calibrating and verifying SSARR. Hourly data will be necessary for implementing a real-time flood warning system. To a large extent, rainfall data measured at Cecil Field Weather Station and at area fire towers were used (Table 1, Figures 3-5).

Table 1. Rain gage stations in and near the Black Creek drainage basin

Station	Label	Location	Type
Black Creek[1,2]	BLCK	North of Wilkies Point, Clay County	daily
Camp Blanding	CAMP	On Camp Blanding, Clay County	hourly
Cecil Field	CFLD	Cecil Field Weather Station, Duval County	daily
Clay Hill	CLAY	Near mouth of Big Branch on North Fork	hourly
Dog Pound	DOGP	Near S.R. 16 bridge over South Fork	hourly
Keystone Heights[1,2]	KEYS	In Keystone Heights, Clay County	daily
Louis Hill[1,2]	LSHL	Near Highland, Bradford County	daily
Penney Farms[1]	PFRM	Near Camp Blanding, Clay County	daily
Sun Garden[1,2]	SUNG	Near Sun Garden, Clay County	daily

[1] Fire tower network
[2] Outside the drainage basin

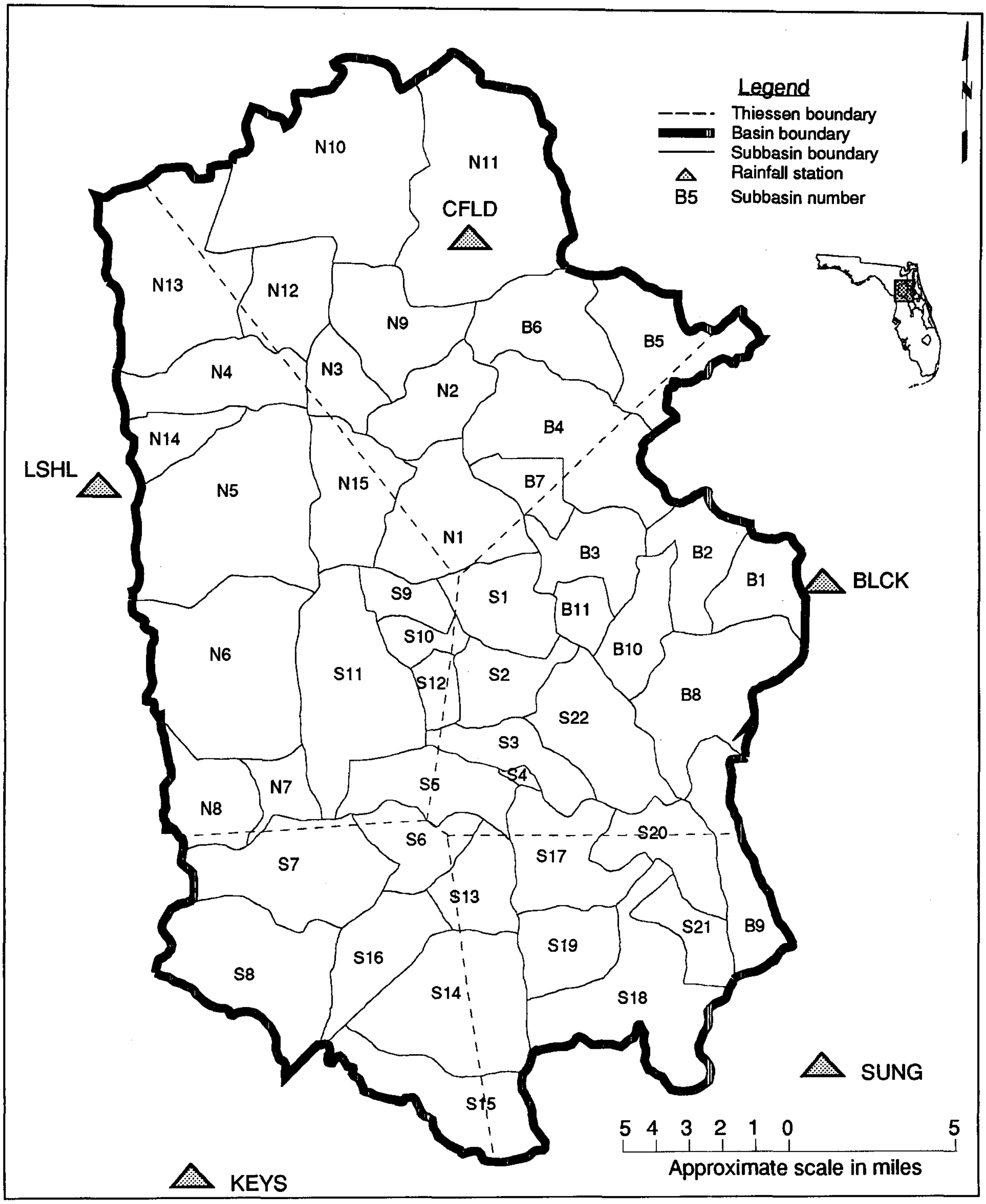

Figure 3. Black Creek Thiessen polygons for gages at Keystone Heights, Sun Garden, Black Creek, Louis Hill, and Cecil Field

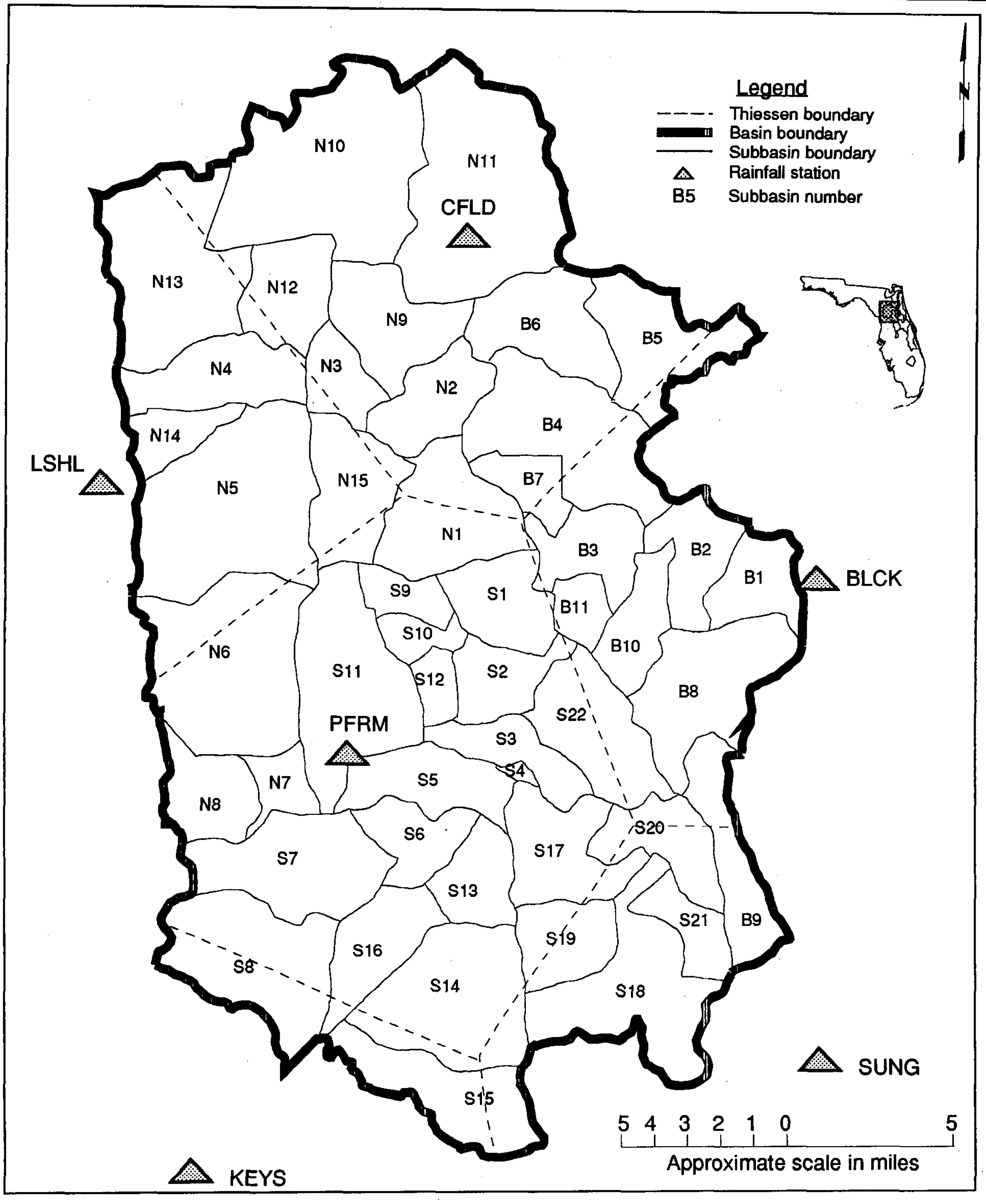

Figure 4. **Black Creek Thiessen polygons for gages at Keystone Heights, Sun Garden, Black Creek, Penney Farms, Louis Hill, and Cecil Field**

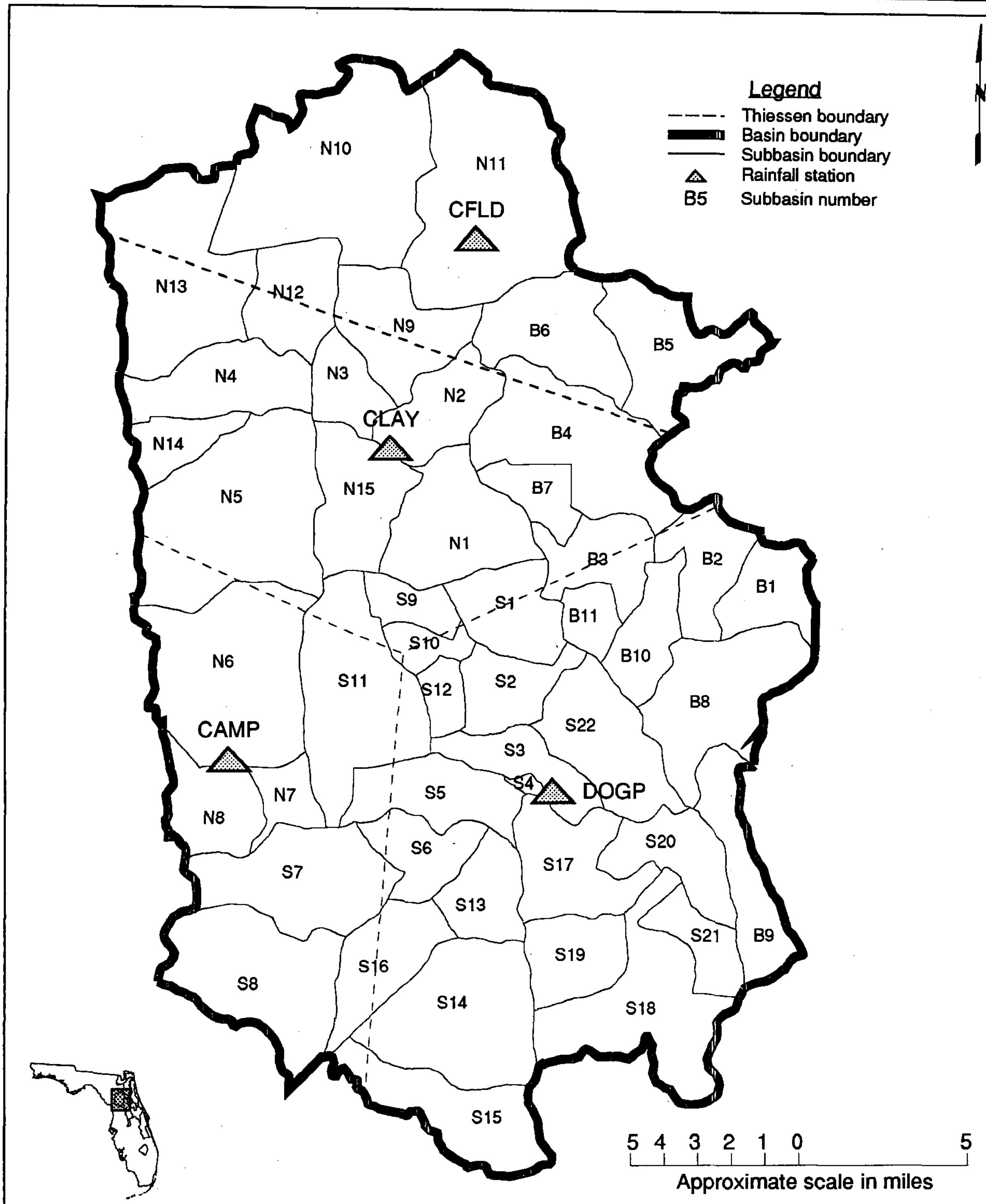

Figure 5. Black Creek Thiessen polygons for gages at Dog Pound, Camp Blanding, Clay Hill, and Cecil Field

Data from the fire tower network have not been consolidated into a usable data base, and what data are available are sometimes incomplete. Data covering the years between 1981 and 1984 were sent directly to SJRWMD under a program discontinued in 1984. Fire tower rainfall amounts pertaining to some of the more significant events (1959, 1964, 1968, and 1970) were obtained from the Florida State Climate Center in Tallahassee. Data for Penney Farms were not available for these years.

As part of the present study, rain gages, providing hourly data, were installed at Clay Hill, at Camp Blanding, and on the dog pound grounds near the town of Penney Farms (Figure 5 and Table 1); they were in operation between April 1989 and December 1990. Data from these rain gages proved to be of limited value, because only one significant flooding event occurred while they were in operation. They have been used, however, to obtain an approximate idea of the warning times in the basin.

For modeling purposes, each rainfall station is identified by a four-letter label (Table 1, Figures 3-5). Thiessen polygon representations (Linsley et al. 1975) of the rain gage networks used in calibrating and verifying SSARR appear in Figures 3 through 5.

STREAM GAGE DATA

Mean daily discharge data from stream gages were used in calibrating and verifying both SSARR and DWOPER. The corresponding stage data also were used for DWOPER. These data were recorded at U.S. Geological Survey (USGS) stream gage stations (Table 2, Figure 6).

Table 2. U.S. Geological Survey (USGS) stream gage stations in the Black Creek drainage basin

Station	USGS Number	Period of Record	Location
North Fork of Black Creek near Middleburg[1,2]	02246000	1931 to present	7.5 miles upstream of the confluence with South Fork
North Fork of Black Creek at Middleburg[2]	02246010	1981 to present	S.R. 21
South Fork of Black Creek near Penney Farms[1,2]	02245500	1939 to present	S.R. 16
Black Creek near Doctors Inlet[1,2]	02246025	1981 to present	S.R. 209

[1] Discharge data published by USGS
[2] Stage data published by USGS

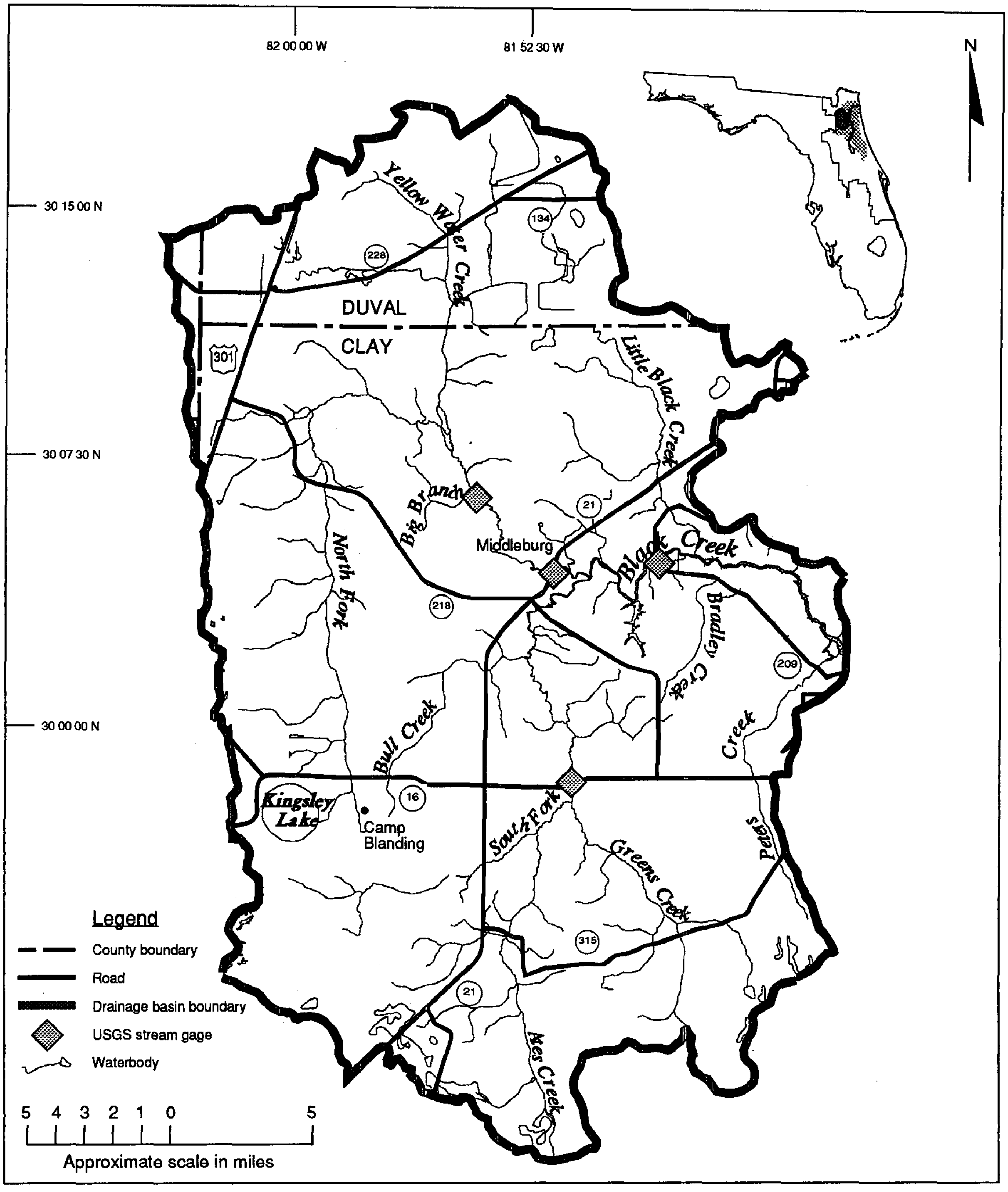

Figure 6. **U.S. Geological Survey (USGS) stream gage stations in the Black Creek drainage basin**

HYDROLOGIC MODEL—SSARR

The Streamflow Synthesis and Reservoir Regulation (SSARR) mathematical model, a rainfall/runoff/routing model developed by the Portland District of the U.S. Army Corps of Engineers (USACE 1986; Ponce 1989), was used to simulate hydrologic conditions in the Black Creek drainage basin.

MODEL DESCRIPTION

SSARR comprises a watershed submodel and a river system submodel. The watershed submodel simulates rainfall-runoff and accounts for interception, evapotranspiration, baseflow infiltration, and routing of runoff into the stream network. The river system submodel routes streamflows from upstream to downstream points through channel storage. The basic routing method used in the watershed and river system submodels is a *cascade of reservoirs* technique (USACE 1986). A watershed or channel is represented as a series of lakes, which conceptually simulate the natural delay of runoff. The SSARR user manual (USACE 1986) contains a complete description of the model. Ponce (1989) also provides a description of SSARR.

INPUT REQUIREMENTS

Input data needed for operation of SSARR include the following.

- Constant characteristics
- Initial conditions data
- Time series data
- Job control parameters

Constant Characteristics

The constant characteristics of a basin are its physical features such as drainage area, watershed characteristics affecting runoff, drainage system configuration, and so on.

The two constant characteristics discussed in detail here are the soil moisture-runoff relationships and the drainage basin configuration.

Soil Moisture-Runoff Relationships. The Soil Moisture Index (SMI), measured in inches, is an indicator of relative soil wetness and, consequently, of watershed runoff potential. Rainfall input is divided by SSARR into runoff and soil moisture increases. The percentage of rainfall available for runoff (Runoff Percentage, ROP) is based on an empirically derived relationship between soil moisture and intensity of rainfall (I) (Figure 7). This relationship determines the runoff percentage; rainfall that is not converted by the model into runoff is added to the SMI.

Soil moisture (the SMI) in SSARR is depleted only by evapotranspiration. Evapotranspiration losses, measured in inches, include transpiration of moisture by vegetation, interception losses, and direct evaporation of water from the soil to the atmosphere. SSARR reduces the SMI by the daily evapotranspiration before calculating discharge.

Evapotranspiration and evaporation from a free-water surface are affected by the same meteorological factors: radiation, humidity, wind, and temperature (Linsley et al. 1975; Ponce 1989). Thus, quite often evapotranspiration is approximated by reducing pan evaporation by a fixed ratio. For the Black Creek SSARR model, pan evaporation measured at the Gainesville Weather Station was used to calculate evapotranspiration.

SSARR calculates the effect of evapotranspiration in one of two ways.

- A simplified approach is to use a fixed, average reduction of pan evaporation.
- A more complex approach is to calculate evapotranspiration as a function of soil moisture. Evapotranspiration varies from a maximum (*potential*) value when the soil is wet to a

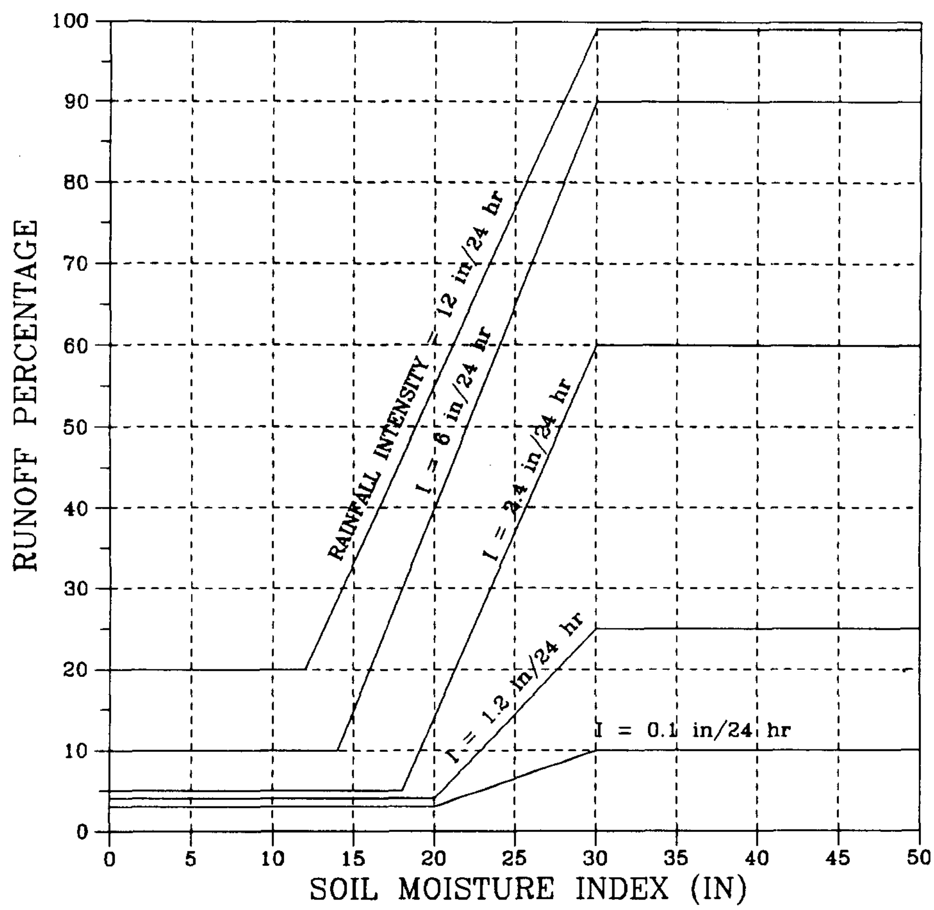

Figure 7. **Runoff percentage versus soil moisture index curves for Black Creek.** *These curves were developed in calibration.*

minimum value when it is dry and loss occurs only from vegetative transpiration (Linsley et al. 1975; Ponce 1989).

Over the long-term, these two methods should provide similar evapotranspiration losses. Since the present model is only preliminary, the simplified approach was used. When a more comprehensive model is developed, the more complex function can be calibrated and used.

Drainage Basins. Drainage basins for individual streams were determined based on elevation contours from USGS quadrangle maps of the area. Other factors such as the location of stream gages and major tributaries were also taken into consideration.

Other Relationships. Other constant characteristics used by SSARR include functions that divide runoff into surface and ground water flows and parameters that determine the shape of hydrographs.

Initial Conditions Data

Initial conditions specify the basin parameters on the starting day of simulation. They include the current value of the SMI and initial discharge from each subbasin. The model automatically saves initial conditions calculated for any given time to be used in subsequent simulations.

Time Series Data

The only time series data required by SSARR are rainfall data, measured in inches (see p. 5). Depending on the availability of evaporation data, evapotranspiration can also be input as a time series.

Job Control Parameters

Job control parameters used by SSARR include the total simulation period, time intervals for the data (daily, hourly, etc.), and input/output instructions.

MODEL CALIBRATION

Fit of Calculated Values

SSARR simulates hydrologic processes which, with input of observed rainfall data (and, if available, pan evaporation data) replicate to some degree observed discharge data. Calibration is the manipulation of various model parameters to optimize the *fit* of calculated data to observed data.

Several factors affect closeness of fit.

- Availability and reliability of rainfall data
- Density of the rain gage network
- Accuracy of USGS discharge data
- Non-coincident times for recording data
- Lack of resolution of the data

Availability and Reliability of Rainfall Data. Most of the available rainfall data were from the fire tower network; data reliability have not been formally assessed. The fire tower data used for this study contained gaps, some of a duration of several months. In addition, sometimes readings were taken after several days of rain, so the actual day of rainfall occasionally could not be determined. The purpose of the fire tower data is to help assess the soil moisture at a given time. For that purpose (but not for the purposes of modeling), the day or the time of day that data are recorded are, to a certain extent, irrelevant.

Density of the Rain Gage Network. For this model, only two or three rain gages were used to cover basins of up to 200 square miles (mi^2). Rainfall is spatially and temporally variable. A sparse network will not accurately represent the true amount and location of rainfall over a basin.

Accuracy of USGS Discharge Data.

The accuracy of streamflow records depends primarily on: (1) the stability of the stage-discharge relation ... ; and (2) the accuracy of measurements of stage, measurements of discharge, and interpretation of records.... The accuracy attributed to the records is indicated.... 'Excellent' means that about 95 percent of the daily discharges are within 5 percent of their true values; 'good,' within 10 percent; and 'fair,' within 15 percent. Records that do not meet the criteria mentioned are rated 'poor' (USGS 1988).

The data for the stream gages on Black Creek appear to be rated in general from fair to good, with some poor data.

Non-coincident Times for Recording Data. Data of different types and from different sources are recorded at different times. Average daily discharges and rainfall at Cecil Field weather station are measured from midnight to midnight. The fire tower rain gages are supposed to be read at 8 A.M. every morning and the rainfall data assigned as rain for the previous day.

Lack of Resolution of the Data. The time step for the data in this study was 24 hours. If two events occur on either side of midnight, for example, they will be simulated by the model as 24 hours apart. The fit of the model would be improved if hourly data were used.

All of these factors combine to make calibration and verification difficult. The model is preliminary; when a real-time system is installed and better data are gathered, the model can be recalibrated and its accuracy improved.

Calibration of SSARR for Black Creek

SSARR was calibrated for Black Creek using observed discharges from only the stream gages on the North and South forks (USGS 02246000 and USGS 02245500). The stream gage at Middleburg (USGS 02246010) was not used because it is a stage-only gage and discharge measurements are not published. The stream gage on Black Creek (USGS 02246025) was not used because USGS considers the quality of the discharge measurements to be poor. The entire Black Creek drainage basin is fairly homogeneous, so the runoff characteristics of the ungaged subbasins downstream of the North Fork and South Fork stream gages were determined based on the size and degree of urbanization of the subbasins.

Since large events are the most important for a flood warning system, the modeling effort concentrated on rainfall events generating more than 3,000 cubic feet per second (cfs) of discharge at either the North Fork or the South Fork stream gage (USGS 02246000 and USGS 02245500, respectively). This magnitude of event—corresponding to a return period of approximately 2 years (USACE 1988)—seems to bring with it the beginning of flooding.

In a number of cases, the model underestimated discharge produced by larger events when rainfall occurred on two consecutive days. The rain could have fallen in one 24-hour period, but the rain gages may have been read and emptied midway through a storm. For the fire tower rain gages, rain falling between midnight and 8 A.M. would be recorded as rain for the previous day. Summing rain recorded on adjacent days was considered, therefore, a legitimate way of improving model fit. This technique will be referred to as *concentration* of rainfall. Concentrating rainfall affects the total amount of runoff simulated by the model because intensity is a factor in determining ROP (Figure 7). This phenomenon has been observed in other studies; the technique of concentrating rainfall is often used in analysis of extreme rainfall events (Rao and Clapp 1986).

The fit of calculated discharge to observed discharge was examined based on a number of criteria. These included coincidence of peaks, magnitude of peaks, hydrograph fit, base flow simulation, and a general measure of the preponderance of either over- or under-estimation of minor peaks. Events with discharge peaks below 3,000 cfs were considered minor; as such, the fit was evaluated only in the general sense of over- or under-estimation. Peaks of 3,000 cfs or larger were examined in greater detail.

Calibration Process

Calibration of SSARR involved a series of trial-and-error runs to obtain the best fit with observed values, adjusting some model parameters while maintaining others fixed.

The first task in the calibration process was to determine the reduction factor for transformation of pan evaporation to evapotranspiration (see p. 13). SSARR was run simulating the 4-year time period between 1981 and 1984. The calculated discharge volume was compared with observed volume at both the North Fork and South Fork stream gages. A relatively extended time period was needed to minimize the short-term effects of the sparse rain gage network. This period was the longest period of record available for rainfall data from the fire tower rain gages. The initial run, based on previous work done for the Upper Etonia Creek (Yobbi and Chappell 1979), used 75 percent of pan evaporation (at Gainesville) for daily evapotranspiration for the entire Black Creek drainage basin.

Although discharge was underestimated by the model in both cases, the shortfall was more pronounced at the North Fork stream gage. The final evapotranspiration values, determined by trial and error, were 70 percent of pan evaporation (at Gainesville) for the entire Black Creek drainage basin except for subbasins N11 (Cecil Field) and N1 (Middleburg) (Figure 3), which were set at 65 percent. Development in these areas—for example, the Cecil Field airstrip—tends to increase runoff and decrease evapotranspiration losses.

Although the main emphasis was on simulation of peak discharge from larger events (3,000 cfs or larger), the baseflow component of discharge was also calibrated as closely as possible. A number of simulations for the period between 1981 and 1984 were performed; the baseflow was fit by trial and error.

The next calibration step was to develop the relationship of ROP to SMI. The period between 1981 and 1982 was used. The initial relationship of ROP to SMI was taken from the Upper Etonia Creek study (Robison 1992). The relationship was adjusted by trial and error based on the shape and peak of the individual event hydrographs until the best overall fit was obtained. The final curves are shown on Figure 7.

The final calibration step was to examine in more detail SSARR 1-year simulations for 1981 and 1982; the initial conditions for 1982 were saved at the end of the 1981 run. Both of these runs were done with rainfall data from Cecil Field, Louis Hill, Black Creek, Penney Farms, Keystone Heights, and Sun Garden (Figure 4). The model runs for 1982 are discussed in more detail in the next section.

Calibration: 1982

At the North Fork stream gage, during 1982, no peak discharges of 3,000 cfs or larger were observed or calculated (Figure 8). Minor peaks correspond to each other fairly well, with over- and under-estimates about equal. The baseflow simulation is good.

At the South Fork stream gage, during 1982, no peak discharges of 3,000 cfs or larger were observed or calculated (Figure 8). Minor peaks correspond to each other fairly well with over- and under-estimates about equal. The calculated baseflow component at the beginning of the year is low, because the model failed to simulate a number of peaks at the South Fork stream gage during 1981. The baseflow component of the events corresponding to these peaks was likewise not simulated (since baseflow lags direct runoff). As the year progresses, the fit of the baseflow improves.

MODEL VERIFICATION

Verification indicates how well the model is performing. The verification of a mathematical model is the simulation of events not used to calibrate the model—the modeler tries to replicate observed data. A determination is made as to the ability of the model, given the calibrated parameters, to replicate observed data and, therefore, to simulate future events. The SSARR model was verified with data from 1983, 1984, and 1968. Verifications for 1984 and 1968 are presented in the next section.

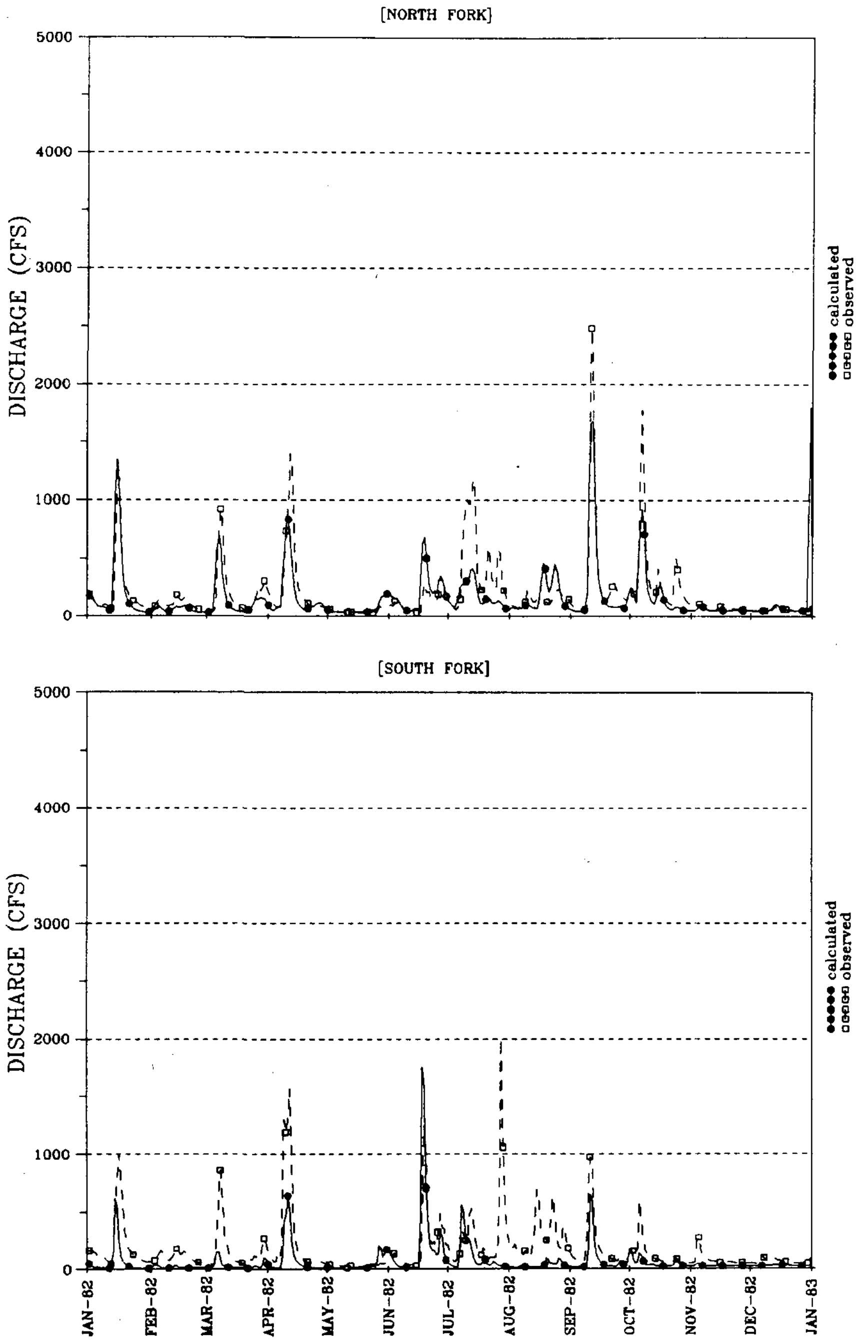

Figure 8. **North Fork and South Fork of Black Creek SSARR calibration, 1982**

Verification: 1984

At the North Fork stream gage, during 1984, three peak discharges larger than 3,000 cfs were observed, but the model calculated only one of them (Figure 9).

The first observed peak discharge occurred around 23 March (Figure 10[A]). On 20 March, the Cecil Field Weather Station recorded 0.1 inches (in.) of rainfall, and the Louis Hill station recorded 0.2 in.; no other rainfall was recorded within 5 days at either station. Even though there are two rain gages in the basin, these gages did not record an event that produced a peak discharge of 4,500 cfs, which could cause flooding problems. This illustrates one of the problems affecting closeness of fit: the density of the rain gage network.

The second observed peak discharge (with a measured peak of 3,600 cfs) occurred around 28 March. This event was simulated adequately (Figure 10[A]). Concentrating the rainfall improves the peak simulation a little (Figure 10[A1]).

The third observed peak discharge occurred on 29 September (Figure 10[B]). Concentrating the rainfall recorded for 27 and 28 September onto 28 September (Figure 10[B1]) improves the simulation. The overall fit of the hydrograph also is improved by concentrating the rainfall.

For 1984 at the North Fork stream gage, the correspondence of minor peaks was good, with over- and under-estimates about equal. The baseflow simulation was good (Figure 9).

At the South Fork stream gage, during 1984, no peaks larger than 3,000 cfs were observed or simulated (Figure 9). The correspondence of minor peaks was good, with over- and under-estimates about equal. The baseflow simulation was good.

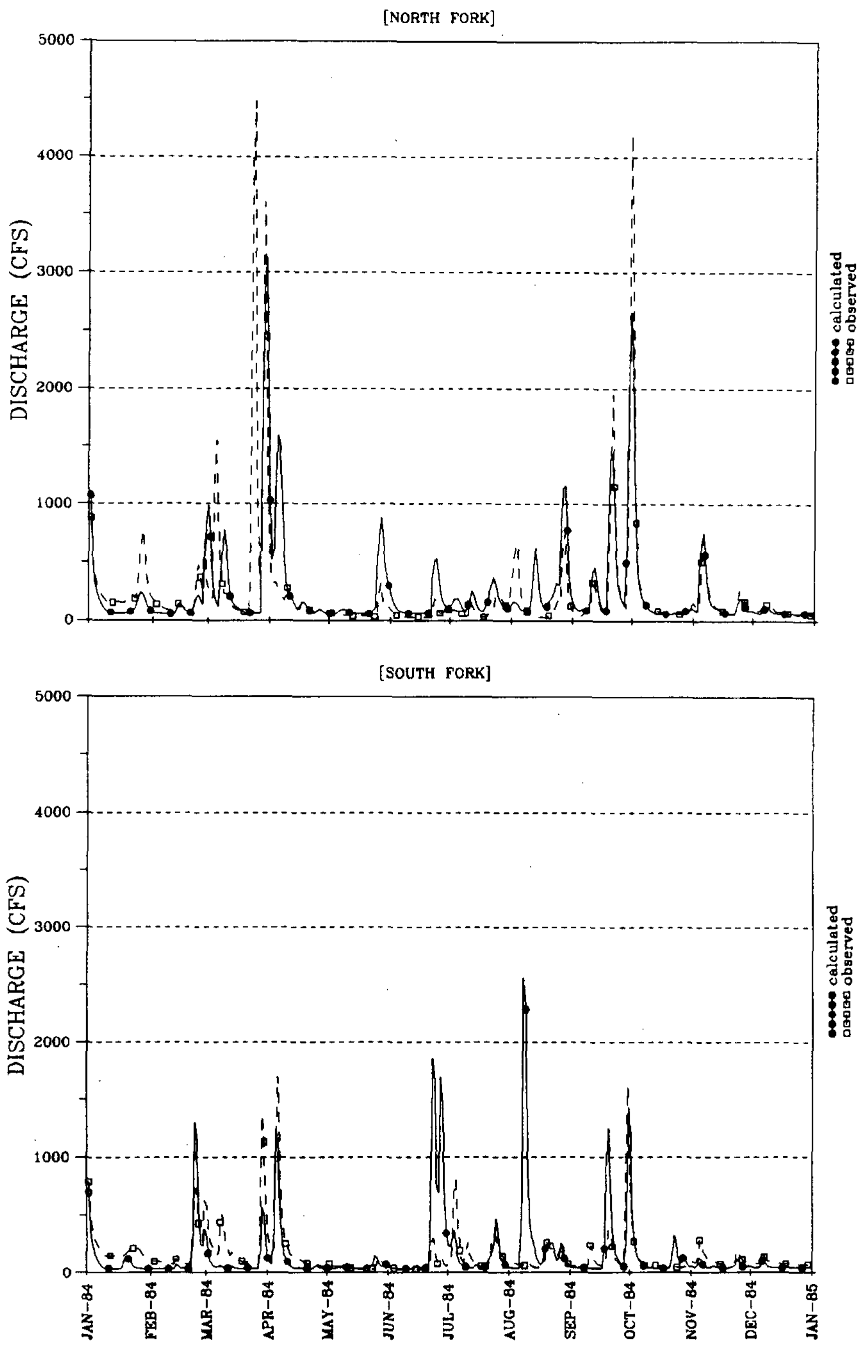

Figure 9. **North Fork and South Fork of Black Creek SSARR verification, 1984**

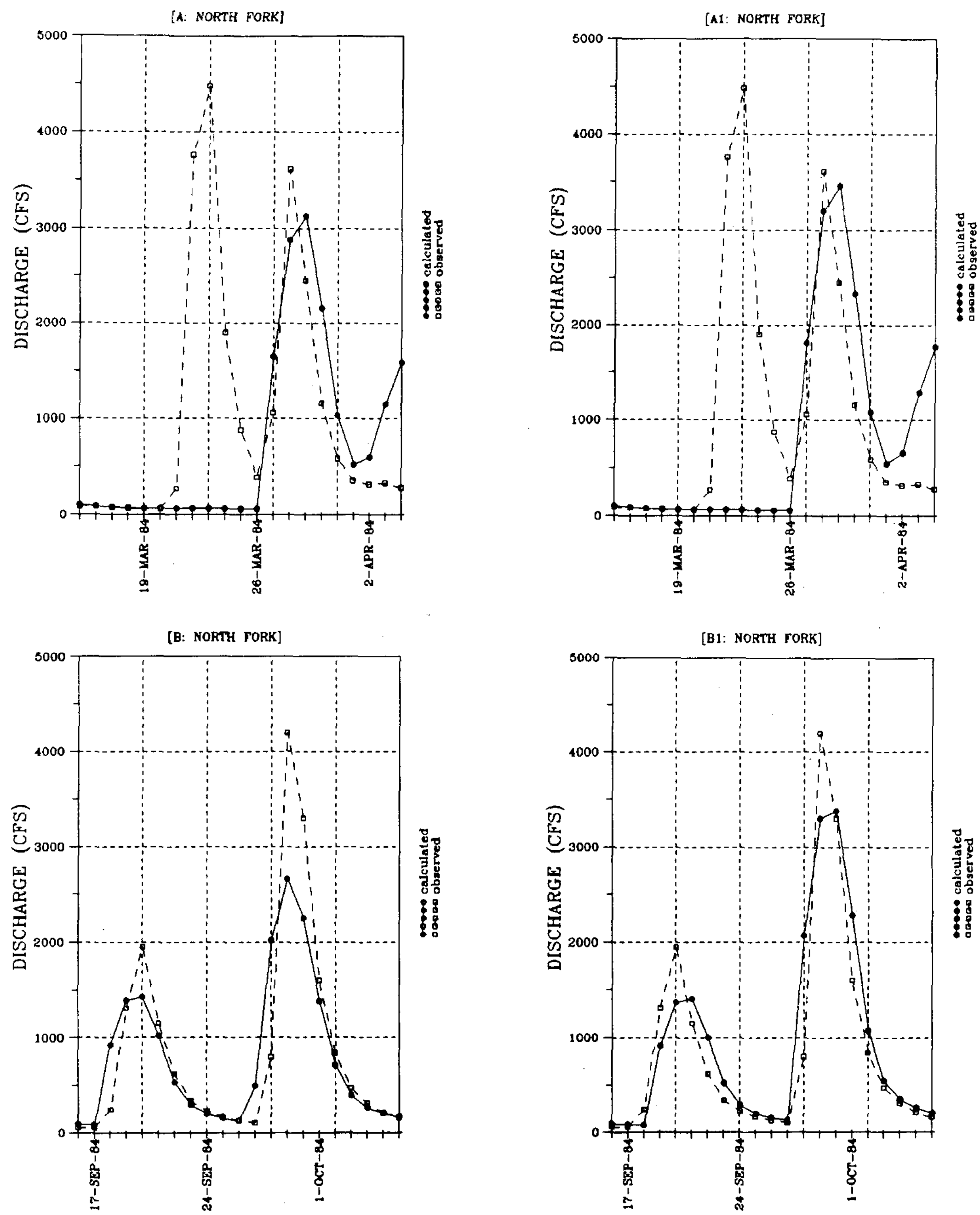

Figure 10. **SSARR verification details for the North Fork, 1984.** *This figure shows details of Figure 9.*

Verification: 1968

The runoff characteristics of a drainage basin change some over time, especially with increased development. Simulations for 1968 were included in this study, however, to examine SSARR performance with respect to extremely high flows. Comparison of simulated results with observed data should indicate whether development has altered the basin runoff characteristics drastically.

At the North Fork stream gage, during 1968, two peak discharges larger than 3,000 cfs were observed and calculated (Figure 11). The observed peak discharge for the event around 7 June was 5,200 cfs. The fit of the calculated event around 7 June is good (Figure 12[A]).

The observed peak discharge for the event around 30 August was 11,200 cfs and the calculated peak was 7,100 cfs (Figure 12[B]). Concentrating rainfall on 30 August improves the fit and peak prediction for this event considerably (Figure 12[B1].

For 1968, at the North Fork stream gage, the correspondence of minor peaks was good, with over- and under-estimates about the same (Figure 11). The simulation of baseflow was good.

At the South Fork stream gage, during 1968, one peak discharge larger than 3,000 cfs was observed and calculated (Figure 11). The observed peak discharge for the event around 30 August was 6,300 cfs. The calculated peak (3,600 cfs) for this event was considerably smaller than the observed peak (Figure 12[C]). Concentrating rainfall on 30 August improved the fit and peak prediction greatly (Figure 12[C1].

For 1968, at the South Fork stream gage, the correspondence of minor peaks was good, with over- and under-estimates about the same (Figure 11). The simulation of baseflow was good.

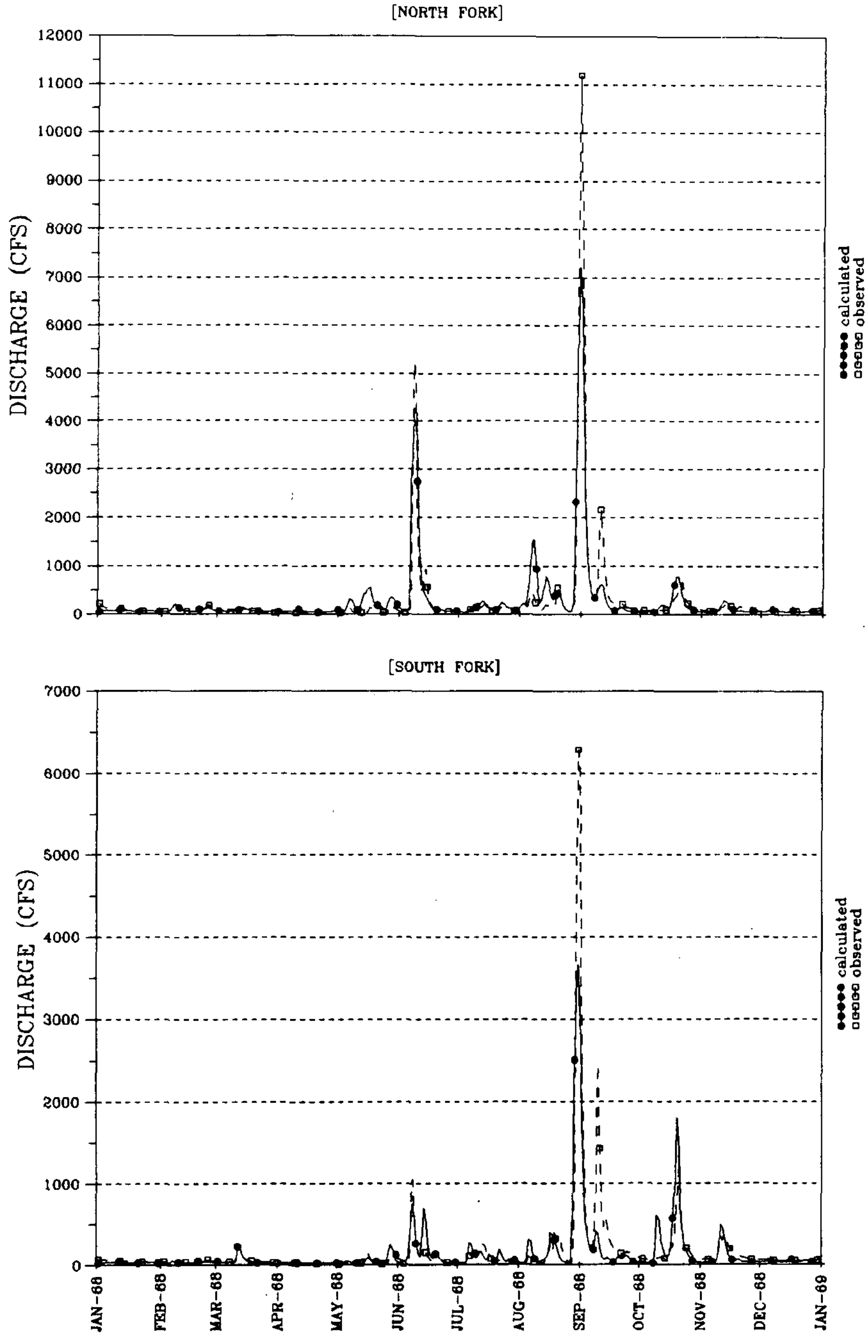

Figure 11. North Fork and South Fork of Black Creek SSARR verification, 1968

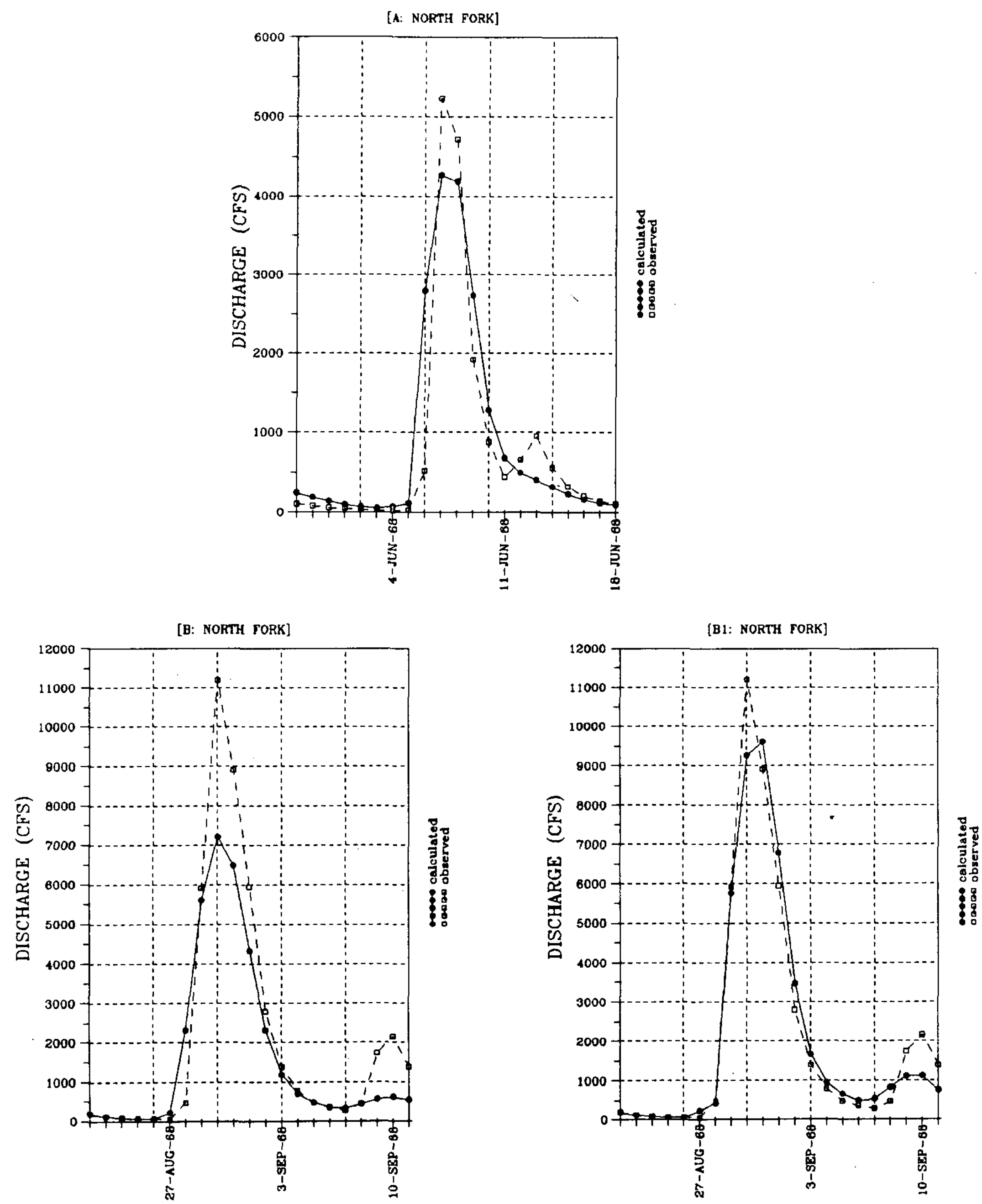

Figure 12. **SSARR verification details, 1968.** *This figure shows details of Figure 11.*

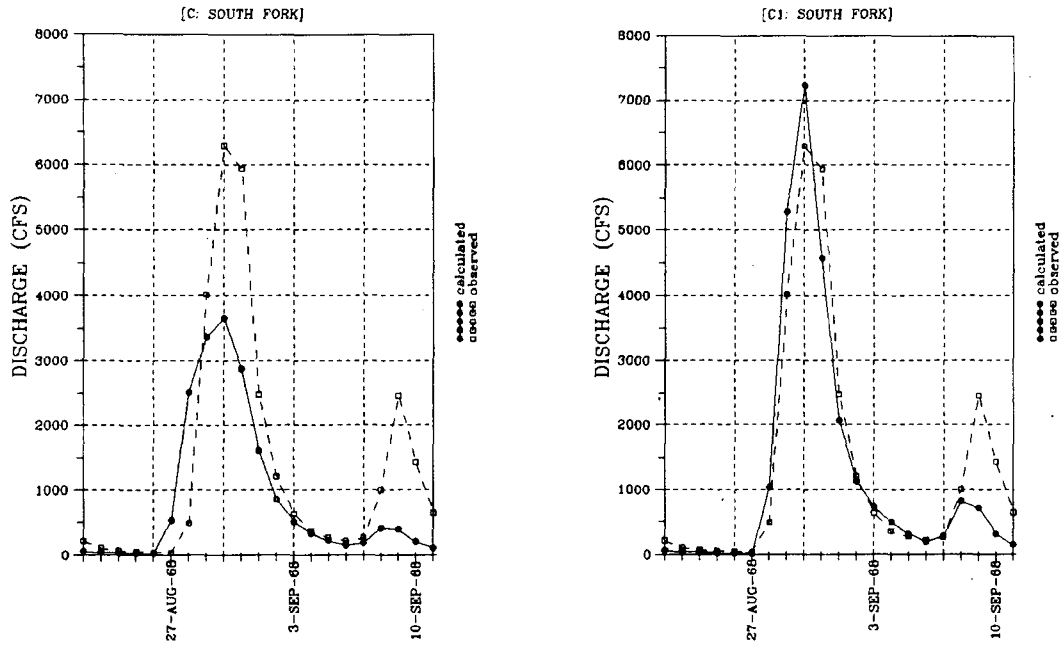

Figure 12—*Continued*

HYDRAULIC MODEL—DWOPER

The flood warning system must have the capability of determining water surface levels (stages) in the Black Creek drainage basin. SSARR has the capability of *conceptually* routing discharges and, given predetermined rating curves at different locations, it could compute stages. Another way to determine stages would be to use the discharge hydrographs from SSARR as input to a steady-flow model such as HEC-2. A third option for calculating stages is to use an unsteady-flow model such as the Dynamic Wave Operational Model (DWOPER), developed in the 1970s by the National Weather Service (Fread 1982).

Two principal factors influenced the choice of an unsteady flow model for the Black Creek flood warning system. The first factor was the presence of tides on the St. Johns River. Tides propagate effects up Black Creek and thus could have a significant effect on stages during a flooding event. The second factor was that very near the confluence of the North and South forks of Black Creek is the location of the principal area of concern, Middleburg. This critical location is subject to changing backwater effects on both forks, which could have significant effects on flood stages.

MODEL DESCRIPTION

DWOPER is based on the finite-difference solution of the St. Venant one-dimensional equations of unsteady flow, which are the equations of conservation of mass and of momentum. A rigorous description of the model is beyond the scope of this report; the reader is referred to the user manual for more information (Fread 1982).

INPUT REQUIREMENTS

Input data needed for operation of DWOPER include the following.

- Cross sections
- Roughness coefficients
- Boundary conditions
- Lateral inflows
- Off-channel storage

Cross Sections

The *x-y* representation of a cross section is converted to a relationship between depth and top width before it can be used in DWOPER. The Clay County flood insurance study (FEMA 1981) surveyed cross sections along Black Creek. The model used these cross sections: 25 along the main stem (from the St. Johns River to the North Fork stream gage) and 13 along the South Fork (from the mouth at Black Creek to the State Road [S.R.] 16 bridge) (Figure 13).

Roughness Coefficients

The roughness coefficient used by DWOPER is Manning's n, which represents the resistance to flow caused by bed forms, bank vegetation, bend effects, and eddy losses (Chow 1959). Manning's n can be defined as a function of either stage or discharge in DWOPER. In the present case, largely to simplify the calibration process, Manning's n was defined as a function of discharge.

Boundary Conditions

Boundary conditions must be specified in order to obtain solutions to the St. Venant equations. In fact, in most unsteady-flow problems, the unsteady disturbance is introduced into the flow at the boundaries of the river system.

DWOPER uses a known discharge hydrograph at the upstream boundaries of the river system. For Black Creek, discharge hydrographs at the North Fork and South Fork stream gage sites were used as upstream boundary conditions.

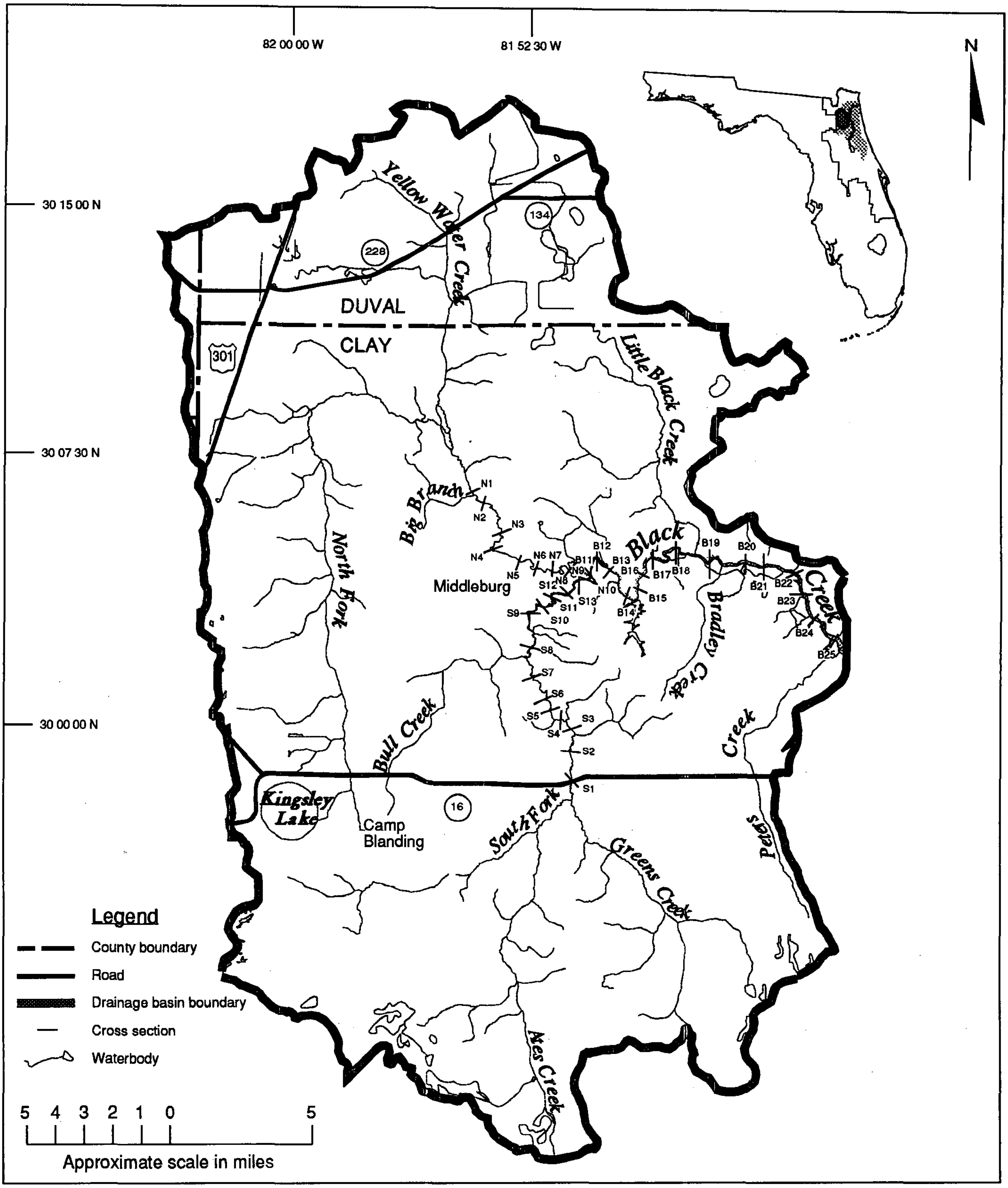

Figure 13. DWOPER cross-sectional locations along Black Creek

St. Johns River Water Management District

DWOPER uses a known stage hydrograph at the downstream boundary of the river system. For Black Creek, the stage at the mouth of Black Creek at the St. Johns River was used as the downstream boundary condition. The average daily observed stage of the St. Johns River at Jacksonville (USGS 02246500) was assumed to represent this boundary. Judging from model results, this seems to be a reasonable assumption.

Lateral Inflows

Lateral inflows were entered into the model as four separate hydrographs: one covering the drainage area between the North Fork stream gage and the confluence of the North and South forks; one covering the drainage area between the South Fork stream gage and the confluence of the North and South forks; one covering the drainage area between the confluence of the North and South forks and the mouth of Little Black Creek at Black Creek (Figure 2); and one covering the area between the mouth of Little Black Creek at Black Creek and the mouth of Black Creek at the St. Johns River.

Off-Channel Storage

Off-channel storage areas, in which the flow velocity is negligible relative to the velocity in more active areas of the stream, are a feature of DWOPER. Such off-channel storage areas can be used to account for parts of the channel that do not pass flow and serve only to store water. Another effective use of off-channel storage is to model a heavily wooded floodplain that stores a portion of the floodwater passing through the channel. Especially below the confluence of the North and South forks, areas of off-channel storage were included in some model cross sections.

Model Calibration

Fit of Calculated Values

Stages in the Black Creek drainage basin are controlled by various channel and boundary conditions. DWOPER simulates different physical processes which, with input of observed discharges, replicate, to some degree, observed stages. Calibration is the manipulation of various model parameters to optimize the *fit* of calculated stages to observed stages.

Although every effort was made to optimize the fit of calculated data to observed data, two factors affect closeness of fit.

- Accuracy of USGS discharge and stage data
- Density of the stream gage network

Accuracy of USGS Discharge and Stage Data. See the discussion relative to SSARR on page 16.

Density of the Stream Gage Network. Data from the North Fork and South Fork stream gages were the principal information used in calibrating the Black Creek model. Little is known about lateral inflows or stages other than those at these two stream gages.

All of these factors combine to make calibration and verification difficult. At the same time, the model is preliminary. Later, when a real-time system is installed and better data are gathered, both models can be recalibrated and the accuracy of the flood warning system improved.

Calibration of DWOPER for Black Creek

In the flood warning system, DWOPER is used only for producing flood-magnitude stage hydrographs. The main emphasis, therefore, was put on model performance as it pertains to events with discharges larger than 3,000 cfs.

Discharges from ungaged subbasins (downstream from the North Fork and South Fork stream gages) were assumed to be proportional to the North Fork and South Fork stream gage values, based on drainage area of the ungaged subbasin. The stream gage at Middleburg (USGS 02246010) is a stage-only gage, and data from the one on Black Creek (USGS 02246025) is considered poor by USGS. Observed discharges were not used from these gages for calibration.

The fit of calculated stages to observed stages was not judged by any set criteria. If calculated stages replicated the general form of the observed-stage hydrograph and were within about 1 foot (ft), then the calibration was considered successful.

Calibration Process

DWOPER includes an automatic calibration option based on optimization of the roughness coefficients (Manning's *n*-values), given stage hydrographs at different locations in the basin. For this automatic calibration, the Black Creek channel was divided into four stretches determined by the locations of the four available USGS stream gages (Figure 6).

- From the USGS North Fork stream gage to the USGS stream gage at Middleburg
- From the USGS stream gage at Middleburg to the USGS stream gage on Black Creek
- From the USGS stream gage on Black Creek to the St. Johns River
- From the USGS stream gage on the South Fork to the confluence of the North and South forks

Events from 29 December 1983, 1 September 1985, and 7 September 1988 were used in this process. This automatic calibration produced a curve of discharge versus Manning's *n*-values for each stretch of the creek. These curves provided initial estimates of Manning's *n*-values for final calibration.

The stretches of North Fork, South Fork, and Black Creek used in the DWOPER automatic calibration do not necessarily correspond to the channel types in the system. The creek, therefore, was redivided into four different stretches based on field inspection, USGS quadrangle maps, and the surveyed cross sections of the creek. Each of these new stretches had a separate family of discharge versus Manning's *n*-value curves. These four stretches covered the following (Figure 13).

- From the mouth of Black Creek at the St. Johns River to the confluence of the North and South forks (the corresponding Manning's *n*-value relationship is labeled *BLACK CREEK* on Figure 14)
- From the confluence of the North and South forks to cross-section N4 on the North Fork and cross-section S8 on the South Fork (*NORTH FORK, SOUTH FORK 2* on Figure 14)
- From cross-section N4 to cross-section N1 (the USGS stream gage location) on the North Fork (*NORTH FORK 1* on Figure 14)
- From cross-section S8 to cross-section S1 (the USGS stream gage location) on the South Fork (*SOUTH FORK 1* on Figure 14)

Starting with the initial estimate of Manning's *n*-values determined by the automatic calibration in DWOPER, the observed events of 29 December 1983 and 7 September 1988 were used to determine, by trial and error, the final *n*-values for the new stretches of the creek (Figure 14). These *n*-values are reasonable when compared with standard values (Chow 1959).

Cross sections vary downstream and upstream of the confluence of the North and South forks. Cross sections downstream (corresponding to the relationship labelled *BLACK CREEK* in Figure 14) include a large, hydraulically smooth channel section and off-channel storage on either side of that channel. Cross sections upstream (corresponding to the relationships labeled *NORTH FORK 1* and *SOUTH FORK 1* in Figure 14) include a small channel section and an active overbank (as opposed to off-channel storage) covered with thick underbrush and trees.

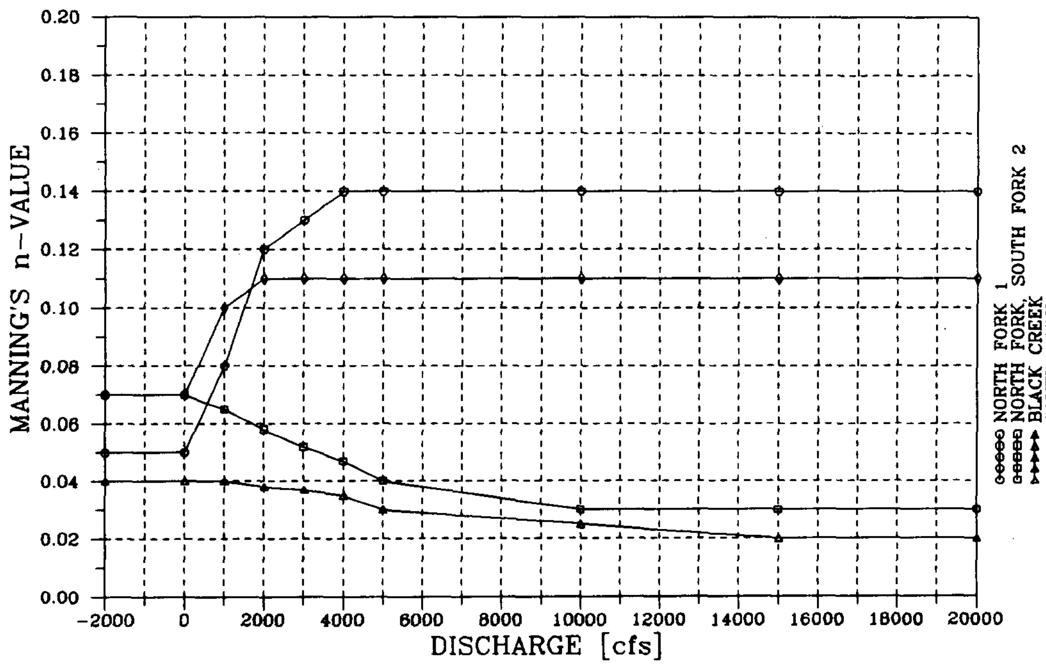

Figure 14. **Relationship of Manning's *n*-values to discharge for DWOPER.** *These curves were developed in DWOPER calibration.*

The shape of the stage hydrographs for observed and calculated stages for 29 December 1983 and 7 September 1988 were replicated quite well (Figures 15 and 16). The calculated stages were generally within 1 ft of the observed stages. The exception at the Middleburg stream gage in 1983 might be an indication of the lack of gaged values for lateral inflows.

MODEL VERIFICATION

Verification indicates how well the model is performing. The verification of a mathematical model is the simulation of events not used to calibrate the model—the modeler tries to replicate observed data. A determination is made as to the ability of the model, given the calibrated parameters, to replicate observed data and, therefore, to simulate future events. Verification of the Black Creek DWOPER model used storm events around 25 February 1987 and around 29 March 1970 (Figures 17 and 18).

The event around 25 February 1987 (Figure 17) was recorded at all four USGS stream gages. The calculated stage hydrographs for the North Fork and South Fork stream gages replicated the form of the observed stage hydrographs well; the calculated stages were generally within 1 ft at the North Fork and South Fork stream gages. The calculated stages at the Middleburg stream gage were consistently lower than observed stages by about 1 ft or less. Calculated stages at the Black Creek stream gage were quite close to the observed stages.

The event around 29 March 1970 (Figure 18) was used in order to include verification of very large events at the North Fork and South Fork stream gages. For this event, the peak discharge at the North Fork stream gage was 9,900 cfs, and the peak discharge at the South Fork stream gage was 7,400 cfs. Calculated stage hydrographs at both stream gages replicate the shape of the observed stage hydrograph, and calculated stages are within 1 ft of observed stages.

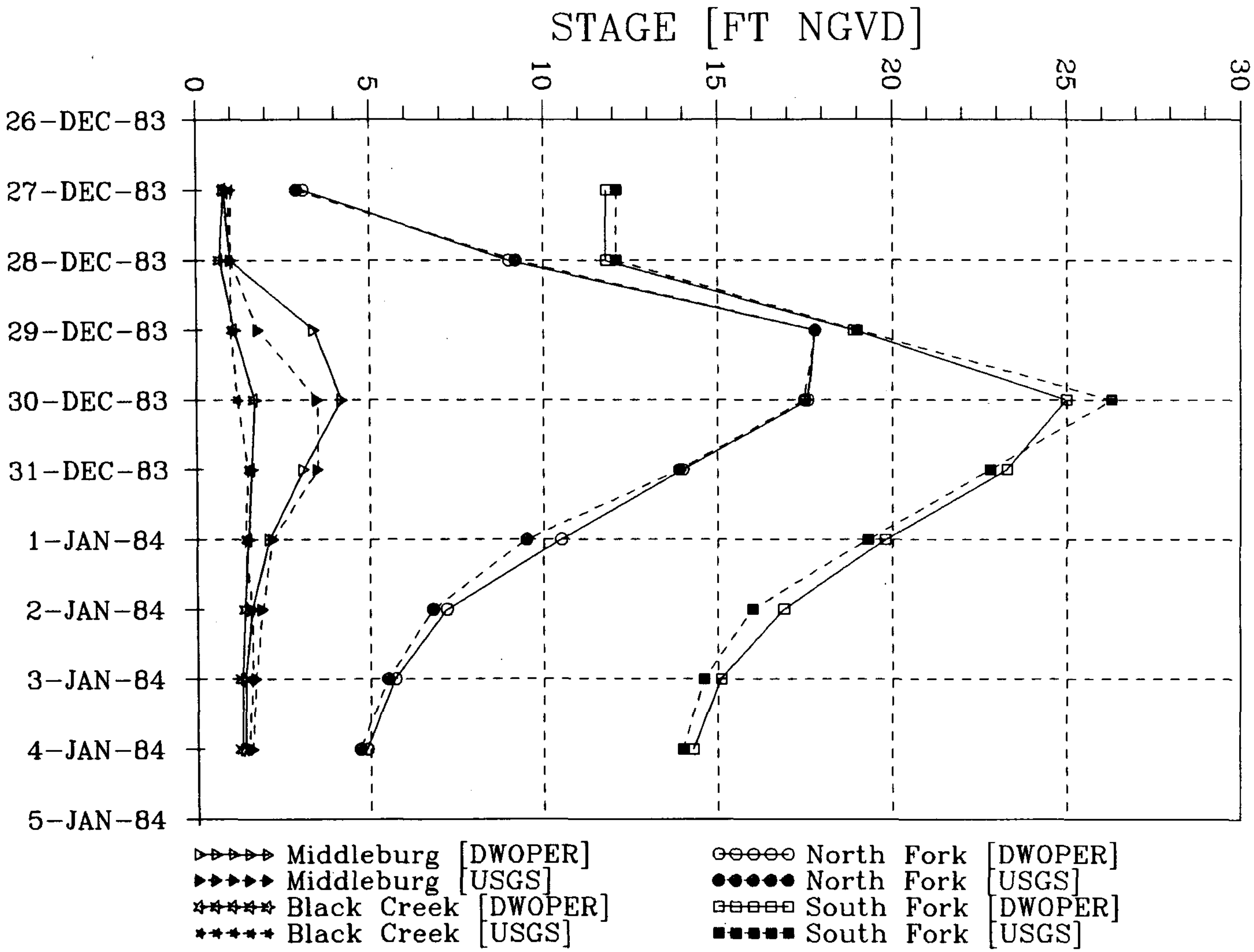

Figure 15. **DWOPER calibration, 1983**

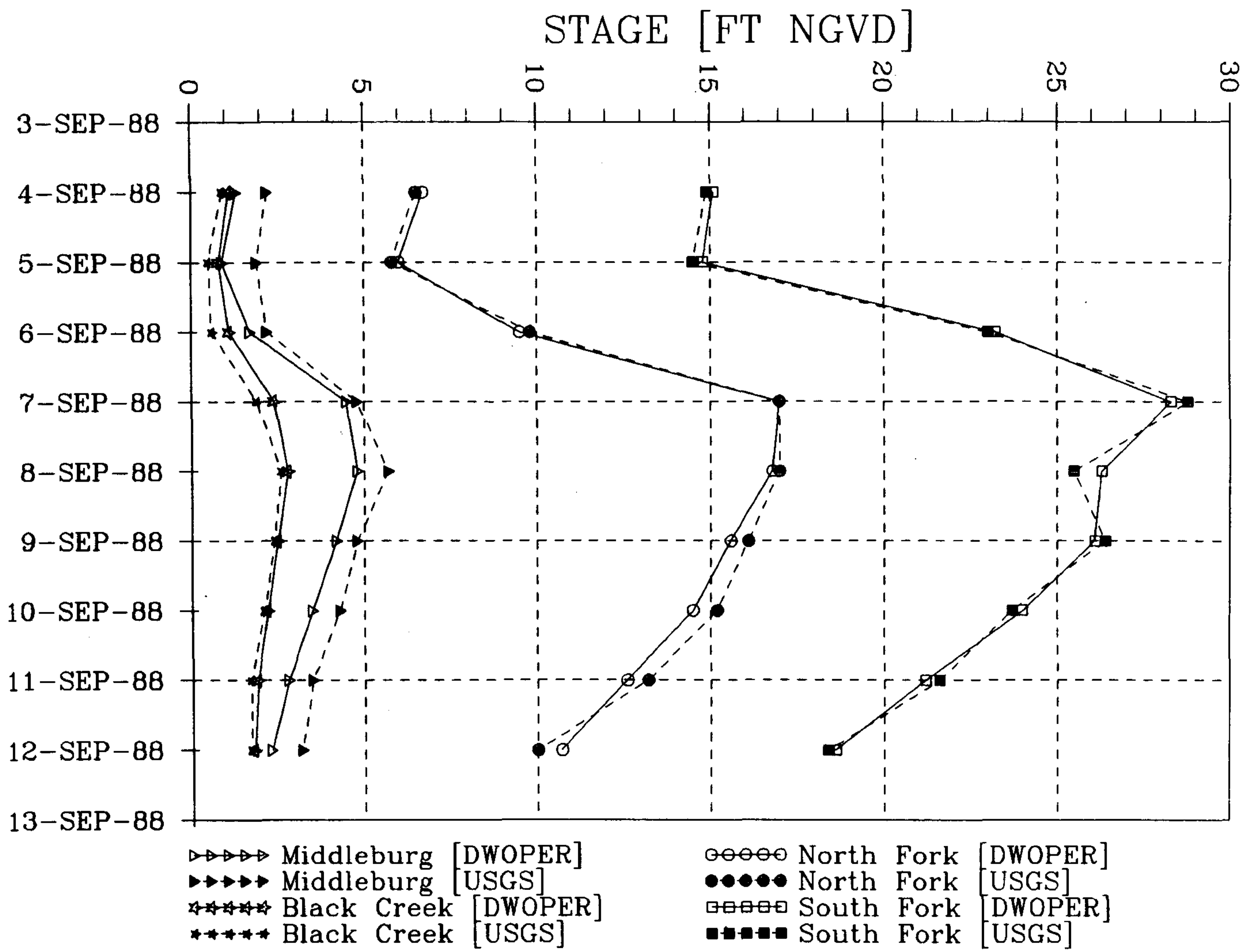

Figure 16. **DWOPER calibration, 1988**

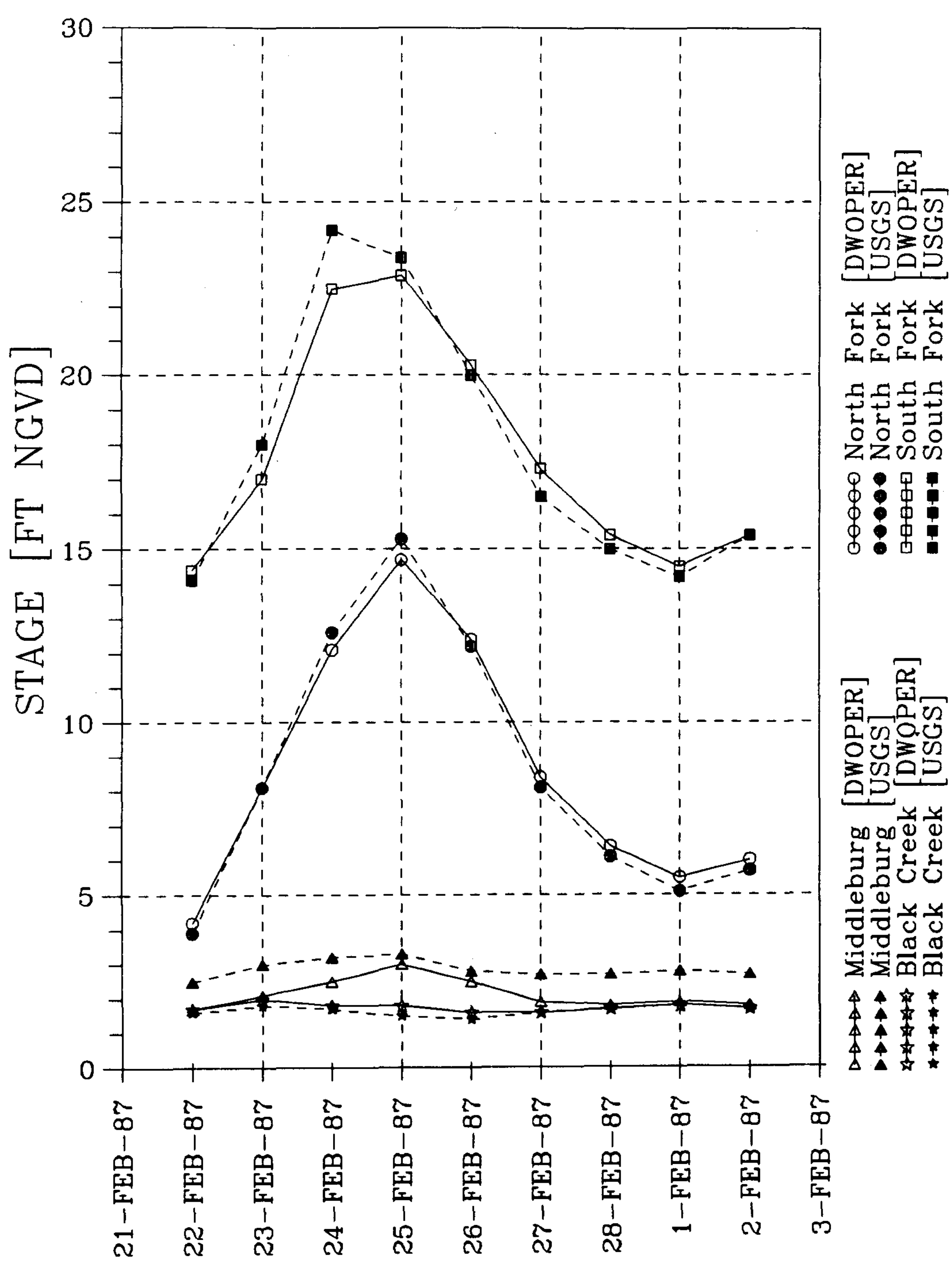

Figure 17. DWOPER verification, 1987

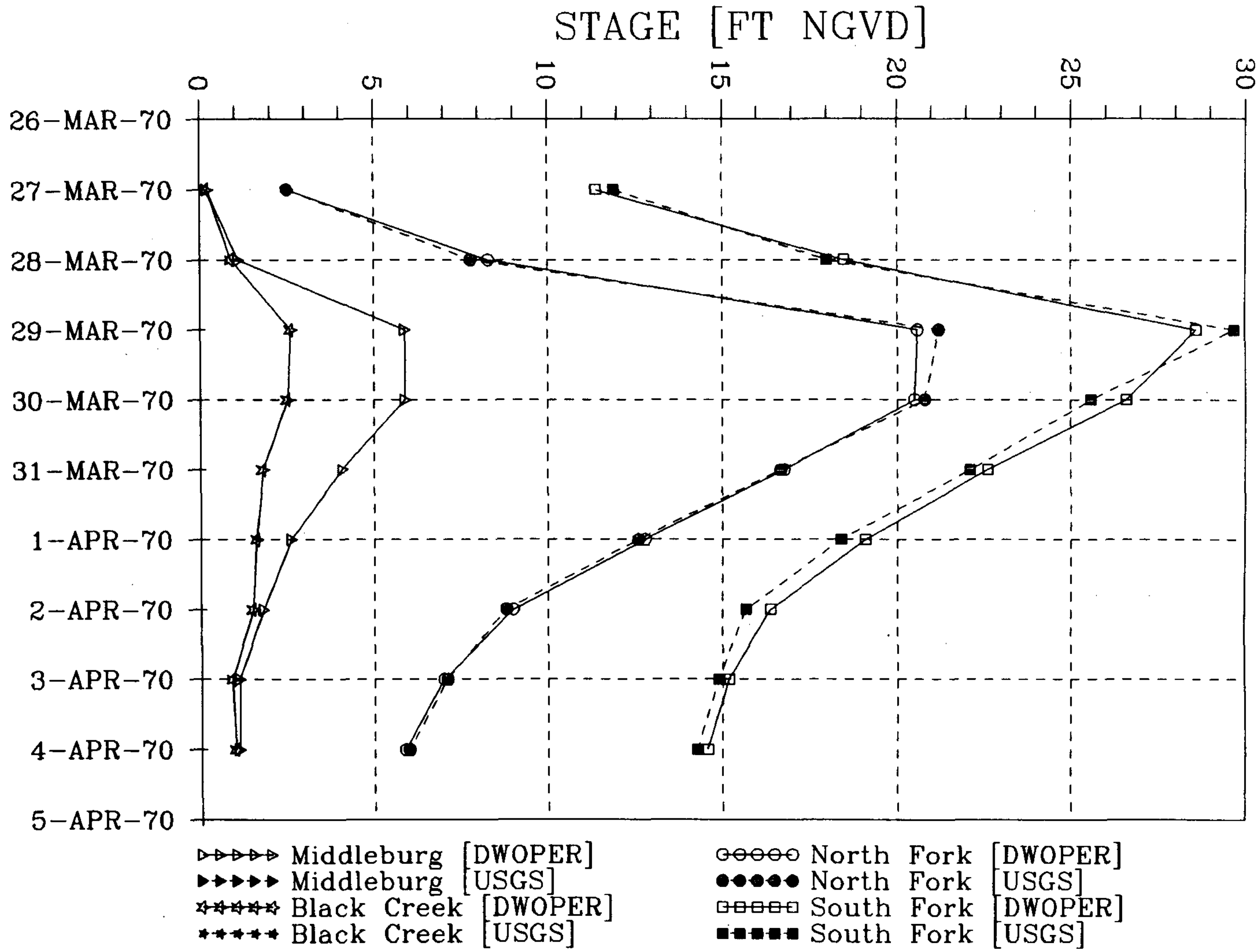

Figure 18. **DWOPER verification, 1970.** *The two downstream gages did not exist in 1970.*

OPERATION OF SSARR AND DWOPER FOR BLACK CREEK

The hydrologic and hydraulic models, SSARR and DWOPER, together can be used to assess flooding potential in the Black Creek drainage basin. There are three different steps for determining the flooding potential in the Black Creek drainage basin using SSARR.

1. Entering rainfall data a month at a time

2. Entering rainfall data leading up to a predicted significant event

3. Simulating 10 days of discharge for a significant event

DWOPER needs to be run only if flooding is expected or actually occurs. This section is a brief conceptual discussion of steps used in the operation of SSARR and DWOPER; a more detailed discussion is contained in the appendix.

MONTHLY UPDATES (SSARR)

In order to keep track of the flooding potential in the Black Creek drainage basin, daily rainfall amounts must be entered into SSARR. The data recorded for the Black Creek drainage basin must be entered manually into SSARR by station, 1 month at a time. Monthly updating maintains current soil moisture levels and calculates the initial conditions for each subbasin for the start of the following month.

Following each month's calculation of soil moisture levels and initial conditions, SSARR is run three times to predict the potential for flooding at that particular time. Theoretical 24-hour rainfall totals of 2, 4, and 6 in. are input into SSARR. Calculated discharge hydrographs for these rainfall amounts at the North Fork and South Fork USGS stream gage locations help indicate the potential for flooding should heavy rainfall be predicted in the area.

In general, a 2-year event is often considered to constitute bank-full stage on natural streams (Linsley et al. 1975). A discharge of 3,000 cfs corresponds approximately to a 2-year event (USACE 1988) at either the North Fork or the South Fork USGS stream gage location. Observed events have confirmed that approximately 3,000 cfs discharge along either the North Fork or the South Fork constitutes a point above which flooding problems might begin.

PRECURSOR TO SIGNIFICANT EVENT (SSARR)

If a major rainfall event is predicted, initial conditions for SSARR need to be established prior to calculating the discharge of the predicted event. If this event does not occur at the beginning of the month, new initial conditions must be created. To do this, the operator enters all daily rainfall amounts from the beginning of the month. SSARR calculates and saves new initial conditions leading into the significant event.

SIGNIFICANT EVENT (SSARR AND DWOPER)

The final step for determining flooding potential is simulation over the Black Creek drainage basin of the major rainfall event. The operator enters predicted and/or actual rainfall amounts. SSARR simulates 10 days of discharge in the Black Creek drainage basin. At the end of the SSARR discharge simulation, the model produces 10-day discharge hydrographs needed as input for the hydraulic model DWOPER.

DWOPER is run to calculate stages for the 10-day event. A comparison of the maximum calculated stage with a predetermined flood stage is printed for each cross section. Hydrographs (both stage and discharge) can be printed for any given cross section.

ADDITIONAL MODELING ANALYSES

Two very important factors determining severity of flooding in the Black Creek drainage basin are warning times and propagation of downstream effects. These two factors are discussed in the following sections.

WARNING TIME IN THE BASIN

Recorded data from three rain gages installed as part of this study were analyzed in an effort to learn something about warning times in the Black Creek drainage basin. These gages were at Clay Hill, Camp Blanding, and the dog pound near the town of Penney Farms (Table 1 and Figure 5). The data were of limited usefulness because only one significant event occurred; it was on 28 September 1989.

The one significant peak discharge in the period of record for these rain gages was recorded at the North Fork USGS stream gage on 29 September 1989. Hourly discharge data from the North Fork USGS stream gage show that the hydrograph started rising (from a baseflow of about 300 cfs) at about 7 A.M. on 28 September. The flow reached 3,000 cfs at about 6 A.M. the next morning. The hydrograph peaked at about 5 P.M. on 29 September at 3,640 cfs.

Rainfall varied throughout the basin on 28 September. The main rainfall during the event was 2.61 in. recorded at Clay Hill. Most of the rainfall occurred between 5 and 7 A.M. (1.8 in). The rain gage at Camp Blanding recorded 0.73 in. The rain gage at the Dog Pound recorded 1.6 in., with 1.06 in. occurring between 6 and 7 A.M.

If the main storm was assumed to be centered around 7 A.M. on 28 September and the discharge reached 3,000 cfs around 6 A.M. the next morning, the warning time for this particular event was about 23 hours. This would be within the range of lag times calculated for this basin of between 20 and 26 hours (USACE

1988). Of course, warning times will depend on where a storm is centered as well as on its extent and duration.

PROPAGATION OF DOWNSTREAM EFFECTS

DWOPER was run a number of times in order to analyze the propagation of downstream effects, such as tides. Three stage hydrographs of the 7 September 1988 event were compared (Figure 19). The baseline simulation used the mean water level at Jacksonville as the downstream boundary condition. This simulation was compared to two others: one adding 1 ft and one adding 2 ft uniformly to the original boundary condition. Stages at the North Fork and South Fork stream gages were unaffected by adding 1 ft or 2 ft to the baseline stage (Figure 19). The effects at the Middleburg stream gage varied according to the stage, but at the peak stage, the effect was roughly half of what it was at the downstream boundary. At the stream gage near Doctors Inlet, the peak stage increased by perhaps four-fifths of the 1 or 2 ft added to the downstream boundary.

Another concern with respect to propagation of downstream effects is the flooding effect on the South Fork as discharge from the North Fork increases, or vice versa. DWOPER was run three times to analyze this effect. All discharges are steady over the period of simulation. For three different simulations, discharge from the North Fork was maintained at 5,000 cfs and discharge from the South Fork was 1,000 cfs, 5,000 cfs, and 10,000 cfs. The downstream boundary condition (the stage of the St. Johns River) was held constant at 1 ft National Geodetic Vertical Datum (NGVD). Stages at the North Fork stream gage were not affected by increased discharges in the South Fork (Figure 20). Water surface levels at Middleburg increased by about 0.6 ft for a South Fork discharge of 5,000 cfs and 1.6 ft for a South Fork discharge of 10,000 cfs. (Middleburg is above the confluence of the two forks; therefore, the discharge there remains 5,000 cfs in all three cases.) The changes in stage at the South Fork and Doctors Inlet gages are due to the increase in discharge.

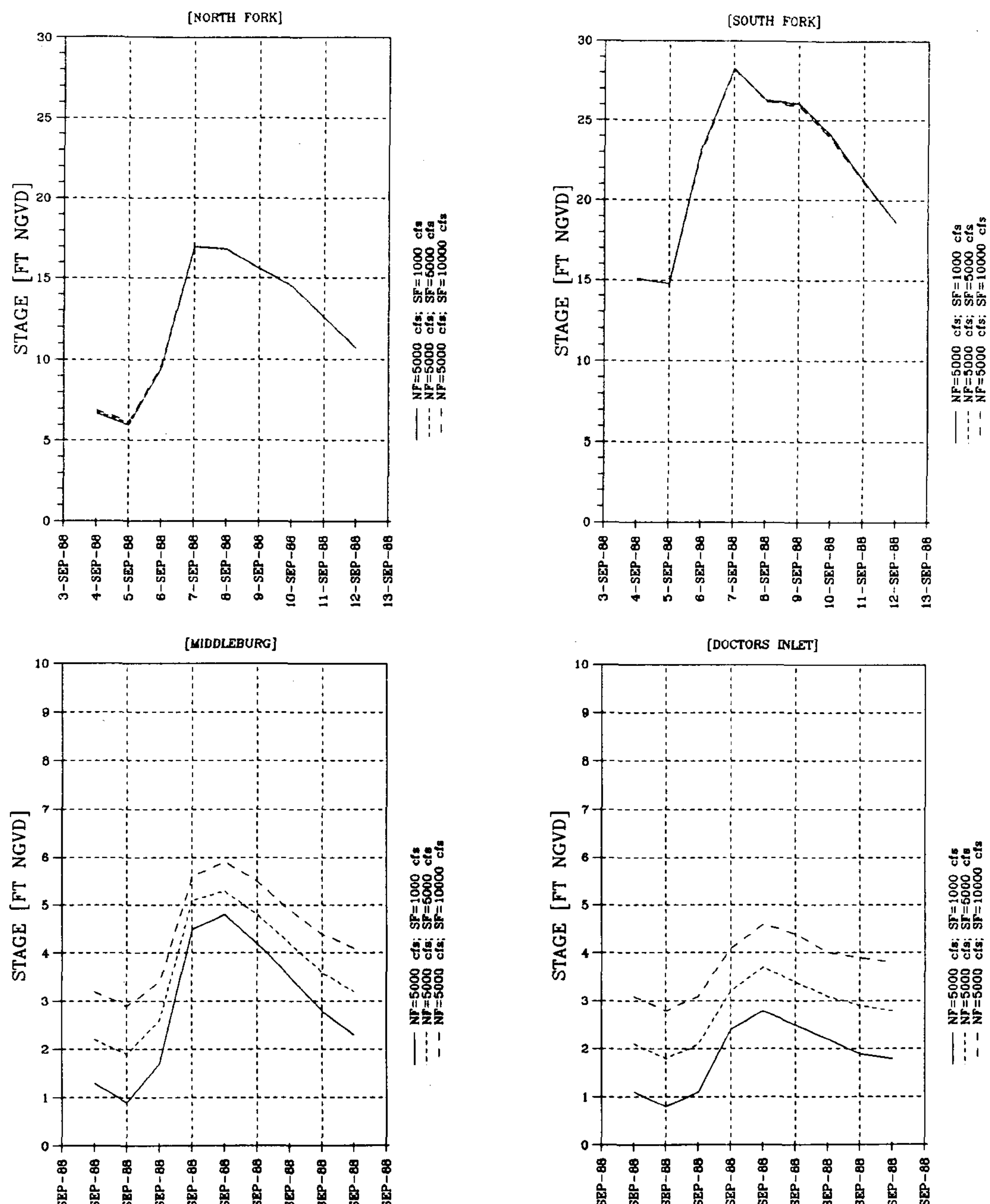

Figure 19. **Propagation of downstream effects: Downstream boundary condition.** *The level of the St. Johns River is increased first by 1 ft and then by 2 ft.*

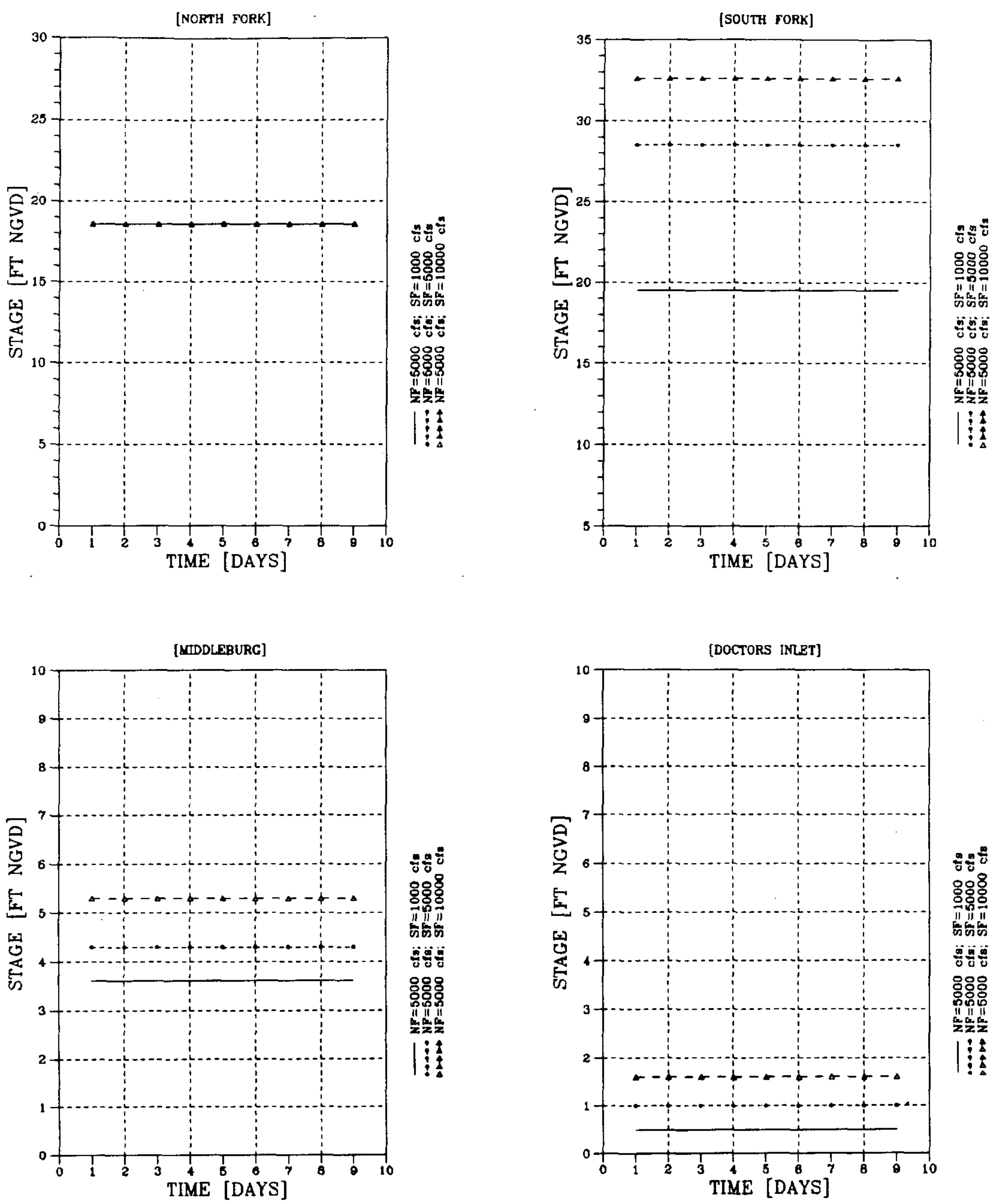

Figure 20. **Propagation of downstream effects: Tributary flow increase.** *The discharge on the North Fork is kept the same while discharge on the South Fork is increased.*

GAGE NETWORK ANALYSIS

The Black Creek versions of SSARR and DWOPER can be quite useful even in preliminary form. SSARR can be used to keep a running account of soil moisture and to evaluate flooding potential at any given time. Both models can be used to simulate events if rainfall forecasts are provided, for example, in the event of a nearby hurricane.

A number of different rainfall networks were used to develop this version of SSARR for the Black Creek drainage basin (Figures 3-5). If SSARR is to be used in its present form, data should be obtained on a regular basis from area fire towers as well as from the Cecil Field Weather Station. A new version of the Black Creek SSARR file can be created easily for a different rain gage network.

Although SSARR and DWOPER can simulate the flooding potential for Black Creek at a given time, the models cannot provide real-time warning of impending flooding. Three tasks need to be accomplished before these models can be used in real-time simulation and warning. First, a real-time flood warning system needs an automated network of rain and stream gages. Second, SSARR and DWOPER need to be converted to use hourly data (as opposed to daily data). Finally, the entire system must be assessed periodically and as necessary to ensure that these gages are accurate, sufficient in number, and in the right location. Only the first of these tasks will be discussed here.

RAIN GAGES

If SSARR and DWOPER models are to be used for real-time flood warning, an expanded and automated network of rain gages is needed in the Black Creek drainage basin. As an example, rainfall occurred around 23 March 1984, causing a significant flood event (4,500 cfs discharge) on the North Fork of Black Creek, but was not registered by the existing rain gages (p. 22).

In an automated network, an operator receives signals from a remote site and the models are run as the data are received and updated. SJRWMD's recommendation as to gage type and peripheral equipment is in a separate report (Osburn 1993). That report also includes cost estimates for an upgraded system.

Above the confluence of the North and South forks, each tributary drains about 200 mi^2. In the discussion that follows, each tributary will be treated separately (rather than as one basin of 400 mi^2) because each is capable of generating damaging floods.

A study has been made of the effect that an imperfect rainfall-gaging network has on the simulation of direct storm runoff (Linsley et al. 1975). Based on the results of the study, the average error expected in estimating discharge volume with two rain gages on a basin of 200 mi^2 is 20 percent. The average error expected with four rain gages is 10 percent. This study did not yield conclusive results about the error in estimating peak flood discharge. Larger errors are expected for estimating peak discharge than for estimating discharge volume; therefore, more rain gages would be needed to attain the same degree of accuracy.

The National Weather Service recommends the number of rain gages in a flood warning network be based on the formula

$$n = A^{.31}$$

where n is the number of rain gages and A is the area in square miles (USACE 1988). For a basin of 200 mi^2, the formula determines five rain gages.

Based on these considerations, an initial network of five rain gages each on the South Fork and North Fork subbasins is necessary. To enhance prediction of downstream conditions, one additional rain gage covering the basin below the confluence of the North and South forks is necessary. After the initial network is installed, data should be evaluated on a regular basis to determine the appropriateness of the rain gage network configuration. The final configuration would also depend on system performance.

STREAM GAGES

In a real-time system, stream gages can be valuable tools in forecasting flood levels. Based on a critical stage or on a critical rate of water level rise, a remote operator can determine if flooding is possible. Stream gage data can also be used to confirm rain gage data.

Because damaging floods can originate in either basin, stream gages should be installed on both the North and South forks. A stream gage downstream of the confluence of the North and South forks would be helpful in monitoring downstream conditions, such as tides, during an event.

SJRWMD RECOMMENDATION

In summary, SJRWMD recommends installing a system of 11 rain gages and 3 stream gages. The estimated cost of such a system is in a separate report (Osburn 1993).

Once the new gage network is installed, both SSARR and DWOPER need to be recalibrated to include hourly data rather than daily data. The data recorded by the new gages would be used in this recalibration.

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APPENDIX: USER'S MANUAL FOR PRELIMINARY BLACK CREEK FLOOD WARNING MODELS

This user's manual briefly discusses the input requirements for the preliminary Black Creek flood warning models, makes some operational recommendations, and then presents an example of the system. Figure A1 shows a schematic of the different steps involved in the operation of the preliminary Black Creek flood warning system.

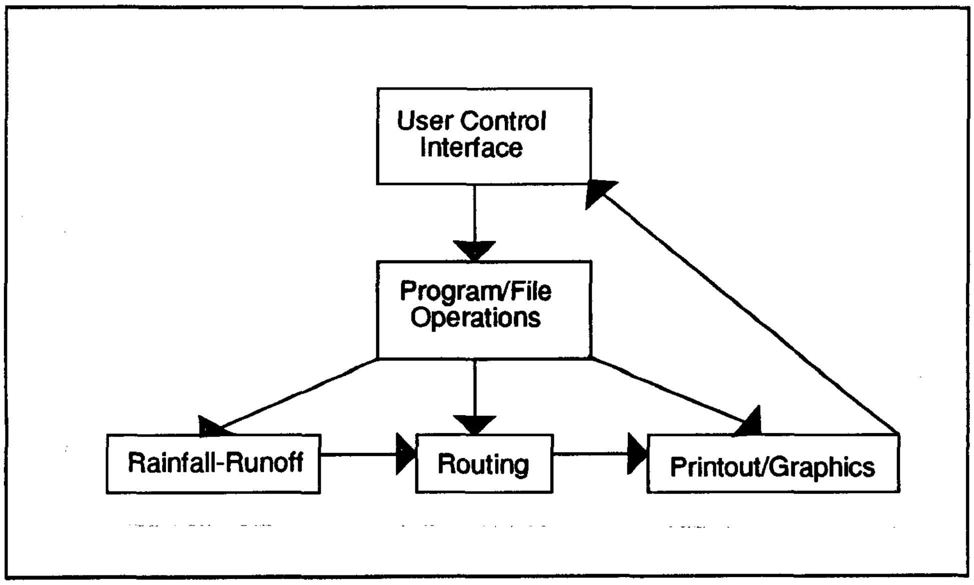

Figure A1. Schematic of the operation of the preliminary Black Creek flood warning system

INPUT REQUIREMENTS

Rainfall

The following rainfall data are needed to run the SSARR model: date of the rainfall, station at which rainfall occurred, and amount of rainfall in inches. The system prompts the operator to input daily rainfall amounts at each station. Four different station configurations are included in the current Black Creek version of SSARR.

Tides

The downstream boundary condition for DWOPER is the water surface level on the St. Johns River. The following tide data are needed to run the DWOPER model: date of water level and the water level itself in feet NGVD. The operator is given the choice of entering either a single level for an entire event or daily levels.

RECOMMENDATIONS FOR MODEL OPERATION

Following are several recommendations that will be helpful in running the Black Creek flood warning models.

Two-day Event

After development of the Black Creek SSARR model, it became apparent that significant rainfall (2 in. or more per day) should be concentrated into 1 day if the rainfall occurs over two consecutive days. Rainfall that is all part of one continuous weather system probably should be concentrated (see p. 25 and Figure 12).

Month(s) of Storm Event

After simulating a storm event, one or both months involved (if the event occurs over parts of 2 months) need to be re-run as monthly updates.

St. Johns River Stage

If actual or expected St. Johns River stages are not available, the stage can be set at 1 ft. Unless unusually high tides and/or water stages are predicted during the time of the storm, 1 ft should be adequate.

EXAMPLE RUN

This example of a typical model run consists of updating data monthly, creating initial conditions using rainfall leading up to a significant event, and simulating 10 days of discharge and stages for a significant event. The example run uses observed data from July to September 1968. Necessary computer input is printed in bold type and enclosed in square brackets (i.e., [ ]).

The opening menu (Figure A2) for operating the models is divided into four parts, based on the grouping of current rainfall stations (Figures 3-5). Each part contains three choices corresponding to the three tasks listed above (monthly update, partial monthly update, and 10-day event simulation).

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Menu #    1 of 1        BLACK CREEK: FLOOD WARNING MODELS

 A  ================================      M  ================================
 B  ******* CLAY,CAMP,DOGP *********      N  * SUNG,KEYS,PFRM,BLCK,LSHL,CFLD*
 C  MONTHLY UPDATE                        O  MONTHLY UPDATE
 D  PARTIAL MONTH [LEADING TO EVENT]      P  PARTIAL MONTH [BEFORE EVENT]
 E  10-DAY EVENT [WITH DWOPER]            Q  10-DAY EVENT [WITH DWOPER]
 F  ================================      R  ================================
 G  ================================      S  ================================
 H  ****** CLAY,CAMP,DOGP,CFLD *****      T  *** SUNG,KEYS,BLCK,LSHL,CFLD ***
 I  MONTHLY UPDATE                        U  MONTHLY UPDATE
 J  PARTIAL MONTH [BEFORE EVENT]          V  PARTIAL MONTH [BEFORE EVENT]
 K  10-DAY EVENT [WITH DWOPER]            W  10-DAY EVENT [WITH DWOPER]
 L  ================================      X  ================================

F1=NEXT MENU  F2=PREV MENU  F3=DOS  F4=DATE/TIME  F5=EDIT MENU  F6=GOTO MENU

    Rel: 1.2 8/87  Copyright 1987, ACR Software, Inc., All Rights Reserved

                  Date: 07-12-93       Time: 12:07:28
```

CLAY	=	Clay Hill	SUNG	=	Sun Garden
CAMP	=	Camp Blanding	KEYS	=	Keystone Heights
DOGP	=	Dog Pond	PFRM	=	Penney Farms
CFLD	=	Cecil Field	BLCK	=	Black Creek
LSHL	=	Louis Hill			

Figure A2. Screen printout: Opening menu

Monthly Updates

The first modeling scenario is updating rainfall data monthly.

Rainfall records for 1968 are available at the Cecil Field Weather Station (CFLD) and the fire towers at Sun Garden (SUNG), Keystone Heights (KEYS), Black Creek (BLCK), and Louis Hill (LSHL). This combination of gages corresponds to line "T" of the menu. The monthly update for that combination of gages corresponds to the menu choice at line "U".

Entering **[U]** on the computer key board will start the model for monthly updates. A statement appears on the screen indicating the month of the last update (Figure A3). In this example run, the last update was June 1968. The run will start with July 1968. The operator chooses a printed confirmation of the entered rainfall amounts, **[Y]**, or a listing on the screen, **[N]**. Then the operator is prompted to enter the month, **[7]**, and year, **[68]**, for the update.

The operator composes a rainfall file for each station, which is input to SSARR. This example begins with the Sun Garden rain gage. The model asks for the number of days in the month that had rainfall, **[11]** (Figure A4). The day of the month, **[5]**, and the rainfall for that day, **[1.7]**, are entered until all data are entered for that station. When rainfall data are entered for each station, the rainfall amounts are printed out, and the model asks for confirmation, **[Y/N]** (Figure A5). If an error is detected, responding **[N]** begins the process anew. Printouts for rain gages at Louis Hill, Cecil Field, Keystone Heights, and Black Creek for this example appear in Figures A6 and A7.

Then SSARR runs various commands. The system prints out the month-long hydrograph for the North Fork and South Fork USGS gage sites (Figures A8 and A9, respectively). The hydrograph for the North Fork includes the calculated discharge, or flow, at the North Fork USGS stream gage (indicated by the symbol "*"), and rainfall at the Louis Hill and Cecil Field rain gages (indicated by symbols "L" and "C"). The discharge axis runs from left to right and is labeled in increments of 1,000 cfs. The rainfall axis runs from right to left and is labeled in increments of 1 in. Alongside the date are the time (1200) and the numerical values for the discharge and the rainfall at the station. For example, on 20 July 1968, the discharge was 167.4 cfs, rainfall recorded at Louis Hill ("L") was 1.6 in., and rainfall recorded at Cecil Field ("C") was 0.3 in.

Finally, the flood warning system runs three SSARR simulations for the month following the updated month to assess the flooding potential in the basin, using basinwide, 1-day rainfall of 2, 4, and 6 in. In this example, around the beginning of August 1968, a basinwide rainfall of at least 4 in. would generate discharges greater than 3,000 cfs for both the North and South forks (Figures A10 and A11). This would signal the beginning of flooding in the Middleburg area along both forks. A rainfall of 6 in. would cause significant flooding.

The monthly update is complete. The model returns to the opening menu.

Precursor to Significant Event

The second modeling scenario is creating initial conditions using rainfall leading up to a significant event.

Rainfall records for 1968 were available at the Cecil Field Weather Station and the fire towers at Sun Garden, Keystone Heights, Black Creek, and Louis Hill. The menu choice for a partial month for that combination of gages is **[V]** (Figure A2).

Significant peak discharges were recorded at the North Fork and South Fork USGS stream gages on 30 August 1968. Most of the rainfall causing this event occurred between 26 August and 29 August. Thus, to provide initial conditions for simulation of the principal event, SSARR was run for the period between 1 and 26 August.

The model is run in the same way as for monthly updates (p. 56), using only data for the partial month. For this example run, printouts for the rain gages at Cecil Field, Louis Hill, Keystone Heights, Sun Garden, and Black Creek appear in Figures A12 and A13. The corresponding hydrographs at the North Fork and South Fork USGS stream gages appear in Figures A14 and A15.

The creation of initial conditions as a precursor to a significant event is complete. The model returns to the opening menu.

Significant Event

The third modeling scenario is simulating 10 days of discharge and stage levels for a significant rainfall event.

If the significant event occurs on the first of the month, the significant event scenario can be run using the previous monthly data as initial conditions data. If the significant event occurs after the first of the month, the model will be run to determine initial conditions as a precursor to a significant event. Rainfall records for 1968 were available at the Cecil Field Weather Station and the fire towers at Sun Garden, Keystone Heights, Black Creek, and Louis Hill. The menu choice for simulating 10 days of discharge for that combination of gages is **[W]** (Figure A2).

The significant rainfall event used in the sample run occurred from 26 August to 4 September 1968. The operator enters actual and/or predicted rainfall for the significant or potentially significant event (Figures A16 and A17).

In addition to rainfall data, the model requests daily tide stages for the St. Johns River. A choice is offered between entering values, **[Y]**, and using the default of sea level, **[N]** (Figure A18). A second choice is offered between single, **[S]**, or multiple, **[M]**, values. In the sample run, tide data are available, so multiple tide values (average daily stages) can be entered for the St. Johns River at Jacksonville.

At the end of the SSARR run, the model prints out the hydrographs for different locations around the basin (Figure A19). Using these SSARR hydrographs as input, DWOPER then determines stages along Black Creek. DWOPER compares maximum stages for 26 August through 4 September 1968 with predetermined flood stages (Table A1), producing a printout (Figure A20). This printout indicates whether the stage is above or below flood stage. This printout identifies the creek—North Fork (NF), South Fork (SF), or Black Creek (BC)—and the cross-section number. The cross-section number is the same as indicated on Figure 13; however, the coding varies. On Figure 13, the prefix for the river is first—N (North Fork), S (South Fork), and B (Black Creek), followed by the cross-section number. For example, cross-section 10 NF on Figure A20 is represented on Figure 13 as N10.

In this example run, at the confluence of the North and South forks, around cross-section 10 NF, the creek is predicted to rise 4.4 ft above flood stage.

The final step in simulating a significant event is examining individual cross sections at important locations along the creek. In this example run, the operator requests printouts for the North Fork USGS stream gage location at cross-section 1 NF (Figure 13), the Middleburg bridge at cross-section 7 NF, the South Fork USGS stream gage location at 1 SF, and the S.R. 218 bridge at 10 SF. The model prints out discharge and stage hydrographs for these selected cross sections (Figures A21 through A24).

The simulation of 10 days of discharge from a significant event is complete. The model returns to the opening menu.

```
MENU
 YOUR LAST UPDATE WAS: JUN 1968
Press any key to continue . . .

 DO YOU WANT CONFIRMATION OF PRECIPITATION ON THE PRINTER [Y/N]?
 OTHERWISE THE CONFIRMATION WILL BE ON THE SCREEN
N
   ENTER MODEL STARTING MONTH    [PLEASE USE NUMBERS  ]
7
   ENTER MODEL STARTING YEAR     [19__                ]
68


  STARTING PARAMETERS:

            MONTH   DAY  YEAR

             JUL     1   1968



IS THIS CORRECT? [Y/N]
Y
```

Figure A3. Screen printout: Starting model operation for monthly updates

```
ENTER RAINFALL AMOUNTS FOR SUN GARDEN
ENTER THE NUMBER OF DAYS WITH RAIN:
11
ENTER THE DAY OF THE MONTH
5
   RAIN FOR THE DAY:  5  JUL

1.7
ENTER THE DAY OF THE MONTH
6
   RAIN FOR THE DAY:  6  JUL

.3
ENTER THE DAY OF THE MONTH
7
   RAIN FOR THE DAY:  7  JUL

.3
ENTER THE DAY OF THE MONTH
8
   RAIN FOR THE DAY:  8  JUL

.5
ENTER THE DAY OF THE MONTH
9
   RAIN FOR THE DAY:  9  JUL

.3
ENTER THE DAY OF THE MONTH
10
   RAIN FOR THE DAY: 10  JUL

.5
ENTER THE DAY OF THE MONTH
11
   RAIN FOR THE DAY: 11  JUL

.3
ENTER THE DAY OF THE MONTH
12
   RAIN FOR THE DAY: 12  JUL

.2
ENTER THE DAY OF THE MONTH
19
   RAIN FOR THE DAY: 19  JUL

.2
ENTER THE DAY OF THE MONTH
20
   RAIN FOR THE DAY: 20  JUL

.4
ENTER THE DAY OF THE MONTH
27
   RAIN FOR THE DAY: 27  JUL

.8
```

Figure A4. **Screen printout: Entering rainfall data.** *This printout corresponds to Sun Garden data for July 1968.*

```
FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: SUN GARDEN

 1   2  JUL       .00     .00
 3   4  JUL       .00     .00
 5   6  JUL      1.70     .30
 7   8  JUL       .30     .50
 9  10  JUL       .30     .50
11  12  JUL       .30     .20
13  14  JUL       .00     .00
15  16  JUL       .00     .00
17  18  JUL       .00     .00
19  20  JUL       .20     .40
21  22  JUL       .00     .00
23  24  JUL       .00     .00
25  26  JUL       .00     .00
27  28  JUL       .80     .00
29  30  JUL       .00     .00
31  32  JUL       .00     .00

IS THIS CORRECT? [Y/N]
Y
```

The date in the first column corresponds to the rainfall in the fourth column. The date in the second column corresponds to data in the last column.

Figure A5. **Screen printout: Rainfall data summary.** *This printout corresponds to Sun Garden data for July 1968.*

FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: LOUIS HILL

1	2	JUL	.00	.30
3	4	JUL	.00	.30
5	6	JUL	.60	.40
7	8	JUL	.20	.50
9	10	JUL	.90	.80
11	12	JUL	.40	.80
13	14	JUL	.00	.00
15	16	JUL	.00	.00
17	18	JUL	.00	.30
19	20	JUL	.00	1.60
21	22	JUL	.10	.20
23	24	JUL	.00	.00
25	26	JUL	.80	.00
27	28	JUL	.00	.00
29	30	JUL	.00	.30
31	32	JUL	.40	.00

FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: CECIL FIELD

1	2	JUL	.00	.00
3	4	JUL	.00	.10
5	6	JUL	.90	.00
7	8	JUL	.20	.20
9	10	JUL	.20	.50
11	12	JUL	.10	.60
13	14	JUL	.00	.00
15	16	JUL	.00	.00
17	18	JUL	.80	.00
19	20	JUL	.00	.30
21	22	JUL	.00	.00
23	24	JUL	.00	.00
25	26	JUL	.60	.00
27	28	JUL	.00	.00
29	30	JUL	.00	.30
31	32	JUL	1.70	.00

Figure A6. **Screen printout: Rainfall summaries for Louis Hill and Cecil Field stations.** *These data correspond to July 1968.*

FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: BLACK CREEK

1	2	JUL	.00	.00
3	4	JUL	.00	.00
5	6	JUL	1.30	.20
7	8	JUL	.20	.40
9	10	JUL	.20	.50
11	12	JUL	.20	.40
13	14	JUL	.00	.00
15	16	JUL	.00	.00
17	18	JUL	.40	.00
19	20	JUL	.10	.40
21	22	JUL	.00	.00
23	24	JUL	.00	.00
25	26	JUL	.30	.00
27	28	JUL	.40	.00
29	30	JUL	.00	.20
31	32	JUL	.80	.00

FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: KEYSTONE HTS.

1	2	JUL	.00	.00
3	4	JUL	.10	.00
5	6	JUL	1.30	.20
7	8	JUL	.00	.40
9	10	JUL	.70	.40
11	12	JUL	.90	.00
13	14	JUL	.00	.00
15	16	JUL	1.40	.00
17	18	JUL	.10	.30
19	20	JUL	.00	1.50
21	22	JUL	.00	.00
23	24	JUL	.00	.00
25	26	JUL	.80	.00
27	28	JUL	.00	.00
29	30	JUL	.00	.20
31	32	JUL	.00	.00

Figure A7. **Screen printout: Rainfall summaries for Black Creek and Keystone Heights stations.** *These data correspond to July 1968.*

```
                                          PLOT      DESCRIPTION                               STATION
                                        CHARACTER                                              NAME   CONTROL

                                            *-COMPUTED FLOW AT NORTH FORK GAGE                 C004        Q
FLOW CFS                      0.     1000.     2000.     3000.     4000.     5000.     6000.     7000.     8000.     9000.    10000.
                                            L-PRECIPITATION                                    LSHL       3  100.
                                            C-PRECIPITATION                                    CFLD       3  100.
              *        L     10.00      9.00      8.00      7.00      6.00      5.00      4.00      3.00      2.00      1.00       0.
 1JUL68 1200     48.0       .0 *        .         .         .         .         .         .         .         .         .         L
 2JUL68 1200     45.7       .3 *        .         .         .         .         .         .         .         .         .      L  C
 3JUL68 1200     44.4       .0 *        .         .         .         .         .         .         .         .         .         L
 4JUL68 1200     51.1       .3 .*       .         .         .         .         .         .         .         .         .      L C.
 5JUL68 1200     99.2       .6 .*       .         .         .         .         .         .         .         .         .C  L     .
 6JUL68 1200    128.9       .4 .*       .         .         .         .         .         .         .         .         .     L   C
 7JUL68 1200    150.3       .2 . *      .         .         .         .         .         .         .         .         .       L .
 8JUL68 1200    151.2       .5 . *      .         .         .         .         .         .         .         .         .    L  C .
 9JUL68 1200    164.1       .9 . *      .         .         .         .         .         .         .         .         .L      C .
10JUL68 1200    212.6       .8 . *      .         .         .         .         .         .         .         .         . L  C    .
11JUL68 1200    246.1       .4 . *      .         .         .         .         .         .         .         .         .     L  C.
12JUL68 1200    295.0       .8 .  *     .         .         .         .         .         .         .         .         . L C     .
13JUL68 1200    268.3       .0 .  *     .         .         .         .         .         .         .         .         .         L
14JUL68 1200    219.7       .0 . *      .         .         .         .         .         .         .         .         .         L
15JUL68 1200    157.0       .0 . *      .         .         .         .         .         .         .         .         .         L
16JUL68 1200    103.6       .0 .*       .         .         .         .         .         .         .         .         .         L
17JUL68 1200     92.7       .0 .*       .         .         .         .         .         .         .         .         . C       L
18JUL68 1200     97.1       .3 .*       .         .         .         .         .         .         .         .         .      L  C
19JUL68 1200    104.2       .0 .*       .         .         .         .         .         .         .         .         .         L
20JUL68 1200    167.4      1.6 . *      .         .         .         .         .         .         .         .   L     .      C  .
21JUL68 1200    209.3       .1 . *      .         .         .         .         .         .         .         .         .        LC
22JUL68 1200    259.9       .2 .  *     .         .         .         .         .         .         .         .         .       L C
23JUL68 1200    218.4       .0 . *      .         .         .         .         .         .         .         .         .         L
24JUL68 1200    142.0       .0 .*       .         .         .         .         .         .         .         .         .         L
25JUL68 1200    143.7       .8 .*       .         .         .         .         .         .         .         .         . L C     .
26JUL68 1200    140.5       .0 .*       .         .         .         .         .         .         .         .         .         L
27JUL68 1200    142.9       .0 .*       .         .         .         .         .         .         .         .         .         L
28JUL68 1200    118.7       .0 .*       .         .         .         .         .         .         .         .         .         L
29JUL68 1200     85.1       .0 .*       .         .         .         .         .         .         .         .         .         L
30JUL68 1200     74.3       .3 .*       .         .         .         .         .         .         .         .         .      L  .
31JUL68 1200    164.2       .4 . *      .         .         .         .         .         .         .         . C       .     L   .
 1AUG68 1200    256.6       .0 .  *     .         .         .         .         .         .         .         .         .         L
```

Figure A8. **Printout: Hydrograph with rainfall data for the North Fork USGS stream gage location.** *This printout corresponds to July 1968.*

```
                                          PLOT     DESCRIPTION                              STATION
                                        CHARACTER                                           NAME   CONTROL

                                            *-COMPUTED FLOW AT SOUTH FORK GAGE              C001        Q
FLOW CFS                      0.     1000.     2000.     3000.     4000.     5000.     6000.     7000.     8000.     9000.    10000.
                                            G-PRECIPITATION                                 SUNG       3 100.
                                            K-PRECIPITATION                                 KEYS       3 100.
                                            B-PRECIPITATION                                 BLCK       3 100.
              *        G     10.00      9.00      8.00      7.00      6.00      5.00      4.00      3.00      2.00      1.00      0.
 1JUL68 1200     25.0       .0 *          .         .         .         .         .         .         .         .         .         G
 2JUL68 1200     23.0       .0 *          .         .         .         .         .         .         .         .         .         G
 3JUL68 1200     22.3       .0 *          .         .         .         .         .         .         .         .         .        KG
 4JUL68 1200     22.4       .0 *          .         .         .         .         .         .         .         .         .         G
 5JUL68 1200     95.9      1.7 .*         .         .         .         .         .         .         .         .  G   K  .         .
 6JUL68 1200    357.3       .3 .   *      .         .         .         .         .         .         .         .         .      GK .
 7JUL68 1200    344.7       .3 .  *       .         .         .         .         .         .         .         .         .      GB K
 8JUL68 1200    195.7       .5 . *        .         .         .         .         .         .         .         .         .    GK   .
 9JUL68 1200    167.3       .3 . *        .         .         .         .         .         .         .         .         .  K   GB .
10JUL68 1200    185.8       .5 . *        .         .         .         .         .         .         .         .         .    GK   .
11JUL68 1200    196.9       .3 . *        .         .         .         .         .         .         .         .         .K     GB .
12JUL68 1200    206.0       .2 . *        .         .         .         .         .         .         .         .         .     B G K
13JUL68 1200    150.7       .0 . *        .         .         .         .         .         .         .         .         .         G
14JUL68 1200     84.4       .0 .*         .         .         .         .         .         .         .         .         .         G
15JUL68 1200     83.7       .0 .*         .         .         .         .         .         .         .         .     K   .         G
16JUL68 1200    175.5       .0 . *        .         .         .         .         .         .         .         .         .         G
17JUL68 1200    153.9       .0 . *        .         .         .         .         .         .         .         .         .     B  KG
18JUL68 1200     83.3       .0 .*         .         .         .         .         .         .         .         .         .       K G
19JUL68 1200     62.3       .2 .*         .         .         .         .         .         .         .         .         .       GBK
20JUL68 1200     99.8       .4 .*         .         .         .         .         .         .         .         .    K    .     G   .
21JUL68 1200    246.4       .0 . *        .         .         .         .         .         .         .         .         .         G
22JUL68 1200    214.6       .0 . *        .         .         .         .         .         .         .         .         .         G
23JUL68 1200    103.7       .0 .*         .         .         .         .         .         .         .         .         .         G
24JUL68 1200     58.0       .0 .*         .         .         .         .         .         .         .         .         .         G
25JUL68 1200     56.0       .0 .*         .         .         .         .         .         .         .         .         . K    B  G
26JUL68 1200     91.5       .0 .*         .         .         .         .         .         .         .         .         .         G
27JUL68 1200     90.9       .8 .*         .         .         .         .         .         .         .         .         . G   B   K
28JUL68 1200     96.9       .0 .*         .         .         .         .         .         .         .         .         .         G
29JUL68 1200     76.9       .0 .*         .         .         .         .         .         .         .         .         .         G
30JUL68 1200     47.0       .0 *          .         .         .         .         .         .         .         .         .       K G
31JUL68 1200     37.9       .0 *          .         .         .         .         .         .         .         .         . B       G
 1AUG68 1200     32.2       .0 *          .         .         .         .         .         .         .         .         .         G
```

Figure A9. Printout: Hydrograph with rainfall data for the South Fork USGS stream gage location. *This printout corresponds to July 1968.*

```
                                    PLOT      DESCRIPTION                                  STATION
                                  CHARACTER                                                NAME    CONTROL

                                    *-COMPUTED FLOW AT NORTH FORK GAGE                     C004        Q
FLOW CFS                  0.        1000.     2000.     3000.     4000.     5000.     6000.     7000.     8000.     9000.     10000.
                                    L-PRECIPITATION                                        LSHL      3  100.
                                    C-PRECIPITATION                                        CFLD      3  100.
          *        L      10.00     9.00      8.00      7.00      6.00      5.00      4.00      3.00      2.00      1.00      0.
1AUG68  1200   257.0   .0 .  *      .         .         .         .         .         .         .         .         .         L
2AUG68  1200   320.7   .0 .  *      .         .         .         .         .         .         .         .         .         L
3AUG68  1200  1761.7  4.0 .         .       * .         .         .         .         L         .         .         .         .
4AUG68  1200  2714.3   .0 .         .         .      *  .         .         .         .         .         .         .         L
5AUG68  1200  2931.6   .0 .         .         .        *.         .         .         .         .         .         .         L
6AUG68  1200  2041.3   .0 .         .         *         .         .         .         .         .         .         .         L
7AUG68  1200   984.1   .0 .         *         .         .         .         .         .         .         .         .         L
8AUG68  1200   510.2   .0 .    *    .         .         .         .         .         .         .         .         .         L
9AUG68  1200   324.2   .0 .  *      .         .         .         .         .         .         .         .         .         L
10AUG68 1200   238.6   .0 . *       .         .         .         .         .         .         .         .         .         L
11AUG68 1200   183.7   .0 . *       .         .         .         .         .         .         .         .         .         L
12AUG68 1200   141.5   .0 .*        .         .         .         .         .         .         .         .         .         L
13AUG68 1200   108.6   .0 .*        .         .         .         .         .         .         .         .         .         L
14AUG68 1200    84.1   .0 .*        .         .         .         .         .         .         .         .         .         L
15AUG68 1200    66.9   .0 .*        .         .         .         .         .         .         .         .         .         L


                                    PLOT      DESCRIPTION                                  STATION
                                  CHARACTER                                                NAME    CONTROL

                                    *-COMPUTED FLOW AT NORTH FORK GAGE                     C004        Q
FLOW CFS                  0.        1000.     2000.     3000.     4000.     5000.     6000.     7000.     8000.     9000.     10000.
                                    L-PRECIPITATION                                        LSHL      3  100.
                                    C-PRECIPITATION                                        CFLD      3  100.
          *        L      10.00     9.00      8.00      7.00      6.00      5.00      4.00      3.00      2.00      1.00      0.
1AUG68  1200   257.0   .0 .  *      .         .         .         .         .         .         .         .         .         L
2AUG68  1200   320.7   .0 .  *      .         .         .         .         .         .         .         .         .         L
3AUG68  1200  3270.8  6.0 .         .         .         .  *      L         .         .         .         .         .         .
4AUG68  1200  5290.7   .0 .         .         .         .         .         .  *      .         .         .         .         L
5AUG68  1200  5623.2   .0 .         .         .         .         .         .     *   .         .         .         .         L
6AUG68  1200  3796.0   .0 .         .         .         .       * .         .         .         .         .         .         L
7AUG68  1200  1798.6   .0 .         .       * .         .         .         .         .         .         .         .         L
8AUG68  1200   884.1   .0 .        *.         .         .         .         .         .         .         .         .         L
9AUG68  1200   555.7   .0 .     *   .         .         .         .         .         .         .         .         .         L
10AUG68 1200   403.6   .0 .   *     .         .         .         .         .         .         .         .         .         L
11AUG68 1200   305.7   .0 .  *      .         .         .         .         .         .         .         .         .         L
12AUG68 1200   229.5   .0 . *       .         .         .         .         .         .         .         .         .         L
13AUG68 1200   169.8   .0 . *       .         .         .         .         .         .         .         .         .         L
14AUG68 1200   125.0   .0 .*        .         .         .         .         .         .         .         .         .         L
15AUG68 1200    93.3   .0 .*        .         .         .         .         .         .         .         .         .         L
```

Figure A10. **Printout: Hydrographs with rainfall data for hypothetical storms at the North Fork USGS stream gage location.** *These hydrographs correspond to conditions at the beginning of August 1968.*

```
                                        PLOT      DESCRIPTION                                   STATION
                                     CHARACTER                                                   NAME    CONTROL

                                          *-COMPUTED FLOW AT SOUTH FORK GAGE                     C001          Q
FLOW CFS                     0.      1000.     2000.     3000.     4000.     5000.     6000.     7000.     8000.     9000.    10000.
                                          G-PRECIPITATION                                        SUNG      3  100.
                                          K-PRECIPITATION                                        KEYS      3  100.
                                          B-PRECIPITATION                                        BLCK      3  100.
                    *       G      10.00      9.00      8.00      7.00      6.00      5.00      4.00      3.00      2.00      1.00      0.
 1AUG68 1200     33.0              .0 *         .         .         .         .         .         .         .         .         .         G
 2AUG68 1200     26.8              .0 *         .         .         .         .         .         .         .         .         .         G
 3AUG68 1200    696.8             4.0 .      *  .         .         .         .         .         G         .    .    .         .         .
 4AUG68 1200   3026.0              .0 .         .         .         *         .         .         .         .         .         .         G
 5AUG68 1200   2702.9              .0 .         .         .      *  .         .         .         .         .         .         .         G
 6AUG68 1200   1156.0              .0 .         . *       .         .         .       . .         .         .         .         .         G
 7AUG68 1200    528.9              .0 .     *   .         .         .         .         .         .         .         .         .         G
 8AUG68 1200    343.4              .0 .   *     .         .         .         .         .         .         .         .         .         G
 9AUG68 1200    245.3              .0 .  *      .         .         .         .         .         .         .         .         .         G
10AUG68 1200    168.1              .0 .  *      .         .         .         .         .         .         .         .         .         G
11AUG68 1200    110.0              .0 .*        .         .         .         .         .         .         .         .         .         G
12AUG68 1200     71.1              .0 .*        .         .         .         .         .         .         .         .         .         G
13AUG68 1200     47.3              .0 *         .         .         .         .         .         .         .         .         .         G
14AUG68 1200     33.7              .0 *         .         .         .         .         .         .         .         .         .         G
15AUG68 1200     26.4              .0 *         .         .         .         .         .         .         .         .         .         G


                                        PLOT      DESCRIPTION                                   STATION
                                     CHARACTER                                                   NAME    CONTROL

                                          *-COMPUTED FLOW AT SOUTH FORK GAGE                     C001          Q
FLOW CFS                     0.      1000.     2000.     3000.     4000.     5000.     6000.     7000.     8000.     9000.    10000.
                                          G-PRECIPITATION                                        SUNG      3  100.
                                          K-PRECIPITATION                                        KEYS      3  100.
                                          B-PRECIPITATION                                        BLCK      3  100.
                    *       G      10.00      9.00      8.00      7.00      6.00      5.00      4.00      3.00      2.00      1.00      0.
 1AUG68 1200     33.0              .0 *         .         .         .         .         .         .         .         .         .         G
 2AUG68 1200     26.8              .0 *         .         .         .         .         .         .         .         .         .         G
 3AUG68 1200   1373.7             6.0 .         .  *      .         .         G         .         .         .    .    .         .         .
 4AUG68 1200   6046.5              .0 .         .         .         .         .         .         *         .         .         .         G
 5AUG68 1200   5399.7              .0 .         .         .         .         .         .    *    .         .         .         .         G
 6AUG68 1200   2298.3              .0 .         .       * .         .         .         .         .         .         .         .         G
 7AUG68 1200   1041.2              .0 .         *         .         .         .         .         .         .         .         .         G
 8AUG68 1200    669.3              .0 .      *  .         .         .         .         .         .         .         .         .         G
 9AUG68 1200    472.9              .0 .    *    .         .         .         .         .         .         .         .         .         G
10AUG68 1200    318.0              .0 .  *      .         .         .         .         .         .         .         .         .         G
11AUG68 1200    201.6              .0 . *       .         .         .         .         .         .         .         .         .         G
12AUG68 1200    123.6              .0 .*        .         .         .         .         .         .         .         .         .         G
13AUG68 1200     75.8              .0 .*        .         .         .         .         .         .         .         .         .         G
14AUG68 1200     48.6              .0 *         .         .         .         .         .         .         .         .         .         G
15AUG68 1200     33.9              .0 *         .         .         .         .         .         .         .         .         .         G
```

Figure A11. **Printout: Hydrographs with rainfall data for hypothetical storms at the South Fork USGS stream gage location.** *These hydrographs correspond to conditions at the beginning of August 1968.*

```
FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: CECIL FIELD


 1   2  AUG       .00     .00
 3   4  AUG       .00    1.50
 5   6  AUG       .00     .00
 7   8  AUG       .00     .00
 9  10  AUG       .00     .00
11  12  AUG       .10     .10
13  14  AUG       .00     .20
15  16  AUG      1.30     .60
17  18  AUG       .00     .50
19  20  AUG       .00     .00
21  22  AUG       .00     .00
23  24  AUG       .00     .00
25  26  AUG       .00     .00
FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: LOUIS HILL


 1   2  AUG       .40     .30
 3   4  AUG       .00    2.10
 5   6  AUG      3.10     .00
 7   8  AUG       .00     .00
 9  10  AUG       .00     .00
11  12  AUG      2.20    1.50
13  14  AUG       .00     .00
15  16  AUG       .30     .10
17  18  AUG       .90    1.60
19  20  AUG       .00     .00
21  22  AUG       .00     .00
23  24  AUG       .00     .00
25  26  AUG       .00     .00

FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: KEYSTONE HTS.


 1   2  AUG       .00     .00
 3   4  AUG       .00    1.50
 5   6  AUG       .60     .00
 7   8  AUG       .00     .00
 9  10  AUG       .00     .20
11  12  AUG       .20     .00
13  14  AUG       .40     .00
15  16  AUG       .50     .00
17  18  AUG       .40     .40
19  20  AUG       .10     .00
21  22  AUG       .00     .00
23  24  AUG       .00     .00
25  26  AUG       .00     .00
```

Figure A12. Screen printout: Rainfall summaries for Cecil Field, Louis Hill, and Keystone Heights stations for the part of the month leading to the significant event. *These data correspond to 1 through 26 August 1968.*

FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: SUN GARDEN

1	2	AUG	.00	1.40
3	4	AUG	.20	.00
5	6	AUG	.00	.00
7	8	AUG	.00	.00
9	10	AUG	.00	.00
11	12	AUG	.60	.00
13	14	AUG	.70	.00
15	16	AUG	2.00	.00
17	18	AUG	1.00	.50
19	20	AUG	.10	.00
21	22	AUG	.00	.00
23	24	AUG	.00	.00
25	26	AUG	.00	.00

FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: BLACK CREEK

1	2	AUG	.00	.00
3	4	AUG	.00	1.40
5	6	AUG	.10	.00
7	8	AUG	.00	.00
9	10	AUG	.00	.00
11	12	AUG	.40	.00
13	14	AUG	.40	.10
15	16	AUG	1.60	.30
17	18	AUG	.50	.50
19	20	AUG	.00	.00
21	22	AUG	.00	.00
23	24	AUG	.00	.00
25	26	AUG	.00	.00

Figure A13. Screen printout: Rainfall summaries for Sun Garden and Black Creek stations for the part of the month leading to the significant event. *These data correspond to 1 through 26 August 1968.*

```
                                          PLOT     DESCRIPTION                             STATION
                                        CHARACTER                                           NAME  CONTROL

                                            *-COMPUTED FLOW AT NORTH FORK GAGE              C004        Q
FLOW CFS                      0.     1000.     2000.     3000.     4000.     5000.     6000.     7000.     8000.     9000.    10000.
                                            L-PRECIPITATION                                 LSHL      3  100.
                                            C-PRECIPITATION                                 CFLD      3  100.
              *        L     10.00      9.00      8.00      7.00      6.00      5.00      4.00      3.00     2.00      1.00      0.
 1AUG68 1200    257.0       .4 .  *      .         .         .         .         .         .         .         .         .     L  C
 2AUG68 1200    325.4       .3 .  *      .         .         .         .         .         .         .         .         .      L C
 3AUG68 1200    257.9       .0 .  *      .         .         .         .         .         .         .         .         .        L
 4AUG68 1200    472.3      2.1 .    *    .         .         .         .         .         .         .        L.    C    .        .
 5AUG68 1200   1010.5      3.1 .         *         .         .         .         .         .        L.         .         .        C
 6AUG68 1200   1568.8       .0 .         .     *   .         .         .         .         .         .         .         .        L
 7AUG68 1200   1606.2       .0 .         .     *   .         .         .         .         .         .         .         .        L
 8AUG68 1200    988.2       .0 .         *         .         .         .         .         .         .         .         .        L
 9AUG68 1200    452.0       .0 .    *    .         .         .         .         .         .         .         .         .        L
10AUG68 1200    254.8       .0 .  *      .         .         .         .         .         .         .         .         .        L
11AUG68 1200    328.6      2.2 .  *      .         .         .         .         .         .       L .         .       C.
12AUG68 1200    561.5      1.5 .     *   .         .         .         .         .         .         .    L    .       C.
13AUG68 1200    799.0       .0 .       * .         .         .         .         .         .         .         .        L
14AUG68 1200    710.7       .0 .      *  .         .         .         .         .         .         .         .      C L
15AUG68 1200    495.2       .3 .    *    .         .         .         .         .         .         .      C  .     L  .
16AUG68 1200    380.3       .1 .   *     .         .         .         .         .         .         .         .   C   L.
17AUG68 1200    380.0       .9 .   *     .         .         .         .         .         .         .         .L       C
18AUG68 1200    466.0      1.6 .    *    .         .         .         .         .         .         .   L     .   C    .
19AUG68 1200    498.8       .0 .    *    .         .         .         .         .         .         .         .        L
20AUG68 1200    489.3       .0 .    *    .         .         .         .         .         .         .         .        L
21AUG68 1200    346.6       .0 .  *      .         .         .         .         .         .         .         .         .        L
22AUG68 1200    201.0       .0 . *       .         .         .         .         .         .         .         .         .        L
23AUG68 1200    126.8       .0 .*        .         .         .         .         .         .         .         .         .        L
24AUG68 1200     90.8       .0 .*        .         .         .         .         .         .         .         .         .        L
25AUG68 1200     71.2       .0 .*        .         .         .         .         .         .         .         .         .        L
26AUG68 1200     58.9       .0 .*        .         .         .         .         .         .         .         .         .        L
```

Figure A14. Printout: Hydrograph with rainfall data for the North Fork USGS stream gage location. *This hydrograph corresponds to the simulation from 1 through 26 August 1968.*

```
                                           PLOT     DESCRIPTION                             STATION
                                        CHARACTER                                            NAME   CONTROL

                                            *-COMPUTED FLOW AT SOUTH FORK GAGE               C001        Q
FLOW CFS                       0.     1000.     2000.     3000.     4000.     5000.     6000.     7000.     8000.     9000.    10000.
                                            G-PRECIPITATION                                  SUNG      3  100.
                                            K-PRECIPITATION                                  KEYS      3  100.
                                            B-PRECIPITATION                                  BLCK      3  100.
              *        G      10.00      9.00      8.00      7.00      6.00      5.00      4.00      3.00      2.00      1.00      0.
 1AUG68 1200     33.0        .0 *         .         .         .         .         .         .         .         .         .         G
 2AUG68 1200     57.8       1.4 .*        .         .         .         .         .         .         .         .     G   .         K
 3AUG68 1200    163.8        .2 . *       .         .         .         .         .         .         .         .         .       G K
 4AUG68 1200    189.6        .0 . *       .         .         .         .         .         .         .         .    KB   .         G
 5AUG68 1200    253.9        .0 .  *      .         .         .         .         .         .         .         .         .   K    BG
 6AUG68 1200    237.7        .0 . *       .         .         .         .         .         .         .         .         .         G
 7AUG68 1200    137.8        .0 .*        .         .         .         .         .         .         .         .         .         G
 8AUG68 1200     75.2        .0 .*        .         .         .         .         .         .         .         .         .         G
 9AUG68 1200     51.8        .0 .*        .         .         .         .         .         .         .         .         .         G
10AUG68 1200     42.0        .0 *         .         .         .         .         .         .         .         .         .       K G
11AUG68 1200     47.9        .6 *         .         .         .         .         .         .         .         .         .   G B K .
12AUG68 1200     73.4        .0 .*        .         .         .         .         .         .         .         .         .         G
13AUG68 1200     77.2        .7 .*        .         .         .         .         .         .         .         .         .  G  K   .
14AUG68 1200    103.6        .0 .*        .         .         .         .         .         .         .         .         .        BG
15AUG68 1200    172.3       2.0 . *       .         .         .         .         .         .         .         G   B     .    K    .
16AUG68 1200    432.4        .0 .   *     .         .         .         .         .         .         .         .         .      B  G
17AUG68 1200    406.4       1.0 .   *     .         .         .         .         .         .         .         .         G    BK   .
18AUG68 1200    323.2        .5 .  *      .         .         .         .         .         .         .         .         .    GK   .
19AUG68 1200    273.8        .1 .  *      .         .         .         .         .         .         .         .         .        GB
20AUG68 1200    174.4        .0 . *       .         .         .         .         .         .         .         .         .         G
21AUG68 1200    100.2        .0 .*        .         .         .         .         .         .         .         .         .         G
22AUG68 1200     66.1        .0 .*        .         .         .         .         .         .         .         .         .         G
23AUG68 1200     49.0        .0 *         .         .         .         .         .         .         .         .         .         G
24AUG68 1200     38.0        .0 *         .         .         .         .         .         .         .         .         .         G
25AUG68 1200     30.5        .0 *         .         .         .         .         .         .         .         .         .         G
26AUG68 1200     25.7        .0 *         .         .         .         .         .         .         .         .         .         G
```

Figure A15. **Printout: Hydrograph with rainfall data for the South Fork USGS stream gage location.** *This hydrograph corresponds to the simulation from 1 through 26 August 1968.*

```
STARTING PARAMETERS:

            MONTH DAY  YEAR

  MODEL      AUG       26 1968

 FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: SUN GARDEN


26  AUG        .00
27  AUG       2.20
28  AUG       2.00
29  AUG       3.20
30  AUG        .70
31  AUG        .50
 1  SEP        .00
 2  SEP        .00
 3  SEP        .00
 4  SEP        .00

 FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: KEYSTONE HTS.


26  AUG        .00
27  AUG       5.00
28  AUG       1.60
29  AUG       2.20
30  AUG       1.70
31  AUG        .60
 1  SEP        .00
 2  SEP        .00
 3  SEP        .00
 4  SEP        .00

 FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: LOUIS HILL


26  AUG        .20
27  AUG       2.40
28  AUG       3.70
29  AUG       3.80
30  AUG       2.30
31  AUG        .60
 1  SEP        .00
 2  SEP        .00
 3  SEP        .00
 4  SEP        .00
```

Figure A16. **Screen printout: Rainfall entered for a significant event at Sun Garden, Keystone Heights, and Louis Hill.** *These data correspond to 26 August through 4 September 1968.*

FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: CECIL FIELD

26	AUG	.00
27	AUG	.50
28	AUG	5.00
29	AUG	4.40
30	AUG	1.80
31	AUG	.60
1	SEP	.00
2	SEP	.00
3	SEP	.00
4	SEP	.00

FOLLOWING ARE THE RAINFALL AMOUNTS ENTERED FOR: BLACK CREEK

26	AUG	.00
27	AUG	1.40
28	AUG	3.50
29	AUG	3.80
30	AUG	1.20
31	AUG	.60
1	SEP	.00
2	SEP	.00
3	SEP	.00
4	SEP	.00

Figure A17. **Screen printout: Rainfall entered for a significant event at Cecil Field and Black Creek.** *These data correspond to 26 August through 4 September 1968.*

```
DO YOU WANT TO ENTER TIDES?  OTHERWISE THE TIDES WILL BE=0. [SEA LEVEL]. [Y/N]
Y
DO YOU WANT TO ENTER SINGLE OR MULTIPLE TIDES? [S/M]
M
TIDES FOR 26  AUG:

REMEMBER: [RETURN]=0.

PLEASE ENTER A ZERO TIDE (SEA LEVEL) AS .01

ANY NON-ENTRY WILL BE INTERPOLATED


   TIDE FOR THE DAY: 26  AUG
         ENTER: (1) NO
                (2) YES
                (3) NO MORE TIDES FOR MODELED PERIOD
2
   TIDE FOR DAY 26   [PLEASE INCLUDE DECIMAL POINT, 0=[RETURN]]
.6
TIDES FOR 27  AUG:

REMEMBER: [RETURN]=0.

PLEASE ENTER A ZERO TIDE (SEA LEVEL) AS .01

ANY NON-ENTRY WILL BE INTERPOLATED


   TIDE FOR THE DAY: 27  AUG
         ENTER: (1) NO
                (2) YES
                (3) NO MORE TIDES FOR MODELED PERIOD
2
   TIDE FOR DAY 27   [PLEASE INCLUDE DECIMAL POINT, 0=[RETURN]]
1.3
TIDES FOR 28  AUG:

REMEMBER: [RETURN]=0.

PLEASE ENTER A ZERO TIDE (SEA LEVEL) AS .01

ANY NON-ENTRY WILL BE INTERPOLATED


   TIDE FOR THE DAY: 28  AUG
         ENTER: (1) NO
                (2) YES
                (3) NO MORE TIDES FOR MODELED PERIOD
2
   TIDE FOR DAY 28   [PLEASE INCLUDE DECIMAL POINT, 0=[RETURN]]
2.2
  REMEMBER: [RETURN]=0.

  PLEASE ENTER A ZERO TIDE (SEA LEVEL) AS .01

  ANY NON-ENTRY WILL BE INTERPOLATED
```

Figure A18. **Screen printout: Entering daily tides.** *These data correspond to daily average levels on the St. Johns River at Jacksonville, between 26 August and 4 September 1968.*

```
   TIDE FOR THE DAY: 29  AUG
         ENTER: (1) NO
                (2) YES
                (3) NO MORE TIDES FOR MODELED PERIOD
2
   TIDE FOR DAY 29   [PLEASE INCLUDE DECIMAL POINT, 0=[RETURN]]
2.9
TIDES FOR 30  AUG:

REMEMBER: [RETURN]=0.

PLEASE ENTER A ZERO TIDE (SEA LEVEL) AS .01

ANY NON-ENTRY WILL BE INTERPOLATED


   TIDE FOR THE DAY: 30  AUG
         ENTER: (1) NO
                (2) YES
                (3) NO MORE TIDES FOR MODELED PERIOD
2
   TIDE FOR DAY 30   [PLEASE INCLUDE DECIMAL POINT, 0=[RETURN]]
3.4
TIDES FOR 31  AUG:

REMEMBER: [RETURN]=0.

PLEASE ENTER A ZERO TIDE (SEA LEVEL) AS .01

ANY NON-ENTRY WILL BE INTERPOLATED


   TIDE FOR THE DAY: 31  AUG
         ENTER: (1) NO
                (2) YES
                (3) NO MORE TIDES FOR MODELED PERIOD
2
   TIDE FOR DAY 31   [PLEASE INCLUDE DECIMAL POINT, 0=[RETURN]]
2.8
TIDES FOR  1  SEP:

REMEMBER: [RETURN]=0.

PLEASE ENTER A ZERO TIDE (SEA LEVEL) AS .01

ANY NON-ENTRY WILL BE INTERPOLATED


   TIDE FOR THE DAY:  1  SEP
         ENTER: (1) NO
                (2) YES
                (3) NO MORE TIDES FOR MODELED PERIOD
2
   TIDE FOR DAY  1   [PLEASE INCLUDE DECIMAL POINT, 0=[RETURN]]
2.4
TIDES FOR  2  SEP:

REMEMBER: [RETURN]=0.

PLEASE ENTER A ZERO TIDE (SEA LEVEL) AS .01

ANY NON-ENTRY WILL BE INTERPOLATED
```

Figure A18—*Continued*

```
    TIDE FOR THE DAY:  2  SEP
          ENTER: (1) NO
                 (2) YES
                 (3) NO MORE TIDES FOR MODELED PERIOD
2
    TIDE FOR DAY  2   [PLEASE INCLUDE DECIMAL POINT, 0=[RETURN]]
2.

     TIDES FOR  3  SEP:

     REMEMBER: [RETURN]=0.

     PLEASE ENTER A ZERO TIDE (SEA LEVEL) AS .01

     ANY NON-ENTRY WILL BE INTERPOLATED


       TIDE FOR THE DAY:  3  SEP
             ENTER: (1) NO
                    (2) YES
                    (3) NO MORE TIDES FOR MODELED PERIOD .
    2
       TIDE FOR DAY  3   [PLEASE INCLUDE DECIMAL POINT, 0=[RETURN]]
    1.9
    TIDES FOR  4  SEP:

    REMEMBER: [RETURN]=0.

    PLEASE ENTER A ZERO TIDE (SEA LEVEL) AS .01

    ANY NON-ENTRY WILL BE INTERPOLATED


       TIDE FOR THE DAY:  4  SEP
             ENTER: (1) NO
                    (2) YES
                    (3) NO MORE TIDES FOR MODELED PERIOD
    2
       TIDE FOR DAY  4   [PLEASE INCLUDE DECIMAL POINT, 0=[RETURN]]
    1.8


       FOLLOWING ARE THE TIDE LEVELS ENTERED FOR: ST JOHNS RIVER


      26  AUG       .60
      27  AUG      1.30
      28  AUG      2.20
      29  AUG      2.90
      30  AUG      3.40
      31  AUG      2.80
       1  SEP      2.40
       2  SEP      2.00
       3  SEP      1.90
       4  SEP      1.80


    IS THIS CORRECT? [Y/N]
    Y
```

Figure A18—*Continued*

```
HYDROGRAPH C001,
     26.      607.     2830.     3690.     3860.     2990.     1670.      891.
    536.      353.        0.        0.        0.        0.        0.        0.

HYDROGRAPH C004,
     59.      253.     2460.     6100.     8100.     7380.     4920.     2630.
   1370.      831.        0.        0.        0.        0.        0.        0.

HYDROGRAPH S004,
     23.       36.      220.      889.     1870.     2250.     1760.     1050.
    590.      375.        0.        0.        0.        0.        0.        0.

HYDROGRAPH N006,
      4.       96.      707.      900.      528.      187.       53.       15.
      6.        4.        0.        0.        0.        0.        0.        0.

HYDROGRAPH C005,
     11.       67.      718.     2040.     2430.     1710.      851.      427.
    259.      175.        0.        0.        0.        0.        0.        0.

HYDROGRAPH C006,
     10.      236.     1570.     2470.     1090.      378.      112.       33.
     14.       10.        0.        0.        0.        0.        0.        0.
```

Figure A19. Screen printout: SSARR hydrograph data as input to DWOPER. *These hydrographs correspond to the 26 August through 4 September 1968 event.*

Table A1. Flood stages on Black Creek

Cross-section Number	Flood Stage (feet NGVD)*	Location
1 NF	20	North Fork USGS gage
2 NF	20	
3 NF	20	
4 NF	20	
5 NF	9	
6 NF	5	
7 NF	4	North Fork USGS gage, Middleburg
8 NF	3	
9 NF	3	
10 NF	3	Confluence of the North and South forks
11 BC	5	
12 BC	5	
13 BC	5	
14 BC	5	
15 BC	5	
16 BC	3	
17 BC	5	Black Creek USGS gage
18 BC	3	
19 BC	4	
20 BC	5	
21 BC	5	
22 BC	5	
23 BC	5	
24 BC	5	
25 BC	5	Mouth of the creek at the St. Johns River

Table A1—*Continued*

Cross-section Number	Flood Stage (feet NGVD)*	Location
1 SF	21	South Fork USGS gage
2 SF	19	
3 SF	19	
4 SF	15	
5 SF	15	
6 SF	14	
7 SF	14	
8 SF	9	
9 SF	7	
10 SF	10	State Road 218 bridge
11 SF	10	
12 SF	6	
13 SF	3	Confluence of the North and South forks

*NGVD is National Geodetic Vertical Datum.

```
THE MAXIMUM STAGES FOR THE PERIOD ARE:
XSECT    STAGE[FT]     TIME & DATE       COMMENT:

 1 NF      21.3     1200 HRS ON 30 AUG    NORTH FORK GAGE
(MODEL TIME =   96. HRS)
THIS READING IS   1.3 FT ABOVE FLOOD STAGE

 2 NF      19.9     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS    .1 FT BELOW FLOOD STAGE

 3 NF      18.6     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS   1.4 FT BELOW FLOOD STAGE

 4 NF      17.9     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS   2.1 FT BELOW FLOOD STAGE

 5 NF      13.9     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS   4.9 FT ABOVE FLOOD STAGE

 6 NF      10.8     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS   5.8 FT ABOVE FLOOD STAGE

 7 NF       8.5     1200 HRS ON 30 AUG    NORTH FORK GAGE @ MIDDLEBURG
(MODEL TIME =   96. HRS)
THIS READING IS   4.5 FT ABOVE FLOOD STAGE

 8 NF       7.8     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS   4.8 FT ABOVE FLOOD STAGE

 9 NF       7.5     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS   4.5 FT ABOVE FLOOD STAGE

10 NF       7.4     1200 HRS ON 30 AUG    CONFLUENCE: NORTH-SOUTH
(MODEL TIME =   96. HRS)
THIS READING IS   4.4 FT ABOVE FLOOD STAGE

11 BC       7.3     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS   2.3 FT ABOVE FLOOD STAGE

12 BC       6.9     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS   1.9 FT ABOVE FLOOD STAGE
```

Figure A20. **Printout: Comparison of predetermined flood stages with DWOPER simulated stages.** *These data correspond to the 26 August through 4 September 1968 event.*

```
13 BC       6.5      1200 HRS ON 30 AUG
(MODEL TIME =    96. HRS)
THIS READING IS   1.5 FT ABOVE FLOOD STAGE

14 BC       5.8      1200 HRS ON 30 AUG
(MODEL TIME =    96. HRS)
THIS READING IS    .8 FT ABOVE FLOOD STAGE

15 BC       5.3      1200 HRS ON 30 AUG
(MODEL TIME =    96. HRS)
THIS READING IS    .3 FT ABOVE FLOOD STAGE

16 BC       5.1      1200 HRS ON 30 AUG
(MODEL TIME =    96. HRS)
THIS READING IS   2.1 FT ABOVE FLOOD STAGE

17 BC       4.8      1200 HRS ON 30 AUG     BLACK CREEK GAGE
(MODEL TIME =    96. HRS)
THIS READING IS    .2 FT BELOW FLOOD STAGE

18 BC       4.5      1200 HRS ON 30 AUG
(MODEL TIME =    96. HRS)
THIS READING IS   1.5 FT ABOVE FLOOD STAGE

19 BC       4.2      1200 HRS ON 30 AUG
(MODEL TIME =    96. HRS)
THIS READING IS    .2 FT ABOVE FLOOD STAGE

20 BC       4.0      1200 HRS ON 30 AUG
(MODEL TIME =    96. HRS)
THIS READING IS   1.0 FT BELOW FLOOD STAGE

21 BC       3.9      1200 HRS ON 30 AUG
(MODEL TIME =    96. HRS)
THIS READING IS   1.1 FT BELOW FLOOD STAGE

22 BC       3.6      1200 HRS ON 30 AUG
(MODEL TIME =    96. HRS)
THIS READING IS   1.4 FT BELOW FLOOD STAGE

23 BC       3.5      1200 HRS ON 30 AUG
(MODEL TIME =    96. HRS)
THIS READING IS   1.5 FT BELOW FLOOD STAGE

24 BC       3.5      1200 HRS ON 30 AUG
(MODEL TIME =    96. HRS)
THIS READING IS   1.5 FT BELOW FLOOD STAGE

25 BC       3.4      1200 HRS ON 30 AUG     ST JOHNS RIVER
(MODEL TIME =    96. HRS)
THIS READING IS   1.6 FT BELOW FLOOD STAGE
```

Figure A20—*Continued*

```
 1 SF     27.5     1200 HRS ON 30 AUG    SOUTH FORK GAGE
(MODEL TIME =   96. HRS)
THIS READING IS   6.5 FT ABOVE FLOOD STAGE

 2 SF     26.9     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS   7.9 FT ABOVE FLOOD STAGE

 3 SF     26.6     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS   7.6 FT ABOVE FLOOD STAGE

 4 SF     26.3     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS  11.3 FT ABOVE FLOOD STAGE

 5 SF     25.8     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS  10.8 FT ABOVE FLOOD STAGE

 6 SF     24.3     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS  10.3 FT ABOVE FLOOD STAGE

 7 SF     17.2     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS   3.2 FT ABOVE FLOOD STAGE

 8 SF     15.3     1200 HRS ON 30 AUG
(MODEL TIME =   96. HRS)
THIS READING IS   6.3 FT ABOVE FLOOD STAGE

 9 SF     13.8     1200 HRS ON 31 AUG
(MODEL TIME =  120. HRS)
THIS READING IS   6.8 FT ABOVE FLOOD STAGE

10 SF     12.5     1200 HRS ON 31 AUG    SR 218 BRIDGE
(MODEL TIME =  120. HRS)
THIS READING IS   2.5 FT ABOVE FLOOD STAGE

11 SF     11.1     1200 HRS ON 31 AUG
(MODEL TIME =  120. HRS)
THIS READING IS   1.1 FT ABOVE FLOOD STAGE

12 SF      9.8     1200 HRS ON 31 AUG
(MODEL TIME =  120. HRS)
THIS READING IS   3.8 FT ABOVE FLOOD STAGE

13 SF      7.4     1200 HRS ON 30 AUG    CONFLUENCE: NORTH/SOUTH
(MODEL TIME =   96. HRS)
THIS READING IS   4.4 FT ABOVE FLOOD STAGE
```

Figure A20—*Continued*

```
FOLLOWING IS THE DISCHARGE HYDROGRAPH [IN CFS] FOR CROSS SECTION NO.  1 NF
[ NORTH FORK GAGE                             ]


                      1000.     3000.     5000.     7000.     9000.    11000.
                    0.     2000.     4000.     6000.     8000.    10000.    12000.
                     +----+----+----+----+----+----+----+----+----+----+----+----+
26AUG1200        59.*         I         I         I         I         I         I
27AUG1200       253.I*        I         I         I         I         I         I
28AUG1200      2460.I         I *       I         I         I         I         I
29AUG1200      6100.I         I         I         *         I         I         I
30AUG1200      8100.I         I         I         I         *         I         I
31AUG1200      7380.I         I         I         I     *   I         I         I
 1SEP1200      4920.I         I         I    *    I         I         I         I
 2SEP1200      2630.I         I  *      I         I         I         I         I
 3SEP1200      1370.I      *  I         I         I         I         I         I
 4SEP1200       831.I   *     I         I         I         I         I         I
                     +----+----+----+----+----+----+----+----+----+----+----+----+
                    0.     2000.     4000.     6000.     8000.    10000.    12000.
                      1000.     3000.     5000.     7000.     9000.    11000.



FOLLOWING IS THE STAGE HYDROGRAPH [IN FT NGVD] FOR CROSS SECTION NO.  1 NF
[ NORTH FORK GAGE                             ]
NOTE: F = FLOOD STAGE


                         3.        8.        13.       18.       23.       28.
                    0.        5.        10.       15.       20.       25.       30.
                     +----+----+----+----+----+----+----+----+----+----+----+----+
26AUG1200       2.1I    *     I         I         I         F         I         I
27AUG1200       4.2I       *  I         I         I         F         I         I
28AUG1200      14.8I          I         I        *I         F         I         I
29AUG1200      19.6I          I         I         I        *F         I         I
30AUG1200      21.3I          I         I         I         F *       I         I
31AUG1200      20.9I          I         I         I         F*        I         I
 1SEP1200      19.1I          I         I         I       * F         I         I
 2SEP1200      15.9I          I         I         I*        F         I         I
 3SEP1200      12.5I          I         I    *    I         F         I         I
 4SEP1200       9.0I          I       * I         I         F         I         I
                     +----+----+----+----+----+----+----+----+----+----+----+----+
                    0.        5.        10.       15.       20.       25.       30.
                         3.        8.        13.       18.       23.       28.
```

Figure A21. **Printout: Simulated discharge and stage hydrographs at cross-section 1 NF.** *Data correspond to the simulation of the 26 August to 4 September 1968 event.*

```
FOLLOWING IS THE DISCHARGE HYDROGRAPH [IN CFS] FOR CROSS SECTION NO.  7 NF
[ NORTH FORK GAGE @ MIDDLEBURG          ]


                      1000.     3000.     5000.     7000.     9000.    11000.
                    0.     2000.     4000.     6000.     8000.    10000.    12000.
                    +----+----+----+----+----+----+----+----+----+----+----+----+
26AUG1200         63.*         I         I         I         I         I         I
27AUG1200        318.I*        I         I         I         I         I         I
28AUG1200       2221.I         I*        I         I         I         I         I
29AUG1200       5757.I         I         I       * I         I         I         I
30AUG1200       8155.I         I         I         I         *         I         I
31AUG1200       7764.I         I         I         I       * I         I         I
 1SEP1200       5656.I         I         I       * I         I         I         I
 2SEP1200       3639.I         I       * I         I         I         I         I
 3SEP1200       1901.I        *I         I         I         I         I         I
 4SEP1200       1023.I    *    I         I         I         I         I         I
                    +----+----+----+----+----+----+----+----+----+----+----+----+
                    0.     2000.     4000.     6000.     8000.    10000.    12000.
                      1000.     3000.     5000.     7000.     9000.    11000.



FOLLOWING IS THE STAGE HYDROGRAPH [IN FT NGVD] FOR CROSS SECTION NO.  7 NF
[ NORTH FORK GAGE @ MIDDLEBURG          ]
NOTE: F = FLOOD STAGE


                         3.        8.       13.       18.       23.       28.
                    0.        5.       10.       15.       20.       25.       30.
                    +----+----+----+----+----+----+----+----+----+----+----+----+
26AUG1200         .6I*       F I         I         I         I         I         I
27AUG1200        1.4I *      F I         I         I         I         I         I
28AUG1200        3.3I      * F I         I         I         I         I         I
29AUG1200        6.5I        F I *       I         I         I         I         I
30AUG1200        8.5I        F I     *   I         I         I         I         I
31AUG1200        8.3I        F I     *   I         I         I         I         I
 1SEP1200        6.6I        F I  *      I         I         I         I         I
 2SEP1200        4.7I        F*I         I         I         I         I         I
 3SEP1200        3.0I      * F I         I         I         I         I         I
 4SEP1200        2.3I    *   F I         I         I         I         I         I
                    +----+----+----+----+----+----+----+----+----+----+----+----+
                    0.        5.       10.       15.       20.       25.       30.
                         3.        8.       13.       18.       23.       28.
```

Figure A22. Printout: Simulated discharge and stage hydrographs at cross-section 7 NF. *Data correspond to the simulation of the 26 August to 4 September 1968 event.*

```
FOLLOWING IS THE DISCHARGE HYDROGRAPH [IN CFS] FOR CROSS SECTION NO.  1 SF
[ SOUTH FORK GAGE                            ]


                     500.     1500.     2500.     3500.     4500.     5500.
                  0.     1000.     2000.     3000.     4000.     5000.     6000.
                   +----+----+----+----+----+----+----+----+----+----+----+----+
26AUG1200       26.*         I         I         I         I         I         I
27AUG1200      607.I     *   I         I         I         I         I         I
28AUG1200     2830.I         I         I       * I         I         I         I
29AUG1200     3690.I         I         I         I     *   I         I         I
30AUG1200     3860.I         I         I         I       * I         I         I
31AUG1200     2990.I         I         I        *I         I         I         I
 1SEP1200     1670.I         I     *   I         I         I         I         I
 2SEP1200      891.I       * I         I         I         I         I         I
 3SEP1200      536.I    *    I         I         I         I         I         I
 4SEP1200      353.I  *      I         I         I         I         I         I
                   +----+----+----+----+----+----+----+----+----+----+----+----+
                  0.     1000.     2000.     3000.     4000.     5000.     6000.
                     500.     1500.     2500.     3500.     4500.     5500.
```

```
FOLLOWING IS THE STAGE HYDROGRAPH [IN FT NGVD] FOR CROSS SECTION NO.  1 SF
[ SOUTH FORK GAGE                            ]
NOTE: F = FLOOD STAGE


                       13.       18.       23.       28.       33.       38.
                 10.       15.       20.       25.       30.       35.       40.
                   +----+----+----+----+----+----+----+----+----+----+----+----+
26AUG1200      10.1*         I         I F       I         I         I         I
27AUG1200      16.2I         I *       I F       I         I         I         I
28AUG1200      24.3I         I         I F     * I         I         I         I
29AUG1200      26.9I         I         I F       I  *      I         I         I
30AUG1200      27.5I         I         I F       I    *    I         I         I
31AUG1200      26.5I         I         I F       I  *      I         I         I
 1SEP1200      24.1I         I         I F     * I         I         I         I
 2SEP1200      21.1I         I         I F       I         I         I         I
 3SEP1200      18.3I         I     *   I F       I         I         I         I
 4SEP1200      15.6I         I*        I F       I         I         I         I
                   +----+----+----+----+----+----+----+----+----+----+----+----+
                 10.       15.       20.       25.       30.       35.       40.
                       13.       18.       23.       28.       33.       38.
```

Figure A23. **Printout: Simulated discharge and stage hydrographs at cross-section 1 SF.** *Data correspond to the simulation of the 26 August to 4 September 1968 event.*

```
FOLLOWING IS THE DISCHARGE HYDROGRAPH [IN CFS] FOR CROSS SECTION NO. 10 SF
[ SR 218 BRIDGE                          ]


                     500.      1500.     2500.     3500.     4500.     5500.
                  0.     1000.     2000.     3000.     4000.     5000.     6000.
                   +----+----+----+----+----+----+----+----+----+----+----+----+
26AUG1200      57.*         I         I         I         I         I         I
27AUG1200     459.I   *     I         I         I         I         I         I
28AUG1200    1623.I         I     *   I         I         I         I         I
29AUG1200    4015.I         I         I         I         *         I         I
30AUG1200    5542.I         I         I         I         I         I    *    I
31AUG1200    5546.I         I         I         I         I         I    *    I
 1SEP1200    4115.I         I         I         I         I*        I         I
 2SEP1200    2612.I         I         I     *   I         I         I         I
 3SEP1200    1517.I         I    *    I         I         I         I         I
 4SEP1200     936.I        *I         I         I         I         I         I
                   +----+----+----+----+----+----+----+----+----+----+----+----+
                  0.     1000.     2000.     3000.     4000.     5000.     6000.
                     500.      1500.     2500.     3500.     4500.     5500.


FOLLOWING IS THE STAGE HYDROGRAPH [IN FT NGVD] FOR CROSS SECTION NO. 10 SF
[ SR 218 BRIDGE                          ]
NOTE: F = FLOOD STAGE

                       3.        8.       13.       18.       23.       28.
                  0.        5.       10.       15.       20.       25.       30.
                   +----+----+----+----+----+----+----+----+----+----+----+----+
26AUG1200       .6I*        I         F         I         I         I         I
27AUG1200      1.5I *       I         F         I         I         I         I
28AUG1200      5.5I         I*        F         I         I         I         I
29AUG1200     11.0I         I         F *       I         I         I         I
30AUG1200     12.5I         I         F   *     I         I         I         I
31AUG1200     12.5I         I         F    *    I         I         I         I
 1SEP1200     11.3I         I         F *       I         I         I         I
 2SEP1200      9.0I         I      *  F         I         I         I         I
 3SEP1200      4.9I        *I         F         I         I         I         I
 4SEP1200      2.6I    *    I         F         I         I         I         I
                   +----+----+----+----+----+----+----+----+----+----+----+----+
                  0.        5.       10.       15.       20.       25.       30.
                       3.        8.       13.       18.       23.       28.
```

Figure A24. **Printout: Simulated discharge and stage hydrographs at cross-section 10 SF.** *Data correspond to the simulation of the 26 August to 4 September 1968 event.*