USERS GUIDE FOR DISTRIBUTED ROUTING RAINFALL-RUNOFF MODEL

By David R. Dawdy, John C. Schaake, Jr., and William M. Alley

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METRIC CONVERSIONS

U.S. Customary units used in this report may be converted to metric units by the following conversion factors:

Multiply U.S. Customary units	By	To obtain metric units
cubic foot per second	0.02832	cubic meter per second
foot	.3048	meter
square foot	.0929	square meter
inch	25.4	millimeter
square mile	2.590	square kilometer

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ABSTRACT

A computer program of a watershed model for routing urban flood discharges through a branched system of pipes or natural channels using rainfall as input has been developed and documented. The model combines soil-moisture-accounting and rainfall-excess components developed by Dawdy and others (1972) with the kinematic-wave routing method presented by Leclerc and Schaake (1973).

INTRODUCTION

The model presented here combines the soil-moisture-accounting and rainfall-excess components of the model developed by Dawdy and others (1972) with the kinematic-wave routing components of the model developed by Leclerc and Schaake (1973). Input to the model includes daily rainfall, unit rainfall (any multiple of 5 minutes), and daily pan evaporation. During unit-rainfall days, the model generates a simulated discharge hydrograph based on input data from as many as three rain gages, and a physical definition of the drainage basin discretized into as many as 50 segments, including overland flow, channel and reservoir segments[1/]. The model maintains a daily soil-moisture accounting between unit-rainfall days.

The model uses a deterministic mathematical approach, which includes, as much as possible, approximations to physical laws. Wherever possible, a physical interpretation is placed upon the parameters used in the model. A particular effort was made to use model parameters which can be estimated on the basis of physical features alone.

STRUCTURE OF THE MODEL

The model described in this report can be divided into four major components: a soil-moisture-accounting component, a rainfall-excess component, a routing component, and an optimization component.

[1/] If one description fits more than one segment, then there can be more than 50 segments.

Soil-Moisture-Accounting Component

The soil-moisture-accounting component determines the effect of antecedent conditions on infiltration. Soil moisture is modeled as a two-layered system, one representing the antecedent base-moisture storage (BMS)[2/], and the other, the upper wetted part caused by infiltration into a saturated moisture storage (SMS).

During unit-rainfall days, moisture is added to SMS based on the Philip infiltration equation (Philip, 1954). On other days, a specified proportion of daily rainfall (RR) infiltrates into the soil. Irrigation (for example, lawn watering) can be accounted for in the daily water balance. This is achieved through user-supplied irrigation rates for each month. If a daily precipitation is less than the daily irrigation rate, the daily precipitation is reset equal to the irrigation rate.

Evapotranspiration takes place from SMS, based on availability, otherwise from BMS, with the rate determined from pan evaporation multiplied by a pan coefficient (EVC). Moisture in SMS drains into BMS with a controlling parameter (DRN) determining the rate. Storage in BMS has a maximum value (BMSN) equivalent to the field-capacity moisture storage of an active soil zone. Zero storage in BMS is assumed to correspond to wilting-point conditions in the active soil zone. When storage in BMS exceeds BMSN, the excess is spilled to deeper storage. These spills could be the basis for routing interflow and baseflow components, if desired. However, this option is not included in the present version of the model. A schematic flow chart of the soil-moisture-accounting component is shown in figure 1.

Rainfall-Excess Component

Impervious Surfaces

Two types of impervious surfaces are considered by the model. The first type, effective impervious surfaces, are those impervious areas which are directly connected to the channel drainage system, such as streets and roofs which drain onto driveways and streets. The second type, noneffective impervious surfaces, are those impervious areas which drain to pervious areas. An example of a noneffective impervious area is a roof which drains onto a lawn.

The only abstraction from rainfall on effective impervious areas is impervious retention. This retention, which is user specified, must be filled before runoff from effective impervious areas can occur. Evaporation occurs from impervious retention during periods of no rainfall.

[2/] Definitions of selected model variables can be found in attachment B.

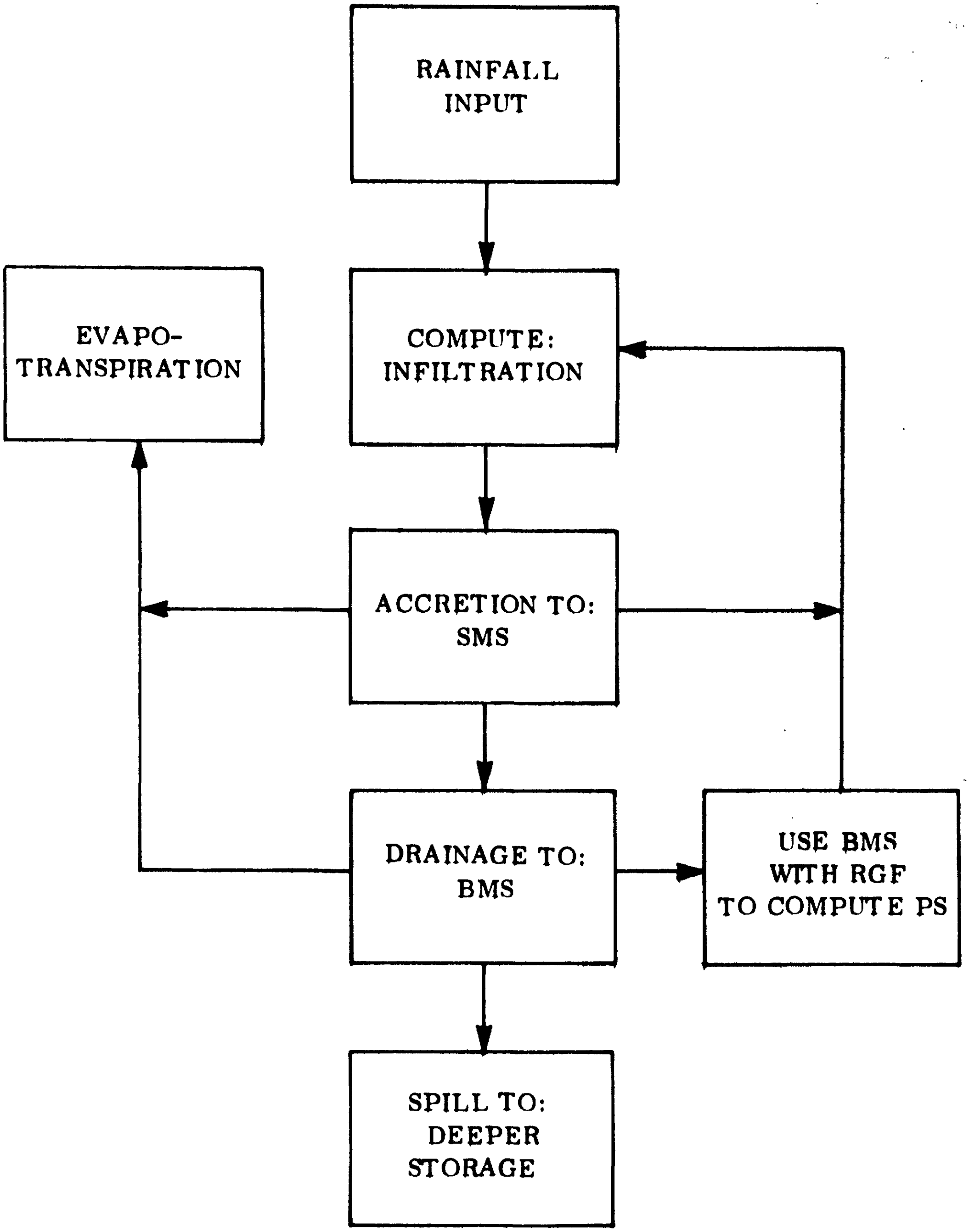


Figure 1.--Schematic flow chart of the soil-moisture-accounting component.

Rain falling on noneffective impervious areas is assumed to run off onto the surrounding pervious area. The model assumes that this occurs instantaneously and that the volume of runoff is uniformly distributed over the contributing pervious area. This volume expressed as inches over the pervious area is added to the rain falling on the pervious areas prior to computation of pervious-area rainfall excess.

Pervious Surfaces

The point-potential infiltration (FR) is computed by a variation of the Green-Ampt equation (Green and Ampt, 1911) known as the Philip equation (Philip, 1954): The Philip equation is

$$FR = KSAT \quad (1 + PS/SMS) \qquad (1)$$

where *KSAT* is the effective saturated soil capillary conductivity and *PS* is the capillary potential at the wetting front. *PS* is varied over the range from field capacity to wilting point by the linear function

$$PS = PSP \quad [RGF - (RGF - 1)\ BMS/BMSN] \qquad (2)$$

where *PSP* is the suction at the wetting front at field capacity, *RGF* is the ratio of suction at wilting point to that at field capacity, and *BMSN* is the effective soil-moisture storage at field capacity (fig. 2).

Point-potential infiltration (FR) computed by the Philip equation is converted to effective infiltration over the basin using a scheme first presented by Crawford and Linsley (1966). Letting SR represent the supply rate of rainfall for infiltration, and QR represent the rate of generation of rainfall excess, the equations are

$$QR = SR^2/2FR \quad SR < FR \qquad (3a)$$

$$QR = SR - (FR/2) \quad SR > FR \qquad (3b)$$

The schematic representation of the relations is shown in figure 3. The parameters for soil-moisture accounting and infiltration are summarized in table 1. Two different soil types can be handled by the model with separate soil-moisture accounting and infiltration parameters for each soil type.

Routing Component

A drainage basin is represented in this model as a set of segments which jointly describe all sub-basins in the total basin. There are four basic types of segments: overland-flow segments, channel segments, reservoir segments and nodal segments. There is wide flexibility to the approach one can take in dividing a basin into segments for runoff computations. At present, it remains largely an art to characterize the total basin in terms of a number of segments which account for the essential basin properties. An example of basin segmentation is illustrated in attachment E.

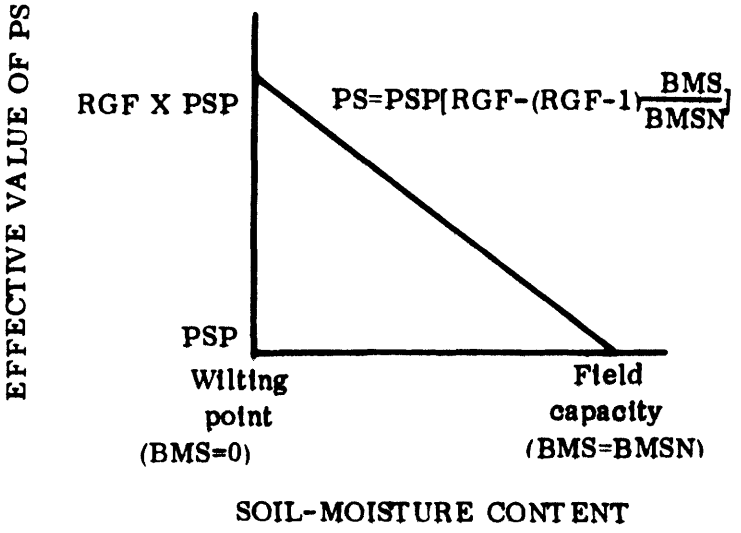


Figure 2.--The relation which determines the effective value of soil-moisture potential (PS) for use in the infiltration equation.

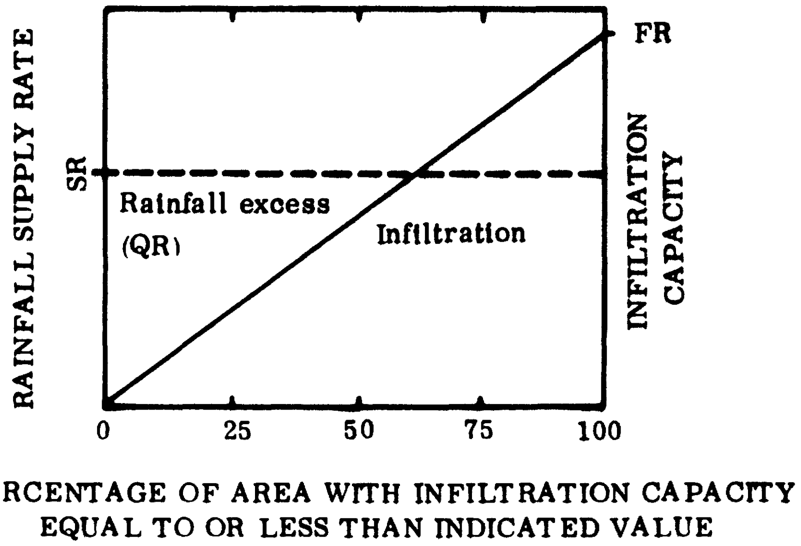


Figure 3.--The relation which determines rainfall excess (QR) as a function of maximum-infiltration capacity (FR) and supply rate of rainfall (SR).

Table 1.--Parameters for soil-moisture accounting and infiltration

Soil-Moisture Accounting

Parameters:

DRN--A constant drainage rate for redistribution of soil moisture between SMS and BMS, in inches per day

EVC--A pan coefficient for converting measured pan evaporation to potential evapotranspiration

RR--The proportion of daily rainfall that infiltrates into the soil for the period of simulation excluding unit-rainfall days.

BMSN--Soil-moisture storage at field capacity, in inches

Infiltration

Parameters:

KSAT--The effective saturated value of hydraulic conductivity, in inches per hour

RGF--Ratio of suction at the wetting front for soil moisture at wilting point to that at field capacity

PSP--Suction at wetted front for soil moisture at field capacity, in inches of pressure

Channel and Overland-Flow Segments

A channel segment is permitted to receive upstream inflow from as many as three other segments, including combinations of other channel segments, reservoir segments, and nodal segments. It also may receive lateral inflow from as many as four overland-flow segments. The overland-flow segments receive uniformly distributed lateral inflow from excess precipitation. A schematic illustrating the relationships between channel and overland-flow segments is shown in figure 4.

Kinematic-wave theory is applied for both overland-flow and channel routing. The kinematic-wave equations are difficult to solve analytically. For practical catchment configurations and natural storms, the analytical solutions are untractable; therefore, numerical solutions must be used. One approach is to solve a finite-difference equation which converges to the differential equation as the step size decreases. That approach has been taken here. The finite-difference scheme used (Leclerc and Schaake, 1973) is unconditionally stable for any values of Δx and Δt.

The Kinematic-Wave Equations

The partial differential equation to be solved for each channel and overland-flow segment is

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \qquad (4)$$

in which A is the area of flow, Q is the rate of flow, q is the rate of lateral inflow, t denotes time, and x denotes distance along the segment increasing in the downstream direction. The dependent variables are A and Q, and these are functions of the two independent variables x and t.

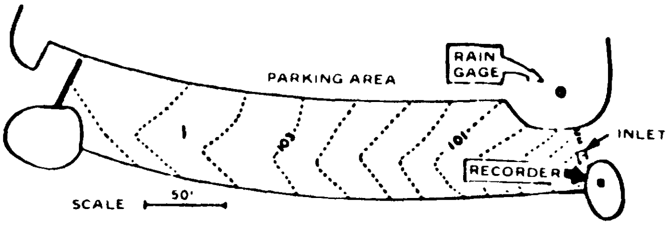
The rate of lateral inflow, q, is generally a function of both x and t, and it serves as an input function, or "forcing function", of the differential equation. In this model the value of q for any particular segment is the same everywhere along the length of that segment, so in this case, q is a function of t but not of x.

The relationship between A and Q is given as

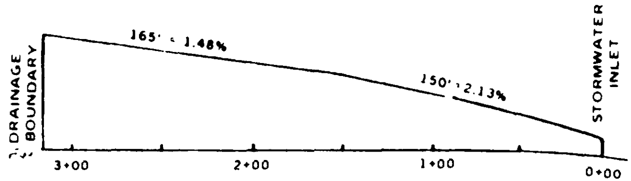
$$Q = \alpha A^{m}. \qquad (5)$$

If the length of the segment is L, the outflow hydrograph from the segment is $Q(L,t)$. The inflow hydrograph to the upstream end of the segment is $Q(0,t)$, and this is the boundary condition needed to solve equation 5. In the case where there is an upstream inflow, the solution will also depend on that inflow. Therefore, the solution must be some function of x, t, q, and $Q(0,t)$. The outflow hydrograph is given by

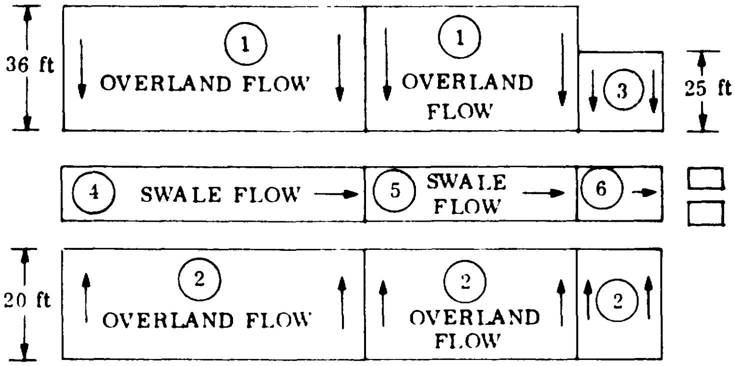
$$Q(L,t) = f[Q(0,t), q(t)] \qquad (6)$$



(a) PLAN



(b) PROFILE OF SWALE



(c) SCHEMATIC REPRESENTATION OF DRAINAGE PLAN

Segment	Length (ft)	Slope (ft/ft)	Inflow to Segment	
			Lateral Inflow	Upstream Inflow
①	36	.019	Rainfall	—
②	20	.0167	Rainfall	—
③	25	.019	Rainfall	—
④	165	.0148	① and ②	—
⑤	100	.0213	① and ②	④
⑥	50	.0213	② and ③	⑤

(d) PHYSICAL CHARACTERISTICS OF COMPONENTS IN THE SCHEMATIC REPRESENTATION

Figure 4.--Discretization of an urban catchment into segments.

The Finite-Difference Scheme

Because $Q(0,t)$ and $q(t)$ are difficult to manage by analytical methods, numerical techniques are used to approximate $Q(x,t)$ at discrete locations in the x-t plane. In this case, a rectangular grid of points was selected. These are spaced at intervals of time, Δt; and distance, Δx. The value of Δx varies from segment to segment, but the value of Δt is constant for all segments.

Four points of a finite-difference mesh are illustrated in figure 5. The purpose of the finite-difference equations is to solve for A and Q at point d, given values of A and Q at points a, b, and c.

In an attempt to keep the solution errors small while maintaining an unconditionally stable solution, the model contains two different finite-difference equations and selects the appropriate one at each point in the solution. The decision depends on the parameter

$$\theta = m \frac{\Delta t}{\Delta x} \frac{Q_b}{A_b} = \alpha m A^{m-1} \left(\frac{\Delta t}{\Delta x} \right) \tag{7}$$

If θ is greater than or equal to unity, the equations used are

$$Q_d = Q_c + q\Delta x - \frac{\Delta x}{\Delta t} (A_c - A_a) \tag{8}$$

and

$$A_d = (Q_d/\alpha)^{1/m} \tag{9}$$

This involves only mesh points a, c, and d. It was derived by substituting $(A_c - A_a)/\Delta t$ for $\partial A/\partial t$ and $(Q_d - Q_c)/\Delta x$ for $\partial Q/\partial x$.

If θ is less than unity, the equations used are

$$A_d = A_b + q\Delta t + \frac{\Delta t}{\Delta x} (Q_a - Q_b) \tag{10}$$

and

$$Q_d = \alpha A_d^{\,m} \tag{11}$$

Equations 8 to 11 are solved by the model beginning with $x = \Delta x$ and proceeding downstream to $x = L$. Initial values of A and Q are given along the entire x - axis. At $t = 0$, the model sets $A = 0$ and $Q = 0$ everywhere. During the solution, upstream inflows are given and equation 5 is used to compute the upstream boundary condition for A.

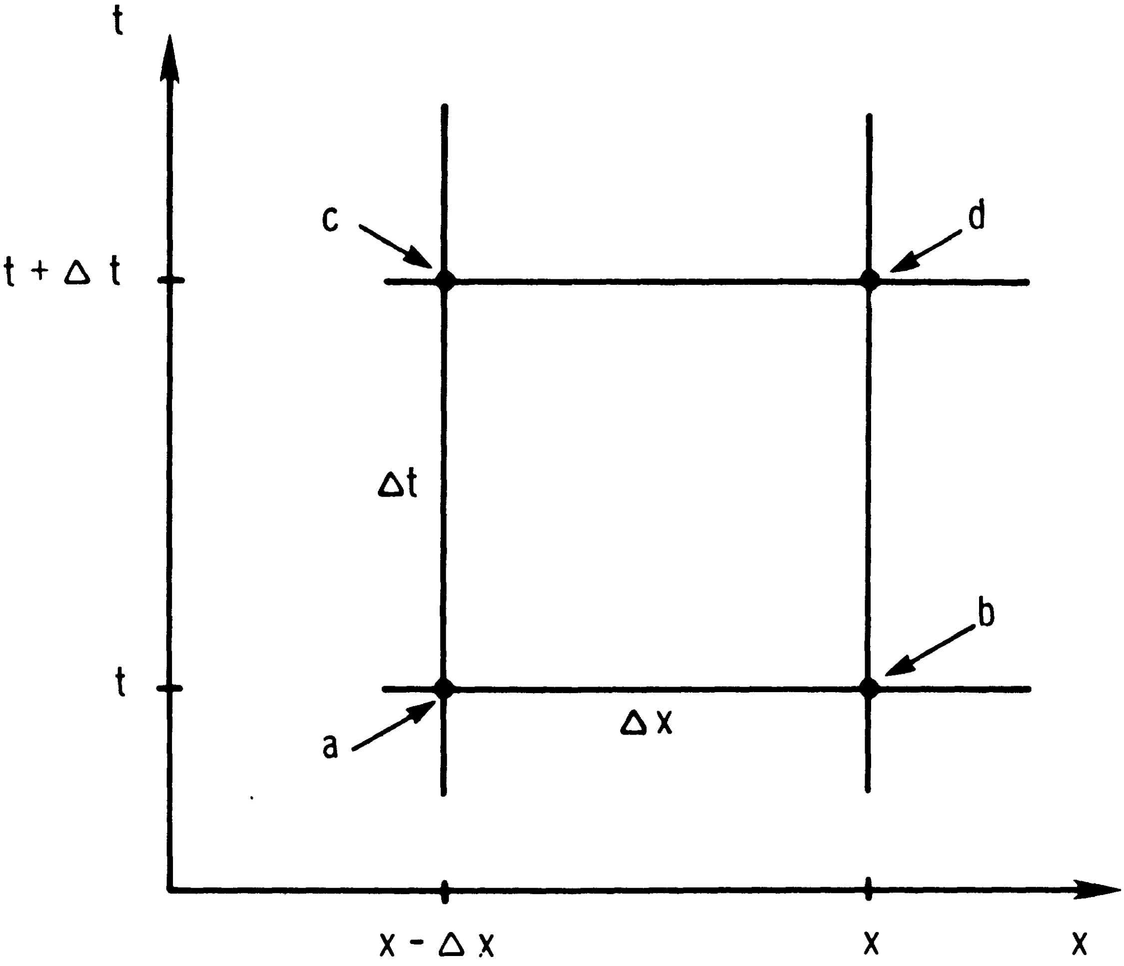


Figure 5.--Four-point finite-difference mesh.

One of the computational problems often encountered in finite-difference approximation is failure to conserve volume. Indeed, there are certain finite-difference approximations of the kinematic-wave equations that lose water during the solution. It can be proved for the special linear case, when $m = 1$, that equations 8 to 11 will conserve volume. Computational experience for $m > 1$ also gives empirical evidence that volume is conserved.

Selecting Δx and Δt

There is obviously no "best" way to select Δx and Δt. One approach would be to choose Δt first and then fix Δx to keep computational errors within acceptable bounds.

Two factors are important for Δt. One is the frequency of the rainfall input to the catchment. The other is the frequency response characteristics of the catchment. If the rainfall input contains many high frequency components, the runoff hydrograph will contain frequency components limited by the high frequency response characteristics of the catchment. A convenient rule of thumb in unit-hydrograph theory is to select Δt so there are about 10 nonzero ordinates. This appears to be a reasonable value to use in the kinematic-wave model also. Applying this rule to a basin having: a typical overland-flow length equal to L_o, overland-flow kinematic-wave parameters α_o and m_o, a main channel length equal to L_c, and channel flow parameters α_c and m_c gives the rule

$$\Delta t \approx 0.1\ (t_o + t_c) \tag{12}$$

where

$$t_o = \left[\frac{L_o}{\alpha_o (i_e/43200)^{m_o - 1}}\right]^{1/m_o} \tag{13}$$

$$t_c = \left[\frac{L_c}{\alpha_c (N i_e L_o/43200)^{m_c - 1}}\right]^{1/m_c} \tag{14}$$

i_e = maximum rainfall intensity, and

N = number of sides of channel with overland-flow segments contributing lateral inflow (1 or 2).

The units are t (seconds), L_o and L_c (feet), and i_e (inches per hour).

After a value of Δt is selected, choose Δx for each segment. This is done by specifying the number, NDX, of Δx increments in each segment. The value of NDX may vary from segment to segment.

The finite-difference solution will be an exact solution if Δx and Δt are selected so that the characteristic passing through point a also passes through point d (fig. 5). Then, the solution A_d, Q_d depends only on A_a, Q_a and the lateral inflow along the characteristic curve between a and d. In the special linear case where $m = 1$, it is possible to achieve the exact solution by setting the ratio $\Delta x/\Delta t$ equal to α. In the general, nonlinear case the ratio $\Delta x/\Delta t$ would need to be equal to α^* where

$$\alpha^* = \alpha m A^{m-1} \tag{15}$$

Hence, the rule is

$$\Delta x \approx \alpha^* \Delta t \tag{16}$$

The parameter α^* is the effective value of α that would be used for a linear approximation ($m = 1$) to a given kinematic-flow segment. For overland flow

$$\alpha_o^* \approx \frac{L_o}{t_o} \tag{17}$$

and for channel flow

$$\alpha_c^* \approx \frac{L_c}{t_c} \tag{18}$$

Thus,

$$\Delta x_o \approx \frac{L_o}{t_o} \Delta t \tag{19}$$

$$\Delta x_c \approx \frac{L_c}{t_c} \Delta t \tag{20}$$

Finally,

$$\mathrm{NDX}_o = \frac{L_o}{\Delta x_o} \approx \frac{t_o}{\Delta t} \tag{21}$$

$$\mathrm{NDX}_c = \frac{L_c}{\Delta x_c} \approx \frac{t_c}{\Delta t} \tag{22}$$

In general, the smallest subarea of interest and the highest intensity rainfall should be used to estimate Δt. If detailed output from the basin outlet is all that is required, the Δt computed as above may be based on the entire channel length through the basin and average basin overland-flow length.

Example to select Δt and Δx

Given the example shown in figure 4,

L_o = 30 feet $\qquad$ L_c = 315 feet

$\alpha_o \approx 7.8$ $\qquad$ $m_o = 1.67$

$\alpha_c \approx 2.0$ $\qquad$ $m_c = 1.33$

i_e = 2 inches per hour and N = 2.

Substituting in equations 13 and 14

$$t_o = \left[\frac{30}{7.8(2/43200)^{.67}}\right]^{1/1.67} = 123 \text{ seconds}$$

and

$$t_c = \left[\frac{315}{2[(2)(2)(30)/43200]^{.33}}\right]^{1/1.33} = 193 \text{ seconds}$$

Then from equation 12

$$\Delta t \approx 0.1(123 + 193) = 31.6 \text{ seconds}$$

Let,

Δt = 30 seconds = 0.5 minutes

Then,

$\text{NDX}_c \approx 193/30 = 6.4$, say 7

$\text{NDX}_o \approx 123/30 = 4.1$, say 4.

Estimation of Parameters α and *m*

The kinematic-wave model contains two parameters, α and *m*. These parameters have no particular physical significance, directly, but they can be determined by analysis of the physical characteristics of the basin segments. The particular functional relationships of α and *m* for channel and overland-flow segments are listed in table 2.

Special Notes on Circular Pipes

The exact relation between *A* and *Q* for circular pipes, assuming the kinematic-wave theory is valid, does not follow the simple algebraic relation (5) with constant values of α and *m*. Rather, these parameters are, in fact, functions of *A*. However, this exact relation may be approximated by (5) with values of α and *m* selected to give a "good fit."

The approximation selected for this model was derived by first recognizing that the dimensionless relation between flow area and flow rate was nearly linear. Let QFULL be the flow rate when the pipe is flowing full.

Table 2.--Relations for estimating α and m on basis of physical characteristics of overland-flow and channel segments

Type of segment	ITYPE(I)	α[1]	m	Definition of PARAM(I,1)
Rectangular Conduit	1	$\frac{1.49\ \sqrt{\mathrm{SLOPE(I)}}}{\mathrm{FRN(I)} * [\mathrm{PARAM(I,1)}^{2/3}]}$	1.67	Width of conduit
Circular pipe	2	$\frac{1.49}{\mathrm{FRN(I)}} \left(\frac{\mathrm{PARAM(I,1)}}{4}\right)^{2/3} \sqrt{\mathrm{SLOPE(I)}}$	1.0	Diameter of pipe
Triangular cross section	3	$\frac{1.41\ \sqrt{\mathrm{SLOPE(I)}}}{\mathrm{FRN(I)} * (\mathrm{PARAM(I,1)}^{1/3})}$	1.33	Width at 1-foot depth
External specification of α and m	4	PARAM(I,1)	PARAM(I,2)	α
Overland flow (turbulent)	5 or 15	$\frac{1.49\ \sqrt{\mathrm{SLOPE(I)}}}{\mathrm{FRN(I)}}$	1.67	----
Overland flow (laminar)	6 or 16	$\frac{64.4\ \mathrm{SLOPE(I)}}{.0000141 * \mathrm{FRN(I)}}$	3.0	----

[1] FRN(I) = Friction coefficient for segment I.

SLOPE(I) = Slope of segment I.

Let AMAX be the cross-sectional area of the pipe. The approximation is then

$$\frac{Q}{\mathrm{QFULL}} \approx \frac{A}{\mathrm{AMAX}} \tag{23}$$

Assuming an equality relation, and rearranging (23), gives

$$Q = \frac{\mathrm{QFULL}}{\mathrm{AMAX}} A \tag{24}$$

so that the parameters are

$$\alpha = \frac{\mathrm{QFULL}}{\mathrm{AMAX}} \tag{25}$$

$$m = 1 \tag{26}$$

The relation between these two curves is illustrated in figure 6.

The capacity of rectangular-conduit and circular-pipe segments is limited to nonpressurized-flow capacity. If that capacity is exceeded during a storm, provision is made to store the water arriving at the upstream end of the segment in excess of the segment capacity. The volume stored increases without upper limit as long as the upstream inflow exceeds segment capacity. After the upstream inflow drops below segment capacity, the volume stored is released to the segment. The upstream inflow to the segment remains at the maximum capacity until the water stored at the upper end of that segment has been released. In the real world, the capacity of a sewer may be controlled by inlets which restrict flow in the sewer to less than full-pipe flow. A second possibility is that a sewer may flow under pressure, thus having more capacity than predicted using kinematic-wave theory. A third possibility is that once a sewer is flowing full, additional inflow to the sewer is transferred to streets parallel to the sewer system. These situations can, at times, be approximated by adjusting the size of the circular segment appropriately. A modified-Puls reservoir segment, described in the next section, can be used to simulate culverts which detain water due to limited capacity and for which outflows are uniquely described as a single-valued function of storage behind the culvert. More complex situations may call for revision of the model.

Reservoir Segments

Provision is made in the model for two types of reservoir routing. The first type is linear-storage routing in which outflow is a linear relation of storage. The user specifies a value of K for the relationship

$$S = KO \tag{27}$$

where,

S = storage, and
O = outflow.

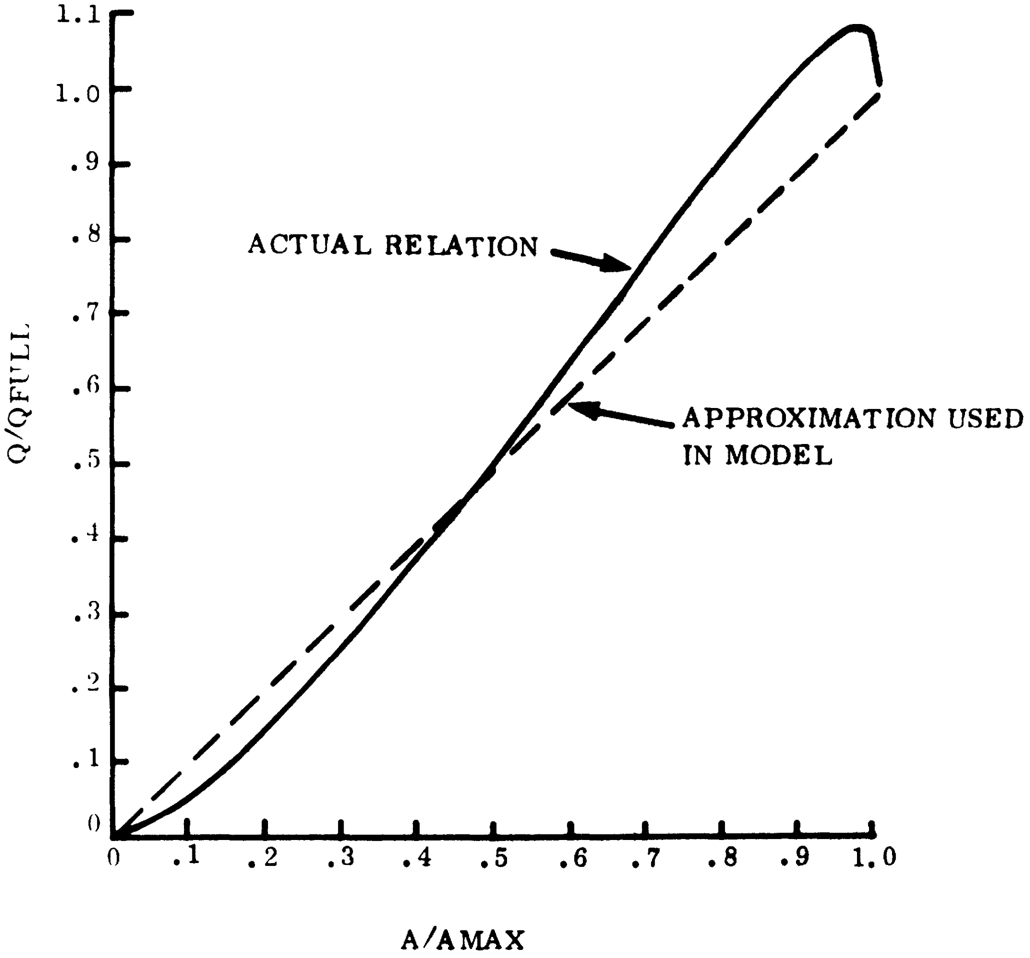


Figure 6.--Relation between $\frac{Q}{QFULL}$ and A/AMAX for circular pipes.

A second type of reservoir routing is modified-Puls routing (Soil Conservation Service, 1972) based on the continuity equation

$$\bar{O} = \bar{I} - \frac{\Delta S}{\Delta t} \tag{28}$$

where,

$\bar{O}$ = average outflow during the time interval Δt,
$\bar{I}$ = average inflow during the time interval Δt, and
ΔS = the change in storage during the time interval Δt.

Equation 28 can be rearranged to

$$\left(\frac{2S_2}{\Delta t} + O_2\right) = (I_2 + I_1) + \left(\frac{2S_1}{\Delta t} - O_1\right) \tag{29}$$

At the beginning of a routing period, all terms on the right-hand side are known. From a user-specified table of storage versus outflow, a table of outflow versus $\left(\frac{2S}{\Delta t} + O\right)$ is determined by the model. Entering this table with the value of $\left(\frac{2S_2}{\Delta t} + O_2\right)$ computed using equation 29, outflow (O_2) at the end of the routing period (Δt) can be determined.

An assumption of the above procedure is that the water surface in the reservoir is level and responds instantaneously to inflows and (or) outflows. The reservoirs are also assumed to be detention reservoirs with no storage in the reservoir at the start of a storm unless the storm immediately follows a previous storm. Direct rainfall on the storage surface, evaporation, bank storage, and leakage are not accounted for by the model.

Nodal Segments

Two types of nodal segments are used by the model. The first type is a junction segment. Junction segments are used when more than three segments contribute inflow to the upstream end of a segment. A second type of nodal segment is an input-hydrograph point where the user may specify an input hydrograph for each storm event. Only one input hydrograph point in the basin is permitted. Nodal segments (both types) do not have a routing component; therefore, the output from the segment is equivalent to the input.

Optimization Component

An option is included in the model to calibrate the soil-moisture and infiltration parameters for drainage basins having observed rainfall-runoff data. The method of determining optimum parameter values is based on an optimization technique devised by Rosenbrock (1960). The utility of the procedure, as related to system identification in hydrologic modeling, was discussed by Dawdy and O'Donnell (1965). The method revises the parameter magnitudes and recomputes the objective function, using the revised set of parameter magnitudes. If the result is an improvement, the revised set is accepted; if not, the method returns to the previous best set of parameters. The objective function is the sum of the squared deviations of the logarithms of computed and measured storm-runoff volumes. Thus, the fitting procedure develops a nonlinear least-squares solution.

Rosenbrock's method of optimization proceeds by stages. During the first stage, each parameter represents one axis in an orthogonal set of search directions until arbitrary end-of-stage criteria are satisfied. At the end of each stage, a new set of orthogonal directions is computed, based on the experience of parameter movement during the preceding stage. The major feature of this procedure is that, after the first stage, one axis is alined in a direction reflecting the net parameter movement experienced during the previous stage.

To start the fitting process, the model is assigned an initial set of parameter values and upper and lower bounds for each parameter. The objective function is calculated and then stored in the computer memory bank as a reference value. A step of user-specified length is attempted in the first-search direction. If the resulting value of the objective function is less than or equal to the reference value, the trial is registered as a success, and the appropriate step size, e, for each parameter is multiplied by ∂ ($\partial > 1$). If a failure results, the step is not allowed and e is multiplied by $-\beta$, where $0 < \beta < 1$. An attempt is made in the next search direction, and the process continues until the end-of-stage criteria are met. At this point, a new orthogonal search pattern is determined, and another stage of optimization undertaken. The objective function value and associated parameter values are printed for each successful trial. Also, a listing by flood event of the simulated hydrologic response and of observed data are output at the start of each stage.

The observed values of runoff volume may be either user specified or computed by the model using unit-discharge data. If unit-discharge data are supplied to the model, surface runoff is calculated by a simple hydrograph-separation technique which assumes a constant base flow equal to the lowest observed discharge for the storm event. The simulated volume of surface runoff is based on rainfall excess. The user can select all storms or any subset of storms to be included in the calculation of the objective function values.

Impervious area is not included as a parameter to be optimized, but is a parameter to which simulated runoff volumes are very sensitive. Therefore, values of imperviousness should be accurately determined before using the optimization option. If initial estimates of imperviousness are grossly in error, resulting volumes and peaks will be grossly in error. In that case, estimates of imperviousness must be adjusted by the modeler, and optimization achieved by trial and error for the estimates of effective and noneffective impervious areas.

DATA INPUT SPECIFICATIONS

Input for this program must be on punched cards.

All listing of numeric data is right justified. All listing of alphabetic data is left justified. The letter "Oh" is written Ø to contrast with the number zero--written 0.

The format F5.0 means that the floating-point magnitude of the variable contains no significant digits to the right of the decimal point. No decimal point need be punched in the card listing. If a significant digit is required to the right of the decimal point, the point must be punched in card listing. The format F4.2 implies that two significant digits lie to the right of the decimal point.

Experience with the program has indicated that great care must be exercised in preparing the input card deck. A schematic of program deck setup is shown in attachment D.

Input item	Program variable	Format	Card columns
Card Group 1 (1 card)			
Option to list data If ØPTIØN = LIST all input rainfall, runoff and evaporation data are printed.	ØPTIØN	A4	1-4
If no unit-discharge data are to be read-in either because storm-runoff volumes are supplied for optimization or no optimization is to be performed, set ØPT = 1. Otherwise, leave blank.	ØPT	I1	5
If daily rainfalls are to be modified for irrigation, set NØPT1 = 1. Otherwise, leave blank.	NØPT1	I1	6

Input item	Program variable	Format	Card columns
Card Group 2 (1 card)			
Include Card 2 only if N0PT1 = 1.			
Irrigation rate (inches/ week) for			
January	IRR(1)	F5.3	1-5
February	IRR(2)	F5.3	6-10
March	IRR(3)	F5.3	11-15
April	IRR(4)	F5.3	16-20
May	IRR(5)	F5.3	21-25
June	IRR(6)	F5.3	26-30
July	IRR(7)	F5.3	31-35
August	IRR(8)	F5.3	36-40
September	IRR(9)	F5.3	41-45
October	IRR(10)	F5.3	46-50
November	IRR(11)	F5.3	51-55
December	IRR(12)	F5.3	56-60
Card Group 3 (1 card)			
Streamflow station number	STAD	I8	1-8
Name of streamflow station	TITLD	50A1	9-58
Drainage area of basin (square miles)	DA	F6.2	59-64
Card Group 4 (1 card)			
Daily-rainfall station number	STAP	I8	1-8
Name of daily-rainfall station	TITLP	50A1	9-58
Card Group 5 (1 card)			
Daily-evaporation station number	STAE	I8	1-8
Name of daily-evaporation station	TITLE	50A1	9-58
Card Group 6 (1 card)			
Beginning year,	BYR	I3	21-23
month, and	BM0	I3	24-26
day of record	BDY	I3	27-29
Ending year,	EYR	I3	33-35
month, and	EM0	I3	36-38
day of record	EDY	I3	39-41

Input item	Program variable	Format	Card columns
Card Group 7 (1 card for each station)			
Unit-rainfall station number	STAUP	I8	1-8
Name of unit-rainfall station	TITLUP	50A1	9-58
Time increments for input of unit rainfall and unit discharge, in minutes. (Must be a multiple of 5.)	PTIME	F6.0	59-64

If more than one rain gage is used, a Card 7 must be placed in front of the data for each rain gage.

The following types of cards contain input data of unit rainfall, unit discharge, daily rainfall, and daily evaporation. The cards must be arranged in chronologic sequence for each data type, in the order listed below. If more than one rain gage is used, all data for one rain gage must be read in chronologic order before the data for another rain gage are input. The number of cards depends upon the number of days of record and the number of flood events. In column 80 of each data card, the type of data will be identified by the CØDE number as follows:

Type of data	Program variable	CØDE
Unit rainfall	UP	1
Unit discharge	UD	2
Daily rainfall	DP	3
Daily evaporation	DE	4

The number of cards required to list a complete day of unit rainfall (UP) or unit discharge (UD) is 120/PTIME. The card format for listing UP and UD provides 12 fields for these data. Each set of 12 units of data is numbered in chronologic sequence by the variable CN. The arrays UP and UD are initialized to zero. Hence, if all 12 units of data for UP and UD are zero, the card may be omitted from the input card deck, but its card sequence number for this day must be taken into account in listing CN on subsequent cards. However, at least one unit-rainfall card must be included for each rain gage for every unit-rainfall day even if no rain occurred during that day.

Input item	Program variable	Format	Card columns

Card Group 8

Cards for unit-rainfall data (CODE=1 in column 80)

Input item	Program variable	Format	Card columns
Station number	STAUP	I8	1-8
Date on which rainfall occurred:			
year	YR	I2	9-10
month	MO	I2	11-12
day	DY	I2	13-14
Unit-time interval in minutes for listing data	CT	I2	15-16
Card sequence number	CN	I2	17-18
Unit rainfall expressed in hundredths of an inch (12 data items per card)	UP	12F5.0	19-78
Data type	CODE	I1	80

At the end of data for a rain gage, when data for another rain gage are to be used, insert a card between the sets of rain-gage data with a CODE of 8 punched in column 80. If no unit-discharge data are to be read-in (OPT = 1), insert a card at the end of the final rain-gage data with a CODE of 9 punched in column 80.

Card Group 9

Cards for unit-discharge data (CODE=2 in column 80)

If OPT=1, skip to Card Group 10

Input item	Program variable	Format	Card columns
Station number	STAD	I8	1-8
Date on which discharge occurred:			
year	YR	I2	9-10
month	MO	I2	11-12
day	DY	I2	13-14
Unit-time interval in minutes for listing data	CT	I2	15-16
Card sequence number	CN	I2	17-18
Unit discharge in cubic feet per second (12 data items per card)	UD	12F5.0	19-78
Data type	CODE	I1	80

At the end of the unit-discharge data, insert a card with a CODE of 9 punched in column 80.

Input item	Program variable	Format	Card columns

Card Group 10

Cards for daily-rainfall data (CODE=3 in column 80)

Station number	STAP	I8	1-8
Year and month for data	YR	I2	9-10
	MO	I2	11-12
Card sequence number (1 or 2)	CN	I1	13
Daily rainfall in inches (up to and including 16 items per card)	DP	16F4.2	14-77
Data type	CODE	I1	80

Two cards are required for listing a complete month of daily precipitation or daily evaporation. Use as many cards as necessary to list data for all months. The card format for listing these daily data provides 16 fields: the first 16 days of data are listed on the first card, identified by the card sequence number CN=1, and the remaining days of data in the month on the second card CN=2.

For unit-rainfall days insert -100 (right justified) as the daily rainfall for that day on the daily-rainfall card. Any negative value signals that unit rainfall is listed for that day. (Therefore, you may alternatively insert negative the sum of the rainfall if the width of field permits). It may be desirable to skip a large gap in time rather than continue with daily soil-moisture accounting (for example, no winter records). In such cases a 9999 should be punched as the daily rainfall for the first and last day of the gap in record. No daily-rainfall cards are required for intervening days. SMS and BMS are set equal to zero at the start of simulation and immediately following a gap in the daily-precipitation record. Therefore, the model should be run for one to two months on a daily soil-moisture accounting basis prior to the first unit-rainfall day and between the end of a gap in record and the first subsequent unit-rainfall day.

Card Group 11

Cards for daily-evaporation data (CODE=4 in column 80)

Station number	STAE	I8	1-8
Year and month for data	YR	I2	9-10
	MO	I2	11-12
Card sequence number (1 or 2)	CN	I1	13
Daily evaporation in inches (up to and including 16 items per card)	DE	16F4.2	14-77
Data type	CODE	I1	80

At the end of the daily-evaporation data, insert a card with a CODE of 9 punched in column 80.

Card Group 12

Card specifying details for optimization round

Input item	Program variable	Format	Card columns
Number of parameters in the soil-moisture accounting and infiltration components	E0	I4	1-4
Number of parameters to be adjusted	F0	I4	5-8
Number of trial adjustments per parameter	K	I4	9-12
Initial step size for parameter adjustment	EPSLN	F8.0	13-20

E0 should be 7 if the basin is to be treated uniformly or 14 if the basin is to be divided into parts with differing infiltration and soil-moisture parameters. If two different soil types are used, each sub-basin is assigned one or the other soil type by Card Group 16. If two soil types are used, up to 14 parameters can be optimized; however, this is not a recommended procedure. A basin with two very different soil types should most probably not be used to calibrate the model.

The initial magnitude and the magnitudes for the upper and lower limits for all parameters must be furnished. Suggested magnitudes are given in table 3. These magnitudes are grouped in the following order for each parameter: initial, lower limit, upper limit. The groups are listed for each parameter according to the order shown in table 3. EVC may be estimated as 0.7 if it is an adjustment of pan evaporation to potential evapotranspiration. EVC may differ from 0.7 by a considerable amount if the pan-evaporation data are collected at a site outside the basin. In that case EVC may include an adjustment to make the pan evaporation representative for the basin. RR is an estimate of the proportion of daily rainfall which infiltrates into *pervious* surfaces for the period of simulation *excluding* unit-rainfall days.

Card Group 13

Cards furnishing initial magnitude, upper and lower limits of parameters

Input items	Program variable	Format	Card columns
Initial magnitude	X(I)	F10.0	1-10
Lower limit	G(I)	F10.0	11-20
Upper limit	H(I)	F10.0	21-30

There should be one card for each parameter. Upper and lower limits of parameters should be specified, even if no optimization is performed.

Table 3.--List of soil-moisture and infiltration parameters in order of input

Parameter	X-array identifier	Initial	Lower limit	Upper limit	Unit
PSP	X (1)	5.0	1.0	15.0	inches
KSAT	X (2)	0.10	0.01	1.0	inches per hour
RGF	X (3)	10.0	5.0	20.0	dimensionless
BMSN	X (4)	5.0	1.0	15.0	inches
EVC	X (5)	.7	.5	1.0	dimensionless
RR	X (6)	.9	.65	1.0	dimensionless
DRN/(24.0*X[2])	X (7)	.5	.1	1.0	dimensionless

If E0 equals 14, the second set of parameters is as above, but numbered X(8) to X(14).

Card Group 14

Parameter-adjustment card

Input item	Program variable	Format	Card columns
Subscripts for parameters to be optimized (should be F0 in number, can be in any order). If no optimization is performed, insert a blank card.	0PTN0	14I2	1-2 3-4 etc.

DETAILED MODEL DESCRIPTION

The model description cards supply the program with information about the physical features of the catchment and the spatial and temporal properties of one or more storms which are to be simulated on the catchment.

The total input data set is divided into several parts. The following is an explanation of the data in each part.

Card Group 15

Model-Control Card

Number of different segments used to describe basin (1 to 50)	NSEG	I5	1-5
Time interval, in minutes, used in finite-difference calculations (Δt) (Maximum of 5 minutes)	DT	F5.0	6-10
Sampling interval, in minutes, for detailed output. The value is not constrained in anyway by the value of DT	0SI	F5.0	11-15
Number of rain gages (1 to 3)	NRG	I5	16-20
Maximum impervious retention (inches)	IMP	F5.0	21-25

Card Group 16

Segment Characteristics

There is one card for each segment, and cards may be arranged in any sequence.

Input item	Program variable	Format	Card columns
Alphanumeric identification for segment (Required for all segments; any alphanumeric identification can be used.)	ISEG(I)	A4	1-4
Alphanumeric identification for up to 3 segments which contribute inflow to the upstream end of this segment (leave blank where upstream segments are not present.)	IUP(I,J) J = 1, 3	3A4	5-8 9-12 13-16
Alphanumeric identification for up to 4 segments which contribute uniform lateral inflow into this segment (leave blank where lateral inflow segments are not present.)	ILAT(I,J) J = 1,4	4A4	17-20 21-24 25-28 29-32
Type of segment	ITYPE(I)	I2	33-34

1 = a rectangular open channel

2 = a pipe

3 = a triangular cross section

4 = to specify explicitly the kinematic channel parameters α and m

5 or 15 = overland-flow segment (turbulent)

6 or 16 = overland-flow segment (laminar)

Only one roughness parameter can be specified for an overland-flow segment. For sub-basins with short distances of pervious runoff from lawns to streets, use of one roughness parameter may be the best approach and ITYPE(I) should be specified as 5 or 6. For sub-basins of mixed pervious and impervious surfaces and comparable distances of flow for reach, two sub-basins can be specified, a pervious and an impervious sub-basin, by the use of ITYPE(I) of 15 or 16, depending upon whether the sections are turbulent or laminar overland flow. In such a case, the ITYPE(I) = 15 (or 16) must immediately follow the ITYPE(I) = 5 (or 6) segment of identical description except for roughness. Any channel which receives lateral inflow from one of the pair must receive lateral inflow from the other. The ITYPE(I) = 5 (or 6) segment must contain the pervious roughness; the ITYPE(I) = 15 (or 16) segment, the impervious roughness.

7 = a junction
8 = a detention reservoir (modified-Puls routing)
9 = a detention reservoir (linear-storage routing)
10 = an input-hydrograph point (only 1 input-hydrograph point is accepted by the model)

Input item	Program variable	Format	Card columns
Outflow print-out indicator	IPR(I)	I2	35-36
1 = if the outflow hydrograph for this segment is to be printed out. 0 = if the outflow hydrograph for this segment is not to be printed out.			
For segment types 1-6, 15, 16: number of intervals into which total length of this segment is to be divided for finite-difference calculations. (Maximum of 10).	NDX(I)	I2	37-38
For segment type 8: number of points in the storage-outflow relationship. (Maximum of 30).			
For segment types 7, 9, 10: leave blank			
Length of segment (feet)	FLGTH(I)	F5.0	39-43

For overland-flow segments the length can be computed as area, in square feet, of the overland-flow segment divided by the length, in feet, of the channel segment into which it contributes lateral inflow. The model computes a basin drainage area based on the length of channels and their adjacent overland-flow segment lengths. If this computed drainage area differs by more than 1 percent from the drainage area input from Card Group 3, a comparison of computed versus input basin drainage area is included in the output. The model uses the computed drainage area for all computations.

Input item	Program variable	Format	Card columns
Slope of segment (feet/feet)	SLØPE(I)	F5.0	44-48
Roughness parameter for segment	FRN(I)	F5.0	49-53
For segments of type 1, 2, 3, 4, 5, or 15, this is a parameter similar to Manning *n*. For segments of type 6 or 16, this is an empirical coefficient for laminar overland flow. Leave blank for segments of type 7 to 10.			

Input item	Program variable	Format	Card columns
A pair of parameters which depend on type of segment	PARAM(I,J) J = 1,2	2F5.0	54-58 59-63

Segment Type	Special Parameters
1	PARAM(I,1) = width (feet) PARAM(I,2) = height (feet)
2	PARAM(I,1) = diameter (feet) PARAM(I,2) = leave blank
3	PARAM(I,1) = width of cross section (feet) at 1-foot depth PARAM(I,2) = leave blank
4	PARAM(I,1) = α PARAM(I,2) = m
5 or 15	PARAM(I,1) = perviousness PARAM(I,2) = effective imperviousness. For example, for a segment of type 5 consisting of 25 percent pervious land cover, 60 percent effective impervious land cover, and 15 percent noneffective impervious land cover, set PARAM(I,1) = .25 and PARAM(I,2) = .60.
6 or 16	PARAM(I,1) = perviousness (same as type 5) PARAM(I,2) = effective imperviousness (same as type 5)
7	PARAM(I,1) = leave blank PARAM(I,2) = leave blank
8	PARAM(I,1) = leave blank PARAM(I,2) = leave blank
9	PARAM(I,1) = constant K in S=KO relationship (hours) PARAM(I,2) = leave blank
10	PARAM(I,1) = leave blank PARAM(I,2) = leave blank

Input item	Program variable	Format	Card columns
Designation of parameter set for overland-flow segments.	KPSET(I)	I2	64-65

For segment types 5, 6, 15, or 16: If E0 = 7, enter 1. If E0 = 14, KPSET(I) equals 1 if X(1) to X(7) apply, KPSET(I) equals 2 if X(8) to X(14) apply. Otherwise, leave blank.

"Thiessen coefficients" for overland-flow segments in same order as station data input by Card Groups 7 and 8.	RC0EF(I,J) J = 1, NRG	3F5.0	66-70 71-75 76-80

The "Thiessen coefficients" are not truly such, because they need not sum to 1.0 for a sub-basin. Rather they are adjustment coefficients for weighting the rainfall at each rain gage. Thus, if only one rain gage is available, its adjusted rainfall over the basin may be distributed by the "Thiessen coefficients," all of which may be less than 1.0 if the rain gage is on a ridge at a higher elevation with a higher rainfall than the basin or all less than 1.0 if the rain gage is at the lower end or below the basin. If more than one rain gage is available, each may be adjusted and then weighted by means of the "Thiessen coefficients."

Card Group 17

Cards specifying outflow-storage relationship for segments of type 8

If there are no segments of type 8, skip to storm-sequencing card. Otherwise for each modified-Puls detention reservoir, in the order in which the detention reservoirs are read in Card Group 16, input the outflow-storage relationship. There should be NDX (I) cards for each detention reservoir (I).

Outflow (in cubic feet per second)	02 (I,II)	F10.0	1-10
Storage (in cubic feet per second-hours)	S2 (I,II) II = 1, NDX (I)	F10.0	11-20

Card Group 18

Storm-sequencing card

Number of storms	I	I2	1-2

Input item	Program variable	Format	Card columns
Number of storms in the sequence of days containing a given storm (up to 6) For example, if the first sequence of consecutive storm days contains 1 storm, NF(1) = 1; if the first sequence contains 3 storms, NF(1) = NF(2) = NF(3) = 3.	NF(K) K=1, I	39I2	3-4, 5-6, etc.

Card Group 19

Storm-separation cards

Input item	Program variable	Format	Card columns
Starting time increment for storm	KS	I4	1-4
Ending time increment for storm	KE	I4	5-8
If the computed and/or measured outflow from the drainage basin is to be plotted for this storm, set IPL = 1. Otherwise, leave blank.	IPL	I1	9
If volumes are supplied, set VØLI equal to runoff volume (inches). Otherwise, leave blank.	VØLI	F6.2	10-15

There should be one storm-separation card for each of the I storms shown on the storm-sequencing card. Starting and ending time increments are specified as the number of the unit-time interval in the sequence of days containing the storm. For example, if the unit-time interval is 15 minutes and the starting time of the storm is 0700 on the first day of a sequence of days, KS should be specified as 28. Likewise, if the starting time was 0700 on the second day of a sequence of days, KS should be specified as 124. If unit-discharge data are input to the model, the starting and ending time increments for each storm must envelope the entire runoff period in order that the correct storm-runoff volumes are calculated. The model stops routing at the ending time increment for each storm.

Input item	Program variable	Format	Card columns
	Card Group 20		
	Routing Card		
1 = routing performed for storm	KØUT(I)	40I2	1-2
0 = no routing for storm	I = 1,NØFE		3-4 etc.
	Card Group 21		
	Optimization card		
1 = storm used in computation of objective function	TESTNØ(I)	40I2	1-2
0 = storm not used in computation of objective function	I = 1,NØFE		3-4 etc.
	Card Group 22		
	Input-hydrograph-indicator card		
1 = storm has input hydrograph	IHYD(I)	40I2	1-2
0 = storm has no input hydrograph	I = 1,NØFE		3-4 etc.
	Card Group 23		
	Cards specifying input hydrograph		

No cards are necessary if there are no input-hydrograph segments (ITYPE(I) = 10 on card group 16). Otherwise the input hydrographs for each storm should be read in the order in which the storms occur. An inflow of 0 cubic feet per second is assumed if no values for a time period are read.

1 = last input hydrograph card for storm	ICØDE	I2	1-2
0 = not last input hydrograph card for storm			

Input item	Program variable	Format	Card columns
Starting time increment for values of inflow read (Same convention as storm-separation cards)	JJJ	I3	3-5
Inflow (in cubic feet per second) (10 values per card)	X2(I) I = 1,10	10F5.3	6-55

COMPUTER REQUIREMENTS

The computer program has been written in FORTRAN IV programming language and was developed and tested on CDC 7600 equipment. The plotting routine included in the program listing of attachment C is IBM-system[3] dependent. Instructions are included in the program listing to eliminate the plotting routine (see lines A24 and A921 in attachment C). With the exception of the plotting routine, the program can be run on any Fortran-based computer.

The program, as dimensioned, will handle up to 50 different segments. A single simulation will analyze a period of record spanning as many as 1,000 days. The maximum number of unit-rainfall days is equal to 5 times the unit-time increment in minutes. All of these limits can be changed easily by redimensioning the program. The program, as dimensioned, requires 302 K bytes of storage on IBM 360 equipment. It takes about 15 to 17 seconds of CPU time for compilation. The first and second runs in attachment E executed in 6 seconds and 12 seconds, respectively.

PROGRAM OUTPUT

Examples of the output listing are given in attachment E. The general output format consists of:

(1) Station numbers and names, drainage area, unit-time interval, period of record, and, if N0PT1 = 1, daily irrigation rates.

(2) All input rainfall, runoff, and evaporation data. (If 0PTI0N = LIST).

(3) List of initial soil-moisture-parameter values and infiltration-parameter values, with identification of those parameters that are to be optimized.

(4) Initial step-size increments for each parameter to be optimized, maximum number of trials used in the optimization, and initial step size for parameter adjustment. (If optimization option is used.)

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[3] The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

(5) Number of segments, time interval used in finite-difference calculations, output sampling interval, number of rain gages, number of soil types and maximum impervious retention.

(6) List of segments and their characteristics

(7) Segment computation sequence and segment α's and m's for kinematic-wave routing.

(8) Number of storms, number of storms in the sequence of days containing a given storm, starting and ending time increment for each storm, identification of storms for which routing is performed and identification of storms which have an input hydrograph.

(9) List of flood events used in the objective function (If optimization is performed.)

(10) Progress report on optimization (if performed)

   a. Value of objective function for initial parameter values and a listing of the parameter values.

   b. For each storm event a listing of measured surface-runoff volume and simulated surface-runoff volume, measured rainfall at each rain gage, and contribution to objective function for each storm event.

   c. Objective function and soil-moisture and infiltration parameter values at each step in the optimization technique that results in a decrease in the objective function.

   d. A repetition of (a) to (c) each time a new orthogonal search pattern in optimization is initiated.

(11) Outflow hydrographs for user-selected segments for routed storm events. Also, the maximum storage required of each detention reservoir for each routed storm event is listed.

(12) Line-printer plot of computed and (or) measured outflow from drainage basin for user-selected storm events.

(13) Value of objective function and soil-moisture and infiltration parameter values for last successful trial.

(14) For each storm event a listing of measured and simulated peak discharge, measured and simulated surface-runoff volume, measured rainfall at each rain gage, and contribution to objective function.

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ATTACHMENTS

A. GENERALIZED PROGRAM FLOW CHART

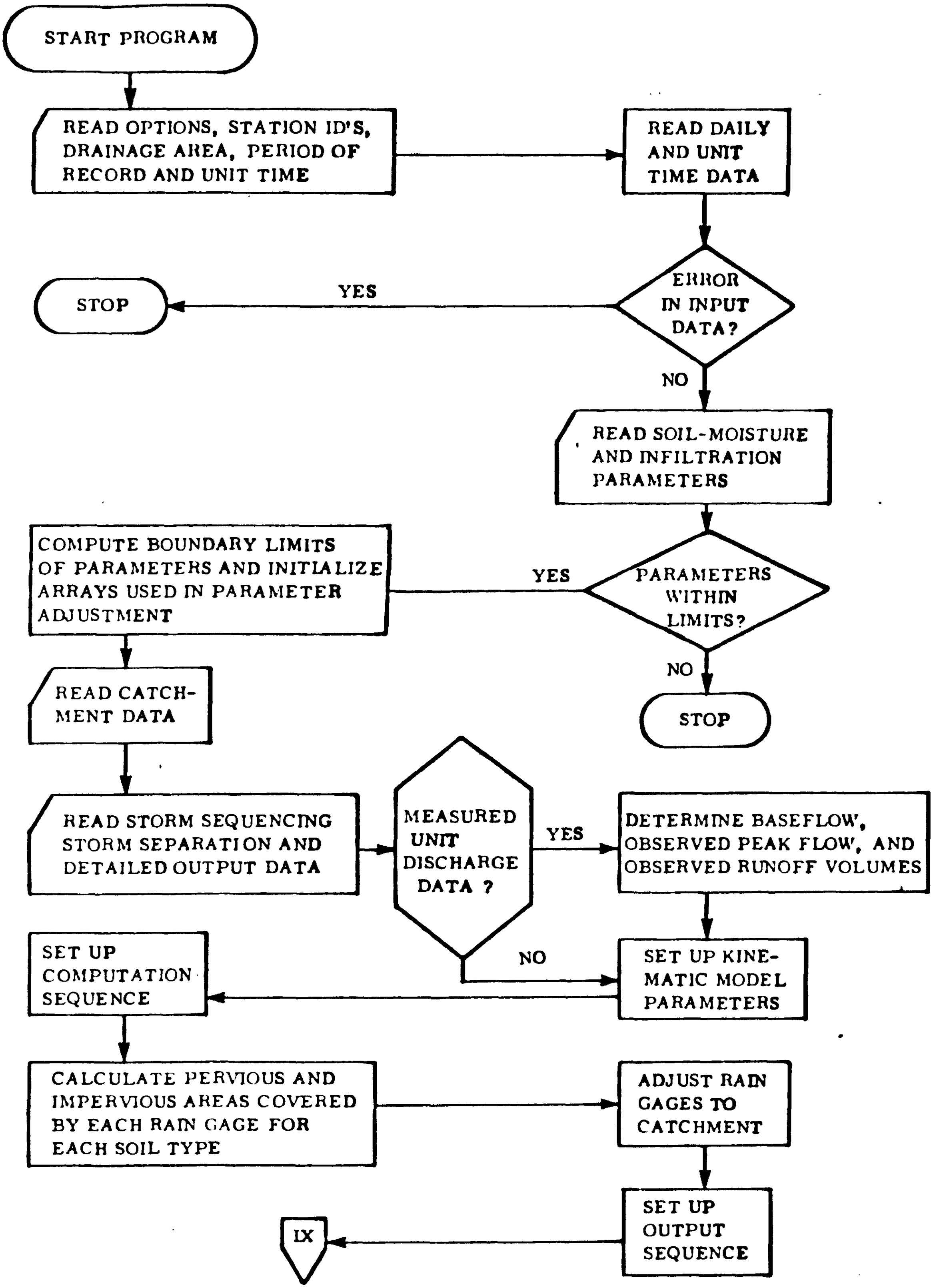

Figure 7.--Flow chart of initial program setup.

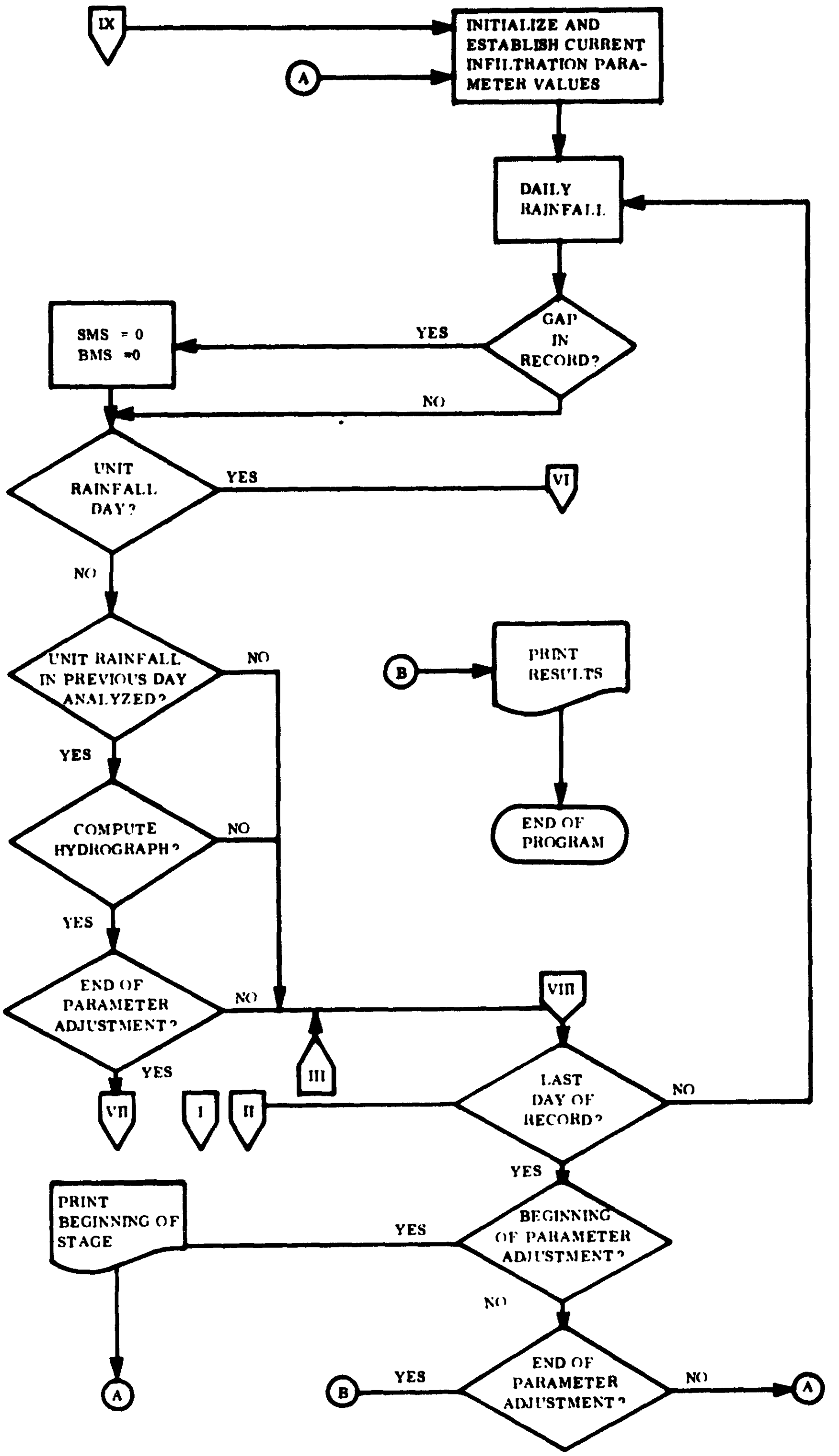

Figure 8.--Flow chart of main program.

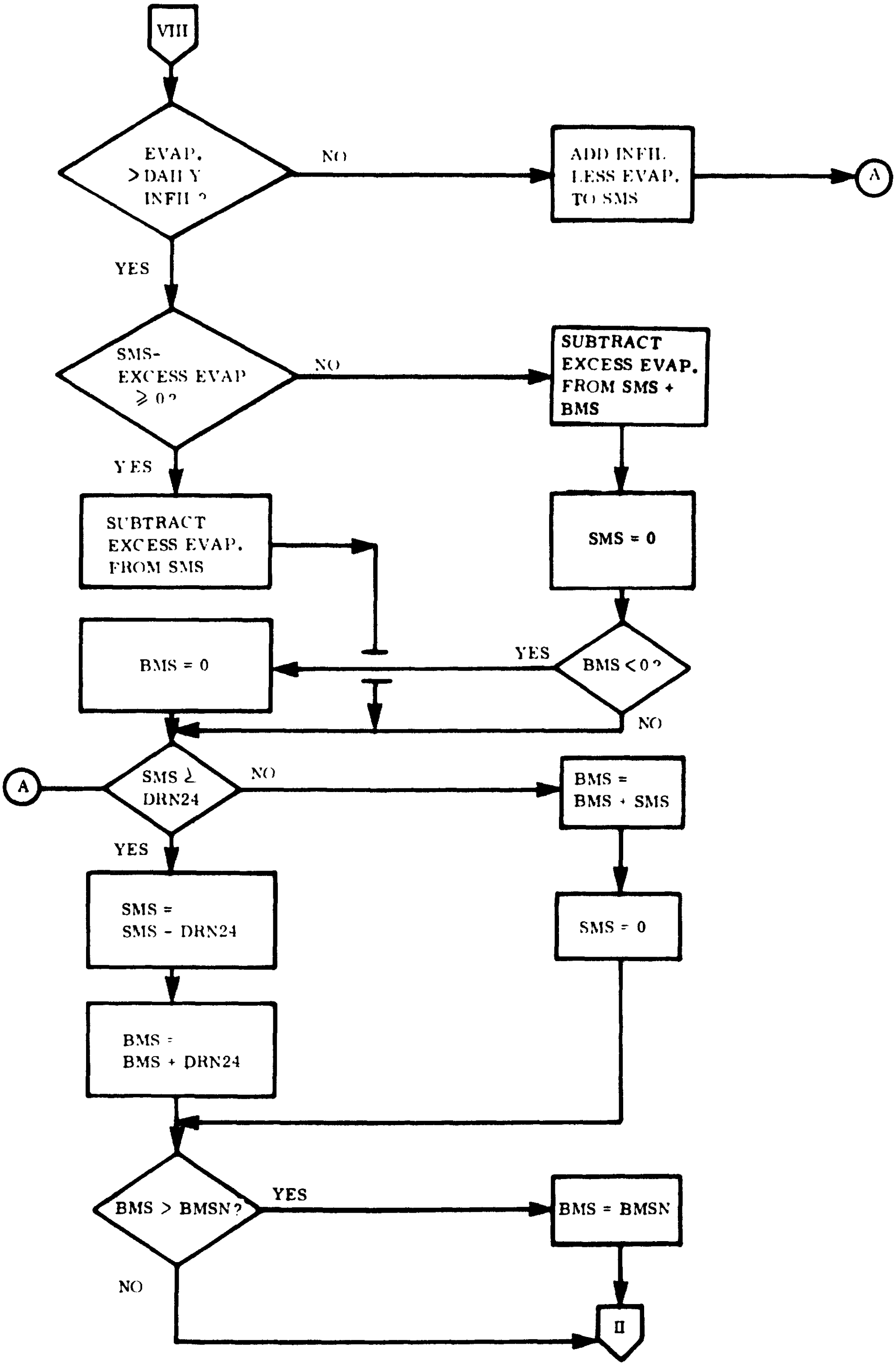

Figure 9.--Flow chart of daily water balance.

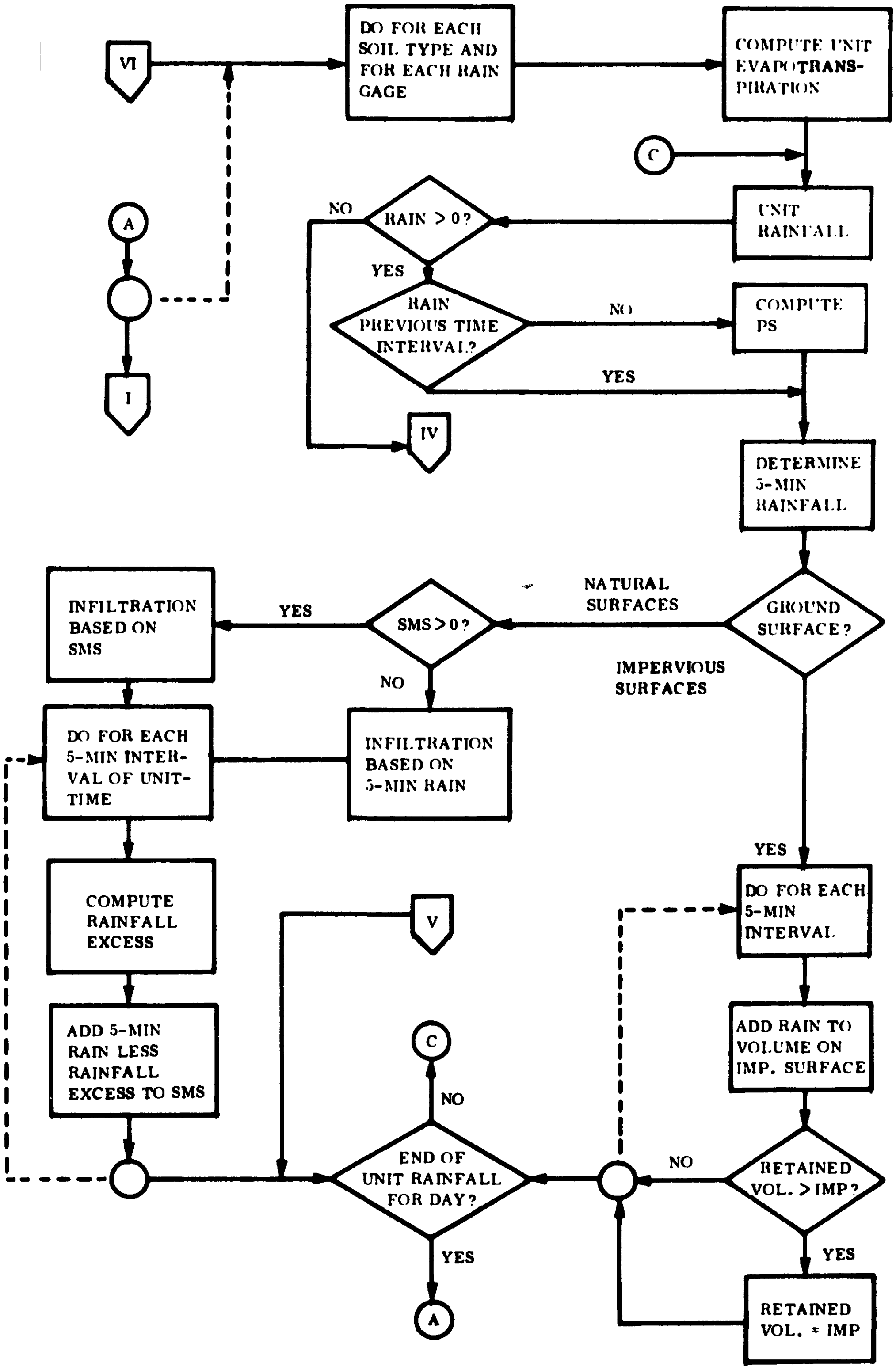

Figure 10.--Flow chart of rainfall excess.

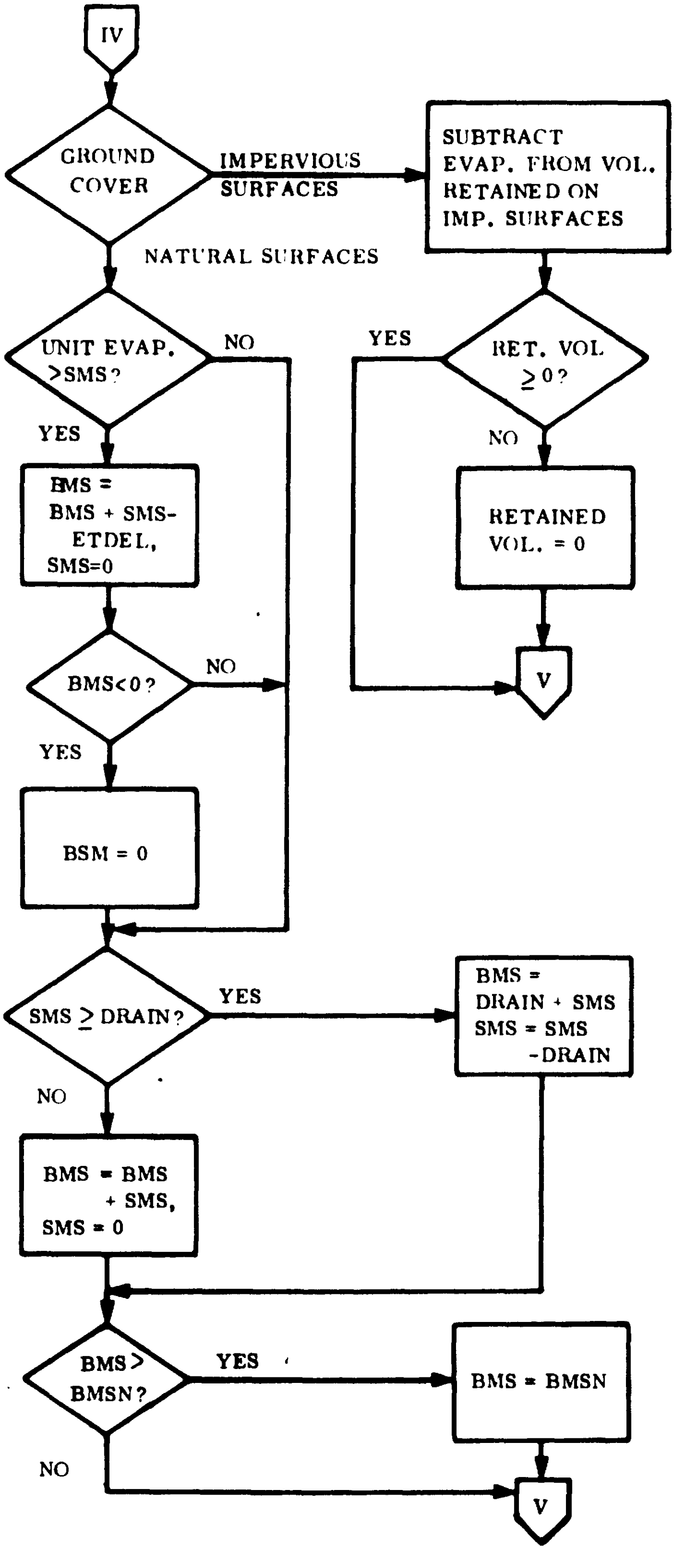

Figure 11.--Flow chart of unit-time water balance during periods of no rainfall.

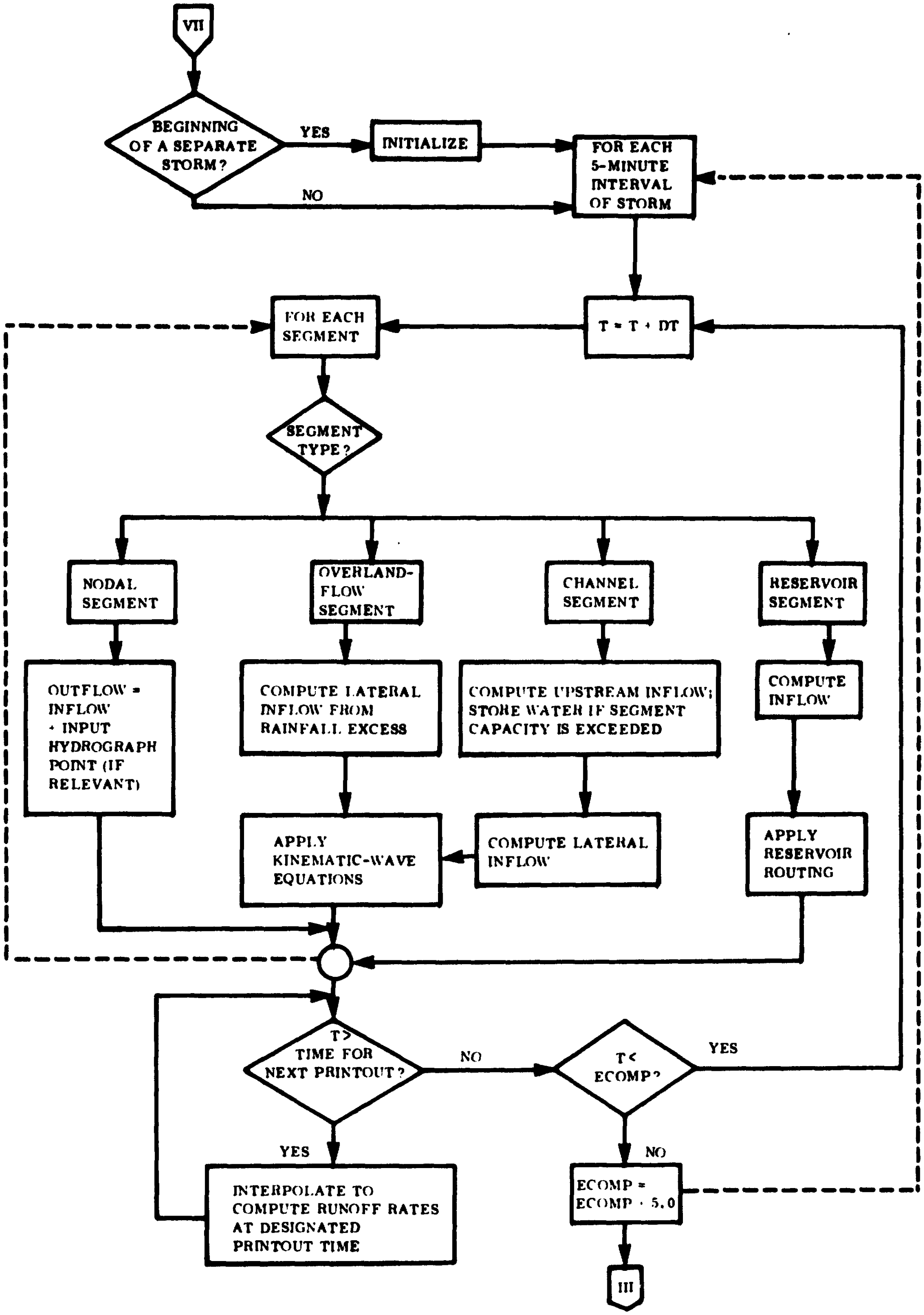

Figure 12.--Flow chart of routing routine.

B. LIST OF SELECTED VARIABLES

(A) Alphanumeric, (I) Integer, (R) Real

A -- Array containing step lengths and orthonormal search vectors used in optimization. First FO elements are step lengths to be applied to various vectors. The next FO x FO elements are used to define search pattern. (R)

ALAT -- Discharge per unit width (q) from lateral segment multiplied by Δt. (R)

ALP -- α. (R)

ALPHA -- Array of α's for segments. (R)

AP -- Excess precipitation per minute on impervious area of a segment. (R)

AMAX -- Array of maximum cross-sectional areas of flow from segments. (R)

AVIN -- Average inflow to a detention reservoir. (R)

BD -- Dummy variable used in orthonormalization. (R)

BDY -- Beginning day of daily rainfall and daily-evaporation data. (I)

BM0 -- Beginning month of daily rainfall and daily-evaporation data. (I)

BMS -- Base soil-moisture storage. (R)

BMSB -- Array of BMS's for rain gages and soil types. (R)

BTIME -- Unit-time interval, in minutes. (I)

BYR -- Beginning year of daily rainfall and daily-evaporation data (last two digits). (I)

B1,B2 -- Dummy variables used in orthonormalization (reflect efficiency of optimization procedures). (R)

B3 -- Indicator of continuing parameter adjustment (0--continuing, 1--terminated). (I)

CHG -- Indicator of whether rain occurred in preceeding time interval or not (0--Yes, 1--No). A 1 requires re-evaluation of PS. (I)

CN -- Card sequence number for various data types. (I)

C0DE -- Identifier of data type. (I)

C0EF -- Factor used in computation of infiltration rate, equivalent to (RGF-1.0)/BMSN. (R)

CØEF2 -- Same as CØEF, but for soil type 2. (R)

CT -- Recording interval of unit data, in minutes. (I)

D -- Array containing cumulative step length taken in direction of each search vector during a stage of optimization. (R)

DA -- Drainage area of basin, in square miles. (R)

DAT -- Computed drainage area of basin, in square miles. (R)

DATE -- Julian date relative to January 1, 1901. (I)

DATERF -- Julian date for beginning of record. (I)

DATERL -- Julian date for end of record. (I)

DCCN -- Dummy variable used to check unit-discharge data. (I)

DE -- Array containing daily evaporation. (R)

DED -- Julian date for observation of daily evaporation. (I)

DELTAT -- Time interval, in fraction of an hour, for reservoir routing. (R)

DEL5 -- Number of 5-minute intervals in unit-time interval. (I)

DEL5P -- DEL5 + 1. (I)

DIMP -- A two-dimensional array of drainage areas. (R)

DIMP(NRGI,1) is total effective impervious area covered by rain gage NRGI
DIMP(NRGI,2) is total effective impervious area covered by rain gage NRGI on subbasins of soil type 2
DIMP(NRGI+3,1) is pervious area covered by rain gage NRGI on subbasins of soil type 1.
DIMP(NRGI+3,2) is pervious area covered by rain gage NRGI on subbasins of soil type 2.
DIMP(NRGI+6,1) is noneffective impervious area covered by rain gage NRGI on subbasins of soil type 1.
DIMP(NRGI+6,2) is noneffective impervious area covered by rain gage NRGI on subbasins of soil type 2.

DP -- Array containing daily precipitation. (R)

DPD -- Julian date for daily precipitation. (I)

DRAIN -- Volume of water drained from saturated zone of soil type 1 in unit time. (R)

DRAIN2 -- Volume of water drained from saturated zone of soil type 2 in unit time. (R)

DRN24 -- Volume of water drained from saturated zone in 24 hours for soil type 1. (R)

DRN242 -- Volume of water drained from saturated zone in 24 hours for soil type 2. (R)

DT -- (a) Time interval (Δt) used in finite-difference calculations, in minutes. (R)

(b) Three-dimensional array of interim drainage areas used in the calculation of DIMP's and drainage area basin. (R)

DTEMP -- Drainage area of overland-flow segment to channel, used in calculation of DT's. (R)

DTEMP1 -- Drainage area used in adjustment of rain gage to basin. (R)

DTS -- Time interval (Δt) used in finite-difference calculations, in seconds. (R)

DX -- Array of length intervals (Δx), in feet, used in finite-difference calculations. (R)

DY -- Day of observed record. (I)

E -- Array containing switches (0,1) used in optimization to test for end of stage criterion (1--all switches). (I)

EC0MP -- Parameter to indicate end of 5-minute routing interval for a particular 5-minute precipitation interval in a detailed storm. (R)

EDY -- Ending day of daily rainfall and evaporation data. (I)

EM -- Array of *m*'s for segments. (R)

EM0 -- Ending month of daily rainfall and evaporation data. (I)

E0 -- Number of infiltration parameters. (I)

EP -- Excess precipitation per minute on pervious area. (R)

EPSLN -- Step size for parameter adjustment at beginning of each stage in optimization. (R)

ETDEL -- Potential unit-time evapotranspiration. (R)

ETW	-- Potential daily evapotranspiration for soil type 1. (R)
ETW2	-- Potential daily evapotranspiration for soil type 2. (R)
EVC	-- Pan coefficient for soil type 1. (R)
EVC2	-- Pan coefficient for soil type 2. (R)
EYR	-- Ending year of daily rainfall and evaporation data (last two digits). (I)
FILE	-- File number used to print plots on. (I)
FLAG	-- Indicator of change from daily rainfall to unit-rainfall day (0--Yes, 1--No). (I)
FLGTH	-- Array of segment flow lengths. (R)
FMTA,FMTB	-- Formatting variables for outputting which flood events are used in the objective function. (A)
FMTP,FMTP1	-- Formatting variables for outputting initial infiltration parameter values and which of these parameters are to be optimized. (A)
FØ	-- Number of parameters to be adjusted in current round. (I)
FPK	-- Array of observed peaks for flood events. (R)
FR	-- Infiltration rate, in inches per 5-minutes. (R)
FRN	-- Array of friction coefficients for segments. (R)
FVØL	-- Array of measured flood volumes for flood events, in inches. (R)
G	-- Array containing lower limits of infiltration parameters. (R)
GD,GØE	-- Dummy variables used in determining bounds of solution space for optimization. (R)
H	-- Array containing upper limits of parameters. (R)
HD	-- Dummy variable used in determining bounds of solution space for optimization. (R)
ICØDE	-- Indicator for termination of input-hydrograph data for a flood event (1--termination, 0--continuing). (I)
IFØP1	-- Do-loop counter for identifying infiltration parameters not to be adjusted in optimization. (I)

IHYD -- Array containing indicator of whether or not flood event has an input hydrograph (1--Yes, 0--No). (I)

IJK -- Five-minute interval within sequence of days at which a storm ends. (I)

IJKS -- Five-minute interval within sequence of days at which a storm starts. (I)

ILAT -- Array of lateral inflow segments into indexed downstream segment. (A)

IMP -- Maximum impervious retention depth, in inches. (R)

IMPRET -- Array of 5-minute incremental depths added to impervious retention, in inches. (R)

IMPST0 -- Array of impervious retention storage for rain gages during previous time interval, in inches. (R)

IMPSTT -- Impervious retention storage for a given rain gage during current time interval. (R)

INC -- Difference between daily infiltrated rainfall and daily evapotranspiration for soil type 1. (R)

INC2 -- Difference between daily infiltrated rainfall and daily evapotranspiration for soil type 2. (R)

INDP -- Array of starting and ending days of gap in daily record. (I)

IN1 -- Array of inflows to detention reservoir segments at beginning of given time interval. (R)

IN2 -- Array of inflows to detention reservoir segments at end of given time interval. (R)

I0UT -- Array used with 0PTI0N to determine whether daily and unit data are to be listed. (A)

IPAR -- Dummy variable used to identify soil type for excess precipitation calculation on a segment. (I)

IPL -- Array containing indicator of whether or not outflow from the drainage basin is to be plotted for a flood event. (1--Yes, 0--No). (I)

IPR -- Array of indicators of outflow hydrograph printing for segments (1--print outflow hydrograph, 0--do not print outflow hydrograph). (I)

IPRNT -- Counter for printing hydrograph. (I)

IRR -- Array of monthly irrigation rates, in inches per week. (R)

ISEG -- Alphanumeric identifier for segment. (A)

ITEST -- Array of indicators of whether or not segment has been sequenced (1--Yes, 0--No). (I)

ITRAN -- Dummy variable used in renumbering lateral and upstream inflow segments. (I)

ITYPE -- Array of segment types. (I)

IUP -- Array of upstream inflow segments into indexed downstream segment. (A)

IW -- Counter for days during simulation. (I)

I2CFSP -- Conversion factor for converting runoff in inches per unit time per unit area to discharge in cubic feet per second. (R)

JLAT -- Array of lateral inflow segments which have been renumbered from ILAT to correspond to ISEG identifications. (I)

J0UT -- Array of segments with output hydrographs. (I)

JUP -- Array of upstream inflow segments which have been renumbered from IUP to correspond to ISEG identifications. (I)

KDAY -- Five-minute precipitation interval in a detailed storm. (I)

KDY -- Five-minute precipitation interval in a detailed storm. (I)

KE -- Ending unit-time interval for storm. (I)

KI -- Counter for channel segments. (I)

KINIT -- Indicator for calling subroutine INIT to initialize catchment (1--Yes, 0--No). (I)

KIT -- Dummy variable used in printing time of peak flow during a flood event. (I)

KNN -- Number of flood events used in optimization. (I)

K0UT -- Indicator of whether or not detailed output is printed for a storm (1--Yes, 0--No). (I)

KPSET -- Array of soil types for segments (1--soil type 1, 2--soil type 2). (I)

KR -- Indicator of whether or not excess precipitation occurred during a 5-minute time interval (1--Yes, 0--No). (I)

KS -- (a) Starting unit-time interval for storm,
    (b) Array of segments which are not overland-flow segments. (I)

KSAT -- Effective hydraulic conductivity of saturated soil type 1. (R)

KSAT2 -- Effective hydraulic conductivity of saturated soil type 2. (R)

KSEG -- Array of segments ordered in downstream order. (I)

KTEMP -- Day of unit-time simulation. (I)

K1 -- Array of beginning times of detailed storms. (I)

K2 -- Array of ending times of detailed storms. (I)

K4DAY -- Number of unit-time increments in a flood event. (I)

LABEL -- Array containing the string of characters to be printed at left edge of all plots. (A)

LEAP -- Indicator of leap year (1--Yes, 0--No). (I)

MAXL -- Maximum lines per page of printed output (55). (I)

MN -- Array containing cumulative numbers of days (in nonleap year) to end of preceding month. (I)

M0 -- Month of observed record. (I)

N -- (a) Dummy variable used for boundary in finite-difference calculations,
    (b) Indicator of whether segment has an upstream segment which has not been sequenced in downstream order yet (1--Yes, 0--No). (I)

NDATE -- Array of storm dates. (I)

NDELS -- Number of unit-time intervals in a day. (I)

NDX -- (a) Number of intervals (Δx) for finite-difference routing. (I)
    (b) Number of points in storage-outflow relationship for a modified-Puls detention reservoir.

NF -- Array of number of storms in the sequence of days containing a given storm. (I)

NFD -- Number of storm sequence. (I)

NFD1 -- Number of days of routing thus far in given storm sequence. (I)

NFE -- Array of ending 5-minute intervals for storms. (I)

NFI1 -- Number of storms remaining to be analyzed for observed volume and peak in given storm sequence. (I)

NFS -- Array of starting 5-minute intervals for storms. (I)

NHL -- Number of horizontal grid lines in the graph. (I)

NIT -- Number of iterations during segment sequencing. (I)

NK -- Total number of iterations in an optimization round. (I)

NL -- Number of lines of output on a given page. (I)

NN -- Subscript for objective function used. (I)

N0 -- Sequence counter to identify current search vector. (I)

N0FE -- Number of flood events. (I)

N0PT1 -- Indicator of whether or not daily rainfalls are to be modified for irrigation (1--Yes, 0--No). (I)

N0UD -- Array containing sequence date for I-th day of unit discharge, I = 1,...,NUDD. (I)

N0UP -- Array containing sequence date of I-th day of unit precipitation, I = 1,...,NUPD. (I)

N0UT -- Number of segments with outflow hydrograph to be printed. (I)

N08 -- Number of modified-Puls detention reservoir segments. (I)

N09 -- Ten + the number of linear-storage detention reservoir segments. (I)

NPAGE -- Page number used by subroutine PAGE to number output pages. (I)

NPAR -- Number of soil types. (I)

NRG -- Number of rain gages. (R)

NRGI -- Rain gage I. (I)

NRG1 -- NRG + 1. (I)

NSBH -- Number of spaces between horizontal grid lines. (I)

NSBV -- Number of spaces between vertical grid lines. (I)

NSCALE -- Variable used to define the format of the ordinate and abscissa label scaling factor. (I)

NSEG -- Number of segments. (I)

NUDD -- Number of days of unit discharge. (I)

NUPD -- Number of days of unit rainfall. (I)

ØF -- Dummy variable containing minimum of error function determined prior to current iteration in optimization. (R)

ØPT -- Option to read in storm volume. (A)

ØPTIØN -- Option to list data (ØPTIØN = LIST--all input data are printed. (A)

ØPTNØ -- Array containing subscripts to identify parameters to be adjusted in round of optimization. (I)

ØSI -- Output sampling interval. (R)

Ø1 -- Indicator of whether current flow is first flow of storm. (0--Yes, 1--No). (I)

Ø2 -- Array of outflows in outflow-storage relationship for modified-Puls detention reservoir segments. (R)

P -- Array of excess precipitation during 5-minute intervals from each rain gage. (R)

PARAM -- Pair of parameters for a segment. (R)

PCCN -- Dummy variable used to check unit-precipitation data. (I)

PDEL -- Unit-time interval expressed as a fraction of a day. (R)

PDT -- Dummy variable used in the calculation of storage due to surcharging. (R)

PIMP -- Array of excess precipitation volumes from pervious surfaces for flood events. (R)

PK -- Indicator of whether or not overland-flow segment is of a particular soil type. (1--Yes, 0--No). (R)

PØBS -- Array of observed rainfall volumes for flood events. (R)

PS -- Product of capillary suction and moisture differential at wetting front. (R)

PSP -- Minimum effective magnitude of PS for soil type 1 (occurs at field capacity, BMS=BMSN). (R)

PSP2 -- Minimum effective magnitude of PS for soil type 2. (R)

PSUM -- Array of total excess precipitation for each flood event and rain gage. (R)

PTIME -- Time increment for unit data, in minutes. (R)

PW -- Amount of daily precipitation which infiltrates for soil type 1. (R)

PW2 -- Amount of daily precipitation which infiltrates for soil type 2. (R)

Q -- Array of times for plotting. (R)

QCW -- Simulated runoff volume in square feet-inches for a flood event. (R)

QFULL -- Discharge at full-pipe flow. (R)

QIH -- Array of input-hydrograph discharges. (R)

QIND -- Current outflow from drainage basin. (R)

QLAT -- Variable for lateral inflow onto a segment (q) in finite-difference routing. (R)

QMAX -- Array of maximum possible discharges for segments. (R)

QMX -- Peak flow during a storm. (R)

QOUT -- Array of computed output discharges for segments. (R)

QPR -- (a) In subroutine LAT,-- $q(t)$ in finite-difference routing;
(b) In subroutine UP-- $Q(o,t)$ in finite-difference routing. (R)

QR -- (a) Excess rainfall in 5-minute interval,
(b) Baseflow. (R)

QSUM -- Array of sum of upstream inflows to segments. (R)

QSUML -- Array of sum of lateral inflows to segments. (R)

QUP -- $Q(o, t+\Delta t)$ in finite-difference routing. (R)

Q1 -- Outflow from a segment at time t. (R)

Q2 -- Outflow from a segment at time t + Δt. (R)

Q3 -- Variable set to current unit discharge when computing baseflow, measured peak flow, and measured discharge volume. (R)

R -- Array of discharges for plotting. (R)

RAT -- Array of ratios of pervious area + noneffective impervious area to pervious area for each rain gage and soil type. (R)

RATI0 -- Dummy variable used in comparing computed drainage area with furnished drainage area. (R)

RC0EF -- Array of "Theissen coefficients" for segments. (R)

RGF -- Ratio of maximum PS (at wilting point) to minimum PS (at field capacity) for soil type 1. (R)

RGF2 -- Ratio of maximum PS to minimum PS for soil type 2. (R)

RITE -- Indicator of progress in parameter adjustment (0--continuing, 1--end of stage in optimization, print results). (I)

RK -- Sum of "Thiessen coefficients" for all rain gages on a segment. (R)

R0DYS -- Number of days from start to end of record. (I)

RR -- Ratio of daily infiltration to daily rainfall for soil type 1. (R)

RR2 -- Ratio of daily infiltration to daily rainfall for soil type 2. (R)

SEG -- Array of segments for outputting hydrographs. (R)

SF -- Scale factor to determine initial step lengths in a stage of optimization. (R)

SFPK -- Array containing maximum simulated discharge for flood events, in cubic feet per second. (R)

SFV0L -- Array containing simulated runoff volume for flood events, in basin inches. (R)

SL0PE -- Array of segment slopes. (R)

SMAX -- Array of maximum storage during a flood event for detention reservoirs. (R)

SMS -- Soil moisture storage in saturated zone (volume of infiltration during period). (R)

SMSB -- Array of SMS's for soil types and rain gages. (R)

SR -- Five-minute rainfall supply rate to pervious surfaces (adjusted for contribution from noneffective impervious surfaces). (R)

SRP -- Five-minute rainfall supply rate to effective impervious surfaces. (R)

SRV -- Dummy variable for simulated runoff volume. (R)

S2 -- Array of storages in outflow-storage relationship for modified-Puls detention reservoir segments. (R)

T -- Time in finite-difference routing. (R)

TEMP -- Dummy variable used in sequencing nonoverland-flow segments in downstream order. (R)

TESTNØ -- Array containing indicator of whether or not flood event is used (1--Yes, 0--No). (I)

TØUT -- Array of times (from beginning of storm) of output hydrograph point. (R)

TRYCT -- Iteration count for set of parameters. (I)

U -- Array containing objective functions. (R)

UD -- Array containing unit-discharge data. (R)

UDD -- Sequence date of unit discharge. (I)

UNN1 -- Boundary value of root mean square error. (R)

UNN2 -- Boundary value of root mean square error. (R)

UPD -- Sequence date of unit rainfall. (I)

UPR -- Array containing unit-precipitation data. (R)

UU -- Dummy variable for objective function in current iteration. (R)

U1,U2 -- Dummy variables for specific objective functions. (R)

VØLI -- Furnished volume of storm runoff, in inches. (R)

W -- Counter for day of record. (I)

X -- (a) Array containing magnitudes of infiltration parameters.
(b) Array of abscissa coordinates for plotting. (R)

XMAX -- Value of abscissa at the rightmost grid line. (R)

XMIN -- Value of abscissa at the leftmost grid line. (R)

XX -- Dummy variable for infiltration parameters. (R)

YMAX -- Value of ordinate at the uppermost grid line. (R)

YMIN -- Value of ordinate at the lowermost grid line. (R)

YN -- Array containing cumulative number of days counted from January 1, 1901 at end of preceding year. (I)

YR -- Year of observed record (last two digits). (I)

C. PROGRAM LISTING

```
C     ****************************************************************
C     *                                                              *
C     *      J347--DISTRIBUTED ROUTING RAINFALL-RUNOFF               *
C     *                             MODEL FOR URBAN PLANNING         *
C     *                                                              *
C     *                 OPERATIONAL MODELS PROJECT                   *
C     *               GULF COAST HYDROSCIENCE CENTER                 *
C     *                 U. S. GEOLOGICAL SURVEY - WRD                *
C     *          DATE OF LAST PROGRAM REVISION: AUG 15, 1978         *
C     *                                                              *
C     ****************************************************************
      INTEGER IOUT(2),INDP(50)
      INTEGER EO,FO,OPTNO(25),B3,TRYCT,D1,MN(13),E(26),F(26)
      INTEGER PCCN,DCCN,RODYS,DELS,DPD,DED,DATERF,DATERL,BTIME,DATE
      INTEGER STA,STAD,STAD1,STAUP,STAUP1,STAP,STAP1,STAE,STAE1
      INTEGER YR,MO,DY,BYR,BMO,BDY,EYR,EMO,EDY,CN,CT,CODE,OPTION,OPT
      INTEGER NOUD(115),NOUP(115),YN(84),UPD,UDD,IPR(50)
      INTEGER RITE,W,CHG,FLAG,DELSP,TESTNO(60)
      INTEGER FILE
      REAL IRR
      DIMENSION TITLD(50), TITLUP(50), TITLP(50), TITLE(50), X2(16)
      DIMENSION PIMP(60,3), IRR(12)
      DIMENSION K1(60), K2(60)
C            IF PLOTTING ROUTINE NOT ACCEPTED BY COMPUTER
C            PULL OUT LOGICAL*1 IMAGE(5200)
      LOGICAL*1 IMAGE(5200)
      REAL ISEG,IUP,ILAT
      COMMON /C1/ NSEG,ISEG(50),IUP(50,3),NPAR,KPSET(50)
      COMMON /C2/ NL,NPAGE
      COMMON /C3/ IPRNT,T,AR(50,11),FLGTH(50),KSEG(50),NDX(50),Q1(50),Q2
     1(50),QSUM(50),QSUML(50),STO(50)
      COMMON /C4/ DEL5,MAXL,QCW,QLAT,ILAT(50,4),ITEST(50),ITYPE(50),JLAT
     1(50,4),JUP(50,3),P(3456,3),PARAM(50,2),RCOEF(50,3),UPR(7200)
      COMMON /C5/ ALPHA(50),EM(50),FRN(50),QMAX(50),SLOPE(50)
      COMMON /C6/ DT,DTS,QUP,DX(50)
      COMMON /C7/ ECOMP,I,KINIT,NOUT,NRG,OSI,JOUT(50),QIND,RAT(3,2)
      COMMON /C8/ I2,I1,IK,TRYCT,KOUT(60),SEG(50)
      COMMON /C9/ I3,I4,QIH(1728),PTIME,IHYD(60),IJ,IP
      COMMON /D1/ DP(1000),RODYS
      REAL IMP,IMPRET,IMPSTT,IMPSTO
      REAL IN1,IN2
      COMMON /E1/ IMPRET(1728,3),IMPSTO(3)
      DIMENSION IRES(30), O2(50,30)
      COMMON /E2/ SMAX(50),IN2(50),IN1(50),S2O2(50)
      COMMON /E3/ DELTAT,NO8,QS(50,11)
      COMMON /E4/ WV(50,30),S1(50,30),C1(50,30)
      COMMON /E5/ S2(50,30),S(50,30),C(50,30)
      COMMON /F1/ ICT,Q(1728),R(1728),IPL(60)
      COMMON /PARAM/ NSCALE(1),NHL,NSBH,NVL,NSBV,XMAX,XMIN,YMAX,YMIN,FIL
     1E,CH,N3,ND,LABEL(12)
      INTEGER NF(60),NFE(60),NFS(60),NDATE(60,3),KQ
      REAL UD(7200),DE(1000)
      REAL KDRAIN,PS,PSP,PW,Q1,QR,DRAIN,RGF,BMSN,FPK(60),PSUM(120,3),RR
      REAL COEF,DRN24,ETDEL,ETW,EVC,FR,INC,KSAT,SQ,BMS,SMS
      REAL SFPK(60),PDEL,I2CFSP
      REAL EPSLN,XX,GOE,OF,B1,B2,X(75),G(75)
      REAL H(75),U(3),A(76),D(76),DIMP(9,2)
      REAL UU,SF,BD,GD,HD
      REAL EVC2,RR2,DRN242,DRAIN2,PW2,ETW2,INC2,KSAT2
      REAL Q3,SRV,QMX,SMSB(3,2),BMSB(3,2),FVOL(60),SFVOL(60),POBS(60,3)
      REAL FMTP(9),FMTP1(10),FMTA(6),FMT3(43)
```

```
      DATA FMTA/1H ,3H,I3,1H(,1H),3H,3X,3H1H+/
      DATA FMTP1/3HPSP,4HKSAT,3HRGF,4HBMSN,3HEVC,2HRR,3HDRN,4H,3X,,3H1H+
     1,1H /
      DATA FMTP/4H(1H ,4H,I3,,4H3X,F,4H12.6,4H,3X,,2HA4,1H ,1H ,1H)/
      DATA MN/0,31,59,90,120,151,181,212,243,273,304,334,365/,QMX/0.0/
      DATA B3/0/,FLAG/1/,O1/0/,IOUT/4HLIST,4H  NO/,Q3/0.0/,SRV/0.0/
      DATA OF/1.0E+50/,B1/0.0/,B2/0.0/,PCCN/0/,DCCN/0/,UPD/0/,UDD/0/
C             INITIALIZE DIMP TO ZERO
      DO 30 J=1,2
      DO 10 K=1,3
   10 RAT(K,J)=0.0
      DO 20 I=1,9
   20 DIMP(I,J)=0.0
   30 CONTINUE
C             JULIAN DATE FOR JAN. 1 OF EACH YEAR
C             STARTING FROM JAN. 1, 1901
      YN(1)=0
      DO 40 I=2,84
      YN(I)=YN(I-1)+365
      IF (MOD(I-1,4).EQ.0) YN(I)=YN(I)+1
   40 CONTINUE
C             INITIALIZE TO ZERO
      DO 50 I=1,7200
   50 UPR(I)=0.0
      NRG=0
      DO 60 I=1,12
   60 IRR(I)=0.0
      JCW=0.0
      NDAY=0
      DO 70 I=1,7200
   70 UD(I)=0.0
      DO 80 I=1,1000
      DP(I)=0.0
   80 DE(I)=0.0
C             OPTION=IOUT(1) LISTS INPUT DATA.
      READ (5,2020) OPTION,OPT,NOPT1
      IF (NOPT1.EQ.0) GO TO 100
      READ (5,2000) (IRR(I),I=1,12)
      DO 90 I=1,12
   90 IRR(I)=IRR(I)/7.
      WRITE (6,2010) (IRR(I),I=1,12)
C             READ-IN STA.NOS. AND NAMES,DA,UNIT TIME, BEGIN AND END
C             DATES.   STATION NUMBERS READ 2A4 FOR IBM WORD SIZE.
  100 READ (5,2040) STAD1,STAD,TITLD,DA
      READ (5,2040) STAP1,STAP,TITLP
      READ (5,2040) STAE1,STAE,TITLE
      READ (5,2060) BYR,BMO,BDY,EYR,EMO,EDY
C             INITIALIZE VARIABLES
      NUPD=0
      DO 110 I=1,115
      NUJD(I)=0
  110 NOUP(I)=0
  120 UPD=0
      PCCN=0
      NRG=NRG+1
      IF (NRG.GT.1) WRITE (6,2510)
      NUDD=0
      READ (5,2050) STAUP1,STAJP,TITLUP,PTIME
C             DETERMINE JULIAN DATE FOR BEGIN AND END OF RECORD.
C             DATE=1 FOR JAN. 1, 1901
      IF (MOD(BYR,4).NE.0) GO TO 130
```

```
      IF (BMO-2) 130,130,140
  130 LEAP=0
      GO TO 150
  140 LEAP=1
  150 DATERF=YN(BYR)+MN(BMO)+BDY+LEAP
      IF (MOD(EYR,4).NE.0) GO TO 160
      IF (EMO-2) 160,160,170
  160 LEAP=0
      GO TO 180
  170 LEAP=1
  180 DATERL=YN(EYR)+MN(EMO)+EDY+LEAP
C               CALCULATE NUMBER OF DAYS OF RECORD
      NODYS=DATERL-DATERF+1
      WRITE (6,2070) STAD1,STAD,TITLD,STAUP1,STAUP,TITLUP,STAP1,STAP,TIT
     1LP,STAE1,STAE,TITLE,DA,PTIME,BMO,BDY,BYR,DATERF,EMO,EDY,EYR,DATERL
C               COMPUTE TIME PARAMETERS
C               NDAY IS SET TO STARTING TIME ELEMENT FOR A RAIN GAGE
      PDEL=PTIME/1440.0
      NDELS=1440/PTIME
      NDAY=NUPD*NDELS*(NRG-1)
      NUPD=0
      BTIME=PTIME
      DPD=DATERF-1
      DED=DPD
      DEL5=BTIME/5
      DEL5P=DEL5+1
C               READ IN DATA FROM A CARD
C               PERFORM EDIT CHECK ON STATION NO., UNIT TIME, AND
C               CHRONOLOGICAL SEQUENCE OF CARD
C               ENTER DATA INTO ARRAYS ACCORDING TO CODING
C               CHECK LAST FOUR CHARACTERS OF STATION NOS. ONLY
C               DATES FOR CODES 1 AND 2
      IF (OPTION.EQ.IOUT(1)) WRITE (6,2510)
      KP=0
  190 READ (5,2080) STA1,STA,YR,MO,DY,CT,CN,(X2(I),I=1,12),CODE
      IF (CODE.EQ.8) GO TO 120
      IF (CODE.EQ.9) GO TO 320
      IF (MOD(YR,4).NE.0) GO TO 200
      IF (MO-2) 200,200,210
  200 LEAP=0
      GO TO 220
  210 LEAP=1
  220 DATE=YN(YR)+MN(MO)+DY+LEAP
      IF (CODE.EQ.2) GO TO 270
C               DATA ENTRIES FOR CODE 1
      IF (STA.NE.STAUP) GO TO 430
      IF (CT.NE.BTIME) GO TO 430
      IF (DATE-UPD) 430,240,230
  230 NUPD=NUPD+1
      NDATE(NUPD,1)=DY
      NDATE(NUPD,2)=MO
      NDATE(NUPD,3)=YR
      NOUP(NUPD)=DATE
      UPD=DATE
      PCCN=CN
      GO TO 250
  240 IF (CN.LE.PCCN) GO TO 430
      PCCN=CN
C               NDAY IS NUPD*NDELS*(NRG-1) WITH NRG UPDATED EACH GAGE READ
  250 K4DAY=NDELS*(NUPD-1)+12*CN+NDAY
      KK=K4DAY-11
```

```
      I=0
      DO 260 K=KK,K4DAY
      I=I+1
      X2(I)=X2(I)/100.0
  260 UPR(K)=X2(I)
      IF (OPTION.NE.IOUT(1)) GO TO 190
      WRITE (6,2090) STAUP1,STA,YR,MO,DY,CT,CN,(X2(I),I=1,12),CODE
      GO TO 190
C               DATA ENTRIES FOR CODE 2
  270 IF (STA.NE.STAD) GO TO 430
      IF (CT.NE.BTIME) GO TO 430
      IF (DATE-UDD) 430,290,280
  280 NUDD=NUDD+1
      NUDD(NUDD)=DATE
      UDD=DATE
      DCCN=CN
      GO TO 300
  290 IF (CN.LE.DCCN) GO TO 430
      DCCN=CN
  300 K4DAY=NDELS*(NUDD-1)+12*CN
C               ENTER DATA INTO ARRAYS ACCORDING TO CODE TYPE
      KK=K4DAY-11
      I=0
      DO 310 K=KK,K4DAY
      I=I+1
  310 UD(K)=X2(I)
      IF (OPTION.NE.IOUT(1)) GO TO 190
      WRITE (6,2090) STAD1,STA,YR,MO,DY,CT,CN,(X2(I),I=1,12),CODE
      GO TO 190
C               DATES FOR CODES 3+4
  320 READ (5,2100) STAD1,STA,YR,MO,CN,(X2(I),I=1,16),CODE
      IF (CODE.EQ.9) GO TO 440
      IF (CODE.EQ.4) GO TO 340
      DO 330 I=1,16
      IF (X2(I).GE.IRR(MO).OR.X2(I).LT.0.0) GO TO 330
      X2(I)=IRR(MO)
  330 CONTINUE
  340 CONTINUE
      IF (OPTION.NE.IOUT(1)) GO TO 350
      WRITE (6,2110) STAD1,STA,YR,MO,CN,(X2(I),I=1,16),CODE
  350 CONTINUE
      LEAP=0
      IF (MOD(YR,4).EQ.0) LEAP=1
      IF (CN.LT.2) GO TO 370
      DATE=YN(YR)+MN(MO)+17
      IF (MO.LE.2) GO TO 360
      DATE=DATE+LEAP
  360 II=YN(YR)+MN(MO+1)-DATE+1
      IF (MO.LE.1) GO TO 390
      II=II+LEAP
      GO TO 390
  370 DATE=YN(YR)+MN(MO)+1
      IF (MO.LE.2) GO TO 380
      DATE=DATE+LEAP
  380 II=16
  390 IF (CODE.EQ.4) GO TO 410
C               DATA ENTRIES FOR CODE 3
      IF (STA.NE.STAP) GO TO 430
      IF (DATE.LE.DPD) GO TO 430
      DPD=DATE
      II=II+DPD-DATERF
```

```
      KK=DPD-DATERF+1
      I=0
      DO 400 K=KK,II
      I=I+1
C               CHECK FOR GAP IN DAILY RECORD
      IF (X2(I).NE.99.99)  GO TO 400
C               IF THERE IS A GAP SET UP INDICATORS FOR THIS
      KP=KP+1
      INDP(KP)=K
      X2(I)=0.0
  400 DP(K)=X2(I)
      GO TO 320
C               DATA ENTRIES FOR CODE 4
  410 IF (STA.NE.STAE) GO TO 430
      IF (DATE.LE.DED) GO TO 430
      DED=DATE
      II=II+DED-DATERF
      KK=DED-DATERF+1
      I=0
      DO 420 K=KK,II
      I=I+1
  420 DE(K)=X2(I)
      GO TO 320
C               PRINT CARD WITH INCONSISTENT DATA
  430 WRITE (6,2120) STA,STAP,DATE,DPD,CODE
      STOP
  440 CONTINUE
      INDP(KP+1)=II+1
      I=0
      J=1
C               CHECK FOR INPUT DATA ERRORS
      L=NOUD(1)
      M=NOUP(1)
      K=0
      IF (OPT.EQ.1) GO TO 480
      IF (L.EQ.M) GO TO 460
  450 WRITE (6,2130) K,L,M
      STOP
  460 DO 470 K=DATERF,DATERL
      I=I+1
      IF (DP(I).GE.0.0) GO TO 470
      IF (K.NE.L) GO TO 450
      IF (K.NE.M) GO TO 450
      J=J+1
      L=NOUD(J)
      M=NOUP(J)
  470 CONTINUE
C               *  INITIAL OPTIMIZATION ROUTINE *
  480 DO 490 I=1,3
  490 U(I)=0.0
      READ (5,2140) EO,FO,K,EPSLN
      NN=2
      NPAR=1
      IF (EO.GT.7) NPAR=2
      DO 500 I=1,EO
  500 READ (5,2150) X(I),G(I),H(I)
      READ (5,2360) (OPTNO(I),I=1,FO)
      IFOP1=FO+1
      DO 510 I=IFOP1,EO
  510 OPTNO(I)=0
C               SET MAXIMUM TRYCT
```

```
      NK=K*FO
      IF (NK.EQ.0) B3=1
      DO 520 I=1,76
      A(I)=0.0
  520 D(I)=0.0
      DO 530 I=1,26
      E(I)=0
  530 F(I)=0
      TRYCT=0
C             CHECK IF INITIAL PARAMETER VALUE WITHIN OUTER BOUNDARY
C             VALUES
      DO 550 I=1,EO
      XX=X(I)
      IF (XX.LE.G(I)) GO TO 540
      IF (XX.GE.H(I)) GO TO 540
C             STORE INITIAL PARAMETER VALUES
      X(EO+I)=XX
      GO TO 550
C             IF PARAMETER VALUES NOT WITHIN BOUNDARY VALUES
C             PRINT ERROR MESSAGE
  540 WRITE (6,2160) I,G(I),X(I),H(I)
      STOP
  550 CONTINUE
      DO 560 I=1,EO
      L=2*EO+I
      G(L)=0.0
      H(L)=0.0
      K=EO+I
C             COMPUTE INNER BOUNDARY VALUES
      GOE=(H(I)-G(I))*0.0001
      G(K)=G(I)+GOE
  560 H(K)=H(I)-GOE
C             ENTER A(I) = 0.0 INTO ARRAY
      L=FO+1
      DO 570 I=1,FO
      LJ=L*I
      A(LJ)=1.0
C             COMPUTE INITIAL STEP SIZE
      J=OPTNO(I)
      A(I)=X(J)*EPSLN
  570 CONTINUE
C             DESCRIBE INFILTRATION PARAMETERS
      WRITE (6,2170)
      J=1
      DO 580 I=1,EO
      FMTP(7)=FMTP1(10)
      FMTP(8)=FMTP1(10)
      K=I
      IF (I.GT.7) K=I-7
      IF (I.NE.OPTNO(J)) GO TO 580
      FMTP(7)=FMTP1(9)
      FMTP(8)=FMTP1(9)
      J=J+1
  580 WRITE (6,FMTP) I,X(I),FMTP1(K)
      NO=0
      IF (NK.EQ.0) GO TO 940
      WRITE (6,2180)
      WRITE (6,2190) (A(I),I=1,FO)
      WRITE (6,2200) NK,EPSLN
      GO TO 940
C             * MODIFIED ROSENBROCK OPTIMIZATION *
```

```
  590 UU=U(NN)
C             CHECK FOR IMPROVEMENT IN OBJECTIVE FUNCTION
      IF (UU.GT.OF) GO TO 650
C              NEW OBJECTIVE FUNCTION LESS THAN OLD OBJ. FUNCTION
      DO 620 I=1,FO
      M=OPTNO(I)
      XX=X(M)
      K=EO+M
      L=2*EO+M
C             CHECK ON INNER LOWER BOUNDARY
      IF (XX.GE.G(K)) GO TO 600
      GD=(G(K)-XX)/(G(K)-G(M))
      HD=UU-G(L)
      GO TO 610
C             CHECK ON INNER UPPER BOUNDARY
  600 IF (XX.LE.H(K)) GO TO 620
      GD=(XX-H(K))/(H(M)-H(K))
      HD=UU-H(L)
  610 UU=UU+((-2.0*GD+4.0)*GD-3.0)*GD*HD
      IF (UU.GT.OF) GO TO 650
  620 CONTINUE
C             SET OF TO NEW OBJ. FCT.
      OF=UU
      DO 630 I=1,FO
C             STORE OLD PARAMETER VALUE IN LAST THIRD OF MATRIX
      M=OPTNO(I)
      XX=X(M)
      K=EO+M
      L=2*EO+M
      X(L)=XX
C             CHECK ON INNER BOUNDARIES
      IF (XX.GT.H(K)) GO TO 630
      IF (XX.LT.G(K)) GO TO 630
C             ENTER CURRENT OBJ. FCT. IN G + H ARRAYS
      G(L)=UU
      H(L)=UU
  630 CONTINUE
      IF (NO.EQ.0) GO TO 640
C             F(I)=1 IF NEW PARAMETER VALUE IMPROVES OBJ. FCT.
      F(NO)=1
      E(NO)=0
C             COMPUTE CUMULATIVE STEP SIZE
      D(NO)=D(NO)+A(NO)
C             COMPUTE NEXT FORWARD STEP SIZE
      A(NO)=3.0*A(NO)
  640 WRITE (6,2210) TRYCT,U(2)
      WRITE (6,2220)
      WRITE (6,2230) (X(I),I=1,EO)
      IF (TRYCT.NE.NK) GO TO 680
      BB=1
      RITE=1
      GO TO 1360
C             IF NEW OBJ. FCT. EXCEEDS OLD OBJ. FCT.
C             SET PARAMETER TO PREVIOUS VALUE
  650 M=2*EO
      DO 660 I=1,FO
      K=OPTNO(I)
      LK=K+M
  660 X(K)=X(LK)
      GO TO 740
C             ROUTINE TO COMPUTE NEW PARAMETER VALUE
```

```
  670 IF (TRYCT.NE.NK) GO TO 680
      GO TO 640
  680 TRYCT=TRYCT+1
      OPTION=IOUT(2)
      IF (NO.EQ.FO) GO TO 690
      NO=NO+1
      GO TO 700
  690 NO=1
  700 DO 730 I=1,FO
      K=OPTNO(I)
      IFO=FO*I+NO
      XX=X(K)+A(IFO)*A(NO)
      IF (XX.LE.G(K).OR.XX.GE.H(K)) GO TO 710
      X(K)=XX
      GO TO 730
  710 L=2*EO
      IF (I.EQ.1) GO TO 740
      II=I-1
      DO 720 IJ=1,II
      I2=II+1-IJ
      K=OPTNO(I2)
      LK=L+K
  720 X(K)=X(LK)
      GO TO 740
  730 CONTINUE
      GO TO 1360
C             COMPUTES BACK STEP LENGTH(WHEN NEW OBJ. FCT. > OLD)
  740 IF (TRYCT.NE.NK) GO TO 750
      BJ=1
      RITE=1
      GO TO 1360
C             COMPUTE NEXT BACKWARD STEP SIZE
  750 A(NO)=-0.5*A(NO)
C             E(I)=1 INDICATES PARAMETER VALUE CHANGED BY BACKWARD
C             STEP SIZE
      E(NO)=E(NO)+1
C             DETERMINE IF BOTH BACKWARD AND FORWARD STEP SIZE
C             ADJUSTMENTS FAILED TO IMPROVE OBJ. FCT.
      DO 760 I=1,FO
      LJ=E(I)*F(I)
      IF (LJ.LE.0) GO TO 670
  760 CONTINUE
C             VECTOR ORTHONORMALIZED WHEN IPEF.GT.0 FOR ALL I
      DO 770 I=1,FO
      L=FO*(I+I)
      A(L)=D(FO)*A(L)
      K=FO*I
      IF (FO.EQ.1) GO TO 780
      LJ=FO-1
      DO 770 LK=1,LJ
      J2=FO-LK
      L=K+J2
  770 A(L)=D(J2)*A(L)+A(L+1)
C             NORMALIZE VECTOR LENGTHS TO 1.0
  780 BD=0.0
      DO 790 I=1,FO
      LJ=FO*I+1
  790 BD=A(LJ)**2+BD
      B1=SQRT(BD)
      DO 800 I=1,FO
      L=FO*I+1
```

```
  800 A(L)=A(L)/B1
C              RECOMPUTE STEP SIZE INCREMENT
      SF=0.0
      DO 810 I=1,FO
      K=OPTNO(I)
      L=FO*I+1
  810 SF=SF+ABS(A(L))*X(K)
      A(1)=SF*EPSLN
      BD=0.0
      DO 820 I=1,FO
      IK=FO*I+2
  820 BD=A(IK)**2+BD
      B2=SQRT(BD)/B1
      WRITE (6,2240) B1,B2
      J=2
  830 IF (FO.LT.J) GO TO 910
      K=1
      BD=0.0
  840 IF (K.GE.J) GO TO 870
      DO 850 I=1,FO
      L=FO*I
      LJ=L+J
      LK=L+K
  850 BD=BD+A(LJ)*A(LK)
      DO 860 I=1,FO
      L=FO*I+J
      LJ=L-J+K
  860 A(L)=A(L)-A(LJ)*BD
      K=K+1
      BD=0.0
      GO TO 840
  870 DO 880 I=1,FO
      LJ=FO*I+J
  880 BD=A(LJ)**2+BD
      BD=SQRT(BD)
      DO 890 I=1,FO
      L=FO*I+J
  890 A(L)=A(L)/BD
      SF=0.0
      DO 900 I=1,FO
      K=OPTNO(I)
      L=FO*I+J
  900 SF=SF+ABS(A(L))*X(K)
      A(J)=SF*EPSLN
      J=J+1
      GO TO 830
  910 WRITE (6,2250)
      DO 920 I=1,FO
      LJ=I*FO+1
      LK=I*FO+FO
  920 WRITE (6,2260) (A(IJ),IJ=LJ,LK)
      NO=0
      WRITE (6,2270) (A(I),I=1,FO)
      DO 930 I=1,FO
      D(I)=0.0
      F(I)=0
      K=OPTNO(I)
      LJ=EO+K
  930 X(LJ)=X(K)
      RITE=1
      GO TO 1360
```

```
  940 CONTINUE
      NPAGE=0
      MAXL=55
C               READ CATCHMENT DATA
      READ (5,2280) NSEG,DT,OSI,NRG,IMP
      DTS=DT*60.
      WRITE (6,2290) NSEG,DT,OSI,NRG,NPAR,IMP
      CALL PAGE
      WRITE (6,2300)
      NL=NL+4
      NO8=0
      NO9=10
      DO 1000 I=1,NSEG
      READ (5,2340) ISEG(I),(IUP(I,J),J=1,3),(ILAT(I,J),J=1,4),ITYPE(I),
     1IPR(I),NDX(I),FLGTH(I),SLOPE(I),FRN(I),(PARAM(I,J),J=1,2),KPSET(I)
     2,(RCOEF(I,J),J=1,NRG)
      IF (ITYPE(I).EQ.8) NO8=NO8+1
      IF (ITYPE(I).EQ.8) IRES(NO8)=I
      IF (ITYPE(I).EQ.9) NO9=NO9+1
      IF (ITYPE(I).EQ.9) IRES(NO9)=I
      IF (NDX(I)) 950,950,960
  950 NDX(I)=10
  960 NL=NL+1
      DX(I)=FLGTH(I)/NDX(I)
      IF (NL-MAXL) 990,980,980
  970 WRITE (6,1990)
      STOP
  980 CALL PAGE
      NL=NL+5
      WRITE (6,2300)
  990 WRITE (6,2350) ISEG(I),(IUP(I,J),J=1,3),(ILAT(I,J),J=1,4),ITYPE(I)
     1,IPR(I),NDX(I),FLGTH(I),SLOPE(I),FRN(I),(PARAM(I,J),J=1,2),KPSET(I
     2),(RCOEF(I,J),J=1,NRG)
      IF (ITYPE(I).NE.15.AND.ITYPE(I).NE.16) GO TO 1000
      IF (I.EQ.1) GO TO 970
      ITYPE(I)=ITYPE(I)-10
      IF (PARAM(I-1,2).NE.PARAM(I,2)) GO TO 970
      PARAM(I-1,2)=-PARAM(I-1,2)
      IF (PARAM(I-1,1).NE.PARAM(I,1)) GO TO 970
      PARAM(I,1)=-PARAM(I,1)
 1000 CONTINUE
      DELTAT=DT/60.
      IF (NO8.EQ.0) GO TO 1060
      DO 1050 I2=1,NO8
      K=IRES(I2)
      DDMIN=DELTAT
      J=NDX(K)
      DO 1010 II=1,J
      READ (5,2150) O2(K,II),S2(K,II)
      WV(K,II)=S2(K,II)/DELTAT+O2(K,II)/2.
      TEST=WV(K,II)-O2(K,II)
      IF (TEST.GE.0.0) GO TO 1010
      DDT=S2(K,II)/(O2(K,II)/2.0)
      IF (DDT.LT.DDMIN) DDMIN=DDT
      WRITE (6,2310) K,DDMIN
 1010 CONTINUE
      DO 1020 II=2,J
      S1(K,II)=(O2(K,II)-O2(K,II-1))/(WV(K,II)-WV(K,II-1))
      C1(K,II)=O2(K,II)-S1(K,II)*WV(K,II)
      S(K,II)=(O2(K,II)-O2(K,II-1))/(S2(K,II)-S2(K,II-1))
      C(K,II)=O2(K,II)-S(K,II)*S2(K,II)
```

```
 1020 CONTINUE
      NL=NL+5+NDX(K)
      IF (NL-MAXL) 1040,1030,1030
 1030 CALL PAGE
      NL=5+NDX(K)
 1040 WRITE (6,2320) ISEG(K)
      WRITE (6,2330) (D2(K,II),S2(K,II),WV(K,II),II=1,J)
 1050 CONTINUE
 1060 IF (NRG.EQ.3) GO TO 1090
C               SET THEISSEN COEFFICIENTS FOR UNUSED RAIN GAGES TO ZERO
      NRG1=NRG+1
      DO 1080 J=NRG1,3
      DO 1070 K=1,NSEG
 1070 RCOEF(K,J)=0.0
 1080 CONTINUE
 1090 CONTINUE
      IF (NL-MAXL+10) 1110,1110,1100
 1100 CALL PAGE
 1110 NL=NL+4
C               SET-UP KINEMATIC MODEL PARAMETERS
      CALL AM
C               SET-UP COMPUTATION SEQUENCE
      CALL SEQ (DA,DIMP)
C               SET-UP OUTPUT SEQUENCE
      NOUT=0
      DO 1130 I=1,NSEG
      IF (IPR(I)) 1130,1130,1120
C               SET-UP INDICATORS FOR SEGMENTS WITH PRINTED OUTFLOW
 1120 NOUT=NOUT+1
      JOUT(NOUT)=I
      SEG(NOUT)=ISEG(I)
 1130 CONTINUE
C               INITIALIZE VARIABLES
      DO 1140 III=1,NRG
 1140 IMPSTO(III)=0.0
      NOFE=1
      I1=1
      DO 1150 I=1,60
      FPK(I)=0.0
 1150 FVOL(I)=0.0
C               * STORM ANALYSIS * (PEAK, BASEFLOW, VOLUME)
C               NDAY IS SET TO NUMBER OF TIME INTERVALS FOR A RAIN GAGE
      NDAY=NUPD*NDELS
C               5280**2/12*60*60*24=26.888:  CONVERTS INCHES TO CFS
      12CFSP=26.8888889*DA*NDELS
C               FOR EACH SET OF EVENTS, THE NO. OF EVENTS IN THE SET
C               IS ENTERED FOR AS MANY TIMES AS THERE ARE EVENTS IN THE
C               SET. A SET OF EVENTS CONSISTS OF A FRACTION OF A DAY OR
C               A SERIES OF CONTINUOUS DAYS.
      READ (5,2360) I,(NF(K),K=1,I)
      WRITE (6,2480) I,(NF(K),K=1,I)
C               BEGIN ANALYSIS OF A SET OF EVENTS
 1160 DO 1170 I=I1,NUPD
      KIT=(I1-1)*NDELS
      IF (NOUP(I+1).NE.(NOUP(I)+1)) GO TO 1180
 1170 CONTINUE
 1180 NFI1=NF(NOFE)
      I4=I1
      I1=I+1
C               BEGIN ANALYSIS OF A STORM
 1190 READ (5,2030) KS,KE,IPL(NOFE),VOLI
```

```
      WRITE (6,2490) NOFE,KS,KE
      FVOL(NOFE)=VOLI
      K1(NOFE)=KIT+KS
      K2(NOFE)=KIT+KE
      KS=(KS-1)*DEL5+1
      KE=KE*DEL5
      NFS(NOFE)=KS
      NFE(NOFE)=KE
      NFI1=NFI1-1
      DO 1200 LJ=1,NRG
 1200 POBS(NOFE,LJ)=0.0
C               FIND PEAK DISCHARGE
      LJ=K1(NOFE)
      LM=K2(NOFE)
      QR=0.0
      IF (OPT.EQ.1) GO TO 1240
      DO 1230 K=LJ,LM
      Q3=UD(K)
      IF (Q3.LE.QMX) GO TO 1220
      QMX=Q3
      I3=I4+(K-KIT)/NDELS
C               NDATE IS USED FOR PRINTING OUT THE DATE OF STORM
      DO 1210 K3=1,3
 1210 NDATE(NOFE,K3)=NDATE(I3,K3)
C               IF FIRST TIME PERIOD OF STORM, SET UD(K)= BASEFLOW
 1220 IF (O1.NE.0) GO TO 1230
      QR=Q3
      O1=1
 1230 CONTINUE
C               FIND RUNOFF VOLUME ABOVE BASEFLOW
C               AND RAINFALL VOLUME
      GO TO 1260
 1240 DO 1250 K3=1,3
      I3=I4+(LJ-KIT)/NDELS
 1250 NDATE(NOFE,K3)=NDATE(I3,K3)
 1260 DO 1290 L=LJ,LM
      DO 1270 I=1,NRG
      I2=NDAY*(I-1)+L
 1270 POBS(NOFE,I)=POBS(NOFE,I)+UPR(I2)
      IF (OPT.EQ.1) GO TO 1290
C               CHECK UNIT DISCHARGE FOR VALUES LESS THAN BASEFLOW
C               IF FOUND SET BASEFLOW TO MINIMUM UNIT DISCHARGE
      IF (UD(L).GE.QR) GO TO 1280
      QR=UD(L)
 1280 SRV=SRV+UD(L)
 1290 CONTINUE
C               IF STORM VOLUMES FURNISHED  GO TO 1300
      IF (OPT.EQ.1) GO TO 1300
      SRV=SRV-QR*(LM-LJ+1)
      FVOL(NOFE)=SRV/I2CFSP
C               FIND PEAK DISCHARGE ABOVE BASEFLOW
 1300 FPK(NOFE)=QMX-QR
      SFPK(NOFE)=0.0
      IF (IPL(NOFE).EQ.0.OR.QR.EQ.0.0) GO TO 1320
      DO 1310 K=LJ,LM
 1310 UD(K)=UD(K)-QR
 1320 NOFE=NOFE+1
      QMX=0.0
      SRV=0.0
      O1=0
C               CHECK FOR MORE STORMS IN SET OF EVENTS
```

```
      IF (NFI1.GT.0) GO TO 1190
C             CHECK TO SEE IF ALL EVENTS HAVE BEEN ANALYZED
      IF (NUPD.GE.I1) GO TO 1150
      NOFE=NOFE-1
      READ (5,2360) (KOUT(I),I=1,NOFE)
      WRITE (6,2500) (KOUT(I),I=1,NOFE)
      READ (5,2360) (TESTNO(I),I=1,NOFE)
      READ (5,2360) (IHYD(I),I=1,NOFE)
      WRITE (6,2380) (IHYD(I),I=1,NOFE)
      IF (NK.EQ.0) GO TO 1340
      WRITE (6,2370)
      FMTB(1)=FMTA(3)
      FMTB(2)=FMTA(1)
      DO 1330 I=3,42
 1330 FMTB(I)=FMTA(5)
      FMTB(43)=FMTA(4)
 1340 KNN=0
C             OUTPUT FLOOD EVENTS TO BE USED IN OPTIMIZATION
      DO 1350 I=1,NOFE
      IF (TESTNO(I).NE.1) GO TO 1350
      KNN=KNN+1
      LJ=I+2
      FMTB(LJ)=FMTA(2)
      WRITE (6,FMTB) I
      FMTB(LJ)=FMTA(5)
      FMTB(2)=FMTA(6)
 1350 CONTINUE
      RITE=1
C             END OF INITIAL PROGRAM SET-UP
 1360 CONTINUE
C             INITIALIZE
      U1=0.0
      U2=0.0
      NO2=NOFE+NOFE
      DO 1390 NRGI=1,NRG
      DO 1370 I=1,NOFE
      PIMP(I,NRGI)=0.0
 1370 SFVOL(I)=0.0
      DO 1380 I=1,NO2
 1380 PSUM(I,NRGI)=0.0
 1390 CONTINUE
      I1=1
      SMS=0.0
      BMS=0.0
      CHG=1
C             ESTABLISH CURRENT INFILTRATION PARAMETER VALUES
      PSP=X(1)
      KSAT=X(2)/12.0
      RGF=X(3)
      BMSN=X(4)
      EVC=X(5)
      RR=X(6)
      DRN24=X(7)*X(2)*24.0
      IF (NPAR.EQ.1) GO TO 1400
      PSP2=X(8)
      KSAT2=X(9)/12.0
      RGF2=X(10)
      BMSN2=X(11)
      EVC2=X(12)
      RR2=X(13)
      DRN242=X(14)*X(9)*24.0
```

```
      DRAIN2=DRN242/NDELS
      COEF2=(RGF2-1.0)/BMSN2
 1400 DRAIN=DRN24/NDELS
      COEF=(RGF-1.0)/BMSN
C               INITIALIZE VARIABLES
      DO 1420 NP=1,NPAR
      DO 1410 I=1,NRG
      SMSB(I,NP)=0.0
 1410 BMSB(I,NP)=0.0
 1420 CONTINUE
      KP=1
      K=1
C               BEGIN SIMULATION
      KINIT=0
      IK=1
      NFD=0
      W=0
      DO 1920 IW=1,RODYS
      W=W+1
      IF(W.GT.RODYS) GO TO 1920
C               FOR GAP IN RECORD, INITIALIZE SOIL MOISTURE TO ZERO
      IF (W.NE.INDP(KP)) GO TO 1450
      LJ=KP+1
      W=INDP(LJ)+1
      KP=KP+2
      BMS=0.0
      DO 1440 NP=1,NPAR
      DO 1430 LJ=1,NRG
      BMSB(LJ,NP)=0.0
 1430 SMSB(LJ,NP)=0.0
 1440 CONTINUE
 1450 CONTINUE
      PW=RR*DP(W)
      IF (NPAR.EQ.2) PW2=RR2*DP(W)
      ETW=EVC*DE(W)
      IF (NPAR.EQ.2) ETW2=EVC2*DE(W)
      IF (PW.LT.0.0) GO TO 1720
C               IF FLAG=0, COMPUTE SIMULATED VOL. AND PEAK FLOW
C               IF FLAG=1, DO DAILY MOISTURE ACCOUNTING
      IF (FLAG.NE.0) GO TO 1700
C               SET-UP FOR ROUTING THE GENERATED EXCESS PRECIPITATION
      NFD1=0
      NFD=NFD+1
      KINIT=1
 1460 IJ=1
      NL=100
      IF (I1.GT.NOFE) GO TO 1680
      ICT=0
      IF (IHYD(I1).EQ.0.OR.B3.EQ.0) GO TO 1500
      I4=0
      JJ=NF(I1)*(288/DEL5)
      DO 1470 I=1,JJ
 1470 QIH(I)=0.0
 1480 READ (5,2390) ICODE,JJJ,(X2(I),I=1,10)
      DO 1490 I=1,10
      QIH(JJJ)=X2(I)
 1490 JJJ=JJJ+1
      IF (ICODE.EQ.0) GO TO 1480
      I3=JJJ
 1500 CONTINUE
      QMX=0.0
```

```
      IF (B3.EQ.0.OR.KOUT(I1).EQ.0) KINIT=0
      KR=0
      IJKS=NFS(I1)
      IJK=NFE(I1)
      I12=I1+NOFE
C               ROUTE EXCESS PPT. FOR A STORM
      DO 1560 I=IJKS,IJK
      IF (I.NE.IJKS.OR.NFD1.NE.0) GO TO 1510
      IK=IK+IJKS/DELS
      IF (DELS.EQ.1) IK=IK-1
 1510 CONTINUE
      KDY=I+1728
      DO 1520 NRGI=1,NRG
      PSUM(I1,NRGI)=PSUM(I1,NRGI)+P(I,NRGI)
      I2=NDAY*(NRGI-1)+IK
      PIMP(I1,NRGI)=PIMP(I1,NRGI)+(UPR(I2)/DELS-IMPRET(I,NRGI))
      IF (NPAR.NE.1) PSUM(I12,NRGI)=PSUM(I12,NRGI)+P(KDY,NRGI)
C               INDICATOR TO BEGIN ROUTING ONCE EXCESS PPT. OCCURS
 1520 IF (P(I,NRGI).NE.0.0) KR=1
C               DO NOT ROUTE IF PARAMETER ADJUSTMENT HAS NOT TERMINATED
C               OR DETAILED OUTPUT NOT PRINTED FOR STORM
      IF (B3.EQ.0) GO TO 1550
      IF (KOUT(I1).EQ.0) GO TO 1550
      IF (KR.EQ.0) GO TO 1550
C               P(I,III)=EXCESS PPT. DURING I 5-MIN. TIME PERIOD
C               FROM III GAGE
      DO 1530 NRGI=1,NRG
C               ROUTE IF DISCHARGE FOR MOST DOWNSTREAM SEGMENT IS NOT 0
C               OR IF EXCESS PPT. > 0
      IF (QIND.NE.0.0.OR.P(I,NRGI).NE.0.0) GO TO 1540
 1530 CONTINUE
      KR=0
      ECOMP=ECOMP+5.0
      T=T+5.0
      GO TO 1550
 1540 CONTINUE
      IF (ICT.EQ.0.AND.IPL(I1).EQ.1) ADZ=(I-IJKS)/DELS
      CALL ROUTE (B3)
      IF (QIND.GT.QMX) QMX=QIND
      ECOMP=ECOMP+5.0
C               DETERMINE WHETHER OR NOT AT END OF UNIT-TIME INTERVAL
 1550 IJ=IJ+1
      IF (IJ.EQ.DELSP) IK=IK+1
      IF (IJ.EQ.DELSP) I4=0
      IF (IJ.EQ.DELSP) IJ=1
 1560 CONTINUE
      IF (KOUT(I1).EQ.0.OR.B3.EQ.0) GO TO 1600
      IF (NO8.EQ.0) GO TO 1580
      DO 1570 JJ=1,NO8
      KS=IRES(JJ)
 1570 WRITE (6,2470) ISEG(KS),SMAX(KS)
 1580 IF (NO9.EQ.10) GO TO 1600
      DO 1590 JJJ=11,NO9
      KS=IRES(JJJ)
 1590 WRITE (6,2470) ISEG(KS),SMAX(KS)
 1600 CONTINUE
      IF (B3.EQ.0.OR.IPL(I1).EQ.0) GO TO 1630
      WRITE (6,2510)
      IX=Q(1)
      IY=Q(ICT)
      XMIN=IX
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      XMAX=IY+1.                                                        A 916
      YMAX=QMX                                                          A 917
      IF (QMX.LT.FPK(I1)) YMAX=FPK(I1)                                  A 918
      JJJ=YMAX/10                                                       A 919
      YMAX=(JJJ+1.)*10.                                                 A 920
C              IF PLOTTING ROUTINE NOT ACCEPTED BY COMPUTER             A 921
C               PULL OUT NEXT 11 STATEMENTS (A 923 THROUGH A 933)       A 922
      CALL PLOT2 (IMAGE,XMAX,XMIN,YMAX,0.0,6)                           A 923
      CALL PLOT3 (IHC,Q,R,ICT)                                          A 924
      IF (OPT.EQ.1) GO TO 1620                                          A 925
      JJ=0                                                              A 926
      LK=K1(I1)+ADZ                                                     A 927
      LJ=K2(I1)                                                         A 928
      DO 1610 KQ=LK,LJ                                                  A 929
      JJ=JJ+1                                                           A 930
 1610 R(JJ)=QO(KQ)                                                      A 931
      CALL PLOT3 (IHO,Q,R,ICT)                                          A 932
 1620 CALL PLOT4 (11,11HFLOW IN CFS)                                    A 933
 1630 CONTINUE                                                          A 934
C              INITIALIZE VARIABLES                                     A 935
C              COPY SIMULATED FLOOD VOLUME AND PEAK                     A 936
C              FOR I-TH EVENT INTO STORAGE ARRAYS SFVOL AND SFPK.       A 937
      DO 1640 LK=1,NRG                                                  A 938
      LJ=LK+3                                                           A 939
 1640 QCW=QCW+DIMP(LJ,1)*PSUM(I1,LK)+DIMP(LK,1)*PIMP(I1,LK)+DIMP(LJ,2)*P A 940
     &SUM(I12,LK)                                                       A 941
      SFVOL(I1)=QCW/(5280.0*5280.0*DA)                                  A 942
      QCW=0.0                                                           A 943
      SFPK(I1)=QMX                                                      A 944
      IF (TESTNO(I1).NE.1) GO TO 1660                                   A 945
      IF (SFVOL(I1).EQ.0) GO TO 1650                                    A 946
      IF (FVOL(I1).EQ.0.0) GO TO 1650                                   A 947
      U2=U2+ALOG(SFVOL(I1)/FVOL(I1))**2                                 A 948
 1650 IF (QMX.EQ.0.) GO TO 1660                                         A 949
      IF (FPK(I1).EQ.0.0) GO TO 1660                                    A 950
      U1=U1+ALOG(QMX/FPK(I1))**2                                        A 951
 1660 I1=I1+1                                                           A 952
      NFD1=NFD1+1                                                       A 953
C              IF HAVE ANALYZED ALL EVENTS OF SET OF EVENTS, GO TO 1680 A 954
      IF (NF(NFD).NE.NFD1) GO TO 1670                                   A 955
      IF (MOD(IK-1,NDELS).EQ.0) GO TO 1680                              A 956
      KQ=(IK-1)/NDELS                                                   A 957
      IK=(KQ+1)*NDELS+1                                                 A 958
      GO TO 1680                                                        A 959
 1670 IJK=IJK+1                                                         A 960
      IJKS=NFS(I1)                                                      A 961
C              IF NEXT STORM DOES NOT BEGIN IMMEDIATELY AFTER LAST      A 962
C              STORM, SET KINIT =1 SO SUBROUTINE INIT WILL BE CALLED    A 963
      IF (IJK.NE.IJKS) KINIT=1                                          A 964
      IK=IK+(IJKS-IJK)/DELS                                             A 965
      GO TO 1460                                                        A 966
 1680 NFD=NFD+NFD1-1                                                    A 967
      IF (W.GT.RODYS) GO TO 1920                                        A 968
      FLAG=1                                                            A 969
      CHG=1                                                             A 970
      DO 1690 III=1,NRG                                                 A 971
 1690 IMPSTO(III)=0.0                                                   A 972
C              DAILY MOISTURE ACCOUNTING                                A 973
C                 DETERMINE IF MOISTURE EXCESS OR DEFICIENCY OCCURS     A 974
 1700 INC=PW-ETW                                                        A 975
      IF (NPAR.EQ.2) INC2=PW2-ETW2                                      A 976
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      DO 1710 III=1,NRG
      CALL DSM (SMSB(III,1),BMSB(III,1),INC,DRN24,BMSN)
      IF (NPAR.EQ.2) CALL DSM (SMSB(III,2),BMSB(III,2),INC2,DRN242,BMSN2
     1)
 1710 CONTINUE
C               FINISHED WITH DAY
      GO TO 1920
C               BEGIN UNIT-TIME SIMULATION
 1720 FLAG=0
      KTEMP=K
      DO 1910 NP=1,NPAR
      DRAIN=KBRAIN
      IF (NP.EQ.2) DRAIN=BRAIN2
      BMST=BMSN
      IF (NP.EQ.2) BMST=BMSN2
      K=KTEMP
      IF (W.GT.RODYS) GO TO 1910
      ETDEL=PDEL*ETW
      IF (NP.EQ.2) ETDEL=PDEL*ETW2
      IF (NP.EQ.1) KINIT=KINIT+1
      DO 1900 III=1,NRG
      CHG=1
      KDAY=288*(KINIT-1)+1
C               COMPUTE SMS,BMS FOR AREAS FOR EACH RAIN GAGE, SOIL TYPE
      SMS=SMSB(III,NP)
      BMS=BMSB(III,NP)
      KKK=K+(III-1)*NUPD*NDELS
      K4DAY=KKK+NDELS-1
      DO 1880 KK=KKK,K4DAY
      IF (UPR(KK).LE.0.0) GO TO 1810
      SRP=UPR(KK)/DELS
      SR=SRP*RAT(III,NP)
      IF (CHG.NE.1) GO TO 1730
C               BEGIN COMPUTATION OF INFILTRATION
C               REDETERMINE PS AFTER BREAK IN RAINFALL
      PS=PSP*(RGF-COEF*BMS)
      IF (NP.EQ.2) PS=PSP2*(RGF2-COEF2*BMS)
      CHG=0
 1730 CONTINUE
C               DEFINE 5-MIN. RAINFALL SUPPLY RATE
      IF (SMS.LE.0.0) GO TO 1740
C               IF SATURATED ZONE EXISTS
      FR=KSAT*(1.0+PS/SMS)
      IF (NP.EQ.2) FR=KSAT2*(1.0+PS/SMS)
      GO TO 1750
C               IF NO SATURATED ZONE EXISTS
 1740 FR=KSAT*(1.0+PS/SR)
      IF (NP.EQ.2) FR=KSAT2*(1.0+PS/SR)
C               DETERMINE EXCESS PPT. IN UNIT TIME
 1750 DO 1800 NKL=1,DELS
      IF (SR.GE.FR) GO TO 1760
      QR=SR**2/(2.0*FR)
      GO TO 1770
C               PONDED CONDITION
 1760 QR=SR-FR/2.0
 1770 SMS=SMS+SR-QR
C               KDAY IS 5-MIN. INTERVAL IN A DETAILED STORM
      KDY=KDAY
      IF (NP.EQ.2) KDY=KDY+1728
      P(KDY,III)=QR
      IF (NP.EQ.2) GO TO 1790
```

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C            CALCULATE 5-MIN ADDITIONS TO IMPERVIOUS RETENTION
      IF (IMPSTO(III).EQ.IMP) GO TO 1780
      IMPSTT=IMPSTO(III)+SRP
      IF (IMPSTT.GT.IMP) IMPSTT=IMP
      IMPRET(KDY,III)=IMPSTT-IMPSTO(III)
      IMPSTO(III)=IMPSTT
      GO TO 1790
 1780 IMPRET(KDY,III)=0.0
 1790 CONTINUE
      KDAY=KDAY+1
C            SMS= NEW MOISTURE CONTENT OF SATURATED ZONE
      FR=KSAT*(1.0+PS/SMS)
 1800 IF (NP.EQ.2) FR=KSAT2*(1.0+PS/SMS)
      GO TO 1880
C            DEPLETION OF SOIL MOISTURE BY ET DURING UNIT-TIME
C            INTERVALS OF NO PPT.
 1810 CONTINUE
      IF (SMS.LE.ETDEL) GO TO 1820
      SMS=SMS-ETDEL
      GO TO 1830
 1820 BMS=BMS+SMS-ETDEL
      SMS=0.0
C            CHECK FOR COMPLETE SOIL DRYING
      IF (BMS.LE.0.0) BMS=0.0
C            REDISTRIBUTION OF SOIL MOISTURE WITH FLOW FROM
C            SATURATED TO UNSATURATED ZONE
 1830 IF (SMS.LE.DRAIN) GO TO 1840
      SMS=SMS-DRAIN
      BMS=BMS+DRAIN
C            BMS= NEW SOIL MOISTURE CONTENT OF UNSATURATED ZONE
      GO TO 1850
 1840 BMS=BMS+SMS
      SMS=0.0
C            DRAINAGE TO LOWER LYING ZONE
 1850 IF (BMS.GT.BMST) BMS=BMST
C            BREAK IN UNIT RAINFALL
      CHG=1
C            NO EXCESS PRECIPITATION
C            REMEMBER KDAY IS 5-MIN. INTERVAL IN A DETAILED STORM
      DO 1870 NKL=1,DELS
      KDY=KDAY
      IF (NP.EQ.2) KDY=KDY+1728
      P(KDY,III)=0.0
      IF (NP.EQ.2) GO TO 1860
C            CALCULATE 5-MIN EVAPORATION FROM IMPERVIOUS RETENTION
      IMPSTO(III)=IMPSTO(III)-ETDEL/DELS
      IF (IMPSTO(III).LT.0.0) IMPSTO(III)=0.0
      IMPRET(KDY,III)=0.0
 1860 CONTINUE
 1870 KDAY=KDAY+1
C            1880 ENDS RAIN GAGE III FOR UNIT-RAINFALL DAY
 1880 CONTINUE
      IF (III.NE.NRG) GO TO 1890
      K=K+NDELS
C            COMPUTE SMS AND BMS FOR AREAS COVERED BY EACH RAIN GAGE
 1890 SMSB(III,NP)=SMS
      BMSB(III,NP)=BMS
C            1910 ENDS UNIT-RAINFALL DAY
 1900 CONTINUE
 1910 CONTINUE
C            1920 ENDS ALL DAYS,W=1,RODYS
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 1920 CONTINUE                                                          A1099
      U(1)=U1                                                           A1100
      U(2)=U2                                                           A1101
      U(3)=U1+0.5*U2                                                    A1102
C              * RITE ROUTINE *                                         A1103
C                                                                       A1104
      IF (RITE.NE.1) GO TO 1980                                         A1105
      IF (KNN.EQ.0) GO TO 1950                                          A1106
      UNN1=EXP(SQRT(U(NN)/KNN))                                         A1107
      UNN2=1.0/UNN1                                                     A1108
      IF (B3.NE.1) GO TO 1930                                           A1109
      WRITE (6,2400)                                                    A1110
      GO TO 1940                                                        A1111
 1930 WRITE (6,2410)                                                    A1112
 1940 WRITE (6,2420) U(NN),UNN1,UNN2,(X(I),I=1,E0)                      A1113
 1950 WRITE (6,2510)                                                    A1114
      DO 1970 I=1,NOFE                                                  A1115
      WRITE (6,2430) I,FPK(I),SFPK(I)                                   A1116
      WRITE (6,2440) (III,POBS(I,III),III=1,NNG)                        A1117
      VR=999.0                                                          A1118
      IF (FVOL(I).EQ.0.0.OR.SFVOL(I).EQ.0.0) GO TO 1960                 A1119
      VR=ALOG(FVOL(I)/SFVOL(I))**2                                      A1120
 1960 CONTINUE                                                          A1121
      WRITE (6,2450) FVOL(I),SFVOL(I)                                   A1122
      IF (TESTNO(I).EQ.0) GO TO 1970                                    A1123
      WRITE (6,2460) VR                                                 A1124
 1970 CONTINUE                                                          A1125
      RITE=0                                                            A1126
 1980 IF (B3.EQ.0) GO TO 590                                            A1127
      STOP                                                              A1128
C                                                                       A1129
 1990 FORMAT (1H ,39HERROR IN SEGMENT DATA FOR TYPE 15 OR 16)           A1130
 2000 FORMAT (12F5.3)                                                   A1131
 2010 FORMAT (1H ,1X,36HDAILY IRRIGATION LOADS IN INCHES ARE/1H ,2X,4HJA A1132
     1N.,2X,4HFEB.,1X,5HMARCH,1X,5HAPRIL,3X,3HMAY,2X,4HJUNE,2X,4HJULY,2X A1133
     2,4HAUG.,1X,5HSEPT.,2X,4HOCT.,2X,4HNOV.,2X,4HDEC./1H ,12(1X,F5.3))  A1134
 2020 FORMAT (A4,2I1)                                                   A1135
 2030 FORMAT (2I4,I1,F6.2)                                              A1136
 2040 FORMAT (2A4,50A1,F6.2)                                            A1137
 2050 FORMAT (2A4,50A1,F6.0)                                            A1138
 2060 FORMAT (20X,3I3,3X,3I3)                                           A1139
 2070 FORMAT (1H0,22HDISCHARGE STATION      ,2A4,50A1/1H ,20HUNIT PRECIP. A1140
     1 STATION,2X,2A4,50A1/1H ,22HDAILY PRECIP. STATION ,2A4,50A1/1H ,18 A1141
     2HPAN-EVAPO. STATION,4X,2A4,50A1/1H ,14HDRAINAGE AREA=,F6.2,8H SQ.  A1142
     3MI./1H ,16HUNIT DATA ARE IN,F9.3,18H MINUTE INCREMENTS/1H ,29HTHE  A1143
     4PERIOD OF RECORD IS FROM ,I2,1H-,I2,1H-,I2,6H (DAY=,I7,5H) TO ,I2, A1144
     51H-,I2,1H-,I2,6H (DAY=,I7,1H))                                    A1145
 2080 FORMAT (2A4,5I2,12F5.0,I2)                                        A1146
 2090 FORMAT (1H ,2A4,5I3,12F8.2,I3)                                    A1147
 2100 FORMAT (2A4,2I2,I1,16F4.2,2X,I1)                                  A1148
 2110 FORMAT (1H ,2A4,2I3,I2,16(1X,F4.2),I3)                            A1149
 2120 FORMAT (10X,A8,5X,A8,5X,I8,5X,I8,5X,I1)                           A1150
 2130 FORMAT (2X,20HERROR IN UNIT DATA--,3I6)                           A1151
 2140 FORMAT (3I4,F8.0)                                                 A1152
 2150 FORMAT (3F10.0)                                                   A1153
 2160 FORMAT (1H ,27HBOUNDARY CHECK OF PARAMETER,I3,3F10.3)             A1154
 2170 FORMAT (1H1,24HINITIAL PARAMETER VALUES/)                         A1155
 2180 FORMAT (///1H ,28HINITIAL STEP SIZE INCREMENTS/)                  A1156
 2190 FORMAT (1X,10F12.6)                                               A1157
 2200 FORMAT (1H //1H ,31HTHE MAX. NUMBER OF ITERATIONS= ,I4//1H ,58HINI A1158
     1TIALLY AND AFTER EACH VECTOR MATRIX ORTHONORMALIZATION,/1H ,40HTHE A11 9
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     2 PARAMETRIC VECTOR INCREMENT SIZE IS,F7.3,19H OF THE VECTOR SIZE/)
2210 FORMAT (1H0,16HAT ITERATION NO.,I3,20H OBJECTIVE FUNCTION=,F11.6)
2220 FORMAT (1H ,20HPARAMETER VALUES ARE)
2230 FORMAT (1H ,7F12.6/1H ,7F12.6)
2240 FORMAT (1H ,4HB1 =,F9.6,3X,4HB2 =,F9.6)
2250 FORMAT (1H ,24HNEW ORTHONORMAL BASIS    )
2260 FORMAT (1H ,16F8.5)
2270 FORMAT (1H ,35HSTART OF STAGE STEP SIZE INCREMENTS/1H ,13F10.6)
2280 FORMAT (I5,2F5.0,I5,F5.0)
2290 FORMAT (//47X,20HNUMBER OF SEGMENTS =,I5/50X,4HDT =,F7.3,8H MINUTE
     1S/40X,28HOUTPUT SAMPLING INTERVAL =,F6.2,8H MINUTES/48X,22HNUMBER
     2OF RAIN GAGES =,I2/46X,26HNUMBER OF PARAMETER SETS =,I2/43X,22HIMP
     3ERVIOUS RETENTION =,F4.2,7H INCHES)
2300 FORMAT (//60X,6HLENGTH,9X,9HROUGHNESS,19X,21HTHIESSEN COEFFICIENTS
     1/8H SEGMENT,1X,17HUPSTREAM SEGMENTS,3X,17HADJACENT SEGMENTS,1X,4HT
     2YPE,1X,3HIPR,1X,3HNDX,1X,6H(FEET),3X,5HSLOPE,1X,9HPARAMETER,1X,16H
     3OTHER PARAMETERS,I4,4(1X,I4))
2310 FORMAT (1H ,40HROUTING INTERVAL FOR DETENTION RESERVOIR,I3,42H IS
     1TOO LARGE, REDUCE TO A VALUE LESS THAN,F6.3)
2320 FORMAT (1H0,9X,18HRESERVOIR SEGMENT ,A4)
2330 FORMAT (1H0,5X,7HOUTFLOW,5X,7HSTORAGE,5X,10HS2/DT+O2/2,//(1X,3(F9.
     12,4X)))
2340 FORMAT (8A4,3I2,5F5.0,I2,3F5.0)
2350 FORMAT (2X,A4,3X,3(1X,A4),3X,4(1X,A4),I3,2I4,F8.0,F8.4,F8.3,2F9.3,
     1I2,5F5.3)
2360 FORMAT (40I2)
2370 FORMAT (1H ,47HTHE FLOOD EVENTS IN THE OBJECTIVE FUNCTION ARE )
2380 FORMAT (1H ,29HINPUT HYDROGRAPHS FOR STORMS ,30I3)
2390 FORMAT (I2,I3,10F5.3)
2400 FORMAT (1H0,11X,44HEND OF RUN--RESULTS OF LAST SUCCESSFUL TRIAL)
2410 FORMAT (1H1,50X,18HBEGINNING OF STAGE)
2420 FORMAT (1H ,20HOBJECTIVE FUNCTION =,E14.7,34H WHICH IS A ROOT MEAN
     1 SQUARE ERROR,E9.3,4H  TO,F9.3/1H ,20HPARAMETER VALUES ARE/1H ,7F1
     22.6/1H ,7F12.6)
2430 FORMAT (1H0,36HDETAILED DISCHARGE FOR FLOOD NUMBER ,I2/1H ,25HOBSE
     1RVED PEAK DISCHARGE =,F9.2,4H CFS/1H ,26HSIMULATED PEAK DISCHARGE
     2=,F9.2,4H CFS)
2440 FORMAT (1H ,31HOBSERVED RAINFALL   GAGE NUMBER,3(I3,3H = ,F9.3,7H
     1INCHES))
2450 FORMAT (1H ,24HOBSERVED DIRECT RUNOFF =,F9.3,7H INCHES/1H ,25HSIMU
     1LATED DIRECT RUNOFF =,F9.3,7H INCHES)
2460 FORMAT (1H ,35HCONTRIBUTION TO OBJECTIVE FUNCTION=,E10.3)
2470 FORMAT (1H0,40HMAXIMUM STORAGE IN DETENTION RESERVOIR  ,A4,4H WAS,
     1F8.3,10H CFS-HOURS)
2480 FORMAT (1H ,9HTHERE ARE,I4,31H FLOOD PEAKS GROUPED AS FOLLOWS,10I6
     1/9(44X,10I6/))
2490 FORMAT (1H ,9HSTORM NO.,I3,22H STARTS AT TIME PERIOD,I5,12H AND EN
     1DS AT,I6)
2500 FORMAT (1H0,27HDETAILED OUTPUT FOR STORMS ,30I3)
2510 FORMAT (1H1)
      END
      SUBROUTINE ROUTE (B3)
C              ROUTING ROUTINE BASED ON SCHAAKE KINEMATIC WAVE MODEL
      INTEGER B3,DELS,MOUT
      DIMENSION QOUT(50)
      COMMON /C1/ NSEG,ISEG(50),IUP(50,3),NPAR,KPSET(50)
      COMMON /C2/ NL,NPAGE
      COMMON /C3/ IPRNT,T,AR(50,11),FLGTH(50),KSEG(50),NDX(50),Q1(50),Q2
     1(50),QSUM(50),QSUML(50),STO(50)
      COMMON /C4/ DELS,MAXL,QCW,QLAT,ILAT(50,4),ITEST(50),ITYPE(50),JLAT
     1(50,4),JUP(50,3),P(3456,3),PARAM(50,2),RCOEF(50,3),UPR(7200)
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```
      COMMON /C6/ DT,DTS,QUP,DX(50)                                     B  11
      COMMON /C7/ ECOMP,T,KINIT,NOUT,NHG,OSI,JOUT(50),QIND,RAT(3,2)     B  12
      COMMON /C8/ I2,I1,IK,TRYCT,KOUT(60),SEG(50)                       B  13
      COMMON /F1/ ICT,Q(1728),R(1728),IPL(60)                           B  14
C             IF AT BEGINNING OF STORM, INITIALIZE CATCHMENT            B  15
      IF (KINIT.NE.1) GO TO 10                                          B  16
      MAXL=55                                                           B  17
      CALL INIT                                                         B  18
      NL=100                                                            B  19
C             COMPUTE OUTFLOW HYDROGRAPHS FOR EACH SEGMENT              B  20
   10 CALL FLOW                                                         B  21
   20 IF (IPRNT*OSI-T) 40,40,30                                         B  22
   30 IF (T-ECOMP) 10,90,90                                             B  23
   40 TOUT=IPRNT*OSI                                                    B  24
      B=(TOUT-(T-DT))/DT                                                B  25
      DO 50 J=1,NOUT                                                    B  26
      K=JOUT(J)                                                         B  27
      QOUT(J)=Q1(K)+(Q2(K)-Q1(K))*B                                     B  28
   50 IF (K.EQ.KSEG(NSEG)) QIND=QOUT(J)                                 B  29
      IF (NL-MAXL+3) 70,70,60                                           B  30
   60 CALL PAGE                                                         B  31
      WRITE (6,100) I1,(SEG(J),J=1,NOUT)                                B  32
   70 NL=NL+(NOUT-1)/10+1                                               B  33
      MOUT=I/288                                                        B  34
      MOUT=MOUT*288                                                     B  35
      TOUT=((I-MOUT)*5.)/60.                                            B  36
      WRITE (6,110) TOUT,I,(QOUT(J),J=1,NOUT)                           B  37
      IF (IPL(I1).NE.1) GO TO 80                                        B  38
      ICT=ICT+1                                                         B  39
      IRV=I/288                                                         B  40
      Q(ICT)=TOUT+IRV*24.0                                              B  41
      R(ICT)=QIND                                                       B  42
   80 CONTINUE                                                          B  43
      IPRNT=IPRNT+1                                                     B  44
      GO TO 20                                                          B  45
   90 CONTINUE                                                          B  46
      RETURN                                                            B  47
C                                                                       B  48
  100 FORMAT (8X,12HFLOOD NUMBER,I3//7X,4HTIME,9X,1HI,6X,32HOUTFLOW HYDR B  49
     1OGRAPHS   (IN CFS)  /7X,5H     ,10X,10(6X,A4)/(19X,A4,9(6X,A4)))  B  50
  110 FORMAT (6X,F7.2,2X,I5,2X,10F10.3/(22X,10F10.3))                   B  51
      END                                                               B  52-
      SUBROUTINE DSM (SMS,BMS,INC,DRN24,BMSN)                           C   1
C             THIS SUBROUTINE DOES SOIL MOISTURE ACCOUNTING             C   2
C             ON DAYS OF DAILY RAINFALL. IT ADDS DAILY RAINFALL TO SMS, C   3
C             SUBTRACTS ET FROM SMS OR (IF SMS=0) FROM BMS, AND         C   4
C             DRAINS SMS DOWNWARD TO BMS                                C   5
      REAL SMS,BMS,DRN24,INC,BMSN                                       C   6
      IF (INC.LE.0.0) GO TO 10                                          C   7
C             ADD EXCESS MOISTURE TO SATURATED ZONE                     C   8
      SMS=SMS+INC                                                       C   9
      GO TO 30                                                          C  10
C             DEDUCT MOISTURE DEFICIENCY FROM SATURATED ZONE            C  11
   10 IF ((SMS+INC).GE.0.0) GO TO 20                                    C  12
C             EVAPOTRANSPIRATION FROM UNSATURATED ZONE                  C  13
      BMS=BMS+SMS+INC                                                   C  14
      SMS=0.0                                                           C  15
C             CHECK FOR COMPLETE SOIL DRYING                            C  16
      IF (BMS.LT.0.0) BMS=0.0                                           C  17
      GO TO 30                                                          C  18
C             EVAPOTRANSPIRATION FROM SATURATED ZONE                    C  19
```

```
   20 SMS=SMS+INC
C             REDISTRIBUTION OF SOIL MOISTURE WITH FLOW FROM
C             SATURATED TO UNSATURATED ZONE
   30 IF (SMS.LE.DRN24) GO TO 40
C             MOISTURE IN SATURATED ZONE ABOVE FIELD CAPACITY
      SMS=SMS-DRN24
      BMS=BMS+DRN24
      GO TO 50
C             SATURATED ZONE COMPLETELY DEPLETED
   40 BMS=BMS+SMS
C             BMS= NEW MOISTURE CONTENT OF UNSATURATED ZONE
      SMS=0.0 .
C             DRAINAGE TO DEEPER LYING ZONE
   50 IF (BMS.GT.BMSN) BMS=BMSN
      RETURN
      END
      SUBROUTINE FLOW
C             THIS SUBROUTINE COMPUTES SEGMENT OUTFLOWS AT T+DT
      REAL ISEG,IUP,ILAT
      REAL IN1,IN2
      INTEGER DELS
      DIMENSION XA(11), XQ(11)
      COMMON /C1/ NSEG,ISEG(50),IUP(50,3),NPAR,KPSET(50)
      COMMON /C3/ IPRNT,T,AR(50,11),FLGTH(50),KSEG(50),NDX(50),Q1(50),Q2
     &(50),QSUM(50),QSUML(50),STO(50)
      COMMON /C4/ DELS,MAXL,QCW,JLAT,ILAT(50,4),ITEST(50),ITYPE(50),JLAT
     &(50,4),JUP(50,3),P(1755,3),PARAM(50,2),RCOEF(50,3),UPR(4000)
      COMMON /C5/ ALPHA(50),EM(50),FRN(50),QMAX(50),SLOPE(50)
      COMMON /C6/ DT,DTS,QUP,DX(50)
      COMMON /C7/ ECOMP,I,KINIT,NOUT,NRG,OSI,JOUT(50),QIND,RAT(3,2)
      COMMON /C8/ I2,I1,IK,TRYCT,KOUT(60),SEG(50)
      COMMON /C9/ I3,I4,QIH(400),PTIME,IHYD(60),IJ,IP
      COMMON /E2/ SMAX(50),IN2(50),IN1(50),S2O2(50)
      COMMON /E3/ DELTAT,NOB,QS(50,11)
      T=T+DT
      DO 140 NSG=1,NSEG
      K=KSEG(NSG)
      IF (ITYRE(K).GE.7) GO TO 40
      N=NDX(K)+1
      ALP=ALPHA(K)
      DTSX=DTS/DX(K)
      XEM=EM(K)-1.
      YEM=EM(K)
      CALL UP (K)
      CALL LAT (K)
      Q1(K)=Q2(K)
      ALAT=QLAT*DTS
      XQ(1)=QUP
      XA(1)=(QUP/ALP)**(1./YEM)
      DO 20 J=2,N
      IF (AR(K,J).LE.0.) GO TO 10
      THETA=DTSX*YEM*QS(K,J)/AR(K,J)
      IF (THETA.LT.1) GO TO 10
      XQ(J)=XQ(J-1)+(ALAT+AR(K,J-1)-XA(J-1))/DTSX
      XA(J)=(XQ(J)/ALP)
      IF (XA(J).LT.0.) XA(J)=0.0
      IF (YEM.NE.1.) XA(J)=XA(J)**(1./YEM)
      GO TO 20
   10 XA(J)=AR(K,J)+ALAT+DTSX*(QS(K,J-1)-QS(K,J))
      IF (XA(J).LT.0.0) XA(J)=0.0
      XQ(J)=ALP*XA(J)
```

```
      IF (YEM.NE.1.) XQ(J)=ALP*(XA(J)**YEM)
   20 CONTINUE
      DO 30 J=1,N
      AR(K,J)=XA(J)
      QS(K,J)=XQ(J)
   30 CONTINUE
      Q2(K)=XQ(N)
      GO TO 140
   40 CALL UP (K)
      Q1(K)=Q2(K)
      IF (ITYPE(K)-8) 60,50,60
   50 CALL PULS (K)
      GO TO 140
   60 IF (ITYPE(K)-9) 90,70,90
   70 IN1(K)=IN2(K)
      IN2(K)=QUP
      AVIN=(IN1(K)+IN2(K))/2.
      STO(K)=STO(K)+AVIN*DELTAT
      Q2(K)=STO(K)/PARAM(K,1)
      STO(K)=STO(K)-Q2(K)*DELTAT
      IF (STO(K).LT.SMAX(K)) GO TO 80
      SMAX(K)=STO(K)
   80 GO TO 140
   90 IF (ITYPE(K)-10) 130,100,130
  100 IF (IHYD(I1).EQ.0.OR.IP.GT.I3) GO TO 120
      I4=I4+1
      IP=(I+DEL5-IJ)/DEL5
      IF (IP.NE.1) GO TO 110
      Q2(K)=(DT/PTIME)*I4*(QIH(IP)-0.0)
      GO TO 140
  110 Q2(K)=(DT/PTIME)*I4*(QIH(IP)-QIH(IP-1))+QIH(IP-1)
      GO TO 140
  120 Q2(K)=0.0
      GO TO 140
  130 Q2(K)=QUP
  140 CONTINUE
      RETURN
      END
      SUBROUTINE LAT (K)
C               THIS SUBROUTINE COMPUTES LATERAL INFLOW FROM OVERLAND
C               FLOW SEGMENTS OR FROM RAINFALL
      INTEGER DEL5
      REAL ISEG,IUP,ILAT
      COMMON /C1/ NSEG,ISEG(50),IUP(50,3),NPAR,KPSET(50)
      COMMON /C3/ IPRNT,T,AR(50,11),FLGTH(50),KSEG(50),NDX(50),Q1(50),Q2
     1(50),QSUM(50),QSUML(50),STO(50)
      COMMON /C4/ DEL5,MAXL,QCW,QLAT,ILAT(50,4),ITEST(50),ITYPE(50),JLAT
     1(50,4),JUP(50,3),P(3456,3),PARAM(50,2),RCOEF(50,3),UPR(7200)
      COMMON /C6/ DT,DTS,QUP,DX(50)
      COMMON /C7/ ECOMP,I,KINIT,NOUT,NRG,OSI,JOUT(50),QIND,RAT(3,2)
      COMMON /C8/ I2,I1,IK,TRYCT,KOUT(60),SEG(50)
      REAL IMPRET,IMPSTO
      COMMON /E1/ IMPRET(1728,3),IMPSTO(3)
C               COMPUTE LAT. INFLOW RATE FROM OVERLAND FLOW TO SEGMENT K
      QLAT=0.
      IF (ITYPE(K)-5) 10,50,10
   10 IF (ITYPE(K)-6) 20,50,20
   20 QPR=QSUML(K)
      DO 40 J=1,4
      IF (JLAT(K,J)) 40,40,30
   30 JJ=JLAT(K,J)
```

```
      QLAT=QLAT+Q2(JJ)
   40 CONTINUE
      QSUML(K)=QLAT
      QLAT=(QLAT+QPR)/2.
      RETURN
C              COMPUTE LATERAL INFLOW RATE FROM RAIN
   50 EP=0.0
      AP=0.0
      TPAR1=PARAM(K,1)
      TPAR2=PARAM(K,2)
      IF (TPAR1.LT.0.0) TPAR1=0.0
      IF (TPAR2.LT.0.0) TPAR2=0.0
      IPAR=I
      IF (KPSET(K).EQ.2) IPAR=IPAR+1728
      DO 60 III=1,NRG
      EP=EP+(RCOEF(K,III)*P(IPAR,III))/5.0
   60 AP=AP+(RCOEF(K,III)*(UPR(I2)/DELS-IMPRET(I,III)))/5.0
      QLAT=(TPAR2*AP+TPAR1*EP)/720.0
C              THE CONSTANT 720 CONVERTS SQFT-IN/MINUTE TO CFS
      QSUML(K)=QLAT
      RETURN
      END
      SUBROUTINE UP (K)
C              THIS SUBROUTINE COMPUTES UPSTREAM INFLOW TO SEGMENT K
      INTEGER DELS
      REAL ILAT
      COMMON /C3/ IPRNT,T,AR(50,11),FLGTH(50),KSEG(50),NDX(50),Q1(50),Q2
     1(50),QSUM(50),QSUML(50),STO(50)
      COMMON /C4/ DELS,MAXL,QCW,QLAT,ILAT(50,4),ITEST(50),ITYPE(50),JLAT
     1(50,4),JUP(50,3),P(3456,3),PARAM(50,2),RCOEF(50,3),UPR(7200)
      COMMON /C5/ ALPHA(50),EM(50),FRN(50),QMAX(50),SLOPE(50)
      COMMON /C6/ DT,DTS,QUP,DX(50)
      QUP=0.
      QPR=QSUM(K)
      DO 20 J=1,3
      IF (JUP(K,J)) 20,20,10
   10 JJ=JUP(K,J)
      QUP=QUP+Q2(JJ)
   20 CONTINUE
      QSUM(K)=QUP
      IF (ITYPE(K).EQ.8.OR.ITYPE(K).EQ.9) GO TO 130
      IF (QUP-QMAX(K)) 80,80,30
   30 IF (QPR-QMAX(K)) 40,70,70
   40 PDT=(QUP-QMAX(K))/(QUP-QPR)
      STO(K)=STO(K)-(DTS*(QMAX(K)-QPR)/2.0)*(1.0-PDT)
      IF (STO(K)) 50,60,60
   50 STO(K)=0.
   60 STO(K)=STO(K)+(DTS*(QUP-QMAX(K))/2.0)*PDT
      QUP=QMAX(K)
      RETURN
   70 STO(K)=STO(K)+(((QPR+QUP)/2.)-QMAX(K))*DTS
      QUP=QMAX(K)
      RETURN
   80 IF (QPR-QMAX(K)) 90,90,110
   90 IF (STO(K)) 120,120,100
  100 STO(K)=STO(K)-(QMAX(K)-((QPR+QUP)/2.))*DTS
      IF (STO(K)) 120,140,140
  110 PDT=(QPR-QMAX(K))/(QPR-QUP)
      STO(K)=STO(K)+((QPR-QMAX(K))*PDT*DTS/2.0)-((QMAX(K)-QUP)*(1.0-PDT)
     1*DTS/2.0)
      IF (STO(K)) 120,140,140
```

```
  120 STO(K)=0.
  130 CONTINUE
      RETURN
  140 JUP=QMAX(K)
      RETURN
      END
      SUBROUTINE SEQ (DA,DIMP)
C               THIS SUBROUTINE SETS UP COMPUTATIONAL SEQUENCE
      REAL ISEG,IUP,ILAT
      REAL DIMP(9,2)
      INTEGER DELS
      COMMON /C1/ NSEG,ISEG(50),IUP(50,3),NPAR,KPSET(50)
      COMMON /C2/ NL,NPAGE
      COMMON /C3/ IPRNT,T,AR(50,11),FLGTH(50),KSEG(50),NDX(50),Q1(50),Q2
     1(50),QSUM(50),QSUML(50),STO(50)
      COMMON /C4/ DELS,MAXL,QCW,QLAT,ILAT(50,4),ITEST(50),ITYPE(50),JLAT
     1(50,4),JUP(50,3),P(3456,3),PARAM(50,2),RCOEF(50,3),UPR(7200)
      COMMON /C5/ ALPHA(50),EM(50),FRN(50),QMAX(50),SLOPE(50)
C               NUMBER CONTRIBUTING SEGMENTS (IUP,ILAT) USING SUBROUTINE
C               ITRAN WHICH GIVES THE CONTRIBUTING SEGMENTS THE SAME
C               NUMBER AS THE ORDER OF THE SEGMENTS (I.E., I)
      DO 20 I=1,NSEG
      ITEST(I)=0
      DO 10 J=1,3
      X=IUP(I,J)
      JUP(I,J)=ITRAN(X)
   10 CONTINUE
      DO 20 J=1,4
      X=ILAT(I,J)
      JLAT(I,J)=ITRAN(X)
   20 CONTINUE
      II=0
C               ORDER OVERLAND FLOW SEGMENTS FIRST
      DO 80 I=1,NSEG
      IF (ITYPE(I).EQ.10) GO TO 40
      IF (ITYPE(I)-5) 30,40,30
   30 IF (ITYPE(I)-6) 80,40,80
   40 N=0
      DO 60 J=1,3
      IF (JUP(I,J)) 60,60,50
   50 N=1
   60 CONTINUE
      IF (N) 70,70,80
   70 II=II+1
      KSEG(II)=I
      ITEST(I)=1
   80 CONTINUE
      NONCH=II
C               CHECK EACH SEGMENT TO SEE IF IT HAS BEEN SEQUENCED
      I=1
      NIT=0
   90 IF (ITEST(I)) 130,130,100
  100 I=I+1
C               CHECK IF SEGMENT SEQUENCING IS COMPLETED AND FOR ERRORS
      IF (I-NSEG) 90,90,110
  110 I=1
      NIT=NIT+1
      IF (NIT-3*NSEG) 120,120,350
  120 IF (II-NSEG) 90,210,210
  130 N=0
C               CHECK SEGMENT FOR UPSTREAM SEGMENTS WHICH HAVE NOT
```

```
C               BEEN SEQUENCED YET
      DO 160 J=1,3
      IF (JUP(I,J)) 160,160,140
  140 K=JUP(I,J)
      IF (ITEST(K)) 150,150,160
  150 N=1
  160 CONTINUE
C               CHECK SEGMENT FOR ANY LATERAL INFLOW SEGMENTS WHICH
C               HAVE NOT BEEN SEQUENCED YET
      DO 190 J=1,4
      IF (JLAT(I,J)) 190,190,170
  170 K=JLAT(I,J)
      IF (ITEST(K)) 180,180,190
  180 N=1
  190 CONTINUE
C               IF SEGMENT HAS NO UNSEQUENCED UPSTREAM OR LATERAL INFLOW
C               SEGMENTS,SEQUENCE IT NEXT
      IF (N) 200,200,100
  200 II=II+1
      KSEG(II)=I
      ITEST(I)=1
      IF (II-NSEG) 100,210,210
  210 IF (NL-MAXL+10) 230,230,220
  220 CALL PAGE
C               OUTPUT COMPUTATION SEQUENCE
  230 N=0
      WRITE (6,370)
      NL=NL+5
      DO 340 I=1,NSEG
      K=KSEG(I)
      IF (ITYPE(K).EQ.8) GO TO 240
      IF (ITYPE(K)-4) 240,240,310
C               CHECK FOR CHANNELS WITH MISSING INFLOW SEGMENT
  240 NN=0
      DO 270 J=1,3
      IF (JLAT(K,J)) 250,250,260
  250 IF (JUP(K,J)) 270,270,260
  260 NN=1
  270 CONTINUE
      IF (NN) 280,280,310
  280 N=1
      IF (NL-MAXL+1) 300,300,290
  290 CALL PAGE
  300 NL=NL+1
      WRITE (6,380) K,ISEG(K)
      GO TO 340
  310 IF (NL-MAXL+1) 330,330,320
  320 CALL PAGE
  330 NL=NL+1
      WRITE (6,390) K,ISEG(K),ALPHA(K),EM(K)
C               CHECK FOR INPUT DATA ERROR
  340 CONTINUE
      IF (N) 360,360,350
  350 WRITE (6,400) II,(ITEST(I),I=1,NSEG)
      WRITE (6,410) (I,(JUP(I,J),J=1,3),(JLAT(I,J),J=1,4),I=1,NSEG)
      STOP
  360 CONTINUE
      CALL AREA (DA,DIMP,NONCH)
      RETURN
C
  370 FORMAT (//10X,20HCOMPUTATION SEQUENCE,16X,28HKINEMATIC CHANNEL PAR
```

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     1AMETERS//12X,5HINDEX,3X,7HSEGMENT,19X,5X,5HALPHA,6X,1HM)
  380 FORMAT (52X,I3,6X,A4,6X,22HMISSING INFLOW SEGMENT)
  390 FORMAT (13X,I3,5X,A4,F31.2,F10.3)
  400 FORMAT (42X,35HINPUT DATA ERROR, EXECUTION STOPPED/5X,I5/(5X,10I5)
     1)
  410 FORMAT (5X,10I5)
      END
      SUBROUTINE INIT
C              THIS SUBROUTINE INITIALIZES CATCHMENT FOR BEGINNING OF
C              NEW STORM
      REAL IN2,ISEG,IUP,ILAT,IN1
      COMMON /C1/ NSEG,ISEG(50),IUP(50,3),NPAR,KPSET(50)
      COMMON /C3/ IPRNT,T,AR(50,11),FLGTH(50),KSEG(50),NDX(50),Q1(50),Q2
     1(50),QSUM(50),QSUML(50),STO(50)
      COMMON /C4/ DELS,MAXL,QCW,QLAT,ILAT(50,4),ITEST(50),ITYPE(50),JLAT
     1(50,4),JUP(50,3),P(3456,3),PARAM(50,2),RCOEF(50,3),UPR(7200)
      COMMON /C7/ ECOMP,I,KINIT,NOUT,NRG,OSI,JOUT(50),QIND,RAT(3,2)
      COMMON /E2/ SMAX(50),IN2(50),IN1(50),S2O2(50)
      COMMON /E3/ DELTAT,NOB,QS(50,11)
      COMMON /E5/ S2(50,30),S(50,30),C(50,30)
      T=0.
      KINIT=0
      ECOMP=5.0
      QIND=0.0
      IPRNT=1
      DO 30 L=1,NSEG
      QSUM(L)=0.
      QSUML(L)=0.
      K=KSEG(L)
      SMAX(K)=0.0
      IN2(K)=0.0
      STO(K)=0.
      IF (ITYPE(K).EQ.9) STO(K)=PARAM(K,2)
      N=NDX(K)+1
      IF (ITYPE(K).GT.7) GO TO 20
      DO 10 J=1,N
      QS(K,J)=0.0
   10 AR(K,J)=0.0
   20 Q2(K)=0.
      Q1(K)=0.
      IF (ITYPE(K).NE.8) GO TO 30
      CALL TABLE (K,PARAM(K,2),S2,S,C,Q2(K),NDX(K))
      S2O2(K)=PARAM(K,2)/DELTAT+Q2(K)/2.
      STO(K)=PARAM(K,2)
   30 CONTINUE
      RETURN
      END
      SUBROUTINE AREA (DA,DIMP,NONCH)
C              THIS SUBROUTINE 1. ADJUSTS RAIN GAGE TO BASIN
C              2. CHECKS COMPUTED DRAINAGE AREA VERSUS FURNISHED
C              DRAINAGE AREA. 3. DETERMINES PERVIOUS AND IMPERVIOUS
C              AREAS COVERED BY EACH RAIN GAGE FOR EACH SOIL TYPE
      INTEGER DELS
      REAL DIMP(9,2),DT(150,6,2)
      DIMENSION KS(50)
      COMMON /C1/ NSEG,ISEG(50),IUP(50,3),NPAR,KPSET(50)
      COMMON /C3/ IPRNT,T,AR(50,11),FLGTH(50),KSEG(50),NDX(50),Q1(50),Q2
     1(50),QSUM(50),QSUML(50),STO(50)
      COMMON /C4/ DELS,MAXL,QCW,QLAT,ILAT(50,4),ITEST(50),ITYPE(50),JLAT
     1(50,4),JUP(50,3),P(3456,3),PARAM(50,2),RCOEF(50,3),UPR(7200)
      COMMON /C7/ ECOMP,I,KINIT,NOUT,NRG,OSI,JOUT(50),QIND,RAT(3,2)
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      COMMON /C8/ I2,I1,IK,TRYCT,KOUT(60),SEG(50)
      KLL=NSEG+100
      DO 30 L=1,NPAR
      DO 20 I=1,KLL
      DO 10 J=1,6
   10 DT(I,J,L)=0.0
   20 CONTINUE
   30 CONTINUE
      DAT=0.0
C              CALCULATE PERVIOUS AND IMPERVIOUS DRAINAGE AREA FROM
C              OVERLAND FLOW SEGMENTS INTO EACH CHANNEL FOR EACH RAIN
C              GAGE AND SOIL TYPE
      DO 120 I=1,NSEG
      IF (ITYPE(I).NE.5.AND.ITYPE(I).NE.6) GO TO 120
      DO 110 KL=1,NSEG
      DO 100 KM=1,4
      KL1=KL+NSEG
      KL2=KL+2*NSEG
      IF (I.NE.JLAT(KL,KM)) GO TO 100
      RK=0.0
      ANEI=1.-PARAM(I,1)-PARAM(I,2)
      IF (PARAM(I,2).LT.0.) ANEI=ANEI+2.*PARAM(I,2)
      DO 40 KMM=1,NRG
   40 RK=RK+RCOEF(I,KMM)
      DO 90 KK=1,NPAR
      PK=0.0
      IF (KPSET(I).EQ.KK) PK=1.0
      DO 80 KMM=1,3
      KMM1=KMM+3
      DTEMP=FLGTH(KL)*FLGTH(I)*RCOEF(I,KMM)*PK
      IF (PARAM(I,2).LT.0.) GO TO 50
      DT(KL,KMM1,KK)=DT(KL,KMM1,KK)+DTEMP*PARAM(I,2)
      IF (PARAM(I,1).LT.0.) GO TO 60
   50 DT(KL1,KMM1,KK)=DT(KL1,KMM1,KK)+DTEMP*PARAM(I,1)
      DT(KL2,KMM1,KK)=DT(KL2,KMM1,KK)+DTEMP*ANEI
   60 DTEMP=DTEMP/RK
      IF (PARAM(I,2).LT.0.) GO TO 70
      DT(KL,KMM,KK)=DT(KL,KMM,KK)+DTEMP*PARAM(I,2)
      IF (PARAM(I,1).LT.0.) GO TO 80
   70 DT(KL1,KMM,KK)=DT(KL1,KMM,KK)+DTEMP*PARAM(I,1)
      DT(KL2,KMM,KK)=DT(KL2,KMM,KK)+DTEMP*ANEI
   80 CONTINUE
   90 CONTINUE
  100 CONTINUE
  110 CONTINUE
  120 CONTINUE
C              AGGREGATE DRAINAGE AREA FOR EACH CHANNEL SEGMENT FOR
C              EACH RAIN GAGE FOR EACH SOIL TYPE
      KM1=NSEG-NONCH
      DO 130 I=1,KM1
      NONCH=NONCH+1
      KS(I)=KSEG(NONCH)
  130 CONTINUE
      KM1=KM1-1
      DO 180 KI=1,KM1
      KJ=KS(KI)
      KJJ=KJ+NSEG
      KJK=KJ+2*NSEG
      KP1=KI+1
      K=KM1+1
      DO 170 I=KP1,K
```

```
      JK=KS(I)
      JKK=JK+NSEG
      JKL=JK+2*NSEG
      DO 160 KMK=1,3
      IF (JUP(JK,KMK).NE.KJ) GO TO 160
      DO 150 KMM=1,NRG
      KMM1=KMM+3
      DO 140 KK=1,NPAR
      DT(JK,KMM,KK)=DT(JK,KMM,KK)+DT(KJ,KMM,KK)
      DT(JK,KMM1,KK)=DT(JK,KMM1,KK)+DT(KJ,KMM1,KK)
      DT(JKK,KMM,KK)=DT(JKK,KMM,KK)+DT(KJJ,KMM,KK)
      DT(JKK,KMM1,KK)=DT(JKK,KMM1,KK)+DT(KJJ,KMM1,KK)
      DT(JKL,KMM,KK)=DT(JKL,KMM,KK)+DT(KJK,KMM,KK)
      DT(JKL,KMM1,KK)=DT(JKL,KMM1,KK)+DT(KJK,KMM1,KK)
  140 CONTINUE
  150 CONTINUE
  160 CONTINUE
  170 CONTINUE
  180 CONTINUE
C              CALCULATE TOTAL DRAINAGE AREA AND TOTAL PERVIOUS AND
C              IMPERVIOUS AREA FOR EACH RAIN GAGE AND SOIL TYPE
      K=KSEG(NSEG)
      KP=K+NSEG
      KQ=K+2*NSEG
      DTEMP1=0.0
      DO 220 KMM=1,3
      KMP=KMM+3
      KMQ=KMM+6
      DO 190 KK=1,NPAR
      DAT=DAT+DT(K,KMM,KK)+DT(KP,KMM,KK)+DT(KQ,KMM,KK)
      DTEMP1=DTEMP1+DT(K,KMP,KK)+DT(KP,KMP,KK)+DT(KQ,KMP,KK)
      DIMP(KMM,KK)=DT(K,KMM,KK)
      DIMP(KMP,KK)=DT(KP,KMM,KK)
      DIMP(KMQ,KK)=DT(KQ,KMM,KK)
  190 CONTINUE
      IF (DIMP(KMP,1).EQ.0.0) GO TO 200
      RAT(KMM,1)=(DIMP(KMP,1)+DIMP(KMQ,1))/DIMP(KMP,1)
  200 IF (DIMP(KMP,2).EQ.0.0) GO TO 210
      RAT(KMM,2)=(DIMP(KMP,2)+DIMP(KMQ,2))/DIMP(KMP,2)
  210 DIMP(KMM,1)=DIMP(KMM,1)+DIMP(KMM,2)
  220 CONTINUE
C              ADJUST RAIN GAGE TO BASIN, IF NECESSARY
      DTEMP1=DTEMP1/DAT
      IF (DTEMP1.LT.0.995.OR.DTEMP1.GT.1.005) CALL RFADJ (DTEMP1,NRG)
C              CHECK COMPUTED DRAINAGE AREA WITH FURNISHED  DRAINAGE AREA
      DAT=DAT/5280.0**2
      DAT1=DAT/DA
      DAT2=DA/DAT
      RATIO=1.01
      IF (DAT1.LT.RATIO.AND.DAT2.LT.RATIO) GO TO 230
      WRITE (6,240) DA,DAT
  230 CONTINUE
      DA =DAT
      RETURN
C
  240 FORMAT (1H ,25HFURNISHED DRAINAGE AREA =,F8.3,2X,12HSQUARE MILES/1
     11H ,25HCOMPUTED  DRAINAGE AREA =,F8.3,38H THESE DIFFER BY MORE THAN
     2 ONE PERCENT)
      END
      SUBROUTINE RFADJ (DTEMP1,NRG)
C              THIS SUBROUTINE ADJUSTS RAIN GAGE TO BASIN
```

```
      INTEGER RODYS,DELS
      COMMON /C1/ NSEG,ISEG(50),IUP(50,3),NPAR,KPSET(50)
      COMMON /C4/ DELS,MAXL,QCW,QLAT,ILAT(50,4),ITEST(50),ITYPE(50),JLAT
     1(50,4),JUP(50,3),P(3456,3),PARAM(50,2),RCOEF(50,3),UPR(7200)
      COMMON /D1/ DP(1000),RODYS
      WRITE (6,50) DTEMP1
      DO 10 KP=1,7200
   10 UPR(KP)=UPR(KP)*DTEMP1
      DO 30 KP=1,NSEG
      IF (ITYPE(KP).NE.5.AND.ITYPE(KP).NE.6) GO TO 30
      DO 20 KMM=1,3
   20 RCOEF(KP,KMM)=RCOEF(KP,KMM)/DTEMP1
      WRITE (6,60) KP,(RCOEF(KP,KMM),KMM=1,NRG)
   30 CONTINUE
      DO 40 KP=1,RODYS
   40 DP(KP)=DP(KP)*DTEMP1
      RETURN
C
   50 FORMAT (1H ,49HALL RAINFALLS HAVE BEEN MULTIPLIED BY A FACTOR OF,F
     19.4/67H TO ADJUST RAIN GAGE TO BASIN. SIMILARLY, ALL THEISSEN COEF
     2FICIENTS/61H HAVE BEEN ADJUSTED TO APPLY TO THE REVISED AVERAGE RA
     3INFALL.)
   60 FORMAT (1H ,I5,3F15.6)
      END
      FUNCTION ITRAN (X)
C             THIS FUNCTION NUMBERS LATERAL AND UPSTREAM INFLOW
C             SEGMENTS TO CORRESPOND TO THE ISEG'S
      REAL ISEG,IUP
      COMMON /C1/ NSEG,ISEG(50),IUP(50,3),NPAR,KPSET(50)
      I=1
   10 IF (X-ISEG(I)) 30,20,30
   20 ITRAN=I
      RETURN
   30 I=I+1
      IF (I-NSEG) 10,10,40
   40 ITRAN=0
      RETURN
      END
      SUBROUTINE AM
C             THIS SUBROUTINE COMPUTES THE PARAMETERS ALPHA AND EM
C             AND THE FULL-SEGMENT FLOW FOR EACH SEGMENT
      INTEGER DELS
      COMMON /C1/ NSEG,ISEG(50),IUP(50,3),NPAR,KPSET(50)
      COMMON /C4/ DELS,MAXL,QCW,QLAT,ILAT(50,4),ITEST(50),ITYPE(50),JLAT
     1(50,4),JUP(50,3),P(3456,3),PARAM(50,2),RCOEF(50,3),UPR(7200)
      COMMON /C5/ ALPHA(50),EM(50),FRN(50),QMAX(50),SLOPE(50)
      DO 80 I=1,NSEG
      N=ITYPE(I)
      IF (N.GE.8) N=7
      GO TO (10,20,30,40,50,70,60), N
   10 ALPHA(I)=1.49/FRN(I)*SQRT(SLOPE(I))/PARAM(I,1)**(2./3.)
      AMAX=PARAM(I,1)*PARAM(I,2)
      EM(I)=1.67
      QMAX(I)=ALPHA(I)*AMAX**EM(I)
      GO TO 80
   20 AMAX=3.14*PARAM(I,1)**2/4.
      QFULL=1.49/FRN(I)*AMAX*(PARAM(I,1)/4.)**(2./3.)*SQRT(SLOPE(I))
      ALPHA(I)=QFULL/AMAX
      EM(I)=1.
      QMAX(I)=QFULL
      GO TO 80
```

```
   30 ALPHA(I)=1.41/FRN(I)*SQRT(SLOPE(I))/PARAM(I,1)**(1./3.)
      QMAX(I)=10.**10
      EM(I)=1.33
      GO TO 80
   40 ALPHA(I)=PARAM(I,1)
      EM(I)=PARAM(I,2)
      QMAX(I)=10.**10
      GO TO 80
   50 ALPHA(I)=1.49/FRN(I)*SQRT(SLOPE(I))
      QMAX(I)=10.**10
      EM(I)=1.67
      GO TO 80
   60 QMAX(I)=10.**10
      ALPHA(I)=0.
      EM(I)=0.
      GO TO 80
   70 QMAX(I)=10.**10
      ALPHA(I)=64.4*SLOPE(I)/(FRN(I)*.0000141)
      EM(I)=3.
   80 CONTINUE
      RETURN
      END
      SUBROUTINE PAGE
C              THIS SUBROUTINE SETS UP A NEW PAGE
      COMMON /C2/ NL,NPAGE
      NPAGE=NPAGE+1
      WRITE (6,10) NPAGE
      NL=3
      RETURN
C
   10 FORMAT (1H1,110X,4HPAGE,I4//20X,20A4)
      END
      SUBROUTINE PULS (K)
C              THIS SUBROUTINE PERFORMS MODIFIED PULS ROUTING
      REAL IN1,IN2
      COMMON /C3/ IPRNT,T,AH(50,11),FLGTH(50),KSEG(50),NDX(50),Q1(50),Q2
     1(50),QSUM(50),QSUML(50),STO(50)
      COMMON /E2/ SMAX(50),IN2(50),IN1(50),S2O2(50)
      COMMON /E3/ DELTAT,NOB,QS(50,11)
      COMMON /E4/ WV(50,30),S1(50,30),C1(50,30)
      IN1(K)=IN2(K)
      IN2(K)=QSUM(K)
      AVIN=(IN1(K)+IN2(K))/2.
      S2O2(K)=S2O2(K)+AVIN-Q1(K)
      IF (IN2(K).LT.0.005) GO TO 10
      CALL TABLE (K,S2O2(K),WV,S1,C1,Q2(K),NDX(K))
   10 IF (IN2(K).LT.0.005) Q2(K)=IN2(K)
      STO(K)=(S2O2(K)-Q2(K)/2.)*DELTAT
      IF (STO(K).LT.SMAX(K)) GO TO 20
      SMAX(K)=STO(K)
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PRPLOT
C        16 MARCH 73
      IMPLICIT LOGICAL*1(W),LOGICAL*1(K)
      DIMENSION NSCALE(5), ABNOS(26), X(1), Y(1)
      LOGICAL*1 NOS(10)/'0','1','2','3','4','5','6','7','8','9'/
      LOGICAL*1 IMAGE(1),CH,LABEL(1),ERR1,ERR3,ERR5
      LOGICAL*1 VC,HC,FOR1(19),FOR2(15),FOR3(19),NC,BL,HF,HF1
      REAL*8 FOX1(3),FOX2(2),FOX3(3)
      INTEGER*2 VCR
      EQUIVALENCE (FOR1,FOX1), (FOR2,FOX2), (FOR3,FOX3), (VC,VCR)
      INTEGER FILE
      DATA HC/'-'/,NC/'+'/,BL/' '/,HF/'F'/,HF1/'.'/
      DATA FOX1/'(1XA1,F9','.2,  121','A1)     '/
      DATA FOX2/'(1XA1, 9','X121A1) '/
      DATA FOX3/'(1H0F  .',' ,  F   ','. )     '/
      DATA VCR/Z4F00/
      DATA KPLOT1/.FALSE./,KPLOT2/.FALSE./
      DATA KABSC,KORD,KBOTGL/3*.FALSE./
C
      ENTRY PLOT1(NSCALE,NHL,NSBH,NVL,NSBV)
      IFL=FILE
      ERR1=.FALSE.
      ERR3=.FALSE.
      ERR5=.FALSE.
      KPLOT1=.TRUE.
      KPLOT2=.FALSE.
      NH=IABS(NHL)
      NSH=IABS(NSBH)
      NV=IABS(NVL)
      NSV=IABS(NSBV)
      NSCL=NSCALE(1)
      IF (NH*NSH*NV*NSV.NE.0) GO TO 1
      KPLOT=.FALSE.
      ERR1=.TRUE.
      RETURN
    1 KPLOT=.TRUE.
      IF (NV.LE.25) GO TO 2
      KPLOT=.FALSE.
      ERR3=.TRUE.
      RETURN
    2 CONTINUE
      NVM=NV-1
      NVP=NV+1
      NDH=NH*NSH
      NDHP=NDH+1
      NDV=NV*NSV
      NDVP=NDV+1
      NIMG=(NDHP*NDVP)
      IF (NDV.LE.120) GO TO 3
      KPLOT=.FALSE.
      ERR5=.TRUE.
      RETURN
    3 CONTINUE
      IF (NSCL.EQ.0) GO TO 4
      FSY=10.**NSCALE(2)
      FSX=10.**NSCALE(4)
      IY=MIN0(IABS(NSCALE(3)),7)+1
      IX=MIN0(IABS(NSCALE(5)),9)+1
      GO TO 5
    4 FSY=1.
      FSX=1.
```

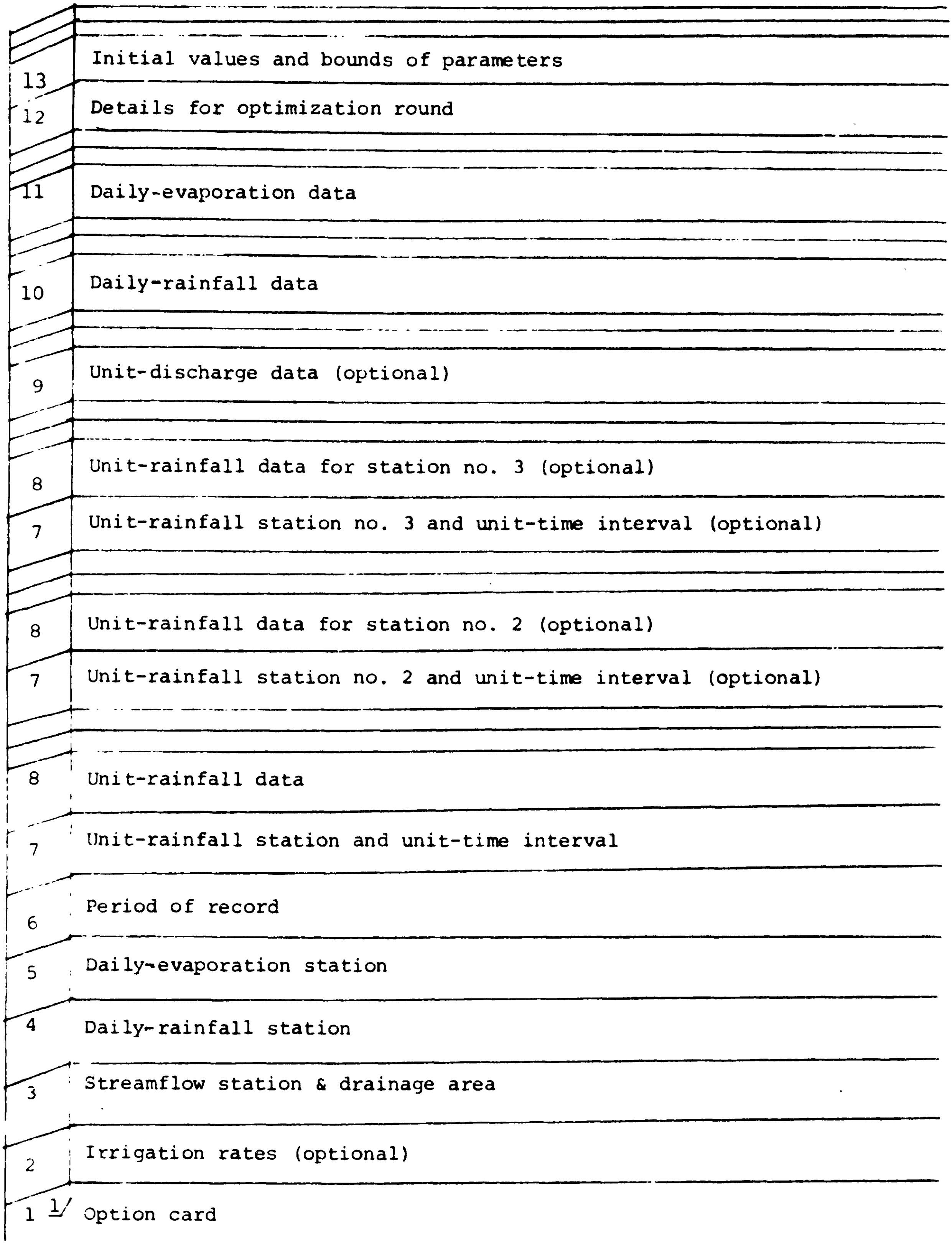
```
      IY=4
      IX=4
    5 FOR1(10)=NOS(IY)
      NA=MIN0(IX,NSV)-1
      NS=NA-MIN0(NA,120-NDV)
      NB=11-NS+NA
      I1=NB/10
      I2=NB-I1*10
      FOR3(6)=NOS(I1+1)
      FOR3(7)=NOS(I2+1)
      FOR3(9)=NOS(NA+1)
      IF (NV.GT.0) GO TO 7
      DO 6 J=11,18
    6 FOR3(J)=BL
      GO TO 8
    7 I1=NV/10
      I2=NV-I1*10
      FOR3(11)=NOS(I1+1)
      FOR3(12)=NOS(I2+1)
      FOR3(13)=HF
      I1=NSV/100
      I3=NSV-I1*100
      I2=I3/10
      I3=I3-I2*10
      FOR3(14)=NOS(I1+1)
      FOR3(15)=NOS(I2+1)
      FOR3(16)=NOS(I3+1)
      FOR3(17)=HF1
      FOR3(18)=FOR3(9)
    8 IF (KPLOT1) RETURN
      KPLOT1=.TRUE.
C
      ENTRY PLOT2(IMAGE,XMAX,XMIN,YMAX,YMIN,FILE)
      IFL=FILE
      KPLOT2=.TRUE.
      IF (KPLOT1) GO TO 9
      NSCL=0
      NH=5
      NSH=10
      NV=10
      NSV=10
      GO TO 1
    9 CONTINUE
      IF (KPLOT) GO TO 10
      IF (ERR1) WRITE (IFL,30)
      IF (ERR3) WRITE (IFL,31)
      IF (ERR5) WRITE (IFL,32)
      RETURN
   10 YMX=YMAX
      DH=(YMAX-YMIN)/FLOAT(NDH)
      DV=(XMAX-XMIN)/FLOAT(NDV)
      DO 11 I=1,NVP
   11 ABNOS(I)=(XMIN+FLOAT((I-1)*NSV)*DV)*FSX
      DO 12 I=1,NIMG
   12 IMAGE(I)=BL
      DO 16 I=1,NDHP
      I2=I*NDVP
      I1=I2-NDV
      KNHOR=MOD(I-1,NSH).NE.0
      IF (KNHOR) GO TO 14
      DO 13 J=I1,I2
```

```
   13 IMAGE(J)=HC
   14 CONTINUE
      DO 16 J=I1,I2,NSV
      IF (KNHOR) GO TO 15
      IMAGE(J)=NC
      GO TO 16
   15 IMAGE(J)=VC
   16 CONTINUE
      XMIN1=XMIN-DV/2.
      YMIN1=YMIN-DH/2.
      RETURN
C
      ENTRY PLOT3(CH,X,Y,N3)
      IF (KPLOT2) GO TO 18
   17 WRITE (IFL,33)
   18 CONTINUE
      IF (.NOT.KPLOT) RETURN
      IF (N3.GT.0) GO TO 19
      KPLOT=.FALSE.
      WRITE (IFL,34)
      RETURN
   19 DO 26 I=1,N3
      IF (DV) 21,20,21
   20 DUM1=0
      GO TO 22
   21 CONTINUE
      DUM1=(X(I)-XMIN1)/DV
   22 IF (DH) 24,23,24
   23 DUM2=0
      GO TO 25
   24 CONTINUE
      DUM2=(Y(I)-YMIN1)/DH
   25 CONTINUE
      IF (DUM1.LT.0..OR.DUM2.LT.0.) GO TO 26
      IF (DUM1.GE.NDVP.OR.DUM2.GE.NDHP) GO TO 26
      NX=1+INT(DUM1)
      NY=1+INT(DUM2)
      J=(NDHP-NY)*NDVP+NX
      IMAGE(J)=CH
   26 CONTINUE
      RETURN
C
      ENTRY PLOT4(NL,LABEL)
      ENTRY FPLOT4(NL,LABEL)
      IF (.NOT.KPLOT) RETURN
      IF (.NOT.KPLOT2) GO TO 17
      DO 28 I=1,NDHP
      IF (I.EQ.NDHP.AND.KBOTGL) GO TO 28
      WL=BL
      IF (I.LE.NL) WL=LABEL(I)
      I2=I*NDVP
      I1=I2-NDV
      IF (MOD(I-1,NSH).EQ.0.AND..NOT.KORD) GO TO 27
      WRITE (IFL,FOR2) WL,(IMAGE(J),J=I1,I2)
      GO TO 28
   27 CONTINUE
      ORDNO=(YMX-FLOAT(I-1)*DH)*FSY
      IF (I.EQ.NDHP) ORDNO=YMIN
      WRITE (IFL,FOR1) WL,ORDNO,(IMAGE(J),J=I1,I2)
   28 CONTINUE
      IF (KABSC) GO TO 29
```

```
      WRITE (IFL,FOR3) (ABNOS(J),J=1,NVP)
   29 RETURN
C
      ENTRY OMIT(LSW)
      KABSC=MOD(LSW,2).EQ.1
      KORD=MOD(LSW,4).GE.2
      KBOTGL=LSW.GE.4
      RETURN
C
C
C
   30 FORMAT (T5,'SOME PLOT1 ARG. ILLEGALLY 0')
   31 FORMAT (T5,'NO. OF VERTICAL LINES >25')
   32 FORMAT (T5,'WIDTH OF GRAPH >121')
   33 FORMAT (T5,'PLOT2 MUST BE CALLED')
   34 FORMAT (T5,'PLOT3, ARG2 ) 0')
      END
      SUBROUTINE TABLE (K,F1,F3,S3,C3,F2,J)
C                THIS SUBROUTINE PERFORMS LINEAR INTERPOLATION FOR
C                 MODIFIED PULS ROUTING
      DIMENSION F3(50,30), S3(50,30), C3(50,30)
      DO 10 I=2,J
      IF (F1.LT.F3(K,I)) GO TO 20
   10 CONTINUE
      I=J
   20 F2=S3(K,I)*F1+C3(K,I)
      RETURN
      END
```

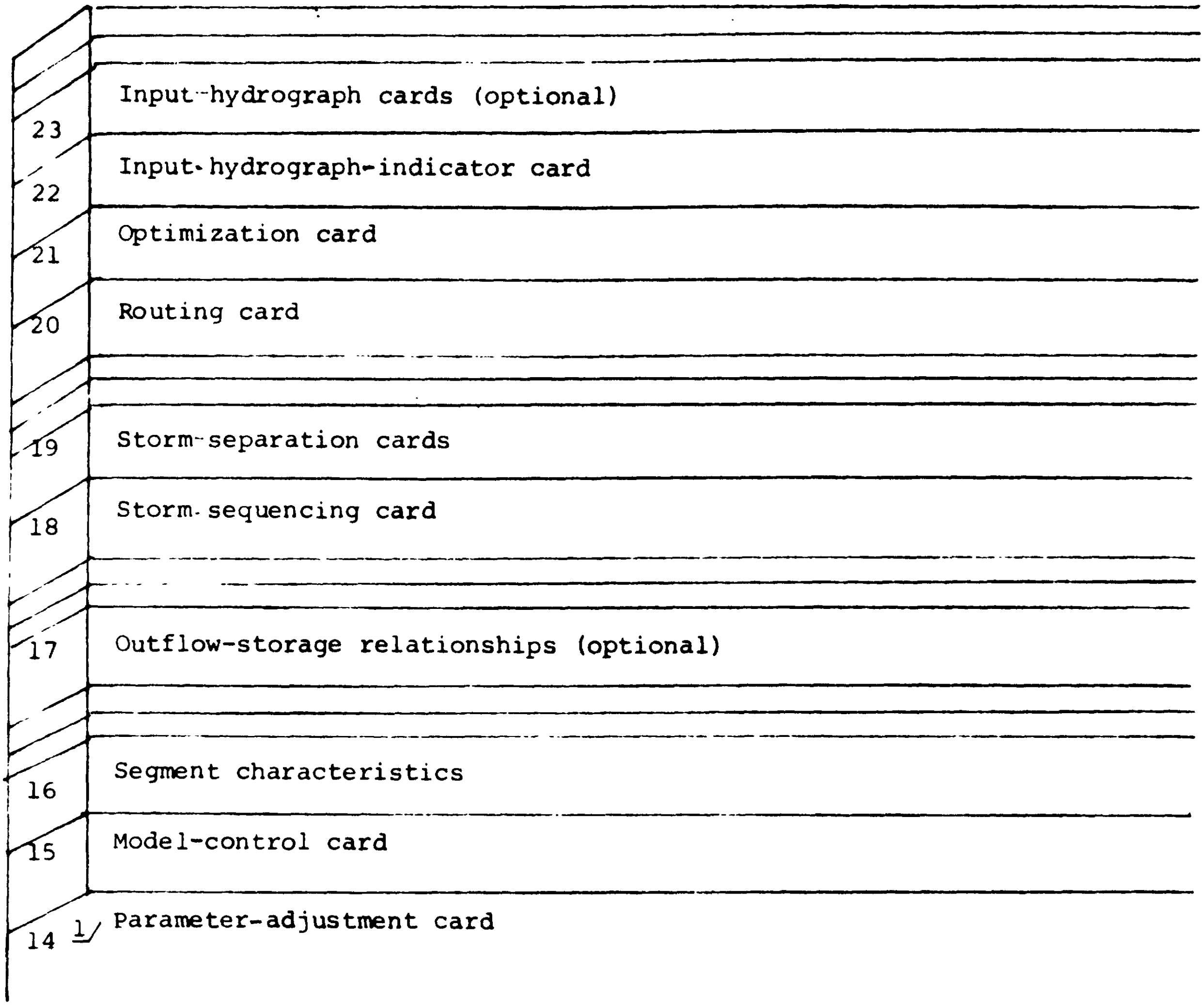
D. SCHEMATIC OF PROGRAM DECK SETUP

D. SCHEMATIC OF PROGRAM DECK SETUP



[1/] Number refers to card group in data input specifications.

SCHEMATIC OF PROGRAM DECK SETUP--continued



1/ Number refers to card group in data input specifications.

E. SAMPLE RUNS

It remains largely an art to characterize a basin in terms of a number of segments which account for the essential basin properties. In order to provide the "artist" with some help; an example, Sand Creek Tributary at Denver, Colorado, will be discussed. The approach illustrated by this example is not meant to provide hard and fast rules but rather to serve as a guide for applying the model. Different objectives and study limitations will require deviations from this guide.

The Sand Creek Tributary at Denver drainage basin is a 183-acre area of predominantly single-family residential land use with some multifamily land use, a church, a recreational center, a fire station, and two small parks. The basin has some storm sewers in its upper end but relies mostly on street gutters and concrete-lined open ditches for flow conveyance. Detailed records of rainfall and stream stage are collected at the station by the operation of dual-digital recorders which code the data on 16-channel paper tape at 5-minute intervals. Use of a single timer provides for simultaneous actuation of both recorders. A stage-discharge relation was developed on the basis of step-backwater analysis of a reach of concrete-lined stream channel and discharge measurements made during storm runoff. The rainfall-runoff data used in this example have been published (Ducret and Hodges, 1975).

Two sample runs will be discussed for the Sand Creek Tributary at Denver basin. The first run was an optimization run without any routing. In the second run, the soil-moisture-accounting and infiltration parameters were set at their final values from the first run and routing was performed for ten storm events. These two runs could have been accomplished with a single computer run; however, experience with the model has shown the two-stage approach to be preferred. The following is a discussion by card group of the input data for the first computer run.

Card Group 1

It was desired to list the input rainfall and evaporation data; therefore, OPTION = LIST. Storm-runoff volumes were included in the model-input data; therefore, OPT = 1.

Card Group 2

No card was included because daily rainfalls were not to be modified for irrigation (NOPT1 = 0).

Card Groups 3, 4, and 5

The streamflow, daily-rainfall and daily-evaporation station identifiers were input to the model using these three cards. Card Group 3 also included the drainage area of the basin (0.286 square miles).

Card Group 6

The first runoff period to be simulated occurred on July 12, 1973. In order to establish initial soil-moisture conditions for this date, the beginning day of record was set at May 1, 1973. The last runoff period to be simulated occurred on July 30, 1974; therefore, the last day of record was set at July 31, 1974 (1 day after last unit-rainfall day).

Card Group 7

The unit-rainfall station number and name were input along with the time increment of unit data (5 minutes for this example).

Card Group 8

Card Group 8 was used to input the unit-rainfall data. Ducret and Hodges (1975) reported data for 14 runoff periods during 1973 and 1974 (table 4). Four of these runoff periods were not selected for simulation for the reasons given in table 4. Because no unit-discharge data were read-in (0PT = 1), a card with a C0DE of 9 punched in column 80 was placed at the end of Card Group 8.

Card Group 9

Card Group 9 was skipped because no unit-discharge data were input for this run.

Card Group 10

Card Group 10 was used to read in the daily-rainfall data. Because a large gap in time existed between runoff-period numbers 8 (September 11, 1973) and 9 (July 22, 1974), 9999's were punched as the daily rainfall for September 15, 1973 and May 1, 1974. Daily-rainfall cards were not included for the intervening period. Continuation of the daily moisture accounting on May 1, 1974 should have allowed sufficient time for the model to establish initial soil-moisture conditions for the runoff of July 22, 1974.

Card Group 11

Card Group 11 was used to read in the daily-evaporation data. Note that daily-evaporation cards were not included for the period between September 15, 1973, and May 1, 1974, as this period was to be skipped by the model. A card with a C0DE of 9 punched in column 80 was placed at the end of Card Group 11.

Card Group 12

There were seven parameters in the soil-moisture and infiltration components because a single soil type was assumed throughout the basin.

Table 4.--Summary of runoff periods at Sand Creek Tributary Basin at Denver, Colorado, 1973 and 1974.

Runoff-period number[1/]	Date	Rainfall, in inches	Runoff volume, in inches	Percent runoff	Peak flow, in cubic feet per second	Comments
--	May 5-6, 1973	4.38	1.2	27	31	Poor temporal correlation of rainfall and runoff
1	July 12, 1973	.33	.080	24	32	
2	July 19, 1973	.63	.16	25	68	
--	July 20, 1973	.11	.054	49	20	Anomalously high percentage of runoff
3	July 22, 1973	.23	.055	24	22	
4	July 24, 1973	.95	.33	35	104	
5	July 30, 1973	.34	.063	19	32	
6	Aug. 7, 1973	1.94	.70	36	236	
--	Sept. 9, 1973	.24	.030	12	21	Very poor temporal correlation of rainfall and runoff
7	Sept. 11, 1973	.51	.073	14	48	
8	Sept. 11, 1973	.56	.23	41	143	
--	June 8, 1974	1.04	---	--	17	Too much estimated flow to accurately determine runoff volume
9	July 22, 1974	1.06	.20	19	98	
10	July 30, 1974	1.38	.53	38	251	

[1/] Number refers to flood-event number used in model output. Runoff periods without a number were not simulated for reasons explained in comments.

The model is primarily sensitive to only four of the seven parameters; therefore, only four parameters were adjusted by the model. Based on experience with the model, the number of trial adjustments per parameter was set at 10 and the initial step size for parameter adjustment at 0.060.

Card Group 13

The soils in the drainage basin are highly pervious sands which would be expected to result in higher values for PSP, KSAT, and BMSN than those suggested as initial values in table 3. However, for this run the initial magnitudes and lower and upper limits of the soil-moisture and infiltration parameters were set at the values suggested in table 3.

Card Group 14

The parameters to be optimized were PSP, KSAT, RGF, and BMSN; therefore, the subscripts for card 14 are 1, 2, 3, and 4.

Card Groups 15 and 16

An aerial photo of the drainage basin is shown in figure 13. The first step in subdividing this drainage basin into segments was to obtain available information on the physical characteristics of the catchment. This consisted of an aerial photograph from a local engineering firm, drainage maps which also showed street-corner elevations from the City of Denver, and the U.S. Geological Survey topographic map for the area. Using the above information, the drainage-basin boundary was approximated in the office and then field checked. The drainage network; inlets to the drainage network; all flow directions on streets, particularly at street intersections; and effective impervious surfaces from roofs, parking lots, etc., were delineated on copies of the aerial photos. This information was obtained and (or) verified by on-site inspection.

It was then the "artist's" turn. Using the marked-up photos from the above exercise, the basin was delineated into sub-basins (overland-flow segments) and a drainage network (channel segments). An attempt was made to balance number of segments (5 to 15 overland-flow segments was selected as an "optimum" range based on difficult to rationalize "engineering judgment"), maximum "uniformity" within segments, segmentation into overland-flow segments with balanced lengths of overland flow to their designated channel segments, and compatibility between overland-flow segments and their designated channel segments (that is, an optimum segmentation for overland-flow segments may result in a poor arrangement of channel segments). Ideally, perhaps, major changes within the drainage network such as in geometry, size, roughness, and (or) slope would result in separate channel segments. However, in many cases the channel segmentation will be governed by the overland-flow segmentations. Likewise, channel intersections often exert a controlling influence on overland-flow segmentation. A schematic of the basin segmentation is illustrated in figure 14.

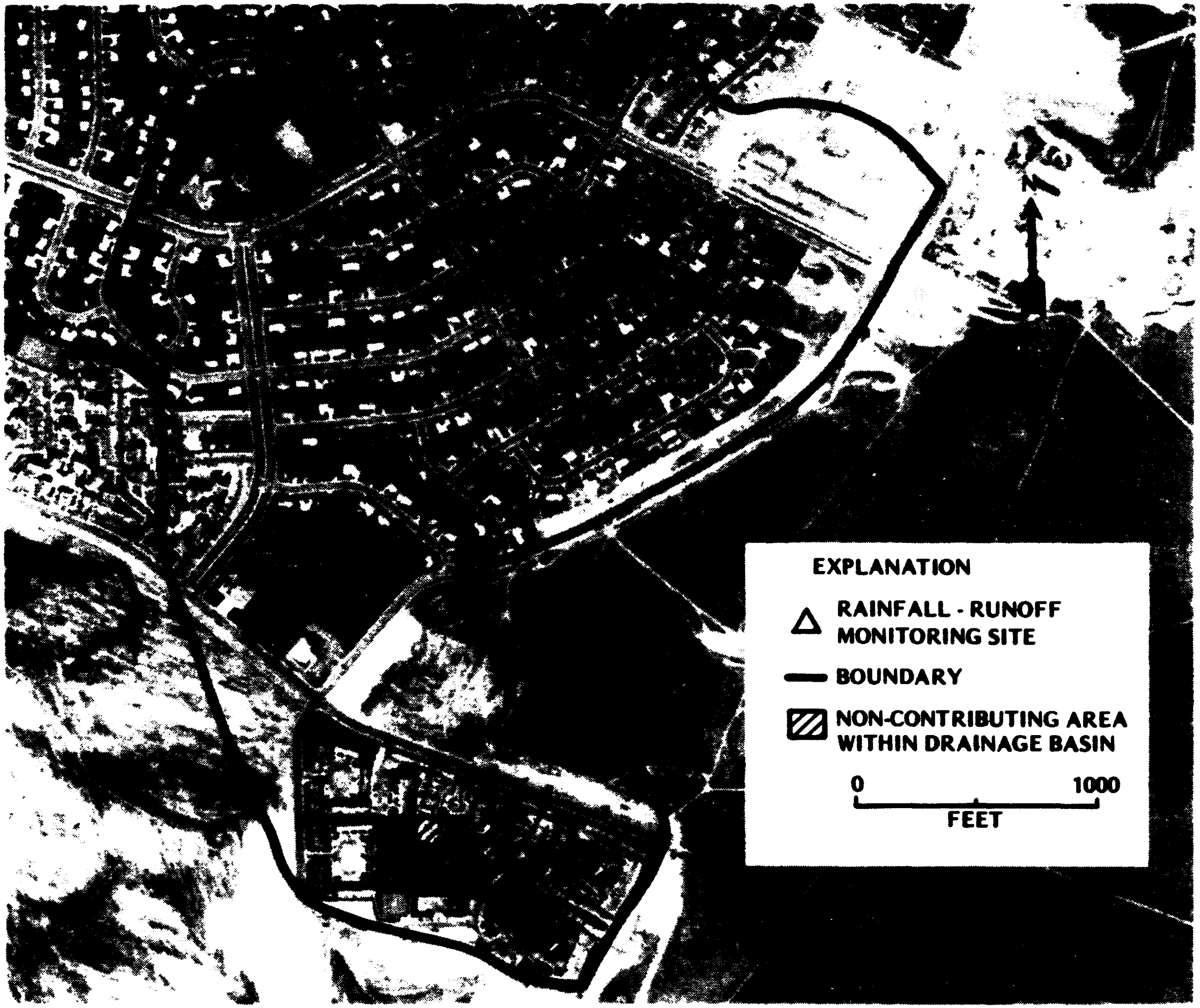


Figure 13.--Aerial photograph of Sand Creek Tributary Basin at Denver, Colorado.

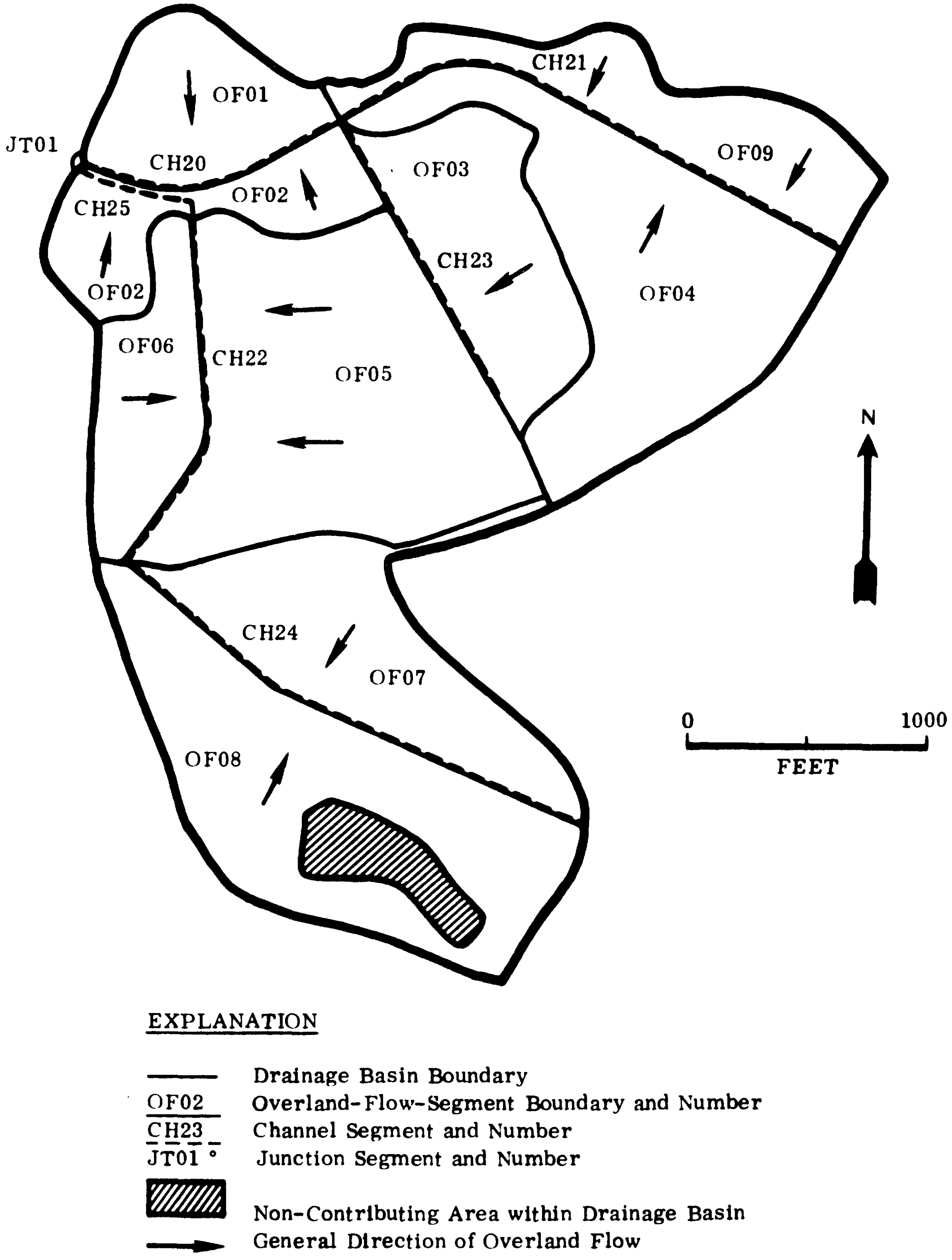


Figure 14.--Schematic of Sand Creek Tributary Basin at Denver, Colorado, showing segmentation for rainfall-runoff modeling.

The rationale behind the basin segmentation of figure 14 is as follows: It is often easiest to start at the downstream end of a basin and that approach was used when segmenting this basin. It was first noted that the major drainage system of the basin consisted of concrete-lined ditches which were located in the positions marked by channel segments CH20, CH21, and CH22. In analyzing the reach of concrete-lined ditch comprised of CH20 and CH21, it was noted that a street, which drained 14 acres of land, 0F03, intersected this reach. Therefore, this reach of concrete-lined ditch was subdivided into channel segments CH20 and CH21, and the intersecting street was designated as channel segment CH23. Overland-flow segments 0F01, 0F02, 0F03, 0F04, and 0F09 were then delineated based on this channel segmentation. It should be noted that overland-flow segment 0F04 does not have balanced lengths of overland flow to CH21. To further subdivide this overland-flow segment would also require that segments CH21 and 0F09 be further subdivided.

The unallocated concrete-lined ditch was then assigned as channel segment CH22. Overland-flow segments 0F06 and 0F05 were then delineated. To avoid the need to subdivide channel segment CH20 which would require subdividing overland-flow segments 0F01 and 0F02, channel segment CH25 was used to bypass channel segment CH20. A junction segment, JT01, was required to sum the flow from the two channel segments at the outlet of the basin. Finally, the remaining part of the basin was drained by a street which was assigned as channel segment CH24.

Once the basin was segmented, the sub-basin boundaries were field checked and representative channel cross sections were determined. Channel slopes were determined from the drainage maps, and overland-flow slopes were estimated from the U.S. Geological Survey topographic map for the area and the street-corner elevations shown on the City of Denver drainage maps. Sub-basin areas were planimetered and lengths of overland flow were computed by dividing the area of each sub-basin, in square feet, by the length, in feet, of the channel segment into which it contributes lateral inflow. The segment characteristics are shown in tables 5 and 6. Note in figure 14 that overland-flow segment 0F08 has a noncontributing area within its boundary. This results from internal drainage to a flood-control lake.

Roughness coefficients for the channel segments were estimated at 0.016 for the concrete-lined channels and 0.013 for the street-gutter channels. Two options are available for roughness coefficients for overland-flow segments. A single roughness coefficient can be assigned to an overland-flow segment or else the segment can be assigned two roughness coefficients, one for pervious surfaces and one for impervious surfaces. For this basin, two roughness coefficients were specified for overland-flow segment numbers 0F01, 0F07, and 0F08; 0.20 for pervious surfaces (0P01, 0P07, 0P08) and 0.013 for impervious surfaces (0I01, 0I07, 0I08). Only one roughness was specified for the other overland-flow segments because distances of pervious-surface overland flow were generally short over lawns and onto streets with the streets dominating the flow conveyance. Roughness coefficients for these segments were set at 0.016.

Table 5.--Overland-flow segment characteristics for Sand Creek Tributary Basin at Denver, Colorado

Segment number	Channel segment for drainage	Area (acre)	Length (feet)	Slope (feet/feet)	Perviousness	Effective imperviousness
0F01	CH20	12.6	454	0.005	0.80	0.15
0F02	CH20	10.6	382	.022	.47	.36
0F03	CH23	14.0	480	.024	.48	.31
0F04	CH21	30.5	593	.018	.54	.32
0F05	CH22	36.5	1,006	.022	.57	.27
0F06	CH22	10.7	295	.004	.44	.42
0F07	CH24	19.0	372	.012	.80	.16
0F08	CH24	31.5	617	.007	.58	.33
0F09	CH21	17.5	340	.010	.70	.22

Table 6.--Channel-segment characteristics for Sand Creek Tributary Basin at Denver, Colorado

Segment number	Upstream segment(s)	Length (feet)	Slope (feet/feet)	Manning *n*	Width (feet) at 1-foot depth
CH20	CH23,CH21	1,210	0.005	0.016	11
CH21	---	2,240	.007	.016	11
CH22	CH24	1,580	.008	.016	4.3
CH23	---	1,270	.029	.013	31
CH24	---	2,225	.005	.013	50
CH25	CH22	460	.005	.016	11

It remained to determine the time interval (Δt) and segment intervals (NDX) for the finite-difference calculations. Detailed output from the basin outlet was all that was required. Therefore, Δt was computed based on the entire channel length through the basin and the average overland-flow length to that channel. Three distinct channel networks drained the basin--a network comprised of channels CH20 and CH21, a network comprised of channels CH20 and CH23, and a network comprised of channels CH22, CH24, and CH25. Equations 12, 13, and 14 were used to calculate Δt for each of these three channel networks. The following illustrates application of these equations to the channel network comprised of channels CH20 and CH21.

The average slope (weighted by sub-basin area) of the sub-basins draining to the channel network (segments 0F01, 0F02, 0F04, and 0F09) is 0.014. Assuming this value for slope and 0.020 for FRN(I) and using the equations for turbulent overland-flow segments from table 2:

$$\alpha_o \simeq \frac{(1.49)\ \sqrt{0.014}}{0.020} = 8.8$$

and

$$m_o = 1.67$$

Letting FRN(I) = 0.016, PARAM (I, 1) = 11 feet and SLØPE(I) = 0.006 in the equations for triangular cross sections from table 2:

$$\alpha_c \simeq \frac{1.41\ \sqrt{0.006}}{(0.016)\ (11)^{1/3}} = 3.1$$

and

$$m_c = 1.33$$

The average length of overland-flow (weighted by sub-basin area) to the channel network is 475 feet. The length of channels CH20 plus CH21 is 3,450 feet. For the storms simulated, the maximum 5-minute rainfall intensity was 5.64 inches per hour, and the maximum 15-minute rainfall intensity was 4.64 inches per hour. Therefore, the maximum rainfall intensity for equations 13 and 14 was set at 5 inches per hour. Substituting the above values into equation 13 results in

$$t_o = \left[\frac{475}{8.8\ (5/43200)^{0.67}}\right]^{1/1.67} = 413 \text{ seconds}$$

and into equation 14 results in

$$t_c = \left[\frac{3{,}450}{3.1 \; ([2 * 5 * 475]/43200)^{0.33}} \right]^{1/1.33} = 338 \text{ seconds}$$

Therefore $\Delta t \simeq 0.1\ (413 + 338) = 75$ seconds. Similar calculations for the network comprised of channels CH20 and CH23 and the network comprised of channels CH22, CH24, and CH25 resulted in a Δt of 57 seconds and 95 seconds, respectively. Based on these results, Δt for the model was set at 1.0 minute.

Calculation of NDX for segments 0P01, 0I01, CH24 and CH22 is discussed below.

For segment 0P01, L_o = 454 feet, α_o = 0.53, i_e = 5 minutes, and m_o = 1.67. Therefore, from equation 13

$$t_o = \left[\frac{454}{(0.53) \; (5/43200)^{0.67}} \right]^{1/1.67} = 2{,}165 \text{ seconds.}$$

Then, from equation 21

$$\text{NDX} = \frac{2{,}165}{60} = 36.1$$

However, the maximum NDX allowed by the model is 10. Therefore, NDX for segment 0P01 was set at 10. This should not present any significant problems as the flow from this segment which is entirely pervious is minor compared to that from the segments with impervious surfaces which were used in the calculation of Δt.

For segment 0I01, L_o = 454 feet, α_o = 8.10, i_e = 5 minutes, and m_o = 1.67 Therefore, from equation 13

$$t_o = \left[\frac{454}{(8.10) \; (5/43200)^{0.67}} \right]^{1/1.67} = 423 \text{ seconds.}$$

Then, from equation 21

$$\text{NDX} = \frac{423}{60} = 7.05, \text{ say } 7.$$

For segment CH24, L_c = 2,225 feet, $L_o \simeq$ 500 feet, α_c = 2.08, i_e = 5 minutes, and m_c = 1.33. Therefore, from equation 14,

$$t_c = \left[\frac{2{,}225}{(2.08) \; ([2 \times 5 \times 500]/43200)^{0.33}} \right]^{1/1.33} = 324 \text{ seconds.}$$

Then, from equation 22

$$\text{NDX} = \frac{324}{60} = 5.4\text{, say } 6.$$

Channel segment CH22 not only has lateral inflow from overland-flow segments but also has upstream inflow from CH24. Therefore, equation 14 does not apply. Assuming the upstream inflow to dominate, the time of concentration of a wave (not a particle) through CH24 could be approximated by

$$t_c \approx \frac{L_c}{\alpha_c m_c A_c^{m_c - 1}} \qquad (30)$$

where A_c is an average cross-sectional area of flow in square feet. Letting L_c = 1,580 feet, α_c = 4.85, m_c = 1.33, and A_c = 2.5 square feet in equation 30

$$t_c \approx \frac{1{,}580}{(4.85)(1.33)(2.5^{0.33})} = 181$$

Then, from equation 22

$$\text{NDX} = \frac{181}{60} = 3.0\text{, say } 3.$$

Card Group 17

Card Group 17 was skipped because there were no modified-Puls detention reservoirs (segments of ITYPE(I) = 8).

Card Group 18

Ten storms were simulated by the model. Of these storms all but two were separated by at least one day without unit-rainfall data. The exceptions were the two storms which occurred on September 11, 1973 (runoff-period numbers 7 and 8). Therefore, NF(I) = 1; I = 1-6, 9, 10 and NF(I) = 2; I = 7, 8.

Card Group 19

The starting and ending time increments for each storm and the observed volumes of runoff, in inches, are input to the model using Card Group 19.

Card Group 20

No runoff was routed for this run; therefore, KØUT(I) = 0, I = 1, NØFE.

Card Group 21

Runoff periods 1-6 and 10 were used in computing the value of the objective function.

Card Group 22

No input hydrographs were necessary; therefore, IHYD(I) = 0, I = 1, NØFE.

Card Group 23

Card Group 23 was skipped, because there were no input-hydrograph segments (ITYPE(I) = 10 on Card Group 16).

The first run resulted in "optimal" values of the infiltration and soil-moisture-accounting parameters. In the second run, these parameters were set at their final values from the first run and routing was performed for all unit-rainfall runoff periods. The results are shown in table 7. The optimization option was not used during the second run. The following changes in input data were made.

Card Group 12

The number of parameters to be adjusted, the number of trial adjustments per parameters, and the initial step size for parameter adjustment were specified as zero.

Card Group 13

The initial values of PSP, KSAT, RGF, and BMSN were changed to 6.03, 0.121, 13.82, and 11.0, respectively, based on the results of the optimization run.

Card Group 14

Card 14 was changed to a blank card.

Card Group 19

It was not necessary to input storm-runoff volumes as no optimization was to be performed for this run. The ending time increment for storm number 7 was changed to 95 to demonstrate that changes in the starting and (or) ending time increments for a storm will only affect simulated storm-runoff volumes if a different rainfall occurred (that is, storm-runoff volumes are independent of routing).

Card Group 20

All unit-rainfall runoff periods were routed for this run; therefore, KØUT(I) = 1, I = 1, NØFE.

Table 7.--Comparison of measured and simulated runoff volumes and peak flows for Sand Creek Tributary Basin at Denver, Colorado.

Runoff-period number	Date	Runoff volume, in inches		Peak flow, in cubic feet per second	
		Measured	Simulated	Measured	Simulated
1	July 12, 1973	0.080	0.080	32	23
2	July 19, 1973	.16	.19	68	74
3	July 22, 1973	.055	.052	22	14
4	July 24, 1973	.33	.28	104	97
5	July 30, 1973	.063	.082	32	28
6	Aug. 7, 1973	.70	.76	236	280
7	Sept. 11, 1973	.073	.14	48	58
8	Sept. 11, 1973	.23	.16	143	68
9	July 22, 1974	.20	.32	98	117
10	July 30, 1974	.53	.47	251	216

Card Group 21

No optimization was performed; therefore, TESTNØ(I) = 0, I = 1, NØFE.

Input for Run Number 1

```
LIST1-------------------------------------------------------------------------------------*** CARD GROUP  1 ***
06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO         0.286--------------------------*** CARD GROUP  3 ***
06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO----------------------------------------*** CARD GROUP  4 ***
40350010  FORT COLLINS--------------------------------------------------------------------*** CARD GROUP  5 ***
                    73 05 01    74 07 31--------------------------------------------------*** CARD GROUP  6 ***
06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO         5.0----------------------------*** CARD GROUP  7 ***
067143107307120519                                                 7    5    1 1----------*** CARD GROUP  9 ***
067143107307120520    4    9    4    2    1                                    1
067143107307190521    0    0    0    0    0    0   28   23    4    2    1    2 1
067143107307190522    1    1    1    0    0    0    0    0    0    0    0    0 1
067143107307220514                                                          11 1
067143107307220515    9    2    1                                              1
067143107307240519    7   25   26    7    1    7    3    1    0    0    0    1 1
067143107307240520    1    2    1    0    0    0    1    2    2    1    2    1 1
067143107307240521    2    0    0    0    0    0    0    0    0    0    0    0 1
067143107307300519                   4    1                                    1
067143107307300520   16    9    4                                              1
067143107308070517    0    0   10   47   33   36   26   25    3    2    8    3 1
067143107308070518    1    0    0    0    0    0    0    0    0    0    0    0 1
067143107309110507   18   21    9    2              1                          1
067143107309110515                        6   22   22    5         1           1
067143107407220501                        2    2    1    1    1    5   23   19 1
067143107407220502   20   12    5    5    3    3    1    1    1    1            1
067143107407300506                                       4   26   33   33   22 1
067143107407300507   10    6    3    1                                         1
                                                                               9
0671431073 51   0 .06   0   0 .394.00 .01   0   0   0   0   0   0   0   0   0  3----------*** CARD GROUP 10 ***
0671431073 52   0   0   0 .01 .12 .29   0 .05   0   0   0   0 .01 .79   0      3
0671431073 61   0   0 .06 .07 .01   0   0 .01   0   0   0   0   0 .02   0   0  3
0671431073 62   0   0   0   0   0   0   0   0   0   0   0   0   0   0          3
0671431073 71   0   0   0   0   0   0   0   0   0   0   0-100   0 .03 .01   0  3
0671431073 72   0 .01-100 .12 .03-100   0-100 .01   0   0   0 .01-100   0      3
0671431073 81   0   0   0   0 .01   0-100   0   0   0   0   0   0   0   0   0  3
0671431073 82   0   0   0   0 .15   0   0 .03   0   0   0   0   0   0   0      3
0671431073 91   0 .01   0   0   0   0   0 .01 .31 .03-100   0   0   09999      3
0671431074 519999   0   0 .01   0   0   0   0   0   0   0   0   0   0   0   0  3
0671431074 52   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0      3
0671431074 61   0   0   0   0   0 .01 .02 .89 .01   0   0   0 .01   0   0   0  3
0671431074 62   0   0   0   0   0   0   0   0   0   0   0   0   0   0          3
0671431074 71   0   0   0   0   0   0   0   0   0   0 .15 .16   0   0 .04   0  3
0671431074 72   0   0   0   0   0-100   0   0 .01 .01   0   0   0-100   0      3
4035001073 51 .18 .18 .17 .15 .19 .16 .13 .16 .17 .16 .19 .21 .19 .16 .16 .18  4----------*** CARD GROUP 11 ***
4035001073 52 .17 .17 .15 .14 .16 .16 .15 .14 .15 .15 .15 .18 .16 .20 .19      4
4035001073 61 .12 .27 .25 .29 .34 .22 .30 .34 .30 .40 .12 .18 .19 .13 .27 .31  4
4035001073 62 .33 .55 .26 .21 .22 .24 .28 .17 .24 .24 .18 .25 .20 .23          4
4035001073 71 .29 .27 .29 .24 .28 .29 .31 .17 .19 .31 .24 .31 .18 .11 .13 .17  4
4035001073 72 .21 .16 .21 .27 .21 .11 .21 .15 .20 .20 .19 .19 .20 .10 .12      4
4035001073 81 .17 .20 .14 .23 .14 .19 .16 .18 .25 .19 .14 .19 .21 .24 .28 .25  4
4035001073 82 .17 .23 .29 .25 .21 .25 .20 .24 .20 .27 .30 .27 .27 .22 .30      4
4035001073 91 .18 .20 .22 .20 .19 .27 .19 .16 .19 .12 .18 .21 .13 .14 .14 .07  4
4035001074 51 .26 .26 .13 .22 .23 .26 .25 .30 .25 .17 .33 .25 .29 .33 .26 .28  4
4035001074 52 .16 .20 .24 .31 .24 .24 .22 .19 .24 .29 .29 .28 .32 .37 .24      4
4035001074 61 .23 .30 .29 .32 .17 .08 .08 .24 .22 .26 .28 .26 .31 .29 .27 .13  4
4035001074 62 .16 .21 .28 .30 .34 .14 .21 .29 .27 .21 .24 .24 .24 .30          4
4035001074 71 .30 .35 .36 .34 .31 .30 .26 .28 .24 .28 .23 .35 .07 .06 .17 .20  4
4035001074 72 .28 .27 .38 .32 .25 .13 .19 .22 .24 .27 .26 .34 .19 .20 .20      4
                                                                               9
   7   4  10     0.06-----------------------------------------------------------------------*** CARD GROUP 12 ***
      5.00       1.0        15----------------------------------------------------------------*** CARD GROUP 13 ***
      .050       .01       1.0
```

```
      5.00         1.0         15.0
       0.7         0.5          1.0
       0.9         0.5          1.0
       0.8         0.1          1.0
 1 2 3 4 ----------------------------------------------------------***  CARD GROUP 14 ***
   19  1.0  5.0     1  .05 ---------------------------------------------***  CARD GROUP 15 ***
OP01                               5 010 454. .005 .20    .80  .15 1   1.0 --------***  CARD GROUP 16 ***
OI01                              15 0 7 454. .005 .013   .80  .15 1   1.0
OF02                               5 0 5 382. .022 .016   .47  .36 1   1.0
OF03                               5 0 6 480. .024 .016   .48  .31 1   1.0
OF04                               5 0 7 593. .018 .016   .54  .32 1   1.0
OF05                               5 0 91006. .022 .016   .57  .27 1   1.0
OF06                               5 0 7 295. .004 .016   .44  .42 1   1.0
OP07                               5 010 372. .012 .20    .80  .16 1   1.0
OI07                              15 0 5 372. .012 .013   .80  .16 1   1.0
OP08                               5 010 617. .007 .20    .58  .33 1   1.0
OI08                              15 0 8 617. .007 .013   .58  .33 1   1.0
OF09                               5 0 6 340. .010 .016   .70  .22 1   1.0
CH20CH23CH21      OP01OI01OF02     3 0 31210. .005 .016   11.
CH21              OF04OF09         3 0 42240. .007 .016   11.
CH22CH24          OF05OF06         3 0 31580. .008 .016   4.3
CH23              OF03             3 0 21270. .029 .013   31.
CH24              OP07OI07OP08OI08 3 0 62225. .005 .013   50.
CH25CH22                           3 0 2 460. .005 .016   11.
JT01CH20CH25                       7 1
10 1 1 1 1 1 1 2 2 1 1 --------------------------------------------***  CARD GROUP 19 ***
 226 250 .0797 ----------------------------------------------------***  CARD GROUP 19 ***
 247 275 .160
 168 190 .0550
 217 260 .325
 220 250 .0632
 195 225 .704
  73  85 .0732
 173 190 .231
   5  35 .198
  68  90 .534
 0 0 0 0 0 0 0 0 0 0 -----------------------------------------------***  CARD GROUP 20 ***
 1 1 1 1 1 1 0 0 0 1 -----------------------------------------------***  CARD GROUP 21 ***
 0 0 0 0 0 0 0 0 0 0 -----------------------------------------------***  CARD GROUP 22 ***
```

Output for Run Number 1

```
DISCHARGE STATION      06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO
UNIT PRECIP. STATION  06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO
DAILY PRECIP. STATION 06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO
PAN-EVAPO. STATION    40350010  FORT COLLINS
DRAINAGE AREA=  0.29 SQ. MI.
UNIT DATA ARE IN    5.000 MINUTE INCREMENTS
THE PERIOD OF RECORD IS FROM  5- 1-73 (DAY=  26419) TO  7-31-74 (DAY=  26875)
```

```
06714310 73  7 12  5 19   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.07   0.05   0.01  1
06714310 73  7 12  5 20   0.04   0.09   0.04   0.02   0.01   0.0    0.0    0.0    0.0    0.0    0.0    0.0   1
06714310 73  7 19  5 21   0.0    0.0    0.0    0.0    0.0    0.0    0.28   0.23   0.04   0.02   0.01   0.02  1
06714310 73  7 19  5 22   0.01   0.01   0.01   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   1
06714310 73  7 22  5 14   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.11  1
06714310 73  7 22  5 15   0.09   0.02   0.01   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   1
06714310 73  7 24  5 19   0.07   0.25   0.28   0.07   0.01   0.07   0.03   0.01   0.0    0.0    0.0    0.01  1
06714310 73  7 24  5 20   0.01   0.02   0.01   0.0    0.0    0.0    0.01   0.02   0.02   0.01   0.02   0.01  1
06714310 73  7 24  5 21   0.02   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   1
06714310 73  7 30  5 19   0.0    0.0    0.0    0.04   0.01   0.0    0.0    0.0    0.0    0.0    0.0    0.0   1
06714310 73  7 30  5 20   0.15   0.09   0.04   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   1
06714310 73  8  7  5 17   0.0    0.0    0.10   0.47   0.33   0.36   0.26   0.25   0.03   0.02   0.08   0.03  1
06714310 73  8  7  5 18   0.01   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   1
06714310 73  9 11  5  7   0.18   0.21   0.09   0.02   0.0    0.0    0.01   0.0    0.0    0.0    0.0    0.0   1
06714310 73  9 11  5 15   0.0    0.0    0.0    0.0    0.06   0.22   0.22   0.05   0.0    0.01   0.0    0.0   1
06714310 74  7 22  5  1   0.0    0.0    0.0    0.0    0.02   0.02   0.01   0.01   0.01   0.05   0.23   0.19  1
06714310 74  7 22  5  2   0.20   0.12   0.05   0.05   0.03   0.03   0.01   0.01   0.01   0.01   0.0    0.0   1
06714310 74  7 30  5  6   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.04   0.25   0.33   0.33   0.22  1
06714310 74  7 30  5  7   0.10   0.06   0.03   0.01   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   1
06714310 73  5 1 0.0  0.06 0.0  0.0  0.39 4.00 0.01 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 73  5 2 0.0  0.0  0.0  0.01 0.12 0.29 0.0  0.05 0.0  0.0  0.0  0.0  0.01 0.79 0.0  0.0   3
06714310 73  6 1 0.0  0.0  0.05 0.07 0.01 0.0  0.0  0.01 0.0  0.0  0.0  0.0  0.0  0.02 0.0  0.0   3
06714310 73  6 2 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 73  7 1 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  **** 0.0  0.03 0.01 0.0   3
06714310 73  7 2 0.0  0.01 **** 0.12 0.03 **** 0.0  **** 0.01 0.0  0.0  0.0  0.01 **** 0.0  0.0   3
06714310 73  8 1 0.0  0.0  0.0  0.0  0.01 0.0  **** 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 73  8 2 0.0  0.0  0.0  0.0  0.15 0.0  0.0  0.03 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 73  9 1 0.0  0.01 0.0  0.0  0.0  0.0  0.0  0.01 0.31 0.03 **** 0.0  0.0  0.0  **** 0.0   3
06714310 74  5 1 **** 0.0  0.0  0.01 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 74  5 2 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 74  6 1 0.0  0.0  0.0  0.0  0.0  0.01 0.02 0.89 0.01 0.0  0.0  0.0  0.01 0.0  0.0  0.0   3
06714310 74  6 2 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 74  7 1 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.15 0.16 0.0  0.0  0.04 0.0   3
06714310 74  7 2 0.0  0.0  0.0  0.0  0.0  **** 0.0  0.0  0.01 0.01 0.0  0.0  0.0  **** 0.0  0.0   3
40350010 73  5 1 0.18 0.18 0.17 0.15 0.19 0.16 0.13 0.16 0.17 0.16 0.19 0.21 0.19 0.15 0.16 0.18  4
40350010 73  5 2 0.17 0.17 0.15 0.14 0.16 0.16 0.15 0.14 0.15 0.15 0.15 0.18 0.16 0.20 0.19 0.0   4
40350010 73  6 1 0.12 0.27 0.25 0.29 0.34 0.22 0.30 0.34 0.30 0.40 0.12 0.18 0.19 0.13 0.27 0.31  4
40350010 73  6 2 0.33 0.55 0.26 0.21 0.22 0.24 0.20 0.17 0.24 0.24 0.18 0.25 0.20 0.23 0.0  0.0   4
40350010 73  7 1 0.29 0.27 0.29 0.24 0.28 0.29 0.31 0.17 0.19 0.31 0.24 0.31 0.18 0.11 0.13 0.17  4
40350010 73  7 2 0.21 0.16 0.21 0.27 0.21 0.11 0.21 0.15 0.20 0.20 0.19 0.19 0.20 0.10 0.12 0.0   4
40350010 73  8 1 0.17 0.20 0.14 0.23 0.14 0.19 0.16 0.10 0.25 0.19 0.14 0.19 0.21 0.24 0.28 0.25  4
40350010 73  8 2 0.17 0.23 0.29 0.25 0.21 0.25 0.20 0.24 0.20 0.27 0.30 0.27 0.27 0.22 0.30 0.0   4
40350010 73  9 1 0.18 0.20 0.22 0.20 0.19 0.27 0.19 0.16 0.18 0.12 0.18 0.21 0.13 0.14 0.14 0.07  4
40350010 74  5 1 0.26 0.26 0.13 0.22 0.23 0.26 0.26 0.30 0.26 0.17 0.33 0.25 0.29 0.33 0.26 0.20  4
40350010 74  5 2 0.16 0.20 0.24 0.31 0.24 0.24 0.22 0.19 0.24 0.29 0.29 0.28 0.32 0.37 0.24 0.0   4
40350010 74  6 1 0.23 0.30 0.29 0.32 0.17 0.08 0.00 0.24 0.22 0.26 0.28 0.26 0.31 0.29 0.27 0.13  4
40350010 74  6 2 0.16 0.21 0.28 0.30 0.34 0.14 0.21 0.29 0.27 0.21 0.24 0.24 0.24 0.30 0.0  0.0   4
40350010 74  7 1 0.30 0.35 0.36 0.34 0.31 0.30 0.26 0.28 0.24 0.20 0.23 0.35 0.07 0.06 0.17 0.20  4
40350010 74  7 2 0.28 0.27 0.38 0.32 0.25 0.13 0.19 0.22 0.24 0.27 0.26 0.34 0.19 0.20 0.20 0.0   4
```

```
INITIAL PARAMETER VALUES

  1       5.000000   PSP    *
  2       0.050000   KSAT   *
  3      10.000000   RGF    *
  4       5.000000   BMSN   *
  5       0.700000   EVC
  6       0.900000   RR
  7       0.800000   DRN


INITIAL STEP SIZE INCREMENTS

    0.300000    0.003000    0.600000    0.300000


THE MAX. NUMBER OF ITERATIONS=   40

INITIALLY AND AFTER EACH VECTOR MATRIX ORTHONORMALIZATION,
THE PARAMETRIC VECTOR INCREMENT SIZE IS.  0.060 OF THE VECTOR SIZE


                                         NUMBER OF SEGMENTS =   19
                                           DT =  1.000 MINUTES
                                    OUTPUT SAMPLING INTERVAL =  5.00 MINUTES
                                          NUMBER OF RAIN GAGES = 1
                                        NUMBER OF PARAMETER SETS = 1
                                      IMPERVIOUS RETENTION =0.05 INCHES
```

```
                                                                                   LENGTH            ROUGHNESS                          THIESSEN COEFFICIENTS
SEGMENT UPSTREAM SEGMENTS    ADJACENT SEGMENTS TYPE IPR NDX (FEET)    SLOPE PARAMETER OTHER PARAMETERS
 UP01                                            5    0  10    454.   0.0050    0.200     0.800      0.150 1 1.00
 OI01                                           15    0   7    454.   0.0050    0.013     0.800      0.150 1 1.00
 OF02                                            5    0   5    382.   0.0220    0.016     0.470      0.360 1 1.00
 OF03                                            5    0   6    480.   0.0240    0.016     0.480      0.310 1 1.00
 OF04                                            5    0   7    593.   0.0180    0.016     0.540      0.320 1 1.00
 OF05                                            5    0   9   1006.   0.0220    0.016     0.570      0.270 1 1.00
 OF06                                            5    0   7    295.   0.0040    0.016     0.440      0.420 1 1.00
 OP07                                            5    0  10    372.   0.0120    0.200     0.800      0.160 1 1.00
 OI07                                           15    0   5    372.   0.0120    0.013     0.800      0.160 1 1.00
 OP08                                            5    0  10    617.   0.0070    0.200     0.580      0.330 1 1.00
 OI08                                           15    0   8    617.   0.0070    0.013     0.580      0.330 1 1.00
 OF09                                            5    0   6    340.   0.0100    0.016     0.700      0.220 1 1.00
 CH20     CH23 CH21         UP01 OI01 OF02       3    0   3   1210.   0.0050    0.016    11.000      0.0    0 0.0
 CH21                       OF04 OF09            3    0   4   2240.   0.0070    0.016    11.000      0.0    0 0.0
 CH22     CH24              OF05 OF06            3    0   3   1580.   0.0080    0.016     4.300      0.0    0 0.0
 CH23                       OF03                 3    0   2   1270.   0.0290    0.013    31.000      0.0    0 0.0
 CH24                       UP07 OI07 UP08 OI08  3    0   6   2225.   0.0050    0.013    50.000      0.0    0 0.0
 CH25     CH22                                   3    0   2    460.   0.0050    0.016    11.000      0.0    0 0.0
 JT01     CH20 CH25                              7    1  10      0.   0.0       0.0       0.0        0.0    0 0.0


         COMPUTATION SEQUENCE                 KINEMATIC CHANNEL PARAMETERS

           INDEX    SEGMENT                           ALPHA       M
             1       UP01                              0.53     1.670
             2       OI01                              8.10     1.670
             3       OF02                             13.81     1.670
             4       OF03                             14.43     1.670
             5       OF04                             12.49     1.670
             6       OF05                             13.81     1.670
             7       OF06                              5.89     1.670
             8       OP07                              0.82     1.670
             9       OI07                             12.56     1.670
            10       OP08                              0.62     1.670
            11       OI08                              9.59     1.670
            12       OF09                              9.31     1.670
            14       CH21                              3.32     1.330
            16       CH23                              5.88     1.330
            17       CH24                              2.08     1.330
            13       CH20                              2.80     1.330
            15       CH22                              4.85     1.330
            18       CH25                              2.80     1.330
            19       JT01                              0.0      0.0
THERE ARE  10 FLOOD PEAKS GROUPED AS FOLLOWS      1     1     1     1     1     1     2     2     1     1

STORM NO.  1 STARTS AT TIME PERIOD  226 AND ENDS AT  250
STORM NO.  2 STARTS AT TIME PERIOD  247 AND ENDS AT  275
STORM NO.  3 STARTS AT TIME PERIOD  168 AND ENDS AT  190
STORM NO.  4 STARTS AT TIME PERIOD  217 AND ENDS AT  260
STORM NO.  5 STARTS AT TIME PERIOD  220 AND ENDS AT  250
STORM NO.  6 STARTS AT TIME PERIOD  195 AND ENDS AT  225
STORM NO.  7 STARTS AT TIME PERIOD   73 AND ENDS AT   86
STORM NO.  8 STARTS AT TIME PERIOD  173 AND ENDS AT  190
STORM NO.  9 STARTS AT TIME PERIOD    5 AND ENDS AT   35
```

```
DETAILED OUTPUT FOR STORMS    0   0   0   0   0   0   0   0   0   0
INPUT HYDROGRAPHS FOR STORMS    0   0   0   0   0   0   0   0   0   0
THE FLOOD EVENTS IN THE OBJECTIVE FUNCTION ARE
 1   2  3   4   5   6          10
```

```
                                             BEGINNING OF STAGE
OBJECTIVE FUNCTION = 0.6309789E 00 WHICH IS A ROOT MEAN SQUARE ERROR0.135E 01  TO    0.741
PARAMETER VALUES ARE
    5.000000    0.050000   10.000000    5.000000    0.700000    0.900000    0.800000
```

```
DETAILED DISCHARGE FOR FLOOD NUMBER  1
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =        0.330 INCHES
OBSERVED DIRECT RUNOFF =    0.080 INCHES
SIMULATED DIRECT RUNOFF =    0.085 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.450E-02

DETAILED DISCHARGE FOR FLOOD NUMBER  2
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =        0.630 INCHES
OBSERVED DIRECT RUNOFF =    0.160 INCHES
SIMULATED DIRECT RUNOFF =    0.247 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.169E 00

DETAILED DISCHARGE FOR FLOOD NUMBER  3
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =        0.230 INCHES
OBSERVED DIRECT RUNOFF =    0.055 INCHES
SIMULATED DIRECT RUNOFF =    0.057 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.893E-03

DETAILED DISCHARGE FOR FLOOD NUMBER  4
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =        0.950 INCHES
OBSERVED DIRECT RUNOFF =    0.325 INCHES
SIMULATED DIRECT RUNOFF =    0.348 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.463E-02

DETAILED DISCHARGE FOR FLOOD NUMBER  5
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =        0.340 INCHES
OBSERVED DIRECT RUNOFF =    0.063 INCHES
SIMULATED DIRECT RUNOFF =    0.089 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.115E 00

DETAILED DISCHARGE FOR FLOOD NUMBER  6
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =        1.940 INCHES
OBSERVED DIRECT RUNOFF =    0.704 INCHES
SIMULATED DIRECT RUNOFF =    1.154 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.244E 00

DETAILED DISCHARGE FOR FLOOD NUMBER  7
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =        0.510 INCHES
OBSERVED DIRECT RUNOFF =    0.073 INCHES
SIMULATED DIRECT RUNOFF =    0.169 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER  8
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =        0.560 INCHES
OBSERVED DIRECT RUNOFF =    0.231 INCHES
SIMULATED DIRECT RUNOFF =    0.229 INCHES
```

```
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =       1.060 INCHES
OBSERVED DIRECT RUNOFF =     0.198 INCHES
SIMULATED DIRECT RUNOFF =     0.411 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER 10
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =       1.390 INCHES
OBSERVED DIRECT RUNOFF =     0.534 INCHES
SIMULATED DIRECT RUNOFF =     0.599 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.728E-01

AT ITERATION NO.  0 OBJECTIVE FUNCTION=    0.630979
PARAMETER VALUES ARE
     5.000000    0.050000   10.000000    5.000000    0.700000    0.900000    0.800000


AT ITERATION NO.  1 OBJECTIVE FUNCTION=    0.597193
PARAMETER VALUES ARE
     5.299999    0.050000   10.000000    5.000000    0.700000    0.900000    0.800000


AT ITERATION NO.  2 OBJECTIVE FUNCTION=    0.544178
PARAMETER VALUES ARE
     5.299999    0.053000   10.000000    5.000000    0.700000    0.900000    0.800000


AT ITERATION NO.  3 OBJECTIVE FUNCTION=    0.504645
PARAMETER VALUES ARE
     5.299999    0.053000   10.599999    5.000000    0.700000    0.900000    0.800000


AT ITERATION NO.  4 OBJECTIVE FUNCTION=    0.503906
PARAMETER VALUES ARE
     5.299999    0.053000   10.599999    5.299999    0.700000    0.900000    0.800000


AT ITERATION NO.  5 OBJECTIVE FUNCTION=    0.408993
PARAMETER VALUES ARE
     6.199999    0.053000   10.599999    5.299999    0.700000    0.900000    0.800000


AT ITERATION NO.  6 OBJECTIVE FUNCTION=    0.328192
PARAMETER VALUES ARE
     6.199999    0.062000   10.599999    5.299999    0.700000    0.900000    0.800000


AT ITERATION NO.  7 OBJECTIVE FUNCTION=    0.265055
PARAMETER VALUES ARE
     6.199999    0.062000   12.399999    5.299999    0.700000    0.900000    0.800000


AT ITERATION NO.  8 OBJECTIVE FUNCTION=    0.263532
PARAMETER VALUES ARE
     6.199999    0.062000   12.399999    6.199999    0.700000    0.900000    0.800000


AT ITERATION NO.  9 OBJECTIVE FUNCTION=    0.174056
PARAMETER VALUES ARE
```

```
    8.599998    0.089000   12.399999    5.199999    0.700000    0.900000    0.800000


AT ITERATION NO. 12 OBJECTIVE FUNCTION=    0.143732
PARAMETER VALUES ARE
    8.899998    0.089000   12.399999    3.899998    0.700000    0.900000    0.800000

B1 = 6.015103   B2 = 0.751328
NEW ORTHONORMAL BASIS
 0.64837-0.76133-0.00002 0.00000
 0.00648 0.00552-0.99996-0.00001
 0.39900 0.33980 0.00450-0.85156
 0.64837 0.55217 0.00729 0.52410
START OF STAGE STEP SIZE INCREMENTS
  0.989343  0.954243  0.012592  0.913502
```

```
                                        BEGINNING OF STAGE
OBJECTIVE FUNCTION = 0.1437320E 00 WHICH IS A ROOT MEAN SQUARE ERROR0.115E 01  TO    0.866
PARAMETER VALUES ARE
    8.899998    0.089000   12.399999    8.899998    0.700000    0.900000    0.800000
```

```
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL    GAGE NUMBER  1 =      0.330 INCHES
OBSERVED DIRECT RUNOFF =    0.090 INCHES
SIMULATED DIRECT RUNOFF =    0.080 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.851E-04

DETAILED DISCHARGE FOR FLOOD NUMBER  2
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL    GAGE NUMBER  1 =      0.530 INCHES
OBSERVED DIRECT RUNOFF =    0.140 INCHES
SIMULATED DIRECT RUNOFF =    0.187 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.235E-01

DETAILED DISCHARGE FOR FLOOD NUMBER  3
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL    GAGE NUMBER  1 =      0.230 INCHES
OBSERVED DIRECT RUNOFF =    0.055 INCHES
SIMULATED DIRECT RUNOFF =    0.052 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.281E-02

DETAILED DISCHARGE FOR FLOOD NUMBER  4
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL    GAGE NUMBER  1 =      0.950 INCHES
OBSERVED DIRECT RUNOFF =    0.325 INCHES
SIMULATED DIRECT RUNOFF =    0.278 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.245E-01

DETAILED DISCHARGE FOR FLOOD NUMBER  5
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL    GAGE NUMBER  1 =      0.340 INCHES
OBSERVED DIRECT RUNOFF =    0.063 INCHES
SIMULATED DIRECT RUNOFF =    0.083 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.720E-01

DETAILED DISCHARGE FOR FLOOD NUMBER  6
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL    GAGE NUMBER  1 =      1.940 INCHES
OBSERVED DIRECT RUNOFF =    0.704 INCHES
SIMULATED DIRECT RUNOFF =    0.763 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.638E-02

DETAILED DISCHARGE FOR FLOOD NUMBER  7
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL    GAGE NUMBER  1 =      0.510 INCHES
OBSERVED DIRECT RUNOFF =    0.073 INCHES
SIMULATED DIRECT RUNOFF =    0.140 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER  8
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL    GAGE NUMBER  1 =      0.560 INCHES
OBSERVED DIRECT RUNOFF =    0.231 INCHES
SIMULATED DIRECT RUNOFF =    0.158 INCHES
```

```
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL    GAGE NUMBER  1 =       1.060 INCHES
OBSERVED DIRECT RUNOFF =     0.198 INCHES
SIMULATED DIRECT RUNOFF =     0.320 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER 10
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL    GAGE NUMBER  1 =       1.390 INCHES
OBSERVED DIRECT RUNOFF =     0.534 INCHES
SIMULATED DIRECT RUNOFF =     0.474 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.144E-01

AT ITERATION NO. 16 OBJECTIVE FUNCTION=    0.143732
PARAMETER VALUES ARE
     8.899998     0.089000    12.399999     8.899998     0.700000     0.900000     0.800000


AT ITERATION NO. 18 OBJECTIVE FUNCTION=    0.143334
PARAMETER VALUES ARE
     8.173506     0.094269    12.724245     9.426899     0.700000     0.900000     0.800000


AT ITERATION NO. 23 OBJECTIVE FUNCTION=    0.142805
PARAMETER VALUES ARE
     8.173506     0.100565    12.724216     9.426852     0.700000     0.900000     0.800000


AT ITERATION NO. 28 OBJECTIVE FUNCTION=    0.142750
PARAMETER VALUES ARE
     8.173506     0.100562    12.529718     9.546543     0.700000     0.900000     0.800000


AT ITERATION NO. 30 OBJECTIVE FUNCTION=    0.142502
PARAMETER VALUES ARE
     7.628636     0.104513    12.772903     9.941719     0.700000     0.900000     0.800000


AT ITERATION NO. 33 OBJECTIVE FUNCTION=    0.142432
PARAMETER VALUES ARE
     7.668727     0.104914    12.797574     9.991810     0.700000     0.900000     0.800000


AT ITERATION NO. 34 OBJECTIVE FUNCTION=    0.142275
PARAMETER VALUES ARE
     6.034122     0.116770    13.527129    11.167338     0.700000     0.900000     0.800000


AT ITERATION NO. 35 OBJECTIVE FUNCTION=    0.141546
PARAMETER VALUES ARE
     6.034122     0.121491    13.527107    11.167303     0.700000     0.900000     0.800000


AT ITERATION NO. 36 OBJECTIVE FUNCTION=    0.141498
PARAMETER VALUES ARE
     6.034121     0.121496    13.818853    10.987766     0.700000     0.900000     0.800000


             END OF RUN--RESULTS OF LAST SUCCESSFUL TRIAL
OBJECTIVE FUNCTION = 0.1414879E 00 WHICH IS A ROOT MEAN SQUARE ERROR0.115E 01  TO     0.867
PARAMETER VALUES ARE
[illegible]
```

```
DETAILED DISCHARGE FOR FLOOD NUMBER  1
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =      0.330 INCHES
OBSERVED DIRECT RUNOFF =    0.090 INCHES
SIMULATED DIRECT RUNOFF =    0.080 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.735E-04

DETAILED DISCHARGE FOR FLOOD NUMBER  2
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =      0.530 INCHES
OBSERVED DIRECT RUNOFF =    0.140 INCHES
SIMULATED DIRECT RUNOFF =    0.186 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.224E-01

DETAILED DISCHARGE FOR FLOOD NUMBER  3
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =      0.230 INCHES
OBSERVED DIRECT RUNOFF =    0.055 INCHES
SIMULATED DIRECT RUNOFF =    0.052 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.294E-02

DETAILED DISCHARGE FOR FLOOD NUMBER  4
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =      0.950 INCHES
OBSERVED DIRECT RUNOFF =    0.325 INCHES
SIMULATED DIRECT RUNOFF =    0.277 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.257E-01

DETAILED DISCHARGE FOR FLOOD NUMBER  5
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =      0.340 INCHES
OBSERVED DIRECT RUNOFF =    0.063 INCHES
SIMULATED DIRECT RUNOFF =    0.082 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.695E-01

DETAILED DISCHARGE FOR FLOOD NUMBER  6
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =      1.940 INCHES
OBSERVED DIRECT RUNOFF =    0.704 INCHES
SIMULATED DIRECT RUNOFF =    0.754 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.479E-02

DETAILED DISCHARGE FOR FLOOD NUMBER  7
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =      0.510 INCHES
OBSERVED DIRECT RUNOFF =    0.073 INCHES
SIMULATED DIRECT RUNOFF =    0.139 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER  8
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =      0.560 INCHES
OBSERVED DIRECT RUNOFF =    0.231 INCHES
SIMULATED DIRECT RUNOFF =    0.157 INCHES
```

```
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =      1.060 INCHES
OBSERVED DIRECT RUNOFF =    0.198 INCHES
SIMULATED DIRECT RUNOFF =    0.318 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER 10
OBSERVED PEAK DISCHARGE =      0.0  CFS
SIMULATED PEAK DISCHARGE =      0.0  CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =      1.390 INCHES
OBSERVED DIRECT RUNOFF =    0.534 INCHES
SIMULATED DIRECT RUNOFF =    0.471 INCHES
CONTRIBUTION TO OBJECTIVE FUNCTION= 0.160E-01
```

Input for Run Number 2

```
LIST1-------------------------------------------------------------------------------------------*** CARD GROUP  1 ***
06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO          0.286-----------------------------------*** CARD GROUP  3 ***
06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO----------------------------------------------------*** CARD GROUP  4 ***
40350010  FORT COLLINS------------------------------------------------------------------------------*** CARD GROUP  5 ***
                        73 05 01    74 07 31--------------------------------------------------------*** CARD GROUP  6 ***
06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO          5.0-------------------------------------*** CARD GROUP  7 ***
067143107307120519                                                           7     5     1 1------*** CARD GROUP  8 ***
067143107307120520     4     9     4     2     1                                             1
067143107307190521     0     0     0     0     0     0    28    23     4     2     1     2 1
067143107307190522     1     1     1     0     0     0     0     0     0     0     0     0 1
067143107307220514                                                                      11 1
067143107307220515     9     2     1                                                       1
067143107307240519     7    25    28     7     1     7     3     1     0     0     0     1 1
067143107307240520     1     2     1     0     0     0     1     2     2     1     2     1 1
067143107307240521     2     0     0     0     0     0     0     0     0     0     0     0 1
067143107307300519                       4     1                                           1
067143107307300520    16     9     4                                                       1
067143107308070517     0     0    10    47    33    36    26    25     3     2     8     3 1
067143107308070518     1     0     0     0     0     0     0     0     0     0     0     0 1
067143107309110507    18    21     9     2                 1                                 1
067143107309110515                             6    22    22     5           1             1
067143107407220501                             2     2     1     1     1     5    23    19 1
067143107407220502    20    12     5     5     3     3     1     1     1     1             1
067143107407300506                                               4    26    33    33    22 1
067143107407300507    10     6     3     1                                                 1
                                                                                           9
0671431073 51   0 .06   0   0 .394.00 .01   0   0   0   0   0   0   0   0   0   3------*** CARD GROUP 10 ***
0671431073 52   0   0   0 .01 .12 .29   0 .05   0   0   0   0 .01 .79   0       3
0671431073 61   0   0 .06 .07 .01   0   0 .01   0   0   0   0   0 .02   0   0   3
0671431073 62   0   0   0   0   0   0   0   0   0   0   0   0   0   0           3
0671431073 71   0   0   0   0   0   0   0   0   0   0   0-100   0 .03 .01   0   3
0671431073 72   0 .01-100 .12 .03-100   0-100 .01   0   0   0 .01-100   0       3
0671431073 81   0   0   0   0 .01   0-100   0   0   0   0   0   0   0   0   0   3
0671431073 82   0   0   0   0 .15   0   0 .03   0   0   0   0   0   0   0       3
0671431073 91   0 .01   0   0   0   0   0 .01 .31 .03-100   0   0   09999       3
0671431074 519999   0   0 .01   0   0   0   0   0   0   0   0   0   0   0   0   3
0671431074 52   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0       3
0671431074 61   0   0   0   0   0 .01 .02 .89 .01   0   0   0 .01   0   0   0   3
0671431074 62   0   0   0   0   0   0   0   0   0   0   0   0   0   0           3
0671431074 71   0   0   0   0   0   0   0   0   0   0 .15 .16   0   0 .04   0   3
0671431074 72   0   0   0   0   0-100   0   0 .01 .01   0   0   0-100   0       3
4035001073 51 .18 .18 .17 .15 .19 .16 .13 .16 .17 .16 .19 .21 .19 .16 .16 .18   4------*** CARD GROUP 11 ***
4035001073 52 .17 .17 .15 .14 .16 .16 .15 .14 .15 .15 .15 .18 .16 .20 .19       4
4035001073 61 .12 .27 .25 .29 .34 .22 .30 .34 .30 .40 .12 .18 .19 .13 .27 .31   4
4035001073 62 .33 .55 .26 .21 .22 .24 .28 .17 .24 .24 .18 .25 .20 .23           4
4035001073 71 .29 .27 .29 .24 .28 .29 .31 .17 .19 .31 .24 .31 .18 .11 .13 .17   4
4035001073 72 .21 .16 .21 .27 .21 .11 .21 .15 .20 .20 .19 .19 .20 .10 .12       4
4035001073 81 .17 .20 .14 .23 .14 .19 .16 .18 .25 .19 .14 .19 .21 .24 .28 .25   4
4035001073 82 .17 .23 .29 .25 .21 .25 .20 .24 .20 .27 .30 .27 .27 .22 .30       4
4035001073 91 .18 .20 .22 .20 .19 .27 .19 .16 .18 .12 .18 .21 .13 .14 .14 .07   4
4035001074 51 .26 .26 .13 .22 .23 .26 .28 .30 .26 .17 .33 .25 .29 .33 .26 .28   4
4035001074 52 .16 .28 .24 .31 .24 .24 .22 .19 .24 .29 .29 .28 .32 .37 .24       4
4035001074 61 .23 .30 .29 .32 .17 .08 .08 .24 .22 .26 .28 .26 .31 .29 .27 .13   4
4035001074 62 .16 .21 .28 .30 .34 .14 .21 .29 .27 .21 .24 .24 .24 .30           4
4035001074 71 .30 .35 .36 .34 .31 .30 .26 .28 .24 .28 .23 .35 .07 .06 .17 .20   4
4035001074 72 .28 .27 .38 .32 .25 .13 .19 .22 .24 .27 .26 .34 .19 .20 .20       4
                                                                                9
    7    0    0     0.0-----------------------------------------------------------------*** CARD GROUP 12 ***
        6.03        1.0         15--------------------------------------------------------*** CARD GROUP 13 ***
        .121        .04        1.0
       13.82        5.0       20.0
```

```
      11.0        1.0      15.0
       0.7        0.5       1.0
       0.9        0.5       1.0
       0.8        0.1       1.0
---------------------------------------------------------------------------------------*** CARD GROUP 14 ***
   19  1.0  5.0    1  .05-------------------------------------------------------------*** CARD GROUP 15 ***
OP01                                  5 010 454. .005 .20   .80  .15 1  1.0-----------*** CARD GROUP 16 ***
OI01                                 15 0 7 454. .005 .013  .80  .15 1  1.0
OF02                                  5 0 5 382. .022 .016  .47  .36 1  1.0
OF03                                  5 0 6 480. .024 .016  .48  .31 1  1.0
OF04                                  5 0 7 593. .018 .016  .54  .32 1  1.0
OF05                                  5 0 91006. .022 .016  .57  .27 1  1.0
OF06                                  5 0 7 295. .004 .016  .44  .42 1  1.0
OP07                                  5 010 372. .012 .20   .80  .16 1  1.0
OI07                                 15 0 5 372. .012 .013  .80  .16 1  1.0
OP08                                  5 010 617. .007 .20   .58  .33 1  1.0
OI08                                 15 0 8 617. .007 .013  .58  .33 1  1.0
OF09                                  5 0 6 340. .010 .016  .70  .22 1  1.0
CH20CH23CH21        OP01OI01OF02      3 0 31210. .007 .016  11.
CH21                OF040F09          3 0 42240. .007 .016  11.
CH22CH24            OF050F06          3 0 31580. .008 .016  4.3
CH23                OF03              3 0 21270. .029 .013  31.
CH24                OP07OI07OP08OI08  3 0 52225. .005 .013  50.
CH25CH22                              3 0 2 450. .005 .016  11.
JT01CH20CH25                          7 1
10 1 1 1 1 1 1 2 2 1 1----------------------------------------------------------------*** CARD GROUP 18 ***
 226 250------------------------------------------------------------------------------*** CARD GROUP 19 ***
 247 275
 168 190
 217 260
 220 250
 195 225
  73  95
 173 190
   5  35
  68  90
 1 1 1 1 1 1 1 1 1 1------------------------------------------------------------------*** CARD GROUP 20 ***
 0 0 0 0 0 0 0 0 0 0------------------------------------------------------------------*** CARD GROUP 21 ***
 0 0 0 0 0 0 0 0 0 0------------------------------------------------------------------*** CARD GROUP 22 ***
```

Output for Run Number 2

```
DISCHARGE STATION      06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO
UNIT PRECIP. STATION   06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO
DAILY PRECIP. STATION 06714310  SAND CREEK TRIBUTARY AT DENVER, COLORADO
PAN-EVAPO. STATION    40350010  FORT COLLINS
DRAINAGE AREA=  0.29 SQ. MI.
UNIT DATA ARE IN    5.000 MINUTE INCREMENTS
THE PERIOD OF RECORD IS FROM  5- 1-73 (DAY=  26419) TO  7-31-74 (DAY=  26875)
```

```
06714310 73  7 12  5 19   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.07    0.05    0.01   1
06714310 73  7 12  5 20   0.04    0.09    0.04    0.02    0.01    0.0     0.0     0.0     0.0     0.0     0.0     0.0    1
06714310 73  7 19  5 21   0.0     0.0     0.0     0.0     0.0     0.0     0.29    0.23    0.04    0.02    0.01    0.02   1
06714310 73  7 19  5 22   0.01    0.01    0.01    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    1
06714310 73  7 22  5 14   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.11   1
06714310 73  7 22  5 15   0.09    0.02    0.01    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    1
06714310 73  7 24  5 19   0.07    0.25    0.28    0.07    0.01    0.07    0.03    0.01    0.0     0.0     0.0     0.01   1
06714310 73  7 24  5 20   0.01    0.02    0.01    0.0     0.0     0.0     0.01    0.02    0.02    0.01    0.02    0.01   1
06714310 73  7 24  5 21   0.02    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    1
06714310 73  7 30  5 19   0.0     0.0     0.0     0.04    0.01    0.0     0.0     0.0     0.0     0.0     0.0     0.0    1
06714310 73  7 30  5 20   0.15    0.09    0.04    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    1
06714310 73  8  7  5 17   0.0     0.0     0.10    0.47    0.33    0.36    0.26    0.25    0.03    0.02    0.08    0.03   1
06714310 73  8  7  5 19   0.01    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    1
06714310 73  9 11  5  7   0.18    0.21    0.09    0.02    0.0     0.0     0.01    0.0     0.0     0.0     0.0     0.0    1
06714310 73  9 11  5 15   0.0     0.0     0.0     0.0     0.06    0.22    0.22    0.05    0.0     0.01    0.0     0.0    1
06714310 74  7 22  5  1   0.0     0.0     0.0     0.0     0.02    0.02    0.01    0.01    0.01    0.05    0.23    0.19   1
06714310 74  7 22  5  2   0.20    0.12    0.05    0.05    0.03    0.03    0.01    0.01    0.01    0.01    0.0     0.0    1
06714310 74  7 30  5  4   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.04    0.25    0.33    0.33    0.22   1
06714310 74  7 30  5  7   0.10    0.06    0.03    0.01    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    1
06714310 73  5 1 0.0  0.06 0.0  0.0  0.39 4.00 0.01 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 73  5 2 0.0  0.0  0.0  0.01 0.12 0.29 0.0  0.05 0.0  0.0  0.0  0.0  0.01 0.79 0.0  0.0   3
06714310 73  6 1 0.0  0.0  0.05 0.07 0.01 0.0  0.0  0.01 0.0  0.0  0.0  0.0  0.0  0.02 0.0  0.0   3
06714310 73  6 2 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 73  7 1 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  **** 0.0  0.03 0.01 0.0   3
06714310 73  7 2 0.0  0.01 **** 0.12 0.03 **** 0.0  **** 0.01 0.0  0.0  0.0  0.01 **** 0.0  0.0   3
06714310 73  8 1 0.0  0.0  0.0  0.0  0.01 0.0  **** 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 73  8 2 0.0  0.0  0.0  0.0  0.15 0.0  0.0  0.03 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 73  9 1 0.0  0.01 0.0  0.0  0.0  0.0  0.0  0.01 0.31 0.03 **** 0.0  0.0  0.0  **** 0.0   3
06714310 74  5 1 **** 0.0  0.0  0.01 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 74  5 2 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 74  6 1 0.0  0.0  0.0  0.0  0.0  0.01 0.02 0.89 0.01 0.0  0.0  0.0  0.01 0.0  0.0  0.0   3
06714310 74  6 2 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   3
06714310 74  7 1 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.15 0.16 0.0  0.0  0.04 0.0   3
06714310 74  7 2 0.0  0.0  0.0  0.0  0.0  **** 0.0  0.0  0.01 0.01 0.0  0.0  0.0  **** 0.0  0.0   3
40350010 73  5 1 0.18 0.18 0.17 0.15 0.19 0.16 0.13 0.16 0.17 0.16 0.19 0.21 0.19 0.16 0.16 0.18  4
40350010 73  5 2 0.17 0.17 0.15 0.14 0.16 0.16 0.15 0.14 0.15 8.15 0.15 0.18 0.16 0.20 0.19 0.0   4
40350010 73  6 1 0.12 0.27 0.25 0.29 0.34 0.22 0.30 0.34 0.30 0.40 0.12 0.18 0.19 0.13 0.27 0.31  4
40350010 73  6 2 0.33 0.55 0.26 0.21 0.22 0.24 0.28 0.17 0.24 0.24 0.18 0.25 0.20 0.23 0.0  0.0   4
40350010 73  7 1 0.29 0.27 0.29 0.24 0.28 0.29 0.31 0.17 0.19 0.31 0.24 0.31 0.18 0.11 0.13 0.17  4
40350010 73  7 2 0.21 0.16 0.21 0.27 0.21 0.11 0.21 0.15 0.20 0.20 0.19 0.19 0.20 0.10 0.12 0.0   4
40350010 73  8 1 0.17 0.20 0.14 0.23 0.14 0.19 0.16 0.18 0.25 0.19 0.14 0.19 0.21 0.24 0.28 0.25  4
40350010 73  8 2 0.17 0.23 0.29 0.25 0.21 0.25 0.20 0.24 0.20 0.27 0.30 0.27 0.27 0.22 0.30 0.0   4
40350010 73  9 1 0.18 0.20 0.22 0.20 0.19 0.27 0.19 0.16 0.18 0.12 0.18 0.21 0.13 0.14 0.14 0.07  4
40350010 74  5 1 0.26 0.26 0.13 0.22 0.23 0.26 0.26 0.30 0.26 0.17 0.33 0.25 0.29 0.33 0.26 0.28  4
40350010 74  5 2 0.16 0.20 0.24 0.31 0.24 0.24 0.22 0.19 0.24 0.29 0.29 0.28 0.32 0.37 0.24 0.0   4
40350010 74  6 1 0.23 0.30 0.29 0.32 0.17 0.08 0.08 0.24 0.22 0.26 0.28 0.26 0.31 0.29 0.27 0.13  4
40350010 74  6 2 0.16 0.21 0.28 0.30 0.34 0.14 0.21 0.29 0.27 0.21 0.24 0.24 0.24 0.38 0.0  0.0   4
40350010 74  7 1 0.30 0.35 0.36 0.34 0.31 0.30 0.26 0.28 0.24 0.28 0.23 0.35 0.07 0.06 0.17 0.20  4
40350010 74  7 2 0.28 0.27 0.38 0.32 0.25 0.13 0.19 0.22 0.24 0.27 0.26 0.34 0.19 0.20 0.20 0.0   4
```

```
INITIAL PARAMETER VALUES

   1        6.030000    PSP
   2        0.121000    KSAT
   3       13.820000    RGF
   4       11.000000    BMSN
   5        0.700000    EVC
   6        0.900000    RR
   7        0.800000    DRN

                          NUMBER OF SEGMENTS =    19
                             DT =  1.000 MINUTES
                    OUTPUT SAMPLING INTERVAL =  5.00 MINUTES
                           NUMBER OF RAIN GAGES = 1
                         NUMBER OF PARAMETER SETS = 1
                       IMPERVIOUS RETENTION =0.05 INCHES
```

```
                                                                     LENGTH              ROUGHNESS                                THIESSEN COEFFICIENTS
SEGMENT UPSTREAM SEGMENTS   ADJACENT SEGMENTS TYPE IPR NDX (FEET)   SLOPE PARAMETER OTHER PARAMETERS
 OP01                                           5    0  10    454.  0.0050   0.200     0.800      0.150 1 1.00
 OI01                                          15    0   7    454.  0.0050   0.013     0.800      0.150 1 1.00
 OF02                                           5    0   5    382.  0.0220   0.016     0.470      0.360 1 1.00
 OF03                                           5    0   6    480.  0.0240   0.016     0.480      0.310 1 1.00
 OF04                                           5    0   7    593.  0.0180   0.016     0.540      0.320 1 1.00
 OF05                                           5    0   9   1006.  0.0220   0.016     0.570      0.270 1 1.00
 OF06                                           5    0   7    295.  0.0040   0.016     0.440      0.420 1 1.00
 OP07                                           5    0  10    372.  0.0120   0.200     0.300      0.160 1 1.00
 OI07                                          15    0   5    372.  0.0120   0.013     0.800      0.160 1 1.00
 OP08                                           5    0  10    617.  0.0070   0.200     0.580      0.330 1 1.00
 OI08                                          15    0   8    617.  0.0070   0.013     0.580      0.330 1 1.00
 OF09                                           5    0   6    340.  0.0100   0.015     0.700      0.220 1 1.00
 CH20     CH23 CH21         OP01 OI01 OF02      3    0   3   1210.  0.0050   0.016    11.000      0.0   0 0.0
 CH21                       OF04 OF09           3    0   4   2240.  0.0070   0.016    11.000      0.0   0 0.0
 CH22     CH24              OF05 OF06           3    0   3   1580.  0.0080   0.016     4.300      0.0   0 0.0
 CH23                       OF03                3    0   2   1270.  0.0290   0.013    31.000      0.0   0 0.0
 CH24                       OP07 OI07 OP08 OI08 3    0   6   2225.  0.0050   0.013    50.000      0.0   0 0.0
 CH25     CH22                                  3    0   2    460.  0.0050   0.016    11.000      0.0   0 0.0
 JT01     CH20 CH25                             7    1  10      0.  0.0      0.0       0.0        0.0   0 0.0


        COMPUTATION SEQUENCE                KINEMATIC CHANNEL PARAMETERS

          INDEX    SEGMENT                        ALPHA       M
            1       OP01                           0.53     1.670
            2       OI01                           8.10     1.670
            3       OF02                          13.81     1.670
            4       OF03                          14.43     1.670
            5       OF04                          12.49     1.670
            6       OF05                          13.81     1.670
            7       OF06                           5.89     1.670
            8       OP07                           0.82     1.670
            9       OI07                          12.56     1.670
           10       OP08                           0.62     1.670
           11       OI08                           9.59     1.670
           12       OF09                           9.31     1.670
           14       CH21                           3.32     1.330
           16       CH23                           5.88     1.330
           17       CH24                           2.08     1.330
           13       CH20                           2.80     1.330
           15       CH22                           4.85     1.330
           18       CH25                           2.80     1.330
           19       JT01                           0.0      0.0
THERE ARE  10 FLOOD PEAKS GROUPED AS FOLLOWS      1      1      1      1      1      1      2      2      1      1

STORM NO.  1 STARTS AT TIME PERIOD  226 AND ENDS AT  250
STORM NO.  2 STARTS AT TIME PERIOD  247 AND ENDS AT  275
STORM NO.  3 STARTS AT TIME PERIOD  168 AND ENDS AT  190
STORM NO.  4 STARTS AT TIME PERIOD  217 AND ENDS AT  260
STORM NO.  5 STARTS AT TIME PERIOD  220 AND ENDS AT  250
STORM NO.  6 STARTS AT TIME PERIOD  195 AND ENDS AT  225
STORM NO.  7 STARTS AT TIME PERIOD   73 AND ENDS AT   95
STORM NO.  8 STARTS AT TIME PERIOD  173 AND ENDS AT  190
STORM NO.  9 STARTS AT TIME PERIOD    5 AND ENDS AT   35
STORM NO. 10 STARTS AT TIME PERIOD   68 AND ENDS AT   90
```

```
FLOOD NUMBER  1

TIME          I        OUTFLOW HYDROGRAPHS    (IN CFS)
                        JT01
 18.83      226        0.004
 18.92      227        0.122
 19.00      228        0.905
 19.08      229        2.778
 19.17      230        6.977
 19.25      231       15.738
 19.33      232       21.932
 19.42      233       22.840
 19.50      234       20.076
 19.58      235       16.025
 19.67      236       12.347
 19.75      237        9.462
 19.83      238        7.312
 19.92      239        5.728
 20.00      240        4.552
 20.08      241        3.673
 20.17      242        3.004
 20.25      243        2.489
 20.33      244        2.085
 20.42      245        1.765
 20.50      246        1.508
 20.58      247        1.300
 20.67      248        1.129
 20.75      249        0.987
 20.83      250        0.865
```

```
FLOOD NUMBER  2

TIME          I        OUTFLOW HYDROGRAPHS    (IN CFS)
                         JT01
 20.58      247         1.255
 20.67      248        29.921
 20.75      249        73.915
 20.83      250        70.151
 20.92      251        50.567
 21.00      252        34.802
 21.08      253        25.038
 21.17      254        18.895
 21.25      255        14.897
 21.33      256        12.054
 21.42      257         9.692
 21.50      258         7.786
 21.58      259         6.279
 21.67      260         5.105
 21.75      261         4.190
 21.83      262         3.479
 21.92      263         2.919
 22.00      264         2.475
 22.08      265         2.119
 22.17      266         1.830
 22.25      267         1.595
 22.33      268         1.401
 22.42      269         1.241
 22.50      270         1.105
 22.58      271         0.993
 22.67      272         0.897
 22.75      273         0.815
 22.93      274         0.744
 22.92      275         0.684
```

```
FLOOD NUMBER  3

TIME          I       OUTFLOW HYDROGRAPHS    (IN CFS)
                        OT01
 14.00      168        0.051
 14.08      169        1.070
 14.17      170        6.608
 14.25      171       11.862
 14.33      172       13.768
 14.42      173       13.027
 14.50      174       11.098
 14.58      175        9.005
 14.67      176        7.184
 14.75      177        5.727
 14.83      178        4.594
 14.92      179        3.725
 15.00      180        3.054
 15.08      181        2.532
 15.17      182        2.122
 15.25      183        1.795
 15.33      184        1.533
 15.42      185        1.320
 15.50      186        1.145
 15.58      187        1.001
 15.67      188        0.881
 15.75      189        0.779
 15.83      190        0.593
```

```
FLOOD NUMBER  4

TIME          I         OUTFLOW HYDROGRAPHS    (IN CFS)
                          JT01
 18.08      217          0.004
 18.17      218          1.717
 18.25      219         37.999
 18.33      220         96.521
 18.42      221         88.985
 18.50      222         62.528
 18.58      223         47.030
 18.67      224         35.829
 18.75      225         26.701
 18.83      226         19.571
 18.92      227         14.404
 19.00      228         10.894
 19.08      229          8.759
 19.17      230          7.627
 19.25      231          7.268
 19.33      232          6.940
 19.42      233          6.325
 19.50      234          5.575
 19.58      235          4.899
 19.67      236          4.629
 19.75      237          4.955
 19.83      238          5.637
 19.92      239          6.331
 20.00      240          7.131
 20.08      241          7.745
 20.17      242          8.206
 20.25      243          7.840
 20.33      244          7.021
 20.42      245          6.067
 20.50      246          5.150
 20.58      247          4.345
 20.67      248          3.67
 20.75      249          3.11
 20.83      250          2.655
 20.92      251          2.275
 21.00      252          1.972
 21.08      253          1.715
 21.17      254          1.505
 21.25      255          1.330
 21.33      256          1.184
 21.42      257          1.060
 21.50      258          0.955
 21.58      259          0.865
 21.67      260          0.785
```

```
FLOOD NUMBER  5

TIME          I        OUTFLOW HYDROGRAPHS    (IN CFS)
                         JT01
 18.33      220         0.000
 18.42      221         0.000
 18.50      222         0.000
 18.58      223         0.000
 18.67      224         0.000
 18.75      225         0.000
 18.83      226         0.000
 18.92      227         0.000
 19.00      228         0.000
 19.08      229         0.419
 19.17      230         7.065
 19.25      231        21.47[illegible]
 19.33      232        28.345
 19.42      233        25.992
 19.50      234        20.405
 19.58      235        15.1[illegible]
 19.67      236        11.247
 19.75      237         8.444
 19.83      238         6.451
 19.92      239         5.041
 20.00      240         4.004
 20.08      241         3.235
 20.17      242         2.655
 20.25      243         2.207
 20.33      244         1.855
 20.42      245         1.577
 20.50      246         1.353
 20.58      247         1.170
 20.67      248         1.020
 20.75      249         0.895
 20.83      250         0.790
```

```
FLOOD NUMBER  6

TIME          I        OUTFLOW HYDROGRAPHS    (IN CFS)
                        JT01
 16.25       195        0.034
 16.33       196        9.688
 16.42       197      128.050
 16.50       198      252.315
 16.58       199      279.563
 16.67       200      248.413
 16.75       201      187.771
 16.83       202      109.460
 16.92       203       69.989
 17.00       204       54.925
 17.08       205       44.053
 17.17       206       34.390
 17.25       207       26.520
 17.33       208       20.765
 17.42       209       16.685
 17.50       210       13.770
 17.58       211       11.640
 17.67       212       10.041
 17.75       213        8.809
 17.83       214        7.835
 17.92       215        7.047
 18.00       216        6.395
 18.08       217        5.849
 18.17       218        5.383
 18.25       219        4.[illegible]
 18.33       220        4.624
 18.42       221        4.310
 18.50       222        4.029
 18.58       223        3.775
 18.67       224        3.545
 18.75       225        3.335
```

```
FLOOD NUMBER  7

TIME          I       OUTFLOW HYDROGRAPHS    (IN CFS)
                        JT01
  6.08       73        0.302
  6.17       74        8.811
  6.25       75       42.639
  6.33       76       57.867
  6.42       77       48.867
  6.50       78       34.329
  6.58       79       23.46[illegible]
  [illegible] [illegible] 16.7[illegible]
  6.75       81       12.18[illegible]
  6.83       82        9.109
  6.92       83        6.96[illegible]
  [illegible] [illegible] [illegible]
  7.08       85        4.32[illegible]
  7.17       [illegible] 3.[illegible]
  7.2[illegible] [illegible] [illegible]
  [illegible]
  [illegible]
  [illegible]

  [illegible]
  [illegible]
  [illegible]
  [illegible]  95      [illegible]
```

```
FLOOD NUMBER

TIME                 OUTFL
                      UT

14.42      173       0.004
14.50      174       1.295
14.58      175      25.111
14.67      176      68.063
14.75      177      67.690
14.83      178      48.089
14.92      179      31.972
15.00      180      21.424
15.08      181      14.894
15.17      182      10.720
15.25      183       7.967
15.33      184       6.088
15.42      185       4.762
15.50      186       3.805
15.58      187       3.094
15.67      188       2.555
15.75      189       2.134
15.83      190       1.810
```

```
FLOOD NUMBER  9

TIME          I        OUTFLOW HYDROGRAPHS    (IN CFS)
                         JT01
 0.42         5         0.000
 0.50         6         0.000
 0.58         7         0.000
 0.67         8         0.001
 0.75         9         0.011
 0.83        10         0.143
 0.92        11         3.957
 1.00        12        38.155
 1.08        13        91.031
 1.17        14       116.772
 1.25        15        99.689
 1.33        16        72.[illegible]
 1.42        17        52.869
 1.50        18        39.792
 1.58        19        30.772
 1.67        20        23.755
 1.75        21        18.529
 1.83        22        14.997
 1.92        23        12.271
 2.00        24         9.925
 2.08        25         8.000
 2.17        26         6.470
 2.25        27         5.277
 2.33        28         4.350
 2.42        29         3.629
 2.50        30         3.064
 2.58        31         2.615
 2.67        32         2.257
 2.75        33         1.969
 2.83        34         1.731
 2.92        35         1.537
```

```
FLOOD NUMBER 10

TIME          I         OUTFLOW HYDROGRAPHS    (IN CFS)
                          OUT01
  5.67      68          0.000
  5.75      69          1.215
  5.83      70         37.229
  5.92      71        151.200
  6.00      72        215.654
  6.08      73        175.276
  6.17      74        116.856
  6.25      75         77.343
  6.33      76         51.940
  6.42      77         35.443
  6.50      78         24.578
  6.58      79         17.662
  6.67      80         13.150
  6.75      81         10.139
  6.83      82          8.073
  6.92      83          6.615
  7.00      84          5.558
  7.08      85          4.771
  7.17      86          4.171
  7.25      87          3.703
  7.33      88          3.329
  7.42      89          3.024
  7.50      90          2.771
```

```
DETAILED DISCHARGE FOR FLOOD NUMBER  1
OBSERVED PEAK DISCHARGE =       0.0  CFS
SIMULATED PEAK DISCHARGE =     22.84 CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =       0.330 INCHES
OBSERVED DIRECT RUNOFF =     0.0   INCHES
SIMULATED DIRECT RUNOFF =     0.050 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER  2
OBSERVED PEAK DISCHARGE =       0.0  CFS
SIMULATED PEAK DISCHARGE =     73.92 CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =       0.530 INCHES
OBSERVED DIRECT RUNOFF =     0.0   INCHES
SIMULATED DIRECT RUNOFF =     0.155 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER  3
OBSERVED PEAK DISCHARGE =       0.0  CFS
SIMULATED PEAK DISCHARGE =     13.77 CF
OBSERVED RAINFALL   GAGE NUMBER  1 =       0.230 INCHES
OBSERVED DIRECT RUNOFF =     0.0   INCHES
SIMULATED DIRECT RUNOFF =     0.052 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER  4
OBSERVED PEAK DISCHARGE =       0.0  CFS
SIMULATED PEAK DISCHARGE =     96.52 CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =       0.950 INCHES
OBSERVED DIRECT RUNOFF =     0.0   INCHES
SIMULATED DIRECT RUNOFF =     0.277 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER  5
OBSERVED PEAK DISCHARGE =       0.0  CFS
SIMULATED PEAK DISCHARGE =     28.35 CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =       0.340 INCHES
OBSERVED DIRECT RUNOFF =     0.0   INCHES
SIMULATED DIRECT RUNOFF =     0.082 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER  6
OBSERVED PEAK DISCHARGE =       0.0  CFS
SIMULATED PEAK DISCHARGE =    279.56 CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =       1.940 INCHES
OBSERVED DIRECT RUNOFF =     0.0   INCHES
SIMULATED DIRECT RUNOFF =     0.755 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER  7
OBSERVED PEAK DISCHARGE =       0.0  CFS
SIMULATED PEAK DISCHARGE =     57.87 CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =       0.510 INCHES
OBSERVED DIRECT RUNOFF =     0.0   INCHES
SIMULATED DIRECT RUNOFF =     0.140 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER  8
OBSERVED PEAK DISCHARGE =       0.0  CFS
SIMULATED PEAK DISCHARGE =     58.06 CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =       0.560 INCHES
OBSERVED DIRECT RUNOFF =     0.0   INCHES
SIMULATED DIRECT RUNOFF =     0.157 INCHES

DETAILED DISCHARGE FOR FLOOD NUMBER  9
OBSERVED PEAK DISCHARGE =       0.0  CFS
SIMULATED PEAK DISCHARGE =    116.77 CFS
OBSERVED RAINFALL   GAGE NUMBER  1 =       1.060 INCHES
OBSERVED DIRECT RUNOFF =     0.0   INCHES
```

```
MULATED DIRECT RUNOFF =    0.319 INCHES

TAILED DISCHARGE FOR FLOOD NUMBER 10
SERVED PEAK DISCHARGE =     0.0  CFS
MULATED PEAK DISCHARGE =   215.65 CFS
SERVED RAINFALL    GAGE NUMBER  1 =      1.330 INCHES
SERVED DIRECT RUNOFF =    0.0   INCHES
MULATED DIRECT RUNOFF =    0.471 INCHES
```

UNITED STATES GEOLOGICAL SURVEY

WATER
RESOURCES
DIVISION

Gulf Coast Hydroscience Center
NSTL Station, Mississippi