PRECIPITATION-RUNOFF MODELING SYSTEM: USER'S MANUAL

By G. H. Leavesley, R. W. Lichty, B. M. Troutman, and L. G. Saindon

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CONVERSION FACTORS

For use of readers who prefer to use metric units, conversion factors for terms used in this report are listed below.

Multiply	*By*	*To obtain*
acre	0.4047	hectare
acre-inch (ac-in)	102.74	cubic meters
calorie (cal)	4.186	joule
degree Fahrenheit (°F)	°C=5/9 (°F-32)	degree Celsius
foot (ft)	0.3048	meter
foot per second (ft/s)	0.3048	meter per second
square foot (ft^2)	0.09294	square meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
inch (in.)	2.54	centimeter
inch per day (in./d)	2.54	centimeter per day
inch per hour (in./hr)	2.54	centimeter per hour
kilogram per square foot per per second ($kg/ft^2/s$)	10.76	kilogram per square meter per second
kilogram per cubic foot (kg/ft^3)	35.31	kilogram per cubic meter
kilogram per cubic foot per second ($kg/ft^3/s$)	35.31	kilogram per cubic meter per second
langley (ly)	4.186	joule per square centimeter

National Geodetic Vertical Datum of 1929 (NGVD of 1929)--A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

The concepts, structure, theoretical development, and data requirements of the precipitation-runoff modeling system (PRMS) are described. The precipitation-runoff modeling system is a modular-design, deterministic, distributed-parameter modeling system developed to evaluate the impacts of various combinations of precipitation, climate, and land use on streamflow, sediment yields, and general basin hydrology. Basin response to normal and extreme rainfall and snowmelt can be simulated to evaluate changes in water-balance relationships, flow regimes, flood peaks and volumes, soil-water relationships, sediment yields, and ground-water recharge. Parameter-optimization and sensitivity analysis capabilities are provided to fit selected model parameters and evaluate their individual and joint effects on model output. The modular design provides a flexible framework for continued model-system enhancement and hydrologic-modeling research and development.

INTRODUCTION

The precipitation-runoff modeling system (PRMS) is a modular-design modeling system that has been developed to evaluate the impacts of various combinations of precipitation, climate, and land use on surface-water runoff, sediment yields, and general basin hydrology. Basin response to normal and extreme rainfall and snowmelt can be simulated on various combinations of land use to evaluate changes in water-balance relationships, flow regimes, flood peaks and volumes, soil-water relationships, sediment yields, and ground-water recharge. PRMS is a deterministic physical-process modeling system. To reproduce the physical reality of the hydrologic system as closely as possible, each component of the hydrologic cycle is expressed in the form of known physical laws or empirical relationships that have some physical interpretation based on measurable watershed characteristics.

The modular design of PRMS provides a flexible modeling capability. Each component of the hydrologic system is defined by one or more subroutines that are maintained in a computer-system library. All subroutines are compatible for linkage to each other. Given a specific hydrologic problem and its associated data constraints, the user can select an established model from the library or can design his own model using selected library and user-supplied subroutines. The library also contains subroutines for parameter optimization, sensitivity analysis, and model output handling and analysis. The initial system subroutines were obtained by modularizing an event-type distributed routing rainfall-runoff model (Dawdy and others, 1978) and a daily flow rainfall- and snowmelt-runoff model (Leavesley and Striffler, 1978), and by writing new algorithms for processes and procedures not available in these models. Additional subroutines will be added and existing subroutines will be modified and improved as experience is gained from model applications in various climatic and physiographic regions.

PRMS is designed to function either as a lumped- or distributed-parameter type model and will simulate both mean daily flows and stormflow hydrographs. PRMS components are designed around the concept of partitioning a watershed into units on the basis of characteristics such as slope, aspect, vegetation type, soil type, and precipitation distribution. Each unit is considered homogeneous with respect to its hydrologic response and is called a hydrologic-response unit (HRU). A water balance and an energy balance are computed daily for each HRU. The sum of the responses of all HRU's, weighted on a unit-area basis, produces the daily system response and streamflow from the watershed. Partitioning provides the ability to impose land-use or climate changes on parts or all of a watershed, and to evaluate resulting hydrologic impacts on each HRU and on the total watershed.

Input variables include descriptive data on the physiography, vegetation, soils, and hydrologic characteristics of each HRU, and on the variation of climate over the watershed. The minimum driving variables required to run in the daily-flow mode are (1) daily precipitation, and (2) maximum and minimum daily air temperatures. Daily pan-evaporation data can be substituted for air temperature for situations where snowmelt simulation is not required; daily solar radiation data are recommended when snowmelt will be simulated. To simulate stormflow hydrographs, rainfall depths for time intervals of 60 minutes or less are required. PRMS is designed to run with data retrieved directly from the U.S. Geological Survey's National Water Data Storage and Retrieval (WATSTORE) system (Hutchinson, 1975). However, PRMS also can use data not stored on the WATSTORE system. Programs are available to read and reformat these data to make them model-compatible.

The modular system approach provides an adaptable modeling system for both management and research applications. For management problems, a model can be tailored to geographic region, data, and problem characteristics. Research applications include development of new model components and the testing and comparison of various approaches to modeling selected components of the hydrologic cycle. New model components proposed as future additions to PRMS include water-quality components and expanded saturated-unsaturated flow and ground-water flow components.

This documentation is designed to provide the user with the basic philosophy and structure of PRMS, instructions for application of established models designed as cataloged procedures, and instructions for interaction with the PRMS library to permit user additions or modifications of model components. The components and subroutines described in this document are those available at the time of publication. However, the library is dynamic and will be enhanced and updated through time. This manual will be updated to reflect major additions and changes through manual inserts or republications.

All components of PRMS except the hydrologic and meteorologic data retrieval subroutines (DVRETR and UVRET) are written in FORTRAN. PRMS data sets are handled using an indexed sequential (ISAM) file structure. Because PRMS has been developed on an AMDAHL computer system, DVRETR and UVRET are written in PL/I programming language. To run PRMS on computer systems that don't have ISAM file or PL/I-FORTRAN interface capabilities will require modifications to DVRETR and UVRET. Descriptions of DVRETR and UVRET are given in attachment VII to facilitate user modifications. Future enhancement of the data management components includes the development of a FORTRAN-based data-management system. This system will permit creation, editing, and limited analysis of a PRMS data set.

SYSTEM STRUCTURE

The PRMS structure has three major components. The first is the data-management component. It handles the manipulation and storage of hydrologic and meteorologic data into a model-compatible direct access file. The second is the PRMS library component. This component consists of both a source-module library and a load-module library for the storage of the compatible subroutines used to define and simulate the physical processes of the hydrologic cycle. In addition, it contains the parameter-optimization and sensitivity-analysis subroutines for model fitting and analysis. The third component is the output component that provides the model output handling and analysis capabilities.

The three PRMS components are shown schematically in figure 1. Hydrologic and meteorologic field data are collected and stored in either user data files or the U.S. Geological Survey's WATSTORE system. Data interface programs accept data from these two sources and convert and store the data in an index-sequential (ISAM) file, which is fully model-compatible. The precipitation-runoff model either is selected as a cataloged procedure from the PRMS library or is created from PRMS library- and user-supplied subroutines. The model reads initialization and basin characteristics information from card-deck input and accesses the ISAM data file for hydrologic and meteorologic data required for model operation. Model outputs can be printed and stored for further analysis.

The major components of the PRMS structure are discussed in greater detail in the following sections. Examples of the use of these components are given in attachments II and III.

Data Management

The U.S. Geological Survey WATSTORE system is used for permanent storage of hydrologic and meteorologic data. Field measurements are transmitted to the U.S. Geological Survey Computer Center in Reston, Va., where WATSTORE data reduction and input programs are used to store the data in the "Daily Values" and "Unit Values" files. Data in these files are identified by a unique station number and 5-digit parameter and statistic codes. STORET EPA parameter codes are used to identify the type of data, and the statistic code defines the frequency of measurement or statistical reduction of the data. Lists and explanations of these codes may be found in Appendices D and E, Volume 1 of the WATSTORE user's manual (Hutchinson, 1975). Typically, the daily file will contain, for each day in the period of record, the maximum, minimum, and mean air temperature in degrees Celsius (°C), total solar radiation in langleys per day (ly/d), total precipitation in inches, and mean

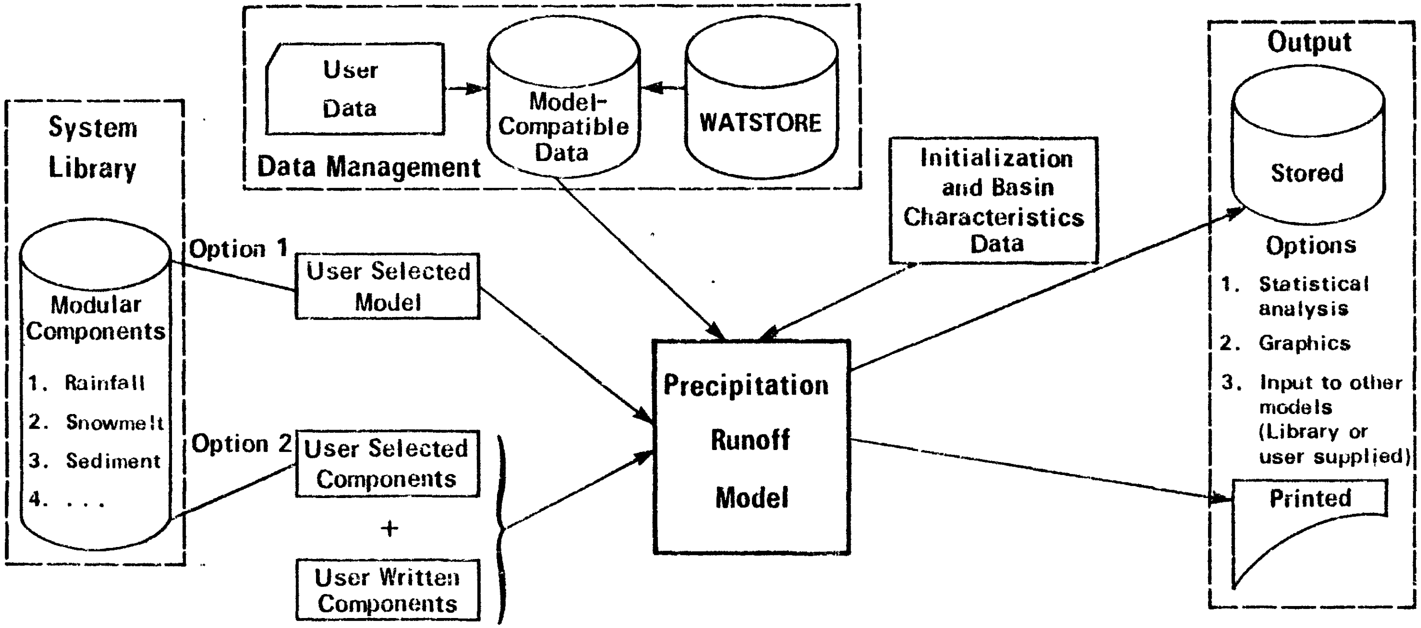


Figure 1.--The precipitation-runoff modeling system.

discharge in cubic feet per second (ft^3/s). The unit file is used for storage of data collected at shorter time intervals, such as 5-minute precipitation and discharge. The WATSTORE system also has statistical, plot, and update capabilities that allow users to inspect and edit data.

The data-handling subroutines within the model do not access data directly from the WATSTORE system. The data-set organization required for use in the model is an indexed sequential (ISAM) file containing both daily- and unit-values data. A cataloged procedure, GENDISK, is available to read sequential files containing standard WATSTORE daily- and unit-values records and create the model-compatible ISAM file. Data contained in the WATSTORE system are made available to GENDISK by executing standard daily- and unit-values retrieval programs. The ISAM file may contain more data than are needed for any particular model run, since the data-handling subroutines within the model will automatically select the years and events requested on the model control cards. However, if more data than are initially included in the ISAM file are required, the file must be recreated, since additions cannot be made to it.

System Library

The system library is the core of the PRMS. It contains all the compatible subroutines that can be used in system-defined or user-defined combinations to simulate the hydrologic cycle. The structure of the library and its subroutines is based on two model-design concepts. The first is that a MAIN program will be used as a central point for time and computational sequence control. Timing control maintains day, month, and year variables and increments them as required. Sequence control establishes the framework in which the sequence of various model functions will be performed. These functions are performed by calls to appropriate library subroutines. The timing and sequence functions are discussed in more detail in subsequent sections. The second concept is that each subroutine represents one component of the hydrologic cycle and is designed to be as independent as possible from other component subroutines. The necessary transfer of information between subroutines is done using COMMON statements.

The PRMS library is composed of both a source-module library and a load-module library. The source-module library contains the FORTRAN coded subroutines. The load-module library consists of the compiled subroutines ready for linkage editing into a complete program. Instructions for obtaining a copy of the source-module library are given in attachment V.

The library provides the user several options in model development and application. One option is the use of the cataloged procedure PRMODEL, which is the compilation of the complete model system. A second option would be to compile a new model using the System MAIN program with a combination of library- and user-supplied subroutines. A third option would be for the user to write his own MAIN program and use a combination of library- and user-supplied subroutines. This manual primarily is directed to the first option. However, the last two options are discussed in detail in the System Modification section.

Output

The output component provides the user with several options for analyzing, displaying, and storing model simulation results. Options include various printed summaries, printer plots of observed and predicted streamflow and sediment, and storage of observed and predicted streamflow for use with PRMS library, WATSTORE, Statistical Analysis System (SAS) (SAS Institute Inc., 1982), or user-written analysis programs. Desired outputs are specified in the data input stream.

Printed output options range from a table of predicted and observed streamflow values to annual, monthly, daily, or storm-event streamflow summaries. Annual, monthly, or daily summaries also are available for major climate and water-balance elements. These detailed summaries are available both for the total basin and for each individual HRU.

Predicted mean daily streamflow data can be stored by water year as a permanent file for further processing and analysis. Two record formats are available for data storage. One is the standard WATSTORE daily-value format, which permits the use of WATSTORE and SAS analysis programs. The second format option is designed for PRMS library and user-written analysis programs. It contains only the water-year date and 366 data values.

The output component is discussed in more detail in the System Output section. Examples of the output options are shown in the System Output section and in the sample model runs in attachment II.

SYSTEM CONCEPTS

The objectives established to guide the design and development of PRMS were that PRMS should:

1. Simulate mean daily flows and shorter time-interval stormflow hydrographs for any combination of precipitation, climate, and land use.
2. Provide model-modification capabilities to permit specific user requirements or limitations to be incorporated.
3. Provide capabilities for system enhancement and expansion.
4. Provide error and sensitivity-analysis capabilities.
5. Provide a data-management capability that is compatible with the U.S. Geological Survey WATSTORE system, but adaptable to other computer systems.

A modular system design was selected to provide the desired flexibility and data-management capabilities, and to allow incorporation of user-specific requirements.

The major component of PRMS is the system library. The use of models or components from the library requires an understanding of the basic concepts used in its design and development. These include the conceptual model of the watershed system, the partitioning scheme used to provide distributed-parameter modeling capabilities, the time basis of model operation, and the interface between daily flow and stormflow hydrograph-generation components.

Conceptual Watershed System

The watershed system and its inputs are schematically depicted in figure 2. System inputs are precipitation, air temperature, and solar radiaion. Precipitation in the form of rain, snow, or a mixture of both is reduced by interception and becomes net precipitation delivered to the watershed surface. The energy inputs of temperature and solar radiation drive the processes of evaporation, transpiration, sublimation, and snowmelt. The watershed system is conceptualized as a series of reservoirs whose outputs combine to produce the total system response.

The impervious-zone reservoir represents an area with no infiltration capacity. The reservoir has a maximum retention storage capacity (RETIP) which must be satisfied before surface runoff (SAS) will occur. Retention storage is depleted by evaporation when the area is snow free.

The soil-zone reservoir represents that part of the soil mantle that can lose water through the processes of evaporation and transpiration. Average rooting depth of the predominant vegetation covering the soil surface defines the depth of this zone. Water storage in the soil zone is increased by infiltration of rainfall and snowmelt and depleted by evapotranspiration. Maximum retention storage occurs at field capacity; minimum storage (assumed to be zero) occurs at wilting point. The soil zone is treated as a two-layered system. The upper layer is termed the recharge zone and is user-defined as to depth and water-storage characteristics. Losses from the recharge zone are assumed to occur from evaporation and transpiration; losses from the lower zone occur only through transpiration.

The computation of infiltration into the soil zone is dependent on whether the input source is rain or snowmelt. All snowmelt is assumed to infiltrate until field capacity is reached. At field capacity, any additional snowmelt is apportioned between infiltration and surface runoff. At field capacity the soil zone is assumed to have a maximum daily snowmelt infiltration capacity, SRX. All snowmelt in excess of SRX contributes to surface runoff. Infiltration in excess of field capacity (EXCS) first is used to satisfy recharge to the ground-water reservoir (SEP). SEP is assumed to have a maximum daily limit. Excess infiltration, available after SEP is satisfied, becomes recharge to the subsurface reservoir. Water available for infiltration as the result of a rain-on-snow event is treated as snowmelt if the snowpack is not depleted, and as rainfall if the snowpack is depleted.

For rainfall with no snowcover, the volume infiltrating the soil zone is computed as a function of soil characteristics, antecedent soil-moisture conditions, and storm size. For daily-flow computations, the volume of rain that becomes surface runoff is computed using a contributing-area concept. Daily infiltration is computed as net precipitation less surface runoff . For stormflow-hydrograph generation, infiltration is computed using a form of the Green and Ampt equation (Philip, 1954). Surface runoff for these events is net precipitation less computed infiltration. Infiltration in excess of field capacity is treated the same as daily infiltration.

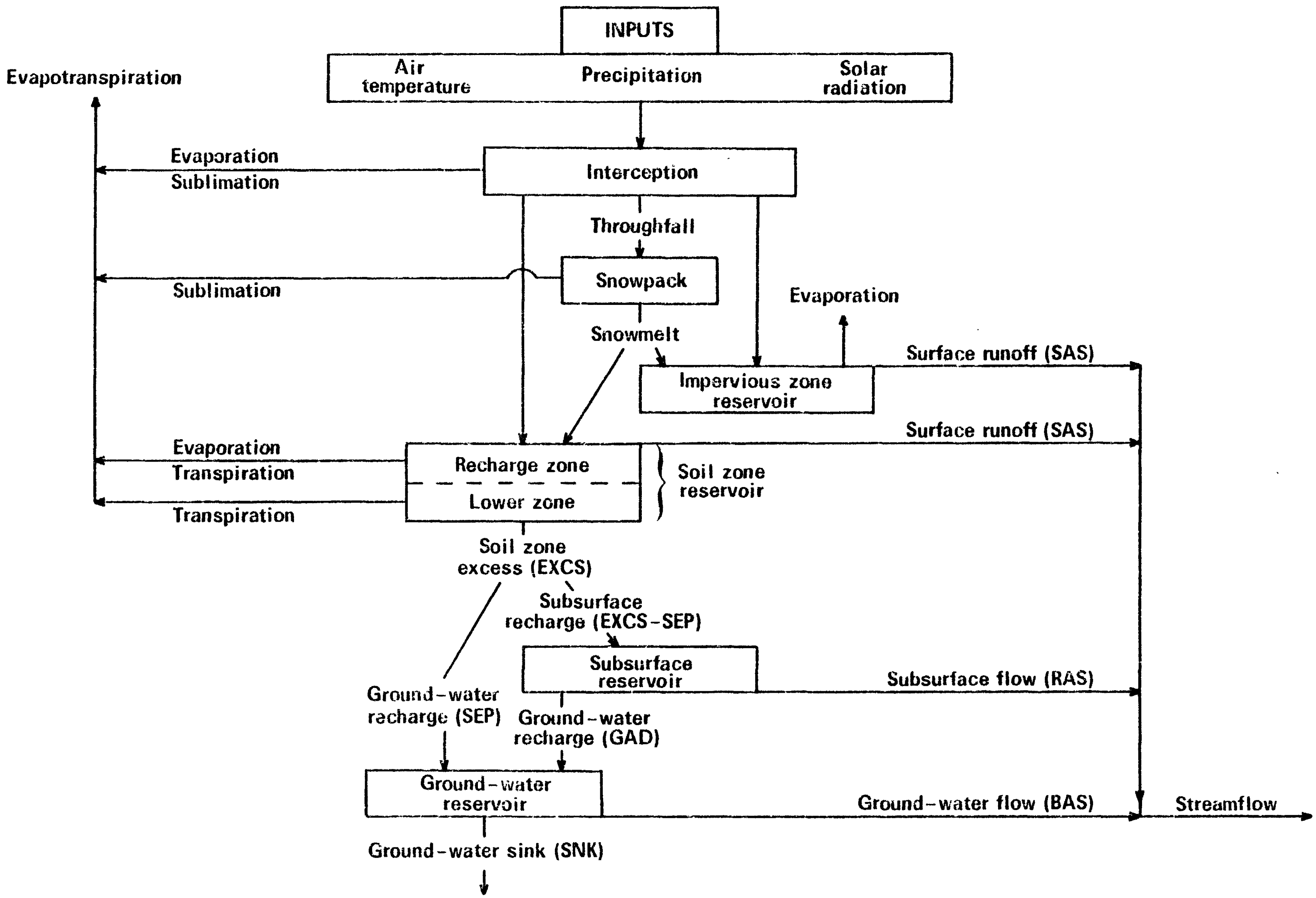


Figure 2.--Schematic diagram of the conceptual watershed system and its inputs.

The subsurface reservoir performs the routing of soil-water excess that percolates to shallow ground-water zones near stream channels or that moves downslope from point of infiltration to some point of discharge above the water table. Subsurface flow (RAS) is considered to be water in the saturated-unsaturated and ground-water zones that is available for relatively rapid movement to a channel system. The subsurface reservoir can be defined either as linear or nonlinear.

Recharge to the ground-water reservoir can occur from the soil zone (SEP) and the subsurface reservoir (GAD). SEP has a daily upper limit and occurs only when field capacity is exceeded in the soil zone. GAD is computed daily as a function of a recharge rate coefficient (RSEP) and the volume of water stored in the subsurface reservoir. The ground-water reservoir is a linear reservoir and is the source of all baseflow (BAS). Movement of water through the ground-water system to points beyond the area of interest or measurement can be handled by flow to a ground-water sink (GSNK) which is computed as a function of storage in the ground-water reservoir.

Streamflow is the sum of SAS, RAS, and BAS. For daily flow simulations, no channel routing is done.

Watershed Partitioning

The distributed-parameter modeling capability is provided by partitioning a watershed into "homogeneous" units. Watershed partitioning can be done on the basis of characteristics such as slope, aspect, elevation, vegetation type, soil type, and precipitation distribution. Each watershed unit delineated is considered to be homogeneous with respect to these characteristics. Partitioning provides the ability to account for spatial and temporal variations of basin physical and hydrologic characteristics, climatic variables, and system response. It also provides the ability to impose land-use or climatic changes on parts or all of a basin. Evaluation can then be made of the impacts of such changes on the hydrology of each unit and the total basin.

Two levels of partitioning are available. The first level divides the basin on the basis of some or all of the physical characteristics mentioned above. The resulting units are called hydrologic response units (HRU's), and each is considered homogeneous with respect to its hydrologic response. A water balance and an energy balance are computed daily for each HRU. The sum of the responses of all HRU's, weighted on a unit-area basis, produces the daily system response and streamflow from a basin.

The conceptual watershed system shown in figure 2 could be defined for each HRU. However, for most small watersheds, one soil-zone reservoir is defined for each HRU, while one ground-water reservoir is defined for the entire watershed. One or more subsurface reservoirs are defined, depending on variations in soils and geology.

PRMS will handle a maximum of 50 HRU's. The number and location of HRU's for any given basin are a function of the number of physical characteristics used in the partitioning scheme, the number and location of precipitation gages available, and the problem to be addressed by the model. There are no hard and fast rules for partitioning currently available; this is an area to be addressed by further research. However, the number of HRU's delineated will influence the calibration fit of many of the model components (Leavesley and Striffler, 1978). A general rule of thumb currently used for daily-flow computations for most problems is not to create HRU's smaller than 4 to 5 percent of the total basin area. Exception would occur if an area smaller than this would have significant influence on streamflow or on general basin hydrology. A common tendency is to overpartition. Therefore, it is recommended that test runs be made at a few levels of partitioning to get a feel for the influence of the numbers of HRU's on model daily-flow response.

A second level of partitioning is available for storm hydrograph simulation. The watershed can be conceptualized as a series of interconnected flow-planes and channel segments. Surface runoff is routed over the flow planes into the channel segments; channel flow is routed through the watershed channel system. An HRU can be considered the equivalent of a flow plane, or it can be delineated into a number of flow planes. Delineation of a basin into 6 overland flow planes and 3 channel segments is shown in figure 3. Overland flow planes have a width equal to the adjacent channel segment, and an equivalent length which, when multiplied by the width, gives the area of the natural basin segment. PRMS will handle a total of 50 overland flow plane and 50 channel segments.

Daily and Storm Modes

A model selected or developed from the PRMS library can simulate basin hydrology on both a daily and a storm time scale. The daily mode simulates hydrologic components as daily average or total values. Streamflow is computed as a mean daily flow. The storm mode simulates selected hydrologic components at time intervals shorter than a day. The minimum time interval is 1 minute. The storm mode is used to compute infiltration, surface-water runoff, and sediment yield from selected rainfall events.

Data required for daily simulations are input to the model 1 water year at a time. Included in the input are the dates of storm periods within the water year, where data are available for rainfall-runoff simulations. The model operates in a daily mode until it reaches one of these dates. It then shifts to the storm mode and inputs the data available for that date. A stormflow hydrograph and sediment-concentration graph can be simulated for that day at a time interval selected by the user. At the end of the storm day, control is returned to selected daily components for updating to insure storm- and daily-mode compatibility and to compute mean daily streamflow. If the storm period is more than 1 day in length, then control returns to the storm mode and another day of data is input. Subsequent storm days of data are read and used in this manner until the storm period terminates. The model then returns to the full daily-mode sequence.

Summaries can be output both for daily and for storm simulations. Daily mode computations can be summarized on a daily, monthly, and annual basis. Storm-mode computations can be summarized for the full storm period and at a user-selected time interval.

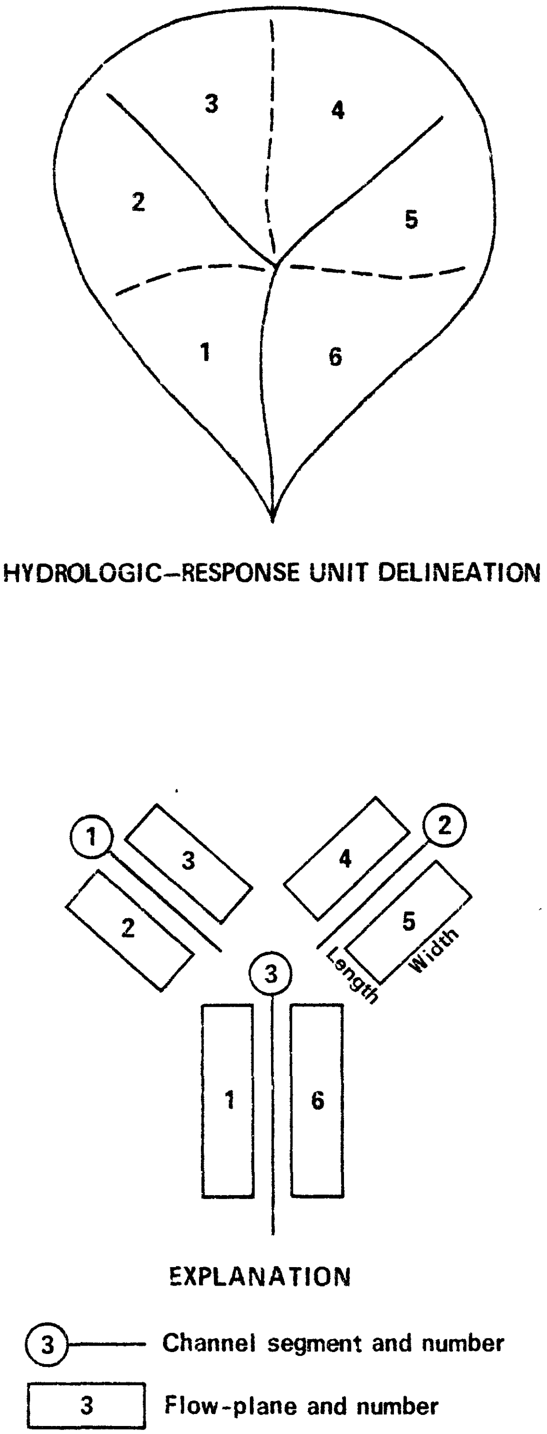


Figure 3.--Flow-plane and channel-segment delineation of a basin.

The daily mode keeps account of days using a day-month-year scheme and three numerical sequencing indices that number days of the year from 1 to 365 or 366. One numerical index is the Julian date. This numbers the days of the year beginning on January 1. A water-year date index also is used; it begins day 1 on October 1. The third numerical index is the solar date. Day 1 begins on December 22, which is the winter solstice, or the date of receipt of minimum potential solar radiation.

THEORETICAL DEVELOPMENT OF SYSTEM LIBRARY COMPONENTS

Meteorologic Data

The meteorologic data components take temperature and solar radiation data from one station and precipitation data from up to 5 gages and adjust these data for each HRU. Adjustment factors are computed as functions of the differences in elevation, slope, and aspect between the measuring station and each HRU. Local and regional climate and precipitation data are the sources for the development of these adjustment factors.

Temperature

Observed daily maximum (TMX) and minimum (TMN) air temperatures are adjusted to account for differences in elevation and slope-aspect between the climate station and each HRU. Air-temperature data can be input either in Fahrenheit (°F) or in Celsius (°C), but these data must be consistent throughout a simulation. All temperature variables and parameters must be in the same units as the temperature data. All daily maximum, minimum, and mean air-temperature computations are made in subroutine TEMP.

A correction factor (TCRX) for adjusting TMX for each HRU is computed each month (MO) by:

$$TCRX(MO) = [TLX(MO) * ELCR] - TXAJ \qquad (1)$$

where

TLX is the maximum temperature lapse rate, in degrees per 1,000 feet change in elevation for month MO;
ELCR is the mean elevation of an HRU minus the elevation of the climate station, in 1,000's of feet; and
TXAJ is an average difference in maximum air temperature between a horizontal surface and the slope-aspect of an HRU.

A correction factor [TCRN(MO)] for adjusting TMN for each HRU is computed monthly with an equation of the same form as equation 1, using the monthly minimum temperature lapse rate [TLN(MO)] and minimum temperature slope-aspect correction (TNAJ).

Adjusted daily maximum air temperature (TM) for each HRU is computed by:

$$TM = TMX - TCRX(MO) \qquad (2)$$

Adjusted daily minimum air temperature (TN) for each HRU is computed using an equation of the same form as equation 2 and the variables TMN and TCRN(MO).

Precipitation

Total daily precipitation depth (PPT) received on an HRU is computed by:

$$PPT = PDV * PCOR \tag{3}$$

where

PDV is the daily precipitation depth observed in the precipitation gage associated with the HRU, in inches (in.), and
PCOR is the correction factor for the HRU.

A maximum of five gages can be used to define the spatial and temporal variation of precipitation on a watershed. Each HRU is associated with one of the available gages by the precipitation gage index KDS. A PCOR value is defined for each HRU and relates to the gage specified by KDS. PCOR accounts for the influences of elevation, spatial variation, topography, and gage-catch efficiency. Different values of PCOR can be specified for different precipitation forms and time scales of measurement--DRCOR for daily rainfall, DSCOR for daily snowfall, and UPCOR for storm-mode rainfall. In some geographic and climatic regions, the influence of elevation on precipitation volume varies seasonally with general storm patterns (Barry, 1972). Frontal origin storms may show a strong elevation effect, while convective storms may show little elevation effect. If DRCOR and DSCOR include strong elevational influence, they can be overridden for a period of time to account for these seasonal changes. All HRU values of DRCOR are replaced by a single constant value PCONR and all values of DSCOR are replaced by a constant value PCONS. The override period is user-specified to begin on the first day of month MPCS and end on the first day of month MPCN.

Precipitation form (rain, snow, or mixture of both) on each HRU is estimated from the HRU maximum (TM) and minimum (TN) daily air temperatures and their relationship to a base temperature (BST) (Willen and others, 1971). Precipitation is all snow if TM is less than or equal to BST, and all rain if TN is greater than BST. If TM is greater than BST and TN is less than BST, then the part of the total precipitation occurring as rain (PRMX) is computed by:

$$PRMX = \frac{TM - BST}{TM - TN} * AJMX(MO) \tag{4}$$

where

AJMX is a monthly mixture adjustment coefficient for month MO. For mixed events, rain is assumed to occur first.

The mixture algorithm can be overridden in two ways. One is the use of variable PAT. PAT is an air-temperature value which, when exceeded by TM, forces all precipitation to be rain, regardless of the TN value. This capability permits accounting for convective rainfall during spring, when minimum daily temperatures are below BST. PAT is user-specified for each month. The second override is used when the form of precipitation is known by the user. Precipitation form then can be specified, using the snow and rain data cards (Card Group 5). These cards designate the Julian dates in each water year that are to be considered all snow or all rain.

All of the computations described above are made in subroutine PRECIP. One additional subroutine, PKADJ, is available for adjusting precipitation input. For snow, gage-catch deficiencies of about 45 to 70 percent can be expected at wind speeds of 10 to 20 miles per hour (Larson and Peck, 1974). To account for gage-catch deficiencies, PKADJ provides the capability of adjusting the snowpack water equivalent on each HRU, based on snowcourse data from each HRU or an index snowcourse. This adjustment option is available only once each year; therefore, it is best used near the anticipated date of maximum snowpack accumulation.

Solar Radiation

Observed daily shortwave radiation (ORAD) expressed in langleys per day (ly/d) is used in snowmelt computations and can be used in evapotranspiration computations. ORAD is an optional input for areas with no snowmelt. For areas where snowmelt will be simulated, ORAD can be input directly or estimated from daily air-temperature data for watersheds where it is not available. All solar radiation computations are made in subroutines SOLRAD and SOLTAB.

ORAD, measured on a horizontal surface, is adjusted to estimate SWRD, the daily shortwave radiation received on the slope-aspect combination of each HRU. SWRD is computed by:

$$SWRD = ORAD * \frac{DRAD}{HORAD} \tag{5}$$

where

DRAD is the daily potential solar radiation for the slope and aspect of an HRU (ly), and
HORAD is the daily potential solar radiation for a horizontal surface (ly).

DRAD and HORAD are linearly interpolated from a table of 13 potential solar radiation values (RAD), which are calculated for each slope-aspect combination and the horizontal surface. Because of the symmetry of the solar year, these 13 values represent potential solar radiation for 24 dates throughout the year. The 13 dates and date pairs are listed in table 1. Table values are computed in subroutine SOLTAB using a combination of methods described in Frank and Lee (1966) and Swift (1976).

Table 1.--*Sequence number and dates of the 13 potential solar radiation values for each slope-aspect combination*

Sequence No.	Date(s)
1	December 22
2	January 10, December 3
3	January 23, November 19
4	February 7, November 5
5	February 20, October 22
6	March 7, October 8
7	March 21, September 23
8	April 4, September 9
9	April 19, August 25
10	May 3, August 10
11	May 18, July 27
12	June 1, July 12
13	June 22

For missing days or periods of record, ORAD can be estimated from air-temperature data. One of two procedures can be selected using variable MRDC. The first is a modification of the degree-day method described by Leaf and Brink (1973). This method was developed for a section of the Rocky Mountain Region of the United States. It appears most applicable to this region of the country, where predominantly clear skies prevail on days without precipitation.

The method is shown graphically in the coaxial relation of figure 4. A daily maximum temperature is entered in the X-axis of part A and intersects the appropriate month curve. From this intersection point, one moves horizontally across the degree-day coefficient axis and intersects the curve in part B. From this point, the ratio of actual-to-potential radiation for a horizontal surface (SOLF) can be obtained. An estimate of ORAD is then computed by:

$$ORAD = SOLF * HORAD. \qquad (6)$$

The ratio SOLF is developed for days without precipitation; thus, the computed ORAD is for dry days. ORAD for days with precipitation is estimated for the period September through April by multiplying the ORAD from equation 6 by a user-defined constant PARW. For days with precipitation in the months May through August, ORAD is adjusted using PARS in place of PARW.

The input data required to use this procedure are the slope (RDM) and the y-intercept (RDC) of the line that expresses the relationship between monthly maximum air temperature and a degree-day coefficient (DD). Estimates

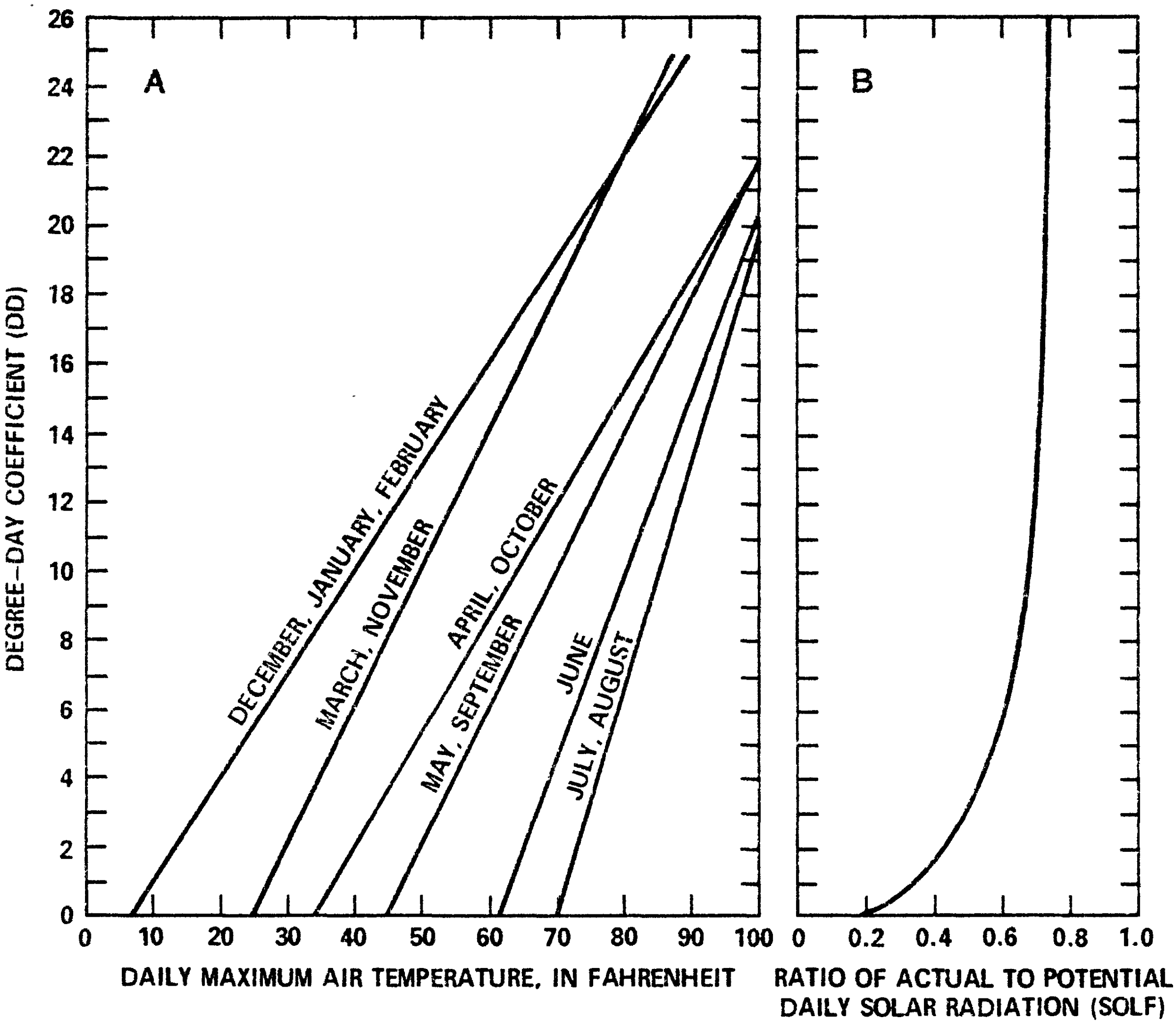


Figure 4.--Example of coaxial relationship for estimating shortwave solar radiation from maximum daily air temperature developed for northwestern Colorado.

of PARW and PARS also are required. DD is computed by:

$$DD = (RDM * TMX) + RDC \tag{7}$$

where TMX is the observed daily maximum air temperature. The DD-SOLF relationship of figure 4 is assumed constant.

Monthly values of RDM and RDC can be estimated from historic air- temperature and solar-radiation data. One method is to make monthly plots of TMX versus their daily degree-day coefficients, DD, for days without precipitation. The DD values for this plot are computed using figure 4 and the daily SOLF ratios computed from historic data. A set of monthly lines then can be drawn through these points either visually or with linear- regression techniques. A more rapid and coarse procedure is to establish two points for each monthly line using some average values. One point for each month is estimated using the average SOLF and average maximum temperature for days without precipitation. The second point is estimated using the maximum observed temperature for each month and a DD value of 15. Using this second procedure, curves shown in part A of figure 4 were estimated for a region in northwest Colorado. Estimates of PARW and PARS are obtained from the radiation record. PARW is the ratio of SOLF for days with precipitation to days without precipitation over the September through April period. PARS is the ratio of SOLF for days with precipitation to days without precipitation over the May through August period.

The second procedure for estimating missing data uses a relationship between solar radiation and sky cover developed by Thompson (1976) and a relationship between sky cover and a daily range in air temperature demonstrated by Tangborn (1978). This procedure appears applicable to the more humid regions of the country where extensive periods of cloud cover occur with and without precipitation. Daily sky cover (SKY) is computed by:

$$SKY = [RDM(MO) * (TMX-TMN)] + RDC(MO) \tag{8}$$

where

RDM is the slope of the sky cover-daily air temperature range relationship for month MO,
TMX is observed maximum air temperature,
TMN is observed minimum air temperature, and
RDC is the intercept of the sky-cover daily air-temperature range relationship for month MO.

This SKY value is used to compute an estimate of the ratio (RAJ) of ORAD to potential clear-sky radiation by:

$$RAJ = RDB + (1.-RDB) * [(1.-SKY)**RDP] \tag{9}$$

where

RDB is the B value obtained from Thompson (1976) figure 1, and
RDP is a parameter, suggested to be 0.61 (Thompson, 1976).

For days with precipitation, RAJ is multiplied by PARS (May through August) or PARW (September through April). An upper limit on RAJ is specified by the parameter RDMX. ORAD is then computed by:

$$ORAD = RAJ * HORAD \qquad (10)$$

Both ORAD estimation procedures are relatively coarse, but appear to work reasonably well. They normally are used to fill in days of missing data. However, where radiation data are unavailable, they have produced reasonable results when used to generate entire periods of solar-radiation record. In such cases, the nearest climate station with radiation and air-temperature data is used to estimate RDM and RDC values. If there is a large difference in elevation between the climate station on the watershed and the station with radiation data, the air-temperature data associated with the radiation data are adjusted to the study-basin elevation.

Impervious Area

Impervious area can be treated in one of two ways. If it exists as large, contiguous areas, then it can be designated as one or several totally impervious HRU's. If it is of significant area but scattered throughout the pervious areas of a watershed, then impervious area can be expressed as composing a percentage of an otherwise pervious HRU. Interception is assumed not to occur on impervious areas. Therefore, input to impervious areas is total precipitation. Impervious surface is assigned a maximum retention storage capacity (RETIP). Available retention storage (RSTOR) is depleted by evaporation. Surface runoff from impervious areas is delivered directly to the channel network and occurs only after RETIP is filled.

Interception

Interception of precipitation is computed as a function of the cover density and the storage available for the predominant vegetation on an HRU. Net precipitation (PTN) is computed by:

$$PTN = [PPT * (1.-COVDN)] + (PTF * COVDN) \qquad (11)$$

where

PPT is the total precipitation received on an HRU (in.),
COVDN is the seasonal cover density, and
PTF is the precipitation falling through the canopy (in.).

COVDN is defined for summer (COVDNS) and winter (COVDNW). PTF is computed by:

$$\begin{array}{ll} PTF = PPT - (STOR-XIN) & PPT > (STOR - XIN) \qquad (12) \\ PTF = 0.0 & PPT \leq (STOR - XIN) \end{array}$$

where

STOR is the maximum interception storage depth on vegetation (in.), and
XIN is the current depth of interception storage (in.).

STOR is defined by season and precipitation form--winter snow (SNST), winter rain (RNSTW), and summer rain (RNSTS). When rain falls on intercepted snow, STOR changes from SNST to the seasonal rain-storage value. Any snow in storage that exceeds the new rain-storage value is added to throughfall PTF. When snow falls on intercepted rain, STOR changes to SNST and currently available rain interception is used to satisfy SNST. Intercepted rain in excess of SNST is added to PTF. SNST generally is considered to be greater than or equal to RNSTW. PTF and XIN are computed in subroutine PRECIP for daily-precipitation events, and in subroutine UNITD for storm events.

Intercepted rain is assumed to evaporate at a free-water surface rate (EVCAN). If pan-evaporation data are used, then EVCAN equals the pan loss. If potential evapotranspiration (PET) is computed from meteorologic variables, EVCAN is computed by:

$$\mathrm{EVCAN} = \frac{\mathrm{PET}}{\mathrm{EVC(MO)}} \tag{13}$$

where EVC is the evaporation-pan coefficient for month MO. Sublimation of intercepted snow (SUBCAN) is assumed to occur at a rate that is expressed as a percentage (CTW) of PET. In addition to sublimation, intercepted snow can be removed from the canopy by melting. An energy balance is computed for a 12-hour period (assumed 0600 to 1800). If the energy balance is zero or negative, no melt occurs. When the energy balance is positive, all melt is delivered to the snowpack or soil surface as net precipitation.

Actual daily loss from interception (XINLOS) is equal to the smaller value of storage XIN or loss rates, EVCAN or SUBCAN. If XIN is not depleted in 1 day, the remainder is carried over to the next day. XINLOS, as computed above, represents loss from the percentage of HRU area expressed in the cover density parameters COVDNS or COVDNW. For water balance computations, XINLOS is adjusted to represent an HRU average value. XINLOS is computed in subroutine INTLOS in the daily mode and in subroutine UNITD in the storm mode.

Soil-Moisture Accounting

Soil-moisture accounting is performed as the algebraic summation of all moisture accretions to, and depletions from, the active soil profile. Depletions include evapotranspiration and recharge to the subsurface and ground-water reservoirs. Accretions are rainfall and snowmelt infiltration. The depth of the active soil profile is considered to be the average rooting depth of the predominant vegetation on an HRU. The maximum available water-holding capacity of the soil zone (SMAX) is the difference between field capacity and wilting point of the profile. The active soil profile is divided into two layers. The upper layer is termed the recharge zone and the lower layer is termed the lower zone. The recharge zone is user-definable as to depth and maximum available water-holding capacity (REMX). The maximum available water-holding capacity (LZMX) of the lower zone is the difference between SMAX and REMX. Losses from the recharge zone occur from evaporation and transpiration; they occur only as transpiration from the lower zone. Evapotranspiration losses occur at a rate that is a function of available soil-moisture storage. The attempt to satisfy potential evapotranspiration is made first from the recharge zone. Soil-moisture accretions must fill the recharge zone storage before water will move to the lower zone. When soil-zone storage reaches SMAX, all additional infiltration is routed to the subsurface and ground-water reservoirs.

Soil-moisture accounting for daily computations is done in subroutine SMBAL. Accounting computations for storm-event periods are done in subroutine UNITD.

Evapotranspiration

Daily estimates of potential evapotranspiration (PET) are computed in subroutine PETS. Three computation procedures are available. Procedure selection is made, using variable IPET. The first procedure uses daily pan-evaporation data. PET (in./day) is computed by:

$$PET = EPAN * EVC(MO) \tag{14}$$

where

EPAN is daily pan-evaporation loss, (in.), and
EVC is a monthly pan-adjustment coefficient for month MO.

A second procedure computes PET as a function of daily mean air temperature and possible hours of sunshine (Hamon, 1961). PET (in./d) is computed by:

$$PET = CTS(MO) * DYL^2 * VDSAT \tag{15}$$

where

CTS is a coefficient for month MO,
DYL is possible hours of sunshine, in units of 12 hours, and
VDSAT is the saturated water-vapor density (absolute humidity) at the daily mean air temperature in grams per cubic meter (g/m^3).

VDSAT is computed by (Federer and Lash, 1978):

$$VDSAT = 216.7 * \frac{VPSAT}{(TAVC + 273.3)} \tag{16}$$

where

VPSAT is the saturated vapor pressure in millibars (mb) at TAVC, and
TAVC is the daily mean air temperature (°C).

VPSAT is computed by (Murray, 1967):

$$VPSAT = 6.108 * EXP\ [17.26939 * \frac{TAVC}{(TAVC + 237.3)}] \tag{17}$$

Hamon (1961) suggests a constant value of 0.0055 for CTS. Other investigators (Leaf and Brink, 1973; Federer and Lash, 1978) have noted that 0.0055 underestimated PET for some regions. Limited experience also has shown that a constant annual value underestimates PET for winter months more than summer months. Therefore, the ability to vary CTS by month is provided. DYL will vary with time of year and HRU slope and aspect. A set of day-length values (SSH) in hours is computed in subroutine SOLTAB for 13 specified date-pairs throughout the year (table 1) for each solar-radiation plane. Each SSH value is divided by 12 to compute its associated DYL value. Daily DYL values are interpolated from the 13 DYL values in subroutine SOLRAD.

The third procedure is one developed by Jensen and Haise (1963). PET (in./d) is computed by:

$$PET = CTS(MO) * (TAVF-CTX) * RIN \tag{18}$$

where

CTS is a coefficient for the month MO,
TAVF is the daily mean air temperature (°F),
CTX is a coefficient, and
RIN is daily solar radiation expressed in inches of evaporation potential.

As with the Hamon procedure, the Jensen-Haise procedure also tends to underestimate winter month PET. Therefore, the ability to change CTS by month is provided. For the warmer months of the year, constant values for CTS and CTX can be estimated using regional air temperature, elevation, vapor pressure, and vegetation data (Jensen and others, 1969). For aerodynamically rough crops, which are assumed to include forests, CTS is computed for the watershed by:

$$CTS = [C1 + (13.0 * CH)]^{-1} \tag{19}$$

where

C1 is an elevation correction factor, and
CH is a humidity index.

C1 is computed by:

$$C1 = 68.0 - [3.6 * (\frac{E1}{1,000})] \tag{20}$$

where

E1 is the median elevation of the watershed (ft).

CH is computed by:

$$CH = \left(\frac{50}{e2 - e1}\right) \tag{21}$$

where

e_2 is the saturation vapor pressure (mb) for the mean maximum air temperature for the warmest month of the year, and
e_1 is the saturation vapor pressure (mb) for the mean minimum air temperature for the warmest month of the year.

CTX is computed for each HRU by:

$$CTX = 27.5 - 0.25 * (e_2 - e_1) - \left(\frac{E2}{1{,}000}\right) \tag{22}$$

where

E2 is the median elevation of the HRU (ft).

Actual evapotranspiration (AET) is the computed rate of water loss which reflects the availability of water to satisfy PET. When available water is nonlimiting, AET equals PET. PET is first satisfied from interception storage, retention storage on impervious areas, and evaporation/sublimation from snow surfaces. Remaining PET demand then is applied to the soil-zone storage. AET is computed separately for the recharge zone and the lower zone using the unsatisfied PET demand and the ratio of currently available water in the soil zone to its maximum available water-holding capacity. For the recharge zone this ratio is $\frac{RECHR}{REMX}$. For the lower zone the ratio $\frac{SMAV}{SMAX}$ is used. AET computed for the recharge zone is used first to satisfy PET; any remaining demand is attempted to be met by AET from the lower zone. HRU soils are designated as being predominantly sand, loam, or clay, using variable ISOIL. The AET-PET relations for these soil types as a function of the soil-water ratio are shown in figure 5 (Zahner, 1967). AET computations are done in subroutine SMBAL.

The time of the year in which transpiration occurs is specified as a period of months between ITST and ITND, which are the starting (ITST) and ending (ITND) months of the transpiration period. The specific date of the start of transpiration is computed for each HRU using the temperature- index parameter TST. For each HRU, the sum of the daily maximum air temperatures is accumulated, starting with the first day of month ITST. When the sum for an HRU exceeds TST, transpiration is assumed to begin on that HRU. This technique permits accounting in part for warmer- or colder-than-normal spring periods. Transpiration is assumed to stop on the first day of ITND.

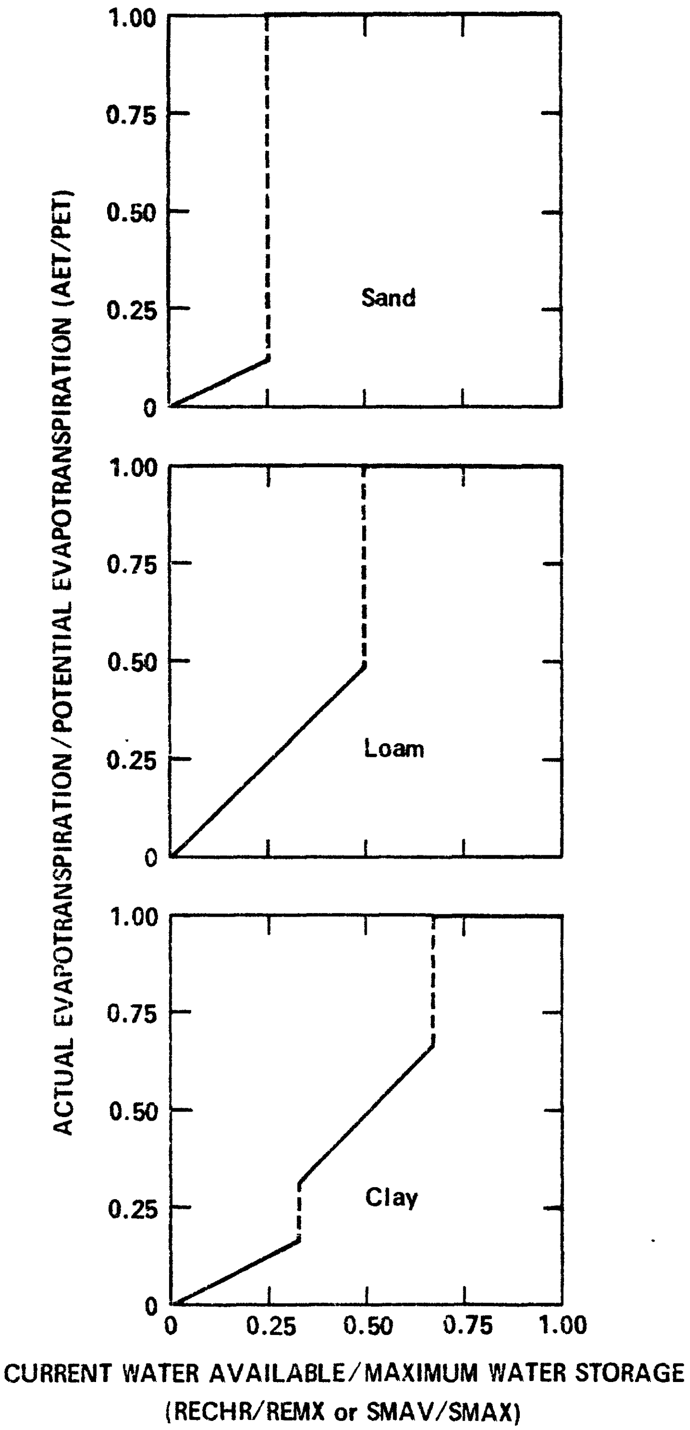


Figure 5.--Soil-water withdrawal functions for evapotranspiration (modified from Zahner, 1967).

Infiltration

Infiltration computations vary depending on the time interval and the form of the precipitation input. For daily rainfall occurring on a snow-free HRU, infiltration is computed as the difference between net rainfall computed in subroutine PRECIP and surface runoff computed in subroutine SRFRO. For snowmelt, infiltration is assumed nonlimiting until the soil reaches field capacity. Once field capacity is reached, a user-defined daily maximum infiltration capacity (SRX) limits the daily-infiltration volume. Any snowmelt in excess of SRX becomes surface runoff. For rain-on-snow, the resulting water available for infiltration is treated as snowmelt if the snowpack is not depleted. If the snowpack is depleted, then the rain and snowmelt are treated as rain on a snow-free surface.

Storm-mode computations are made only for rainfall and only when the basin is snow free. Infiltration during storms is computed in subroutine UNITD, using a variation of the Green-Ampt equation (Green and Ampt, 1911). Net rainfall (PTN) reaching the soil surface is allocated to rainfall excess (QR) and infiltration (FIN), either at the user-specified time interval or at 5 minutes, whichever is less. Point-infiltration capacity (FR) is computed as:

$$FR = KSAT * (1.0 + \frac{PS}{SMS}) \qquad (23)$$

where

KSAT is hydraulic conductivity of the transmission zone in inches per hour,
PS is effective value of the product of capillary drive and moisture deficit (in.), and
SMS is the current value of accumulated infiltration (in.).

PS is varied linearly as a function of the ratio $\frac{RECHR}{REMX}$ over the range from PSP, the value of the product of capillary drive and moisture deficit at field capacity, to a maximum value, RGF times PSP, expressed as:

$$PS = PSP * [RGF - (RGF-1) * (\frac{RECHR}{REMX})], \qquad (24)$$

where

RECHR is the current moisture storage in the recharge zone of the soil profile (in.), and
REMX is the maximum moisture storage in the recharge zone of the soil profile (in.).

This relationship is shown in figure 6. Net infiltration FIN then is computed, assuming that infiltration capacity varies linearly from zero to FR (fig. 7). Thus, FIN is computed as:

$$\mathrm{FIN} = \mathrm{PTN} - \frac{\mathrm{PTN}^2}{2\mathrm{FR}} \qquad \mathrm{PTN} < \mathrm{FR} \tag{25}$$

$$\mathrm{FIN} = \frac{\mathrm{FR}}{2} \qquad \text{otherwise.}$$

Rainfall excess (QR) is simply the net rainfall minus net infiltration

$$\mathrm{QR} = \mathrm{PTN} - \mathrm{FIN}. \tag{26}$$

Increments of rainfall excess are stored in the array UPE(1440) to be available for subsequent overland-flow computations. Net infiltration enters the recharge zone and is accumulated in the variable SMS for the purpose of computing point infiltration in equation 23. During periods when net rainfall is equal to zero, SMS is reduced at a rate which is computed by a factor DRN times KSAT. SMS also is depleted by evapotranspiration during zero net rainfall periods.

In both daily and storm-mode computations, all infiltration in excess of SMAX is routed to the subsurface and ground-water reservoirs. The excess first is used to satisfy the maximum ground-water recharge rate SEP, and the remainder is routed to the subsurface reservoir.

Surface Runoff

The computation of surface runoff varies with the computation time mode and source of runoff. Daily mean surface runoff is computed in subroutines SMBAL and SRFRO. Surface runoff for storms is computed in subroutine UNITD.

Daily Mode

Surface runoff from snowmelt is computed only on a daily basis. Snowmelt runoff from pervious areas is assumed to occur only when the soil zone of an HRU reaches field capacity. At field capacity, a daily maximum infiltration rate (SRX) is assumed. Any daily snowmelt in excess of SRX becomes surface runoff. For impervious areas, snowmelt first satisfies available retention storage, and the remaining snowmelt becomes surface runoff. Available retention storage is computed by subtracting current-retention storage (RSTOR) from maximum-retention storage (RETIP). RSTOR is depleted by evaporation after the snowpack melts. Snowmelt generated by rain on a snowpack is treated as all snowmelt, if the snowpack is not depleted by the rain. If rain totally depletes a snowpack, the resulting rain and snowmelt mix is treated as if it were all rain on a snow-free HRU.

Daily surface runoff from rainfall on pervious snow-free HRU's is computed using a contributing-area concept (Dickinson and Whiteley, 1970; Hewlett and Nutter, 1970). The percent of an HRU contributing to surface

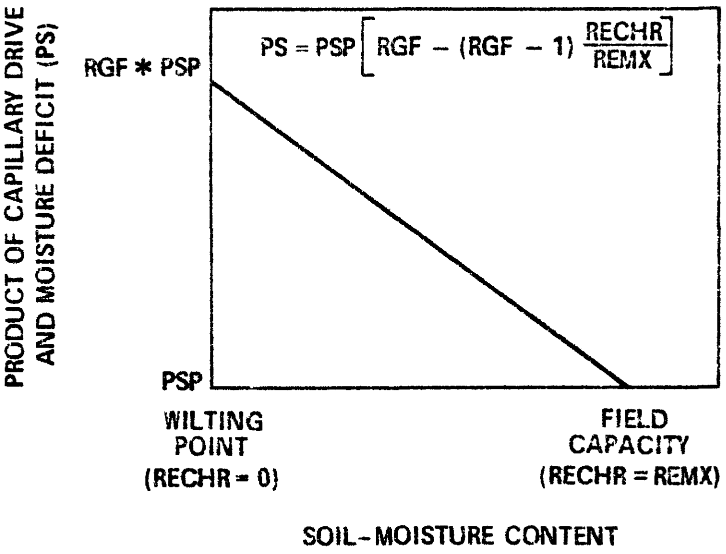


Figure 6.--The relation that determines the value of the product of capillary drive and moisture deficit (PS) as a function of soil-moisture content.

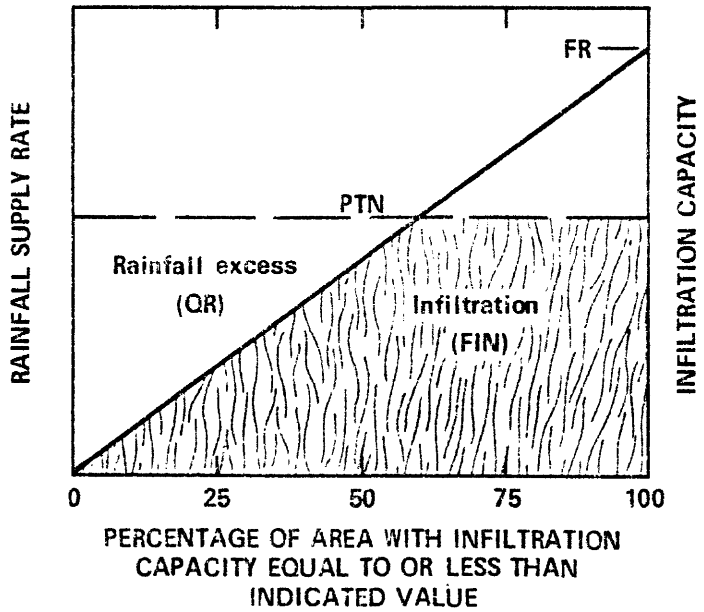


Figure 7.--The relation that determines rainfall excess (QR) as a function of maximum infiltration capacity (FR) and supply rate of rainfall (PTN).

runoff can be computed as either a linear or a nonlinear function of antecedent soil moisture and rainfall amount. In the linear relationship, the contributing area (CAP) expressed as a decimal fraction of the total HRU area is computed by:

$$CAP = SCN + [(SCX-SCN) * (\frac{RECHR}{REMX})] \tag{27}$$

where

SCN is the minimum possible contributing area,
SCX is the maximum possible contributing area,
RECHR is the current available water in the soil recharge zone (in.), and
REMX is maximum storage capacity of the recharge zone (in.).

Surface runoff (SRO) then is computed by:

$$SRO = CAP * PTN \tag{28}$$

where

PTN is the daily net precipitation (in.).

The nonlinear scheme uses a moisture index (SMIDX) similar to that developed by Dickinson and Whiteley (1970) for estimating CAP. CAP is computed by:

$$CAP = SCN * 10.**(SC1 * SMIDX) \tag{29}$$

where

SCN and SC1 are coefficients,
SMIDX is the sum of the current available water in the soil zone (SMAV) plus one-half of the daily net precipitation (PTN).

A maximum CAP is specified using variable SCX. SRO then is computed using equation 28.

Estimates of SCX, SCN, and SC1 and direct-surface runoff can be made from observed runoff and soil-moisture data. Where soil-moisture data are not available, estimates of soil-moisture values can be obtained from preliminary model runs. A regression of log CAP versus SMIDX can be done for these data to determine the coefficients:

$$\log CAP = a + b * SMIDX \tag{29a}$$

then

SCN=10.**a,
SC1=b, and
SCX is a maximum value of CAP.

An example of a CAP versus SMIDX plot for Blue Creek, Ala., and the fitted equation for CAP are shown in figure 8. The soil-moisture values used in computing SMIDX were obtained from preliminary model runs.

Daily surface runoff from impervious areas is computed using total daily precipitation (PPT). Available retention storage, computed as above, first is satisfied, and the remaining PPT becomes runoff.

Storm Overland Flow

Surface runoff for storm-mode simulation is computed using the kinematic wave approximation to overland flow. Overland flow computations on pervious areas are performed using the rainfall excess computed using equation 26 as inflow. Impervious areas use the observed rainfall trace as inflow. An HRU can be considered a single overland flow plane, or it can be divided into 2 or more flow planes to account for variations in slope and surface roughness. All flow planes must discharge to a channel segment; cascading flow planes are not permitted. All flow planes delineated on an HRU use the same rainfall excess trace. The partial differential equation to be solved for each overland flow-plane segment is:

$$\frac{\partial h}{\partial t} + \frac{\partial q}{\partial x} = re \qquad (30)$$

where

- h is the depth of flow (ft),
- q is the rate of flow per unit width in cubic feet per second per foot ($ft^3/s/ft$),
- re is the rate of rainfall excess inflow (ft/s),
- t is time (s), and
- x is distance down plane (ft).

The relation between h and q is given as:

$$q = \alpha h^m \qquad (31)$$

where

- α and m are functions of overland flow-plane characteristics and are computed in subroutine AM.

Equations used to compute α (ALPHA) and m (RM) from selected overland flow-plane and channel-segment characteristics are given in table 2. These equations may be overridden by user-defined values for ALPHA and RM. The numerical technique developed by Leclerc and Schaake (1973) and described by Dawdy, Schaake, and Alley (1978) is used to approximate $q(x,t)$ at discrete locations in the x-t plane. A rectangular grid of points spaced at intervals of time, Δt, and distance, Δx, is used. Values of Δt and Δx may vary from segment to segment, as required to maintain computational stability, and to produce desired resolution in computed results.

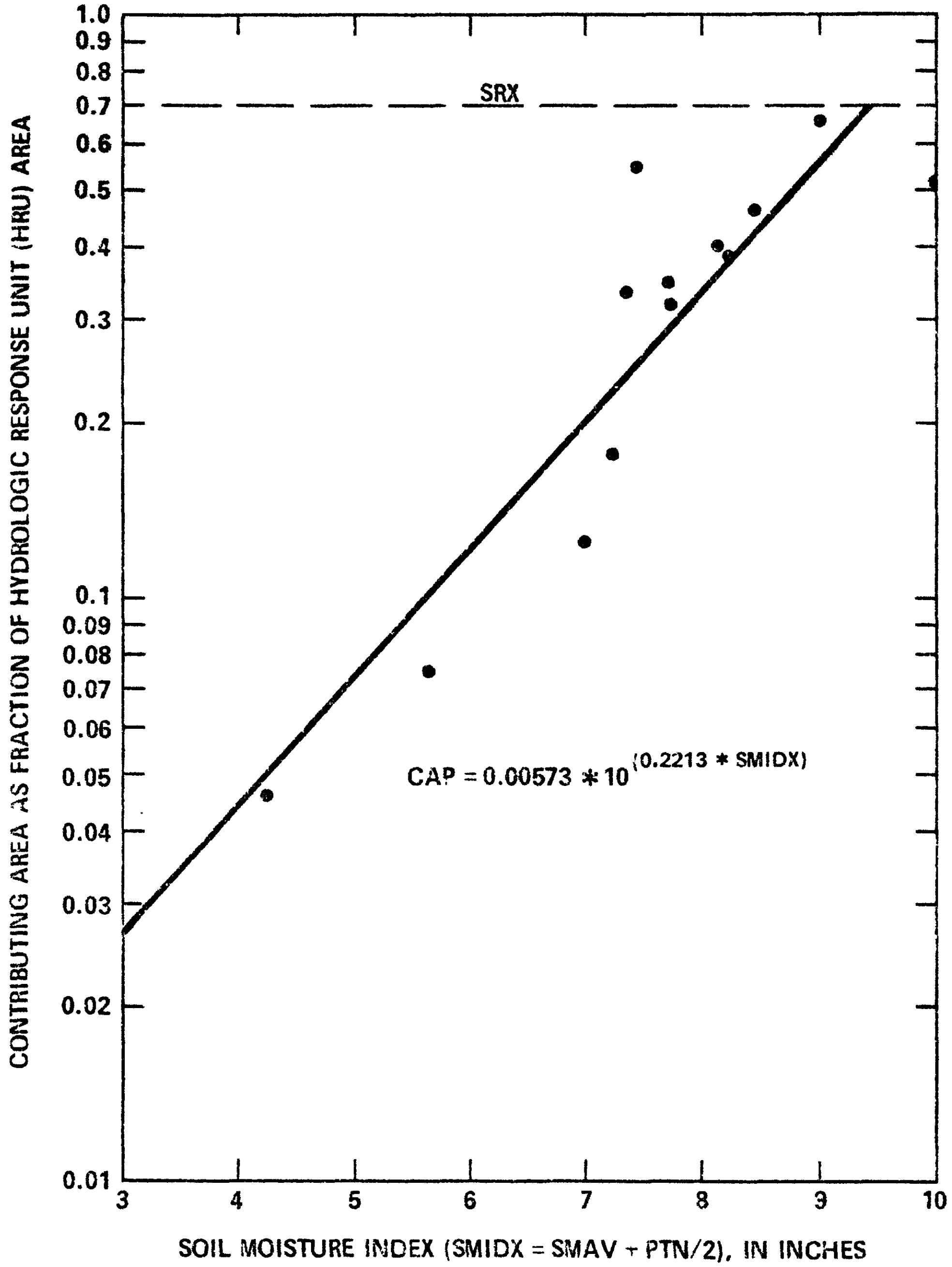


Figure 8.--The relation between contributing area (CAP) and soil-moisture index (SMIDX) for Blue Creek, Ala.

Table 2.--*Equations for computation of ALPHA and RM from selected overland flow-plane and channel-segment characteristics*

[α=ALPHA and m=RM]

Type of segment	TYPE	ALPHA	RM	Definition of PARAM: PARAM (I,1)	Definition of PARAM: PARAM (I,2)
Rectangular cross-section.	1	$\dfrac{1.49\ \sqrt{SLOPE\ (I)}}{FRN(I) * PARAM(I,1)^{2/3}}$	1.67	Width	----------------
Triangular cross-section.	3	$\dfrac{1.18\ \sqrt{SLOPE\ (I)}}{FRN\ (I)} * \left[\dfrac{\sqrt{PARAM\ (I,1) + PARAM\ (I,2)}}{\sqrt{[PARAM\ (I,1)]^2+1.} + \sqrt{[PARAM\ (I,2)]^2+1.}}\right]^{2/3}$	1.33	Width from left bank to center at 1 ft depth	Width from right bank to center at 1 ft depth
External specification of α and m.	4	PARAM (I,1)	PARAM (I,2)	α	m
Overland flow (turbulent).	5	$\dfrac{1.49\ \sqrt{SLOPE\ (I)}}{FRN\ (I)}$	1.67	---------------	----------------
Overland flow (laminar).	6	$\dfrac{64.4\ \ SLOPE\ (I)}{0.0000141 * FRN\ (I)}$	3.00	---------------	----------------
Junction----------	7	------------------------	----------	---------------	----------------

Subsurface Flow

Subsurface flow is considered to be the relatively rapid movement of water from the unsaturated zone to a stream channel. Subsurface flow occurs during, and for a period of time after, rainfall and snowmelt. The source of subsurface flow is soil water in excess of field capacity. This excess percolates to shallow ground-water zones or moves downslope at shallow depths from point of infiltration to some point of discharge above the water table. Subsurface flow is computed using a reservoir routing system.

Inflow to a subsurface reservoir occurs when the maximum available water-holding capacity (SMAX) of the soil zone of an HRU is exceeded, and this excess is greater than the recharge rate (SEP) to the ground-water reservoir. That is, the difference between soil-water excess and SEP is subsurface reservoir inflow. The continuity of mass equation for the subsurface-flow system is expressed as:

$$RAS = INFLOW - \frac{d(RES)}{dt} \tag{32}$$

where

RAS is the rate of outflow from the subsurface reservoir (in./Δt);
INFLOW is the rate of inflow to the subsurface reservoir (in./Δt), and
RES is the storage volume in the subsurface reservoir (in.).

RAS is expressed in terms of RES using the relationship:

$$RAS = RCF * RES + RCP * RES^2 \tag{33}$$

where

RCF and RCP are routing coefficients.

This is a nonlinear relationship. However, setting RCP equal to 0 makes the relationship linear. Substituting equation 33 into equation 32 produces:

$$\frac{d(RES)}{dt} = INFLOW - (RCF * RES) - (RCP * RES^2) \tag{34}$$

Equation 34 is solved for RES with the initial conditions RES = RES_0. This solution is combined with the continuity equation, producing:

$$RAS * \Delta t = INFLOW * \Delta t + SOS * \frac{(1 + \frac{RCP}{XK3} * SOS) * (1-e^{-XK3*\Delta t})}{1 + \frac{RCP}{XK3} * SOS * (1-e^{-XK3*\Delta t})} \tag{35}$$

where

Δt is time interval,

$SOS = RES_0 - \frac{XK3 - RCF}{2 * RCP}$, and

$XK3 = \sqrt{RCF^2 + 4 * RCP * INFLOW}$.

A second discharge point from the subsurface reservoir provides recharge (GAD) to the ground-water reservoir. The computation of GAD is discussed under the topic ground water in this section of the manual.

A subsurface reservoir can receive inflow from one or several HRU's. The number of subsurface reservoirs delineated in a basin can range from one to the number of HRU's delineated. HRU's contributing to each subsurface reservoir are specified by the index, KRES.

Initial storage volumes and routing coefficients must be determined for each subsurface reservoir. The initial estimate of storage normally is zero. Values of RCF and RCP can be fitted from historic streamflow data. For the nonlinear routing scheme, there are no procedures currently developed for making initial estimates of RCF and RCP. However, for the linear case, RCF can be estimated using the hydrograph separation technique on semilogarithmic paper described by Linsley, Kohler, and Paulhus (1958). Integrating the characteristic depletion equation:

$$q_t = q_o * K_r^{\,t} \tag{36}$$

where

q_t, q_o are streamflows at times t and o, and

K_r is a recession constant,

they show a relationship between RAS and RES that is expressed as:

$$RES = - \frac{RAS}{\log_e K_r} \tag{37}$$

where

K_r is the slope of the subsurface flow recession obtained from the semilog plot for t=1 day.

Rewriting equation 37 as:

$$RAS = -\log_e K_r * RES \tag{38}$$

shows that $-\log_e K_r$ is equivalent to RCF in equation 33 when RCP is zero.

Daily flow computations of RAS are made in subroutine BASFLW using Δt equals 24 hours. Unit storm computations of RAS are made in subroutine UNSM, using Δt equals 15 minutes.

Ground Water

The ground-water system is conceptualized as a linear reservoir and is assumed to be the source of all baseflow (BAS). Water can move to a ground-water reservoir from both a soil zone and a subsurface reservoir (fig. 2). Movement from a soil zone occurs when field capacity is exceeded and is limited by a maximum daily recharge rate, SEP. SEP is defined for each HRU. The reservoir receiving recharge from an HRU is specified by the index KGW. Movement to a ground-water reservoir from a subsurface reservoir (GAD) is computed by:

$$GAD = RSEP * \left(\frac{RES}{RESMX} \right)^{REXP} \tag{39}$$

where

RSEP is a daily recharge coefficient,
RES is the current storage in the subsurface reservoir (in.),
RESMX is a coefficient, and
REXP is a coefficient.

RESMX and REXP are used to define the routing characteristics of GAD. Setting them to 1.0 makes the routing a linear function of RES. The ground-water reservoir receiving GAD is specified by the index KRSP. The shape of the baseflow recession of the simulated hydrograph will be influenced by the relative proportion of ground-water recharge from the two source terms, SEP and GAD. Recharge from SEP occurs only on days when SMAX is exceeded by infiltration, while GAD occurs every day there is water available in the subsurface reservoir. Therefore, the use of GAD to recharge ground water preferentially over SEP could decrease subsurface flow and increase ground-water flow contributions to the simulated hydrograph.

BAS expressed in acre-inches (acre-in.) is computed by:

$$BAS = RCB * GW \tag{40}$$

where

RCB is the reservoir routing coefficient, and
GW is the ground-water reservoir storage (acre-in.).

RCB and the initial value of GW can be estimated from available streamflow records using equation 36 and a reformulated equation 37:

$$GW = - \frac{BAS}{\log_e K_r} \tag{41}$$

where

K_r is the slope of the ground-water flow recession from a semilog plot of discharge versus time. The value $-\log_e K_r$ is equivalent to RCB in equation 40.

The movement of water through the ground-water reservoir to points beyond the area of interest or measurement is treated using a ground-water sink. The daily accretion to the sink (SNK) in acre-inches is computed by:

$$SNK = GSNK * GW \tag{42}$$

where

GSNK is a seepage constant.

One or more ground-water reservoirs can be delineated in a watershed. More than one reservoir requires sufficient data to estimate initial storage volumes and routing coefficients. On small watersheds, only one ground-water reservoir normally is specified.

For mean daily flows, BAS and GAD are computed in subroutine BASFLW and the water in excess of field capacity available to satisfy SEP is computed in subroutine SMBAL. For storm events, BAS and GAD are computed in subroutine UNSM at 15-minute time intervals and the water in excess of field capacity is computed in subroutine UNITD at the same time interval as the infiltration computations.

Channel Flow

Channel-flow routing of daily streamflow is done only when surface reservoirs are designated. In these cases, the only routing is that accomplished by the reservoirs. Reservoir routing is discussed in detail under the reservoir topic in this section of the manual.

Channel-flow routing for storms is implemented by characterizing the drainage network as an ensemble of channel, reservoir, and junction segments that jointly describe the drainage pattern. The total number of channel, reservoir, and channel segments cannot exceed 50. Each type of segment can receive upstream inflow from as many as three other segments. In addition, channel segments may receive lateral inflow from as many as two overland flow planes (left bank and right bank). The upstream inflow hydrograph and the lateral inflow per unit length of channel times the channel length serve as the input or driving functions for channel-segment flow computations.

Channel-flow routing uses the same approach as that used for overland-flow computations--a finite difference approximation of the continuity equation

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \tag{43}$$

and the kinematic wave approximation relating discharge and the cross-sectional area of flow

$$Q = \alpha A^m \tag{44}$$

where

A is the area of flow (ft^2),
Q is the flow rate (ft^3/s),
q is the lateral inflow per unit length of channel ($ft^3/s/ft$),
t is time(s),
x is distance down the channel (ft), and
α and m are kinematic wave parameters.

The equations used to compute α (ALPHA) and m (RM) from selected channel segment characteristics are given in table 2. These equations can be overridden with user-defined values for ALPHA and RM. The numerical technique described by Dawdy, Schaake, and Alley (1978) is used to approximate Q(x,t) at discrete locations in the x-t plane.

The kinematic-wave parameters α and m for channel flow can be estimated for channel segments using Manning's equation if the wetted perimeter, W, can be expressed as a power function of the area of flow

$$W = cA^d \tag{45}$$

where

c and d are constants. Defining the hydraulic radius as

$$R = \frac{A}{W} = \frac{A^{1-d}}{c}, \tag{46}$$

then Manning's equation for the flow rate is

$$Q = AV = \frac{1.49\sqrt{S}}{nc^{2/3}} \; A^{\left(\frac{5}{3} - \frac{2}{3}d\right)} \tag{47}$$

where

V is flow velocity (ft/s),
n is Manning's n, and
S is slope (ft/ft);

then

$$\alpha = \frac{1.49\sqrt{S}}{nc^{2/3}} \quad , \tag{48}$$

and

$$m = \frac{5}{3} - \frac{2}{3}\,d \quad . \tag{49}$$

Dawdy, Schaake, and Alley (1978) suggest that the time and space steps, Δt and Δx, used in the numerical computations, be selected on the frequency-response characteristic (time to equilibrium) of "fastest" channel segment, the highest expected lateral inflow rate and a unit-hydrograph rule of thumb. A linear-stability criterion (Woolhiser and others, 1970) also can be used to temper the selection of the time and space steps for channel segments with predominantly upstream flow. This criterion is

$$\frac{\Delta x}{\Delta t} \geq m\alpha A^{m-1} \tag{50}$$

where

A is a maximum expected cross-sectional area of flow.

Reservoir Routing

Reservoir routing is based on a general form of the continuity equation:

$$O = I - \frac{d(STO)}{dt} \tag{51}$$

where

O is reservoir outflow,
I is reservoir inflow,
STO is reservoir storage, and
t is time.

For daily streamflow computations, I is the sum of the streamflow contributions from all HRU's and the part of subsurface- and ground-water reservoirs above the channel reservoir. Reservoir inflow also can include the outflow of up to 3 upstream channel reservoirs. For storm-mode computations, the reservoir is treated as an individual stream segment in the channel-routing scheme. Reservoir inflow in this case is the upstream input of any combination of up to three channel, reservoir, and junction segments.

Two types of reservoir routing are available. One is linear storage routing which uses equation 51 and the relationship

$$O = RCS * STO \tag{52}$$

where

RCS is a routing parameter.

Substituting equation 52 into equation 51 and rearranging terms produces

$$\frac{d(STO)}{dt} = I - (RCS * STO) \tag{53}$$

Equation 53 is solved for STO, and this solution is substituted back in equation 51 producing:

$$0 = (1- \frac{1-e^{-(RCS*\Delta t)}}{RCS*\Delta t}) * I * \Delta t + (1-e^{-(RCS*\Delta t)}) * STO, \qquad (54)$$

where

Δt is the time interval, and
STO is the reservoir storage at the start of Δt.

STO is recomputed at the end of each Δt and used in the next iteration of equation 54.

The second type of reservoir routing available is modified-Puls routing (U.S. Soil Conservation Service, 1971). In this procedure, the O and I terms of equation 51 are the averages of O and I at the beginning and end of time interval Δt. Rearranging equation 51 using these average values gives

$$\frac{2STO_2}{\Delta t} + O_2 = (I_2 + I_1) + \frac{2STO_1}{\Delta t} - O_1 \qquad (55)$$

where the subscripts 1 and 2 specify start and end values for time interval Δt. All terms on the right-hand side of equation 55 are known at the beginning of a routing period. An interpolation procedure described by Dawdy, Schaake, and Alley (1978) is used to solve for O_2. A table of outflow versus $\frac{2STO}{\Delta t} + O$ values is computed by the model from a user-specified table of storage versus outflow. O_2 can be determined by entering the computed table with the value of $\frac{2STO_2}{\Delta t} + O_2$ computed from equation 55. Reservoir evaporation, leakage, bank storage, and inflow by direct precipitation are not accounted for by the model.

The type of routing for each reservoir is selected with varibles IRTYP for daily routing and TYPE for storm routing. IRTYP and TYPE must be the same value for a given reservoir. Reservoir routing for daily streamflow simulation is done in subroutine RESVRD. Reservoir routing for storm events is done in subroutine RESVRU.

Sediment

Sediment detachment and transport from overland flow-planes is computed only for storms. Computations are done in subroutine UNITD. The conservation of mass equation used to describe sediment detachment and transport is one presented by Hjelmfelt, Piest, and Saxon (1975) and is expressed as:

$$\frac{\partial(ch)}{\partial t} + \frac{\partial(cq)}{\partial x} = ER + EF \qquad (56)$$

where

c is sediment concentration, in kilograms per cubic foot (Kg/ft^3),
h is flow depth (ft),
q is flow rate per unit width ($ft^3/s/ft$),
ER is the rainfall detachment rate of sediment ($Kg/ft^2/s$),
EF is the overland flow detachment rate of sediment ($Kg/ft^2/s$),
x is distance down the flow plane (ft), and
t is time(s).

ER is computed using a relationship described by Smith (1976) which is expressed as:

$$ER = KR * PPT^2 * e^{-(HC*HBAR^2)} \tag{57}$$

where

PPT is the rainfall rate (ft/s),
HBAR is the mean depth of flow (ft), and
KR and HC are parameters.

EF is computed using a relationship described by Hjelmfelt, Piest, and Saxon (1975) which is expressed as

$$EF = KF * (TC-TR) \tag{58}$$

where

TC is the sediment transport capacity (Kg/s),
TR is the current sediment transport rate (Kg/s), and
KF is a parameter.

TC is computed by

$$TC = MM * HBAR^{EN} \tag{59}$$

where

MM and EN are parameters.

For a given time step, the rainfall detachment rate (ER) is added to the current transport rate (TR) and the sum is compared to the transport capacity (TC). If the sum is greater than the transport capacity, then the current transport rate is set equal to the transport capacity. If the sum is less than the transport capacity, then the flow detachment (EF) computations are made and added to the current transport rate.

Equations for overland flow are solved to obtain the appropriate values of q and h for use in equation 56. The time trace of sediment-transport rate per unit width of overland flow plane is written to a temporary disk file for use in channel-transport computations performed in subroutine ROUTE.

Sediment is transported as a conservative substance in the channel system; sediment detachment and deposition in the channel are not included. Channel transport is computed using the channel network described under the Channel Flow heading of this section. The continuity of mass equation used to describe sediment transport is expressed as:

$$\frac{\partial cA}{\partial t} + \frac{\partial cQ}{\partial x} = TLAT \tag{60}$$

where

A is the cross-sectional area of flow (ft^2),
Q is the flow rate (ft^3/s), and
TLAT is the lateral inflow rate of sediment to the channel (Kg/s/ft).

TLAT is obtained from the temporary disk file written in subroutine UNITD.

Snow

The snow components simulate the initiation, accumulation, and depletion of a snowpack on each HRU. A snowpack is maintained and modified both on a water-equivalent basis and as a dynamic-heat reservoir. A snowpack-water balance is computed daily, and an energy balance is computed twice each day for two 12-hour periods (designated day and night). Most snow computations are done in subroutine SNOBAL.

The conceptual model for the snowpack system and its energy relationships is one described by Obled and Rosse (1977). The snowpack is assumed to be a two-layered system. The surface layer consists of the upper 3 to 5 centimeters of the snowpack, and the lower layer is the remaining snowpack. Heat transfer between the surface layer and the lower layer occurs by conduction when the temperature of the surface layer (TS) is less than 0°C (Celsius). When TS equals 0°C, heat transfer occurs as conduction when the net energy balance at the air-snow interface is negative, and as mass transfer by surface melting when the net energy balance is positive. Heat transfer from precipitation occurs as a mass-transfer process. Conduction of heat across the soil-snow interface is assumed to be zero, since it is negligible compared to the energy exchange at the air-snow interface. The conceptual snowpack system and the components of the snowpack energy-balance equations are shown in figure 9.

Temperature of the surface layer for the daylight period is computed as the mean of the maximum and mean-daily air temperature for an HRU. For the night period, it is computed as the mean of the minimum and mean-daily air temperature for a HRU. Snow surface temperature equals 0°C when these means exceed 0°C. When the surface temperature is less than 0°C, the mean air temperature for that 12-hour period is assumed to integrate the effects of the radiation, latent heat, sensible heat, and diffusion processes expressed in the complete equation for the surface temperature. See Anderson (1968) for a complete discussion of the equation.

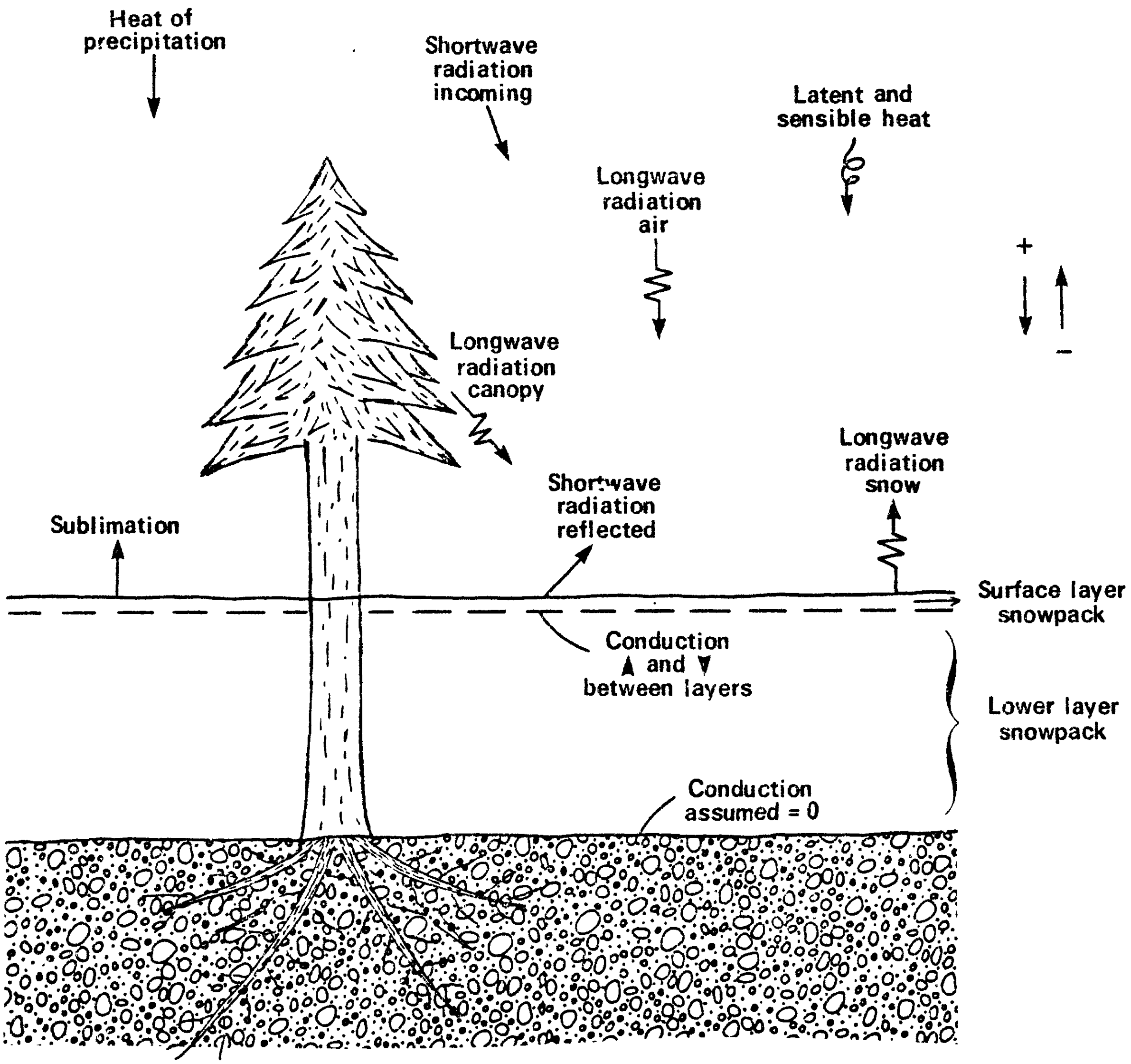


Figure 9.--Components of the snowpack energy-balance equations.

The conduction of heat between the snow surface and the lower layer of the snowpack (QCOND) is computed by:

$$QCOND = 2 * DEN * CS * \sqrt{\frac{KEFF}{(DEN*CS)} * \frac{\Delta t}{\Pi}} * (TS-PACT) \tag{61}$$

where

DEN is snowpack density (g/cm^3),
CS is the specific heat of ice in calories per gram per °C (cal/g/°C),
KEFF is the effective thermal conductivity of the snowpack (cal/s/cm/°C),
Δt is the time interval(s),
Π is pi, and
PACT is the temperature of the lower layer of the snowpack (°C).

KEFF is assumed equal to $0.0077 * DEN^2$ (Anderson, 1968). DEN is computed by:

$$DEN = PWEQV/DPT \tag{62}$$

where

PWEQV is snowpack water equivalent (in.); and
DPT is snowpack depth (in.).

DPT is computed using a finite difference scheme to solve the equation (Riley, Israelsen, and Eggleston, 1973):

$$\frac{d[DPT(t)]}{dt} + [SETCON*DPT(t)] = \frac{PSN}{DENI} + \frac{SETCON}{DENMX} * PSS \tag{63}$$

where

SETCON is a settlement-time constant,
PSN is net daily snowfall (inches water equivalent),
DENI is initial density of new-fallen snow,
DENMX is the assumed average maximum snowpack density,
t is time in days (t=0 at date of snowpack initiation), and
PSS is accumulated sum of PSN from time of snowpack initiation (in. water equivalent).

The temperature of the lower layer of the snowpack, PACT, is recomputed each 12-hour period by:

$$PACT = \frac{-PKDEF}{(PWEQV*1.27)} \tag{64}$$

where

PKDEF is the number of calories of heat required to bring the lower layer to an isothermal state at 0°C.

The constant 1.27 is the product of the specific heat of ice (0.5 calories/gram/°C) and the conversion factor for inches to centimeters (2.54).

When the temperature of the surface layer equals 0°C, an energy balance at the air-snow interface is computed. For each 12-hour period the energy balance CALN in calories is computed by:

$$CALN = SWN + LWN + CEN \tag{65}$$

where

SWN is net shortwave radiation (cal),
LWN is net longwave radiation (cal), and
CEN is an approximation of the convection-condensation energy terms (cal).

An additional energy term for the heat content of precipitation (CALPR) is computed in subroutine PRECIP and is added to the snowpack before CALN is computed.

Net shortwave radiation SWN is computed by:

$$SWN = SWRD * (1.0 - ALB) * TRNCF \tag{66}$$

where

SWRD is the computed shortwave solar radiation received (ly),
ALB is the albedo of the snowpack surface, and
TRNCF is the transmission coefficient for the vegetation canopy over the snowpack.

For albedo computations, the snowpack is considered to be in either an accumulation phase or a melt phase. A new snowpack begins in the accumulation phase and continues in this phase until the temperature of the lower layer is 0°C for 5 consecutive days or the Julian date exceeds a forcing date ISP2. At this point, the snowpack shifts to the melt phase. The date to begin checking for the start of the melt phase (ISP1) and the date to force the start of melt phase (ISP2) are user-specified. Snow surface albedo is computed as a function of the snowpack phase and the number of days since the last snowfall (SLST). A separate albedo-SLST relationship (U.S. Army, 1956) is used for each phase. The albedo of new snow decays daily according to the albedo-SLST relationship in effect at the time of the snowfall. The number of days since the last snowfall (SLST) is reset to zero when all-snow precipitation of at least 0.05 inches water equivalent during the accumulation phase, or 0.1 inches water equivalent during the melt phase, occurs. For precipitation that is a mixture of rain and snow, SLST is not reset if the percentage rain in the mixture (PRMX) is greater than or equal to user-defined value of RMXA for the accumulation phase or RMXM for the melt phase.

The transmission coefficient (TRNCF) is estimated using a winter forest-cover density (COVDNW)-TRNCF relationship for the vegetation canopy over the snowpack. Miller (1959) developed a COVDNW-TRNCF relationship for several species of pine, and Vézina and Péch (1964) developed similar relationship for both jack pine and balsam fir. Both pine relationships are shown in figure 10, with an average of the two curves that has given reasonable results in model applications (Leavesley and Striffler, 1978).

Longwave net radiation (LWN) has two components--the longwave exchange between the air and snowpack surface and the longwave exchange between the vegetation canopy and the snowpack surface. LWN is computed by:

$$\begin{aligned} LWN = {} & (1.0 - COVDNW) * [(EMIS*AIRN)-SNON] \\ & + COVDNW * (AIRN-SNON) \end{aligned} \tag{67}$$

where

COVDNW is the winter cover density of the predominant vegetation above the snowpack,
EMIS is the emissivity of air,
AIRN is the longwave energy emitted from a perfect black body at the average air temperature for the 12-hour period (cal), and
SNON is the longwave energy emitted from the snowpack surface at the surface temperature (TS) for the 12-hour period (cal).

AIRN and SNON are computed using the Stefan-Boltzmann law. The temperature used for AIRN is the average of the daily-minimum and daily-mean air temperatures for the night period, and the average of the daily-maximum and daily-mean air temperature for the daylight period. The snowpack and the vegetation canopy are assumed to radiate as perfect black bodies and, thus, have an emissivity of 1.0. Emissivity of the air (EMIS) is a function of its moisture content and ranges between 0.757 and 1.0 (U.S. Army, 1956). For days without precipitation, EMIS is user specified as EAIR. For days with precipitation, EMIS is computed separately for the day and night periods as a function of storm type and observed solar radiation. A period of months during which storms are predominantly convective in origin can be user-specified with the first month (MTSS) and last month (MTSE) parameters. Storms occurring outside these months are assumed to be frontal in origin with an associated EMIS of 1.0 for both day and night periods. During the convective storm period, days with precipitation are assumed to have an EMIS of 0.85 for the night period. For the associated day period, EMIS is assumed to vary between EAIR and 1.0 as a function of the ratio of observed to potential solar radiation received on a horizontal surface. If solar radiation is computed from temperature data, the day period EMIS is assumed to be 1.0.

The full equation for computing latent and sensible heat flux includes terms for temperature, vapor pressure, wind speed, and diffusivities of heat and vapor (U.S. Army, 1956). However, wind and vapor pressure or humidity data generally are not available. Therefore, the full equation is simplified

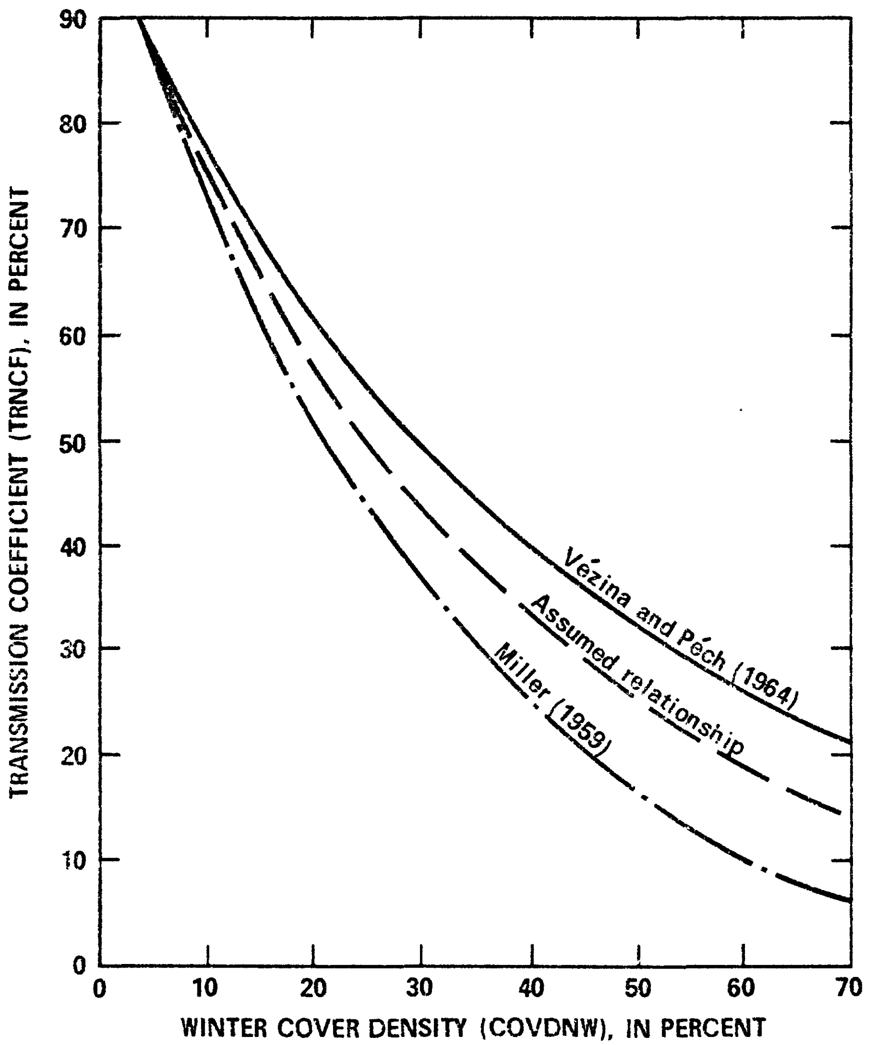


Figure 10.--Functional relationships between winter forest-cover density (COVDNW) and the transmission coefficient (TRNCF) of the forest canopy.

to a temperature index form to estimate latent and sensible heat terms. It is computed by:

$$CEN = CECN(MO) * TAVC \tag{68}$$

where

CEN is an estimate of latent and sensible heat,
CECN is a parameter for month MO, and
TAVC is the mean air temperature for the 12-hour period (°C).

To provide a measure of the influence of wind in the full equation for CEN, areas of forest cover are assumed to receive only one-half of CEN computed by equation 68. Vapor pressure influences are considered by computing CEN only on days of rainfall or when the ratio of observed to potential shortwave solar radiation is less than or equal to 0.33.

When the 12-hour energy balance (CALN) is negative, heat flow occurs by conduction only. The amount and direction of heat flow is computed from equation 61. When the 12-hour energy balance is positive, this energy is assumed to melt snow in the surface layer. Snowmelt transports heat into the snowpack by mass transfer. Snowmelt and subsequent thermal and water equivalent changes in the snowpack are computed in subroutine CALIN. Snowmelt (SMLT) is computed by:

$$SMLT = \frac{CALN}{203.2} \tag{69}$$

where

203.2 is the number of calories required to melt 1 inch of water-equivalent ice at 0°C.

If the temperature of the lower snowpack (PACT) is less than 0°C, then part or all of the snowmelt is refrozen, releasing 203.2 calories per inch of snowmelt refrozen. This heat is used to satisfy part or all of the heat deficit in the lower snowpack (PKDEF), and a new temperature is computed for the lower snowpack using equation 64. When the temperature of the lower snowpack reaches 0°C, any additional snowmelt is used to satisfy the free water-holding capacity (FWCAP) of the snowpack. FWCAP ranges from 2 to 5 percent of the water equivalent of the snowpack existing in the ice phase (U.S. Army, 1956; Leaf, 1966) and is user-specified. Once FWCAP is satisfied, the remaining snowmelt moves out of the snowpack and becomes available for infiltration and surface runoff.

When the temperature of the lower snowpack is 0°C and the surface temperature is less than 0°C, heat is conducted from the lower snowpack to the snowpack surface. The amount of heat conducted to the surface is computed using equation 61. The heat loss from the lower snowpack first causes any FREWT held in the pack to freeze. The calorie loss (CALND) required to freeze the FREWT is computed by:

$$CALND = FREWT * 203.2 \tag{70}$$

Any loss available after FREWT is frozen is accumulated as a heat deficit in variable PKDEF, and a new temperature for the lower snowpack is computed using equation 64. These computations are done in subroutine CALOSS.

Evaporation and sublimation from the snow surface are assumed to occur only when there is no transpiration occurring from vegetation above the snowpack. The loss from the snow surface (SNEV) is computed daily as a percentage of the potential evapotranspiration (PET) value computed in subroutine PETS. The equation used is:

$$\begin{aligned} SNEV &= (CTW*PET) - XINLOS \qquad (CTW*PET) > XINLOS \\ SNEV &= 0 \qquad \text{otherwise;} \end{aligned} \tag{71}$$

where

CTW is a loss coefficient, and
XINLOS is the evaporation and sublimation loss from interception computed in subroutine INTLOS (in.).

Optimization

This component controls the automatic adjustment of a specified set of parameters (NV in number) to obtain better agreement between observed and predicted runoff, a process known as optimization. The user selects the parameters to be adjusted by specifying the parameter numbers in an array LOP(J), J=1,2,...,NV. The parameters and their corresponding numbers are given in table 3. A maximum of 20 parameters may be adjusted during an optimization run, or NV≦20. The capability to optimize 20 parameters is not provided to encourage the optimization of a large number of parameters. Rather, it is provided to permit a sensitivity analysis of many parameters. This capability is discussed in the Sensitivity Analysis section of this report.

The agreement between observed and predicted runoff is measured by an objective function. The optimization attempts to adjust the parameters to minimize the value of the objective function. The user specifies whether the objective function is to be computed using daily runoff volumes (IOPT=1 or 2), storm volumes (IOPT=3), storm peaks (IOPT=4), or storm volumes and peaks simultaneously (IOPT=5 ; see section Optimization Using Peaks and Volumes Simultaneously). If daily volumes are used, setting IOPT=2 allows the correlations between the daily runoff prediction errors to be modeled as a stationary time series (see section Correlated Daily Errors); if IOPT=1, no correlation is assumed. When IOPT is either 1 or 2, the user must specify the months within each year (month MFS through month MFN, inclusive) to be included in computation of the daily objective functions. When IOPT is 3, 4, or 5, the model must be run in the storm mode, and the user must specify the storms (TESTNO(J), J=1,2,...,NST, where NST is the number of storms) to be included in computation of the objective function.

The objective function when IOPT is 1, 3, or 4 is computed in one of two ways; it is the sum either of the squared differences (IOBF=2) or of the absolute differences (IOBF=1) between the observed and predicted runoff values. Logarithms (natural) of the runoff values can be used for computing

Table 3.--*Model parameters and the associated values of the array, LOP*

Parameter identification No. (LOP)	Number of parameter elements	Parameter	Parameter identification No. (LOP)	Number of parameter elements	Parameter
1	NRU	COVDNS	50	NRES	RCF
2	NRU	COVDNW	51	NRES	RCP
3	NRU	TRNCF	52	NRES	RSEP
4	NRU	SNST	53	NRES	RESMX
5	NRU	CTX	54	NRES	REXP
6	NRU	TXAJ	60	NGW	RCB
7	NRU	TNAJ	61	NGW	GSNK
8	NRU	SMAX	70	12	TLX
9	NRU	REMX	71	12	TLN
10	NRU	SRX	72	12	RDM
11	NRU	SCX	73	12	RDC
12	NRU	SCN	74	12	EVC
13	NRU	RNSTS	75	12	PAT
14	NRU	RNSTW	76	12	CECN
15	NRU	KSAT	80	NOFSEG	ALPHA
16	NRU	PSP	81	NOFSEG	RM
17	NRU	DRN	85	NCRSEG	ALPHAC
18	NRU	RGF	86	NCRSEG	RMC
19	NRU	NOT USED	90	12	CTS
20	NRU	D50	91	1	NOT USED
21	NRU	KR	92	1	BST
			93	1	SETCON
22	NRU	HC	94	1	PARS
23	NRU	KF	95	1	PARW
24	NRU	KM	96	1	CSEL
25	NRU	EN	97	1	RMXA
26	NRU	SC1	98	1	RMXM
27	NRU	SEP	99	1	CTW
28	NRU	DRCOR	100	1	EAIR
29	NRU	DSCOR	101	1	FWCAP
30	NRU	TST	102	1	DENI
			103	1	DENMX

either objective function if ITRANS is set to 1; otherwise, ITRANS is 0. When IOPT is 1 or 2 and ITRANS is 1, one is added to the daily runoff values before logarithms are taken to avoid taking the logarithm of zero. When IOPT is 2 or 5, a special form of the objective function is used, as described in following sections.

There are two algorithms available for performing an optimization: the Rosenbrock and the Gauss-Newton routines. To use the latter, the value of IOPT as described above is made negative; if IOPT is positive, the Rosenbrock routine is used.

The user has the option of running the model for a period of time before the optimization process is begun. When this is done, the beginning and ending dates for the initialization period (BYRIN/BMOIN/BDYIN and EYRIN/EMOIN/EDYIN) and for the optimization period (BYROP/BMOOP/BDYOP and EYROP/EMOOP/EDYOP) must be specified. If no initialization period is desired, BYRIN is set to 0. The optimization period always must begin immediately after the initialization period ends. Several optimizations may be performed simply by placing the data for each in succession at the proper point in the data deck (see input data instructions).

Rosenbrock Optimization

The Rosenbrock optimization technique is described in detail in a paper by Rosenbrock (1960) and is discussed in a hydrologic context by Dawdy and O'Donnell (1965) and Dawdy, Lichty, and Bergmann (1972).

The parameter adjustment proceeds by stages. During the first stage, each parameter represents one axis in an orthogonal set of NV search directions. Adjustments are made in these search directions until arbitrary end-of-stage criteria are satisfied. Then another stage is begun by computing a new set of NV orthogonal search directions based on the experience of parameter movement during the preceding stage. This process is repeated and continues until convergence has occurred or until a specified number of adjustments (NV x NTRY, where NTRY is the number of adjustments per parameter) has been tried. 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 (HU) and lower (GU) bounds for each parameter. The model is run, and the objective function (OBF) is calculated and stored as a reference value. A step of user-specified length (a proportion P of the parameter magnitude) is attempted in the first search direction, and the model is run again with the adjusted parameter value. 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 for each parameter is multiplied by 3 for the next adjustment along this axis. If a failure results, the step is not allowed and the step size is multiplied by -1/2. That is, the next adjustment along this search axis will be in the opposite direction and only one-half the magnitude of the current adjustment. 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 trial.

Gauss-Newton Optimization

The Gauss-Newton optimization algorithm essentially is identical to the linearization method described by Draper and Smith (1966, p. 267-270) and by Beck and Arnold (1977, p. 340-349), and in addition incorporates the Box-Kanemasu interpolation modification (see Beck and Arnold, 1977, p. 362-368).

Let $\hat{\beta}^{(k)}$ be the set of NV parameter values obtained at the k-th iteration of the routine; the (k+1)th set is then computed by

$$\hat{\beta}^{(k+1)} = \hat{\beta}^{(k)} + h^{(k)} \, c^{(k)} \tag{72}$$

where

$$c^{(k)} = Z^{-1}A^{T}(O-P) \ .$$

The NV x 1 vector $c^{(k)}$ is the parameter correction vector, and $h^{(k)}$ is a scalar multiplier that is equal to one in the ordinary Gauss-Newton algorithm. The matrix $A=(a_{ij})$ is the sensitivity matrix, and $Z=(z_{ij})=A^{T}A$ is the information matrix (described in the section Sensitivity Analysis Components), both evaluated at $\hat{\beta}^{(k)}$. The superscript T denotes transpose and the superscript -1 denotes inverse. The vectors O and P are observed and predicted runoff, the latter computed with parameters $\hat{\beta}^{(k)}$.

The correction vector at each iteration is found by a call to subroutine SENST, which performs a partial sensitivity analysis to obtain the magnitude and direction of $c^{(k)}$. The multiplier $h^{(k)}$ initially is 1 for each iteration. If the resulting parameters $\hat{\beta}^{(k+1)}$ are outside the constraints imposed by the user, $h^{(k)}$ then is halved repeatedly until all values lie within the constraints. Next, if the objective function obtained with parameters $\hat{\beta}^{(k+1)}$ is not smaller than that with $\hat{\beta}^{(k)}$, the scalar $h^{(k)}$ again is halved until the objective function shows some improvement. At this point, the Box-Kanemasu interpolation scheme is used to obtain a final value for $h^{(k)}$.

As in the Rosenbrock optimization, the initial parameter values $\hat{\beta}^{(0)}$ are those assigned by the user in the input data. Iterations continue until the elements of $\hat{\beta}^{(k+1)}$ differ from those in $\hat{\beta}^{(k)}$ by a small percentage, or until the number of iterations exceeds NTRY, whichever comes first.

Distributed Parameters

Distributed parameters are defined to be those that are a function of hydrologic response unit, of subsurface reservoir, of ground-water reservoir, of overland flow-plane or channel segment, or of time. Optimization of these parameters presents a special problem because the number of elements over which a parameter is distributed typically is large, and because the observed runoff values used in an optimization are the responses from all the elements lumped together. These two factors make changes in predicted runoff because of changes in any particular element difficult to detect; that is, sensitivities to changes in the individual elements are apt to be small.

The model provides two options for dealing with these problems, both of which actually are just ways of constraining the optimization. Consider, for example, adjustment of the parameter COVDNW. There actually are NRU hydrologic response units (HRU's) into which the basin has been divided; thus, there are NRU values of this parameter. If there are a large number of HRU's, it probably is not feasible to adjust the NRU values of COVDNW independently. Thus, the user is provided with the option of constraining the optimization so the NRU values are all adjusted in the same direction. Initial values of COVDNW for each of the NRU HRU's are user-specified. The user then may elect to adjust these NRU values, or any subset of these values, (1) by the same <u>magnitude</u> or (2) by the same <u>percentage</u> of the initial value. A variable ILOPL must be specified for each parameter to be optimized. If the user wishes to adjust a parameter using option (1) above, ILOPL is set to 0; if option (2) is to be used, ILOPL=1.

Also, variables NVAR and NDVR must be specified for each parameter. The number of values of a distributed parameter that are to be adjusted together is NVAR. For the parameter COVDNW, for example, NVAR would be NRU if it is desired to adjust all COVDNW values together; or, NVAR could be less than NRU if it is desired to adjust only a subset of the COVDNW values. The numbers of the elements on which a distributed parameter is to be adjusted are specified by the values NDVR(.,J), J=1,2,..., NVAR. For example, if COVDNW is defined on a watershed with five HRU's (NRU=5), and it is desired to optimize the values only on even-numbered units, leaving the value on odd-numbered HRU's unchanged, then NVAR=2, NDVR(.,1)=2, NDVR(.,2)=4.

The program also allows one to adjust different subsets of distributed parameter values independently. In the example in the preceding paragraph, if one wished to adjust COVDNW on even-numbered HRU's and COVDNW on odd-numbered HRU's independently, the NVAR and NDVR for the former would be as given above, and for the latter, NVAR=3 and NDVR(.,1)=1, NDVR(.,2)=3, NDVR(.,3)=5. As a special case of this, the values on all HRU's may be adjusted independently.

Optimization instructions for parameters distributed over subsurface reservoir, ground-water reservoir, flow segment, or time are specified in an analogous manner. The variable NVAR must always be less than or equal to the maximum number of parameter elements (table 3) for a given distributed parameter configuration. For parameters that are not distributed, NVAR is set to 1.

When adjustments according to option (1) are to be performed, the program first calculates an average parameter value (XXAVE). For example, XXAVE for COVDNW is calculated by:

$$\text{XXAVE} = \Sigma_{J=1}^{NRU} \text{COVDNW(J)/NRU}$$

if all NRU values are to be adjusted. Adjustments are then made on XXAVE; deviations from the average, XXDEV, are kept constant. Thus, although there are a total of NRU parameters, there are also NRU-1 linear constraints, resulting in only one parameter being adjusted.

On the other hand, adjustments of the same percentage [option (2)] are made by first transforming the parameters, and then using the same procedure involving XXAVE and XXDEV on the transformed values. The transformed parameters are calculated by taking the natural logarithm of the original value plus 20. Due to the logarithmic transformation, linear changes in the transformed parameters are equivalent to multiplicative changes in the original parameters. The constant 20 is added to keep the transformed values positive.

Correlated Daily Errors

When performing an optimization or sensitivity analysis using daily runoff predictions, the user may elect (by setting IOPT=±2 or ISEN=2) to include an analysis of the error correlations. It is recommended that this option be used whenever a daily optimization is performed; parameter estimates so obtained are likely to be more physically reasonable, and prediction errors in noncalibration periods usually will be smaller. Correlated errors are discussed by Beck and Arnold (1977) and, in a rainfall-runoff modeling context, by Sorooshian and Dracup (1980).

The error structure is assumed to be of the form

$$O_i = P_i + e_i,$$

where

O_i and P_i are the observed and predicted runoff, and

e_i is the prediction error, for the i-th day.

In the usual least-squares optimization, the objective function $\Sigma(O_i-P_i)^2$ is minimized. This is equivalent to obtaining maximum likelihood parameter estimates with errors e_i that have a normal distribution and are uncorrelated with each other. In a daily optimization, the assumption of no correlation among the errors e_i is clearly violated; the correlation between errors 1 day apart (lag-one correlation) typically will be greater than 0.9, and the correlation between errors K days apart (lag-K correlation) decreases rather slowly as a function of K. This fact should be incorporated in doing an optimization.

The correlation of the errors is modeled by fitting an autoregressive-moving average (ARMA) time-series structure (see Box and Jenkins, 1976); that is, it is assumed that the errors e_i obey a model of the form

$$\begin{aligned} & e_i - \phi_1 e_{i-1} - \ldots - \phi_p e_{i-p} \\ & = \eta_i - \Theta_1 \eta_{i-1} - \ldots - \Theta_q \eta_{i-q}. \end{aligned} \tag{74}$$

This model is said to be a mixed ARMA model of order (p,q). The $\{\eta_i\}$ sequence is a zero-mean white noise process, and ϕ_k, Θ_k are parameters that are estimated by the optimization routine along with the physical model parameters. The user must specify the orders p and q.

As an example, when p=1 and q=0, the parameters are found by minimizing the following objective function:

$$U = \Sigma\, [O_i - \phi_1 O_{i-1} - (P_i - \phi_1 P_{i-1})]^2 \tag{75}$$

The predicted runoffs P_i and P_{i-1} here are a function of the physical parameters. When $\phi_1 = 0$, this reduces to the ordinary least-squares objective function. For more general p and q, see Beck and Arnold (1977).

Constraints (Prior Information)

For both the Rosenbrock and Gauss-Newton optimization schemes, lower and upper bounds outside which the parameters cannot be adjusted must be specified. It should be noted that if the minimum of the objective function for this constrained optimization is located at one of the boundaries, the Gauss-Newton routine usually will not perform satisfactorily in finding this minimum; it is recommended that the Rosenbrock algorithm be used in this case. Also, an optimization may be made essentially unconstrained if the specific bounds are made sufficiently wide.

Lower and upper bounds on the parameters are equivalent to what is known as a uniform (or rectangular) prior-probability distribution on the parameters. (See Beck and Arnold, 1977.) That is, it is known before the optimization that the parameters fall somewhere within the range given, but nothing is known regarding where within this range of values the true parameters lie.

As an alternative to the uniform prior-probability distribution the user may specify a prior distribution that is normal by setting IPRIOR=1. Thus, prior knowledge about the true parameter values is assumed to be better represented by a bell-shaped normal distribution than by a rectangular-shaped distribution. The most likely true value of the parameter (that is, the mean of the prior distribution) is that specified in the data input, with the likelihood of the value decreasing as distance from the mean increases. The tightness of the constraint with a normal prior is defined by user specification of the variance (standard deviation squared) of the distribution. As a rough guide to determining the standard deviation, it should be recalled that about 95 percent of the area under a normal curve lies within two standard deviations of the mean.

The normal distribution alternative is useful for another reason. One may incorporate knowledge not only about the likely values of the parameters individually, but also about how parameters are presumed to be related to each other. This is done by specifying the correlations between each pair of parameters. (The parameters taken together are taken to have a multivariate normal prior.) A correlation of ±1 between a pair of parameters would signify a direct linear relationship between the two; in practice, however, all correlations must be given as less than one. It is recalled that the user is given the option of specifying linear constraints among values of a distributed parameter by proceeding as described in the section Distributed Parameters. The use of the normal prior information option, on the other hand, would allow one to place somewhat weaker constraints on distributed parameters, if desired.

The objective function for normal prior information is:

$$U = [\Sigma(O_i - P_i)^2] \exp [(\beta-\mu)^T V^{-1} (\beta-\mu)/n] \tag{76}$$

where

β is the vector of parameters being optimized, and
μ and V are the user-supplied mean and covariance of the prior distribution.

Note that, as the constraints become looser, the elements of V become larger and U approaches an ordinary least-squares objective function. As mentioned before, the elements of μ are the user-specified parameter values in the data input. The elements of V are given as input (array VB) in Card Group 7. One row of V is on each card. For example, if for two parameters (NV=2)

$$V = \begin{bmatrix} 1.0 & 1.5 \\ 1.5 & 3.0 \end{bmatrix},$$

the first card would have values (1.0, 1.5) and the second card would have (1.5, 3.0). The diagonal elements 1.0 and 3.0 are the parameter variances and 1.5 is the covariance between the two parameters. The correlation is:

$$\frac{1.5}{[(1.0)(3.0)]^{\frac{1}{2}}} = 0.87.$$

Optimization Using Volumes and Peaks Simultaneously

Setting IOPT=±5 allows optimization using flood peaks and volumes simultaneously. The estimation procedure is maximum likelihood, under the assumption that volume errors and peak errors have a bivariate normal distribution (see, for example, Hiemstra and Francis, 1981) with zero means and covariance matrix that is estimated along with the physical parameters. The objective function that is minimized is:

$$U = \Sigma E_v^2 \, \Sigma_p^2 - (\Sigma \, E_v \, E_p)^2 \tag{77}$$

where

E_v is observed minus predicted volume, and
E_p is observed minus predicted peak, and the summation is over the n storms.

The covariance between peak errors and volume errors is estimated by $n^{-1} \, \Sigma E_v E_p$, and the variances are $n^{-1} \, \Sigma E_v^2$ and $n^{-1} \, \Sigma E_p^2$, so U may be expressed as:

$$U = \Sigma E_v^2 \, \Sigma E_p^2 \, (1 - r^2) \, , \tag{78}$$

letting r be the sample correlation between peak and volume errors.

Use of this option permits optimization on parameters that influence both volumes and peaks simultaneously. Individual parameters may influence both, and there may be parameters that influence one but not the other. The form of the objective function automatically sorts out sensitivity of both model responses with respect to changes in each parameter, giving each parameter an appropriate influence on the value of U. For example, if one were to use this option with parameters that had no influence on volumes, the optimization would be equivalent to a least-squares fit using peaks.

Statistical Analysis

Daily Error Summaries

Several error summaries are available to aid the user in comparing observed and predicted runoff. At the end of each month, a table summarizing the errors for that month is printed. In the first row of that table, four objective function values are given:

$$\Sigma\left|e\right|, \; \Sigma\left|e_L\right|, \; \Sigma e^2, \text{ and } \Sigma e_L^2 \; ,$$

where

$e = O - P$,
$e_L = \ln(O+1) - \ln(P+1)$,
O = observed runoff, and
P = predicted runoff.

The quantity e is the error, or residual, associated with the daily prediction, and e_L is the error in log-transformed daily prediction. The cumulative sums of these values for month MFS through month MFN (see Optimization Section) are given in the next row of the table. Then, mean values obtained by dividing the objective function by the number of days in the month are printed. Finally, these means expressed as a percentage of the mean observed runoff for the month are given for the untransformed runoff. For the Σe^2 objective function, the percentage is obtained by first taking the square root of the mean objective function (yielding a "standard error"), then dividing by the mean observed runoff.

By setting ISTAT equal to 1 on the "PRINT-OP" input card (card 7, Card Group 1), the user may obtain a statistical summary for the entire period of record. First, a table showing monthly total and mean runoff, both observed and predicted, is given. The number of positive and negative residuals and the total number of positive and negative runs in the residuals also are shown month by month. A positive run is defined to be a sequence of positive residuals, preceded and followed by a negative residual, and a negative run is defined analogously. These quantities also are shown for each year and for the total period.

In addition, setting ISTAT=1 results in the following statistics being computed for both the total period and the MFS-to-MFN season:

coefficient of determination $=1 - \Sigma e^2/\Sigma e_M{}^2$;

coefficient of persistence $=(r-m)/s$;

coefficient of gain from daily averages $=1 - \Sigma e^2/\Sigma e_D{}^2$;

coefficient of correlation between predicted and residual runoff $=\Sigma(e_L-\bar{e}_L)(P_L-\bar{P}_L)/[\Sigma(e_L-\bar{e}_L)^2\ \Sigma(P_L-\bar{P}_L)^2]^{\frac{1}{2}}$;

where

$e=O-P$,

$e_M=O-\bar{O}$,

$\bar{O}$=mean observed runoff for full period of simulation,

r=total number of runs,

m=mean number of runs, and

s=standard deviation of number of runs under the hypothesis that the order of signs of the residuals is random (Weeks and Hebbert, 1980),

$e_D=O - \bar{O}_D$,

$\bar{O}_D$=mean value for that day of the year,

$e_L = \ln(O+1) - \ln(P+1)$,

$\bar{e}_L$=mean of e_L's,

$P_L = \ln(P+1)$,

$\bar{P}_L$=mean of P_L's.

Finally, when ISTAT=1, a table is given showing sums Σe, Σe_L, $\Sigma|e|$, $\Sigma|e_L|$, Σe^2, Σe_L^2, means of these values, and these means expressed as a percent of mean observed runoff. This table is given for both total period and MFS-MFN season.

The coefficient of determination is equivalent to R^2 for a regression analysis. It is always between 0 and 1 and measures the fraction of the total runoff variation (Σe_M^2) explained by using the model.

Ideally, one wants to obtain mean errors near zero with mean absolute errors and mean squared errors as small as possible. The mean error, together with the table giving the number of positive and negative residuals, tells the user whether the model seems to be consistently overpredicting or underpredicting. The correlation coefficient between residual and predicted values tells whether there is any consistent association between these two variables; a positive correlation signifies that e=O-P is large when P is large, or that the model generally is underpredicting for large events and overpredicting for small events. This problem may result from model error, input error, parameter error, or a combination of these; the user must decide whether it is desirable or possible to reduce parameter error by an optimization (parameter adjustment) procedure.

The coefficient of persistence measures the serial correlation, or persistence, in the residuals. A highly negative value indicates a large degree of persistence, or tendency for positive errors to follow positive errors and negative errors to follow negative errors. The coefficient of persistence is standardized so that under the hypothesis that the order of signs of residuals is random, it is distributed for large samples as a standard normal random variable. The significance of the computed coefficient can be determined from a standard normal table. For example, the probability that a standard normal random variable is -1.65 or less is 0.05. Therefore, if the computed coefficient is less than -1.65, it is unlikely that the order of the signs is random. Thus, there is significant persistence.

The coefficient of gain from daily averages compares model predictions to predictions based solely on means for each day of the year. For example, the daily average prediction for July 1, given 4 years of record, would be the mean of the four observations for that date. The coefficient is between 0 and 1; a value closer to 1 indicates better predictions using the model over the daily average predictions.

Storm Error Summaries

When the model is run with storm data, a table showing $\Sigma|e|$, $\Sigma|e_L|$, Σe^2, Σe_L^2 is given, where $e=O-P$ and $e_L=\ln O - \ln P$ are now computed with storm volumes (in inches). If routing is performed, these error measures also are given for storm peaks. The mean values of these objective functions, and these means as a percentage of the mean observed values, also are printed.

Sensitivity Analysis

These subroutines perform a sensitivity analysis on the parameters of the model. The results of this analysis allow the user to determine the extent to which uncertainty in the parameters results in uncertainty in the predicted runoff, and to assess the magnitude of parameter errors and parameter intercorrelations when an optimization is performed. Complete discussions of interpretation of the output of the sensitivity analysis are given by Mein and Brown (1978) and Beck and Arnold (1977).

The user selects the parameters to be analyzed by specification of the parameter numbers in array LOP(J), J=1,..., NV. The parameters and the corresponding parameter numbers are given in table 3. Variables NVAR and NDVR must be specified for a sensitivity analysis; they are interpreted exactly as those variables in an optimization and are discussed in the Optimization Components section. A sensitivity analysis of daily runoff parameters normally is run separately from a sensitivity analysis of storm runoff parameters.

Let n denote the number of days (events) under consideration, and let P_i denote the predicted runoff volume for the ith day (event) $1 \leq i \leq n$. First, a matrix with n rows and p columns (where p is the number of parameters), known as the sensitivity matrix, is computed. The element in the ith row and jth column of this matrix is $a_{ij}=\partial P_i/\partial \beta_j|_{\hat{\beta}}$. This notation indicates that the partial derivative is evaluated at $\hat{\beta}$, where $\hat{\beta}$ is the vector of parameters values used for the model run. The jth component of the vector $\hat{\beta}$ is denoted by $\hat{\beta}_j$.

These partial derivatives are approximated by running the model first with parameter value $\hat{\beta}_j$, and then again with parameter $\hat{\beta}_j + \Delta\hat{\beta}_j$, where $\Delta\hat{\beta}_j$ is a small fraction of $\hat{\beta}_j$. The quantity $\partial P_i/\partial\beta_j|_{\hat{\beta}}$ is approximated by the change in P_i divided by $\Delta\hat{\beta}_j$. The increment $\Delta\hat{\beta}_j$ is taken to be a user-specified quantity (PINC) multiplied by $\hat{\beta}_j$.

The quantities a_{ij} are known as "absolute" sensitivities (McCuen, 1973). Comparison of these values for different parameters is difficult because the magnitude is highly dependent on the magnitude of the parameter value itself. Therefore, dimensionless "relative" sensitivities a'_{ij} are displayed, where $a'_{ij}=a_{ij}\cdot(\hat{\beta}_j/P_i)$. For example, if $a'_{ij}=1.40$, a 10-percent change in the parameter value would produce a 14-percent change in predicted runoff.

Next, a matrix Z with p rows and p columns, known as the (scaled) information matrix, is computed. This matrix is the transpose of the sensitivity matrix times the sensitivity matrix itself, so the element in the ith row and jth column is $z_{ij}=\Sigma_k a_{ki}a_{kj}$. The extent to which parameter uncertainty is, on the average, propagated to uncertainty in runoff prediction is examined by evaluating $d_i=\bar{z}_{ii}\ (\Delta\hat{\beta}_i)^2$ for $\Delta\hat{\beta}_i=k\hat{\beta}_i$, k=0.05, 0.10, 0.20, and 0.50, where $\bar{z}_{ii}=\Sigma z_{ii}/n$ is an average squared sensitivity. The results are displayed as an error propagation table which gives d_i for the four values of k and for each of the parameters under consideration. For example, in the column labeled 10 percent (k=0.10), a value of 150. would mean that a 10-percent error in the given parameter results in an increase of 150. in the mean squared error of prediction for the model. Units of the values in the table depend on the mode in which the model is being run (daily or unit) and on whether runoff is being logarithmically transformed (as indicated by the switch ITRANS). For example, in a daily mode with no logarithmic transform, the units of the value 150. above would be cubic feet per second squared (cfs^2). In any case, the values in the table should be compared to the mean squared error of prediction (a residual variance) σ^2 as defined below.

With correlated daily errors (ISEN=2), the matrix Z is computed as the transpose of the sensitivity matrix times the inverse of the estimated error correlation matrix times the sensitivity matrix. With normal prior information on the parameters (IPRIOR=1), Z is altered by adding the inverse of the user-specified parameter covariance matrix divided by σ^2, defined below. (See Beck and Arnold, 1977, section 6.6.)

When the parameter estimates are obtained by optimization, the covariance matrix of these estimates may be approximated using asymptotic nonlinear regression theory. When a least squares optimization is performed (IOBF=2), this covariance matrix is the product of the inverse of Z and the scalar $\hat{\sigma}^2$, the residual variance. The residual variance is taken to be the squared difference objective function divided by n-p; this variance and its square root (that is, the residual standard error, $\hat{\sigma}$) are printed. For the minimum absolute deviation estimates (IOBF=1) the covariance matrix is obtained as when IOBF=2 except $\hat{\sigma}^2$ is replaced by the scalar w^2, the estimated asymptotic variance of the sample median from samples having the given error distribution (see Bassett and Koenker, 1978). The variance w^2 is computed by

$$w^2=(2f)^{-1}$$

where f, an estimate of the error density at the median, is given by $[2(e_{.75} - e_{.25})]^{-1}$, e_q being the qth percentile of the sample of errors (see Sen, 1968). The parameter standard errors s_j and correlation matrix (c_{ij}) are then readily obtainable from the resulting parameter covariance matrix, and are printed.

If the parameter standard error obtained from the covariance matrix is referred to as a "joint" standard error, an "individual" standard error for $\hat{\beta}_j$ is computed by $s_j=(z_{jj})^{-\frac{1}{2}}\, s$, where $s=\hat{\sigma}$ if IOBF=2 and s=w if IOBF=1. (This actually is the standard error of $\hat{\beta}_j$ conditioned on given values of the other parameter estimates, or the standard error that would be obtained if $\hat{\beta}_j$ alone were being optimized.)

The parameter standard errors give an idea of the uncertainty in the optimized parameter estimates. Results of an optimization may conveniently be given in the form "parameter estimate ± standard error." The parameter correlations give an indication of parameter interaction. A positive correlation between two parameters means that an increase in one parameter has the same effect on predicted runoff as an increase in the other parameter. A negative correlation means they have opposite effects on predicted runoff.

Finally a matrix known as the "HAT" matrix is computed as a product of three matrices: sensitivity matrix, inverse of the information matrix, and the transpose of the sensitivity matrix. The diagonal elements (h_i) of this matrix are printed. These values, which must all lie between 0 and 1, give an indication of the relative influence of a day or a storm on an optimization. Values closer to 1 signify greater influence. A complete discussion of the interpretation of the HAT matrix is given by Hoaglin and Welsch (1978).

The variables referred to above, and the corresponding computer program names, are summarized in table 4.

Table 4.--*Major variables used in sensitivity-analysis components*

Variable	Computer variable	Description
P_i		ith predicted runoff volume
$Ø_i$		ith observed runoff volume
n	NØBF	number of variables in objective function
P	NV	number of parameters
$U=\Sigma(Ø_i-P_i)^2$	ØBF	objective function
$\hat{\sigma}^2=\frac{U}{n-p}$	RESVAR	residual variance
$\hat{\sigma}$	RESTD	residual standard error
$\hat{\beta}_j$	ZØPT(J)	jth parameter estimate
$a_{ij}=\left.\frac{\partial P_i}{\partial \beta_j}\right\rvert_{\hat{\beta}}$	ASENS(I,J)	(i,j)th element of sensitivity matrix
$z_{ij} = \left.\sum_k \frac{\partial P_k}{\partial \beta_{ij}} \frac{\partial P_k}{\partial \beta_j}\right\rvert_{\hat{\beta}}$	ZINFC(I,J)	(i,j)th element of information matrix
s_j	PARSTD(J)	estimated ("joint") standard error of jth parameter
s'_j	PARSTD(J)	estimated ("individual") standard error of jth parameter
c_{ij}	ZINV(I,J)	estimated correlation between ith and jth parameters
h_i	PDENT(I)	ith diagonal element of "HAT" matrix

Data Handling

The data-handling components input basin characteristics, meteorologic, and hydrologic data, conduct general housekeeping functions on these data, and generate model output in tabular and graphic forms. Subroutines DATIN, INVIN, DVRETR, and UVRET provide data input capabilities. Subroutines SUMALL, PRTHYD, DVPLOT, and UVPLOT provide simulation output capabilities. More detailed descriptions of input data specifications and output options are described in sections Control and System Input Specifications, and System Output.

LINKAGE OF SYSTEM LIBRARY COMPONENTS

The PRMS system library subroutine MAIN controls the sequencing and timing of model operations. Control is accomplished through a logical sequence of subroutine CALL statements to perform data initialization and input, hydrologic-component simulation, and output summarization. Knowledge of the structure and operation of MAIN, and of the library components called, is required to fully understand model logic and to make model modifications.

The following is a brief discussion of MAIN, the subroutine calling sequence, and data links established between library subroutines. A flow chart of MAIN is shown in figure 11. The version of MAIN discussed here is the one used in the PRMS catalog-procedure, PRMODEL. PRMODEL uses all the subroutines in the PRMS system library; table 5 is an annotated list of these subroutines. The names in parentheses in the following discussion are the subroutines called to perform the functions described.

The first functions performed in MAIN are the input of all initialization and basin descriptive data (DATIN, INVIN). In INVIN a number of disk data files are initialized or established for use in storage and transfer of data for stormflow computations. These files are listed in table 6. Next a check is made to determine if the current run is an optimization (ROSOPT), sensitivity analysis (SENST), or straight simulation. After all data, parameter, and variable initialization is completed, the timing structure of the model is initialized. The timing structure is a set of 3 nested DO-loops. The outer loop is incremented on water years. Within this loop, 1 water year of daily data for all meteorologic and hydrologic driving variables is input to the model (DVRETR). These daily data are stored in core. In addition, all water year counters and variables are initialized (TIMEY). The next loop is incremented on months. When a full year of data is available, the period runs from October to September. In this loop, all monthly counters and variables are initialized (TIMEY). The inner loop is incremented on days. It is within the day loop that all hydrologic computations are made.

The first function within the day loop is to increment the counters for the Julian date JLDY, water-year date JWDY, and solar-year date JSOL. The meteorologic data for this date are then obtained. Temperature and solar-radiation data are adjusted for application on each HRU, based on differences in elevation, slope, and aspect between the climate station and each HRU (TEMP, SOLRAD). The adjusted data then are used to compute a potential evapotranspiration value for each HRU (PETS).

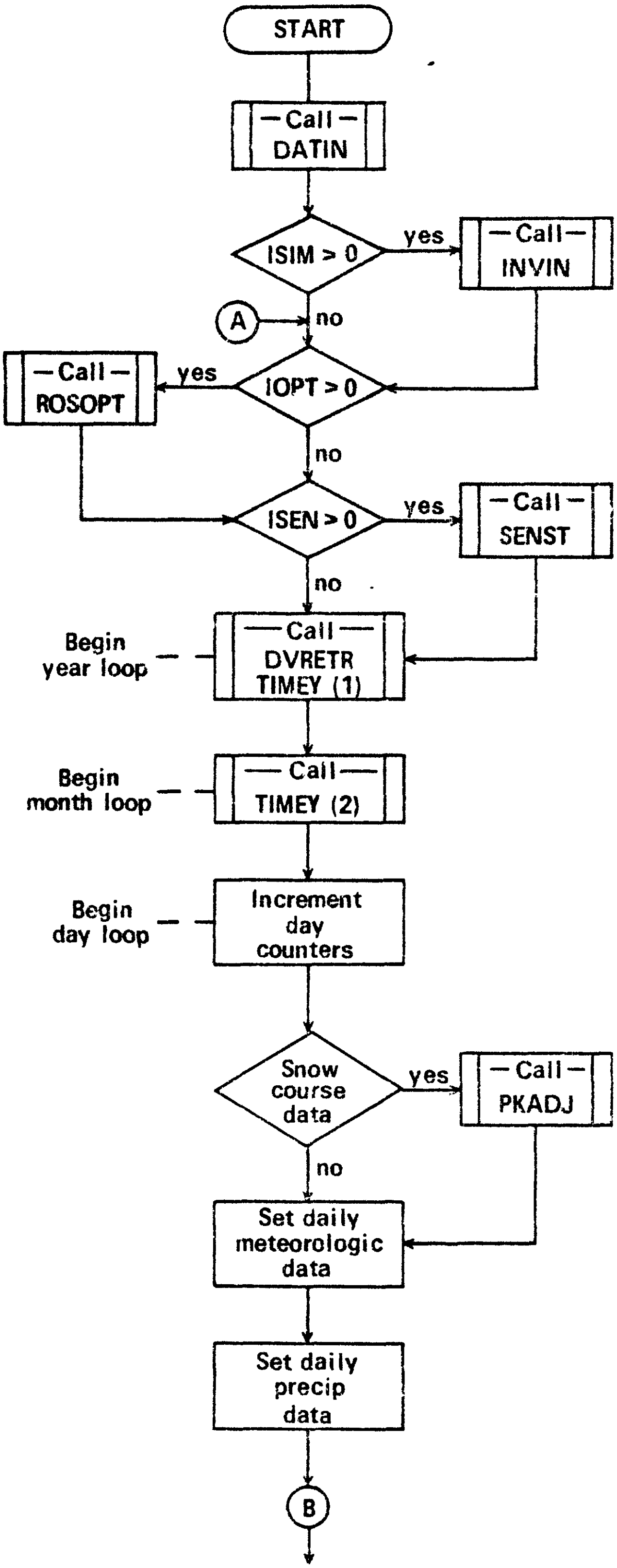


Figure 11.--Flow chart of the MAIN program.

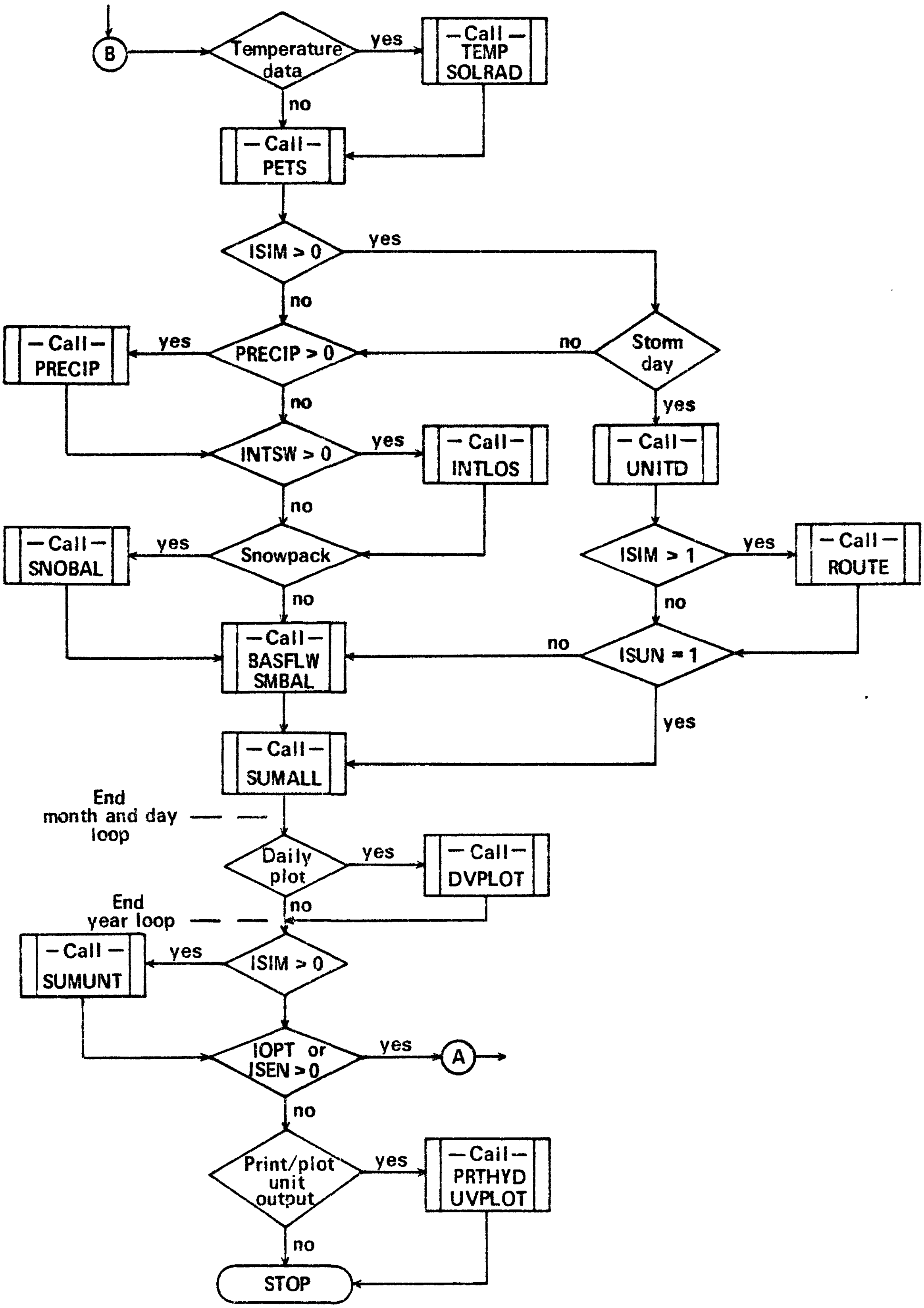


Figure 11.--Flow chart of the MAIN program--Continued.

Table 5.--*List of subroutines included in cataloged procedure PRMODEL*

Subroutine	Calling subroutine	Description
Daily components:		
BASFLW	MAIN	Computes baseflow and subsurface flow components of the streamflow hydrograph.
CALIN	SNOBAL PRECIP	Computes change in snowpack when a net gain in heat energy has occurred.
CALOSS	SNOBAL PRECIP	Computes change in snowpack when a net loss in heat energy has occurred.
INTLOS	MAIN	Computes the evaporation and sublimation of intercepted rain and snow.
PETS	MAIN	Computes daily estimate of potential evapotranspiration.
PKADJ	MAIN	Adjusts snowpack water equivalent based on snowcourse data.
PRECIP	MAIN	Computes precipitation form, total precipitation depth, depth intercepted by vegetation and the net precipitation.
RESVRD	SUMALL	Performs daily routing for surface-water detention reservoirs.
SMBAL	MAIN	Performs daily soil-moisture accounting.
SNOBAL	MAIN	Computes snowpack energy balance.
SOLRAD	MAIN	Computes daily incoming shortwave solar radiation for each HRU.
SOLTAB	DATIN	Computes potential solar radiation and daylight hours for radiation planes.
SRFRO	PRECIP SMBAL	Computes daily storm runoff from rainfall.
SUMALL	MAIN DATIN	Computes daily, monthly, and annual data summaries for total basin and individual HRU's.
TEMP	MAIN	Adjusts daily maximum and minimum air temperature to account for differences in elevation and aspect from point of measurement to each HRU.

Table 5.--*List of subroutines included in cataloged procedure PRMODEL*--Continued

Subroutine	Calling subroutine	Description
Daily components:		
TIMEY	MAIN	Performs initialization and maintenance of the time accounting variables.
Storm components:		
AM	INVIN	Computes kinematic routing parameters α and m.
RESVRU	ROUTE	Performs storm-period routing for surface-water detention reservoirs.
ROUTE	MAIN	Performs channel routing of water and sediment
UNITD	MAIN	Computes rainfall excess and performs overland flow routing of water and sediment.
UNSM	UNITD	Performs subsurface and ground-water reservoir routing for storms.
Optimization components:		
BDRY	SUB1	Determines whether any of the parameters being optimized lie close to their boundaries and penalizes the objective function if they do.
COROPT	ROSOPT	Performs a correlation analysis of the residuals in a daily optimization.
OPINIT	ROSOPT	Reads input data and initializes variables for optimization.
PARAM	ROSOPT	Adjusts selected model parameters at the beginning of each parameter fitting iteration.
ROSOPT	MAIN	Initializes model variables and selected model parameters at the beginning of each parameter fitting iteration.
SCALE	SUB1	Scales parameter and constraint values and unscales parameter and constraint values.
SNORT	SUB3	Determines which of new search directions is most parallel to each of the old directions following an end of stage.

Table 5.--*List of subroutines included in cataloged procedure PRMODEL*--Continued

Subroutine	Calling subroutine	Description
SUB1	ROSOPT	Controls the main strategy of the Rosenbrock optimization procedure.
SUB3	SUB1	Does Gram-Schmidt orthogonalization to establish new orthogonal search directions.
Sensitivity analysis components:		
MATINV	SENST	Performs matrix inversion.
OPINIT	SENST	Reads input data and initializes variables for a sensitivity analysis.
SENMAT	SENST	Computes the sensitivity matrix.
SENST	MAIN	Controls the main strategy of the sensitivity analysis procedure.
PARAM	OPINIT	Adjusts selected model parameters for use in sensitivity analysis routines.
Statistical analysis components:		
STATS	SUMUNT	Computes daily statistics.
SUMUNT	MAIN	Computes summary statistics.
Data handling components:		
BLKDAT	--	Initializes data for common areas.
DATIN	MAIN	Reads input of model options, parameters, and variables.
DVPLOT	MAIN	Provides line printer plot of predicted and observed daily mean streamflow.
DVRETR	MAIN	Selects required daily records from ISAM file.
INVIN	MAIN	Reads input data for storm periods and handles accounting for storms.
PRTHYD	MAIN	Provides tabular output of stormflow hydrograph.
UVPLOT	MAIN	Provides line printer plot of predicted and observed stormflow hydrographs and sediment concentration graphs.
UVRET	INVIN	Selects required storm records from ISAM file.

Table 6.--*Data files developed in subroutine INVIN for stormflow-hydrograph computations*

File name	Remarks
INV	Inventory of storm rainfall data by water year.
FHS	Hydrograph separation information for each storm period.
DFHS	Hydrograph separation information for each storm day.
UNITP	Rainfall data for each rain gage for each storm day.
UNITQ	Discharge data for each storm period.
LATIN	Direct access file used to store lateral and upstream inflow of water (ISIM=2) and sediment (ISIM=3) to channel segments.

A check is then made to see if this date is a storm-mode simulation date. If it is, then infiltration and rainfall excess computations are made on each HRU (UNITD). If channel-flow routing is to be performed, overland-flow computations are made on each flow plane (UNITD). The time trace of overland flow from each flow plane is written to the LATIN disk file for use in the channel-flow routing computations (ROUTE). If the subsurface and ground-water reservoirs are routed on a stormflow time interval, all daily-flow computations are bypassed. If these reservoirs are not routed on a stormflow time interval, daily-flow subroutines are called to perform these operations and provide continuity between storm-and daily-mode computations (SMBAL, BASFLW).

If the date is not a storm-mode date, daily-flow computations are made. A check is made for precipitation. If it occurs, the observed depth is adjusted to account for elevation, topography, and interception, and its form as rain, snow, or a mixture of both is determined (PRECIP). Intercepted precipitation is subject to evaporation or sublimation from the vegetation canopy (INTLOS). If a snowpack exists, energy and water balances are computed and the amount of snowmelt, if any, is computed (SNOBAL). Infiltration of rainfall or snowmelt is determined (SMBAL), and any surface runoff is computed (SRFRO). Subsurface flow and ground-water flow contributions to streamflow are then computed (BASFLW). The last subroutine called in the day loop (SUMALL) performs summary operations on all HRU, subsurface reservoir, and ground-water reservoir computations.

At the termination of the month loop, a check is made for a request to provide a plot of daily observed and simulated streamflows (DVPLOT). At the termination of the water-year loop, a check is made for stormflow summary output to be printed. A check is then made to see if an optimization or sensitivity analysis is in progress. If so, control is returned to the beginning of MAIN for another iteration on the data set. If the run is a simulation only, then a check is made for output on individual storms to be printed (PRTHYD) or plotted (UVPLOT).

The sequence of operations established in MAIN and its associated subroutines attempts to provide a logical and efficient sequence for computation purposes and to simulate the timing of these hydrologic processes in nature. Results of computations in most of the subroutines are used in subsequent subroutines. Proposed changes to MAIN or other library components must incorporate these interactions or provide alternative computation procedures.

CONTROL AND SYSTEM INPUT SPECIFICATIONS

Input to PRMS can be supplied from both punched cards and on-line disk files. All meteorologic and discharge data are stored on index-sequential files, using the procedure GENDISK. Job-control information, system initialization, and basin-characteristics information are input in card format. This section describes the GENDISK procedure and defines the control and data cards required for model operation using the cataloged procedure, PRMODEL. The examples presented are for application of PRMS on the U.S. Geological Survey AMDAHL computer system. Application of PRMS to other computer systems may require modifications to the GENDISK procedure and the data-input subroutines DVRET and UVRET. A discussion of these modifications is presented in attachment VII.

In this discussion, a number of guidelines and standard coding practices have been used. All listings of numeric data are right-justified. All listings of alphabetic data are 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. If a significant digit is required to the right of the decimal point, the point must be punched in the card listing. The format F4.2 implies that two significant digits lie to the right of the decimal point.

GENDISK

GENDISK reads sequential files containing standard WATSTORE daily- and unit-values records, and creates the PRMS compatible ISAM file. Unit-values records are the storm-period records which contain data at time intervals less than 24 hours. These sequential-files are created either from the WATSTORE system using standard daily- and unit-values retrieval programs or from user-formatted data cards using a procedure called DCARDS (attachment III). An example set of job-control language (JCL) cards for using GENDISK to create an ISAM file immediately following the job steps of a WATSTORE daily- and unit-values retrieval is shown in figure 12.

See Volumes 1 and 5, respectively, of the WATSTORE users manual (Hutchinson, 1975) for daily- and unit-values retrieval control cards. In the examples included here, users should substitute their own catalog pointer (for example, DG4812S), and data set names (for example, TESTIS1.ISAM), for underlined items. Instructions for establishing a catalog pointer (user I.D.) and naming data sets on the U.S. Geological Survey computer system are included in Section 5.2 of the U.S. Geological Survey Computer User Manual, (1970).

```
//---JØB CARD---
//PRØCLIB DD DSN=WRD.PRØCLIB,DISP=SHR
//         DD DSN=DG4812S.PRDAT.LIB,DISP=SHR
// EXEC UNRETR,AGENCY=USGS
//HDR.SYSIN DD *
        .
        .
     unit retrieval control cards
        .
/*
// EXEC DVRETR,AGENCY=USGS
//HDR.SYSIN DD *
        .
        .
     daily retrieval control cards
        .
/*
// EXEC GENDISK,ISNAME='DG4812S.TESTIS1.ISAM'
/*
//
```

Figure 12.--JCL for running GENDISK with a WATSTORE unit- and daily-values retrieval.

The output from any WATSTORE retrieval can be stored as a sequential file on disk, for later use as input to GENDISK. Daily- and unit-values data should be kept in separate files, however, because they are in different formats. An example of saving the sequential files following a unit- or daily-values retrieval is shown in figure 13. Again, users should substitute user I.D. and dataset names for underlined items. These files are then used as input to GENDISK in a separate job, as shown in figure 14.

The catalog procedure GENDISK contains several symbolic parameters that may be specified on the EXEC card. These include: DVAL, which specifies the sequential daily-input file; UNITD, which is the device type for DVAL; UVAL, which specifies the sequential unit-values input file; UNITU, which is the device type for UVAL; and ISNAME, which specifies the name of the output index sequential data set that will be used with the model. ISNAME always must be included on the EXEC card. The other parameters default to the temporary data sets created by WATSTORE retrievals. If unit data are not to be included in the ISAM file, code UVAL=NULLFILE.

Data that are not stored in WATSTORE can be used to create the model compatible ISAM file, if they first are converted to the standard WATSTORE daily- and unit-values record format. A procedure called DCARDS is available that will convert user-defined datacard formats to the WATSTORE record format. These converted records then can be added to the files created by previous WATSTORE retrievals or used directly as input to GENDISK. The control cards and JCL for DCARDS are shown in attachment III.

```
//---JØB CARD---
//PRØCLIB DD DSN=WRD.PRØCLIB,DISP=SHR
// EXEC UNRETR,AGENCY=USGS
//HDR.SYSIN DD *
        .
        .
     unit retrieval control cards
        .
/*
//UNR.DATAØUT DD DSN=DG4812S.UVDATA.DATA,DISP=(NEW,CATLG),
// UNIT=ØNLINE,SPACE=(TRK,(10,5),RLSE)
/*
// EXEC DVRETR,AGENCY=USGS
//HDR.SYSIN DD *
        .
        .
     daily retrieval control cards
        .
/*
//DVR.BAKFILE DD DSN=DG4812S.DVDATA.DATA,DISP=(NEW,CATLG),
// UNIT=ØNLINE,SPACE=(TRK,(10,5),RLSE)
/*
//
```

Figure 13.--JCL for saving unit- and daily-values sequential-output files.

```
//---JØB CARD---
//PRØCLIB DD DSN=DG4812S.PRDAT.LIB,DISP=SHR
// EXEC GENDISK,DVAL='DG4812S.DVDATA.DATA',UNITD=ØNLINE,
// UVAL='DG4812S.UVDATA.DATA',UNITU=ØNLINE,
// ISNAME='DG4812S.TESTIS1.ISAM'
/*
//
```

Figure 14.--JCL for running GENDISK with previously stored online-sequential files.

Job Control Cards

The cataloged-procedure PRMODEL has been established on the U.S. Geological Survey computer system. The JCL cards required to use the procedure are shown in figure 15. The name of the ISAM file created by GENDISK should be inserted, in single quotes, after INFILE=. The full procedure is listed in attachment I.

A number of input/output units are used in the procedure for data storage, internal data management, and data-output files. An annotated list of these units and the file structure established on each is shown in table 7. With the exception of the files on units 2, 3, 20, and 21, all files have been established as temporary or permanent, and the deletion or retention of each has been predetermined. Files on unit 2 receive plot output for each HRU, and files on unit 3 receive daily data for each HRU. These files can be printed using the JCL shown in figure 16a. Unit 20 receives the predicted mean daily discharge file for permanent storage and further processing, when this option has been selected on card 1 of Card Group 1. A default Data Control Block (DCB) for a standard daily-values WATSTORE record has been established on the DD card for unit 20. However, a null Data Set Name (DSN) parameter has been included. A user DSN must be supplied when the output from a model run is to be saved. An example of how to insert the DSN parameter is shown in figure 16b. If the user selects the second data format option, the DCB parameters of Logical Record Length (LRECL) and Block Size (BLKSIZE) must be included with the DSN parameter on the override card shown in figure 16c. The LRECL parameter should be set to 1480, and the BLKSIZE parameter should be set to 10360.

The predicted storm hydrograph may be saved as a permanent file on unit 21 in the standard unit values format if this option has been selected on card 1 of Card Group 1. A user DSN should be supplied, as shown in figure 16d.

```
//---JØB CARD---
//PRØCLIB DD DSN=DG4812S.PRDAT.LIB,DISP=SHR
// EXEC PRMODEL,INFILE='DG4812S.TESTIS1.ISAM'
//PR.SYSIN DD *
        .
        .
     CARD GROUPS 1-8
        .
/*
//
```

Figure 15.--JCL for using catalog-procedure PRMODEL.

Table 7.--*List of input/output and file structures*

I/O unit	DSNAME	Unit	Space	Disposition at job end	RECFM	LRECL	BLKSIZE	DSORG	Description
2	*	Line printer	---	---	---	---	---	---	Output file if daily plots selected.
3	*	Line printer	---	---	---	---	---	---	Output file if printout of individual HRU'S selected.
4	---	SYSDK	TRK(5,5)	DELETE	---	---	---	---	Work file for optimization.
5	---	CARD INPUT	---	---	---	---	---	---	Input data cards (card group 1).
6	---	Line printer	---	---	---	---	---	---	Line printer output from fortran programs.
8	---	SYSDK	TRK(5,5)	DELETE	---	---	---	---	Work file for sensitivity analysis.
9	---	SYSDK	128(1000)	DELETE	F	128	---	DA	Direct access work file for optimization and sensitivity analysis.
11	&INV	SYSDK	TRK(10,1)	DELETE	VBS	1472	5896	---	Inventory of unit-values rainfall data by water year.
12	&FHS	SYSDK	TRK(5,1)	DELETE	VBS	656	6568	---	Hydrograph separation information for each storm period.
13	&DFHS	SYSDK	TRK(10,5)	DELETE	VBS	108	1088	---	Hydrograph separation information for each unit-values day.
14	&UNITQ	SYSDK	TRK(100,5)	DELETE	VB	5820	5830	---	Unit-values discharge data for selected storm periods.
15	&UNITP	SYSDK	TRK(100,5)	DELETE	VBS	5820	5830	---	Unit-values rainfall data for each rain gage for each day.
17	&LAIIN	SYSDK	5768(200)	DELETE	F	---	5760	DA	Direct access file to store lateral and upstream inflow to channel segments.
18	&SFILE	SYSDK	TRK(100,5)	DELETE	VBS	5764	12000	---	Temporary file for channel segment storm hydrograph data.
20	*	ONLINE	TRK(5,5)	NEW,CATLG	FB	1656	11592	---	Output file to save predicted daily discharge.
21	*	ONLINE	TRK(5,5)	NEW,CATLG	VB	11604	12932	---	Output file to save predicted unit discharge.
22	---	CARD INPUT	---	---	---	---	---	---	Input data cards (card group 2).
23	---	CARD INPUT	---	---	---	---	---	---	Input data cards (card group 3).
24	---	CARD INPUT	---	---	---	---	---	---	Input data cards (card group 4).
25	---	CARD INPUT	---	---	---	---	---	---	Input data cards (card group 5).
26	---	CARD INPUT	---	---	---	---	---	---	Input data cards (card group 6).
27	---	CARD INPUT	---	---	---	---	---	---	Input data cards (card group 7,8).
30	---	SYSDK	TRK(5,15)	DELETE	FB	1480	10360	---	Temporary file for predicted and observed daily discharge data.
DISK(PL1)	**	ONLINE	CYL(1)	KEEP	VB	11604	12932	IS	Input ISAM file containing daily and unit values.
SYSPRINT(PL1)	---	Line printer	---	---	---	---	---	---	Line printer output from PL1 programs.

*Dummy files unless overridden in JCL.
**Assigned by user.

Figure 16a.

```
//---JØB CARD---
//PRØCLIB DD DSN=DG4812S.PRDAT.LIB,DISP=SHR
// EXEC PRMØDEL,INFILE='DG4812S.TESTIS1.ISAM'
//PR.FT02F001 DD SYSØUT=A     (include to print plots)
//PR.FT03F001 DD SYSØUT=A     (include if daily HRU data to be printed)
//PR.SYSIN DD *
        .
        .
     CARD GROUPS 1-8
        .
/*
//
```

Figure 16b.

```
//---JØB CARD---
//PRØCLIB DD DSN=DG4812S.PRDAT.LIB,DISP=SHR
// EXEC PRMØDEL,INFILE='DG4812S.TESTIS1.ISAM',
// DVØUT='DG4812S.DVALUES.DATA'
//PR.SYSIN DD *
        .
        .
     CARD GROUPS 1-8
        .
/*
//
```

Figure 16.--JCL modifications to cataloged procedure PRMODEL. (a) Generate printer plot and HRU output; (b) include Data Set Name (DSN) to store simulated daily flows; (c) include DSN, Logical Record Length (LRECL) and Block Size (BLKSIZE) to store simulated daily flows; and (d) include DSN to store simulated stormflows.

Figure 16c.

```
//---JØB CARD---
//PRØCLIB DD DSN=DG4812S.PRDAT.LIB,DISP=SHR
// EXEC PRMØDEL,DVØUT='DG4812S.DVALUES.DATA',DVLREC=1480,DVBLK=10360,
// INFILE='DG4812S.TESTIS1.ISAM'
//PR.SYSIN DD *
        .
        .
     CARD GROUPS 1-8
        .
/*
//
```

Figure 16d.

```
//---JØB CARD---
//PRØCLIB DD DSN=DG4812S.PRDAT.LIB,DISP=SHR
// EXEC PRMØDEL,UVØUT='DG4812S.UVALUES.DATA',
// INFILE='DG4812S.TESTIS1.ISAM'
//PR.SYSIN DD *
        .
        .
     CARD GROUPS 1-8
        .
/*
//
```

Figure 16.--JCL modifications to cataloged procedure PRMODEL. (a) generate printer plot and HRU output; (b) include Data Set Name (DSN) to store simulated daily flows; (c) include DSN, Logical Record Length (LRECL) and Block Size (BLKSIZE) to store simulated daily flows; and (d) include DSN to store simulated stormflows--Continued.

The options selected in the system input stream will determine the number of files and input/output units that will be used in a particular model run. A daily-flow simulation requires fewer files than a daily and storm-event simulation. The number of files required will influence the core-storage requirements for model execution. The default REGION of 600 K should be sufficient for most model runs, but may need to be increased for a model run that includes optimization and storm simulation. This can be specified in the REGION parameter of the Execute (EXEC) card, as shown in figure 17. Parameters that may be specified on the EXEC card and their default values are listed in table 8.

System Input Cards

The PRMS input cards have been delineated into eight Card Groups. Card Group 1 is required for all model runs. The inclusion of one or more additional groups is a function of the options specified in Card Group 1. The Card Groups to be included in a data deck as a function of selected values for the variables IOPT, ISIM, ISEN, IPSW, and INPK are given in table 9.

Variable and parameter names and their definitions are given in all card groups. Additional information on most of these variables and parameters can be found in the Theoretical Development of System Library Components section. The subsections within the Theoretical Development section that provide this information are listed in brackets [] under the Definitions heading for each data card. When the subsection title appears with Card I.D., most or all items on that card are discussed in the referenced subsection. Variables and parameters that are self-explanatory have no subsection reference.

```
//---JØB CARD---
//PRØCLIB DD DSN=DG4812S.PRDAT.LIB,DISP=SHR
// EXEC PRMØDEL,REGIØN.PR=750K,TIME.PR=5,INFILE='DG4812S.TESTIS1.ISAM'
//PR.SYSIN DD *
          .
          .
     CARD GROUPS 1-8
          .
/*
//
```

Figure 17.--JCL for region and time modification to cataloged procedure PRMODEL.

Table 8.--*Default values for parameters specified on EXEC card*

Parameter	Description	Default
REGIØN.PR	Core storage requirement	600K
TIME.PR	Time in minutes	3
DVØUT	Name of file to save predicted daily values	NULLFILE
DVLREC	Record length of DVØUT	1656
DVBLK	Blocksize for DVØUT	11592
UVØUT	Name of file to save predicted unit values	NULLFILE

Table 9.--*Input data-card groups needed for various model configurations*

Variable	Card number	Selected value	Card groups to be included in addition to 1
ISIM	1	0	-----
		1	2,3
		2,3	2,3,4
IØPT	1	0	-----
		1,2,3,4,5	7,8
ISEN	1	0	-----
		1,2,3,4,5	7,8
IPSW	1	0	-----
		1	5
INPK	27	All values 0	-----
		Any value >0	6

Card Group 1: Parameter and Variable Initialization

This card group is read on input unit 5 in subroutine DATIN and is required for all simulation runs. Simulation options, types of input data, and output options are established in this group. Model parameters and variables are initialized, and the physical characteristics of the basin hydrologic response units (HRU's) are established. Card group 1 follows a //PR.SYSIN DD * card in the input card deck.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
1	1-9	'01SIMØPT'		Card I.D.
	15	I1	ISIM	Simulation mode switch 0=daily mode 1=storm and daily mode 2=storm and daily mode with flow routing 3=storm and daily mode with flow and sediment routing
	20	I1	IØBS	Observed discharge data switch 0=no observed discharge data 1=observed discharge data input
	25	I1	IØPT	Optimization mode switch [Optimization] 0=no optimization 1=daily optimization 2=daily optimization with correlation analysis 3=optimization on storm volumes 4=optimization on storm peaks 5=optimization on storm peaks and volumes

NOTE: IOPT is positive for Rosenbrock and negative for Gauss-Newton optimization.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
1	30	I1	ISEN	Sensitivity analysis switch [Sensitivity Analysis] 0=no sensitivity analysis 1=daily sensitivity analysis 2=daily sensitivity analysis with correlation analysis 3=sensitivity analysis on storm volumes 4=sensitivity analysis on storm peaks 5=sensitivity analysis on storm volumes and peaks simultaneously

NOTE: An optimization and a sensitivity analysis cannot be run simultaneously. They can be run sequentially. See Card Group 8.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
	35	I1	IDØUT	Store predicted daily mean streamflow values switch 0=no storage 1=store predicted and observed daily values as sequential direct access data file by water year. Format is 370-word record with 4-word header and 366 data values. 2=Same as 1, except format is standard WATSTORE daily-values record.
	40	I1	IUØUT	Store predicted stormflow values switch 0=no storage 1=store predicted stormflow values as sequential direct-access data file by storm. Format is standard WATSTORE unit-values record.
	44-45	A2	SCODE	State code for daily- or unit-values output

NOTE: If IDØUT or IUØUT≠0, output data set name must be included on //EXEC card.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
1	55	I1	IPSW	Precipitation form data switch [Precipitation] 0=no precipitation form data 1=precipitation form data to be read from cards

NOTE: If IPSW=1, card group 5 must be included in card deck.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
2	1-10	'02SIM/CØMP'		Card I.D.
	20	I1	IPET	Potential evapotranspiration (ET) calculation switch [Evapotranspiration] 0=calculate potential ET from temperature and solar radiation data 1=calculate potential ET from temperature data only 2=calculate potential ET from evaporation pan data
	25	I1	ISSR1	Daily surface runoff computation method switch [Surface Runoff] 0=compute surface runoff contributing area as a linear function of soil moisture 1=compute surface runoff contributing area as a nonlinear function of soil moisture and precipitation volume
	30	I1	MRDC	Solar radiation computation method switch [Solar Radiation] 0=Solar radiation data not used 1=missing days calculated using degree day coefficients 2=missing days calculated using sky cover-temperature relation

NOTE: MRDC must be 1 or 2 for snowmelt simulation.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
2	35		ISUN	Switch for unit subsurface and ground water flow routing [Subsurface Flow, Ground Water] 0=surface runoff only included in stormflow computation 1=surface, subsurface, and ground water included in stormflow computations
3	1-6	'03TITL'		Card I.D.
	11-80	17A4,A2	TITL	Any title user wishes to print as heading for all output
4	1-7	'04INIT1'		Card I.D.
	11-15	I5	NDS	Number of rain-gage data sets
	16-20	I5	NRU	Number of hydrologic response units (HRU's)
	21-25	I5	NRD	Number of solar radiation planes (one slope and aspect combination equals a plane). Equals all defined planes on basin plus 1 for horizontal surface [Solar Radiation]
	26-30	I5	NRES	Number of subsurface flow routing reservoirs [Subsurface Flow]
	31-35	I5	NGW	Number of ground-water flow routing reservoirs [Ground Water]
	36-40	I5	NSTØR	Number of surface-water detention storage reservoirs [Reservoir Routing]
	41-50	F10.0	DAT	Total basin drainage area, in acres
5	1-7	'05INIT2'		Card I.D.
	11-15	I5	BYR	Beginning year of data set (for example, 1978)
	16-20	I5	BMØ	Beginning month of data set (1-12)
	21-25	I5	BDY	Beginning day of data set (1-31)
	26-30	I5	EYR	Ending year of data set (for example, 1979)
	31-35	I5	EMØ	Ending month of data set (1-12)
	36-40	I5	EDY	Ending day of data set (1-31)

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
6	1-9	'06MFS-MFN'		Card I.D. [Optimization]
	11-15	I5	MFS	Beginning month of objective function computation (daily flow option)
	16-20	I5	MFN	Ending month of objective function computation (daily flow option)
7	1-10	'07PRINT-ØP'		Card I.D.
	11-15	I5	IPØP1	Daily mean values print switch 0=print summary table 1=0 plus annual summary 2=1 plus monthly summary 3=2 plus daily summary
	16-20	I5	IPUN3	Beginning month for printing daily basin average values
	21-25	I5	IPUN4	Ending month for printing daily basin average values
	26-30	I5	IPØP2	Individual HRU values print switch 0=no print 1=annual summary 2=1 plus monthly summary 3=2 plus daily summary
	31-35	I5	IPUN1	Julian date to start printing individual HRU values
	36-40	I5	IPUN2	Julian date to stop printing individual HRU values
	41-45	I5	ISTAT	0=statistical summary not printed 1=statistical summary printed
8	1-6	'08PLØT'		Card I.D.
	11-15	I5	IPLØT	Plot switch--daily 0=no plot output 1=plot output
	16-20	I5	IPLTYP	Plot type switch 0=linear scale 1=semilog scale
	21-25	I5	IMPLB	Month plot begins (1-12)
	26-30	I5	IDPLB	Day plot begins (1-31)
	31-35	I5	IMPLE	Month plot ends (1-12)
	36-40	I5	IDPLE	Day plot ends (1-31)
	41-50	F10.0	PLMX	The maximum plot value. For semilog plots, this must be a power of 10 and equal 1,000 * PLMN
	51-60	F10.0	PLMN	The minimum plot value. For semilog plots, this must be a power of 10 and non-zero

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
9	1-10	'09DATATYPE'		Card I.D.
	11-15	I5	NDTY	Number of data types being used in the simulation
	16-65	10I5	IDUS(I)	Specifies input data types. Ten data types (I) in positional order are: 1) daily mean discharge 2) daily pan evaporation 3) daily maximum air temperature 4) daily minimum air temperature 5) daily solar radiation 6) daily, user defined 7) daily, user defined 8) storm discharge 9) daily precipitation 10) storm precipitation 0=data type not used 1=data type used.
10	1-6	'10PARM'		Card I.D.
	11-60	10I5	PARMCA(I)	Parameter code (WATSTORE) used with data types (I) specified in IDUS (positional using IDUS sequence, blank field if IDUS(I)=0). See table 10.
11	1-6	'11STAT'		Card I.D.
	11-60	10I5	STATCA(I)	Statistic code (WATSTORE) corresponding to parameter codes on card 10 (positional using IDUS sequence, blank field if IDUS(I)=0). See table 10.
12 (2 cards)	1-8	'12STAIDC'		Card I.D.
	11-26,29-44, 47-62,65-80	4(2X,4A4)	STAIDC(I)	Station I.D. for data types 1 through 8. D or U in first column of each field to indicate daily or unit station, respectively, plus station identification number which is either 15-digit latitude-longitude-sequence number, or 8-digit downstream order number, right-justified. Identification

Table 10.--*Parameter codes and statistic codes used for input data types (IDUS)*

Data type	IDUS	Parameter code	Statistic code
Daily mean discharge---------------	1	60	3
Daily pan evaporation--------------	2	50	6
Daily maximum air termperature-----	3		
°C---------------------------		20	1
°F---------------------------		99998	1
Daily minimum air temperature------	4		
°C---------------------------		20	2
°F---------------------------		99998	2
Daily solar radiation--------------	5	30	6
Storm discharge--------------------	8	60	11
Daily precipitation----------------	9	45	6
Storm precipitation----------------	10	45	6

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
12				number is left-justified when GENDISK was run using a standard WATSTORE retrieval. (positional using IDUS sequence, blank field if IDUS(I)=0)
13 (NDS cards)	1-8	'13STAIDP'		Card I.D.
	11-26,29-44	2(2X,4A4)	STAIDP(I,J)	Station I.D. for precipitation data types 9 and 10. D or U in first column of each field to indicate daily or unit station, respectively, plus station identification number which is either 15-digit latitude-longitude-sequence number, or 8-digit downstream order number, right-justified. Identification number is left-justified when GENDISK was run using a standard WATSTORE retrieval. One card required for each set of rain-gage data (I,J=1, NDS)

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
14 (NRD cards)	1-4	'14RD'		Card I.D. [Solar Radiation]
	5-6	I2	I	Index of this solar radiation plane, I=1 is horizontal surface.
	10-13	A4	SA(I)	Slope and aspect I.D. of this plane (for example, NW20 is northwest aspect, 20 percent slope)
	20-25	F5.2	SL	Slope of plane (decimal ft/ft)
	26-30	F5.2	ASP	Aspect of plane (degrees clockwise from north; for example, north=0.;E=90.0, and so forth)
	31-35	F5.2	ALAT	Latitude of basin (degrees)

NOTE: One no. 14 card is required for each solar radiation plane defined on the basin. The number of no. 14 cards is equal to NRD specified on card no. 4. The first card in this set is always the horizontal surface values. Not required if MRDC=0 and IPET=0 or 2. Required when MRDC > 0 or IPET=1.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
15	1-5	'15RDM'		Card I.D. [Solar Radiation]
	11-70	12F5.2	RDM(I)	MRDC=1 Slope of maximum air temperature(x) - degree day(y) relationship for months I=1,12 MRDC=2 Slope of max-min air temperature(x) - sky cover(y) relationship for months I=1,12
16	1-5	'16RDC'		Card I.D. [Solar Radiation]
	11-70	12F5.2	RDC(I)	MRDC=1 Y-intercept of maximum air temperature(x) - degree day(y) relationship for months I=1-12 MRDC=2 Y-intercept of max-min air temperature(x) - sky cover(y) relationship for months I=1-12
17	1-9	'17RAD-CØR'		Card I.D. [Solar Radiation]
	11-15	F5.2	PARS	Predicted solar radiation correction factor for summer day with precipitation

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
17	16-20	F5.2	PARW	Predicted solar radiation correction factor for winter day with precipitation
	21-25	F5.2	RDB	MRDC=1 blank MRDC=2 sky cover-solar radiation computation coefficient
	26-30	F5.2	RDP	MRDC=1 blank MRDC=2 sky cover-solar radiation computation coefficient
	31-35	F5.2	RDMX	Maximum percent of potential solar radiation receivable

NOTE: Cards 15, 16, and 17 are not required if MRDC=0.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
18	1-9	'18CLIM-PR'		Card I.D. [Precipitation]
	11-20	F10.0	CSEL	Climate station elevation (ft)
	21-25	F5.2	RMXA	Proportion of rain in a rain-snow precipitation event above which snow albedo is not reset (snowpack accumulation stage) [Snow]
	26-30	F5.2	RMXM	Same as RMXA but for snowpack melt stage [Snow]
	31-35	I5	MPCS	Month that override of DRCØR and DSCØR begins (1-12)
	36-40	I5	MPCN	Month that override of DRCØR and DSCØR ends (1-12); ends last day of previous month.
	41-45	I5	MPC1	Starting value of override switch for DRCØR and DSCØR 0=non-override period 1=override period
	46-50	F5.2	PCØNR	Override value for DRCØR
	51-55	F5.2	PCØNS	Override value for DSCØR
	56-60	I5	MTSS	Month that convective thunderstorms become the predominant storm type (1-12)
	61-65	I5	MTSE	Last month that convective thunderstorms are the predominant storm type (1-12)
19	1-9	'19CTS-CTW'		Card I.D. [Evapotranspiration]
	11-70	12F5.5	CTS(I)	Air temperature ET coefficient for months I=1,12. IPET=0--Jensen-Haise Formulation IPET=1--Hamon Formulation

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
19	71-75	F5.2	CTW	Proportion of potential evapotranspiration that is sublimated from a snow surface (decimal form) [Snow]
20	1-5	'20PAT'		Card I.D.
	11-70	12F5.2	PAT(J)	Maximum air temperature, which when exceeded forces precipitation to be rain regardless of minimum air temperature, for months J=1,12
21	1-6	'21AJMX'		Card I.D. [Precipitation]
	11-70	12F5.2	AJMX(J)	Adjustment proportion of rain in a rain-snow mix event, for months J=1,12
22	1-5	'22TLX'		Card I.D. [Temperature]
	11-70	12F5.2	TLX(I)	Lapse rate for maximum daily air temperature for months I=1,12
23	1-5	'23TLN'		Card I.D. [Temperature]
	11-70	12F5.2	TLN(I)	Lapse rate for minimum daily air temperature for months I=1,12
24	1-5	'24EVC'		Card I.D. [Evapotranspiration]
	11-70	12F5.2	EVC(I)	Evaporation pan coefficient for months I=1,12
25	1-9	'25SNØ-VAR'		Card I.D. [Snow]
	11-15	I5	ISP1	Julian date to start looking for spring snowmelt stage
	16-20	I5	ISP2	Julian date to force snowpack to spring snowmelt stage
	21-25	F5.2	EAIR	Emissivity of air on days without precipitation
	26-30	F5.2	FWCAP	Free water-holding capacity of snowpack expressed as decimal fraction of total snowpack water equivalent
	31-35	F5.2	DENI	Initial density of new-fallen snow (gm/cm^3)
	36-40	F5.2	DENMX	Average maximum snowpack density (gm/cm^3)

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
25	41-45	F5.2	SETCØN	Snowpack settlement time constant
	46-50	F5.0	BST	Temperature above which precipitation is all rain and below which it is all snow [Precipitation]
26	1-5	'26CEN'		Card I. D. [Snow]
	11-70	12F5.0	CECN(I)	Convection-condensation energy coefficient for months I=1,12 (cal/°C above zero)
27	1-7	'27PKADJ'		Card I.D. [Precipitation]
	11-80	14I5	INPK(I)	Julian dates for adjusting computed snowpack water equivalents from snowcourse data. One date for each water-year run. Use zero for years without an update. For each water year with a nonzero value, one Group 6 data card is required.
28	1-5	'28RES'		Card I.D. [Sursurface Flow]
	11-80	14F5.2	RES(I)	Storage in each subsurface flow routing reservoir (in.)
29	1-4	'29GW'		Card I.D. [Ground Water]
	11-80	14F5.2	GW(I)	Storage in each ground-water flow routing reservoir (in.)
30	1-6	'30KRSP'		Card I.D. [Ground Water]
	11-80	14I5	KRSP(I)	The index of the ground-water reservoir receiving recharge from subsurface reservoir I; I=1, NRES
31	1-10	'31RESMX-EX'		Card I.D. [Ground Water]
	11-15 21-25 31-35, etc.	F5.2	RESMX(I)	Coefficient for computing recharge from subsurface reservoir I to its designated ground-water reservoir
	16-20 26-30 36-40, etc.	F5.2	REXP(I)	Exponent coefficient for computing recharge from subsurface reservoir I to its designated ground-water reservoir

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
32	1-6	'32RSEP'		Card I.D. [Ground Water]
	11-80	14F5.2	RSEP(I)	Coefficient used in computing recharge rate from subsurface reservoir I to its designated ground-water reservoir
33	1-6	'33GSNK'		Card I.D. [Ground Water]
	11-80	14F5.2	GSNK(I)	Coefficient used in computing the recharge rate from ground-water reservoir I to a ground-water sink
34	1-5	'34RCB'		Card I.D. [Ground Water]
	11-80	14F5.2	RCB(I)	Ground-water routing coefficient for each ground-water reservoir I
35	1-9	'35RCF-RCP'		Card I.D. [Subsurface Flow]
	11-20, 31-40, 51-60	F10.0	RCF(I)	Subsurface flow routing coefficient for each subsurface reservoir I
	21-30, 41-50, 61-70	F10.0	RCP(I)	Subsurface flow routing coefficient for each subsurface reservoir I

NOTE: One set of cards, 36 through 38, is required for each HRU (NRU on card 3).

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
36	1-5	'36RU1'		Card I.D.
	9-10	I2	IRU	HRU I.D.
	11-13	I3	IRD	Solar radiation plane index associated with this HRU
	14-18	F5.0	SLP	Slope (decimal form)
	19-25	F7.0	ELV	Mean elevation of HRU (feet above MSL)
	26-30	I5	ICØV	Predominant vegetation cover type, 0=bare 1=grasses 2=shrubs 3=trees
	31-35	F5.2	CØVDNS	Summer vegetation cover density (decimal)
	36-40	F5.2	CØVDNW	Winter vegetation cover density (decimal)

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
36	41-45	F5.2	TRNCF	Transmission coefficient for short-wave radiation through the winter vegetation canopy (decimal form) [Snow]
	46-50	F5.2	SNST	Interception storage capacity of major winter vegetation for snow (inches water equivalent)
	51-55	F5.2	RNSTS	Summer rain interception storage capacity of major vegetation (in.)
	56-60	F5.2	RNSTW	Winter rain interception storage capacity of major vegetation (in.)
	61-62	I2	ITST	Month to look for start of transpiration (1-12) [Evapotranspiration]
	63-64	I2	ITND	Month transpiration ends (1-12); ends last day of previous month [Evapotranspiration]
	65	I1	ITSW	Starting value for transpiration switch 0=vegetation dormant 1=vegetation transpiring [Evapotranspiration]
	66-70	F5.2	CTX	Air temperature coefficient for evapotranspiration computations [Evapotranspiration] IPET=0 Jensen-Haise Formulation IPET=1 Blank IPET=2 Blank
	71-75	F5.2	TXAJ	Adjustment for maximum air temperature for slope and aspect [Temperature]
	76-80	F5.2	TNAJ	Adjustment for minimum air temperature for slope and aspect [Temperature]
37	1-5	'37RU2'		Card I.D.
	9-10	I2	IRU	HRU I.D.
	11-15	I5	ISØIL	Soil type, 1=sand, 2=loam, 3=clay
	16-20	F5.2	SMAX	Maximum available water-holding capacity of soil profile (0.3 - 15 bars) (in.) [Soil Moisture]

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
37	21-25	F5.2	SMAV	Current available water in soil profile (in.) [Soil Moisture]
	26-30	F5.2	REMX	Maximum available water-holding capacity of soil recharge zone (0.3 - 15 bars) (in.) [Soil Moisture]
	31-35	F5.2	RECHR	Current available water-holding capacity of recharge zone (in.) [Soil Moisture]
	36-40	F5.2	SRX	Maximum daily snowmelt infiltration capacity of soil profile (in.) when profile is at field capacity [Soil Moisture]
	41-45	F5.2	SCX	Maximum possible contributing area as proportion of total HRU area (decimal form) [Surface Runoff]
	46-50	F5.2	SCN	ISSR1=0 Minimum possible contributing area as proportion of total HRU area (decimal form) [Surface Runoff] ISSR1=1 Coefficient in contributing area moisture index relationship [Surface Runoff]
	51-55	F5.2	SC1	ISSR1=0 blank ISSR1=1 Coefficient in contributing area moisture index relationship [Surface Runoff]
	56-60	F5.2	IMPERV	Effective impervious area as proportion of total HRU (decimal form) [Surface Runoff]
	61-65	F5.2	RETIP	Maximum retention storage on impervious area (in.) [Surface Runoff]
	66-70	F5.2	SEP	Maximum daily recharge from soil moisture excess to designated ground-water reservoir (KGW), (in./d)
	71-73	I3	KRES	Index of subsurface reservoir receiving recharge from HRU [Subsurface Flow]
	74-76	I3	KGW	Index of ground-water reservoir receiving recharge from HRU

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
37	77-79	I3	KSTØR	Index of surface-water detention storage reservoir receiving runoff from HRU [Reservoir Routing]
38	1-5	'38RU3'		Card I.D. [Precipitation]
	9-10	I2	IRU	HRU I.D.
	11-13	I3	KDS	Index of rain gage
	14-20	F7.0	DARU	Drainage area for HRU (acres)
	21-25	F5.2	UPCØR	Rain correction for storm precipitation for rain gage KDS
	26-30	F5.2	DRCØR	Rain correction for daily precipitation for rain gage KDS
	31-35	F5.2	DSCØR	Snow correction for daily precipitation for rain gage KDS
	36-40	F5.2	TST	Temperature index to determine specific date of start of transpiration
39	1-6	'39STØR'		Card I.D. [Reservoir Routing]
	11-15	I5	KSTØR	Index of surface water storage reservoir
	16-20	I5	IRTYP	Type of reservoir routing 8=Puls routing 9=Linear routing
	21-25	I5	NSØS	IRTYP=8 The number of outflow-storage data pairs to be input (maximum of 10) IRTYP=9 blank
	26-30	I5	IRUP1	Index (KSTØR) of upstream surface-water storage reservoir 1, else blank
	31-35	I5	IRUP2	Index (KSTØR) of upstream surface-water storage reservoir 2, else blank
	36-40	I5	IRUP3	Index (KSTØR) of upstream surface-water storage reservoir 3, else blank
	41-50	F10.2	RCS	IRTYP=8 blank IRTYP=9 routing coefficient
	51-60	F10.2	STØ	Initial reservoir storage (cfs-days)
	61-70	F10.2	QRØ	Initial day mean outflow (cfs)
	71-80	F10.2	DIN1	Initial day mean inflow (cfs)

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
40	1-6	'40Ø2S2'		
	11-20 31-40 51-60	F10.2	Ø2	Outflow values in outflow-storage table for Puls routing (cfs), lowest value first
	21-30 41-50 61-70	F10.2	S2	Storage values in outflow-storage table for Puls routing (cfs-days), lowest value first

NOTE: Cards 39 and 40 are not required if NSTØR=0. One set of cards 39 and 40 is required for each surface-water reservoir. Up to 10 pairs of Ø2-S2 can be input (4 card 40's) and the card 40's must immediately follow their associated card 39. Card 40 is not required if IRTYP=9.

Card Group 2: Storm Period Selection

This card group is read on input unit 22 in subroutine INVIN and is required only when the ISIM variable (Card Group 1, card 1) is greater than zero. These data define the storm periods to be simulated in a storm mode and the options for storm peak and volume computations. A storm period is defined as one or more consecutive days of storm rainfall. Each storm-period selection card set also describes the number of stormflow hydrograph segments within the storm period. A hypothetical storm period containing two hydrograph segments is shown in figure 18. If storm-mode subsurface and ground-water flow routing are selected (ISUN=1), storm computations are made on full-day time intervals, and hydrograph segmentation is not required. Card group 2 follows a //SYSIN2 DD * card in the input deck.

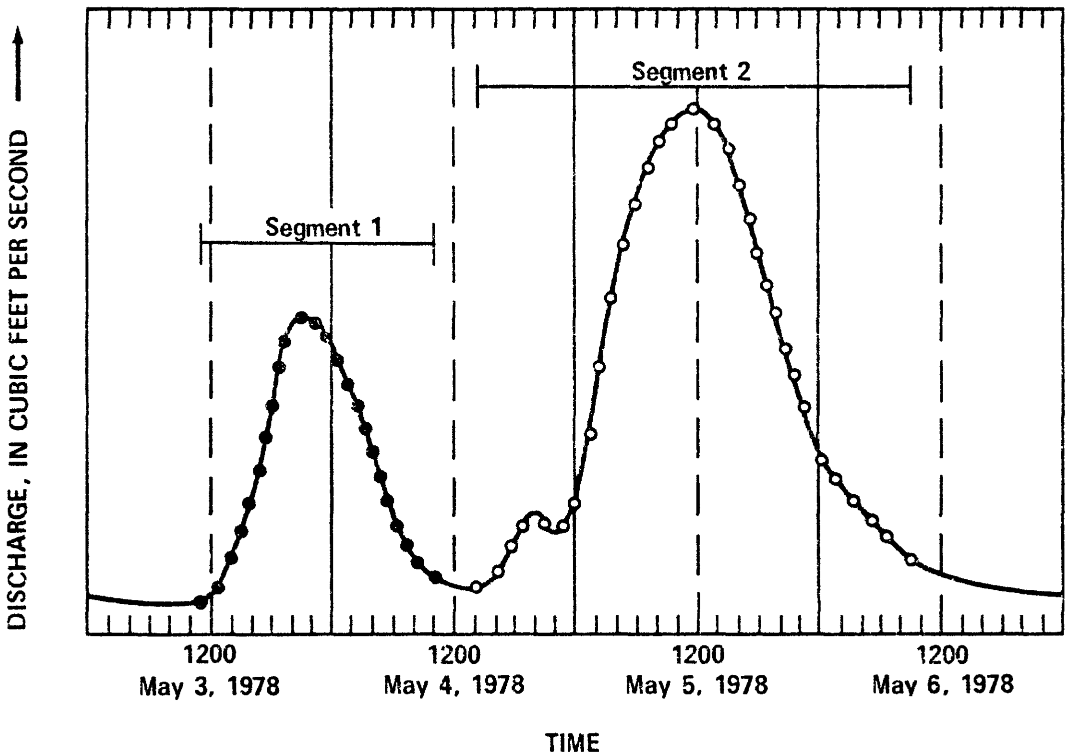


Figure 18.--Delineation of hydrograph segments within a storm period.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
1	1-8	'01STORMS'		Card I.D.
	11-15	I5	NSP	Number of storm periods (maximum of 50)
2 (NSP card sets)	1-7	'02STSEG'		Card I. D.
	11-15	I5	ISS	Storm period sequence number
	16	I1	CD	Data availability code 1=storm rainfall 2=storm rainfall and discharge 3=storm rainfall, discharge, and sediment concentration
	17-20	I4	IHS	Number of hydrograph segments this storm period
	21-25	I5	NY	Beginning year of storm period
	27-28	I2	NM	Beginning month of storm period
	29-30	I2	ND	Beginning day of storm period
	31-35	I5	JY	Ending year of storm period
	37-38	I2	JM	Ending month of storm period
	39-40	I2	JD	Ending day of storm period
	41-45	I5	KD	Beginning day of hydrograph segment 1.
	46-50	I5	KT	Beginning time this hydrograph segment (1:30 pm is coded as 1330)
	51-55	I5	LD	Ending day this hydrograph segment
	56-60	I5	LT	Ending time this hydrograph segment
	65	I1	IC2	Peak and volume code 0=segment peak and volume are computed from observed storm discharge 1=segment peak and volume are supplied by user
	71-75	F5.0	RC1	IC2=0 and ISUN=0 Average base-flow rate IC2=0 and ISUN=1 Blank IC2=1 Peak discharge rate
	76-80	F5.0	RC2	IC2=0 Blank IC2=1 Runoff in inches computed as: $\frac{\text{VOL (acre-in.)}}{\text{AREA (acre)}}$

NOTE: Card columns 41-80 are repeated on as many cards as are required to describe IHS hydrograph segments.

Card Group 3: Infiltration/Upland Erosion Parameters

This card group is read on input unit 23 in subroutine INVIN and is required when the variable ISIM (Card Group 1, card 1) is greater than zero. It defines the infiltration and erosion characteristics of an HRU for storm-mode computations. The parameters KSAT, PSP, RGF, and DRN are always included on the card. However, the remaining parameters are only required if ISIM equals 3. One card is required for each HRU defined. Card group 3 follows a //SYSIN3 DD * card in the input card deck.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
1 (NRU cards)	1-7	'01IN-ER'		Card I.D. [Infiltration, Sediment]
	8-10	I3	IRU	HRU I.D.
	11-15	F5.0	KSAT	Hydraulic conductivity of transmission zone (inches per hour)
	16-20	F5.0	PSP	The product of moisture deficit and capillary drive for RECHR equal to field capacity, REMX (in.)
	21-25	F5.0	RGF	Ratio of PSP at field capacity (RECHR=REMX) to PSP at wilting point (RECHR=0)
	26-30	F5.0	DRN	Drainage factor for redistribution of saturated moisture storage, SMS, to recharge zone moisture storage, RECHR, as a fraction of hydraulic conductivity, KSAT
	31-40	F10.0	KR*	Parametric coefficient in rain drop-flow depth soil detachment relation
	41-50	F10.0	HC*	Parametric coefficient in raindrop-flow depth soil detachment relation
	51-60	F10.0	KF*	Parametric coefficient in runoff detachment relation
	61-70	F10.0	KM*	Parametric coefficient in sediment transport capacity relation
	71-80	F10.0	EN*	Parametric coefficient in sediment transport capacity relation

*NOTE: Required only if ISIM=3.

Card Group 4: Flow and Sediment Routing Specifications

This card group is read on input unit 24 in subroutine INVIN and is required only if the variable ISIM (Card Group 1, card 1) is equal to 2 or 3. These cards define the type and flow characteristics of the overland flow planes and channel, reservoir, and junction segments into which the basin has been divided. One card 2 is required for each overland flow plane defined and one card 4 is required for each channel, reservoir, and junction segment defined. Card group 4 follows a //SYSIN4 DD * card in the input card deck.

An example watershed with three HRU's is shown in figure 19a. HRU 1 is the headwater area of the watershed, HRU 2 is the area adjacent to the main channel and major tributaries, and HRU 3 is an area adjacent to the main channel in the lower part of the watershed. A schematic diagram delineating the segmentation of the figure 19a sample watershed into nine overland-flow planes and nine channel segments is shown in figure 19b. It should be noted that overland-flow planes delineated within an HRU and having the same length, slope, and roughness characteristics can be assigned the same plane identification (PCRID). All the overland-flow planes defined except ØF8 have each been used at least twice in their respective HRU's. Flow-plane characteristics are described on card 2 of this group and one card is completed for each overland-flow plane defined. There is no sequential order required for card 2's. The model computes the rainfall excess and overland-flow hydrograph for a unit width on each defined flow plane. This information then is stored and reused each time a given flow plane is specified as lateral inflow to a channel segment.

Channel segments also can be reused when two or more channel segments have the same length, lateral inflows, and upstream inflows. The outflow hydrograph for the channel segment will be computed once and reused as many times as specified. In figure 19b, channel segments C1, C2, and C6 each are used at least twice. Reuse of overland-flow plane and channel segments where possible decreases storm-mode computation time by eliminating repetitive computations for similar areas. However, areas reused must be within the same HRU to ensure use of the same antecedent soil-moisture conditions and storm-precipitation record.

The channel segments from figure 19b and the upstream and lateral inflows to each are listed in table 11. This information is placed on card 4 of this group and one card 4 for each channel segment is required. Table 11 is presented to illustrate the two card-sequencing requirements for card 4's. The first is that for any channel to be used as an upstream inflow, it must be defined in the channel segment sequence prior to its use. The second requirement is specified for efficient processing and storage. It states that when a channel segment uses as an upstream inflow the channel segment defined by the previous card 4, this previous card 4 segment must appear as upstream inflow 1 (UP1). For example, in table 11, channel segment C2 must appear as Upstream 1 inflow for channel segment C3. This eliminates the need to store and retrieve this segment information before it is processed.

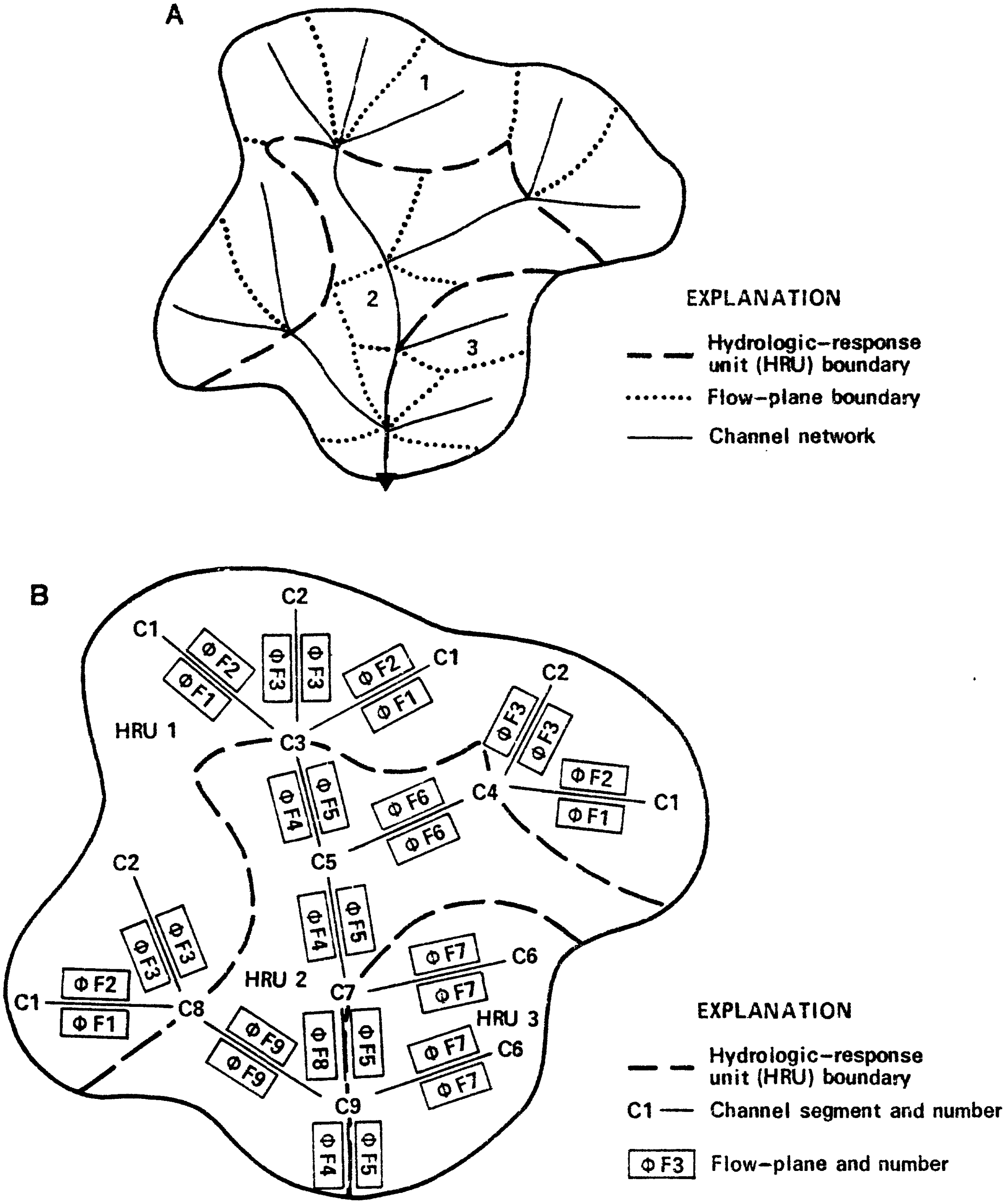


Figure 19.--Delineation of sample watershed: (A) Hydrologic response unit (HRU), flow-plane boundaries, and channel network; (B) schematic of flow planes and channel segments.

Table 11.--*List of channel segments delineated in figure 19b and their upstream and lateral inflows*

Channel segment	Upstream 1	Upstream 2	Upstream 3	Lateral 1	Lateral 2
C1-------------				ØF1	ØF2
C2-------------				ØF3	ØF3
C3-------------	C2	C1	C1	ØF4	ØF5
C4-------------	C1	C2		ØF6	ØF6
C5-------------	C4	C3		ØF4	ØF5
C6-------------				ØF7	ØF7
C7-------------	C6	C5		ØF8	ØF5
C8-------------	C1	C2		ØF9	ØF9
C9-------------	C8	C7	C6	ØF4	ØF5

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
1	1-8	'01NØFSEG'		Card I.D.
	14-15	I2	NØFSEG	Number of overland-flow planes (maximum of 50)
2	1-6	'02ØFID'		Card I.D.
(NØFSEG				[UNITD]
cards)	11-14	A4	PCRID	Overland-flow plane identification
	15-27			Blank
	28-32	F5.2	IMPV	Impervious area, decimal fraction

NOTE: If IMPV equals 0.0 or 1.0 then all values on this card are for the pervious or impervious area, respectively. If 0.0 < IMPV < 1.0 then two no. 2 cards are read with the first card being the values for the pervious area and the second card being the values for the impervious area.

	33-34	I2	TYPE	Type of overland-flow plane 4=explicit specification of kinematic parameters α and m 5=turbulent overland-flow plane 6=laminar overland-flow plane 99=no routing done. Precipitation excess used as outflow from plane.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
2	35	I1	PRTIN	Print inflow switch 0=no 1=print rainfall excess 2=plot rainfall excess, see note after card 4
	36	I1	PRTØUT	Print outflow switch 0=no 1=print outflow 2=plot outflow, see note after card 4
	37-38	I2	NDX	Number of intervals into which length of overland-flow plane is subdivided for finite-difference calculations, maximum=10
	39-43	F5.0	FLGTH	Length of overland-flow plane (ft)
	44-48	F5.0	SLØPE	Slope of overland-flow plane (ft/ft) if TYPE=5 or 6. If TYPE=4, then leave blank
	49-53	F5.0	FRN	Roughness parameter for TYPE=5 or 6. If TYPE=4, then leave blank
	54-58	F5.0	PARM1	If TYPE=4, then kinematic parameter α, else blank
	59-63	F5.0	PARM2	If TYPE=4, then kinematic parameter m, else blank
	64-65	I2	NIRU	Sequence number of the HRU associated with this overland-flow plane
	66-70	F5.0	THRES	Minimum depth of flow to continue overland-flow routing (in.)
	71-75	F5.0	DTM	Time interval for overland-flow routing (minutes)
	76-80	F5.0	DTØS	Time interval for printing segment outflow (minutes) (omit if PRTØUT=0)
3	1-8	'03NCRSEG'		Card I.D.
	14-15	I2	NCRSEG	Number of channel, reservoir, and junction segments (maximum of 50)
4 (NCRSEG cards)	1-6	'04CHID'		Card I.D. [ROUTE]
	7-10	A4	PCRID	Channel, reservoir, or junction segment identification

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
4	11-14	A4	UP1	Identification of upstream inflow segment number 1, else blank if none. If immediately preceding channel segment (PCRID) is used as upstream inflow, it must be designated as UP1.
	15-18	A4	UP2	Identification of upstream inflow segment number 2, else blank if none.
	19-22	A4	UP3	Identification of upstream inflow segment number 3, else blank if none
	23-26	A4	RBC	Identification of overland-flow plane that contributes lateral inflow to right side of channel, else blank if none
	27-30	A4	LBC	Identification of overland-flow plane that contributes lateral inflow to left side of channel, else blank if none
	33-34	I2	TYPE	Type of segment 1=rectangular open channel 3=triangular open channel 4=explicit specification of kinematic parameters α and m 7=junction 8=reservoirs, Puls routing 9=reservoir, linear routing
	35	I1	PRTIN	Print/plot inflow switch 0=no 1=print inflow to segment 2=plot inflow to segment, see note
	36	I1	PRTØUT	Print/plot outflow switch 0=no 1=print outflow from segment 2=plot outflow from segment, see note
	37-38	I2	NDX	If TYPE < 7 Number of intervals into which the length of channel segment

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
4				is to be subdivided for finite-difference computations, maximum=10 If TYPE=8, number of outflow-storage pairs in Puls routing table If TYPE=9, blank
	39-43	F5.0	FLGTH	Length of channel segment in feet
	44-48	F5.0	SLØPE	Slope of channel segment (ft/ft), not required if TYPE=4, 7, 8, or 9
	49-53	F5.0	FRN	Roughness (Manning's "n") of channel segment, not required if TYPE=4, 7, 8, or 9
	54-58	F5.0	PARM1	If TYPE=1, the width of channel (ft) If TYPE=3, then ratio of horizontal to vertical change in side slope (right side) If TYPE=4, then kinematic parameter α Else leave blank
	59-63	F5.0	PARM2	If TYPE=3, same as TYPE 3 above (left side) If TYPE=4, then kinematic parameter m, Else leave blank
	66-70	F5.0	THRES	Minimum rate of discharge to continue channel flow routing (cfs)
	71-75	F5.0	DTM	Time interval for channel flow routing (minutes) If ITYPE=8 must be 5 or 15 minutes
	76-80	F5.0	DTØS	Time interval for printing segment outflow (minutes) (omit if PRTØUT=0)

Note: Stormflow plots for up to 8 overland-flow planes and/or channel segments may be requested.

Card Group 5: Precipitation Form Adjustment

This card group is read on input unit 25 in subroutine TIMEY and is required only if the variable IPSW (Card Group 1, card 1) is equal to 1. A set of cards 1 and 2 are required for each water year in a simulation run. Precipitation occurring on the Julian dates specified will be considered all snow or all rain, thus overriding the algorithm in subroutine PRECIP which apportions snow and rain on the basis of air temperature. These cards normally are used when continuous records of precipitation and air temperature are available to delineate precipitation form. The cards are read on the first day of each water year. Card group 5 follows a //SYSIN5 DD * card in the input card deck.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
1	1-6	'01SPFS'		Card I.D. [PRECIP]
	11-15	I5	K1	Number of dates to be read (at least 1)
	16-80	13I5	KSV	Julian dates of days with precipitation events whose form should be considered all snow. Zero for the first date indicates no snow form changes
	11-80	14I5	KSV	Continuation cards if more than 13 values are used
2	1-6	'02SPFR'		Card I.D. [PRECIP]
	11-15	I5	K2	Number of dates to be read (at least 1)
	16-80	13I5	KSV	Julian dates of days with precipitation events whose form should be considered all rain. Zero for the first date indicates no rain form changes
	11-80	14I5	KSV	Continuation cards if more than 13 values are used

Card Group 6: Snowpack Adjustment

This card group is read on input unit 26 in subroutine TIMEY and is required only when the array INPK (Card Group 1, card 27) has a nonzero value in the array element associated with the current water year. INPK is an array containing one Julian date for each water year when snowcourse data are to be input to update snowpack water equivalent values computed by the model. The data from this card group are used to adjust the snowpack water equivalents on each hydrologic response unit. These cards are read on the first day of each water year. Card group 6 follows a //FT26F001 DD * in the input card deck.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
1	1-10	'01PKADJ-WE'		Card I.D. [PKADJ]
	11-80	14F5.2	DP(I)	Snowpack water equivalent on HRU(I) as measured or estimated from snowcourse data (in.). Data are sequential from HRU(1) to HRU(NRU). For basins with greater than 14 HRU's, the data are continued on a second card. For DP(I) > 0 the snowpack is set to the specified value on HRU(I). For DP(I) < 0 the snowpack is not not adjusted on HRU(I). For DP(I)=0 the snowpack on HRU(I) is melted and becomes available for infiltration and surface run-off.

Card Group 7: Optimization or Sensitivity Analysis Data

This card group is read on input unit 27 in subroutines DATIN and ØPINIT and is required only when variable IØPT or ISEN (Card Group 1, card 1) is not equal to 0. Card Group 7, for either optimization or sensitivity analysis, followed by Card Group 8 must be included for each optimization or sensitivity analysis desired. Card group 7 follows a //FT27F001 DD * card in the input card deck.

Data cards for both optimization and sensitivity analysis

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
1	1-6	'01ØPT1'		Card I.D. [OPTIMIZATION]
	11-15	I5	BYRIN	Beginning year of initialization period (for example, 1978)
	16-20	I5	BMØIN	Beginning month of initialization period (1-12)
	21-25	I5	BDYIN	Beginning day of initialization period (1-31)
	26-30	I5	EYRIN	Ending year of initialization period (for example, 1979)
	31-35	I5	EMØIN	Ending month of initialization period (1-12)
	36-40	I5	EDYIN	Ending day of initialization period (1-31)

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
2	1-6	'02ØPT2'		Card I.D. [OPTIMIZATION]
	11-15	I5	BYRØP	Beginning year of optimization or sensitivity analysis period (for example, 1979)
	16-20	I5	BMØØP	Beginning month of optimization or sensitivity analysis period (1-12)
	21-25	I5	BDYØP	Beginning day of optimization or sensitivity analysis period (1-31)
	26-30	I5	EYRØP	Ending year of optimization or sensitivity analysis period (for example, 1980)
	31-35	I5	EMØØP	Ending month of optimization or sensitivity analysis period (1-12)
	36-40	I5	EDYØP	Ending day of optimization or sensitivity analysis period (1-31)
3	1-6	'03IØBF'		Card I.D. [OPTIMIZATION]
	11-15	I5	IØBF	Objective function selection switch 1=sum of absolute values of the differences between predicted and observed flows 2=sum of squares of differences between predicted and observed flows
	16-20	I5	ITRANS	Logarithmic transformation switch 0=do not transform predicted and observed runoff values before objective function computation 1=transform predicted and observed runoff values before objective function computation

NOTE: If this is a sensitivity analysis run, skip to the "Data cards for sensitivity analysis" section for card 4.

Data cards for optimization

These data cards define which model parameters are to be optimized in a given run and the boundary constraints on each parameter. The storm periods for optimizing unit storm parameters are also specified here.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
4	1-6	'04ØPT4'		Card I.D. [OPTIMIZATION]
	11-15	I5	NV	Number of parameters to be optimized
	16-20	I5	NTRY	Number of optimization cycles
	21-25	I5	IPRIØR	Prior information switch 0=no normal prior information 1=normal prior information

NOTE: One set of cards 5 and 6 is required for each parameter to be optimized (NV on card 4).

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
5	1-8	'05PARAM1'		Card I.D. [OPTIMIZATION]
	11-15	I5	LØP	Parameter to be optimized. See table 3 for parameter numbers
	16-20	I5	ILØPL	Switch indicating whether each value of a distributed parameter is to be adjusted by the same magnitude or same percentage of the initial value 0=same magnitude 1=same percentage of initial value
	21-25	I5	NVAR	Number of values of a distributed parameter that are to be adjusted (Set NVAR=1 for parameters that are not distributed)
	26-30	I5	IDSW	Switch indicating whether card 6 is included for this parameter. If NVAR equals the total number of parameter elements, then IDSW=0. 0=not included 1=included
	31-35	F5.2	P	Initial step size for parameter adjustment, expressed as a fraction of parameter magnitude (These are identical in function to PINC in a sensitivity analysis and should be identical for all the

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
				parameters if IØPT is negative; when IOPT is negative, a suggested value is 0.01.)
5	36-40	F5.1	GU	Lower constraint for parameter
	41-45	F5.1	HU	Upper constraint for parameter

NOTE: Include card 6 for this parameter only if IDSW on card 5 is 1.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
6	1-8	'06PARAM2'		Card I.D. [OPTIMIZATION]
	11-80	35I2	NDVR(.,J)	The index numbers of the units on which a distributed parameter is to be adjusted (J=1, NVAR). If these numbers are the consecutive integers 1,2, 3,..., NVAR, this card should be omitted and IDSW on card 5 set to 0

NOTE: Include card 7 if |IOPT| > 2; otherwise delete.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
7	1-7	'07STØRM'		Card I.D. [OPTIMIZATION]
	11-80	35I2	TESTNØ(J)	Storm events to be included in objective function 1=storm used in computation of objective function 0=storm not used (J=1 to NSP; refers to sequential order of storm periods defined in Card Group 2)

NOTE: Include NV Card 8's, only if IPRIØR=1

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
8	1-7	'08PRIØR'		Card I.D. [OPTIMIZATION]
	11-80	14F5.2	VB(.,J)	One row of the covariance matrix of the prior information goes on each card (J=1,NV)

NOTE: Include Card 9 if IOPT=±2.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
9	1-7	'09CØRØPT'		Card I.D. [OPTIMIZATION]
	11-15	I5	IP	Autoregressive order
	16-20	I5	IQ	Moving-average order

Data cards for sensitivity analysis

CARD	COLUMNS	FORMAT	VARIABLÉS	DEFINITIONS
4	1-7	'04SENST'		Card I.D. [SENSITIVITY ANALYSIS]
	11-15	I5	NV	Number of parameters to be analyzed
	16-20	F5.2	PINC	Fraction by which parameters are to be varied to estimate sensitivities (a suggested value is 0.01)
	21-25	I5	IPRIØR	Prior information switch 0=no normal prior information 1=normal prior information

NOTE: One set of cards 5 and 6 is required for each parameter to be analyzed (NV on card 1)

5 Identical to card 5 for optimization except no values for P, GU and HU are needed.

6 Identical to card 6 for optimization.

NOTE: Include card 7 if ISEN>2; otherwise delete.

7 Identical to card 7 for optimization.

NOTE: Include NV card 8's only if IPRIØR=1.

8 Identical to card 8 for optimization.

NOTE: Include card 9 if ISEN=2.

9 Identical to card 9 for optimization.

Card Group 8: Optimization/Sensitivity Analysis Continuation

This card group is read on input unit 27 in subroutines RØSØPT or SENST and is required only if one of the variables IØPT or ISEN (Card Group, card 1) is not equal to 0. This card group permits successive optimization or sensitivity analysis runs on a data set. When an optimization or sensitivity analysis is selected, this card group must be followed by cards 4 to 9 of Card Group 7 to supply the necessary information. Any number of Group 8 cards may be used. A blank Card Group 8 terminates the simulation. Card Group 8 always follows Card Group 7.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS

NOTE: Switches are as described on cards 1 and 6, Card Group 1 and on card 3, Card Group 7.

CARD	COLUMNS	FORMAT	VARIABLES	DEFINITIONS
1	1-10	'01OPT/SENS'		Card I.D.
	11-15	I5	IØPT	Optimization switch
	16-20	I5	ISEN	Sensitivity analysis switch
	21-25	I5	IØBF	Objective function switch
	26-30	I5	ITRANS	Log transformation switch
	31-35	I5	MFS	Beginning month of objective function application
	36-40	I5	MFN	Ending month of objective function application

SYSTEM OUTPUT

System output can be in the form of tabular summaries of hydrologic and climatic variables, printer plots displaying observed and predicted mean daily flow and stormflow hydrographs, statistical summaries, and files of predicted discharge stored on direct-access devices for further hydrologic analysis. The specific combination of these output options is selected by the user in the input data stream.

Tabular summaries are available for both the daily and storm components of the System. The daily flow summaries can be output as averages and totals for the entire basin and for each HRU. Summary tables can range from a simple table of predicted versus observed discharge to annual, monthly, and daily averages and totals for certain hydrologic and climatic variables. The desired daily mean and totals options for basin values are selected using the System variable IPØP1. An example of the output summary table of predicted versus observed mean daily discharge (IPØP1=0) is shown in figure 20. Examples of the output tables for annual (IPØP1=1), monthly (IPØP1=2), and daily (IPØP1=3) summaries of hydrologic and climatic variables are shown in figures 21, 22, and 23. For a specified value of IPØP1, the table indicated plus all tables for IPØP1 values less than the value selected are output. The variable identifiers used in these tables, and the definition of each, are listed in table 12.

OBSERVED AND PREDICTED RUNOFF FOR WY 1957

DAY	OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH	
	OBS	PRED	OBS	PRED	OBS	PRED	OBS	PRED	OBS	PRED	OBS	PRED
1	0.04	0.00	0.15	0.12	0.04	0.01	0.26	0.67	8.30	7.97	1.80	1.30
2	0.04	0.00	0.05	0.08	0.04	0.01	0.20	0.62	4.90	5.19	1.60	1.15
3	0.09	0.02	0.05	0.05	0.04	0.00	0.18	0.58	2.80	3.20	1.30	1.05
4	0.11	0.02	0.04	0.04	0.04	0.00	0.82	3.18	1.90	2.31	1.10	0.96
5	0.04	0.00	0.04	0.03	0.04	0.00	1.70	2.05	2.80	3.61	0.94	0.89
6	0.04	0.00	0.04	0.02	0.04	0.00	1.20	1.48	2.70	2.67	1.00	1.98
7	0.04	0.00	0.05	0.02	0.04	0.01	0.94	1.19	2.50	2.31	3.10	2.73
8	0.03	0.00	0.05	0.02	0.06	0.03	0.78	1.51	2.50	2.53	4.00	2.01
9	0.03	0.00	0.05	0.01	0.05	0.01	5.50	4.20	2.70	1.88	2.70	3.35
10	0.03	0.00	0.05	0.01	0.04	0.00	6.50	5.00	3.70	2.52	2.60	2.44
11	0.04	0.00	0.04	0.01	0.05	0.03	2.60	3.25	2.40	1.75	2.50	2.31
12	0.04	0.00	0.04	0.01	1.30	0.97	1.70	2.18	1.90	1.53	2.00	1.94
13	0.04	0.00	0.04	0.01	7.30	3.35	1.20	1.64	1.50	1.37	1.60	1.47
14	0.04	0.00	0.03	0.01	6.60	3.59	0.88	1.33	1.10	1.25	1.30	1.26
15	0.04	0.00	0.04	0.04	1.50	1.68	0.78	1.12	0.88	1.38	1.20	1.24
16	0.04	0.00	0.19	0.03	0.68	1.03	0.60	0.98	0.83	1.09	0.94	1.00
17	0.04	0.00	0.04	0.01	0.42	0.77	0.49	0.88	0.68	1.00	0.83	0.91
18	0.06	0.00	0.04	0.01	0.43	0.80	0.42	0.80	0.64	0.94	0.78	0.87
19	0.05	0.00	0.03	0.01	0.31	0.47	0.39	0.73	3.00	5.01	0.68	0.79
20	0.05	0.00	0.03	0.01	0.38	0.89	0.48	1.26	3.50	3.48	0.60	0.73
21	0.05	0.01	0.21	0.07	4.90	11.53	0.94	1.12	2.40	2.36	0.56	0.88
22	0.19	0.03	0.06	0.01	12.00	8.25	11.00	9.74	2.00	1.94	0.72	0.80
23	0.09	0.00	0.04	0.01	5.10	5.48	8.50	6.90	1.70	1.64	0.56	0.60
24	0.08	0.00	0.04	0.01	2.50	3.75	2.90	3.59	1.50	1.39	0.49	0.60
25	0.09	0.00	0.04	0.01	1.40	2.24	1.90	2.38	1.20	1.22	0.66	0.74
26	0.19	0.04	0.04	0.01	0.94	1.63	1.30	1.73	1.40	1.59	0.56	0.64
27	0.06	0.00	0.04	0.01	0.68	1.29	2.20	1.60	1.10	1.07	0.56	0.48
28	0.06	0.00	0.04	0.01	0.56	1.24	12.00	11.77	1.70	1.96	0.49	0.46
29	0.06	0.00	0.04	0.01	0.49	0.93	84.00	70.19	0.00	0.00	0.49	0.43
30	0.05	0.00	0.04	0.01	0.36	0.84	6.10	17.77	0.00	0.00	0.49	0.41
31	0.44	0.19	0.00	0.00	0.31	0.74	3.70	7.87	0.00	0.00	0.45	0.39

Figure 20.--Summary table of predicted versus observed daily mean discharge.

ANNUAL SUMMARY 1957 OBSERVED PRECIP= 55.70 POTENTIAL ET= 60.28 PREDICTED RUNOFF(IN) = 20.13 OBSERVED RUNOFF(IN) = 2

NET PRECIP= 51.50 ACTUAL ET= 29.22 (CFS)= 363.42 (CFS)= 38

INTERCEPTION LOSS= 4.20 SNOWMELT= 7.40 MEAN DAILY(CFS)= 1.00 MEAN DAILY(CFS)=

GW IN= 3.23 SSR IN= 11.52 SSR TO GW= 1.92 SURFACE RO= 5.40 SSR FLOW= 9.59 GW FLOW= 5.14 GW SINK= 0.00

Figure 21.--Annual summary table for basin average and total values.

MO SUMMARY 1/1957	O-PPT	N-PPT	INLOS	P-ET	A-ET	SMELT	GW-FL	RS-FL	SRO	P-ROFF	O-ROFF
	11.76	11.59	0.16	1.24	0.94	7.00	1.20	4.63	3.55	169.33	162.16
										(9.38)	(8.98)
									MEAN CFS	5.46	5.23

ERROR SUMMARY

	ABS VALUE OBJ FNC		SUM OF SQUARES OBJ FNC	
	NO LOG	LOG	NO LOG	LOG
SUM	47.75	7.97	362.98	3.31
CUM SUM	76.51	17.16	451.07	5.91
MEAN	1.54	0.26	11.71	0.11
PERCENT	29.45		65.42	

Figure 22.-- Monthly summary table for basin average and total values.

CANE BRANCH, KY 7HRUS, DAILY

MO	DY	YEAR	TMX	TMN	ORAD	O-PPT	N-PPT	INLOS	P-ET	A-ET	SMAV	%SN	#SN	PWEQV	SMELT	GW-ST	RS-ST	GW-FL	RS-FL	SRO	TRO	P-ROFF	O-ROFF
1	1	1957	7.	-6.	309.7	0.00	0.00	0.00	0.03	0.03	5.60	0	0	0.00	0.00	0.53	0.11	0.028	0.009	0.000	0.037	0.67	0.26
1	2	1957	-2.	-14.	310.7	0.00	0.00	0.00	0.02	0.02	5.58	0	0	0.00	0.00	0.51	0.10	0.027	0.007	0.000	0.034	0.62	0.20
1	3	1957	9.	-12.	311.8	0.00	0.00	0.00	0.03	0.03	5.55	0	0	0.00	0.00	0.49	0.09	0.026	0.006	0.000	0.032	0.58	0.18
1	4	1957	7.	-2.	78.2	0.90	0.89	0.01	0.04	0.03	5.78	0	0	0.00	0.00	0.60	0.44	0.031	0.049	0.096	0.176	3.18	0.82
1	5	1957	5.	-1.	75.6	0.02	0.01	0.01	0.04	0.03	5.76	0	0	0.00	0.00	0.58	0.34	0.031	0.081	0.001	0.113	2.05	1.70
1	6	1957	2.	1.	42.7	0.01	0.01	0.00	0.03	0.03	5.73	0	0	0.00	0.00	0.57	0.27	0.030	0.052	0.000	0.082	1.48	1.20
1	7	1957	7.	-1.	79.0	0.02	0.02	0.01	0.04	0.03	5.71	0	0	0.00	0.00	0.55	0.22	0.029	0.035	0.001	0.066	1.19	0.94
1	8	1957	8.	-6.	79.2	0.25	0.24	0.01	0.04	0.03	5.78	0	0	0.00	0.00	0.63	0.20	0.033	0.028	0.023	0.084	1.51	0.78
1	9	1957	17.	4.	79.5	0.76	0.75	0.01	0.06	0.05	5.76	0	0	0.00	0.00	0.74	0.59	0.039	0.103	0.091	0.233	4.20	5.50
1	10	1957	17.	-5.	79.7	0.44	0.43	0.01	0.05	0.04	5.77	0	0	0.00	0.00	0.84	0.59	0.044	0.188	0.045	0.277	5.00	6.50
1	11	1957	3.	-5.	321.5	0.00	0.00	0.00	0.03	0.03	5.74	0	0	0.00	0.00	0.81	0.43	0.043	0.137	0.000	0.180	3.25	2.60
1	12	1957	11.	-3.	324.0	0.00	0.00	0.00	0.04	0.04	5.70	0	0	0.00	0.00	0.79	0.33	0.042	0.079	0.000	0.121	2.18	1.70
1	13	1957	8.	-4.	326.6	0.00	0.00	0.00	0.04	0.04	5.66	0	0	0.00	0.00	0.76	0.27	0.040	0.051	0.000	0.091	1.64	1.20
1	14	1957	1.	-9.	329.1	0.00	0.00	0.00	0.03	0.03	5.63	0	0	0.00	0.00	0.74	0.22	0.039	0.035	0.000	0.074	1.33	0.88
1	15	1957	-2.	-7.	307.4	0.00	0.00	0.00	0.03	0.03	5.61	0	0	0.00	0.00	0.71	0.19	0.037	0.025	0.000	0.062	1.12	0.78
1	16	1957	-4.	-11.	334.2	0.00	0.00	0.00	0.02	0.02	5.59	0	0	0.00	0.00	0.68	0.16	0.036	0.019	0.000	0.054	0.98	0.60
1	17	1957	-4.	-19.	84.2	0.01	0.01	0.00	0.02	0.00	5.59	99	7	0.01	0.00	0.66	0.14	0.035	0.014	0.000	0.049	0.88	0.49
1	18	1957	-1.	-10.	84.8	0.11	0.08	0.00	0.02	0.00	5.59	99	7	0.09	0.00	0.63	0.12	0.033	0.011	0.000	0.044	0.80	0.42
1	19	1957	9.	-10.	341.9	0.00	0.02	0.01	0.03	0.00	5.59	99	7	0.11	0.00	0.60	0.11	0.032	0.009	0.000	0.041	0.73	0.39
1	20	1957	7.	-4.	86.1	0.30	0.29	0.01	0.04	0.02	5.79	29	2	0.01	0.39	0.68	0.13	0.036	0.010	0.024	0.070	1.26	0.48
1	21	1957	17.	2.	86.8	0.13	0.12	0.01	0.07	0.05	5.76	0	0	0.00	0.04	0.73	0.12	0.038	0.011	0.012	0.062	1.12	0.94
1	22	1957	16.	10.	87.3	1.61	1.60	0.01	0.08	0.07	5.74	0	0	0.00	0.00	0.85	1.01	0.045	0.241	0.254	0.539	9.74	11.00
1	23	1957	17.	-4.	88.0	0.05	0.04	0.01	0.05	0.04	5.73	0	0	0.00	0.00	0.84	0.64	0.044	0.335	0.003	0.382	6.90	8.50
1	24	1957	7.	-6.	355.3	0.00	0.00	0.00	0.04	0.03	5.70	0	0	0.00	0.00	0.82	0.46	0.043	0.156	0.000	0.199	3.59	2.90
1	25	1957	7.	3.	72.3	0.03	0.02	0.01	0.05	0.04	5.67	0	0	0.00	0.00	0.80	0.35	0.042	0.088	0.002	0.132	2.38	1.90
1	26	1957	4.	-2.	361.2	0.00	0.00	0.00	0.04	0.04	5.64	0	0	0.00	0.00	0.77	0.28	0.041	0.055	0.000	0.096	1.73	1.30
1	27	1957	2.	-2.	69.5	0.71	0.68	0.00	0.04	0.00	5.76	99	7	0.53	0.01	0.76	0.23	0.040	0.038	0.011	0.089	1.60	2.20
1	28	1957	8.	-1.	92.0	1.18	1.19	0.01	0.05	0.00	5.81	99	7	0.27	1.45	0.87	0.87	0.046	0.204	0.402	0.652	11.77	12.00
1	29	1957	15.	4.	92.7	4.83	4.82	0.01	0.07	0.05	5.75	0	0	0.00	5.09	1.03	1.92	0.054	1.284	2.549	3.887	70.19	84.00
1	30	1957	5.	-3.	93.5	0.04	0.03	0.01	0.04	0.03	5.75	0	0	0.00	0.01	1.02	0.94	0.054	0.928	0.003	0.984	17.77	6.10
1	31	1957	9.	-1.	94.3	0.36	0.35	0.01	0.05	0.04	5.77	0	0	0.00	0.00	1.11	0.70	0.059	0.341	0.036	0.436	7.87	3.70

Figure 23.--Daily summary table for basin average and total values.

Table 12.--*Variable identifiers used in output summary tables for basin averages and totals, and their definitions*

Variable	Definition
TMX	Maximum temperature (°F or °C, depending on input data)
TMN	Minimum temperature (°F or °C, depending on input data)
ORAD	Observed solar radiation (langleys)
O-PPT	Observed precipitation (inches)
N-PPT	Net precipitation (inches)
INLOS	Interception loss (inches)
P-ET	Potential evapotranspiration (inches)
A-ET	Actual evapotranspiration (inches)
SMAV	Available water in soil profile (inches)
%SN	Percent of basin with snow cover
#SN	Number of HRU's with snow cover
PWEQV	Snowpack water equivalent (inches)
SMELT	Snowmelt (inches)
GW-ST	Ground-water reservoir storage (inches)
RS-ST	Subsurface reservoir storage (inches)
GW-FL	Ground-water flow (inches)
RS-FL	Subsurface flow (inches)
SRO	Surface runoff (inches)
TRO	Predicted runoff (inches)
P-ROFF	Predicted mean daily discharge (cfs)
O-ROFF	Observed mean daily discharge (cfs)
GW IN	Inflow to ground-water reservoirs from HRU's (inches)
SSR IN	Inflow to subsurface reservoirs (inches)
SSR to GW	Inflow to ground-water reservoirs from subsurface reservoirs (inches)
SURFACE RO	Total surface runoff (inches)
SSR FLOW	Total outflow from subsurface reservoirs (inches)
GW FLOW	Total outflow from ground-water reservoirs (inches)
GW SINK	Seepage to ground water that does not contribute to ground-water outflow from basin (inches)

Tabular summaries of certain hydrologic and climatic variables can also be output for each HRU. The desired HRU summaries are selected using the System variable IPØP2. Inflow and outflow summaries for each ground water and subsurface reservoir also are included. When IPØP2 equals zero, there are no HRU summaries output. Examples of the output tables for annual (IPØP2=1), monthly (IPØP2=2), and daily (IPØP2=3) summaries for hydrologic and climatic variables associated with each HRU are shown in figures 24, 25, and 26. For a specified value of IPØP2, the table indicated plus those tables for IPØP2 values less than the value specified, will be output. The variable identifiers used in the HRU summaries and the definition of each are listed in table 13. The specific period within the water year for the printing of daily HRU values can be specified by using the beginning Julian date for the output in variable IPUN1 and the ending Julian date for the output in variable IPUN2.

```
      IRU        SL-AS  ELEV     O-PPT    N-PPT  INTLOS      PET      AET   SMELT      UGS      USS     SRO
AUS 1957  1       NE20  1100.    55.70    51.25    4.45    57.71    28.19    8.07     3.90    11.14    5.95
AUS 1957  2       SW30  1100.    55.70    51.19    4.51    58.91    29.94    7.02     3.27    10.09    6.24
AUS 1957  3        S10  1250.    55.70    51.19    4.51    64.66    30.63    7.16     3.13     9.58    5.95
AUS 1957  4        E20  1250.    55.70    51.22    4.48    57.63    29.00    7.17     3.35    10.83    6.25
AUS 1957  5       SW10  1250.    55.70    51.19    4.51    64.70    30.53    7.07     3.16     9.62    6.13
AUS 1957  6       NE20  1250.    55.70    51.26    4.44    56.95    27.97    8.13     3.96    11.29    5.95
AUS 1957  7        E20  1200.    55.70    55.70    0.00    57.88    26.39    7.19     0.00    27.86    1.54
      RES#  SSR-IN  SSR-STO  SSR-FLOW  SSR-TO-GW          GW-IN   GWSS-IN  GW-STOR  GW-FLOW  GW-SINK
       1    10.401   0.000    8.606     1.795             3.227    1.918    0.011    5.137    0.000
       2    27.863   0.061   24.093     3.715             0.000    0.000    0.000    0.000    0.000
```

Figure 24.--Annual summary table for HRU's.

```
MUS  IRU MO   YEAR  SA    ELEV    O-PPT   N-PPT   INTCP   POTET   ACTET   SM-AV   PWEQV   SMELT     UGS      USS      SRO
       1  4   1957  NE20  1100.    4.47    3.86    0.61    4.92    4.31    3.20    0.00    0.00    0.23     0.86     0.37
       2  4   1957  SW30  1100.    4.47    3.86    0.61    4.98    4.38    3.17    0.00    0.00    0.12     0.78     0.34
       3  4   1957   S10  1250.    4.47    3.86    0.61    5.52    4.92    2.75    0.00    0.00    0.12     0.59     0.30
       4  4   1957   E20  1250.    4.47    3.86    0.61    4.90    4.29    3.23    0.00    0.00    0.12     0.85     0.36
       5  4   1957  SW10  1250.    4.47    3.86    0.61    5.49    4.88    2.76    0.00    0.00    0.12     0.65     0.31
       6  4   1957  NE20  1250.    4.47    3.86    0.61    4.85    4.24    3.25    0.00    0.00    0.26     0.86     0.37
       7  4   1957   E20  1200.    4.47    4.47    0.00    4.92    2.97    2.14    0.00    0.00    0.00     1.67     0.04
      RES#  SSR-IN  SSR-STO  SSR-FLOW  SSR-TO-GW          GW-IN   GWSS-IN  GW-STOR  GW-FLOW  GW-SINK
       1    0.761   0.030    0.569     0.191              0.150    0.199    0.210    0.529    0.000
       2    1.667   0.033    1.355     0.311              0.000    0.000    0.000    0.000    0.000
```

Figure 25.--Monthly summary table for HRU's.

```
IRU    MO DY  YR   SWR TMX TMN OPPT NPPT INT  INLS PET  AET  SMAV PWEQV DEN  PACT ALB  TCAL SMLT INFL UGS  USS  SRO
 1      4 28 1957 170. 84. 55. 0.17 0.11 0.00 0.06 0.25 0.19 3.66 0.00  0.23  0.000.77 112.3 0.00 0.11 0.00 0.00 0.00
 2      4 28 1957 179. 87. 58. 0.17 0.11 0.00 0.06 0.25 0.19 3.63 0.00  0.21  0.000.91  14.2 0.00 0.11 0.00 0.00 0.00
 3      4 28 1957 185. 86. 56. 0.17 0.11 0.00 0.06 0.28 0.22 3.25 0.00  0.21  0.000.91  11.1 0.00 0.11 0.00 0.00 0.00
 4      4 28 1957 178. 86. 56. 0.17 0.11 0.00 0.06 0.25 0.19 3.68 0.00  0.21  0.000.80  16.3 0.00 0.11 0.00 0.00 0.00
 5      4 28 1957 184. 87. 57. 0.17 0.11 0.00 0.06 0.28 0.22 3.27 0.00  0.21  0.000.91  12.9 0.00 0.11 0.00 0.00 0.00
 6      4 28 1957 170. 84. 54. 0.17 0.11 0.00 0.06 0.25 0.19 3.71 0.00  0.23  0.000.77 109.9 0.00 0.11 0.00 0.00 0.00
 7      4 28 1957 178. 86. 57. 0.17 0.17 0.00 0.00 0.25 0.08 2.23 0.00  0.21  0.000.91  17.4 0.00 0.17 0.00 0.00 0.00
      RES#  SSR-IN  SSR-STO  SSR-FLOW  SSR-TO-GW          GW-IN   GWSS-IN  GW-STOR  GW-FLOW  GW-SINK
       1    0.000   0.036    0.001     0.002              0.000    0.002    0.230    0.012    0.000
       2    0.000   0.040    0.002     0.002              0.000    0.000    0.000    0.000    0.000
```

Figure 26.--Daily summary table for HRU's.

Table 13.--*Variable identifiers used in output summary table for HRU values, and their definitions*

Variable	Definition
SWR	Shortwave solar radiation (langleys)
TMX	Maximum temperature (°F)
TMN	Minimum temperature (°F)
OPPT	Observed precipitation (inches)
NPPT	Net precipitation (inches)
INT	Computed interception (inches)
INLS	Evaporated and sublimated moisture loss from interception (inches)
PET	Potential evapotranspiration (inches)
AET	Actual evapotranspiration (inches)
SMAV	Available water in soil profile (inches)
PWEQV	Snowpack water equivalent (inches)
DEN	Snowpack density (grams per cubic centimeter)
PACT	Snowpack temperature (°C)
ALB	Computed albedo
TCAL	Net energy balance of snowpack (calories)
SMELT	Snowmelt (inches)
INFL	Infiltration (inches)
UGS	Seepage to ground-water reservoir (inches)
USS	Seepage to subsurface reservoir (inches)
SRO	Surface runoff (inches)
SA	Slope and aspect
ELEV	Elevation (feet)
SSR-IN	Inflow to subsurface reservoir (inches)
SSR-STO	Storage in subsurface reservoir (inches)
SSR-FLOW	Outflow from subsurface reservoir to streamflow (inches)
SSR-TO-GW	Outflow from subsurface reservoir to ground-water reservoir (inches)
GW-IN	Inflow to ground-water reservoir from HRU's (inches)
GWSS-IN	Inflow to ground-water reservoir from subsurface reservoirs (inches)
GW-STOR	Storage in ground-water reservoir (inches)
GW-FLOW	Outflow from ground-water reservoir (inches)
GW-SINK	Seepage from ground water that does not contribute to ground-water outflow from basin (inches)

HRU summaries are written to input/output unit 3. In the cataloged procedure PRMODEL, unit 3 is defined as a dummy unit. Therefore, if HRU summary output is desired, unit 3 must be redefined as a SYSOUT file. See Control and System Input Specifications for details.

A summary table of observed and predicted peak flows and runoff volumes for each storm period simulated is printed after the last yearly summary; figure 27 is an example of this table. Small differences may occur between "storm predicted volume" and "routed outflow." This is because the predicted volume is computed as the sum of the rainfall excess, subsurface flow and baseflow, whereas the routed outflow is the computed volume past the outflow point at the end of the user-defined storm period. Some rainfall excess may remain to be routed if the storm period is ended early in the hydrograph recession.

Tabular summaries of inflow and outflow for specified overland-flow planes and channel segments can be output for all storm events. The overland-flow plane and channel segments are selected using the PRTIN and PRTØUT System variables. The time interval for printing segment outflows can be specified in the variable DTØS. An example of inflow and outflow summary table for a storm is shown in figure 28.

Printer plots of observed and predicted discharge for mean daily flows, stormflows, and sediment concentrations can be output. Mean daily flow plots are selected by setting variable IPLØT=1. Plot scale can be linear (IPLTYP=0) or semilog (IPLTYP=1). The starting and ending month and day for the plot period and the maximum and minimum values for the Y-axis are user-definable. An example of a linear printer plot is shown in figure 29; an example of a linear semilog printer plot is shown in figure 30. Storm-flow plots are obtained by setting the variables PRTIN/PRTØUT=2 for up to eight overland-flow or channel segments. An example of the stormflow hydrograph plot is shown in figure 31; an example of a sediment concentration plot is shown in figure 32.

Predicted mean daily and stormflow discharges can be stored on a direct-access device for later processing by WATSTORE, SAS, or user-written data analysis programs. Two output formats are available for storing mean daily discharges by water year. One is the standard WATSTORE daily-values format (IDØUT=2), which makes the record compatible with WATSTORE and SAS programs on the U.S. Geological Survey computer system. The other (IDØUT=1) is simply a record with 366 data values and a header containing four data items, one of which is the water year of the record. All storm discharges are output by storm period, and are in the standard WATSTORE unit-values format.

An example of the statistical summary that may be obtained by setting ISTAT=1 is shown in figure 33. This summary is provided by month for each water year simulated, followed by the summary for the entire period simulated.

Some output sections will require redefining and renaming of system data sets established in the cataloged procedure, PRMØDEL. See the Control and System Input Specifications section for the required control cards (JCL) to make these modifications.

STORM	PREDICTED VOLUME (INCHES)	ROUTED OUTFLOW (INCHES)	OBSERVED OUTFLOW (INCHES)	PREDICTED PEAK (CFS)	OBSERVED PEAK (CFS)	PREDICTED SEDIMENT (TONS)
1	2.44	2.39	2.82	96.83	83.80	1094.26
2	1.07	1.03	1.52	64.56	75.00	525.59
3	0.70	0.65	1.17	64.34	97.80	451.48
4	0.01	0.01	0.01	0.36	0.61	2.60
5	0.03	0.03	0.01	1.28	0.64	32.27

STORM VOLUME ERROR SUMMARY

	ABS VALUE OBF FNC		SUM OF SQUARES OBF FNC	
	NO LOG	LOG	NO LOG	LOG
SUM	1.31	2.27	0.56	1.37
MEAN	0.26	0.45	0.11	0.27
PERCENT	23.63		30.14	

STORM PEAK ERROR SUMMARY

	ABS VALUE OBF FNC		SUM OF SQUARES OBF FNC	
	NO LOG	LOG	NO LOG	LOG
SUM	57.84	1.95	1399.28	0.99
MEAN	11.57	0.39	279.86	0.20
PERCENT	22.43		32.44	

Figure 27.--Storm summary table.

HYDROGRAPH SEGMENT # 1 M/D/Y=10/ 5/1981 START= 15.0 MIN., END=1440.0 MIN., DT=15.0 MIN.

TIME HH:MM:SS	INFLOW TO SEGMENT CH20 (CFS)	OUTFLOW FROM SEGMENT CH20 (CFS)	INFLOW TO SEGMENT CH21 (CFS)	OUTFLOW FROM SEGMENT CH21 (CFS)	INFLOW TO SEGMENT CH22 (CFS)	OUTFLOW FROM SEGMENT CH22 (CFS)
00:15:00	1.715E+02		1.955E+02		2.085E+02	
00:30:00	1.695E+02		1.934E+02		2.074E+02	
00:45:00	1.678E+02		1.906E+02		2.061E+02	
01:00:00	1.662E+02	1.711E+02	1.881E+02	1.985E+02	2.040E+02	2.104E+02
01:15:00	1.649E+02		1.857E+02		2.011E+02	
01:30:00	1.641E+02		1.834E+02		1.979E+02	
01:45:00	1.636E+02		1.816E+02		1.950E+02	
02:00:00	1.634E+02	1.653E+02	1.800E+02	1.910E+02	1.924E+02	2.047E+02
02:15:00	1.632E+02		1.789E+02		1.899E+02	
02:30:00	1.628E+02		1.779E+02		1.881E+02	
02:45:00	1.623E+02		1.770E+02		1.865E+02	
03:00:00	1.615E+02	1.635E+02	1.760E+02	1.826E+02	1.853E+02	1.941E+02
03:15:00	1.607E+02		1.748E+02		1.843E+02	
03:30:00	1.601E+02		1.737E+02		1.834E+02	
03:45:00	1.598E+02		1.729E+02		1.824E+02	
04:00:00	1.595E+02	1.612E+02	1.724E+02	1.780E+02	1.812E+02	1.869E+02
04:15:00	1.588E+02		1.720E+02		1.801E+02	
04:30:00	1.576E+02		1.712E+02		1.793E+02	
04:45:00	1.562E+02		1.700E+02		1.788E+02	
05:00:00	1.547E+02	1.587E+02	1.686E+02	1.744E+02	1.783E+02	1.827E+02
05:15:00	1.534E+02		1.671E+02		1.776E+02	
05:30:00	1.521E+02		1.657E+02		1.764E+02	
05:45:00	1.509E+02		1.644E+02		1.750E+02	
06:00:00	1.499E+02	1.535E+02	1.632E+02	1.709E+02	1.736E+02	1.795E+02
06:15:00	1.491E+02		1.621E+02		1.721E+02	
06:30:00	1.487E+02		1.613E+02		1.709E+02	
06:45:00	1.484E+02		1.608E+02		1.697E+02	
07:00:00	1.484E+02	1.497E+02	1.606E+02	1.656E+02	1.686E+02	1.751E+02
07:15:00	1.485E+02		1.605E+02		1.678E+02	
07:30:00	1.487E+02		1.606E+02		1.672E+02	
07:45:00	1.488E+02		1.607E+02		1.669E+02	
08:00:00	1.490E+02	1.492E+02	1.609E+02	1.625E+02	1.668E+02	1.703E+02
08:15:00	1.492E+02		1.611E+02		1.668E+02	
08:30:00	1.493E+02		1.612E+02		1.670E+02	
08:45:00	1.495E+02		1.614E+02		1.671E+02	
09:00:00	1.496E+02	1.498E+02	1.615E+02	1.623E+02	1.673E+02	1.683E+02
09:15:00	1.496E+02		1.616E+02		1.674E+02	
09:30:00	1.496E+02		1.616E+02		1.676E+02	
09:45:00	1.495E+02		1.616E+02		1.677E+02	
10:00:00	1.494E+02	1.502E+02	1.616E+02	1.630E+02	1.678E+02	1.685E+02
10:15:00	1.493E+02		1.615E+02		1.679E+02	
10:30:00	1.491E+02		1.613E+02		1.679E+02	
10:45:00	1.489E+02		1.611E+02		1.678E+02	
11:00:00	1.487E+02	1.498E+02	1.609E+02	1.631E+02	1.677E+02	1.690E+02
11:15:00	1.485E+02		1.607E+02		1.675E+02	
11:30:00	1.482E+02		1.605E+02		1.674E+02	
11:45:00	1.480E+02		1.602E+02		1.672E+02	
12:00:00	1.477E+02	1.489E+02	1.600E+02	1.626E+02	1.669E+02	1.689E+02
12:15:00	1.475E+02		1.597E+02		1.667E+02	
12:30:00	1.472E+02		1.594E+02		1.665E+02	
12:45:00	1.470E+02		1.592E+02		1.662E+02	
13:00:00	1.467E+02	1.480E+02	1.589E+02	1.617E+02	1.659E+02	1.682E+02
13:15:00	1.465E+02		1.587E+02		1.657E+02	
13:30:00	1.462E+02		1.584E+02		1.654E+02	
13:45:00	1.460E+02		1.581E+02		1.652E+02	
14:00:00	1.457E+02	1.469E+02	1.579E+02	1.606E+02	1.649E+02	1.672E+02

Figure 28.--Inflow and outflow summary table for a storm event.

```
CANE BRANCH, KY    7HRUS, DAILY                                                         WATER YEAR= 1956

 O=OBSERVED  P=PREDICTED  *=O AND P  R=OUT OF RANGE

                                           DAILY MEAN DISCHARGE, IN CFS

      0.        3.        6.        9.       12.       15.       18.       21.       24.       27.       30.
       I---------+---------+---------+---------+---------+---------+---------+---------+---------+---------I
FEB 11 IR        !         !         !         !         !         !         !         !         !         I
FEB 12 IR        !         !         !         !         !         !         !         !         !         I
FEB 13 IR        !         !         !         !         !         !         !         !         !         I
FEB 14 IR        !         !         !         !         !         !         !         !         !         I
FEB 15 IR        !         !         !         !         !         !         !         !         !         I
FEB 16 I         ! *       !         !         !         !         !         !         !         !         I
FEB 17 I         !         !         !         !         !         !         !         ! PO      !         I
FEB 18 I         !         !         !         !         !   P     !         !         !  O      !         I
FEB 19 I         !         !    O    !   P     !         !         !         !         !         !         I
FEB 20 I         !        P!O        !         !         !         !         !         !         !         I
FEB 21 I        O!P        !         !         !         !         !         !         !         !         I
FEB 22 I     O P !         !         !         !         !         !         !         !         !         I
FEB 23 I   O P   !         !         !         !         !         !         !         !         !         I
FEB 24 I        O! P       !         !         !         !         !         !         !         !         I
FEB 25 I         !    P O  !         !         !         !         !         !         !         !         I
FEB 26 I         OP        !         !         !         !         !         !         !         !         I
FEB 27 I       O P         !         !         !         !         !         !         !         !         I
FEB 28 I      *  !         !         !         !         !         !         !         !         !         I
FEB 29 I     *   !         !         !         !         !         !         !         !         !         I
MAR  1 I---O-P---+---------+---------+---------+---------+---------+---------+---------+---------+---------I
MAR  2 I     PO  !         !         !         !         !         !         !         !         !         I
MAR  3 I        *!         !         !         !         !         !         !         !         !         I
MAR  4 I      P O!         !         !         !         !         !         !         !         !         I
MAR  5 I     *   !         !         !         !         !         !         !         !         !         I
MAR  6 I    *    !         !         !         !         !         !         !         !         !         I
MAR  7 I         !     P O !         !         !         !         !         !         !         !         I
MAR  8 I         !P      O !         !         !         !         !         !         !         !         I
MAR  9 I       PO!         !         !         !         !         !         !         !         !         I
MAR 10 I     *   !         !         !         !         !         !         !         !         !         I
MAR 11 I    *    !         !         !         !         !         !         !         !         !         I
MAR 12 I     O  P!         !         !         !         !         !         !         !         !         I
MAR 13 I         !O      P !         !         !         !         !         !         !         !         I
MAR 14 I         !         !         ! P       !         !         !         !         O         !         I
MAR 15 I         !     O   !P        !         !         !         !         !         !         !         I
MAR 16 I         !         O P       !         !         !         !         !         !         !         I
MAR 17 I         !  O P    !         !         !         !         !         !         !         !         I
MAR 18 I        OP         !         !         !         !         !         !         !         !         I
MAR 19 I      P O!         !         !         !         !         !         !         !         !         I
MAR 20 I     P O !         !         !         !         !         !         !         !         !         I
MAR 21 I    *    !         !         !         !         !         !         !         !         !         I
MAR 22 I   PO    !         !         !         !         !         !         !         !         !         I
MAR 23 I  OP     !         !         !         !         !         !         !         !         !         I
MAR 24 I   O P   !         !         !         !         !         !         !         !         !         I
MAR 25 I  OP     !         !         !         !         !         !         !         !         !         I
MAR 26 I  *      !         !         !         !         !         !         !         !         !         I
MAR 27 I  *      !         !         !         !         !         !         !         !         !         I
MAR 28 I O P     !         !         !         !         !         !         !         !         !         I
MAR 29 I  *      !         !         !         !         !         !         !         !         !         I
MAR 30 I OP      !         !         !         !         !         !         !         !         !         I
MAR 31 I *       !         !         !         !         !         !         !         !         !         I
               .2               .5         1.0        2.0             5.0         10.        20.              50.
```

Figure 29.--Linear plot of mean daily discharge.

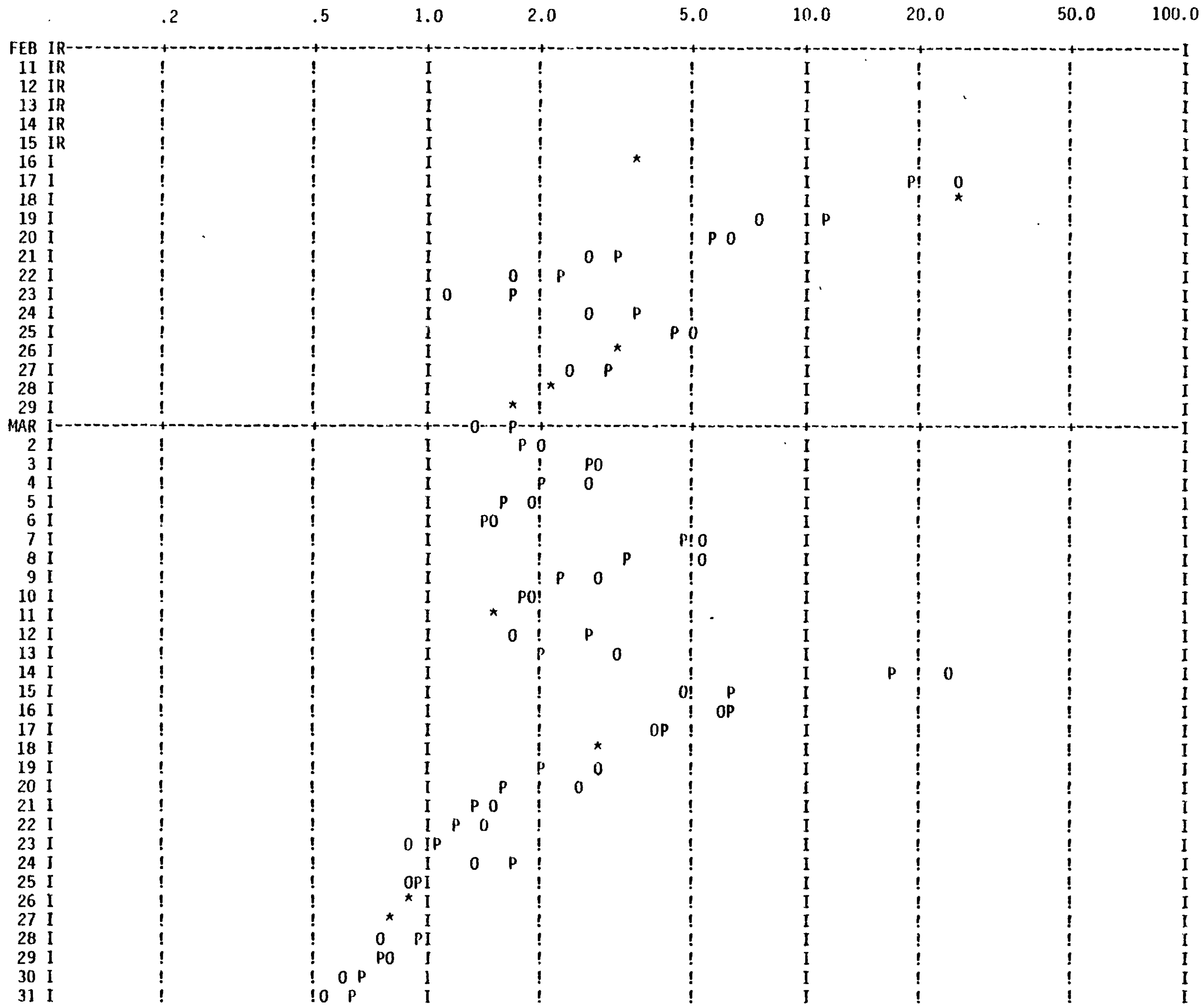
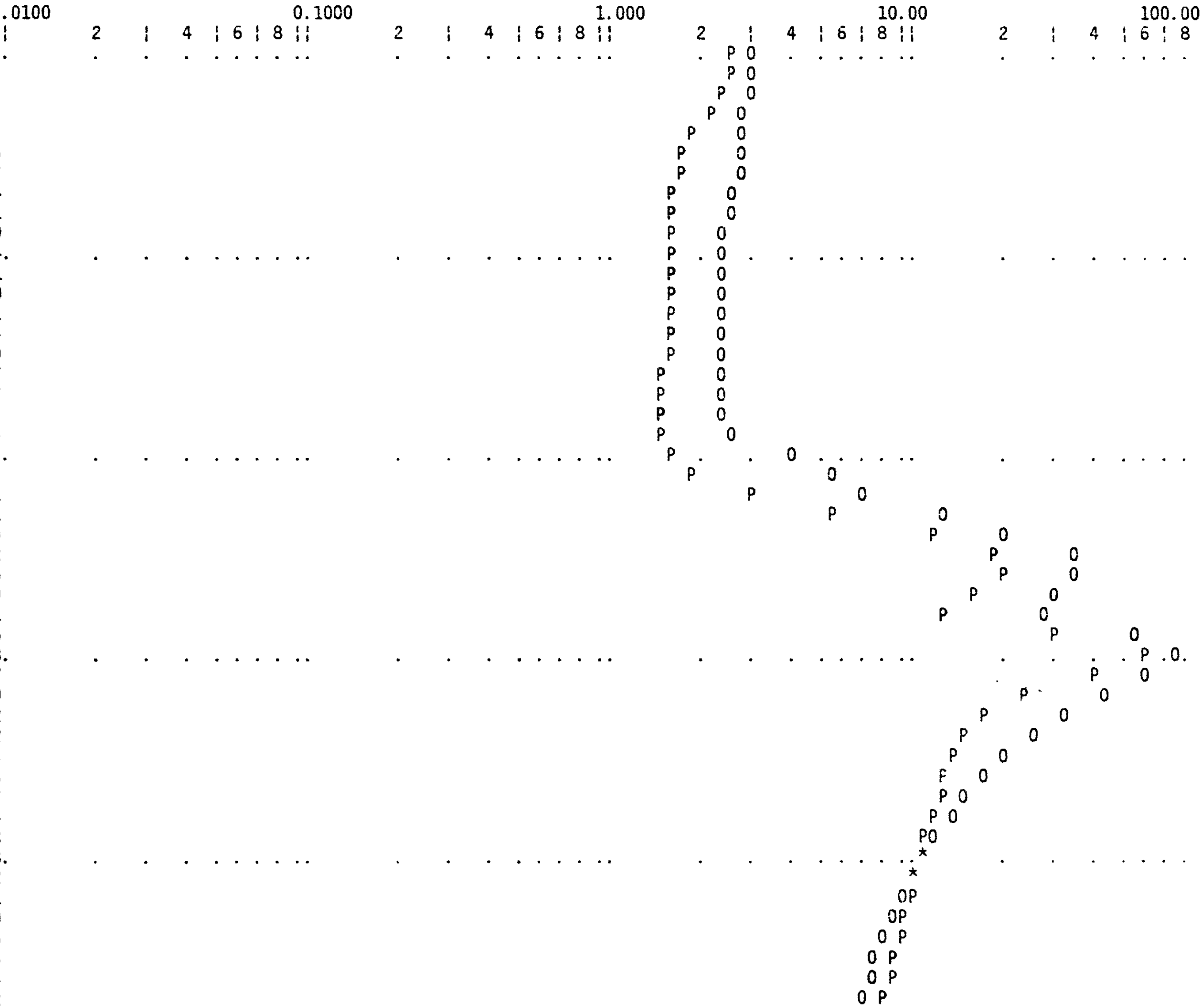


Figure 30.--Semilog plot of mean daily discharges.

CANE BRANCH, KY 7HRUS , DISCHARGE IN CFS
SEGMENT CH31 OUT 3/13/1956 - 3/14/1956
PREDICTED (P), OBSERVED (O), BOTH (*), OUT OF PLOT RANGE (R)
VALUE = PREDICTED DIVIDED BY 10 TO THE APPROPRIATE POWER



TIME	VALUE
100	2.5910
200	2.4564
300	2.2762
400	2.1133
500	1.9012
600	1.7335
700	1.6567
800	1.6284
900	1.6131
1000	1.6000
1100	1.5874
1200	1.5751
1300	1.5630
1400	1.5511
1500	1.5394
1600	1.5280
1700	1.5167
1800	1.5057
1900	1.4949
2000	1.4874
2100	1.5390
2200	1.8402
2300	2.8651
2400	5.3871
100	1.1710
200	1.8262
300	1.9616
400	1.6299
500	1.2951
600	2.9326
700	6.0668
800	3.8717
900	2.3179
1000	1.7652
1100	1.5242
1200	1.3873
1300	1.2928
1400	1.2187
1500	1.1564
1600	1.1018
1700	1.0528
1800	1.0082
1900	0.9671
2000	0.9290
2100	0.8935
2200	8.6033
2300	8.2924
2400	8.0002

Figure 31.--Stormflow hydrograph plot.

```
CANE BRANCH, KY    7HRUS                                              , SEDIMENT IN G/L
                              SEGMENT CH31 OUT   3/13/1956 -  3/14/1956
PREDICTED (P), OBSERVED (O), BOTH (*), OUT OF PLOT RANGE (R)
VALUE = PREDICTED DIVIDED BY 10 TO THE APPROPRIATE POWER

           0.0100                        0.1000                        1.000                       10.00                     100.
TIME VALUE  ¦        2    ¦   4  ¦ 6 ¦ 8 ¦¦        2    ¦   4  ¦ 6 ¦ 8 ¦¦        2    ¦   4  ¦ 6 ¦ 8 ¦¦        2    ¦   4  ¦ 6 ¦
 100  0.0000R        .    .   .  . . . . ..        .    .   .  . . . . ..        .    .   .  . . . . ..        .    .   .  . . .
 200  0.0000R
 300  0.0000R
 400  0.0000R
 500  0.0000R
 600  0.0000R
 700  0.0000R
 800  0.0000R
 900  0.0000R
1000  0.0000R
1100  0.0000R        .    .   .  . . . . ..        .    .   .  . . . . ..        .    .   .  . . . . ..        .    .   .  . . .
1200  0.0000R
1300  0.0000R
1400  0.0000R
1500  0.0000R
1600  0.0000R
1700  0.0000R
1800  0.0000R
1900  0.0000R
2000  0.5321R
2100  1.8428.        .    .   .  . . . . ..       P.    .   .  . . . . ..        .    .   .  . . . . ..        .    .   .  . . .
2200  1.1915                                                              P
2300  3.5176                                                                            P
2400  6.2298                                                                                    P
 100  1.4944                                                                                               P
 200  1.5493                                                                                                P
 300  1.5306                                                                                                P
 400  1.5456                                                                                                P
 500  1.4967                                                                                               P
 600  1.4757                                                                                               P
 700  1.3942.        .    .   .  . . . . ..        .    .   .  . . . . ..        .    .   .  . . . . ..   P    .    .   .  . . .
 800  1.6309                                                                                                P
 900  1.6342                                                                                                P
1000  1.4864                                                                                               P
1100  1.2864                                                                                             P
1200  1.1061                                                                                           P
1300  0.9475                                                                                         P
1400  7.9204                                                                                       P
1500  6.3991                                                                                    P
1600  5.0285                                                                                 P
1700  3.8991.        .    .   .  . . . . ..        .    .   .  . . . . ..        .    .   P  . . . . ..        .    .   .  . . .
1800  3.0286                                                                          P
1900  2.3835                                                                       P
2000  1.9124                                                                    P
2100  1.5672                                                                  P
2200  1.3106                                                                P
2300  1.1160                                                             P
2400  0.9651                                                            P
```

Figure 32.--Storm sediment-concentration plot.

CANE BRANCH, KY   7HRUS, DAILY
SUMMARY STATISTICS FOR WATER YEAR 1957

	MEAN RUNOFF (CFS)		TOTAL RUNOFF (CFS DAYS)		# OF RESIDUALS		# OF RUNS
	OBSV.	PRED.	OBSV.	PRED.	+	-	
OCT	0.074	0.011	2.290	0.345	31	0	1
NOV	0.056	0.023	1.680	0.701	27	3	5
DEC	1.569	1.664	48.640	51.592	15	16	4
JAN	5.231	5.462	162.160	169.331	7	24	7
FEB	2.294	2.363	64.230	66.159	14	14	10
MAR	1.245	1.187	38.600	36.788	17	14	7
APR	1.494	0.885	44.830	26.553	27	3	4
MAY	0.255	0.156	7.920	4.831	19	12	7
JUN	0.284	0.072	8.510	2.175	29	1	2
JUL	0.072	0.018	2.230	0.550	31	0	1
AUG	0.027	0.004	0.830	0.126	31	0	1
SEP	0.210	0.142	6.300	4.270	28	2	3
YEAR	1.064	0.996	388.219	363.421	276	89	45
MFS-MFN SEASON	1.064	0.996	388.219	363.421	276	89	45

RESIDUAL = OBSERVED - PREDICTED
MFS-MFN SEASON IS OCT TO SEP

CANE BRANCH, KY   7HRUS, DAILY
SUMMARY STATISTICS FOR OPTIMIZATION PERIOD 1956 TO 1958

	MEAN RUNOFF (CFS)		TOTAL RUNOFF (CFS DAYS)		# OF RESIDUALS		# OF RUNS
	OBSV.	PRED.	OBSV.	PRED.	+	-	
TOTAL	0.981	0.829	1075.308	908.417	660	436	120
MFS-MFN SEASON	0.981	0.829	1075.308	908.417	660	436	120

RESIDUAL = OBSERVED - PREDICTED
MFS-MFN SEASON IS OCT TO SEP

Figure 33.--Statistical summary.

VERIFICATION CRITERIA

	DAILY		MONTHLY	
	TOTAL	MFS-MFN	TOTAL	MFS-MFN
COEFFICIENT OF DETERMINATION	0.872	0.872	0.918	0.918
(LOGS)	0.881	0.881		
COEFFICIENT OF PERSISTENCE	-25.616	-25.616		
COEFFICIENT OF GAIN FROM DAILY AVERAGES	0.870	0.870		
RESIDUAL-PREDICTED CORRELATION	-0.015	-0.015		

ERROR SUMMARY (MFS-MFN PERIOD)

	ERRORS		ABSOLUTE ERRORS		SQUARED ERRORS	
	NO LOG	LOG	NO LOG	LOG	NO LOG	LOG
SUM	166.88	38.54	403.33	127.13	1679.80	42.56
MEAN	0.15	0.04	0.37	0.12	1.53	0.04
PERCENT	15.52		37.51		126.18	

ERROR SUMMARY (TOTAL PERIOD)

	ERRORS		ABSOLUTE ERRORS		SQUARED ERRORS	
	NO LOG	LOG	NO LOG	LOG	NO LOG	LOG
SUM	166.88	38.54	403.33	127.13	1679.80	42.56
MEAN	0.15	0.04	0.37	0.12	1.53	0.04
PERCENT	15.52		37.51		126.18	

Figure 33.--Statistical summary--Continued.

SYSTEM MODIFICATION

The modular design of the precipitation-runoff modeling system gives users the flexibility to add or replace subroutines to fit their particular modeling needs. Two options to modify the System are described in this section: (1) Replacing model subroutines with user subroutines, and (2) adding and (or) replacing model subroutines that require a new main program.

Several things must be taken into consideration when substituting a user subroutine for one of the system subroutines. The common areas used in the new subroutines should have the same labels as the system commons, although the variable names within the common area may be different as long as they are in the same order. The user should determine if all the data needed for the new subroutine are available through the common areas. A list of the labeled commons, the variables included, and the subroutines they are used in is given in attachment VI. If new data items need to be read from cards, the placement of these cards within the input stream is critical. Any input/output (I/O) of data within the new subroutine should be compatible with the existing I/O for the rest of the system.

An example of substituting user subroutines for system subroutines, using source-card decks is given in figure 34. If the new subroutines have different names than the system subroutines, the REPLACE card in the example is

```
//---JØB CARD---
//PRØCLIB DD DSN=DG4812S.PRDAT.LIB,DISP=SHR
//STEP1 EXEC FØRTXCL,PARM.FØRT='ØPT(2)'
//FØRT.SYSIN DD *
       .
       .
    fortran source decks
       .
/*
//LKED.DD1 DD DSN=DG4812S.PRRØTEST.LØAD,DISP=SHR
//LKED.SYSIN DD *
     REPLACE oldsr1(newsr1),oldsr2(newsr2)  } needed only if subroutines have
     INCLUDE DD1(PRMØD1)                    }        different names
     ENTRY MAIN
/*
// EXEC PRMØDLK,INFILE='DG4812S.TESTIS1.ISAM'
//PR.SYSIN DD *
       .
       .
    card groups 1-8
       .
/*
//
```

Figure 34.--JCL to compile and replace system subroutines with user subroutines.

needed; otherwise, it should be omitted. Subroutines with identical names will be replaced automatically. When the new subroutines have been debugged and are running correctly, a copy of the model containing the user modifications may be stored in a userdefined load module library, as shown in figure 35. By selecting one of the two //LKED.SYSLMØD cards shown, a new library can be created or an existing library can be updated. The library, designated by 'userid.libname' in the example, may contain more than one version of the model. The names for the library and any of the modified versions of the model are user options. The model, including the user subroutines, then may be run, using the JCL shown in figure 36. The underlined items should be replaced with the same names assigned by the user in figure 35. The catalog procedure PRMØDLK has the same I/O options and symbolic parameters as PRMØDEL. The two additional symbolic parameters shown on the EXEC card and the JØBLIB card in figure 36 always must be included when PRMØDLK is used alone.

A new subroutine can be incorporated using the procedure described above. The new subroutine and the existing subroutines from which the CALL is made to the new subroutine must be recompiled and link-edited. A copy of the resulting load module may be stored and executed, using figures 35 and 36.

```
//---JØB CARD---
//STEP1 EXEC FØRTXCL,PARM.FØRT='OPT(2)'
//FØRT.SYSIN DD *
       .
       .
    fortran source decks
       .
/*
//LKED.SYSLMØD DD DSN=userid.libname,DISP=(NEW,CATLG),UNIT=ØNLINE,   to create
// SPACE=(TRK(10,10,10))                                             new user
                                                                     library
     --or--

//LKED.SYSLMØD DD DSN=userid.libname,DISP=ØLD,UNIT=ØNLINE      to add to or
//LKED.DD1 DD DSN=DG4812S.PRRØTEST.LØAD,DISP=SHR               replace model
                                                               in user library
//LKED.SYSIN DD *
     REPLACE oldsr1(newsr1),oldsr2(newsr2)---
     INCLUDE DD1(PRMØD1)                                       add new module
     NAME PRMØD2                                               to library

     --or--

     NAME PRMØD2(R)                                           replace existing
                                                              module in library

     ENTRY MAIN
/*
//
```

Figure 35.--JCL to store modified program as user-defined load module.

```
//---JØB CARD---
//PRØCLIB DD DSN=DG4812S.PRDAT.LIB,DISP=SHR
// EXEC PRMØDLK,PRØG='PRMØD2',CØNDL=
//STEPLIB DD DSN=userid.libname,DISP=SHR
//PR.SYSIN DD *
       .
       .
    card groups 1-8
       .
/*
//
```

Figure 36.--JCL to execute stored user-modified program.

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ATTACHMENT I

PRMODEL Cataloged Procedure

A cataloged procedure has been written that includes all of the JCL required to use the Precipitation-Runoff Modeling System. This procedure, named PRMODEL, is stored in the procedure library DG4812S.PRDAT.LIB. Figure I-1 is a listing of PRMODEL.

ATTACHMENT II

Simulation Examples

The simulation examples for this attachment were developed using the Cane Branch watershed located in the Cumberland Plateau physiographic section of southeastern Kentucky. The watershed is described by Musser (1963). It has an area of 429 acres and relief of about 400 feet. The highest altitude above mean sea level is about 1,380 feet. Except for a small area of strip mining, the watershed is completely forested with a mix of hardwoods and pines. Soils generally are silt loam in texture. The topography and channel network of Cane Branch are shown in figure II-1. For daily mean flow simulation, the watershed was divided into seven HRU's. HRU 7 is the 27.4-acre strip-mined area. For stormflow simulation, an average overland-flow plane was defined in each HRU and reused several times to describe the flow plane network of each HRU. The channel system was delineated into 28 segments. The HRU and the channel segments defined are shown in figure II-2. A listing of the input card deck created to run a daily and stormflow simulation on Cane Branch from February 16, 1956, to September 30, 1957, is given in figure II-3. The deck consists of card groups 1, 2, 3, and 4, and includes the cards necessary for water and sediment routing of five storms. Card group 1 contains the physical description of the HRU's shown in figure II-2 and card groups 3 and 4 contain the physical description of the overland-flow plane and channel segments shown.

Selected segments of the output from this simulation run are shown in figures II-4 through II-9. The summary of the input data as they are displayed to the user in the model output is shown in figure II-4. It is important that the user always review this section of the output to ensure that the data supplied in the input card groups are correct. The daily mean flow summary table and the annual summary for water year 1956 are shown in figure II-5. Note that the simulation began in February; therefore, the annual summary is for a period less than 1 year. The line printer plot of the daily mean flows for the period February and March 1956 is shown in figure II-6. The plot is on a semilog scale.

The summary for water and sediment discharge for the five storms simulated is shown in figure II-7. There were no observed sediment data available for this example. Therefore, the sediment parameters used in card group 3 were just estimated values to permit the generation of a sediment summary and a sediment-concentration graph. The stormflow hydrograph for storm no. 2 (March 13-14, 1956) is shown in figure II-8, and the hypothetical sediment-concentration graph for this storm is shown in figure II-9.

```
//PRMODEL      PROC   INFILE=NULLFILE,DVOUT=NULLFILE,DVLREC=1656,
//             DVBLK=11592,UVOUT=NULLFILE,UVLREC=11604,UVBLK=12932
//PR  EXEC PGM=PRMOD1,REGION=600K,TIME=3
//STEPLIB DD DSN=DG4812S.PRROTEST.LOAD,DISP=SHR
//        DD DSN=SYS1.FORTG.LINKLIBX,DISP=SHR
//        DD DSN=SYS1.PLIX.TRANSLIB,DISP=SHR
//FT02F001 DD DUMMY
//FT03F001 DD DUMMY
//FT04F001 DD UNIT=SYSDK,SPACE=(TRK,(5,5)),DISP=(,DELETE)
//FT05F001 DD DDNAME=SYSIN1
//FT06F001 DD SYSOUT=A
//FT08F001 DD UNIT=SYSDK,SPACE=(TRK,(5,5)),DISP=(,DELETE)
//FT09F001 DD DISP=(,DELETE),SPACE=(128,(1000)),
//            DCB=(RECFM=F,LRECL=128,DSORG=DA),UNIT=SYSDK
//FT10F001 DD UNIT=SYSDK,SPACE=(TRK,(5,5)),DISP=(,DELETE)
//INV      DD DSN=&INV,UNIT=SYSDK,DISP=(,DELETE),SPACE=(TRK,(10,1)),
//            DCB=(RECFM=VBS,LRECL=1472,BLKSIZE=5896,BUFNO=2)
//FT11F001 DD DSN=*.INV,DISP=(OLD,DELETE),VOL=REF=*.INV
//FT12F001 DD DSN=&FHS,UNIT=SYSDK,DISP=(,DELETE),SPACE=(TRK,(5,1)),
//            DCB=(RECFM=VBS,LRECL=656,BLKSIZE=6568,BUFNO=2)
//DFHS     DD DSN=&DFHS,UNIT=SYSDK,DISP=(,DELETE),SPACE=(TRK,(10,5)),
//            DCB=(RECFM=VBS,LRECL=108,BLKSIZE=1088)
//FT13F001 DD DSN=*.DFHS,DISP=(OLD,DELETE),VOL=REF=*.DFHS
//UNITQ    DD DSN=&UNITQ,UNIT=SYSDK,DISP=(,DELETE),SPACE=(TRK,(100,5)),
//            DCB=(RECFM=VB,LRECL=5820,BLKSIZE=5830,BUFNO=2)
//FT14F001 DD DSN=*.UNITQ,DISP=(OLD,DELETE),VOL=REF=*.UNITQ
//UNITP    DD DSN=&UNITP,UNIT=SYSDK,DISP=(,DELETE),SPACE=(TRK,(100;5)),
//            DCB=(RECFM=VB,LRECL=5820,BLKSIZE=5830,BUFNO=2)
//FT15F001 DD DSN=*.UNITP,DISP=(OLD,DELETE),VOL=REF=*.UNITP
//FT17F001 DD DSN=&LATIN,DISP=(,DELETE),SPACE=(5768,(200)),
//            DCB=(RECFM=F,BLKSIZE=5760,DSORG=DA),UNIT=SYSDK
//QSFILE   DD DSN=&SFILE,DISP=(,DELETE),UNIT=SYSDK,SPACE=(TRK,(100,5)),
//            DCB=(RECFM=VBS,LRECL=5764,BLKSIZE=12000,BUFNO=3)
//FT18F001 DD DSN=*.QSFILE,DISP=(OLD,DELETE),VOL=REF=*.QSFILE
//FT20F001 DD DSN=&DVOUT,DISP=(NEW,CATLG),SPACE=(TRK,(5,5),RLSE),
//            DCB=(RECFM=FB,LRECL=&DVLREC,BLKSIZE=&DVBLK,BUFNO=2),
//            UNIT=ONLINE
//FT21F001 DD DSN=&UVOUT,DISP=(NEW,CATLG),SPACE=(TRK,(5,5),RLSE),
//            DCB=(RECFM=VB,LRECL=&UVLREC,BLKSIZE=&UVBLK,BUFNO=2),
//            UNIT=ONLINE
//DISK     DD DSN=&INFILE,DISP=SHR,UNIT=ONLINE,
//            DCB=(RECFM=VB,LRECL=11604,BLKSIZE=12932,
//            KEYLEN=28,DSORG=IS)
//FT30F001 DD UNIT=SYSDK,SPACE=(TRK,(5,5)),DISP=(,DELETE)
//FT22F001 DD DDNAME=SYSIN2
//FT23F001 DD DDNAME=SYSIN3
//FT24F001 DD DDNAME=SYSIN4
//FT25F001 DD DDNAME=SYSIN5
//SYSPRINT DD SYSOUT=A
```

Figure I-1.--Cataloged procedure PRMODEL.

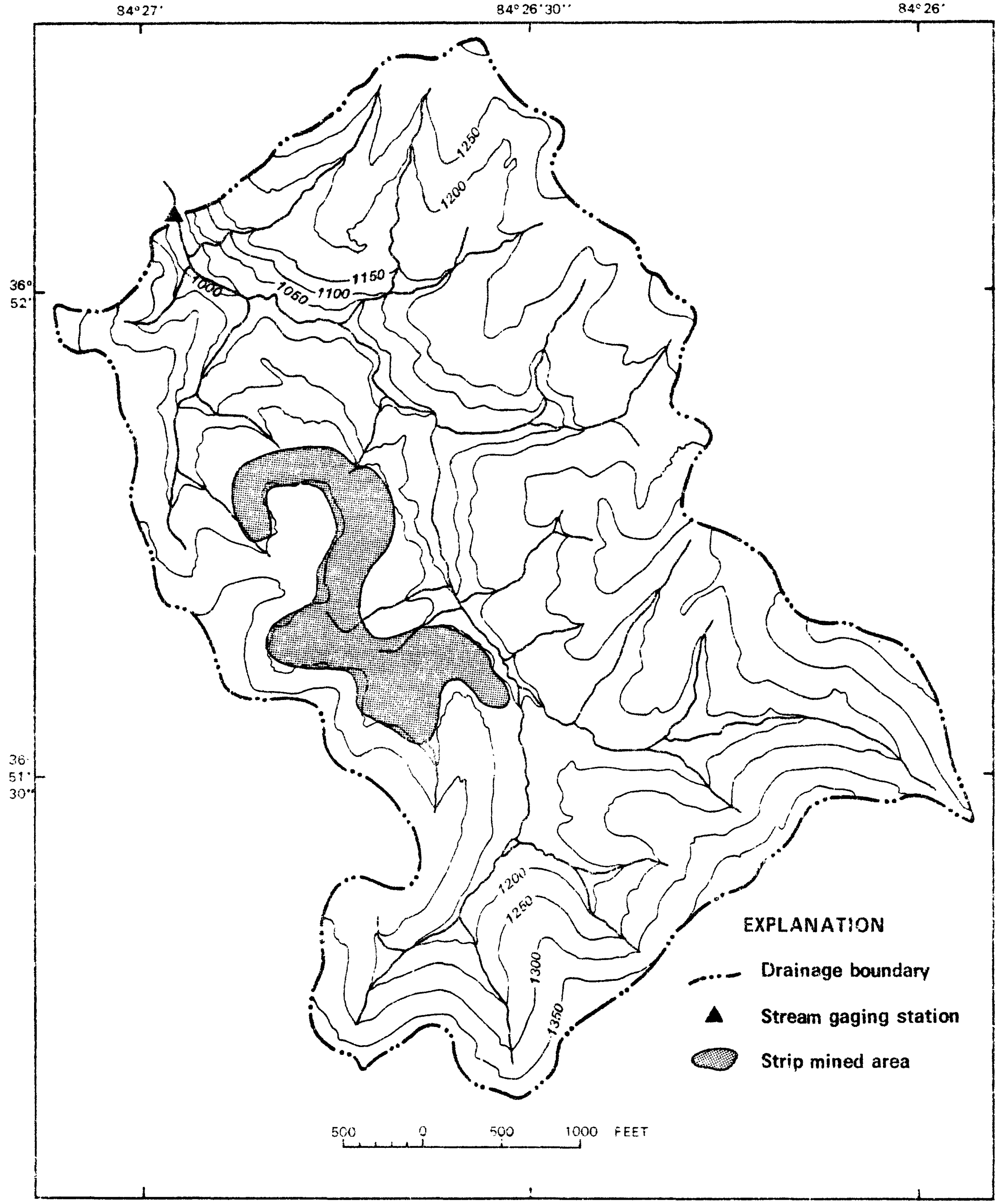

Figure II-1.--Topography and channel network of Cane Branch watershed.

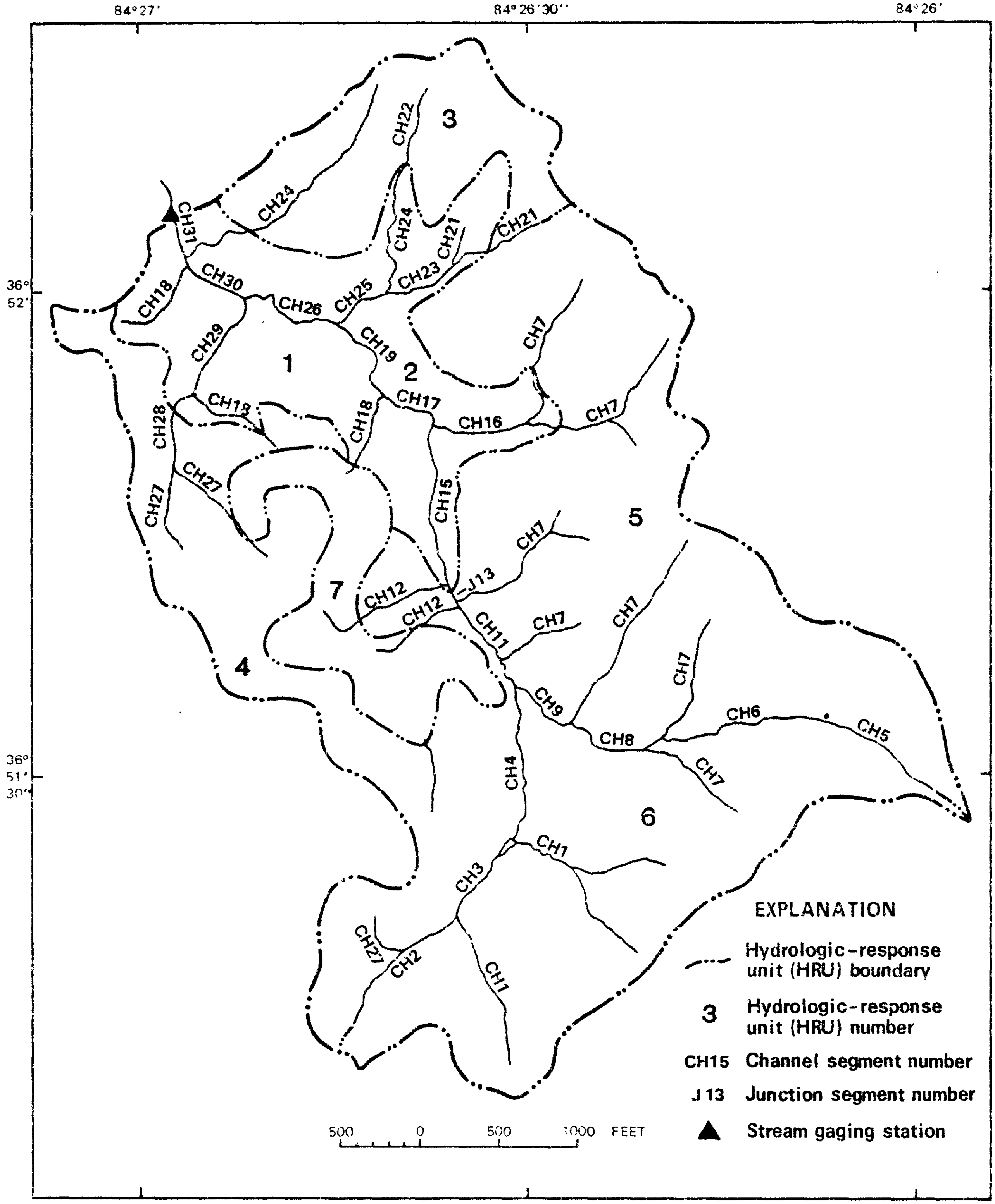

Figure II-2.--HRU and channel segments delineated for Cane Branch watershed.

CARD GROUP 1

```
01SIM/OPT     3    1    0    0    0    0    0    0
02SIM/COMP         1    1    2    1
03TITL    CANE BRANCH, KY    7HRUS, DAILY
04INIT1       1    7    6    2    1    0      429.
05INIT2    1956   02   16 1957   09   30
06MFS-MFN    10    9    1
07PRINT-OP    2   10    9
08PLOT        1    1   10    1    9   30      100.         .1
09DATATYPE    6    1    0    1    1    0    0    0    1    1    1
10PARM    00060000500002000020                000600004500045
11STAT    00003000060000100002                000110000600006
12STAID   D 03407100        D365200085090000  D370700084370000  D370700084370000
12STAID                                                         U 03407100
13STAIDP  D365205084265702  U365205084265702
14RD 1    HOR          0.0  0.0  37.
14RD 2   NE20          0.2  45.  37.
14RD 3   SW30          0.3 225.  37.
14RD 4    S10          0.1 180.  37.
14RD 5    E20          0.2  90.  37.
14RD 6   SW10          0.1 225.  37.
15RDM      -.10 -.10-.075 -.05 -.05 -.05 -.05 -.05 -.05 -.05-.075 -.10
16RDC       1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
17RAD-COR   .50 .25  .25  .61   .8
18CLIM-PR     1050.   .8   .6    0    0    0
19CTW      .012 .012 .012 .012 .012 .012 .012 .012 .012 .012 .012 .012    .1
20PAT       4.5  4.5  4.5  4.5  4.5  4.5  4.5  4.5  4.5  4.5  4.5  4.5
21AJMX      1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
22TLX       1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
23TLN       1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
24EVC       1.3  1.2  .72  .75  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.5
25SNO-VAR    90  120 .757  .04  .20  .40   .1  1.0
26CEN        5.   5.   6.   6.   6.   6.   6.   6.   6.   6.   5.   5.
27PKADJ
28RES        .6   .6
29GW         .7
30KRSP        1    1
31RESMX-EX 1.0  1.0  1.0  1.0
32RSEP      .05  .05
33GSNK       0.   0.
34RCB       .05
35RCF-RCP        .02       .47       .02       .47
```

Figure II-3.--Input card deck for daily and stormflow simulation on Cane Branch watershed.

CARD GROUP 1--Continued

```
36RU1    1  2  .25  1100.    3  .60  .30  .42   .1   .1  .05 4111 24. -.78 -.78
37RU2    1    2  6.0  5.8  2.0  1.8  1.0  .60.0016   .3   0.    0.  .12  1  1  0
38RU3    1  1   39.5  1.0  1.0  1.0
36RU1    2  3  .35  1100.    3  .60  .30  .42   .1   .1  .05 4111 24.  .78  .78
37RU2    2    2  6.0  5.8  2.0  1.8  1.0  .60.0016   .3   0.    0.  .12  1  1  0
38RU3    2  1   38.0  1.0  1.0  1.0
36RU1    3  4  .10  1250.    3  .60  .30  .42   .1   .1  .05 4111 24.  .39  .39
37RU2    3    2  6.0  5.8  2.0  1.8  1.0  .60.0016   .3   0.    0.  .12  1  1  0
38RU3    3  1   38.2  1.0  1.0  1.0
36RU1    4  5  .20  1250.    3  .60  .30  .42   .1   .1  .05 4111 24.  .39  .39
37RU2    4    2  6.0  5.8  2.0  1.8  1.0  .60.0016   .3   0.    0.  .12  1  1  0
38RU3    4  1   77.7  1.0  1.0  1.0
36RU1    5  6  .12  1250.    3  .60  .30  .42   .1   .1  .05 4111 24.  .78  .78
37RU2    5    2  6.0  5.8  2.0  1.8  1.0  .60.0016   .3   0.    0.  .12  1  1  0
38RU3    5  1  122.7  1.0  1.0  1.0
36RU1    6  2  .23  1250.    3  .60  .30  .42   .1   .1  .05 4111 24. -.78 -.78
37RU2    6    2  6.0  5.8  2.0  1.8  1.0  .60.0016   .3   0.    0.  .12  1  1  0
38RU3    6  1   85.5  1.0  1.0  1.0
36RU1    7  5  .10  1200.    0   0.   0.  1.0   0.   0.   0. 4111 24.  .39  .39
37RU2    7    2  3.0  2.5  1.0   .5  1.0  .01.0016   .3   0.    0.   .0  2  1  0
38RU3    7  1   27.4  1.0  1.0  1.0
```

CARD GROUP 2

```
01STORMS      5
02STSEG       12    1 1956 0217 1956 0218   17 0000   18 2400
02STSEG       22    1 1956 0313 1956 0314   13 0000   14 2400
02STSEG       32    1 1956 0406 1956 0406    6 0000    6 2400
02STSEG       42    1 1956 0526 1956 0526   26 0000   26 2400
02STSEG       52    1 1956 0613 1956 0614   13 0000   14 2400
```

CARD GROUP 3

```
IN-ER    1   .5   .1  9.5  1.0        1.        10.        1.        1.       1.5
IN-ER    2   .5   .1  9.5  1.0        1.        10.        1.        1.       1.5
IN-ER    3   .5   .1  9.5  1.0        1.        10.        1.        1.       1.5
IN-ER    4   .5   .1  9.5  1.0        1.        10.        1.        1.       1.5
IN-ER    5   .5   .1  9.5  1.0        1.        10.        1.        1.       1.5
IN-ER    6   .5   .1  9.5  1.0        1.        10.        1.        1.       1.5
IN-ER    7  1.0   .1  9.5  1.0       10.        10.       10.        1.       1.5
```

Figure II-3.--Input card deck for daily and stormflow simulation on Cane Branch watershed--Continued.

CARD GROUP 4

```
NOFSEG       7
02OFID    OF1                    400 2 170.          2.35 1.67 1   0.    5.    5
02OFID    OF2                    400 2 170.         2.63  1.67 2   0.    5.    5
02OFID    OF3                    400 5 530.          1.67 1.67 3   0.    5.    5.
02OFID    OF4                    400 5 500.          1.86 1.67 4   0.    5.    5.
02OFID    OF5                    400 3 310.          1.49 1.67 5   0.    5.    5.
02OFID    OF6                    400 3 320.          2.20 1.67 6   0.    5.    5.
02OFID    OF7                    400 2 200.         1.18  1.67 7   0.    5.    5.
NCRSEG      28
04CHIDCH1             OF6 OF6    400 31000.         0.69  1.67     0.    5.    5.
04CHIDCH27            OF4 OF4    400 2 700.           .56 1.67     0.    5.    5.
04CHIDCH2             OF4 OF6    400 31000.           .61 1.67     0.    5.    5.
04CHIDCH3 CH2 CH1 CH27OF4 OF6    400 3 860.           .24 1.67     0.    5.    5.
04CHIDCH4 CH3 CH1     OF4 OF6    400 2 650.           .16 1.67     0.   10.   10.
04CHIDCH5             OF5 OF6    400 3 900.           .56 1.67     0.    5.    5.
04CHIDCH6 CH5         OF5 OF6    400 41100.           .34 1.67     0.    5.    5.
04CHIDCH7             OF5 OF5    400 41100.           .54 1.67     0.    5.    5.
04CHIDCH8 CH7 CH6 CH1 OF5 OF6    400 2 600.           .25 1.67     0.    5.    5.
04CHIDCH9 CH8 CH7     OF5 OF6    400 2 500.           .19 1.67     0.   10.   10.
04CHIDCH11CH9 CH7 CH4 OF5 OF7    400 2 660.           .09 1.67     0.   10.   10.
04CHIDCH12            OF7 OF7    400 2 500.           .44 1.67     0.    5.    5.
04CHID J13CH12CH11CH7            700                               0.   10.   10.
04CHIDCH15 J13CH12    OF1 OF1    400 41200.           .07 1.67     0.   10.   10.
04CHIDCH16CH7 CH7     OF2 OF2    400 2 670.           .30 1.67     0.    5.    5.
04CHIDCH17CH16CH15    OF1 OF2    400 2 500.           .07 1.67     0.   10.   10.
04CHIDCH18            OF1 OF1    400 2 560.           .75 1.67     0.    5.    5.
04CHIDCH19CH18CH17    OF1 OF2    400 2 600.           .06 1.67     0.   10.   10.
04CHIDCH21            OF2 OF2    400 2 560.           .70 1.67     0.    5.    5.
04CHIDCH22            OF3 OF3    400 3 780.           .53 1.67     0.    5.    5.
04CHIDCH23CH21CH21    OF2 OF2    400 2 410.           .35 1.67     0.    5.    5.
04CHIDCH24CH22        OF2 OF2    400 3 770.           .61 1.67     0.    5.    5.
04CHIDCH25CH24CH23    OF2 OF2    400 2 420.           .37 1.67     0.   10.   10.
04CHIDCH26CH25CH19    OF1 OF2    400 2 660.           .04 1.67     0.   15.   15.
04CHIDCH28CH27CH27    OF4 OF4    400 2 400.           .35 1.67     0.    5.    5.
04CHIDCH29CH28CH18    OF1 OF1    400 3 850.           .26 1.67     0.   10.   10.
04CHIDCH30CH29CH26    OF1 OF2    400 2 430.           .03 1.67     0.   15.   15.
04CHIDCH31CH30CH18CH24OF1 OF2    402 2 320.           .03 1.67     0.   15.   60.
```

Figure II-3.--Input card deck for daily and stormflow simulation on Cane Branch watershed--Continued.

CANE BRANCH, KY   7HRUS

```
IOPT=    0     ISIM=    3     IOBS=    1     ISEN=    0
IDOUT=   0     IUOUT=   0     SCODE==319     ICBC=    0     IPSW=    0

IPET=    1     ISSR1=   1     MRDC=    2     ISUN=    1
NYR=     2     NDS=     1     NRU=     7     NRD=     6     NRES=   2    NGW=    1    NSTOR=   0    DAT=         429.00

BYR/BMO/BDY= 1956/ 2/16     EYR/EMO/EDY= 1957/ 9/30

MFS= 10     MFN=  9
```

DATA TYPE	PARAMETER CODE	STATISTIC CODE	STATION ID 1
DAILY DISCHARGE	00060	00003	03407100
DAILY EVAP	00050	00006	365200085090000
DAILY MAX TEMP	00020	00001	370700084370000
DAILY MIN TEMP	00020	00002	370700084370000
DAILY SOLAR RAD			
USER VARIABLE 1			
USER VARIABLE 2			
UNIT DISCHARGE	00060	00011	03407100
DAILY PRECIP	00045	00006	365205084265702
UNIT PRECIP	00045	00006	365205084265702

POT SOLAR RADIATION

1	HOR	374.4	398.6	440.2	499.1	571.5	651.1	732.4	809.8	877.2	933.2	975.4	1003.7	1019.7
2	NE20	260.2	284.6	327.0	388.6	466.4	554.6	647.9	739.7	823.0	894.6	950.6	989.2	1011.4
3	SW30	536.4	558.4	595.2	645.6	704.7	765.8	824.2	875.4	915.7	945.8	965.8	977.8	984.1
4	S10	458.8	482.2	521.7	576.7	642.8	713.6	783.7	848.2	902.4	945.7	977.0	997.4	1008.6
5	E20	376.5	400.5	441.6	499.7	571.1	649.4	729.3	805.1	871.0	925.7	966.8	994.3	1009.8
6	SW10	433.7	457.4	497.5	553.7	621.9	695.3	769.0	837.4	895.5	942.5	977.0	999.7	1012.2

```
RDM(1-12)= -0.10 -0.10 -0.08 -0.05 -0.05 -0.05 -0.05 -0.05 -0.05 -0.05 -0.08 -0.10
RDC(1-12)=  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00

MRDC=  2 PARS=  0.50 PARW=  0.25 RDB=  0.25RDP=  0.61RDMX=  0.80
```

SUNLIGHT HOURS/12

1	HOR	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.2
2	NE20	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2
3	SW30	0.8	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1
4	S10	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2
5	E20	0.7	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.1
6	SW10	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.2	1.2

Figure II-4.--Variables, parameters, and initial conditions for daily and stormflow simulation on Cane Branch watershed.

CANE BRANCH, KY 7HRUS

CSEL= 1050. RMXA= 0.80 RMXM= 0.60 MTSS= 0 MTSE= 0

MPCS= 0 MPCN= 0 MPC1= 0 PCONR= 1.00 PCONS= 1.00

CTS(1-12)=0.0120000.0120000.0120000.0120000.0120000.0120000.0120000.0120000.0120000.0120000.0120000.012000
CTW= 0.10

PAT(1-12)=	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
AJMX(1-12)=	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TLX(1-12)=	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
TLN(1-12)=	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
EVC(1-12)=	1.300	1.200	0.720	0.750	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.500

ISP1= 90 ISP2=120 EAIR= 0.757 FWCAP= 0.04 DENI= 0.20 DENMX= 0.40 SETCON= 0.10 BST= 1.00

CECN(1-12)=	5.00	5.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	5.00	5.00

RES-RSEP 1- 0.60 0.05 2- 0.60 0.05

RESMX-REXP 1.0000 1.0000
1.0000 1.0000

KRSP= 1 1

RCF-RCP 1- 0.0200000 0.4700000 2- 0.0200000 0.4700000

GW-GSNK 1- 0.700 0.000

RCB 1- 0.0500

Figure II-4.--Variables, parameters, and initial conditions for daily and stormflow simulation on Cane Branch watershed--Continued.

CANE BRANCH, KY 7HRUS

IRU	IRD	ITST	ITSW	TXAJ	RNSTS	SNST	COVDS	ICOV	SMAX	REMX	SCN	SRX	RETIP	SEP	KRES
	ELEV	ITND	CTX	TNAJ	RNSTW	TRNCF	COVDW	ISOIL	SMAV	RECHR	SC1	SCX	IMPRV	KSTOR	KGW
1	2	4	1	-0.78	0.10	0.10	0.60	3	6.00	2.00	0.00160	1.00	0.00	0.12	1
	1100.	11	24.00	-0.78	0.05	0.42	0.30	2	5.80	1.80	0.30000	0.60	0.00	0	1
2	3	4	1	0.78	0.10	0.10	0.60	3	6.00	2.00	0.00160	1.00	0.00	0.12	1
	1100.	11	24.00	0.78	0.05	0.42	0.30	2	5.80	1.80	0.30000	0.60	0.00	0	1
3	4	4	1	0.39	0.10	0.10	0.60	3	6.00	2.00	0.00160	1.00	0.00	0.12	1
	1250.	11	24.00	0.39	0.05	0.42	0.30	2	5.80	1.80	0.30000	0.60	0.00	0	1
4	5	4	1	0.39	0.10	0.10	0.60	3	6.00	2.00	0.00160	1.00	0.00	0.12	1
	1250.	11	24.00	0.39	0.05	0.42	0.30	2	5.80	1.80	0.30000	0.60	0.00	0	1
5	6	4	1	0.78	0.10	0.10	0.60	3	6.00	2.00	0.00160	1.00	0.00	0.12	1
	1250.	11	24.00	0.78	0.05	0.42	0.30	2	5.80	1.80	0.30000	0.60	0.00	0	1
6	2	4	1	-0.78	0.10	0.10	0.60	3	6.00	2.00	0.00160	1.00	0.00	0.12	1
	1250.	11	24.00	-0.78	0.05	0.42	0.30	2	5.80	1.80	0.30000	0.60	0.00	0	1
7	5	4	1	0.39	0.00	0.00	0.00	0	3.00	1.00	0.00160	1.00	0.00	0.00	2
	1200.	11	24.00	0.39	0.00	1.00	0.00	2	2.50	0.50	0.30000	0.01	0.00	0	1

IRU	IDS	SLOPE	AREA	PERV AREA	IMPERV AREA	UPCOR	DRCOR	DSCOR	TST
1	1	0.25	39.5	39.5	0.0	1.00	1.00	1.00	0.0
2	1	0.35	38.0	38.0	0.0	1.00	1.00	1.00	0.0
3	1	0.10	38.2	38.2	0.0	1.00	1.00	1.00	0.0
4	1	0.20	77.7	77.7	0.0	1.00	1.00	1.00	0.0
5	1	0.12	122.7	122.7	0.0	1.00	1.00	1.00	0.0
6	1	0.23	85.5	85.5	0.0	1.00	1.00	1.00	0.0
7	1	0.10	27.4	27.4	0.0	1.00	1.00	1.00	0.0
TOTAL			429.0	429.0	0.0				

Figure II-4.--Variables, parameters, and initial conditions for daily and stormflow simulation on Cane Branch watershed--Continued.

```
BYR= 1956 BMO=    2 BDY=   16
NSP=    5
  1  11956 2171956 218  NE= 16
  2  11956 3131956 314  NE= 16
  3  11956 4 61956 4 6  NE= 16
  4  11956 5261956 526  NE= 16
  5  11956 6131956 614  NE= 16
INV=1956
INV=1957
```

STORMFLOW HYDROGRAPH PARAMETERS FOR EACH HYDROLOGIC RESPONSE UNIT(IRU)

IRU	KSAT	PSP	RGF	DRN	KR	HC	KF	MM	EN
1	0.500	0.100	9.500	1.000	1.00	10.0	1.00000	1.00	1.50
2	0.500	0.100	9.500	1.000	1.00	10.0	1.00000	1.00	1.50
3	0.500	0.100	9.500	1.000	1.00	10.0	1.00000	1.00	1.50
4	0.500	0.100	9.500	1.000	1.00	10.0	1.00000	1.00	1.50
5	0.500	0.100	9.500	1.000	1.00	10.0	1.00000	1.00	1.50
6	0.500	0.100	9.500	1.000	1.00	10.0	1.00000	1.00	1.50
7	1.000	0.100	9.500	1.000	10.00	10.0	10.00000	1.00	1.50

WY	WYD	#HS	ST#	RFL	SFL	BEGIN AND END TIMES FOR #HS
1956	140	1	1	0	1	0.1440.
1956	141	1	1	1	0	0.1440.
1956	165	1	2	0	1	0.1440.
1956	166	1	2	1	0	0.1440.
1956	189	1	3	0	0	0.1440.
1956	239	1	4	0	0	0.1440.
1956	257	1	5	0	1	0.1440.
1956	258	1	5	1	0	0.1440.

Figure II-4.--Variables, parameters, and initial conditions for daily and stormflow simulation on Cane Branch watershed--Continued.

NUMBER OF OVERLAND FLOW PLANE SEGMENTS IS 7. THEIR CHARACTERISTICS ARE AS FOLLOWS:

SEGMENT #	NAME	IDS	IRU	THRES DEPTH	TYPE	PRINT IN	PRINT OUT	NDX	LENGTH	SLOPE	ROUGH-NESS	PARM1	PARM2	ALPHA	EXPM	ROUTE INT.	PRINT INT.
1	OF1	1	1	0.0000	4	0	0	2	170.0	.0000	.000	2.35	1.67	2.35	1.67	5.0	5.0
2	OF2	1	2	0.0000	4	0	0	2	170.0	.0000	.000	2.63	1.67	2.63	1.67	5.0	5.0
3	OF3	1	3	0.0000	4	0	0	5	530.0	.0000	.000	1.67	1.67	1.67	1.67	5.0	5.0
4	OF4	1	4	0.0000	4	0	0	5	500.0	.0000	.000	1.86	1.67	1.86	1.67	5.0	5.0
5	OF5	1	5	0.0000	4	0	0	3	310.0	.0000	.000	1.49	1.67	1.49	1.67	5.0	5.0
6	OF6	1	6	0.0000	4	0	0	3	320.0	.0000	.000	2.20	1.67	2.20	1.67	5.0	5.0
7	OF7	1	7	0.0000	4	0	0	2	200.0	.0000	.000	1.18	1.67	1.18	1.67	5.0	5.0

NUMBER OF CHANNEL AND RESERVOIR SEGMENTS IS 28

SEGMENT #	NAME	UPSTREAM SEGMENTS			ADJACENT SEGMENTS		INC. AREA	CUM. AREA	THRES DISC.	TYPE	PRINT IN	PRINT OUT	NDX	LENGTH	SLOPE	ROUGH-NESS	PARM1	PARM2	ALPHA	EXPM	ROUTE INT.	PRINT INT.
1	CH1				OF6	OF6	14.7	14.7	0.00	4	0	0	3	1000.0	.0000	.000	0.69	1.67	0.69	1.67	5.0	5.0
2	CH27				OF4	OF4	16.1	16.1	0.00	4	0	0	2	700.0	.0000	.000	0.56	1.67	0.56	1.67	5.0	5.0
3	CH2				OF4	OF6	18.8	18.8	0.00	4	0	0	3	1000.0	.0000	.000	0.61	1.67	0.61	1.67	5.0	5.0
4	CH3	CH2	CH1	CH27	OF4	OF6	16.2	65.8	0.00	4	0	0	3	860.0	.0000	.000	0.24	1.67	0.24	1.67	5.0	5.0
5	CH4	CH3	CH1		OF4	OF6	12.2	92.7	0.00	4	0	0	2	650.0	.0000	.000	0.16	1.67	0.16	1.67	10.0	10.0
6	CH5				OF5	OF6	13.0	13.0	0.00	4	0	0	3	900.0	.0000	.000	0.56	1.67	0.56	1.67	5.0	5.0
7	CH6	CH5			OF5	OF6	15.9	28.9	0.00	4	0	0	4	1100.0	.0000	.000	0.34	1.67	0.34	1.67	5.0	5.0
8	CH7				OF5	OF5	15.7	15.7	0.00	4	0	0	4	1100.0	.0000	.000	0.54	1.67	0.54	1.67	5.0	5.0
9	CH8	CH7	CH6	CH1	OF5	OF6	8.7	68.0	0.00	4	0	0	2	600.0	.0000	.000	0.25	1.67	0.25	1.67	5.0	5.0
10	CH9	CH8	CH7		OF5	OF6	7.2	90.8	0.00	4	0	0	2	500.0	.0000	.000	0.19	1.67	0.19	1.67	10.0	10.0
11	CH11	CH9	CH7	CH4	OF5	OF7	7.7	206.9	0.00	4	0	0	2	660.0	.0000	.000	0.09	1.67	0.09	1.67	10.0	10.0
12	CH12				OF7	OF7	4.6	4.6	0.00	4	0	0	2	500.0	.0000	.000	0.44	1.67	0.44	1.67	5.0	5.0
13	J13	CH12	CH11	CH7			0.0	227.2	0.00	7	0	0	0	0.0	.0000	.000	0.00	0.00	0.44	1.67	10.0	10.0
14	CH15	J13	CH12		OF1	OF1	9.4	241.1	0.00	4	0	0	4	1200.0	.0000	.000	0.07	1.67	0.07	1.67	10.0	10.0
15	CH16	CH7	CH7		OF2	OF2	5.2	36.5	0.00	4	0	0	2	670.0	.0000	.000	0.30	1.67	0.30	1.67	5.0	5.0
16	CH17	CH16	CH15		OF1	OF2	3.9	281.6	0.00	4	0	0	2	500.0	.0000	.000	0.07	1.67	0.07	1.67	10.0	10.0
17	CH18				OF1	OF1	4.4	4.4	0.00	4	0	0	2	560.0	.0000	.000	0.75	1.67	0.75	1.67	5.0	5.0
18	CH19	CH18	CH17		OF1	OF2	4.7	290.6	0.00	4	0	0	2	600.0	.0000	.000	0.06	1.67	0.06	1.67	10.0	10.0
19	CH21				OF2	OF2	4.4	4.4	0.00	4	0	0	2	560.0	.0000	.000	0.70	1.67	0.70	1.67	5.0	5.0
20	CH22				OF3	OF3	19.0	19.0	0.00	4	0	0	3	780.0	.0000	.000	0.53	1.67	0.53	1.67	5.0	5.0
21	CH23	CH21	CH21		OF2	OF2	3.2	11.9	0.00	4	0	0	2	410.0	.0000	.000	0.35	1.67	0.35	1.67	5.0	5.0
22	CH24	CH22			OF2	OF2	6.0	25.0	0.00	4	0	0	3	770.0	.0000	.000	0.61	1.67	0.61	1.67	5.0	5.0
23	CH25	CH24	CH23		OF2	OF2	3.3	40.2	0.00	4	0	0	2	420.0	.0000	.000	0.37	1.67	0.37	1.67	10.0	10.0
24	CH26	CH25	CH19		OF1	OF2	5.2	336.0	0.00	4	0	0	2	660.0	.0000	.000	0.04	1.67	0.04	1.67	15.0	15.0
25	CH28	CH27	CH27		OF4	OF4	9.2	41.3	0.00	4	0	0	2	400.0	.0000	.000	0.35	1.67	0.35	1.67	5.0	5.0
26	CH29	CH28	CH18		OF1	OF1	6.6	52.3	0.00	4	0	0	3	850.0	.0000	.000	0.26	1.67	0.26	1.67	10.0	10.0
27	CH30	CH29	CH26		OF1	OF2	3.4	391.7	0.00	4	0	0	2	430.0	.0000	.000	0.03	1.67	0.03	1.67	15.0	15.0
28	CH31	CH30	CH18		OF1	OF2	2.5	423.5	0.00	4	0	2	2	320.0	.0000	.000	0.03	1.67	0.03	1.67	15.0	60.0

Figure II-4.--Variables, parameters, and initial conditions for daily and stormflow simulation on Cane Branch watershed--Continued

OBSERVED AND PREDICTED RUNOFF FOR WY 1956

DAY	OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH	
	OBS	PRED	OBS	PRED	OBS	PRED	OBS	PRED	OBS	PRED	OBS	PRED
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	1.63
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	1.73
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.80	2.66
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.70	2.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	1.62
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	1.39
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.40	4.74
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.40	3.27
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.80	2.26
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	1.75
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	1.48
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	2.62
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.20	1.94
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.00	16.61
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.80	6.46
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.50	3.52	5.90	6.18
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	18.53	4.00	4.23
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	24.50	2.80	2.85
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.40	11.12	2.80	2.02
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.40	5.56	2.50	1.62
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.60	3.19	1.50	1.37
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	2.19	1.40	1.20
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.10	1.67	0.88	1.07
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.70	3.49	1.30	1.71
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	4.46	0.88	0.95
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.10	3.18	0.88	0.88
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40	3.04	0.78	0.81
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10	2.07	0.73	0.96
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	1.66	0.78	0.73
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.67
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.63

Figure II-5.--Daily mean flow summary table and annual summary for daily simulation on Cane Branch watershed.

OBSERVED AND PREDICTED RUNOFF FOR WY 1956--Continued

DAY	APRIL OBS	APRIL PRED	MAY OBS	MAY PRED	JUNE OBS	JUNE PRED	JULY OBS	JULY PRED	AUGUST OBS	AUGUST PRED	SEPTEMBER OBS	SEPTEMBER PRED
1	0.49	0.60	0.56	0.36	0.41	0.14	0.21	0.03	0.12	0.03	0.06	0.02
2	0.94	1.24	0.67	0.46	0.09	0.07	0.30	0.07	0.30	0.08	0.06	0.01
3	0.90	1.09	0.73	0.35	0.08	0.06	0.09	0.01	0.19	0.02	0.05	0.01
4	3.50	0.97	0.60	0.28	0.06	0.06	0.06	0.02	0.12	0.02	0.05	0.01
5	2.00	0.58	0.52	0.27	0.06	0.06	0.13	0.04	0.09	0.02	0.07	0.02
6	21.00	11.76	0.45	0.26	0.05	0.06	0.08	0.01	0.08	0.02	0.12	0.02
7	5.30	5.61	0.45	0.24	0.05	0.05	0.05	0.01	0.08	0.02	0.08	0.01
8	2.60	2.64	0.36	0.23	0.05	0.05	0.13	0.03	0.06	0.02	0.06	0.01
9	1.70	1.78	0.31	0.22	0.06	0.07	0.06	0.01	0.06	0.01	0.05	0.01
10	1.30	1.35	0.26	0.21	0.06	0.05	0.05	0.01	0.06	0.01	0.04	0.01
11	1.60	1.06	0.22	0.20	0.05	0.04	0.04	0.01	0.08	0.02	0.04	0.01
12	0.88	0.89	0.18	0.19	0.04	0.04	0.08	0.04	0.06	0.01	0.04	0.01
13	0.68	0.77	0.16	0.18	0.05	0.04	0.69	0.28	0.06	0.01	0.04	0.01
14	0.64	0.81	0.15	0.17	0.14	0.43	0.48	0.17	0.53	0.09	0.03	0.01
15	2.80	3.48	0.15	0.19	0.06	0.09	0.13	0.11	0.09	0.01	0.03	0.01
16	5.50	1.99	0.15	0.16	0.06	0.03	0.74	0.27	0.08	0.01	0.03	0.01
17	2.70	1.39	0.12	0.15	0.05	0.03	0.56	0.12	0.06	0.01	0.03	0.01
18	2.00	1.10	0.10	0.14	1.10	0.03	0.15	0.08	0.06	0.01	0.03	0.01
19	1.50	0.91	0.10	0.13	0.31	0.03	0.10	0.06	0.69	0.24	0.04	0.01
20	1.10	0.79	0.09	0.13	0.16	0.03	0.08	0.05	0.46	0.18	0.04	0.00
21	0.83	0.70	0.08	0.12	0.12	0.03	0.06	0.04	0.21	0.09	0.03	0.00
22	0.78	0.99	0.08	0.12	0.09	0.03	0.06	0.03	0.12	0.06	0.04	0.00
23	1.00	0.66	0.06	0.11	0.08	0.03	0.82	0.26	0.09	0.05	0.04	0.01
24	0.68	0.57	0.06	0.10	0.08	0.02	0.82	0.28	0.06	0.04	0.05	0.00
25	0.60	0.49	0.06	0.10	0.32	0.08	0.39	0.16	0.06	0.03	0.05	0.00
26	0.56	0.45	0.18	0.16	0.09	0.02	0.20	0.10	0.06	0.03	0.04	0.00
27	0.56	0.42	0.13	0.19	0.06	0.02	0.13	0.07	0.06	0.02	0.04	0.00
28	0.49	0.40	0.10	0.09	0.05	0.02	0.33	0.12	0.19	0.05	0.04	0.00
29	0.45	0.40	0.09	0.08	0.05	0.02	0.64	0.12	0.09	0.02	0.04	0.00
30	0.45	0.45	0.06	0.08	0.06	0.03	0.32	0.04	0.08	0.02	0.04	0.00
31	0.00	0.00	0.08	0.11	0.00	0.00	0.16	0.03	0.06	0.01	0.00	0.00

ANNUAL SUMMARY 1956 OBSERVED PRECIP= 34.01 POTENTIAL ET= 49.56 PREDICTED RUNOFF(IN) = 12.53 OBSERVED RUNOFF(IN) = 15.04
NET PRECIP= 30.12 ACTUAL ET= 23.72 (CFS)= 226.25 (CFS)= 271.63
INTERCEPTION LOSS= 3.89 SNOWMELT= 0.02 MEAN DAILY(CFS)= 0.62 MEAN DAILY(CFS)= 0.74

GW IN= 1.37 SSR IN= 7.40 SSR TO GW= 1.22 SURFACE RO= 2.46 SSR FLOW= 6.78 GW FLOW= 3.29 GW SINK= 0.00

Figure II-5.--Daily mean flow summary table and annual summary for daily simulation on Cane Branch watershed--Continued.

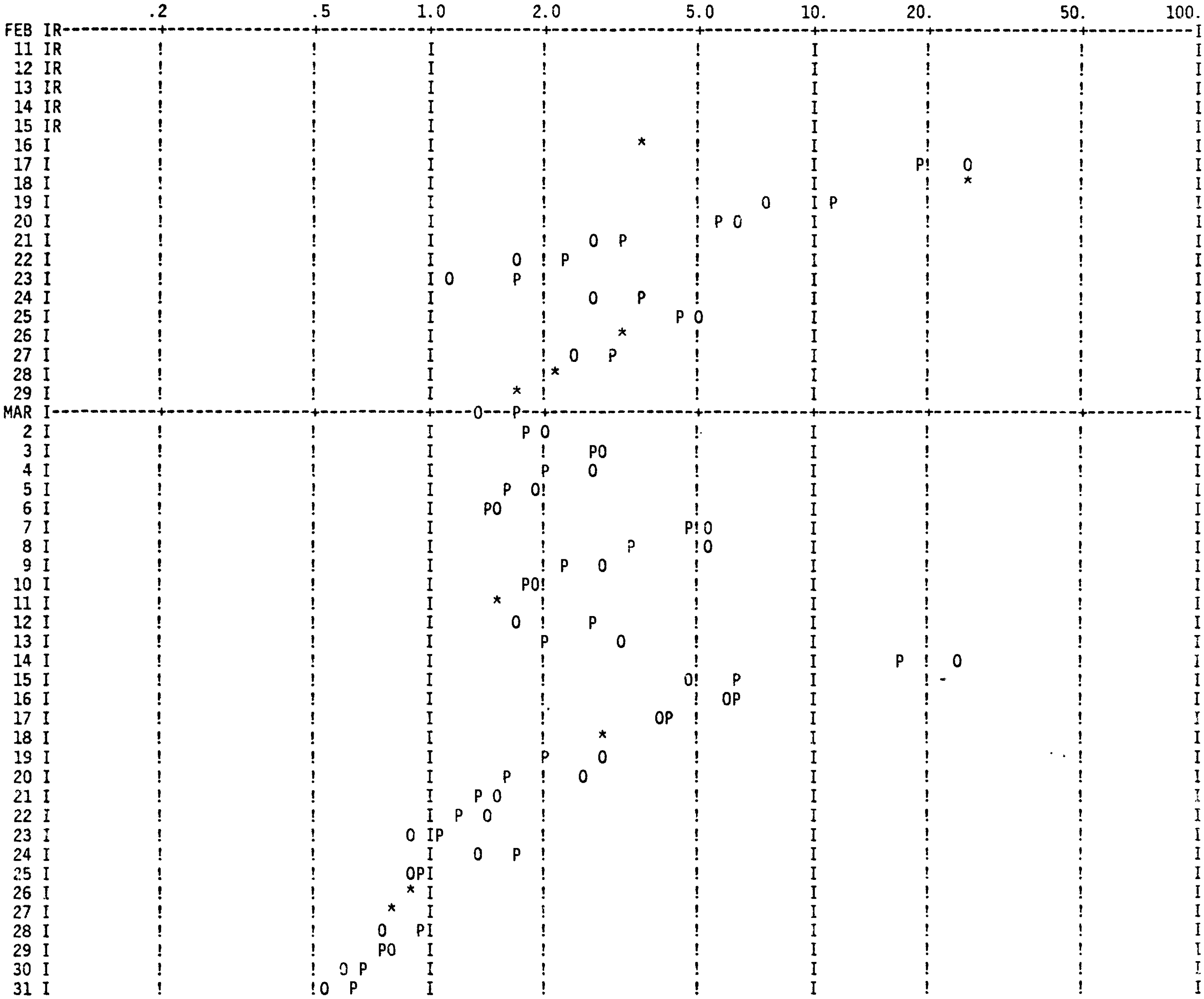

Figure II-6.--Line printer plot of simulated and observed daily mean discharge for Cane Branch watershed, February and March, 1956.

STORM	PREDICTED VOLUME (INCHES)	ROUTED OUTFLOW (INCHES)	OBSERVED OUTFLOW (INCHES)	PREDICTED PEAK (CFS)	OBSERVED PEAK (CFS)	PREDICTED SEDIMENT (TONS)
1	2.44	2.39	2.82	96.83	83.80	1094.26
2	1.07	1.03	1.52	64.56	75.00	525.59
3	0.70	0.65	1.17	64.34	97.80	451.48
4	0.01	0.01	0.01	0.36	0.61	2.60
5	0.03	0.03	0.01	1.28	0.64	32.27

STORM VOLUME ERROR SUMMARY

	ABS VALUE OBF FNC		SUM OF SQUARES OBF FNC	
	NO LOG	LOG	NO LOG	LOG
SUM	1.31	2.27	0.56	1.37
MEAN	0.26	0.45	0.11	0.27
PERCENT	23.63		30.14	

STORM PEAK ERROR SUMMARY

	ABS VALUE OBF FNC		SUM OF SQUARES OBF FNC	
	NO LOG	LOG	NO LOG	LOG
SUM	57.84	1.95	1399.28	0.99
MEAN	11.57	0.39	279.86	0.20
PERCENT	22.43		32.44	

Figure II-7.--Summary for water and sediment discharge for five storms simulated on Cane Branch watershed.

CANE BRANCH, KY   7HRUS   , DISCHARGE IN CFS

SEGMENT CH31 OUT   3/13/1956 - 3/14/1956

PREDICTED (P), OBSERVED (O), BOTH (*), OUT OF PLOT RANGE (R)

VALUE = PREDICTED DIVIDED BY 10 TO THE APPROPRIATE POWER

TIME	VALUE
100	2.5910
200	2.4564
300	2.2762
400	2.1133
500	1.9012
600	1.7335
700	1.6567
800	1.6284
900	1.6131
1000	1.6000
1100	1.5874
1200	1.5751
1300	1.5630
1400	1.5511
1500	1.5394
1600	1.5280
1700	1.5167
1800	1.5057
1900	1.4949
2000	1.4874
2100	1.5390
2200	1.8402
2300	2.8651
2400	5.3871
100	1.1710
200	1.8262
300	1.9616
400	1.6299
500	1.2951
600	2.9326
700	6.0668
800	3.8717
900	2.3179
1000	1.7652
1100	1.5242
1200	1.3873
1300	1.2928
1400	1.2187
1500	1.1564
1600	1.1018
1700	1.0528
1800	1.0082
1900	0.9671
2000	0.9290
2100	0.8935
2200	8.6033
2300	8.2924
2400	8.0002

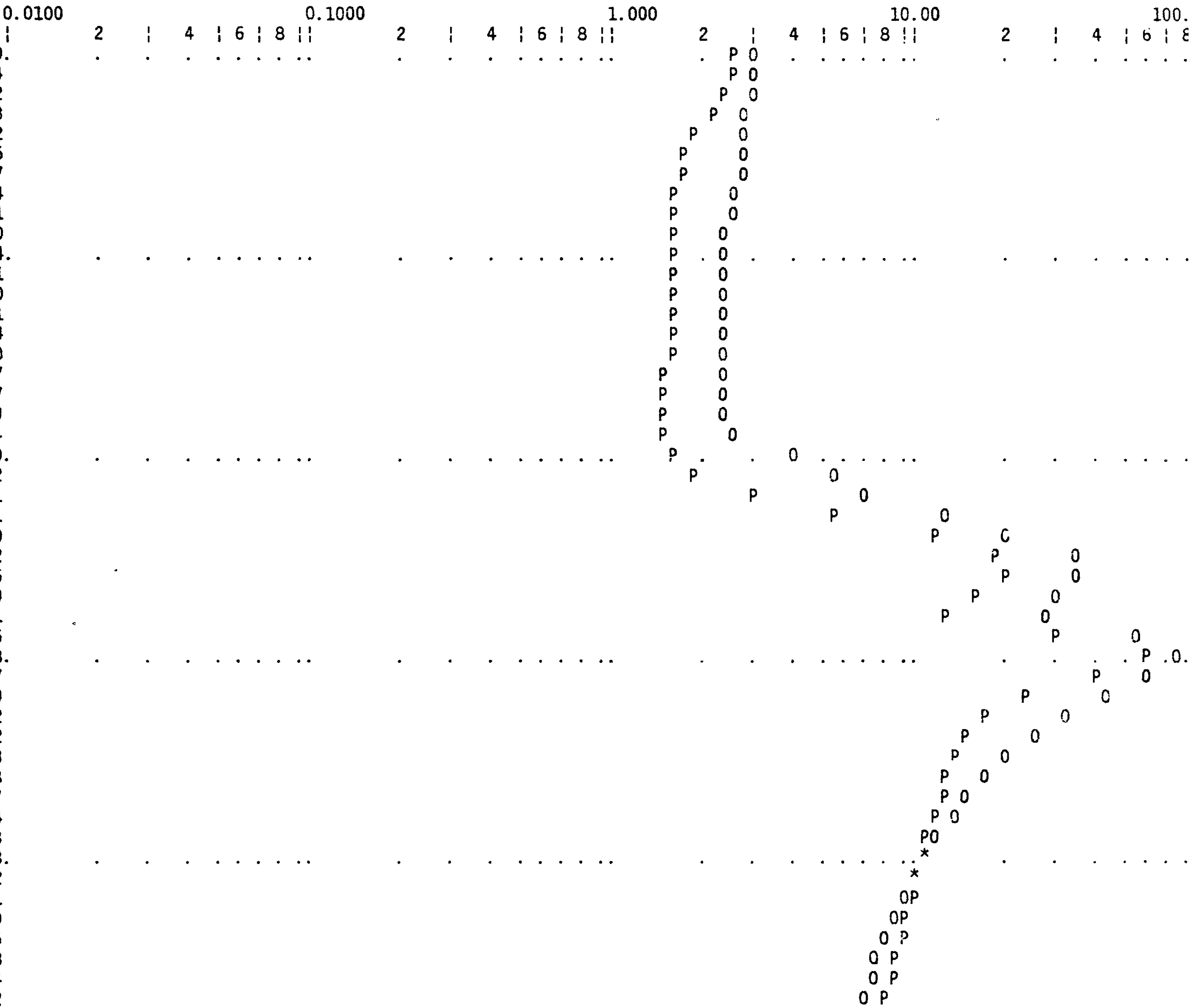

Figure II-8.--Line printer plot of simulated and observed discharge for storm 2 (March 13-14, 1956) on Cane Branch watershed.

```
CANE BRANCH, KY    7HRUS                                              , SEDIMENT IN G/L
                               SEGMENT CH31 OUT   3/13/1956 -  3/14/1956
PREDICTED (P), OBSERVED (O), BOTH (*), OUT OF PLOT RANGE (R)
VALUE = PREDICTED DIVIDED BY 10 TO THE APPROPRIATE POWER

          0.0100                        0.1000                       1.000                       10.00                     100.0
TIME VALUE ¦        2    ¦   4  ¦ 6 ¦ 8 ¦¦        2    ¦   4  ¦ 6 ¦ 8 ¦¦        2    ¦   4  ¦ 6 ¦ 8 ¦¦        2    ¦   4  ¦ 6 ¦ 8
 100 0.0000R        .    .   .  . . . . ..        .    .   .  . . . . ..        .    .   .  . . . . ..        .    .   .  . . . .
 200 0.0000R
 300 0.0000R
 400 0.0000R
 500 0.0000R
 600 0.0000R
 700 0.0000R
 800 0.0000R
 900 0.0000R
1000 0.0000R
1100 0.0000R        .    .   .  . . . . ..        .    .   .  . . . . ..        .    .   .  . . . . ..        .    .   .  . . . .
1200 0.0000R
1300 0.0000R
1400 0.0000R
1500 0.0000R
1600 0.0000R
1700 0.0000R
1800 0.0000R
1900 0.0000R
2000 0.5321R
2100 1.8428.        .    .   .  . . . . ..       P.    .   .  . . . . ..        .    .   .  . . . . ..        .    .   .  . . . .
2200 1.1915                                                              P
2300 3.5176                                                                            P
2400 6.2298                                                                                    P
 100 1.4944                                                                                               P
 200 1.5493                                                                                                P
 300 1.5306                                                                                                P
 400 1.5456                                                                                                P
 500 1.4967                                                                                               P
 600 1.4757                                                                                               P
 700 1.3942.        .    .   .  . . . . ..        .    .   .  . . . . ..        .    .   .  . . . . ..   P    .    .   .  . . . .
 800 1.6309                                                                                                P
 900 1.6342                                                                                                P
1000 1.4864                                                                                               P
1100 1.2864                                                                                             P
1200 1.1061                                                                                           P
1300 0.9475                                                                                         P
1400 7.9204                                                                                       P
1500 6.3991                                                                                    P
1600 5.0285                                                                                P
1700 3.8991.        .    .   .  . . . . ..        .    .   .  . . . . ..        .    .   P  . . . . ..        .    .   .  . . . .
1800 3.0286                                                                          P
1900 2.3835                                                                      P
2000 1.9124                                                                   P
2100 1.5672                                                                 P
2200 1.3106                                                               P
2300 1.1160                                                            P
2400 0.9651                                                           P
```

Figure II-9.--Line printer plot of simulated sediment concentration graph for storm 2 (March 13-14, 1956) on Cane Branch watershed.

Rosenbrock Optimization and Sensitivity Analysis Example

An example of selected segments of the input and output for a daily simulation run using the Rosenbrock optimization option followed by the sensitivity analysis option is shown in figures II-10 through II-14. The four parameters SMAX (LOP=8), EVC (LOP=74), RCF (LOP=50), and RCP (LOP=51) were optimized. Card groups 1, 7, and 8 are shown in figure II-10. The input values in card group 7 for the optimization are displayed in the model output as shown in figure II-11. An initialization period of February through September, 1956, was used and parameters were fitted only on the period October, 1956, through September, 1957. The results of each step in the Rosenbrock optimization procedure are displayed along with the summary of best fit parameter values as shown in figure II-12. The first line of output shows the initial objective function value in the first column followed by a zero in the second column and then four columns showing the parameter values used to obtain the initial objective function. Parameter columns are in the same order as the '05PARAM1' cards in card group 7. The second row begins the iterations of the optimization procedure. The first column is the iteration number and the second column is the sequence number of the parameter being adjusted. The next column is the old objective function from the previous iteration and it is followed by the objective function value computed during the current iteration. The remaining four columns are again the parameter values used in this iteration. In this example, log transforms were selected so that parameters were adjusted as a percentage of their initial value. Therefore, the tabular values are log values. This table is followed by the initial and final parameter and objective function values. Again, these values are log values. The base 10 parameter values are given in the last section of the optimization output. The values for the distributed parameters SMAX and EVC are output in the same sequential order as they are expressed on the '06PARAM2' card. If the '06PARAM2' card is not used, then the sequence is 1 to n, where n is the maximum number of HRU's, months, or reservoirs about which the parameter is distributed.

Using the Rosenbrock optimization option with correlation analysis produces a different output from that shown in figure II-12. The correlation analysis option for daily simulation is selected by changing the IOPT parameter on card 1 of card group 1 (fig. II-10) from a "1" to a "2." Output from iterations 0 and 1 for a Rosenbrock optimization with correlation analysis is shown in figure II-13. A table of parameter values and options precedes the output shown in figure II-13 and is identical to the output shown in figure II-11. Iteration 0 presents the results of the simulation run for the optimization period using the initial parameter values. The subiterations shown are the iterations for fitting the autoregressive moving average (ARMA) model being used to model the correlation of errors on successive days. Subiterations are terminated when no further improvement is made in the sum of squares computation which is the objective function. The ARMA parameters are shown for each subiteration. Subiteration 0 shows the objective function without the ARMA model. The final set of ARMA parameters are carried forward to the next major iteration to provide a starting point in the subiterations.

A Chi-squared statistic and the lag 1-10 correlations are presented for this major iteration for the cases of before and after ARMA model application. This is followed by the variance of the original series and the white noise

CARD GROUP 1

```
01SIM/OPT     0    1    1    0    0    0    0    0
02SIM/COMP         1    1    2    1
03TITL      CANE BRANCH, KY     7HRUS, DAILY
04INIT1       1    7    6    2    1    0      429.
05INIT2     1956   02   16 1957   09   30
06MFS-MFN    10    9    1
07PRINT-OP    2   10    9
08PLOT        1    1   10    1    9   30      100.         .1
09DATATYPE    6    1    0    1    1    0    0    0    1    1    1
10PARM      00060000500002000020              000600004500045
11STAT      00003000060000100002              000110000600006
12STAID     D 03407100        D365200085090000  D370700084370000  D370700084370000
12STAID                                                           U 03407100
13STAIDP    D365205084265702  U365205084265702
14RD 1      HOR          0.0  0.0  37.
14RD 2     NE20          0.2  45.  37.
14RD 3     SW30          0.3 225.  37.
14RD 4      S10          0.1 180.  37.
14RD 5      E20          0.2  90.  37.
14RD 6     SW10          0.1 225.  37.
15RDM       -.10 -.10-.075 -.05 -.05 -.05 -.05 -.05 -.05 -.05-.075 -.10
16RDC        1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
17RAD-COR    .50 .25  .25  .61   .8
18CLIM-PR       1050.   .8   .6    0    0    0
19CTW       .012 .012 .012 .012 .012 .012 .012 .012 .012 .012 .012 .012    .1
20PAT        4.5  4.5  4.5  4.5  4.5  4.5  4.5  4.5  4.5  4.5  4.5  4.5
21AJMX       1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
22TLX        1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
23TLN        1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
24EVC        1.3  1.2  .72  .75  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.5
25SNO-VAR     90  120 .757  .04  .20  .40   .1  1.0
26CEN         5.   5.   6.   6.   6.   6.   6.   6.   6.   6.   5.   5.
27PKADJ
28RES         .6   .6
29GW          .7
30KRSP         1    1
31RESMX-EX   1.0  1.0  1.0  1.0
32RSEP       .05  .05
33GSNK        0.   0.
34RCB        .05
35RCF-RCP         .02       .47       .02       .47
```

Figure II-10.--Input card deck for a Rosenbrock optimization followed by a sensitivity analysis on Cane Branch watershed.

CARD GROUP 1--Continued

```
36RU1    1  2  .25  1100.    3  .60  .30  .42   .1   .1  .05 4111 24. -.78 -.78
37RU2    1    2  6.0  5.8  2.0  1.8  1.0  .60.0016   .3  0.    0.   .12  1  1  0
38RU3    1  1   39.5  1.0  1.0  1.0
36RU1    2  3  .35  1100.    3  .60  .30  .42   .1   .1  .05 4111 24.  .78  .78
37RU2    2    2  6.0  5.8  2.0  1.8  1.0  .60.0016   .3  0.    0.   .12  1  1  0
38RU3    2  1   38.0  1.0  1.0  1.0
36RU1    3  4  .10  1250.    3  .60  .30  .42   .1   .1  .05 4111 24.  .39  .39
37RU2    3    2  6.0  5.8  2.0  1.8  1.0  .60.0016   .3  0.    0.   .12  1  1  0
38RU3    3  1   38.2  1.0  1.0  1.0
36RU1    4  5  .20  1250.    3  .60  .30  .42   .1   .1  .05 4111 24.  .39  .39
37RU2    4    2  6.0  5.8  2.0  1.8  1.0  .60.0016   .3  0.    0.   .12  1  1  0
38RU3    4  1   77.7  1.0  1.0  1.0
36RU1    5  6  .12  1250.    3  .60  .30  .42   .1   .1  .05 4111 24.  .78  .78
37RU2    5    2  6.0  5.8  2.0  1.8  1.0  .60.0016   .3  0.    0.   .12  1  1  0
38RU3    5  1  122.7  1.0  1.0  1.0
36RU1    6  2  .23  1250.    3  .60  .30  .42   .1   .1  .05 4111 24. -.78 -.78
37RU2    6    2  6.0  5.8  2.0  1.8  1.0  .60.0016   .3  0.    0.   .12  1  1  0
38RU3    6  1   85.5  1.0  1.0  1.0
36RU1    7  5  .10  1200.    0  0.   0.   1.0  0.   0.    0. 4111 24.  .39  .39
37RU2    7    2  3.0  2.5  1.0   .5  1.0  .01.0016   .3  0.    0.    .0  2  1  0
38RU3    7  1   27.4  1.0  1.0  1.0
```

CARD GROUPS 7 AND 8

```
01OPT1      1956    2   16 1956    9   30
02OPT2      1956   10    1 1957    9   30
03IOBF         2    1
04OPT4         4    8    0
05PARAM1       8    1    7    0   .1   0.   10.
05PARAM1      74    1   12    0   .1   0.    2.
05PARAM1      50    0    1    0   .1   0.    1.
05PARAM1      51    0    1    0   .1   0.    1.
01OPT/SENS     0    1    2    1   10    9
04SENST        4  .01    0
05PARAM1       8    1    7    0
05PARAM1      74    1   12    0
05PARAM1      50    0    1    0
05PARAM1      51    0    1    0
01OPT/SENS     0    0
```

Figure II-10.--Input card deck for a Rosenbrock optimization followed by a sensitivity analysis on Cane Branch watershed--Continued.

```
CANE BRANCH, KY    7HRUS, DAILY

  IOPT=    1     ISIM=    0     IOBS=    1     ISEN=    0
  IDOUT=   0     IUOUT=   0     SCODE==319     ICBC=    0     IPSW=    0

  IPET=    1     ISSR1=   1     MRDC=    2     ISUN=    1
  NYR=     2     NDS=     1     NRU=     7     NRD=     6     NRES=   2    NGW=    1    NSTOR=   0    DAT=        429.00

  BYR/BMO/BDY= 1956/ 2/16     EYR/EMO/EDY= 1957/ 9/30

  INIT-BYR/BMO/BDY= 1956/ 2/16     EYR/EMO/EDY= 1956/ 9/30   OPT -BYR/BMO/BDY= 1956/10/ 1     EYR/EMO/EDY= 1957/ 9/30
  IOBF=    2     ITRANS=    1
  MFS= 10     MFN=  9
```

DATA TYPE	PARAMETER CODE	STATISTIC CODE	DSN	STATION ID 1
DAILY DISCHARGE	00060	00003	4	03407100
DAILY EVAP	00050	00006	0	365200085090000
DAILY MAX TEMP	00020	00001	6	370700084370000
DAILY MIN TEMP	00020	00002	7	370700084370000
DAILY SOLAR RAD			0	
USER VARIABLE 1			0	
USER VARIABLE 2			0	
UNIT DISCHARGE	00060	00011	9	03407100
DAILY PRECIP	00045	00006	3	365205084265702
UNIT PRECIP	00045	00006	8	365205084265702

POT SOLAR RADIATION

1	HOR	374.4	398.6	440.2	499.1	571.5	651.1	732.4	809.8	877.2	933.2	975.4	1003.7	1019.7
2	NE20	260.2	284.6	327.0	388.6	466.4	554.6	647.9	739.7	823.0	894.6	950.6	989.2	1011.4
3	SW30	536.4	558.4	595.2	645.6	704.7	765.8	824.2	875.4	915.7	945.8	965.8	977.8	984.1
4	S10	458.8	482.2	521.7	576.7	642.8	713.6	783.7	848.2	902.4	945.7	977.0	997.4	1008.6
5	E20	376.5	400.5	441.6	499.7	571.1	649.4	729.3	805.1	871.0	925.7	966.8	994.3	1009.8
6	SW10	433.7	457.4	497.5	553.7	621.9	695.3	769.0	837.4	895.5	942.5	977.0	999.7	1012.2

```
RDM(1-12)= -0.10 -0.10 -0.08 -0.05 -0.05 -0.05 -0.05 -0.05 -0.05 -0.05 -0.08 -0.10
RDC(1-12)=  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00

MRDC=  2 PARS=  0.50 PARW=  0.25 RDB=  0.25RDP=  0.61RDMX=  0.80
```

SUNLIGHT HOURS/12

1	HOR	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.2
2	NE20	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2
3	SW30	0.8	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1
4	S10	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2
5	E20	0.7	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.1
6	SW10	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.2	1.2

Figure II-11.--Variables, parameters, and initial conditions for Rosenbrock optimization run on Cane Branch watershed.

```
CANE BRANCH, KY    7HRUS, DAILY

  CSEL=     1050.          RMXA= 0.80     RMXM= 0.60     MTSS=     0     MTSE=     0

  MPCS=   0          MPCN=    0     MPC1=    0     PCONR=  1.00     PCONS=  1.00

  CTS(1-12)=0.0120000.0120000.0120000.0120000.0120000.0120000.0120000.0120000.0120000.0120000.0120000.012000
  CTW=    0.10

  PAT(1-12)=    4.50    4.50    4.50    4.50    4.50    4.50    4.50    4.50    4.50    4.50    4.50    4.50
  AJMX(1-12)=    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00

  TLX(1-12)=    1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50
  TLN(1-12)=    1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50

  EVC(1-12)=   1.300   1.200   0.720   0.750   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.500

  ISP1= 90     ISP2=120     EAIR= 0.757     FWCAP= 0.04     DENI= 0.20     DENMX= 0.40     SETCON= 0.10     BST=  1.00

  CECN(1-12)=    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00

  RES-RSEP        1-    0.60    0.05   2-    0.60    0.05

  RESMX-REXP    1.0000    1.0000
   1.0000    1.0000

  KRSP=    1    1

  RCF-RCP       1- 0.0200000 0.4700000      2- 0.0200000 0.4700000

  GW-GSNK       1-    0.700    0.000

  RCB      1-   0.0500
```

Figure II-11.--Variables, parameters, and initial conditions for Rosenbrock optimization run on Cane Branch watershed--Continued.

CANE BRANCH, KY   7HRUS, DAILY

IRU	IRD	ITST	ITSW	TXAJ	RNSTS	SNST	COVDS	ICOV	SMAX	REMX	SCN	SRX	RETIP	SEP	KRES
	ELEV	ITND	CTX	TNAJ	RNSTW	TRNCF	COVDW	ISOIL	SMAV	RECHR	SC1	SCX	IMPRV	KSTOR	KGW
1	2	4	1	-0.78	0.10	0.10	0.60	3	6.00	2.00	0.00160	1.00	0.00	0.12	1
	1100.	11	24.00	-0.78	0.05	0.42	0.30	2	5.80	1.80	0.30000	0.60	0.00	0	1
2	3	4	1	0.78	0.10	0.10	0.60	3	6.00	2.00	0.00160	1.00	0.00	0.12	1
	1100.	11	24.00	0.78	0.05	0.42	0.30	2	5.80	1.80	0.30000	0.60	0.00	0	1
3	4	4	1	0.39	0.10	0.10	0.60	3	6.00	2.00	0.00160	1.00	0.00	0.12	1
	1250.	11	24.00	0.39	0.05	0.42	0.30	2	5.80	1.80	0.30000	0.60	0.00	0	1
4	5	4	1	0.39	0.10	0.10	0.60	3	6.00	2.00	0.00160	1.00	0.00	0.12	1
	1250.	11	24.00	0.39	0.05	0.42	0.30	2	5.80	1.80	0.30000	0.60	0.00	0	1
5	6	4	1	0.78	0.10	0.10	0.60	3	6.00	2.00	0.00160	1.00	0.00	0.12	1
	1250.	11	24.00	0.78	0.05	0.42	0.30	2	5.80	1.80	0.30000	0.60	0.00	0	1
6	2	4	1	-0.78	0.10	0.10	0.60	3	6.00	2.00	0.00160	1.00	0.00	0.12	1
	1250.	11	24.00	-0.78	0.05	0.42	0.30	2	5.80	1.80	0.30000	0.60	0.00	0	1
7	5	4	1	0.39	0.00	0.00	0.00	0	3.00	1.00	0.00160	1.00	0.00	0.00	2
	1200.	11	24.00	0.39	0.00	1.00	0.00	2	2.50	0.50	0.30000	0.01	0.00	0	1

IRU	IDS	SLOPE	AREA	PERV AREA	IMPERV AREA	UPCOR	DRCOR	DSCOR	TST
1	1	0.25	39.5	39.5	0.0	1.00	1.00	1.00	0.0
2	1	0.35	38.0	38.0	0.0	1.00	1.00	1.00	0.0
3	1	0.10	38.2	38.2	0.0	1.00	1.00	1.00	0.0
4	1	0.20	77.7	77.7	0.0	1.00	1.00	1.00	0.0
5	1	0.12	122.7	122.7	0.0	1.00	1.00	1.00	0.0
6	1	0.23	85.5	85.5	0.0	1.00	1.00	1.00	0.0
7	1	0.10	27.4	27.4	0.0	1.00	1.00	1.00	0.0
TOTAL			429.0	429.0	0.0				

Figure II-11.--Variables, parameters, and initial conditions for Rosenbrock optimization run on Cane Branch watershed--Continued.

ROSENBROCK OPTIMIZATION

```
     IOPT    1                              NTRY    8
       NV    4                            IPRIOR    0
     IOBF    2                            ITRANS    1
      MFS   10                               MFN    9


THE FOLLOWING PARAMETERS ARE TO BE ADJUSTED:
    LOP=   8  74  50  51
  ILOPL=   1   1   0   0
   NVAR=   7  12   1   1
THE LOWER CONSTRAINTS ARE
  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
THE UPPER CONSTRAINTS ARE
  0.100000E+02  0.200000E+01  0.100000E+01  0.100000E+01
THE TRANSFORMED LOWER CONSTRAINTS ARE
  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
THE TRANSFORMED UPPER CONSTRAINTS ARE
  0.223026E+02  0.206931E+02  0.100000E+01  0.100000E+01
THE STARTING PARAMETER VALUES ARE
  0.216927E+02  0.200195E+02  0.200000E-01  0.470000E+00
THE INITIAL STEP SIZE INCREMENTS ARE
  0.100000E+00  0.100000E+00  0.100000E+00  0.100000E+00
THE TRANSFORMED INITIAL STEP SIZE INCREMENTS ARE
  0.460984E-02  0.499513E-02  0.100000E+00  0.100000E+00
```

Figure II-11.--Variables, parameters, and initial conditions for Rosenbrock optimization run on Cane Branch watershed--Continued.

INIT		0.13436401E+02	0.00000000E+00	0.21692726E+02	0.20019493E+02	0.20000000E-01	0.47000003E+00
1	1	0.13436401E+02	0.13755552E+02	0.21792725E+02	0.20019493E+02	0.20000000E-01	0.47000003E+00
1	2	0.13436401E+02	0.13436049E+02	0.21692726E+02	0.20119492E+02	0.20000000E-01	0.47000003E+00
1	3	0.13436049E+02	0.13447371E+02	0.21692726E+02	0.20119492E+02	0.21999996E-01	0.47000003E+00
1	4	0.13436049E+02	0.13311890E+02	0.21692726E+02	0.20119492E+02	0.20000000E-01	0.51699996E+00
2	1	0.13311890E+02	0.14238367E+02	0.21642723E+02	0.20119492E+02	0.20000000E-01	0.51699996E+00
2	2	0.13311890E+02	0.13301014E+02	0.21692726E+02	0.20419491E+02	0.20000000E-01	0.51699996E+00
2	3	0.13301014E+02	0.13295477E+02	0.21692726E+02	0.20419491E+02	0.18999998E-01	0.51699996E+00
2	4	0.13295477E+02	0.13083899E+02	0.21692726E+02	0.20419491E+02	0.18999998E-01	0.65799987E+00
3	1	0.13083899E+02	0.12797766E+02	0.21717720E+02	0.20419491E+02	0.18999998E-01	0.65799987E+00
3	2	0.12797766E+02	0.12799482E+02	0.21717720E+02	0.20644485E+02	0.18999998E-01	0.65799987E+00
3	3	0.12797766E+02	0.12784101E+02	0.21717720E+02	0.20419491E+02	0.15999995E-01	0.65799987E+00
3	4	0.12784101E+02	0.12771284E+02	0.21717720E+02	0.20419491E+02	0.15999995E-01	0.86949980E+00
4	1	0.12771284E+02	0.13509754E+02	0.21792717E+02	0.20419491E+02	0.15999995E-01	0.86949980E+00
4	2	0.12771284E+02	0.12774082E+02	0.21717720E+02	0.20306988E+02	0.15999995E-01	0.86949980E+00
4	3	0.12771284E+02	0.12733070E+02	0.21717720E+02	0.20419491E+02	0.69999946E-02	0.86949980E+00
4	4	0.12733070E+02	0.12775019E+02	0.21717720E+02	0.20419491E+02	0.69999946E-02	0.94881213E+00
5	1	0.12733070E+02	0.13122808E+02	0.21680218E+02	0.20419491E+02	0.69999946E-02	0.86949980E+00
5	2	0.12733070E+02	0.12732435E+02	0.21717720E+02	0.20475735E+02	0.69999946E-02	0.86949980E+00
5	3	0.12732435E+02	0.12703945E+02	0.21717720E+02	0.20475735E+02	0.24999498E-03	0.86949980E+00
5	4	0.12703945E+02	0.12689768E+02	0.21717720E+02	0.20475735E+02	0.24999498E-03	0.82984352E+00
6	1	0.12689768E+02	0.12722698E+02	0.21736469E+02	0.20475735E+02	0.24999498E-03	0.82984352E+00
6	2	0.12689768E+02	0.12691196E+02	0.21717720E+02	0.20644482E+02	0.24999498E-03	0.82984352E+00
6	3	0.12689768E+02	0.12689260E+02	0.21717720E+02	0.20475735E+02	0.91791808E-04	0.82984352E+00
6	4	0.12689768E+02	0.12686590E+02	0.21717720E+02	0.20475735E+02	0.24999498E-03	0.71087480E+00

Figure II-12.--Rosenbrock optimization run on Cane Branch watershed.

```
INIT
   7    1 0.12686590E+02 0.12769295E+02 0.21708344E+02 0.20475735E+02 0.24999498E-03 0.71087480E+00
   7    2 0.12686590E+02 0.12687773E+02 0.21717720E+02 0.20391357E+02 0.24999498E-03 0.71087480E+00
   7    3 0.12686590E+02 0.12687071E+02 0.21717720E+02 0.20475735E+02 0.32909651E-03 0.71087480E+00
   7    4 0.12686590E+02 0.13445370E+02 0.21717720E+02 0.20475735E+02 0.24999498E-03 0.35396862E+00
   8    1 0.12686590E+02 0.12660789E+02 0.21722404E+02 0.20475735E+02 0.24999498E-03 0.71087480E+00
   8    2 0.12660789E+02 0.12660435E+02 0.21722404E+02 0.20517918E+02 0.24999498E-03 0.71087480E+00
   8    3 0.12660435E+02 0.12660250E+02 0.21722404E+02 0.20517918E+02 0.21044415E-03 0.71087480E+00
   8    4 0.12660250E+02 0.12690474E+02 0.21722404E+02 0.20517918E+02 0.21044415E-03 0.88932788E+00
THE INITIAL PARAMETER VALUES WERE
    0.2169E+02    0.2002E+02    0.2000E-01    0.4700E+00
THE FINAL PARAMETER VALUES ARE
    0.2172E+02    0.2052E+02    0.2104E-03    0.7109E+00
THE INITIAL AND FINAL OBJ FUNCTION VALUES ARE
   0.13436D+02  0.12660D+02


SUMMARY OF NEW PARAMETER VALUES:

 LOP=  8
    6.1799     6.1799     6.1799     6.1799     6.1799     6.1799     3.0900

 LOP= 74
    2.1397     1.9751     1.1851     1.2344     1.6459     1.6459     1.6459     1.6459     1.6459     1.6459     1.6

 LOP= 50
    0.0002

 LOP= 51
    0.7109
```

Figure II-12.--Rosenbrock optimization run on Cane Branch watershed--Continued.

ITERATION NO. 0

SUB-ITERATION	SUM OF SQUARES	ARMA PARAMETERS	
0	0.134364D+02	0.000	0.000
1	0.821386D+01	0.688	0.000
2	0.814668D+01	0.684	0.047
3	0.811939D+01	0.693	0.086
4	0.810565D+01	0.704	0.118
5	0.809795D+01	0.715	0.143
6	0.809347D+01	0.725	0.163
7	0.809086D+01	0.732	0.177
8	0.808935D+01	0.738	0.189
9	0.808848D+01	0.743	0.197
10	0.808799D+01	0.746	0.204
11	0.808771D+01	0.748	0.209
12	0.808756D+01	0.750	0.212
13	0.808747D+01	0.752	0.215
14	0.808742D+01	0.753	0.217
15	0.808739D+01	0.754	0.219
16	0.808738D+01	0.754	0.220
17	0.808737D+01	0.755	0.220
18	0.808737D+01	0.755	0.221
19	0.808736D+01	0.755	0.222

	CHI-SQUARED STATISTIC	CORRELATIONS LAG 1	2	3	4	5	6	7	8	9	10
BEFORE ARMA MODELING	352.5	0.62	0.41	0.38	0.34	0.25	0.20	0.11	0.09	0.13	0.10
AFTER ARMA MODELING	17.7	0.02	-0.15	0.04	0.09	0.02	0.04	-0.08	-0.05	0.07	-0.00

VARIANCE, ORIGINAL SERIES= 0.036
VARIANCE, WHITE NOISE SERIES= 0.022

RESULTS FOR INITIAL PARAMETER VALUES

PARAMETERS : 21.693
20.019
0.020
0.470

OBJ. FNC. : 8.087

AUTOREGRESSIVE, MOVING AVE. PARAMETERS:
0.755 0.222

Figure II-13.--Rosenbrock optimization with correlation analysis run on Cane Branch watershed.

ITERATION NO. 1

SUB-ITERATION	SUM OF SQUARES	ARMA PARAMETERS	
0	0.137556D+02	0.000	0.000
1	0.970586D+01	0.755	0.222
2	0.960905D+01	0.756	0.278
3	0.957381D+01	0.768	0.323
4	0.955986D+01	0.779	0.354
5	0.955434D+01	0.788	0.375
6	0.955221D+01	0.794	0.388
7	0.955141D+01	0.797	0.396
8	0.955112D+01	0.800	0.401
9	0.955101D+01	0.801	0.403
10	0.955097D+01	0.802	0.405
11	0.955095D+01	0.803	0.406
12	0.955095D+01	0.803	0.407
13	0.955095D+01	0.803	0.407

	CHI-SQUARED STATISTIC	CORRELATIONS LAG 1	2	3	4	5	6	7	8	9	10
BEFORE ARMA MODELING	222.1	0.50	0.33	0.33	0.28	0.18	0.13	0.06	0.04	0.08	0.03
AFTER ARMA MODELING	13.1	0.02	-0.12	0.04	0.07	-0.02	-0.01	-0.06	-0.07	0.07	-0.03

VARIANCE, ORIGINAL SERIES= 0.036
VARIANCE, WHITE NOISE SERIES= 0.026

RESULTS FOR ADJUSTMENT 1, PARAMETER 1

	OLD	NEW
PARAMETERS :	21.693	21.793
	20.019	20.019
	0.020	0.020
	0.470	0.470
OBJ. FNC. :	8.087	9.551

AUTOREGRESSIVE, MOVING AVE. PARAMETERS:
0.803 0.407

Figure II-13.--Rosenbrock optimization with correlation analysis run on Cane Branch watershed--Continued.

```
THE INITIAL PARAMETER VALUES WERE
   0.2169E+02   0.2002E+02   0.2000E-01   0.4700E+00
THE FINAL PARAMETER VALUES ARE
   0.2171E+02   0.2069E+02   0.1215E-03   0.7109E+00
THE INITIAL AND FINAL OBJ FUNCTION VALUES ARE
  0.80874D+01  0.78978D+01


SUMMARY OF NEW PARAMETER VALUES:


LOP=  8
   6.0936    6.0936    6.0936    6.0936    6.0936    6.0936    3.0468


LOP= 74
   2.5431    2.3474    1.4085    1.4671    1.9562    1.9562    1.9562    1.9562    1.9562    1.9562    1.9562    2.9343


LOP= 50
   0.0001


LOP= 51
   0.7109


AUTOREGRESSIVE, MOVING AVE. PARAMETERS:
    0.776     0.281
```

Figure II-13.--Rosenbrock optimization with correlation analysis run on Cane Branch watershed--Continued.

SENSITIVITY ANALYSIS

ISEN	1	PINC	0.010
NV	4	IPRIOR	0
IOBF	2	ITRANS	1
MFS	10	MFN	9

THE FOLLOWING PARAMETERS ARE TO BE ADJUSTED:

LOP=	8	74	50	51
ILOPL=	1	1	0	0
NVAR=	7	12	1	1

LOP	VALUE
8	5.5973
74	1.6783
50	0.0002
51	0.7109

SENSITIVITY MATRIX (ASENS)

1	0.000	0.000	0.000	0.000
2	0.002	-0.000	-0.000	-0.000
3	0.021	-0.000	-0.000	-0.000
4	0.020	0.092	-0.000	-0.000
5	0.005	0.001	-0.000	-0.000
6	0.006	0.003	-0.000	-0.000
7	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000

Figure II-14.--Sensitivity analysis run on Cane Branch watershed.

SENSITIVITY MATRIX (ASENS)--Continued

16	0.000	0.000	0.000	0.000	
17	0.004	0.001	0.000	0.000	
18	0.019	0.004	-0.000	-0.000	
19	0.000	0.000	0.000	0.000	
20	0.000	0.000	0.000	0.000	
21	0.034	0.005	-0.000	-0.000	
22	0.044	0.115	-0.000	-0.000	
23	0.000	0.000	0.000	0.000	
24	0.000	0.000	0.000	0.000	
25	0.000	0.000	0.000	0.000	
26	0.045	0.023	-0.000	-0.000	
27	0.000	0.000	0.000	0.000	
28	0.000	0.000	0.000	0.000	
29	0.000	0.000	0.000	0.000	
30	0.000	0.000	0.000	0.000	
31	-2.386	0.012	0.003	0.004	OCTOBER
⋮	⋮	⋮	⋮	⋮	
1	-0.219	0.001	-0.006	-0.221	SEPTEMBER
2	-0.218	0.000	-0.006	-0.221	
3	-0.218	0.001	-0.006	-0.222	
4	-0.217	0.001	-0.006	-0.222	
5	-0.217	0.001	-0.006	-0.223	
6	-0.217	0.001	-0.006	-0.223	
7	-0.216	0.001	-0.006	-0.224	
8	-0.216	0.001	-0.006	-0.224	
9	0.880	-0.001	-0.001	-0.015	
10	0.457	-0.000	-0.001	-0.004	
11	-0.094	0.001	0.002	-0.026	
12	0.236	0.000	0.000	-0.012	
13	0.139	-0.000	-0.000	-0.000	
14	0.073	-0.000	-0.000	-0.000	
15	0.006	-0.000	0.000	-0.000	
16	0.153	-0.000	-0.000	-0.000	
17	-0.001	0.000	-0.000	-0.001	
18	-0.001	0.000	-0.000	-0.001	
19	0.106	-0.000	-0.000	-0.001	
20	0.115	-0.000	-0.000	-0.002	
21	-0.003	0.000	-0.000	-0.003	
22	0.399	-0.000	-0.000	-0.002	
23	0.025	0.000	-0.000	-0.003	
24	-0.004	0.000	-0.000	-0.004	
25	-0.004	0.000	-0.000	-0.004	
26	-0.005	0.000	-0.000	-0.004	
27	-0.005	0.000	-0.000	-0.004	
28	0.502	-0.000	-0.001	-0.002	
29	0.614	0.099	-0.001	-0.002	
30	-0.005	0.000	-0.000	-0.005	

Figure II-14.--Sensitivity analysis run on Cane Branch watershed--Continued.

INFORMATION MATRIX (ZINFC)

0.2500E-01	-0.5066E-04	-0.4489E-04	-0.7683E-04
-0.5066E-04	0.2667E-06	0.7054E-07	-0.2756E-06
-0.4489E-04	0.7054E-07	0.1674E-06	0.2058E-05
-0.7683E-04	-0.2756E-06	0.2058E-05	0.2139E-03

ERROR PROPOGATION:
TABLE OF MEAN SQUARED RUNOFF PREDICTION ERROR
RESULTING FROM PARAMETER ERRORS

	MAGNITUDE OF PARAMETER ERROR			
LOP	5%	10%	20%	50%
8	0.00122	0.00489	0.01956	0.12227
74	0.00000	0.00000	0.00000	0.00000
50	0.00000	0.00000	0.00000	0.00000
51	0.00001	0.00004	0.00017	0.00105
JOINT	0.00123	0.00493	0.01973	0.12332

RESIDUALS ANALYSIS

VARIANCE	0.03507
STD DEV	0.18727
MEAN ABS	0.11180

PARAMETER	VALUE	STANDARD ERROR	
		JOINT	INDIVIDUAL
8	5.5973	0.1375	0.0785
74	1.6783	9.3196	7.2014
50	0.0002	0.0018	0.0011
51	0.7109	0.1204	0.1077

PARAMETER CORRELATION MATRIX (ZINV)

1.000	0.555	0.684	-0.255
0.555	1.000	0.155	-0.004
0.684	0.155	1.000	-0.441
-0.255	-0.004	-0.441	1.000

Figure II-14.--Sensitivity analysis run on Cane Branch watershed--Continued.

DIAGONAL ELEMENTS OF HAT MATRIX (PDENT)

0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.008	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
0.002									

0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
0.001	0.003	0.010	0.051	0.296	0.218	0.134	0.093	0.074	0.112
0.056	0.038	0.005	0.123	0.051	0.032	0.025	0.013	0.019	0.015
0.014									

0.013	0.012	0.011	0.018	0.040	0.008	0.027	0.023	0.026	0.033
0.073	0.022	0.017	0.016	0.015	0.013	0.012	0.010	0.009	0.022
0.069	0.062	0.092	0.016	0.026	0.028	0.026	0.125	0.011	0.134
0.114									

0.014	0.086	0.037	0.031	0.021	0.026	0.028	0.029	0.014	0.008
0.010	0.009	0.008	0.008	0.005	0.005	0.007	0.006	0.027	0.061
0.006	0.047	0.020	0.014	0.012	0.014	0.035	0.058		

0.005	0.004	0.003	0.006	0.006	0.015	0.013	0.024	0.024	0.025
0.048	0.048	0.023	0.014	0.011	0.009	0.008	0.007	0.006	0.006
0.006	0.046	0.005	0.004	0.005	0.004	0.003	0.003	0.003	0.003
0.003									

0.016	0.002	0.002	0.023	0.005	0.002	0.002	0.036	0.097	0.010
0.009	0.012	0.012	0.012	0.010	0.009	0.008	0.007	0.006	0.005
0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.002	0.002	0.002

0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001
0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
0.001	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000									

0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000									

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000									

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.078	0.000

Figure II-14.--Sensitivity analysis on Cane Branch watershed--Continued.

series. The initial parameter values, objective function value, and the ARMA parameters are then listed.

Iteration 1 presents the same output sequence as iteration 0, except that parameter 1 has now been adjusted. The new parameter value and the new objective function are shown. In this example, the increase in parameter 1 by 10 percent had a deleterious effect on the simulation which is evidenced by the increase in the objective function. For the next iteration parameter 1 will be returned to its original value and parameter 2 will be changed. This iteration sequence and iteration step output will be repeated until NV (number of variables) times NTRY (number of cycles through parameters) iterations are completed. These will be followed by a summary table of initial and final parameter and objective function values and a listing of the distributed parameter values in the same format as shown in figure II-12.

The operational sequence for an optimization run begins with a complete simulation for the period designated using the initial parameter estimates. The results of this simulation are output in a form dependent on the choices selected on the '07PRINTØP' card in card group 1. This is followed by the optimization output shown in figure II-12. Then another complete model simulation is run using the new 'best fit' parameter values. The results of this simulation are output after the optimization tables in the same format as the initial simulation run.

The sensitivity analysis output is shown in figure II-14. The first section lists the input values specified in card group 7 and is followed by the summary of parameter values fitted in the previous optimization. The next section is the sensitivity matrix which is n x p in size where n is the number of days or storm periods and p is the number of parameters. The values output are relative sensitivities. Only the 61 values for October and September are shown out of the total 365 daily values output. This is followed by the information matrix. The diagonal elements of this matrix are the sums of squares of the sensitivity matrix columns. The off diagonal elements are the cross products of the sensitivity matrix columns.

Parameter errors are expressed in the next three sections. The first is the error propogation table showing the increase in the mean squared runoff prediction error resulting from various size errors in each parameter. These are the increases that would occur in the variance value expressed in the residuals analysis shown next. The error and variance values shown are log values because ITRANS=1 was selected in card group 7. The residuals analysis is followed by a list of the parameter values with their joint and individual error values.

Parameter correlations are shown in the next output segment which is the parameter correlation matrix. This is followed by the diagonal elements of the hat matrix.

ATTACHMENT VIII

Instructions for obtaining a copy of PRMS

A copy of PRMS on magnetic tape (9 track, 1600 BPI) may be obtained by sending a magnetic tape along with a written request to:

U.S. Geological Survey
Water Resources Division, Surface Water Branch
National Center, Mail Stop 415
12201 Sunrise Valley Drive
Reston, VA 22092

A listing only may also be obtained by writing to the same address.

Inquiry should be made to this address regarding the cost of a copy request. Prepayment of the costs of producing a magnetic tape copy or listing is required. Check or money order, in exact amount, should be made payable to the U.S. Geological Survey.

Gauss-Newton Optimization Example

A second optimization procedure that can be selected is the Gauss-Newton procedure. This option is selected by making the IOPT parameter on card 1 of card group 1 negative. Figure II-15 shows the output for one iteration of a daily simulation run using the Gauss-Newton optimization with correlation analysis. Input parameter values and options are presented in a form identical to figure II-11 and immediately precede the output shown in figure II-15.

Unlike the Rosenbrock procedure, the Gauss-Newton procedure moves all parameters at once during an iteration step. The first item output in each iteration is the sensitivity matrix which is used in computing the direction and magnitude of movement for each parameter. This is followed by the subiteration table of the ARMA modeling procedure used in the error correlation analysis. This table and the subsequent ARMA output are the same as that described in the preceding section. The first subiteration table uses the parameter values available at the beginning of the current major iteration. For iteration 1, these are the initial parameter estimates. The first ARMA procedure is followed by the information matrix, the initial correction vector, and the correction vector multiplier. A table of the old and new adjusted parameters is then output. Using these new parameters, a second ARMA fitting is conducted and the results printed. A final correction vector multiplier is then computed using the Box-Kanemasu interpolation modification (Beck and Arnold, 1977). The old parameter values and the new parameter values computed using the new correction vector are output. A final ARMA fitting is conducted and the results are printed.

The sequence of procedures described and the outputs shown are repeated for each NTRY iteration requested. After the last iteration a table of initial and final objective functions and parameter values are output along with a table of the distributed parameter values in the same format as shown in figure II-12.

```
 GAUSS-NEWTON OPTIMIZATION
 -------------------------
      IOPT   -2                               NTRY    8
        NV    4                              IPRIOR   0
      IOBF    2                              ITRANS   1
       MFS   10                                 MFN   9


 THE FOLLOWING PARAMETERS ARE TO BE ADJUSTED:

     LOP=   8  74  50  51
   ILOPL=   1   1   0   0
    NVAR=   7  12   1   1

0THE LOWER CONSTRAINTS ARE
   0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00

0THE UPPER CONSTRAINTS ARE
   0.100000E+02  0.200000E+01  0.100000E+01  0.100000E+01

0THE TRANSFORMED LOWER CONSTRAINTS ARE
   0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00

0THE TRANSFORMED UPPER CONSTRAINTS ARE
   0.223026E+02  0.206931E+02  0.100000E+01  0.100000E+01

0THE STARTING PARAMETER VALUES ARE
   0.216927E+02  0.200195E+02  0.200000E-01  0.470000E+00

0THE INITIAL STEP SIZE INCREMENTS ARE
   0.100000E+00  0.100000E+00  0.100000E+00  0.100000E+00

0THE TRANSFORMED INITIAL STEP SIZE INCREMENTS ARE
   0.460984E-02  0.499513E-02  0.100000E+00  0.100000E+00
```

Figure II-15.--One iteration of Gauss-Newton optimization with correlation analysis on Cane Branch watershed.

ITERATION NUMBER 1

SENSITIVITY MATRIX (ASENS)

1	0.000	0.000	0.000	0.000	
2	0.033	0.000	0.000	0.000	
3	0.449	-0.000	0.000	-0.000	
4	0.441	-0.000	0.000	-0.000	
5	0.100	0.000	0.000	0.000	
6	0.138	-0.000	0.000	-0.000	
7	0.000	0.000	0.000	0.000	
8	0.000	0.000	0.000	0.000	
9	0.000	0.000	0.000	0.000	
10	0.000	0.000	0.000	0.000	
11	0.000	0.000	0.000	0.000	
12	0.000	0.000	0.000	0.000	
13	0.000	0.000	0.000	0.000	
14	0.000	0.000	0.000	0.000	
15	0.000	0.000	0.000	0.000	
16	0.000	0.000	0.000	0.000	
17	0.095	0.000	0.000	0.000	
18	0.414	-0.000	-0.000	-0.000	
19	0.000	0.000	0.000	0.000	
20	0.000	0.000	0.000	0.000	
21	0.729	-0.000	-0.000	-0.000	
22	0.936	-0.000	-0.000	-0.000	
23	0.000	0.000	-0.000	0.000	
24	0.000	0.000	-0.000	0.000	
25	0.000	0.000	-0.000	0.000	
26	0.960	0.000	-0.000	-0.000	
27	0.000	0.000	-0.000	0.000	
28	0.000	0.000	-0.000	-0.000	
29	0.000	0.000	-0.000	0.000	
30	0.000	0.000	-0.000	0.000	
31	-44.871	0.153	0.000	0.000	OCTOBER
⋮	⋮	⋮	⋮	⋮	
1	-6.323	0.019	-0.095	-0.141	SEPTEMBER
2	-6.313	0.019	-0.095	-0.141	
3	-6.303	0.019	-0.095	-0.140	
4	-6.293	0.019	-0.095	-0.140	
5	-6.283	0.019	-0.095	-0.140	
6	-6.273	0.019	-0.095	-0.140	
7	-6.264	0.019	-0.095	-0.140	
8	-6.255	0.019	-0.096	-0.140	
9	20.338	-0.000	-0.005	-0.008	
10	10.253	-0.001	-0.001	-0.002	
11	-2.284	-0.012	-0.012	-0.017	
12	5.932	-0.006	-0.005	-0.008	
13	3.091	-0.001	-0.000	-0.000	

Figure II-15.--One iteration of Gauss-Newton optimization with correlation analysis on Cane Branch watershed--Continued.

SENSITIVITY MATRIX (ASENS)--Continued

14	1.632	-0.000	-0.000	-0.000
15	0.134	0.000	-0.000	-0.000
16	3.397	-0.000	-0.000	-0.000
17	-0.025	0.000	-0.000	-0.000
18	-0.037	0.000	-0.000	-0.001
19	2.204	-0.000	-0.001	-0.001
20	2.421	-0.000	-0.001	-0.001
21	-0.076	0.000	-0.001	-0.001
22	9.754	-0.001	-0.000	-0.001
23	0.608	0.000	-0.001	-0.002
24	-0.107	0.000	-0.001	-0.002
25	-0.114	0.000	-0.002	-0.002
26	-0.120	0.000	-0.002	-0.002
27	-0.126	0.000	-0.002	-0.002
28	21.765	-0.001	-0.001	-0.001
29	26.286	-0.001	-0.000	-0.000
30	-0.136	0.000	-0.002	-0.003

SUB-ITERATION	SUM OF SQUARES	ARMA PARAMETERS	
0	0.134364D+02	0.000	0.000
1	0.821386D+01	0.688	0.000
2	0.814668D+01	0.684	0.047
3	0.811939D+01	0.693	0.086
4	0.810565D+01	0.704	0.118
5	0.809795D+01	0.715	0.143
6	0.809347D+01	0.725	0.163
7	0.809086D+01	0.732	0.177
8	0.808935D+01	0.738	0.189
9	0.808848D+01	0.743	0.197
10	0.808799D+01	0.746	0.204
11	0.808771D+01	0.748	0.209
12	0.808756D+01	0.750	0.212
13	0.808747D+01	0.752	0.215
14	0.808742D+01	0.753	0.217
15	0.808739D+01	0.754	0.219
16	0.808738D+01	0.754	0.220
17	0.808737D+01	0.755	0.220
18	0.808737D+01	0.755	0.221
19	0.808736D+01	0.755	0.222

Figure II-15.--One iteration of Gauss-Newton optimization with correlation analysis on Cane Branch watershed--Continued.

	CHI-SQUARED STATISTIC	CORRELATIONS LAG 1	2	3	4	5	6	7	8	9	10
BEFORE ARMA MODELING	352.5	0.62	0.41	0.38	0.34	0.25	0.20	0.11	0.09	0.13	0.10
AFTER ARMA MODELING	17.7	0.02	-0.15	0.04	0.09	0.02	0.04	-0.08	-0.05	0.07	-0.00

VARIANCE, ORIGINAL SERIES= 0.036
VARIANCE, WHITE NOISE SERIES= 0.022

INFORMATION MATRIX (ZINFC)

0.6983E+01	-0.1803E-02	-0.5094E-03	0.9923E-04
-0.1803E-02	0.3767E-04	-0.2712E-06	-0.1841E-04
-0.5094E-03	-0.2712E-06	0.3320E-06	0.3652E-05
0.9923E-04	-0.1841E-04	0.3652E-05	0.1241E-03

INITIAL CORRECTION VECTOR:
-0.0588 12.1704 -0.5256 0.5898
PARAMETER 2 OUTSIDE CONSTRAINTS, ALPHA HALVED, ALP= 1.000
PARAMETER 2 OUTSIDE CONSTRAINTS, ALPHA HALVED, ALP= 0.500
PARAMETER 2 OUTSIDE CONSTRAINTS, ALPHA HALVED, ALP= 0.250
PARAMETER 2 OUTSIDE CONSTRAINTS, ALPHA HALVED, ALP= 0.125
PARAMETER 2 OUTSIDE CONSTRAINTS, ALPHA HALVED, ALP= 0.063

CORRECTION VECTOR MULTIPLIER: 0.031

	OLD	NEW
PARAMETERS :	21.693	21.691
	20.019	20.400
	0.020	0.004
	0.470	0.488

SUB-ITERATION	SUM OF SQUARES	ARMA PARAMETERS	
0	0.133020D+02	0.000	0.000
1	0.804972D+01	0.755	0.222
2	0.804967D+01	0.754	0.222
3	0.804966D+01	0.754	0.222

Figure II-15.--One iteration of Gauss-Newton optimization with correlation analysis on Cane Branch watershed--Continued.

	CHI-SQUARED STATISTIC	CORRELATIONS LAG 1	2	3	4	5	6	7	8	9	
BEFORE ARMA MODELING	345.5	0.61	0.41	0.38	0.34	0.25	0.19	0.10	0.09	0.13	0.
AFTER ARMA MODELING	17.4	0.02	-0.14	0.04	0.09	0.02	0.04	-0.08	-0.05	0.07	-0.

VARIANCE, ORIGINAL SERIES= 0.036
VARIANCE, WHITE NOISE SERIES= 0.022

OBJ. FNC. : 8.087 8.050

FINAL RESULTS FOR ITERATION 1
CORRECTION VECTOR MULTIPLIER: 0.034

	OLD	NEW
PARAMETERS :	21.693	21.691
	20.019	20.438
	0.020	0.002
	0.470	0.490

SUB-ITERATION	SUM OF SQUARES	ARMA PARAMETERS	
0	0.132890D+02	0.000	0.000
1	0.804628D+01	0.754	0.222
2	0.804627D+01	0.753	0.222

	CHI-SQUARED STATISTIC	CORRELATIONS LAG 1	2	3	4	5	6	7	8	9	
BEFORE ARMA MODELING	344.8	0.61	0.41	0.38	0.34	0.25	0.19	0.10	0.09	0.12	0.
AFTER ARMA MODELING	17.4	0.02	-0.14	0.04	0.09	0.02	0.04	-0.08	-0.05	0.07	0.

VARIANCE, ORIGINAL SERIES= 0.036
VARIANCE, WHITE NOISE SERIES= 0.022

OBJ. FNC. : 8.087 8.046

Figure II-15.--One iteration of Gauss-Newton optimization with correlation analysis on Cane Branch watershed--Continued.

ATTACHMENT III

Procedure DCARDS

This procedure contains several subroutines that will read cards with different input formats and write records to online disk storage in the WATSTORE sequential format. The card formats that are currently available for input are: (1) WATSTORE standard daily- and unit-values input formats; (2) "Carter Card" format for daily and unit values; and (3) a variable daily format. Formats of the control cards and data cards are described below.

Input Format--WATSTORE Daily

This subroutine will read data in the U.S. Geological Survey WATSTORE standard daily values card format. Program control cards as shown below are inserted before and after data cards.

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION
1	1	I1	ITYP	WATSTORE Daily=0
2	17-64	12A4	TITL	Station name
3	2-16	3A4,A3	STAID	15-digit station identification number
	29-33	I5	PARM	WATSTORE 5-digit parameter code
	34-38	I5	STAT	WATSTORE 5-digit statistic code
4-51	2-16	3A4,A3	STAID	15-digit station identification
	17-20	I4	YEAR	Water year of record
	21-22	I2	IMØ	Month
	23-24	I2	ICD	Sequence number of card within month (ICD=1,2,3,4)
	25-80	8F7.0	DATA(I)	8 data values per card

Repeat cards 4-51 for each year.

52		I1	ICODE	8=end of parameter code or statistic code 9=end of station

NOTE: For new parameter or statistic code, start at card 3. For new station, start at card 1.

Input Format--WATSTORE unit

1	1	I1	ITYP	WATSTORE Unit=4
2	17-64	12A4	TITL	Station name
3	2-16	3A4,A3	STAID	15-digit station identification number
	29-33	I5	PARM	WATSTORE 5-digit parameter code

Input Format--WATSTORE Unit--Continued.

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION
	34-38	I5	STAT	WATSTORE 5-digit statistic code
4	1	A1	FLAG	B=unit values data
	17-20	I4	LYR	Calendar year
	21-22	I2	LMO	Month
	23-24	I2	LDY	Day
	25-26	I2	LHR	Hour (1st observation)
	27-28	I2	LMN	Minute
	29-30	I2	LSC	Second
	31-35	I5	RPD	Readings per day
	39-80	6F7.0	DATA(I)	Unit values for six consecutive time intervals

Repeat card 4 as necessary

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION
5	1	A1	FLAG	"2"=new time interval, continue with card 4 "7"=new station, continue with card 2 "8"=new parameter or statistic code, continue with card 3 "9"=end of WATSTORE Unit values card

Input Format--Carter Cards

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION
1	1	I1	ITYP	Carter=1
2	9-56	12A4	TITL	Station name
	59-64	F6.0	PTIME	Time interval for unit data
	65-79	3A4,A3	STAID	15-digit station identification
	80	I1	ICØDE	Unit sediment=0 Unit precipitation=1 Unit discharge=2 Daily precipitation=3 Daily evaporation=4 Daily maximum temperature (°C)=5 Daily minimum temperature (°C)=6 Daily solar radiation=7
3--(unit data)	9-10	I2	IYR	Year
	11-12	I2	IMØ	Month
	13-14	I2	IDY	Day
	17-18	I2	ICD	Card sequence number
	19-78	12F5.0	DATA(I)	Unit data
	80	I1	ICØDE	Same as card 2

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION
3--(daily data)	9-10	I2	IYR	Year
	11-12	I2	IMØ	Month
	13	I1	ICD	Card sequence (1 or 2)
	14-77	16F4.2	DATA(I)	Daily data
	80	I1	ICØDE	Same as card 2
4	80	I1	ICØDE	'8' to signify end of record

Repeat cards 2-4 for all records.

5		79X,I1	ICØDE	'9' to signify end of Carter cards

Input Format--Variable Daily

This option reads in daily data, one card per day with up to 8 variables per card. The format of the data cards is read in along with parameter and statistic codes corresponding to the variables.

CARD	COLUMNS	FORMAT	VARIABLE	DESCRIPTION
1	1	I1	ITYPE	Variable format=2
2	2-16	3A4,A3	STAID	15-digit station identification
	17-64	12A4	TITL	Title
	65-66	I2	NV	Number of variables read per day (maximum=8)
3	1-40	8I5	PARM(I)	WATSTORE parameter code for each data item
4	1-40	8I5	STAT(I)	Statistic code for each data item
5	1-80	20A4	FØRM(I)	Format of data cards, in parentheses
6--(One	1-2	I2	IMØ	Month of observation
card	3-4	I2	IDY	Day
per	5-8	I4	IYR	Year
day)	9-80	Variable	DV(I)	Variables--up to 8 per card

Note: Place 99 in columns for 'IMØ' at end of variable format data.

The JCL and deck setup to run DCARDS is as follows:

```
//---JØB CARD---
//PRØCLIB  DD DSN=DG4812S.PRDAT.LIB,DISP=SHR
// EXEC DCARDS,UVAL='userid.dsname.DATA',
// DVAL='userid.dsname.DATA'
//SYSIN DD *
      .
      .
      program control cards and data
      .
      .
/*
//
```

Underlined items should be replaced with the data set name for the unit values (UVAL) and daily values (DVAL) sequential output files.

An example of WATSTORE card format for daily values and Carter card format for storm period values is shown in figure III-1. One water year of daily data for streamflow, precipitation, maximum and minimum air temperature and pan evaporation, in WATSTORE card format, and 45 storm days of streamflow and precipitation at 15-minute intervals in Carter card format were input to DCARDS. The resulting DCARDS output which indicates by water year and storm day the station identification, parameter code, and statistics code of each record created is shown in figure III-2. DCARDS creates both a daily records file and a storm days file. These two output files were then used as input to program GENDISK to create a PRMS compatible ISAM file. The GENDISK output is shown in figure III-3.

```
//DG4812SD JOB (*********,D000),'SAINDON',CLASS=B
//PROCLIB DD DSN=DG4812S.PRDAT.LIB,DISP=SHR
//  EXEC DCARDS,DVAL='DG4812S.TESTD.DATA',
// UVAL='DG4812S.TESTU.DATA'
//SYSIN DD *


0
N       02462500BLACK WARRIOR R AT BANKHEAD L&D NEAR BESSEMER AL
2       02462500            0002000001                    ENT
3       0246250019761001  23.90  27.80  30.00  30.00  30.50  30.00  20.50  22.20
3       0246250019761002  16.10  18.30  23.30  25.50  25.50  26.70  28.30  27.20
3       0246250019761003  24.40  18.30  20.50  20.50  11.70  17.20  22.20  24.40
3       0246250019761004  20.50  21.10  15.60  13.90  14.40  13.90  18.30
                       .
                       .
                       .
3       0246250019770901  35.50  35.50  34.40  34.40  32.80  31.70  25.50  26.70
3       0246250019770902  31.70  31.10  31.70  30.50  31.70  29.40  31.10  30.00
3       0246250019770903  30.00  31.10  33.30  26.10  28.90  30.50  29.40  31.70
3       0246250019770904  29.40  28.90  31.70  31.70  30.00  21.10
8
2       02462500            0002000002                    ENT
3       0246250019761001  12.20  12.20  12.20  15.00  15.00  19.40  11.10  12.20
3       0246250019761002  10.00   5.60   6.70   7.20   9.40  10.00  10.00  10.00
3       0246250019761003  11.10   6.10   5.00   7.20   3.30   4.40   4.40   8.30
3       0246250019761004  15.00  10.00   3.90   3.90   3.30   3.30   8.30
                       .
                       .
                 .     .
3       0246250019770901  20.50  19.40  18.90  22.20  21.70  21.70  22.20  20.50
3       0246250019770902  20.00  20.00  19.40  15.60  16.10  20.50  20.50  20.50
3       0246250019770903  20.50  19.40  18.90  17.80  16.70  17.20  15.60  18.30
3       0246250019770904  20.00  20.00  15.60  20.50  19.40  18.90
8
2       02462500            0006000003                    ENT
3       02462500197610011960.00 590.00 890.00 530.002260.002770.002350.003760.00
3       02462500197610022740.00 530.00 590.00 470.00 300.00 590.00 300.00 720.00
3       0246250019761003 530.00 530.00 590.00 410.002630.001500.00 410.00 470.00
3       0246250019761004 590.001570.00 770.00 840.001520.00 470.00 710.00
                       .
                       .
                       .
3       02462500197709011500.001330.00 700.00 590.00 650.001590.00 10300. 15100.
3       02462500197709025100.00 800.001340.002860.003700.004730.004940.004900.00
3       02462500197709035200.00 710.005020.003990.003080.002760.002410.00 150.00
3       02462500197709041680.009960.006940.007430.006190.00 10000.
9
```

Figure III-1.--Card deck used to run DCARDS procedure.

```
0
N      02462990YELLOW CREEK NEAR NORTHPORT AL
2      02462990             0004500006               ENT
3      0246299019761001     0      0      0      0      0   0.59      0      0
3      0246299019761002     0      0      0      0      0      0      0   0.33
3      0246299019761003     0      0      0   0.10      0      0      0   0.01
3      0246299019761004  1.64      0      0      0   0.03   0.19      0
                   .
                   .
                   .
3      0246299019770901     0      0      0   0.32   0.44   4.38   0.38      0
3      0246299019770902     0      0      0      0   0.01   0.53   0.64   1.31
3      0246299019770903     0      0   0.03      0      0      0      0      0
3      0246299019770904  0.04   0.78   0.08      0   0.70   0.26

9
0
N324000085550001EVAPORATION STATION AT MARTIN DAM AL
2324000085550001            0005000006               ENT
33240000855500011976100 1  0.17   0.10   0.13   0.11   0.13      0   0.10   0.10
33240000855500011976100 2  0.08   0.12   0.15   0.12   0.09   0.10   0.18   0.02
33240000855500011976100 3  0.12   0.14      0   0.08   0.13   0.09   0.12   0.02
33240000855500011976100 4  0.06   0.17   0.12   0.06   0.07   0.09   0.08
                   .
                   .
                   .
332400008555000119770901  0.19   0.15   0.14   0.09   0.10   0.03   0.10   0.07
332400008555000119770902  0.11   0.18   0.19   0.16   0.13   0.11   0.21   0.26
332400008555000119770903  0.10   0.06   0.08   0.14   0.15   0.20   0.15   0.08
332400008555000119770904  0.26   0.07   0.07   0.23   0.07   0.11
9
1
      YELLOW CR NR NORTHPORT, AL                            15.      024629901
0246299076122015 1    0    0    1    1    1    1    0    1    1    2    2   0 1
0246299076122015 2    1    1    2    5    3    4    4    7    7   20    5  19 1
0246299076122015 3    7    7    5    7    1    0    1    2    1    1    1   1 1
0246299076122515 3    0    0    0    0    0    0    0    1    2    4    5   4 1
0246299076122515 4    5    7    3    7   11    8    9   19    7    7    8   7 1
0246299076122515 5    6    8    8    4    2    1    0    1    0    1    2   1 1
0246299076122515 6    0    0    0    2    1    0    1    0    0    0    0   0 1
0246299076122515 7    0    0    0    0    0    0    1    0    0    0    0   0 1
0246299076122615 1    0    0    0    0    0    0    0    0    0    0    0   0 1
0246299077 1 915 1    0    0    0    0    1    0    0    0    0    0    1   3 1
0246299077 1 915 2    3    3    1    0    5    4    4    3    5    4    5   4 1
                   .
                   .
                   .
0246299077 22515 1    0    0    0    0    0    0    0    0    0    0    0   0 1
0246299077 22615 8    0    0    0    0    0   49    5    3    3    7    8   5 1
0246299077 22715 1    4    4    6    4    1    3    2    1    0    0    0   0 1
0246299077 22815 1    0    0    0    0    0    0    0    0    0    0    0   0 1
                                                                             8
```

Figure III-1.--Card deck used to run DCARDS procedure--Continued.

```
       YELLOW CR NR NORTHPORT, AL                                         15.       024629902
0246299076122015 1 8.10 8.10 8.10 8.10 8.10 8.10 8.10 8.10 8.10 8.10 8.10 8.40 2
0246299076122015 2 8.40 8.40 8.40 8.40 8.80 8.80 9.10 9.10 9.50 9.90 10.0 11.0 2
0246299076122015 3 13.0 15.0 17.0 20.0 24.0 28.0 30.0 33.0 37.0 44.0 49.0 53.0 2
0246299076122015 4 56.0 60.0 61.0 62.0 62.0 62.0 62.0 61.0 60.0 61.0 60.0 58.0 2
0246299076122015 5 57.0 56.0 56.0 55.0 53.0 52.0 51.0 49.0 48.0 46.0 45.0 45.0 2
0246299076122015 6 43.0 42.0 40.0 39.0 38.0 36.0 35.0 35.0 34.0 32.0 32.0 31.0 2
0246299076122015 7 30.0 29.0 29.0 28.0 27.0 27.0 26.0 25.0 25.0 24.0 24.0 23.0 2
0246299076122015 8 23.0 23.0 22.0 22.0 21.0 21.0 21.0 21.0 21.0 20.0 20.0 20.0 2
0246299076122515 1 9.50 9.50 9.50 9.10 9.10 9.10 9.10 9.10 9.10 9.10 9.10 9.10 2
0246299076122515 2 9.10 9.10 9.10 9.10 9.10 9.10 9.10 9.10 9.10 9.10 9.10 9.10 2
0246299076122515 3 9.10 9.10 9.10 9.10 9.10 9.10 9.10 9.10 9.10 9.10 9.10 9.10 2
0246299076122515 4 9.10 9.50 9.50 9.50 9.90 10.0 10.0 11.0 11.0 12.0 13.0 15.0 2
0246299076122515 5 18.0 21.0 26.0 32.0 37.0 43.0 50.0 59.0 68.0 76.0 83.0 85.0 2
0246299076122515 6 88.0 90.0 90.0 91.0 88.0 87.0 87.0 85.0 84.0 82.0 81.0 79.0 2
0246299076122515 7 77.0 76.0 75.0 74.0 73.0 72.0 71.0 69.0 67.0 67.0 65.0 64.0 2
0246299076122515 8 62.0 61.0 59.0 58.0 56.0 54.0 52.0 51.0 49.0 47.0 46.0 44.0 2
0246299076122615 1 44.0 43.0 42.0 41.0 40.0 39.0 38.0 37.0 37.0 36.0 35.0 35.0 2
0246299076122615 2 35.0 34.0 33.0 32.0 32.0 32.0 32.0 31.0 31.0 30.0 30.0 30.0 2
0246299076122615 3 30.0 29.0 29.0 28.0 28.0 28.0 28.0 28.0 28.0 27.0 27.0 27.0 2
0246299076122615 4 26.0 26.0 25.0 25.0 25.0 25.0 25.0 25.0 24.0 24.0 24.0 23.0 2
0246299076122615 5 23.0 23.0 23.0 23.0 23.0 23.0 23.0 23.0 22.0 22.0 22.0 22.0 2
0246299076122615 6 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 20.0 2
0246299076122615 7 20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0 19.0 19.0 2
0246299076122615 8 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 2
0246299077 1 915 1 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 2
0246299077 1 915 2 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 15.0 2
                  .
                  .
0246299077 22515 1 24.0 24.0 24.0 24.0 24.0 23.0 23.0 23.0 23.0 23.0 23.0 23.0 2
0246299077 22515 2 23.0 23.0 22.0 22.0 22.0 22.0 21.0 21.0 21.0 21.0 21.0 21.0 2
0246299077 22515 3 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0 2
0246299077 22515 4 21.0 21.0 20.0 20.0 21.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0 2
0246299077 22515 5 20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0 19.0 19.0 19.0 19.0 2
0246299077 22515 6 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 19.0 18.0 18.0 2
```

Figure III-1.--Card deck used to run DCARDS procedure--Continued.

```
0246299077 22515 7 18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 2
0246299077 22515 8 18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0 17.0 17.0 2
0246299077 22615 1 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 2
0246299077 22615 2 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 2
0246299077 22615 3 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 17.0 2
0246299077 22615 4 17.0 17.0 17.0 17.0 17.0 16.0 16.0 16.0 16.0 16.0 16.0 16.0 2
0246299077 22615 5 16.0 16.0 16.0 16.0 16.0 16.0 16.0 16.0 16.0 16.0 16.0 16.0 2
0246299077 22615 6 16.0 16.0 16.0 16.0 15.0 16.0 15.0 15.0 15.0 15.0 15.0 15.0 2
0246299077 22615 7 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 2
0246299077 22615 8 15.0 15.0 15.0 18.0 17.0 18.0 18.0 20.0 23.0 25.0 27.0 30.0 2
0246299077 22715 1 32.0 36.0 40.0 45.0 49.0 52.0 54.0 56.0 56.0 57.0 59.0 60.0 2
0246299077 22715 2 60.0 61.0 61.0 59.0 59.0 58.0 57.0 56.0 55.0 54.0 53.0 52.0 2
0246299077 22715 3 50.0 49.0 48.0 46.0 45.0 45.0 43.0 42.0 41.0 39.0 38.0 38.0 2
0246299077 22715 4 37.0 36.0 35.0 35.0 34.0 34.0 33.0 32.0 32.0 32.0 31.0 31.0 2
0246299077 22715 5 30.0 30.0 30.0 29.0 29.0 29.0 28.0 28.0 28.0 28.0 27.0 27.0 2
0246299077 22715 6 27.0 27.0 26.0 26.0 26.0 25.0 25.0 25.0 25.0 25.0 25.0 25.0 2
0246299077 22715 7 25.0 25.0 25.0 24.0 24.0 24.0 24.0 24.0 24.0 23.0 23.0 23.0 2
0246299077 22715 8 23.0 23.0 23.0 23.0 23.0 23.0 23.0 23.0 22.0 22.0 22.0 22.0 2
0246299077 22815 1    0    0    0    0    0    0    0    0    0    0    0    0 2
                                                                               9
0
/*
//
```

Figure III-1.--Card deck used to run DCARDS procedure--Continued.

```
    *** ITYPE = 0
       02462500     20      1  1977
       02462500     20      2  1977
       02462500     60      3  1977
    *** ITYPE = 0
       02462990     45      6  1977
       02462990     60      3  1977
    *** ITYPE = 0
324000085550001     50      6  1977
    *** ITYPE = 1
       02462990     45      6  1976  12  20
       02462990     45      6  1976  12  25
       02462990     45      6  1976  12  26
       02462990     45      6  1977   1   9
       02462990     45      6  1977   1  10
       02462990     45      6  1977   1  13
       02462990     45      6  1977   1  14
       02462990     45      6  1977   1  23
       02462990     45      6  1977   1  24
       02462990     45      6  1977   2  23
       02462990     45      6  1977   2  24
       02462990     45      6  1977   2  25
       02462990     45      6  1977   2  26
       02462990     45      6  1977   2  27
       02462990     45      6  1977   2  28
       02462990     60     11  1976  12  20
       02462990     60     11  1976  12  25
       02462990     60     11  1976  12  26
       02462990     60     11  1977   1   9
       02462990     60     11  1977   1  10
       02462990     60     11  1977   1  13
       02462990     60     11  1977   1  14
       02462990     60     11  1977   1  23
       02462990     60     11  1977   1  24
       02462990     60     11  1977   2  23
       02462990     60     11  1977   2  24
       02462990     60     11  1977   2  25
       02462990     60     11  1977   2  26
       02462990     60     11  1977   2  27
       02462990     60     11  1977   2  28
```

Figure III-2.--Sample printout from DCARDS procedure.

```
                              PROGRAM DSK268 REVISED 04-01-75

                    CREATES A TEMPORARY ISAM FILE FOR RAINFALL-RUNOFF PROGRAMS


SUMMARY OF RECORDS ENTERED INTO ISAM FILE:

STA=D        02462500     PARM=  20     STAT=   1      RECORDS WRITTEN=   1

STA=D        02462500     PARM=  20     STAT=   2      RECORDS WRITTEN=   1

STA=D        02462500     PARM=  60     STAT=   3      RECORDS WRITTEN=   1

STA=D        02462990     PARM=  45     STAT=   6      RECORDS WRITTEN=   1

STA=D        02462990     PARM=  60     STAT=   3      RECORDS WRITTEN=   1

STA=D324000085550001      PARM=  50     STAT=   6      RECORDS WRITTEN=   1

STA=U        02462990     PARM=  45     STAT=   6      RECORDS WRITTEN=  45

STA=U        02462990     PARM=  60     STAT=  11      RECORDS WRITTEN=  45


END PROGRAM DSK268
```

Figure III-3.--Sample printout from GENDISK procedure.

ATTACHMENT IV

Definitions of System Variables

Definitions are listed alphabetically in table IV-1 for all input and common variables used in PRMS. Dimensions and labeled common areas are also indicated in the table.

ATTACHMENT V

Instructions for obtaining MAIN and subroutine listings

To obtain a listing of main and all Fortran subroutines, submit the following job (approximately 5,000 lines of print):

```
//---JØB CARD---
//  EXEC PGM=PDSLIST,PARM='LIST,INDEX,SPACE'
//STEPLIB DD DSN=SYS1.USERLIB,DISP=SHR
//SYSPRINT DD SYSØUT=A
//SYSUT9 DD DSN=DG4812S.PRMS83.FØRT,DISP=SHR
//SYSIN DD DUMMY
/*
//
```

The following job can be run to obtain listings of selected subroutines:

```
//---JØB CARD---
//  EXEC PGM=PDSLIST,PARM='ALPHA,LIST,SPACE'
//STEPLIB DD DSN=SYS1.USERLIB,DISP=SHR
//SYSPRINT DD SYSØUT=A
//SYSUT9 DD DSN=DG4812S.PRMS83.FØRT,DISP=SHR
//SYSIN DD *
PRMAIN
BASFLW                  } selected subroutine names
   .
   .
   .
/*
//
```

Table IV-1.--*Definitions of system variables*

VARIABLE	DIMENSION	COMMON	DESCRIPTION
AA	11,100	INITCD	INITIAL AREA VALUE FOR EACH X-SECTION FOR EACH OVERLAND FLOW AND CHANNEL SEGMENT(SQ FT) - STORM MODE
AAI	11,50	INITCD	INITIAL AREA VALUES FOR EACH X-SECTION FOR IMPERVIOUS AREA OF EACH OVERLAND FLOW PLANE(SQ FT) - STORM MODE
AET	50	SM	COMPUTED ACTUAL EVAPOTRANSPRIATION (INCHES)
AJMX	12	DPR	RAIN/SNOW MIXTURE ADJUSTMENT COEFFICIENT, BY MONTH
ALB	50	SNO	COMPUTED ALBEDO FOR EACH HRU
ALPIA	50	PCRCHA	COEFFICIENT IN KINEMATIC ROUTING EQUATION FOR IMPERVIOUS AREA OF EACH OVERLAND FLOW PLANE - STORM MODE
ALPI1A	50	PCRCHA	INVERSE OF ALPIA - STORM MODE
ALPRA	100	PCRCHA	COEFFICIENT IN KINEMATIC ROUTING EQUATION FOR PERVIOUS AREA OF EACH OVERLAND FLOW PLANE AND CHANNEL SEGMENTS - STORM MODE
ALPR1A	100	PCRCHA	INVERSE OF ALPRA - STORM MODE
ANSW	--	SNO	NOT CURRENTLY USED
ARG	50	BS	CONTRIBUTING AREA ASSOCIATED WITH SPECIFIC GROUND WATER RESERVOIR(ACRES)
ARS	50	BS	CONTRIBUTING AREA ASSOCIATED WITH SPECIFIC SUBSURFACE RESERVOIR(ACRES)
ASENS	366,20	SENT1	SENSITIVITY MATRIX - SENSITIVITY ANALYSIS
BAS	--	BS	TOTAL DAILY FLOW FROM ALL GROUNDWATER RESERVOIRS(ACRE-INCHES)
BASQ	50	BS	DAILY FLOW FROM EACH GROUNDWATER RESERVOIR (ACRE-INCHES)
BDY	--	DATES	BEGIN DAY OF SIMULATION
BDYIN	--	DATOP	BEGIN DAY OF INITIALIZATION PERIOD FOR OPTIMIZATION OR SENSITIVITY ANALYSIS
BDYOP	--	DATOP	BEGIN DAY OF OPTIMIZATION OR SENSITIVITY ANALYSIS
BMO	--	DATES	BEGIN MONTH OF SIMULATION
BMOIN	--	DATOP	BEGIN MONTH OF INITIALIZATION PERIOD FOR OPTIMIZATION OR SENSITIVITY ANALYSIS
BMOOP	--	DATOP	BEGIN MONTH OF OPTIMIZATION OR SENSITIVITY ANALYSIS
BMSA	50	DSM	MOISTURE STORAGE IN RECHARGE ZONE OF SOIL PROFILE (INCHES) - STORM MODE
BPK	50	VOL	COMPUTED PEAK FLOW FOR EACH STORM PERIOD(CFS)
BRO	50	VOL	COMPUTED RUNOFF VOLUME FROM EACH STORM PERIOD(INCHES)
BST	--	DPR	TEMPERATURE BELOW WHICH PRECIPITATION IS SNOW AND ABOVE WHICH IT IS RAIN (DEGREES F OR C)
BWY	--	SIZE	BEGIN WATER YEAR FOR SIMULATION
BYL	--	ALL	NOT CURRENTLY USED
BYR	--	DATES	BEGIN CALENDAR YEAR FOR SIMULATION
BYRIN	--	DATOP	BEGIN YEAR OF INITIALIZATION PERIOD FOR OPTIMIZATION OR SENSITIVITY ANALYSIS
BYROP	--	DATOP	BEGIN YEAR OF OPTIMIZATION OR SENSITIVITY ANALYSIS
B4	--	--	OBJECTIVE FUNCTION SWITCH (-1.0=MINIMIZE)

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
CECN	12	SNOP	CONVECTION-CONDENSATION ENERGY COEFFICIENT FOR MONTHS 1-12 (CAL/DEGREE ABOVE 0C)
CD	--	--	STORM DATA AVAILABILITY CODE (1=PRECIPITATION; 2=1+DISCHARGE; 3=2+SEDIMENT) - STORM MODE
CDA	50	UNSS	CUMULATIVE DRAINAGE AREA FOR EACH CHANNEL SEGMENT (ACRES) - STORM MODE
CMIA	50	PCRCHA	EXPONENT IN KINEMATIC ROUTING EQUATION FOR IMPERVIOUS AREA OF EACH OVERLAND FLOW PLANE - STORM MODE
CMI1A	50	PCRCHA	INVERSE OF CMIA - STORM MODE
CMPA	100	PCRCHA	EXPONENT IN KINEMATIC ROUTING EQUATIONS FOR PERVIOUS AREA OF EACH OVERLAND FLOW PLANE AND CHANNEL SEGMENTS - STORM MODE
CMP1A	100	PCRCHA	INVERSE OF CMPA - STORM MODE
COVDNS	50	DPR	SUMMER COVER DENSITY FOR MAJOR VEGETATION FOR EACH HRU (DECIMAL PERCENT)
COVDNW	50	DPR	WINTER COVER DENSITY FOR MAJOR VEGETATION FOR EACH HRU (DECIMAL PERCENT)
CSEL	--	WX	CLIMATE STATION ELEVATION(FT ABOVE MSL)
CTS	12	ET	AIR TEMPERATURE COEFFICIENT FOR ET COMPUTATION FOR MONTHS 1-12
CTW	--	ET	COEFFICIENT FOR COMPUTING SNOWPACK SUBLIMATION FROM PET
CTX	50	ET	AIR TEMPERATURE COEFFICIENT FOR ET COMPUTATION FOR EACH HRU
CX	20	SENT1	INITIAL PARAMETER VALUES IN OPTIMIZATION AND SENSITIVITY ANALYSIS
C15	10,10	STOR	Y INTERCEPT OF LINE DRAWN BETWEEN TWO ADJACENT POINTS IN THE PULS ROUTING TABLE FOR 15 MINUTE RESERVOIR ROUTING - STORM MODE
C24	10,10	STOR	Y INTERCEPT OF LINE DRAWN BETWEEN TWO ADJACENT POINTS IN THE PULS ROUTING TABLE FOR 24 HOUR RESERVOIR ROUTING
C5	10,10	STOR	Y INTERCEPT OF LINE DRAWN BETWEEN TWO ADJACENT POINTS IN THE PULS ROUTING TABLE FOR 5 MINUTE RESERVOIR ROUTING - STORM MODE
DARIP	50	IMPRV	IMPERVIOUS DRAINAGE AREA FOR EACH HRU (ACRES)
DARP	50	IMPRV	PERVIOUS DRAINAGE AREA FOR EACH HRU (ACRES)
DARU	50	ALL	DRAINAGE AREA OF EACH HRU (ACRES)
DAT	--	ALL	TOTAL BASIN DRAINAGE AREA (ACRES)
DATIP	--	IMPRV	TOTAL IMPERVIOUS DRAINAGE AREA (ACRES)
DATP	--	IMPRV	TOTAL PERVIOUS DRAINAGE AREA (ACRES)
DEN	50	SNO	DENSITY OF SNOWPACK ON EACH HRU
DENI	--	SNO	INITIAL DENSITY OF NEW-FALLEN SNOW (DECIMAL PERCENT)
DENMX	--	SNO	AVERAGE MAXIMUM DENSITY OF SNOW PACK (DECIMAL PERCENT)
DFH	20	DFHSEG	BEGAN AND END TIMES FOR EACH HYDROGRAPH SEGMENT WITHIN SPECIFIED DAY - STORM MODE
DIAG	20	SENT2	SQUARE ROOT OF DIAGONAL ELEMENTS OF INFORMATION MATRIX-OPTIMIZATION AND SENSITIVITY ANALYSIS

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
DIN1	10	STOR	SURFACE WATER RESERVOIR INFLOW FROM THE PREVIOUS TIME STEP (CFS)
DIRL	--	ALL	NOT CURRENTLY USED
DPT	50	OPSNO	DEPTH OF SNOWPACK ON EACH HRU (INCHES)
DRAD	--	--	DAILY POTENTIAL SOLAR RADIATION FOR SLOPE-ASPECT COMBINATION OF AN HRU (LANGLEYS)
DRCOR	50	DPR	DAILY PRECIPITATION CORRECTION FACTOR FOR RAIN FOR EACH HRU
DRN	--	--	DRAINAGE FACTOR FOR REDISTRIBUTION OF SATURATED MOISTURE STORAGE AS A FRACTION OF KSAT
DS	366,7	DVDT	DAILY CLIMATE DATA FOR ONE YEAR AND UP TO 7 VARIABLE TYPES
DSCOR	50	DPR	DAILY PRECIPITATION CORRECTION FACTOR FOR SNOW FOR EACH HRU
DTDXA	100	PCRCHA	DT/DX FOR EACH OVERLAND FLOW AND CHANNEL ROUTING SEGMENT (SEC/FT) - STORM MODE
DTDXMA	100	PCRCHA	(DT/DX) * CMA FOR EACH OVERLAND FLOW AND CHANNEL ROUTING SEGMENT - STORM MODE
DTM	--	--	ROUTING TIME INTERVAL FOR OVERLAND FLOW OR CHANNEL SEGMENT (MINUTES) - STORM MODE
DTMA	100	PCRCHA	ROUTING TIME INTERVAL FOR EACH OVERLAND FLOW AND CHANNEL SEGMENT (MINUTES) - STORM MODE
DTMN	--	DTMN1	OUTPUT SWITCH - STORM MODE
DTOS	--	--	PRINT OR PLOT OUTPUT TIME INTERVAL FOR OVERLAND FLOW OR CHANNEL SEGMENT (MINUTES) - STORM MODE
DTOSA	100	PCRCHA	PRINT OR PLOT INTERVAL FOR EACH OVERLAND FLOW AND CHANNEL ROUTING SEGMENT (MINUTES) - STORM MODE
DTSA	100	PCRCHA	ROUTING TIME IN SECONDS FOR EACH OVERLAND FLOW AND CHANNEL SEGMENT - STORM MODE
DUM1	--	DUMV	USER DEFINED INPUT CLIMATE VARIABLE.
DUM2	--	DUMV	USER DEFINED INPUT CLIMATE VARIABLE.
DVP	366,5	DVDT	DAILY OBSERVED PRECIPITATION FOR ONE YEAR AND UP TO 5 GAGES (INCHES).
DXA	100	PCRCHA	LENGTH/NDX FOR EACH OVERLAND FLOW AND CHANNEL SEGMENT - STORM MODE
DXDTA	100	PCRCHA	DX/DT FOR EACH OVERLAND FLOW AND CHANNEL ROUTING SEGMENT (FT/SEC)
DYL	50	ET	POSSIBLE HOURS OF SUNSHINE, IN UNITS OF 12 HOURS
D50	--	--	NOT CURRENTLY USED
D50A	50	PCRCHA	NOT CURRENTLY USED
EAIR	--	SNO	EMISSIVITY OF AIR ON DAYS WITHOUT PRECIPITATION
EDY	--	DATES	END DAY OF SIMULATION
EDYIN	--	DATOP	END DAY OF INITIALIZATION PERIOD FOR OPTIMIZATION AND SENSITIVITY ANALYSIS
EDYOP	--	DATOP	END DAY OF OPTIMIZATION OR SENSITIVITY ANALYSIS
ELCR	--	--	ELEVATION DIFFERENCE FROM CLIMATE STATION TO HRU (THOUSANDS OF FEET)
ELV	50	WX	ELEVATION OF HRU (FEET ABOVE MSL)

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
EMO	--	DATES	END MONTH OF SIMULATION
EMOIN	--	DATOP	END MONTH OF INITIALIZATION PERIOD FOR OPTIMIZATION AND SENSITIVITY ANALYSIS
EMOOP	--	DATOP	END MONTH OF OPTIMIZATION OR SENSITIVITY ANALYSIS
EN	--	--	SEDIMENT PARAMETER FOR OVERLAND FLOW PLANE - STORM MODE
ENA	50	PCRCHA	EN FOR EACH OVERLAND FLOW PLANE - STORM MODE
ENFIL	50	SM	PRECIPITATION AVAILABLE FOR INFILTRATION ON EACH HRU (INCHES)
EPAN	--	ET	DAILY INPUT VALUE FOR PAN EVAPORATION (INCHES)
EVC	12	ET	EVAPORATION PAN COEFFICIENT FOR MONTHS 1-12
EVCAN	--	--	MAXIMUM POTENTIAL DAILY INTERCEPTION LOSS (INCHES)
EVIMP	50	IMPRV	EVAPORATION LOSS FROM IMPERVIOUS AREA FOR EACH HRU (INCHES)
EWY	--	SIZE	END WATER YEAR FOR SIMULATION
EXCS	50	SM	DAILY SOIL WATER IN EXCESS OF SOIL MOISTURE CAPACITY (SMAX) FOR EACH HRU (INCHES)
EXSS	50	BS	DAILY ACCUMULATED VOLUME OF WATER ADDED TO A SUBSURFACE RESERVOIR (ACRE-INCHES)
EYR	--	DATES	END CALENDAR YEAR FOR SIMULATION
EYRIN	--	DATOP	END YEAR OF INITIALIZATION PERIOD FOR OPTIMIZATION AND SENSITIVITY ANALYSIS
EYROP	--	DATOP	END YEAR OF OPTIMIZATION OR SENSITIVITY ANALYSIS
FLGTH	--	--	LENGTH OF OVERLAND FLOW PLANE OR CHANNEL SEGMENT (FEET) - STORM MODE
FREWT	50	SNO	FREE WATER CONTENT OF SNOW ON EACH HRU (INCHES)
FRN	--	--	ROUGHNESS PARAMETER FOR OVERLAND FLOW PLANE OR CHANNEL SEGMENT - STORM MODE
FWCAP	--	SNO	FREE WATER HOLDING CAPACITY OF SNOWPACK (DECIMAL PERCENT OF SNOWPACK WATER EQUIVALENT)
G	60	SENT1	LOWER CONSTRAINT FOR EACH PARAMETER FOR OPTIMIZATION
GSNK	50	BS	COEFFICIENT TO COMPUTE SEEPAGE FROM EACH GROUND-WATER RESERVOIR TO A GROUND-WATER SINK
GU	--	--	LOWER CONSTRAINT OF PARAMETER FOR OPTIMIZATION
GW	50	BS	STORAGE IN EACH GROUND-WATER RESERVOIR (ACRE-INCHES)
GWE1	--	DATOP	NOT CURRENTLY USED
GWE2	--	DATOP	NOT CURRENTLY USED
GWS	--	BS	DAILY INFLOW TO ALL GROUND-WATER RESERVOIRS (INCHES)
GWSNK	50	BS	TOTAL SEEPAGE TO GROUND WATER SINK FOR EACH GROUND-WATER RESERVOIR (ACRE-INCHES)
H	60	SENT1	UPPER CONSTRAINT FOR EACH PARAMETER FOR OPTIMIZATION
HA	1440	UNITRF	ROUTED OUTFLOW FOR OVERLAND FLOW OR CHANNEL SEGMENTS FOR 1-60 MINUTE INTERVALS - STORM MODE
HC	--	--	SEDIMENT PARAMETER FOR OVERLAND FLOW PLANE - STORM MODE

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
HCA	50	PCRCHA	HC FOR EACH HRU - STORM MODE
HORAD	--	ALL	POTENTIAL SHORTWAVE RADIATION ON HORIZONTAL SURFACE FOR GIVEN DATE (LANGLEYS)
HU	--	--	UPPER CONSTRAINT OF PARAMETER FOR OPTIMIZATION
ICBC	--	EXC	CHANGE PARAMETER VALUES SWITCH (0 = NO CHANGES MADE TO PARAMETER VALUES DURING RUN; 1 = CHANGES MADE)
ICHG	--	VOL	COMPUTATION MODE SWITCH (0 = STORM COMPUTATIONS; 1 = DAILY COMPUTATION)
ICOV	50	SM	VEGETATION COVER TYPE FOR EACH HRU (0= BARE, 1= GRASSES, 2= SHURBS, 3= TREES)
IC1	--	--	NOT CURRENTLY USED
IC2	--	--	PEAK AND VOLUME SWITCH (0 = VALUES COMPUTED FROM OBSERVED DISCHARGE; 1 = VALUES SUPPLIED BY USER) - STORM MODE
IDB	--	DATES	BEGIN DAY OF MONTH
IDE	--	DATES	END DAY OF MONTH
IDOUT	--	OPT	STORE PREDICTED DAILY VALUES SWITCH (0= NO STORAGE; 1,2 = STORAGE FORMAT OPTIONS)
IDPLB	--	PLOT	BEGIN DAY FOR DAILY PLOTS
IDPLE	--	PLOT	END DAY FOR DAILY PLOTS
IDS	--	SIZE	INDEX FOR SPECIFIC RAIN GAGE DATA SET
IDSW	--	--	DISTRIBUTED PARAMETER ADJUSTMENT SWITCH FOR OPTIMIZATION OR SENSITIVITY ANALYSIS (0 = ADJUST ALL PARAMETERS; 1 = ADJUST SELECTED PARAMETERS)
IDUM	--	SIZE	DUMMY VARIABLE
IDUS	10	SIZE	DATA USE SWITCH FOR DATA TYPES 1-10 (0= NOT USED; 1= USED)
IDY	--	SIZE	CURRENT DAY OF MONTH COUNTER
IGOPT	--	DATOP	NOT CURRENTLY USED
IHS	--	--	NUMBER OF HYDROGRAPH SEGMENTS IN A STORM PERIOD - STORM MODE
ILOPL	100	SENT1	DISTRIBUTED PARAMETER ADJUSTMENT SWITCH FOR OPTIMIZATION AND SENSITIVITY ANALYSIS (0= EQUAL INCREMENTS; 1=PROPORTIONAL INCREMENTS)
IMO	--	SIZE	CURRENT MONTH COUNTER
IMPERV	50	UPR	PERCENT IMPERVIOUS AREA FOR EACH HRU (DECIMAL)
IMPLB	--	PLOT	BEGIN MONTH FOR DAILY PLOTS
IMPLE	--	PLOT	END MONTH FOR DAILY PLOTS
INIT	--	OPT	INITIALIZATION SWITCH - OPTIMIZATION AND SENSITIVITY ANALYSIS
INPR	50	DPR	JULIAN DATES FOR ADJUSTING SNOWPACK WATER EQUIVALENTS FOR EACH YEAR
INQ	1440	UNITRF	ACCUMULATED UPSTREAM INPUT TO A CHANNEL SEGMENT FOR FLOW ROUTING FOR 1-60 MINUTE INTERVALS - STORM MODE
INS	1440	UNITRF	WEIGHTED AVERAGE UPSTREAM INPUT TO A CHANNEL SEGMENT FOR SEDIMENT ROUTING FOR 1-60 MINUTE INTERVALS - STORM MODE
INSW	50	DPR	INTERCEPTION FORM SWITCH (0 = RAIN; 1 = SNOW)

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
INTSW	--	ALL	INTERCEPTION SWITCH (0 = NO INTERCEPTED PRECIPITATION; 1 = INTERCEPTED PRECIPITATION AVAILABLE)
IOBF	--	OPT	OBJECTIVE FUNCTION SELECTION SWITCH (1= SUM ABSOLUTE VALUES OF DIFFERENCE; 2= SUM SQUARED DIFFERENCES)
IOBS	--	OPT	OBSERVED DISCHARGE SWITCH (0= NO DATA; 1= DATA AVAILABLE)
IOBSW	--	OPT	OBJECTIVE FUNCTION COMPUTATION SWITCH (0 = VALUES NOT INCLUDED IN COMPUTATION; 1 = INCLUDED)
IOBSWK	--	SENT2	OBJECTIVE FUNCTION COMPUTATION SWITCH (0 = VALUES NOT INCLUDED IN COMPUTATION; 1 = INCLUDED)
IOPT	--	OPT	OPTIMIZATION MODE SWITCH (0 = NO OPTIMIZATION; 1,2 = DAILY OPTIONS; 3,4,5 = STORM OPTIONS)
IOSW	--	OPT	INPUT/OUTPUT SWITCH - OPTIMIZATION AND SENSITIVITY ANALYSIS
IP	--	SENT1	AUTOREGRESSIVE ORDER FOR CORRELATED DAILY ERRORS FOR OPTIMIZATION OR SENSITIVITY ANALYSIS WHEN IOPT OR ISEN=2
IPET	--	ET	POTENTIAL EVAPOTRANSPIRATION METHOD SWITCH (0 = JENSEN-HAISE; 1 = HAMON; 2 = USE PAN DATA)
IPK	--	ALL	JULIAN DATE TO ADJUST SNOWPACK ON HRUS USING OBSERVED SNOW COURSE DATA
IPLOT	--	PLOT	DAILY VALUES PLOT SWITCH (0= NO PLOTS; 1= PLOT OUTPUT)
IPLTYP	--	PLOT	DAILY PLOT TYPE SWITCH (0= LINEAR SCALE; 1= SEMI-LOG SCALE)
IPOP1	--	OPT	DAILY MEAN VALUES PRINT SWITCH (0 = SUMMARY TABLE; 1 = 0 + ANNUAL SUMMARY; 2 = 1 + MONTHLY SUMMARY; 3 = 2 + DAILY SUMMARY)
IPOP2	--	OPT	INDIVIDUAL HRU VALUES PRINT SWITCH (0= NOT PRINTED; 1= ANNUAL SUMMARY; 2= 1 + MONTHLY SUMMARY; 3= 2 + DAILY SUMMARY)
IPPT	--	DPR	INITIALIZATION SWITCH FOR PRECIPITATION VARIABLES, SUBROUTINE PRECIP
IPRIOR	--	SENT1	PRIOR INFORMATION SWITCH FOR OPTIMIZATION OR SENSITIVITY ANALYSIS (0 = NONE; 1 = PRIOR INFORMATION AVAILABLE)
IPRT	--	DTMN1	PRINT STORM HYDROGRAPH SWITCH (= NUMBER OF X-SECTION AT WHICH STORM HYDROGRAPH DATA WILL BE PRINTED) - STORM MODE
IPSR	366	DVDT	DAILY PRECIPITATION FORM ADJUSTMENT SWITCH (0 = NO CHANGE; 1 = SNOW; 2 = RAIN)
IPSW	--	DVDT	PRECIPITATION FORM SWITCH (0= NO DATA; 1= READ INPUT DATA)
IPUN1	--	OPT	CALENDAR YEAR JULIAN DATE TO START PRINTING INDIVIDUAL HRU VALUES
IPUN2	--	OPT	CALENDAR YEAR JULIAN DATE TO STOP PRINTING INDIVIDUAL HRU VALUES
IPUN3	--	OPT	CALENDAR YEAR JULIAN DATE TO START PRINTING DAILY BASIN AVERAGES

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
IPUN4	--	OPT	CALENDAR YEAR JULIAN DATE TO STOP PRINTING DAILY BASIN AVERAGES
IQ	--	SENT1	MOVING AVERAGE FOR CORRELATED DAILY ERRORS FOR OPTIMIZATION OR SENSITIVITY ANALYSIS WHEN IOPT OR ISEN=2
IR	--	SENT1	IP + IQ FOR OPTIMIZATION OR SENSITIVITY ANALYSIS WHEN IOPT OR ISEN=2
IRD	50	RD	SOLAR RADIATION PLANE ASSOCIATED WITH EACH HRU
IRTYP	10	STOR	TYPE OF ROUTING FOR EACH SURFACE RESERVOIR (8 = PULS; 9 = LINEAR)
IRU	--	--	INDEX FOR SPECIFIC HYDROLOGIC RESPONSE UNIT
IRUP1	10	STOR	INDEX OF UPSTREAM SURFACE WATER STORAGE RESERVOIR 1 FOR EACH SURFACE WATER STORAGE RESERVOIR
IRUP2	10	STOR	INDEX OF UPSTREAM SURFACE WATER STORAGE RESERVOIR 2 FOR EACH SURFACE WATER STORAGE RESERVOIR
IRUP3	10	STOR	INDEX OF UPSTREAM SURFACE WATER STORAGE RESERVOIR 3 FOR EACH SURFACE WATER STORAGE RESERVOIR
IS	--	DFHSEG	STORM EVENT INDEX - STORM MODE
ISAVE	--	VOL	PRINT/PLOT RECORD COUNTER - STORM MODE
ISBAS	--	SWITCH	INITIALIZATION SWITCH, SUBROUTINE BASFLW
ISEN	--	OPT	SENSITIVITY ANALYSIS SWITCH (0= NO ANALYSIS; 1, 2 = DAILY OPTIONS; 3, 4 = STORM OPTIONS)
ISIM	--	OPT	SIMULATION MODE SWITCH (0= DAILY; 1,2,3= STORM OPTIONS)
ISNO	--	SNO	SNOW SWITCH (0 = NO SNOWPACK; 1 = SNOWPACK)
ISNOSW	--	OPSNO2	INITIALIZATION SWITCH FOR SNOW VARIABLES, SUBROUTINE SNOBAL
ISNOYR	--	OPSNO	INITIALIZATION SWITCH, SUBROUTINE SNOBAL
ISO	50	OPSNO2	SNOWPACK MELT SWITCH FOR EACH HRU (1= ACCUMULATION STAGE; 2= SPRING MELT STAGE)
ISOIL	50	SM	SOIL TYPE FOR EACH HRU (1=SAND; 2=LOAM; 3=CLAY)
ISP1	--	SNO	JULIAN DATE TO START LOOKING FOR SPRING SNOW MELT STAGE.
ISP2	--	SNO	JULIAN DATE TO FORCE SNOWPACK TO SPRING SNOW MELT STAGE.
ISS	--	--	SEQUENCE NUMBER OF STORM PERIOD - STORM MODE
ISSOL	--	OPT	INITIALIZATION SWITCH, SUBROUTINE SOLRAD
ISSRO	--	SWITCH	INITIALIZATION SWITCH, SUBROUTINE SRFRO
ISSR1	--	SWITCH	SURFACE RUNOFF METHOD SWITCH (0 = LINEAR; 1 = NON-LINEAR)
ISTAT	--	SENT2	STATISTICAL SUMMARY SWITCH (0=NONE; 1=STATISTICAL SUMMARY AT END OF RUN)
ISTMP	--	OPT	INITIALIZATION SWITCH, SUBROUTINE TEMP
ISUN	--	SWITCH	STORM SUBSURFACE AND GROUNDWATER ROUTING SWITCH (0 = NOT DONE; 1 = SUBSURFACE AND GROUND WATER INCLUDED IN STORM COMPUTATION)
ISX1	--	SWITCH	INITIALIZATION SWITCH, SUBROUTINE UNITD
IT	50	ET	TEST FOR START OF TRANSPIRATION PERIOD SWITCH (0 = NO TEST; 1 = TEST SUM OF DAILY MAX TEMPERATURES VS TST)

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
ITND	50	ET	MONTH THAT TRANSPIRATION ENDS FOR EACH HRU
ITRANS	--	SENT2	LOG TRANSFORMATION SWITCH FOR OPTIMIZATION OR SENSITIVITY ANALYSIS (0 = NO TRANSFORMATION OF RUNOFF VALUES; 1 = TRANSFORM)
ITST	50	ET	MONTH TO BEGIN CHECKING FOR START OF TRANSPIRATION FOR EACH HRU
ITSW	50	ALL	TRANSPIRATION SWITCH FOR EACH HRU (0 = VEGETATION DORMANT; 1= VEGETATION TRANSPIRING)
IUOUT	--	OPT	STORE PREDICTED STORM VALUES SWITCH (0= NO STORAGE; 1= STORE)
IWSW	--	OPT	INPUT/OUTPUT SWITCH-OPTIMIZATION AND SENSITIVITY
IWSW2	--	SENT	WRITE SWITCH, OPTIMIZATION AND SENSITIVITY ANALYSIS
IWY	--	SIZE	CURRENT WATER YEAR COUNTER
JD	--	--	END DAY OF STORM PERIOD - STORM MODE
JDS	--	DATES	NUMBER OF RAIN GAGE DATA SETS
JLDY	--	ALL	JULIAN DATE, CALENDAR YEAR (1 = JANUARY 1)
JM	--	--	END MONTH OF STORM PERIOD - STORM MODE
JPL	--	DTMN1	PLOT SWITCH (0 = NO PLOTS; 1 = PLOT) - STORM MODE
JPR	--	DTMN1	PRINT SWITCH (0 = NO PRINT; 1 = PRINT) - STORM MODE
JSOL	--	ALL	JULIAN DATE, SOLAR YEAR (1 = DECEMBER 22)
JWDY	--	ALL	JULIAN DATE, WATER YEAR (1 = OCTOBER 1)
JY	--	--	END YEAR OF STORM PERIOD - STORM MODE
KD	--	--	BEGIN DAY OF HYDROGRAPH SEGMENT - STORM MODE
KDS	50	ALL	INDEX OF RAIN GAGE ASSOCIATED WITH EACH HRU
KF	--	--	SEDIMENT PARAMETER FOR OVERLAND FLOW PLANE
KFA	50	PCRCHA	KF FOR EACH OVERLAND FLOW PLANE
KGW	50	BS	INDEX OF GROUND WATER RESERVOIR RECEIVING SEEPAGE FROM EACH HRU
KJDY	--	EXC	JULIAN DAY TO READ IN CHANGES TO HRU PARAMETERS
KNT	--	BS	NUMBER OF HRUS WITH SNOW COVER
KR	--	--	SEDIMENT PARAMETER FOR OVERLAND FLOW PLANE
KRA	50	PCRCHA	KR FOR EACH OVERLAND FLOW PLANE
KRES	50	BS	INDEX OF SUBSURFACE RESERVOIR RECEIVING SEEPAGE FROM EACH HRU
KRSP	50	BS	INDEX OF GROUND WATER RESERVOIR RECEIVING SEEPAGE FROM EACH SUBSURFACE RESERVOIR
KSAT	--	--	HYDRAULIC CONDUCTIVITY OF TRANSMISSION ZONE (INCHES/HOUR) - STORM MODE
KSTOR	50	STOR	INDEX OF SURFACE WATER RESERVOIR RECEIVING RUNOFF FROM EACH HRU
KSV	--	--	JULIAN DAY FOR PRECIPITATION FORM ADJUSTMENT
KT	--	--	BEGIN TIME OF HYDROGRAPH SEGMENT - STORM MODE
KYR	--	EXC	CALENDAR YEAR TO READ IN CHANGES TO HRU PARAMETERS
K1	--	--	NUMBER OF DAYS IN WATER YEAR FOR PRECIPITATION FORM ADJUSTMENT TO SNOW
K2	--	--	NUMBER OF DAYS IN WATER YEAR FOR PRECIPITATION FORM ADJUSTMENT TO RAIN
LBA	50	PCRCHA	INDEX OF OVERLAND FLOW SEGMENT TO BE USED AS INPUT TO CHANNEL SEGMENT - STORM MODE

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
LBC INFLOW	--	--	I.D. OF OVERLAND FLOW PLANE PROVIDING LATERAL TO CHANNEL SEGMENT - STORM MODE
LD	--	--	END DAY OF HYDROGRAPH SEGMENT - STORM MODE
LMO	--	SIZE	PREVIOUS MONTH COUNTER
LOP	20	OPT	INDEX NUMBER OF PARAMETER TO BE OPTIMIZED
LSO	50	OPSNO2	COUNTER FOR CONSECUTIVE DAYS OF ISOTHERMAL SNOWPACK FOR EACH HRU (5= START SPRING MELT STAGE)
LST	50	OPSNO	SNOWPACK ALBEDO ADJUSTMENT SWITCH (0 = NO ADJUSTMENT 1 = ADJUST FOR SHALLOW SNOWFALL)
LT	--	--	END TIME OF HYDROGRAPH SEGMENT - STORM MODE
LYR	--	SIZE	PREVIOUS YEAR COUNTER
MB	--	DATES	BEGIN MONTH OF WATER YEAR
MDY	--	ALL	DAY OF MONTH
ME	--	DATES	END MONTH OF WATER YEAR
MFN	--	OPT	END MONTH OF OBJECTIVE FUNCTION COMPUTATION
MFS	--	OPT	BEGIN MONTH OF OBJECTIVE FUNCTION COMPUTATION
MMA	50	PCRCHA	SEDIMENT PARAMETER FOR OVERLAND FLOW PLANE - STORM MODE
MO	--	ALL	CURRENT MONTH COUNTER
MPCN	--	DPR	MONTH THAT OVERRIDE OF DRCOR AND DSCOR ENDS
MPCS	--	DPR	MONTH THAT OVERRIDE OF DRCOR AND DSCOR BEGINS
MPC1	--	DPR	OVERRIDE SWITCH FOR DRCOR AND DSCOR (0= NON-OVERRIDE PERIOD; 1= OVERRIDE PERIOD)
MRDC	--	RD	SWITCH TO DETERMINE METHOD USED TO COMPUTE SOLAR RADIATION FOR MISSING DAYS (0= RADIATION DATA NOT USED; 1= DEGREE - DAY; 2= SKY COVER)
MSO	50	OPSNO2	ENERGY BALANCE SWITCH FOR EACH HRU (1=WINTER PERIOD; 2 = BEGIN LOOKING FOR SPRING MELT PERIOD)
MTSE	--	ET	MONTH THAT THUNDERSTORM TYPE EVENTS END
MTSS	--	ET	MONTH THAT THUNDERSTORM TYPE EVENTS START
MXDY	--	ALL	NUMBER OF DAYS IN YEAR
MYR	--	ALL	CURRENT CALENDER YEAR
NCRSEG	--	VOL	NUMBER OF CHANNEL ROUTING SEGMENTS - STORM MODE
ND	--	--	BEGIN DAY OF STORM PERIOD - STORM MODE
NDELSA	100	PCRCHA	NUMBER OF TIME INCREMENTS FOR ROUTING FOR EACH OVERLAND FLOW AND CHANNEL SEGMENT - STORM MODE
NDOP	--	OPT	OPTIMIZATION SWITCH (0= CONTINUE; 1= END)
NDS	--	ALL	NUMBER OF RAIN GAGE DATA SET
NDSN	--	SENT	SENSITIVITY ANALYSIS SWITCH (0= CONTINUE; 1= END)
NDTY	--	SIZE	NUMBER OF DATA TYPES USED IN SIMULATION
NDVR	20,50	SENT1	INDICES OF DISTRIBUTED PARAMETERS TO BE ADJUSTED IN OPTIMIZATION AND SENSITIVITY ANALYSIS
NDX	--	--	NUMBER OF INTERVALS TO SUBDIVIDE OVERLAND FLOW PLANES OR CHANNEL SEGMENT FOR FINITE-DIFFERENCE CALCULATIONS - STORM MODE
NDY	12	SIZE	NUMBER OF DAYS IN EACH MONTH
NGW	--	BS	NUMBER OF GROUND WATER STORAGE RESERVOIRS
NIRU	--	--	IRU ASSOCIATED WITH OVERLAND FLOW PLANE - STORM MODE

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
NM	--	--	BEGIN MONTH OF STORM PERIOD - STORM MODE
NMOBF	--	SENT	NUMBER OF MONTHS IN DAILY OBJECTIVE FUNCTION FOR OPTIMIZATION
NOBF	--	SENT	NUMBER OF DAYS OR EVENTS INCLUDED IN OBJECTIVE FUNCTION FOR OPTIMIZATION
NOFSEG	--	VOL	NUMBER OF OVERLAND FLOW PLANES - STORM MODE
NPRNT	--	OPT	PRINT SWITCH DURING OPTIMIZATION (0= NO PRINT; 1= PRINT)
NRD	--	RD	NUMBER OF SOLAR RADIATION PLANES
NREC	--	SENT2	INDEX FOR DIRECT ACCESS FILE USED IN OPTIMIZATION OR SENSITIVITY ANALYSIS
NRES	--	BS	NUMBER OF SUBSURFACE STORAGE RESERVOIRS
NRU	--	ALL	NUMBER OF HYDROLOGIC RESPONSE UNITS
NS	--	DFHSEG	NUMBER OF HYDROGRAPH SEGMENTS IN A STORM PERIOD - STORM MODE
NSOS	10	STOR	NUMBER OF STORAGE-OUTFLOW VALUES IN TABLE FOR PULS ROUTING OF SURFACE-WATER RESERVOIR
NSP	--	--	NUMBER OF STORM PERIODS - STORM MODE
NST	--	VOL	TOTAL NUMBER OF HYDROGRAPH SEGMENTS IN ALL STORM EVENTS - STORM MODE
NSTOR	--	STOR	NUMBER OF SURFACE WATER STORAGE RESERVOIRS
NSW	50	SNOP	
NTRY	--	SENT1	NUMBER OF ADJUSTMENTS PER PARAMETER FOR OPTIMIZATION
NV	--	SENT	NUMBER OF PARAMETERS TO BE OPTIMIZED
NVAR	20	SENT1	NUMBER OF VALUES OF A DISTRIBUTED PARAMETER TO BE ADJUSTED DURING OPTIMIZATION
NXSA	100	PCRCHA	NUMBER OF CROSS-SECTIONS FOR ROUTING FOR EACH OVERLAND FLOW AND CHANNEL SEGMENT - STORM MODE
NY	--	--	BEGIN YEAR OF STORM PERIOD - STORM MODE
NYR	--	SIZE	NUMBER OF WATER YEARS TO BE SIMULATED
NYRI	--	OPT	NUMBER OF YEARS IN INITIALIZATION PERIOD OPTIMIZATION OR SENSITIVITY ANALYSIS
OBF	10	OPT	COMPUTED OBJECTIVE FUNCTIONS
OBFOPT	--	SENT2	FINAL OBJECTIVE FUNCTION VALUE FOR OPTIMIZATION
OBPK	50	VOL	OBSERVED STORM PEAK (CFS) - STORM MODE
OBRO	50	VOL	OBSERVED STORM RUNOFF VOLUME (INCHES) - STORM MODE
OBSRUN	366	SENT1	OBSERVED RUNOFF ARRAY USED IN OPTIMIZATION AND SENSITIVITY ANALYSIS
ODELSA	100	PCRCHA	NUMBER OF TIME INCREMENTS FOR PRINT OR PLOT FOR EACH OVERLAND FLOW AND CHANNEL SEGMENT - STORM MODE
OFIPA	50	PCRCHA	PORTION OF OVERLAND FLOW PLANE THAT IS IMPERVIOUS (DECIMAL PERCENT) - STORM MODE
OFLT	50	SED	TOTAL AREA FOR EACH OVERLAND FLOW PLANE - STORM MODE
ORAD	--	ALL	COMPUTED SHORTWAVE RADIATION ON HORIZONTAL SURFACE (LANGLEYS)
ORO	--	ALL	DAILY VALUE OF OBSERVED DISCHARGE (CFS)
O2	10,10	STOR	OUTFLOW-STORAGE TABLE VALUES FOR PULS ROUTING

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
P	20	SENT1	INITIAL ADJUSTMENT FACTOR FOR EACH PARAMETER FOR OPTIMIZATION
PACT	50	SNO	SNOWPACK TEMPERATURE (DEGREES C), EACH HRU
PARMCA	10	SIZE	FIVE DIGIT CODE TO IDENTIFY EACH TYPE OF INPUT CLIMATE, PRECIPITATION AND DISCHARGE DATA
PARM1	--	--	KINEMATIC PARAMETER ALPHA FOR TYPE = 4 OR WIDTH OF CHANNEL FOR CHANNEL TYPE = 1 OR 3 - STORM MODE
PARM2	--	--	KINEMATIC PARAMETER M FOR TYPE = 4 - STORM MODE
PARS	--	RD	CORRECTION FACTOR FOR COMPUTED SOLAR RADIATION ON SUMMER DAY WITH PRECIPITATION (DECIMAL PERCENT)
PARW	--	RD	CORRECTION FACTOR FOR COMPUTED SOLAR RADIATION ON WINTER DAY WITH PRECIPITATION (DECIMAL PERCENT)
PAT	12	DPR	MAXIMUM AIR TEMPERATURE, WHICH WHEN EXCEEDED, FORCES PRECIPITATION TO BE ALL RAIN
PCONR	--	DPR	OVERRIDE VALUE FOR RAINFALL ADJUSTMENT FACTOR DRCOR WHEN MPC1=1
PCONS	--	DPR	OVERRIDE VALUE FOR SNOWFALL ADJUSTMENT FACTOR DSCOR WHEN MPC1=1
PCOR	--	--	CORRECTION FACTOR FOR PRECIPITATION ON AN HRU
PCRID	--	--	IDENTIFICATION CHARACTERS FOR OVERLAND FLOW PLANES, CHANNEL AND RESERVOIR SEGMENTS AND JUNCTIONS - STORM MODE
PCRIDA	100	PCRCHA	PCRID FOR EACH PLANE, CHANNEL, RESERVOIR OR JUNCTION - STORM MODE
PERV	50	UPR	PERCENT OF PERVIOUS AREA ON EACH HRU (DECIMAL)
PET	50	ALL	COMPUTED POTENTIAL EVAPOTRANSPIRATION FOR EACH HRU (INCHES)
PHI	10	SENT2	ARRAY OF AUTOREGRESSIVE AND MOVING AVERAGE PARAMETERS FOR OPTIMIZATION AND SENSITIVITY ANALYSIS
PICE	50	SNO	PORTION OF SNOWPACK EXISTING AS ICE ON EACH HRU (INCHES)
PINC	--	SENT1	FRACTION BY WHICH PARAMETERS ARE ADJUSTED IN A SENSITIVITY ANALYSIS
PKAD	50	SNOP	ADJUSTED SNOWPACK WATER EQUIVALENT COMPUTED FROM OBSERVED SNOW COURSE DATA
PKDEF	50	SNO	CALORIES REQUIRED TO BRING PACK TO ISOTHERMAL STATE, EACH HRU
PLMN	--	PLOT	MINIMUM VALUE FOR DAILY PLOT
PLMX	--	PLOT	MAXIMUM VALUE FOR DAILY PLOT
PP	--	ALL	AREA WEIGHTED PRECIPITATION FOR BASIN (INCHES)
PPAR	5	DPR	AREA ASSOCIATED WITH EACH PRECIPITATION GAGE (ACRES)
PPT	--	ALL	MEASURED PRECIPITATION (INCHES)
PPTI	50	ALL	ADJUSTED PRECIPITATION FOR IMPERVIOUS AREA OF EACH HRU (INCHES)
PQ	50	SED	TOTAL ROUTED FLOW FOR EACH STORM PERIOD (INCHES) - STORM MODE
PRMX	50	SNOP	PERCENT OF TOTAL PRECIPITATION IN A MIXED RAIN-SNOW EVENT THAT IS RAIN (DECIMAL)

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
PRORO	366	PLOT	OBSERVED MEAN DISCHARGE VALUES FOR EACH DAY OF WATER YEAR (CFS)
PROUTA	100	PCRCHA	PRTOUT FOR EACH ROUTING SEGMENT - STORM MODE
PRPRO	366	PLOT	PREDICTED MEAN DISCHARGE VALUES FOR EACH DAY OF WATER YEAR (CFS)
PRTIN	--	--	SWITCH TO PRINT OR PLOT INFLOW TO ROUTING SEGMENTS - STORM MODE (0 = NONE; 1 = PRINT; 2 = PLOT)
PRTINA	100	PCRCHA	PRTIN FOR EACH ROUTING SEGMENT - STORM MODE
PRTOUT	--	--	SWITCH TO PRINT OR PLOT OUTFLOW TO ROUTING SEGMENTS - STORM MODE (0 = NONE; 1 = PRINT; 2 = PLOT)
PSED	50	SED	TOTAL ROUTED SEDIMENT LOAD FOR EACH STORM PERIOD (TONS) - STORM MODE
PSN	50	SNOP	WATER EQUIVALENT OF NEW SNOW ON EACH HRU (INCHES)
PSP	--	--	COMBINED EFFECT OF MOISTURE DEFICIT AND CAPILLARY POTENTIAL (INCHES) - STORM MODE
PSS	50	OPSNO	ACCUMULATED SUM OF NET PRECIPITATION BEGINNING ON THE FIRST DAY OF SNOWPACK FORMATION
PTF	--	--	PRECIPITATION WHICH FALLS THROUGH VEGETATION CANOPY (INCHES)
PTN	50	ALL	NET PRECIPITATION FOR EACH HRU (INCHES)
PWEQV	50	SNO	WATER EQUIVALENT OF SNOWPACK ON EACH HRU (INCHES)
QA	1440	UNITRF	ROUTED OUTFLOW FOR AN OVERLAND FLOW OR CHANNEL SEGMENT FOR 1-60 MINUTE INTERVALS (CFS/FT) - STORM MODE
QCOND	--	--	HEAT CONDUCTION BETWEEN SNOW SURFACE AND SNOWPACK (CALORIES)
QLAT	1440	UNITRF	ACCUMULATED LATERAL INFLOW TO A CHANNEL SEGMENT FOR FLOW ROUTING FOR 1-60 MINUTE INTERVALS (CFS/FT) STORM MODE
QMXA	100	INITCD	MAXIMUM ROUTED DISCHARGE FOR EACH OVERLAND FLOW OR CHANNEL SEGMENT FOR A STORM EVENT - STORM MODE
QQ	11,100	INITCD	INITIAL DISCHARGE VALUES FOR EACH X-SECTION OF EACH OVERLAND FLOW AND CHANNEL SEGMENT - STORM MODE
QQI	11,50	INITCD	INITIAL FLOW VALUE FOR EACH X-SECTION FOR IMPERVIOUS AREA OF EACH OVERLAND FLOW PLANE - STORM MODE
QRO	10	STOR	INITIAL DAY MEAN OUTFLOW FOR EACH SURFACE STORAGE RESERVOIR (CFS)
QSDY	--	QSOUT	DAY OF OUTPUT RECORD FOR PLOT OR PRINT - STORM MODE
QSID	--	QSOUT	OVERLAND FLOW OR CHANNEL SEGMENT ID FOR OUTPUT RECORD FOR PLOT OR PRINT - STORM MODE
QSIO	--	QSOUT	INFLOW/OUTFLOW SWITCH FOR OUTPUT RECORD FOR PLOT OR PRINT (1 = INFLOW TO SEGMENT; 2 = OUTFLOW) - STORM MODE
QSMO	--	QSOUT	MONTH OF OUTPUT RECORD FOR PLOT OR PRINT - STORM MODE

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
QSQS	--	QSOUT	TYPE SWITCH FOR OUTPUT RECORD FOR PLOT OR PRINT (1 = PRINT DISCHARGE; 2 = PRINT SEDIMENT; 3 = PLOT DISCHARGE; 4 = PLOT SEDIMENT) - STORM MODE
QSRPD	--	QSOUT	VALUES PER DAY FOR OUTPUT RECORD FOR PLOT OR PRINT-STORM MODE
QSWY	--	QSOUT	WATER YEAR OF OUTPUT RECORD FOR PLOT OR PRINT - STORM MODE
RAD	20,13	RD	POTENTIAL SHORTWAVE RADIATION FOR EACH SOLAR RADIATION PLANE FOR 13 DATES (LANGLEYS)
RAJ	--	--	RATIO OF ACTUAL TO POTENTIAL SOLAR RADIATION FOR A HORIZONTAL SURFACE
RAS	--	BS	DAILY SUBSURFACE FLOW FOR ALL SUBSURFACE RESERVOIRS (ACRE-INCHES)
RASQ	50	BS	DAILY SUBSURFACE FLOW FROM EACH SUBSURFACE RESERVOIR (ACRE-INCHES)
RBA	50	PCRCHA	INDEX OF OVERLAND FLOW SEGMENT TO BE USED AS INPUT TO CHANNEL SEGMENT - STORM MODE
RBC	--	--	I.D. OF OVERLAND FLOW PLANE PROVIDING LATERAL INFLOW TO CHANNEL SEGMENT - STORM MODE
RCB	50	BS	ROUTING COEFFICIENT FOR EACH GROUNDWATER RESERVOIR
RCF	50	BS	LINEAR ROUTING COEFFICIENT FOR EACH SUBSURFACE RESERVOIR
RCP	50	BS	NON-LINEAR ROUTING COEFFICIENT FOR EACH SUB-SURFACE RESERVOIR
RCS	10	STOR	SURFACE STORAGE RESERVOIR LINEAR ROUTING COEFFICIENT FOR EACH RESERVOIR
RC1	--	--	AVERAGE BASEFLOW OR PEAK DISCHARGE WHEN IC2 = 0 OR 1 - STORM MODE
RC2	--	--	VOLUME OF RUNOFF IN INCHES PER SQUARE MILE WHEN IC2 = 1 - STORM MODE
RDB	--	RD	COEFFICIENT USED IN SKY COVER - SOLAR RADIATION RELATION
RDC	12	RD	Y - INTERCEPT FOR RELATION BETWEEN TEMPERATURE (X) AND 1) DEGREE DAY (Y) OR 2) SKY COVER (Y) WHEN MRDC = 1 OR 2
RDM	12	RD	SLOPE FOR RELATION BETWEEN TEMPERATURE (X) AND 1) DEGREE DAY (Y) OR 2) SKY COVER (Y) WHEN MRDC = 1 OR 2
RDMX	--	RD	MAXIMUM PERCENT OF POTENTIAL SOLAR RADIATION (DECIMAL)
RDP	--	RD	COEFFICIENT USED IN SKY COVER - SOLAR RADIATION RELATION
RECHR	50	SM	STORAGE IN UPPER PART OF SOIL PROFILE WHERE LOSSES OCCUR AS EVAPORATION AND TRANSPIRATION (INCHES)
REMX	50	SM	MAXIMUM VALUE OF RECHR FOR EACH HRU (INCHES)
RES	50	BS	STORAGE IN EACH SUBSURFACE RESERVOIR (ACRE-INCHES)

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
RESMX	50	BS	COEFFICIENT FOR ROUTING WATER FROM EACH SUB-SURFACE RESERVOIR TO GROUNDWATER RESERVOIR
RETIP	50	IMPRV	MAXIMUM RETENTION STORAGE ON IMPERVIOUS AREA FOR EACH HRU (INCHES)
REXP	50	BS	COEFFICIENT FOR ROUTING WATER FROM EACH SUB-SURFACE RESERVOIR TO GROUNDWATER RESERVOIR
RFL	--	DFHSEG	READ FLAG FOR CONTINUATION OF STORM HYDROGRAPH FROM PREVIOUS DAY - STORM MODE
RGF	--	--	RATIO OF COMBINED EFFECTS OF MOISTURE DEFICIT AND CAPILLARY POTENTIAL AT WETTING FRONT FROM WILTING POINT TO FIELD CAPACITY - STORM MODE
RITEA	50	PCRCHA	WRITE SWITCH FOR EACH CHANNEL, RESERVOIR OR JUNCTION (0 = NO STORAGE; 1 = OUTPUT DATA STORED FOR INPUT TO SUBSEQUENT SEGMENT) - STORM MODE
RMXA	--	SNOP	PROPORTION OF RAIN IN RAIN/SNOW EVENT ABOVE WHICH SNOW ALBEDO IS NOT RESET FOR SNOWPACK ACCUMULATION STAGE
RMXM	--	SNOP	PROPORTION OF RAIN IN RAIN/SNOW EVENT ABOVE WHICH SNOW ALBEDO IS NOT RESET FOR SNOWPACK MELT STAGE
RNSTS	50	DPR	INTERCEPTION STORAGE CAPACITY OF UNIT AREA OF VEGETATION FOR RAIN DURING SUMMER PERIOD, FOR EACH HRU (INCHES)
RNSTW	50	DPR	INTERCEPTION STORAGE CAPACITY OF UNIT AREA OF VEGETATION FOR RAIN DURING WINTER PERIOD FOR EACH HRU (INCHES)
RQD	--	SED	DAILY ROUTED FLOW DURING STORM PERIOD - STORM MODE
RSEP	50		SEEPAGE RATE FROM EACH SUBSURFACE RESERVOIR TO GROUND WATER RESERVOIR (INCHES/DAY)
RSTOR	50	IMPRV	RETENTION STORAGE ON IMPERVIOUS AREA FOR EACH HRU (INCHES)
SA	50	WX	SLOPE AND ASPECT FOR EACH RADIATION PLANE
SALB	50	OPSNO	ALBEDO ON DAY PRIOR TO LAST SNOW FOR EACH HRU
SAS	--	SM	TOTAL SURFACE RUNOFF FROM ALL HRUS (ACRE-INCHES)
SCN	50	SM	MINIMUM CONTRIBUTING AREA FOR SURFACE RUNOFF WHEN ISSR1 = 0; COEFFICIENT IN CONTRIBUTING AREA - SOIL MOISTURE INDEX RELATION WHEN ISSR1 = 1
SCT	50	SM	DIFFERENCE BETWEEN MAXIMUM AND MINIMUM CONTRIBUTING AREA FOR SURFACE RUNOFF FOR EACH HRU
SCX	50	SM	MAXIMUM POSSIBLE CONTRIBUTING AREA FOR SURFACE RUNOFF AS PROPORTION OF EACH HRU
SC1	50	SM	COEFFICIENT IN SURFACE RUNOFF CONTRIBUTING AREA - SOIL MOISTURE INDEX RELATION
SEP	50	BS	SEEPAGE RATE FROM SOIL MOISTURE EXCESS TO EACH GROUNDWATER RESERVOIR (INCHES/DAY)
SETCON	--	SNO	SNOWPACK SETTLEMENT TIME CONSTANT
SFL	--	DFHSEG	STORE FLAG FOR CONTINUATION OF HYDROGRAPH TO NEXT DAY - STORM MODE
SGW	--	BS	TOTAL DAILY GROUNDWATER FLOW FROM ALL GROUNDWATER RESERVOIRS (ACRE-INCHES)

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
SIMOPT	3	VOL	NOT CURRENTLY USED
SLP	50	SM	SLOPE OF EACH HRU (DECIMAL PERCENT)
SLST	50	OPSNO	NUMBER OF DAYS SINCE LAST SNOWFALL ON EACH HRU
SMAV	50	SM	DAILY AVAILABLE WATER IN SOIL PROFILE FOR EACH HRU (INCHES)
SMAX	50	SM	MAXIMUM AVAILABLE WATER HOLDING CAPACITY OF SOIL PROFILE FOR EACH HRU (INCHES)
SMLT	50	SNO	DAILY SNOWMELT FOR EACH HRU (INCHES)
SMSA	50	DSM	ACCUMULATED INFILTRATION FOR EACH HRU (INCHES) - STORM MODE
SMVOPT	366	SENT1	PREDICTED RUNOFF PRODUCED FROM FINAL PARAMETER VALUES OBTAINED IN OPTIMIZATION
SNEV	50	SNO	EVAPORATION FROM SNOWPACK FOR EACH HRU (INCHES)
SNST	50	DPR	INTERCEPTION STORAGE CAPACITY OF UNIT AREA OF VEGETATION FOR SNOW, FOR EACH HRU (INCHES, WATER EQUIVALENT)
SNSV	50	OPSNO	DEPTH OF NEW SNOW ON EACH HRU (INCHES)
SOLF	--	--	RATIO OF ACTUAL TO POTENTIAL SOLAR RADIATION FOR A HORIZONTAL SURFACE
SRO	50	SM	SURFACE RUNOFF FROM EACH HRU (INCHES)
SRS	--	BS	TOTAL DAILY SUBSURFACE FLOW FROM ALL SUBSURFACE RESERVOIRS (ACRE-INCHES)
SRX	50	SM	MAXIMUM DAILY SNOWMELT INFILTRATION CAPACITY OF SOIL PROFILE AT FIELD CAPACITY FOR EACH HRU (INCHES)
SSGW	--	BS	TOTAL FLOW FROM ALL SUBSURFACE RESERVOIRS TO GROUND-WATER RESERVOIRS FOR WATER YEAR (INCHES)
SSH	20,13	ET	HOURS BETWEEN SUNRISE AND SUNSET FOR EACH RADIATION PLANE FOR 13 DATES
STAIDC	32	SIZE	ARRAY OF 16 DIGIT STATION IDENTIFICATION NUMBERS FOR CLIMATE DATA
STAIDP	8,5	SIZE	ARRAY OF 16-DIGIT STATION IDENTIFICATION NUMBERS FOR PRECIPITATION DATA
STATCA	10	SIZE	FIVE DIGIT CODE USED IN CONJUNCTION WITH PARMCA TO DISTINGUISH INPUT DATA TYPES
STO	10	STOR	INITIAL STORAGE IN EACH SURFACE RESERVOIR (CFS-DAYS)
SWRD	50	ALL	COMPUTED SW RADIATION FOR EACH HRU (LANGLEYS)
SX	50	BS	PORTION OF SNOWMELT THAT BECOMES SURFACE RUNOFF (INCHES)
S15	10,10	STOR	SLOPE OF LINE DRAWN BETWEEN TWO ADJACENT POINTS IN THE PULS ROUTING TABLE FOR 15 MINUTE RESERVOIR ROUTING - STORM MODE
S2	10,10	STOR	STORAGE VALUES IN OUTFLOW/STORAGE TABLE FOR PULS ROUTING (CFS DAYS)
S24	10,10	STOR	SLOPE OF LINE DRAWN BETWEEN TWO ADJACENT POINTS IN THE PULS ROUTING TABLE FOR 24 HOUR RESERVOIR ROUTING
S5	10,10	STOR	SLOPE OF LINE DRAWN BETWEEN TWO ADJACENT POINTS IN THE PULS ROUTING TABLE FOR 5 MINUTE RESERVOIR ROUTING - STORM MODE

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
TA	1440	UNITRF	ROUTED SEDIMENT OUTFLOW FOR AN OVERLAND FLOW OR CHANNEL SEGMENT FOR 1-60 MINUTE INTERVALS (KG/CU.FT./S) - STORM MODE
TAVC	50	ALL	DAILY AVERAGE TEMPERATURE FOR EACH HRU (DEGREES C)
TAVF	50	ALL	DAILY AVERAGE TEMPERATURE FOR EACH HRU (DEGREES F)
TCAL	50	SNO	DAILY NET ENERGY BALANCE FOR EACH HRU WITH SNOW
TCRN	--	--	MONTHLY MINIMUM TEMPERATURE ADJUSTMENT FACTOR FOR AN HRU (DEGREES C OR F)
TCRX	--	--	MONTHLY MAXIMUM TEMPERATURE ADJUSTMENT FACTOR FOR AN HRU (DEGREES C OR F)
TESTNO	50	OPT	SWITCH TO INCLUDE STORM IN OPTIMIZATION OR SENSITIVITY ANALYSIS (0= NOT INCLUDED; 1= INCLUDED)
THRES	--	--	MINIMUM DEPTH OF FLOW FOR CONTINUATION OF ROUTING (FT) - STORM MODE
THRESA	100	PCRCHA	THRES FOR EACH OVERLAND FLOW PLANE OR CHANNEL ROUTING SEGMENT (FT) - STORM MODE
TITL	18	SIZE	TITLE FOR PRINTED OUTPUT (UP TO 70 CHARACTERS)
TLAT	1440	UNITRF	LATERAL SEDIMENT INFLOW TO A CHANNEL SEGMENT FOR SEDIMENT ROUTING FOR 1-60 MINUTE INTERVALS (KG/SQ.FT./S) - STORM MODE
TLN	12	WX	LAPSE RATE FOR MINIMUM DAILY TEMPERATURE FOR MONTHS 1-12 (DEGREES C OR F)
TLPS	--	WX	NOT CURRENTLY USED
TLX	12	WX	LAPSE RATE FOR MAXIMUM DAILY AIR TEMPERATURE FOR MONTHS 1-12 (DEGREES C OR F)
TMN	--	WX	DAILY MINIMUM TEMPERATURE MEASURED AT CLIMATE STATION (DEGREES C OR F)
TMNF	50	ALL	DAILY MINIMUM TEMPERATURE FOR EACH HRU (DEGREES F)
TMX	--	WX	DAILY MAXIMUM TEMPERATURE MEASURED AT CLIMATE STATION (DEGREES C OR F)
TMXF	50	ALL	DAILY MAXIMUM TEMPERATURE FOR EACH HRU (DEGREES F)
TNAJ	50	WX	ADJUSTMENT FOR MINIMUM AIR TEMPERATURE FOR SLOPE AND ASPECT FOR EACH HRU (DEGREES C OR F)
TRNCF	50	SNO	TRANSMISSION COEFFICIENT FOR SHORTWAVE RADIATION THROUGH VEGETATION CANOPY FOR EACH HRU
TSM	50	SENT2	SUM OF DAILY MAXIMUM TEMPERATURE TO DETERMINE START OF ACTIVE ET PERIOD FOR EACH HRU
TST	50	ET	ACCUMULATED DAILY MAXIMUM TEMPERATURE VALUE FOR MONTH ITST AT WHICH TRANSPIRATION BEGINS FOR EACH HRU
TSUW	50	SED	SEDIMENT LOAD FROM EACH OVERLAND FLOW PLANE (TONS/DAY) - STORM MODE
TT	11,100	INITCD	INITIAL SEDIMENT VALUES FOR EACH X-SECTION FOR EACH OVERLAND FLOW AND CHANNEL SEGMENT (KG/CU.FT) - STORM MODE
TXAJ	50	WX	ADJUSTMENT FOR MAXIMUM AIR TEMPERATURE FOR SLOPE AND ASPECT FOR EACH HRU (DEGREES C OR F)
TYPE	--	--	TYPE OF OVERLAND FLOW PLANE OR CHANNEL ROUTING SEGMENT - STORM MODE

Table IV-1.--*Definitions of system variables*--Continued

VARIABLE	DIMENSION	COMMON	DESCRIPTION
TYPEA	100	PCRCHA	TYPE FOR EACH OVERLAND FLOW PLANE OR CHANNEL ROUTING SEGMENT - STORM MODE
UGS	50	BS	SEEPAGE TO GROUND WATER RESERVOIRS FROM EACH HRU (INCHES)
UINF	50,96	UNSS	SUBSURFACE FLOW FOR EACH SUBSURFACE RESERVOIR AT 15 MINUTE INTERVALS (INCHES) - STORM MODE
UNBAS	50,96	UNSS	GROUND WATER FLOW FOR EACH GROUND WATER RESERVOIR AT 15 MINUTE INTERVALS (INCHES) - STORM MODE
UPA	50,3	PCRCHA	UPSTREAM INFLOW SEGMENT I.D.S FOR EACH CHANNEL ROUTING SEGMENT - STORM MODE
UPCOR	50	UPR	STORM PRECIPITATION CORRECTION FACTOR FOR EACH HRU
UPE	1440	UNITRF	PRECIPITATION EXCESS FOR 1 TO 15 MINUTE INTERVALS (INCHES) - STORM MODE
UPSWA	50	PCRCHA	UPSTREAM INFLOW SWITCH FOR EACH CHANNEL ROUTING SEGMENT - STORM MODE (0 = NONE; 1 = UPSTREAM INFLOW)
UP1	--	--	UPSTREAM INFLOW SEGMENT FOR CHANNEL ROUTING SEGMENT - STORM MODE
UP2	--	--	UPSTREAM INFLOW SEGMENT FOR CHANNEL ROUTING SEGMENT - STORM MODE
UP3	--	--	UPSTREAM INFLOW SEGMENT FOR CHANNEL ROUTING SEGMENT - STORM MODE
USS	50	BS	SEEPAGE TO SUBSURFACE RESERVOIRS FROM EACH HRU (INCHES)
UVWY	367	UVRT	STORM VALUES SWITCH FOR EACH DAY OF WATER YEAR - STO MODE (0 = NONE; 1 = PRECIPITATION; 2 = PRECIPITATION AND DISCHARGE)
VBIN	20,20	SENT1	PRIOR INFORMATION COVARIANCE MATRIX FOR OPTIMIZATION OR SENSITIVITY ANALYSIS
WCTX	--	ET	NOT CURRENTLY USED
WVD	10,10	STOR	CALCULATED TABLE VALUES OF (2S/DT + O) TO DETERMINE OUTFLOW FOR DAILY PULS ROUTING
WV15	10,10	STOR	CALCULATED TABLE VALUES OF (2S/DT + O) TO DETERMINE OUTFLOW FOR 15 MINUTE PULS ROUTING
WV5	10,10	STOR	CALCULATED TABLE VALUES OF (2S/DT + O) TO DETERMINE OUTFLOW FOR 5 MINUTE PULS ROUTING
WY	--	DFHSEG	WATER YEAR OF STORM EVENT - STORM MODE
WYD	--	--	WATER YEAR DAY OF STORM EVENT - STORM MODE
X	5,50	VOL	INFILTRATION PARAMETERS FOR EACH HRU - STORM MODE
XIN	50	DPR	INTERCEPTION FOR EACH HRU (INCHES)
XINLOS	50	ALL	INTERCEPTION LOSS FOR EACH HRU (INCHES)
XOPT	20	SENT	FINAL VALUES OF PARAMETERS OBTAINED FROM OPTIMIZATION
XX	20	SENT	ARRAY OF PARAMETERS FOR OPTIMIZATION OR SENSITIVITY ANALYSIS
XXAVE	20	SENT1	AVERAGE VALUE OF DISTRIBUTED PARAMETERS FOR OPTIMIZATION OR SENSITIVITY ANALYSIS
XXDEV	20,50	SENT1	DEVIATION OF DISTRIBUTED PARAMETERS FROM AVERAGE FOR OPTIMIZATION OR SENSITIVITY ANALYSIS
ZINFC	20,20	SENT1	INFORMATION MATRIX FOR SENSITIVITY ANALYSIS
ZINV	20,20	SENT1	INVERSE OF INFORMATION MATRIX FOR SENSITIVITY ANALYSIS

ATTACHMENT VI

System labeled COMMON areas

The labeled common areas used in PRMS, the variables included in each common area and the subroutines in which they are used are listed in table VI-1.

Table VI-1.--*System labeled common areas*

COMMON	VARIABLES				SUBROUTINES		
ALL	SCODE	PPTI(50)	DAT	DARU(50)	BASFLW	BLKDAT	DATIN
	DIRL	HORAD	INTSW	IPK	INTLOS	INVIN	PETS
	ITSW(50)	JLDY	JSOL	JWDY	PKADJ	PRECIP	PRMAIN
	KDS(50)	MDY	MO	MXDY	PRTHYD	RESVRD	ROSOPT
	MYR	NDS	NRU	ORAD	ROUTE	SENST	SMBAL
	ORO	PET(50)	PP	PPT	SNOBAL	SOLRAD	SRFRO
	PTN(50)	SWRD(50)	TAVC(50)	TAVF(50)	SUMALL	SUMUNT	TEMP
	TMNF(50)	TMXF(50)	XINLOS(50)		TIMEY	UNITD	UNSM
					UVRET		
BS	ARG(50)	ARS(50)	BAS	GW(50)	BASFLW	DATIN	OPINIT
	GWS	KGW(50)	KNT	KRES(50)	PARAM	RESVRD	ROSOPT
	KRSP(50)	NGW	NRES	RAS	ROUTE	SENST	SMBAL
	RCB(50)	RCF(50)	RCP(50)	RES(50)	SUMALL	UNSM	
	SEP(50)	SGW	SRS	SX(50)			
	UGS(50)	USS(50)	RESMX(50)	REXP(50)			
	KRS	EXSS(50)	GSNK(50)	GWSNK(50)			
	BASQ(50)	RASQ(50)	RSEP(50)				
DATES	BYR	BMO	BDY	EYR	DATIN	DVRETR	INVIN
	EMO	EDY	MB	ME	PETS	PRMAIN	ROSOPT
	IDB	IDE	JDS		SENST	SUMALL	TIMEY
DATOP	BYRIN	BMOIN	BDYIN	EYRIN	DATIN	ROSOPT	SENST
	EMOIN	EDYIN	BYROP	BMOOP			
	BDYOP	EYROP	EMOOP	EDYOP			
	IGOPT	GWE1	GWE2				

Table VI-1.--*System labeled common areas*--Continued.

COMMON	VARIABLES				SUBROUTINES		
DFHSEG	WY	WYD	NS	IS	PRTHYD	ROUTE	UNITD
	RFL	SFL	DFH(20)		UNSM		
DPR	BST	DRCOR(50)	DSCOR(50)	INPK(50)	BLKDAT	DATIN	INTLOS
	IPPT	AJMX(12)	PAT(12)	RNSTS(50)	PARAM	PETS	PRECIP
	RNSTW(50)	SNST(50)	XIN(50)	INSW(50)	PRMAIN	ROSOPT	SENST
	PPAR(3)	COVDNS(50)	COVDNW(50)	MPC1	SMBAL	SNOBAL	SOLRAD
	MPCS	MPCN	PCONR	PCONS	SUMALL	TIMEY	UNITD
DSM	BMSA(50)	SMSA(50)			BLKDAT	UNITD	
DTMN1	DTMN	JPL	JPR	IPRT	INVIN	PRMAIN	PRTHYD
DUMV	DUM1	DUM2			PRMAIN		
DVDT	DVP(366,5)	DS(366,7)	IPSR(366)	IPSW	BLKDAT	DATIN	DVRETR
					PRECIP	PRMAIN	ROSOPT
					SENST	SUMALL	TIMEY
ET	CTS(12)	CTW	CTX(50)	IT(50)	DATIN	INTLOS	PARAM
	ITND(50)	ITST(50)	TST(50)	WCTX	PETS	PRMAIN	ROSOPT
	EVC(12)	EPAN	IPET	SSH(20,13)	SENST	SNOBAL	SOLRAD
	DYL(50)	MTSS	MTSE		SOLTAB	UNITD	
IMPRV	DARP(50)	DARIP(50)	RSTOR(50)	RETIP(50)	BLKDAT	DATIN	SMBAL
	EVIMP(50)	DATIP	DATP		SRFRO	SUMALL	UNITD
					UNSM		
INITCD	QMXA(100)	AA(11,100)	QQ(11,100)	TT(11,100)	UNITD	ROUTE	
	AAI(11,50)	QQI(11,50)					
OPSNO	LST(50)	SNSV(50)	SALB(50)	SLST(50)	BLKDAT	CALIN	PKADJ
	ISNOYR	DPT(50)	PSS(50)		ROSOPT	SENST	SNOBAL
OPSNO2	ISO(50)	LSO(50)	MSO(50)	ISNOSW	BLKDAT	PRMAIN	ROSOPT
					SENST	SNOBAL	TIMEY

Table VI-1.--*System labeled common areas*--Continued.

COMMON	VARIABLES				SUBROUTINES		
OPT	IOPT	IOSW	IPOP1	IPOP2	BLKDAT	COROPT	DATIN
	IPUN1	IPUN2	IPUN3	IPUN4	DVRETR	INVIN	OPINIT
	ISSOL	ISTMP	LCP(20)	MFN	PARAM	PKADJ	PRMAIN
	MFS	INIT	NYRI	NDOP	ROSOPT	ROUTE	SENMAT
	NPRNT	IWSW	ISEN	ISIM	SENST	SOLRAD	STATS
	IOBS	OBF(10)	IOBF	IOBSW	SUMALL	SUMUNT	TEMP
	TESTNO(50)	IDOUT	IUOUT		TIMEY	UNITD	UVPLOT
PCRCHA	UPA(50,3)	PCRIDA(100)	RBA(50)	LBA(50)	INVIN	PARAM	ROUTE
	RITEA(50)	UPSWA(50)	TYPEA(50)	PRTINA(100)	UNITD	UVPLOT	
	PROUTA(100)	NXSA(100)	NDELSA(100)	ODELSA(100)			
	THRESA(100)	DXA(100)	DTMA(100)	DTSA(100)			
	DTDXMA(100)	DTOSA(100)	DXDTA(100)	DTDXA(100)			
	ALP1A(100)	CM1A(100)	ALPRA(100)	CMPA(100)			
	ALPIA(50)	ALPI1A(50)	CMIA(50)	CMI1A(50)			
	OFIPA(50)	D50A(50)	KRA(50)	HCA(50)			
	KFA(50)	MMA(50)	ENA(50)				
PLOT	PRPRO(366)	PRORO(366)	IPLOT	IMPLB	DATIN	DVPLOT	PRMAIN
	IDPLB	IMPLE	IDPLE	PLMX	ROSOPT	ROUTE	SENST
	PLMN	IPLTYP			SUMALL		
QSOUT	QSWY	QSMO	QSDY	QSIO	PRTHYD	ROUTE	UNITD
	QSQS	QSID	QSRPD				
RD	IRD(50)	NRD	RAD(20,13)	RDC(12)	DATIN	PARAM	SOLRAD
	RDM(12)	PARS	PARW	MRDC	SOLTAB	SUMALL	
	RDB	RDP	RDMX	COSSL(20)			
SED	OFLT(50)	SEDSG	TSUW(50)	PSED(50)	BLKDAT	INVIN	ROUTE
	PQ(50)				PRMAIN	ROSOPT	SENST
					SUMALL	SUMUNT	UNITD
SENT	IWSW2	NOBF	NMOBF	NDSN	BLKDAT	COROPT	OPINIT
	NV	XX(20)	XOPT(20)		PARAM	ROSOPT	SENMAT
					SENST	SUMALL	

Table VI-1.--*System labeled common areas*--Continued.

COMMON	VARIABLES	SUBROUTINES
SENT1	XXDEV(20,50) XXAVE(20) PINC ILOPL(100) NVAR(20) NDVR(20,50) ASENS(366,20) SMVOPT(366) OBSRUN(366) ZINV(20,20) OBFOPT NTRY IPRIOR VBIN(20,20) G(60) H(60) CX(20) P(20) IP IQ IR ZINFC(20,20)	COROPT OPINIT PARAM ROSOPT SENMAT SENST
SENT12	PHI(10)	ROSOPT SENST
SENT13	ITRANS	COROPT DATIN OPINIT ROSOPT SENMAT SENST
SENT14	OFSPR(10)	ROSOPT SUMALL
SENT15	TSM(50)	BLKDAT ROSOPT SENST
SENT16	NREC	COROPT ROSOPT SENMAT SENST SUMALL
SENT17	IOBSWK	ROSOPT SENST
SENT18	ISTAT	DATIN SUMALL SUMUNT
SENT22	IPTEMP	ROSOPT SENST
SIZE	BYW EWY IDS IDUS(10) LMO LYR NDTY NDY(12) NMO NYR PARMCA(10) STATCA(10) STAIDC(32) STAIDP(8,5) TITL(18) IWY IMO IDY IDUM	BLKDAT DATIN DVPLOT DVRETR INVIN PETS PRECIP PRMAIN PRTHYD ROSOPT ROUTE SENST SNOBAL SOLRAD STATS SUMALL TEMP TIMEY UNITD UVPLOT UVRET
SM	AET(50) ENFIL(50) EXCS(50) ICOV(50) ISOIL(50) RECHR(50) REMX(50) SAS SCT(50) SLP(50) SMAV(50) SMAX(50) SRO(50) SRX(50) SCX(50) SCN(50) SC1(50)	DATIN PARAM PRECIP RESVRD ROSOPT SENST SMBAL SNOBAL SRFRO SUMALL UNITD UNSM

Table VI-1.--*System labeled common areas*--Continued.

COMMON	VARIABLES				SUBROUTINES		
SNO	ALB(50)	ANSW	EAIR	FREWT(50)	BLKDAT	CALIN	CALOSS
	IPS1	IPS2	PACT(50)	PICE(50)	DATIN	INTLOS	PARAM
	PKDEF(50)	PWEQV(50)	SMLT(50)	SNEV(50)	PKADJ	PRECIP	PRMAIN
	TCAL(50)	TRNCF(50)	FWCAP	ISNO	ROSOPT	SENST	SMBAL
	DENI	DENMX	SETCON	DEN(50)	SNOBAL	SRFRO	SUMALL
SNOP	NSW(50)	PRMX(50)	PSN(50)	RMXA	DATIN	INTLOS	PARAM
	RMXM	PKAD(50)	CECN(12)		PKADJ	PRECIP	SMBAL
					SNOBAL	SRFRO	SUMALL
					TIMEY		
SWITCH	ISBAS	ISSRO	ISX1	ISSR1	BASFLW	BLKDAT	DATIN
	ISUN				PRMAIN	ROSOPT	ROUTE
					SENST	SRFRO	SUMALL
					UNITD		
UNITRF	UPE(1440)	INQ(1440)	INS(1440)	QLAT(1440)	PRTHYD	RESVRU	ROUTE
	TLAT(1440)	QA(1440)	TA(1440)	HA(1440)	UNITD	UVPLOT	
UNSS	UINF(50,96)	UNBAS(50,96)	CDA(50)	PROLST	INVIN	ROUTE	SUMALL
UPR	IMPERV(50)	PERV(50)	UPCOR(50)		DATIN	INTLOS	SUMALL
					UNITD		
UVRT	UVWY(367)				BLKDAT	DATIN	DVRETR
					INVIN	PRMAIN	SENST
					SMBAL	SUMALL	UVPLOT
					UVRET		
VOL	NST	BRO(50)	X(5,50)	OBRO(50)	BLKDAT	INVIN	OPINIT
	OBPK(50)	ICHG	SIMOPT(3)	NCRSEG	PARAM	PRMAIN	PRTHYD
	NOFSEG	KRU(50)	ISAVE	BPK(50)	ROSOPT	ROUTE	SENMAT
					SENST	SMBAL	SUMUNT
					UNITD	UNSM	UVPLOT
WX	CSEL	ELV(50)	TLN(12)	TLPS	DATIN	PARAM	PRMAIN
	TLX(12)	TMN	TMX	TNAJ(50)	SOLRAD	SUMALL	TEMP
	TXAJ(50)	SA(50)					

ATTACHMENT VII

Modifying PRMS Data Retrieval Subroutines

PRMS uses an indexed sequential (ISAM) file structure for input of streamflow and meteorologic data. Daily data are stored 1 water year per record and storm data are stored 1 day per record. Each record has a key which consists of the station identification, WATSTORE parameter and statistic code, and the year, month, and day of the record. The subroutines DVRETR and UVRET read these ISAM file records. Both subroutines are written in PL1.

Some computer systems do not have ISAM file-handling capabilities that are compatible with the AMDAHL computer system, while others may have no ISAM or PL1 capabilities. To run PRMS on these machines, a compatible file structure will have to be selected and the subroutines DVRETR and UVRET will have to be modified or rewritten to read the data from the new file structure. This section describes the subroutines DVRETR and UVRET, their input and output requirements, and data specifications to facilitate any necessary modifications required for data storage and retrieval.

Subroutine DVRETR is called at the beginning of each water year and retrieves 366 values for each daily data type. The data are entered into arrays which are included in a labeled common area. The daily meteorologic and streamflow data are entered into the array DS (I,J) where J is dimensioned at 366 and represents the water year day. I is dimensioned at seven and indicates the data type as follows:

I	Data type
1	Daily discharge
2	Daily pan evaporation
3	Daily maximum air temperature
4	Daily minimum air temperature
5	Daily solar radiation
6	Daily data--user defined
7	Daily data--user defined

For example, DS (3,15) would be the maximum air temperature value for October 15 of the water year being simulated. The array IDUS indicates which data types need to be retrieved for the model run. The values for IDUS are read in subroutine DATIN, Card Group 1, card 9.

PRMS can use up to five precipitation gages. Daily data for the water year for all precipitation gages are entered into the array DVP (I,J) where J again is dimensioned at 366 and corresponds to the water year day. I is dimensioned at five and corresponds to the precipitation gage. For example, DVP (3,15) is the precipitation at rain gage 3 for October 15 of the water year being simulated. JDS is the number of rain gages and is read in subroutine DATIN, Card Group 1, card 4 (NDS).

For a storm simulation, the array UVWY (366) is read in DVRETR from file unit 11. This file was written in subroutine INVIN and contains a 0,1 or 2 for every day of the water year, indicating the types of storm data available for that day. A "1" indicates precipitation data only are to be retrieved and a "2" indicates that precipitation and discharge data are available.

The labeled common areas required in DVRETR and the variables used in each of them are the following:

Common	Variable	Description
DATES	JDS	Number of precipitation gages
OPT	ISIM	Indicates type of simulation (ISIM=0 is daily only; ISIM >0 is daily and storm)
SIZE	IWY	Water year
	IDUS(10)	Data types
	PARMCA(10)	WATSTORE parameter code corresponding to IDUS
	STATCA(10)	WATSTORE statistic code corresponding to IDUS
	STAIDC(8)	Station I.D.'s for IDUS(1) through IDUS(8)
	STAIDP(5,2)	Station I.D.'s for IDUS(9) and IDUS(10) for up to five precipitation gages
UVRT	UVWY(366)	Storm day indicator (0=no storm; 1=storm day, precipitation data only; 2=storm day with precipitation and discharge data)
DVDT	DS(7,366)	Daily meteorologic and streamflow data
	DVP(5,366)	Daily precipitation data

The type specifications necessary when the above common areas are used in a subroutine are as follows:

```
INTEGER*2  STATCA, IWY, IMO, IDY,IDUM
INTEGER   UVWY, BYR, BMO, BDY, EYR, EMO, EDY, TESTNO, BWY, EWY, PARMCA
```

Subroutine UVRET is called from subroutine INVIN at the beginning of a storm simulation run. Precipitation and discharge data for all storm days specified in Card Group 2 are retrieved and written sequentially to temporary files for later use in the model run. Precipitation data are written to temporary file unit 15 and the discharge data are written to temporary file unit 14. The UVWY array specifying storm days also is created using the storm day information in Card Group 2.

The following unformatted Fortran write statement is an example of how the temporary files are written:

```
WRITE (15)  UVDEL, UVSTA, UVPARM, UVSTAT, UVYR, UVMO, UVDY, UVRPD,
UVRDG1, UVNRDG, IDUM, UVNVAL, (UVDATA(J), J=1, UVNRDG)
```

where UVDEL is a blank,
UVSTA is the station identification from STAIDC or STAIDP,
UVPARM is the WATSTORE parameter code from PARMCA,
UVSTAT is the WATSTORE statistic code from STATCA,
UVYR is the calendar year,
UVMO is the month,
UVDY is the day,
UVRPD is the maximum number of data values possible (for example, for 15-minute-interval data, UVRPD = 96),
UVRDG1 is the starting index of the first data value (for example, for UVRPD = 96 and first data at 0115, then UVRDG1 = 5),
UVNRDG is the number of data values to be written,
IDUM is a dummy variable, and
UVDATA(J) is the data array.

UVDATA is dimensioned at 1440 to permit the use of 1-minute data.

Labeled commons "SIZE" and "UVRT" are required in subroutine UVRET. The following type declarations and dimensions also should be used.

```
LOGICAL*1  UVDEL
INTEGER*2  STATCA, IWY, IMO, IDY, UVYR, UVMO, UVDY, UVRPD, UVRDG1,
             UVNRDG, IDUM, UVSTAT
INTEGER    BWY, EWY, PARMCA, UVWY, UVPARM, OWY
DIMENSION  UVSTA(4), UVDATA (1440)
```