Attachment 02.04.03-08AQ
TVA letter dated February 2, 2010
RAI Response

ASSOCIATED ATTACHMENTS/ENCLOSURES:

Attachment 02.04.03-8AP: Software Requirements Specification(SRS), Software Design Description(SDD), Software Verification and Validation(SVVR) and Users Manual for UNITGRPH FLDHYDRO, CHANROUT.

(423 Pages including Cover Sheet)

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Tennessee Valley Authority

SOFTWARE REQUIREMENTS SPECIFICATION

(SRS)

UNITGRPH Version 1.0
FLDHYRDO Version 1.0
TRBROUTE Version 1.1
CHANROUT Version 1.0

	R0	R1	R2	R3
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Tennessee Valley Authority

SOFTWARE REQUIREMENTS SPECIFICATION

(SRS)

UNITGRPH Version 1.0
FLDHYRDO Version 1.0
TRBROUTE Version 1.0
CHANROUT Version 1.0

	R0	R1	R2	R3
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	REVISION LOG	
Revision Number	**Description of Revision**	**Date Approved**
0	Initial Issue for UNITGRPH Version 1.0, FLDHYRDO Version 1.0, TRBROUTE Version 1.0, and CHANROUT Version 1.0	
1	• Revised FLDHYDRO Section 3.2.2 to add additional user warnings – Page 10 • Revised TRBROUTE Section 5.2.2 (Page 17) to increase the maximum number of storms from three (3) to nine (9).	

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ACRONYMS

API	Antecedent precipitation index
ARMA	Autoregressive Moving Average
NPG	Nuclear Power Group
RI	Runoff index
SOCH	Simulated Open Channel Hydraulics
TVA	Tennessee Valley Authority

1. INTRODUCTION

1.1 Description

The four computer codes in this specification were developed to provide part of the required input to the Simulated Open Channel Hydraulic (SOCH) code, used for flood routing calculations in the Tennessee River basin. Specifically the function of the four codes is:

UNITGRPH	Computes unit hydrographs from historical flood data.
FLDHYDRO	Determines inflows from unit hydrographs and rainfall.
CHANROUT	Determines channel routing method coefficients.
TRBROUTE	Routes hydrographs from one point to another using different routing procedures (channel & reservoir).

The Tennessee River basin has been divided into watershed sub-basins (unit areas). Unit hydrographs, as determined by the UNITGRPH code, are used to compute flows from each unit area. These unit area flows computed by the flood hydrograph code (FLDHYDRO) are combined with appropriate channel routing coefficients (computed using CHANROUT) to compute inflows into the most upstream reservoirs which in turn are routed through the reservoirs using the TRBROUTE code. Resulting outflows are combined with additional local inflows and carried downstream using appropriate time sequencing or routing procedures (TRBROUTE code), including unsteady flow routing (SOCH code).

These computer programs are used to meet United States Nuclear Regulatory Commission guidance set forth in Nuclear Regulatory Guide 1.59 (American National Standards Institute [ANSI] ANSI/ANS-2.8-1992) and TVA SPP-2.6, R1, Computer Software Control.

1.2 Purpose

The quality-assured purpose of the group of computer codes UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT is to compute flood flows and routing parameters in the Tennessee River basin and other data required for the execution of the SOCH computer code. SOCH is then used to determine the maximum flood level at specific locations along the Tennessee River.

Section 2 discusses the theoretical basis, and presents the input and output features, and testing plan for UNITGRPH. Section 3 presents the same information for FLDHYDRO, Section 4 for CHANROUT, and Section 5 for TRBROUTE. References are provided in Section 6.

1.3 Assumptions and Limitations

There are no major limitations in the use of UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT related to the nature of the calculations performed by these codes. The primary limitations arise from the dimensions of arrays in these codes. These limitations can be addressed by editing the source code and creating a new executable. Source code revisions must adhere to Reference 1, Section 3.3.2.

1.4 Computer System Requirements

UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT were originally programmed to run on a mainframe computer and were later transferred to the personal computer (PC). The latest version of these codes has been compiled using the Compaq Visual FORTRAN compiler, Professional Edition 6.6A.

The UNITGRPH, FLDHYDRO, TRUBROUTE, and CHANROUT applications owner is the Nuclear Power Group (NPG) Corporate Civil Engineering. User support needs will be arranged through the NPG Corporate Civil Engineering with the technically cognizant TVA organization or vendor. Any problems identified with the software should be reported to NPG Corporate Civil Engineering.

2. UNITGRPH

2.1 Theoretical basis

The UNITGRPH code is used to develop unit hydrographs for the sub-basins of the Tennessee River basin. The highest historical floods for which data are available are used for this purpose. The historic flood information is obtained from recording stream gages, tributary dam headwater elevation, discharge and storage relationships which permit calculation of the flood, and estimates on ungaged watersheds where historic flood information upstream and downstream of the watershed under consideration are available to make flow estimates.

The UNITGRPH code implements the method for unit hydrograph development described in "Computer-Determined Unit Hydrographs from Floods", by Newton and Vinyard (Reference 2), which uses matrix algebra and a least squares approach to iteratively solve for the unit hydrograph and precipitation excess values that provide the best fit to the observed flood or a series of floods.

The UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 3) presents the theoretical basis of UNITGRPH in detail.

2.2 Input and Output Features

UNITGRPH uses one user-specified input file for all the required data input and produces two output files; one with the data needed to plot the key results, and the main output file.

UNITGRPH input and output files are associated with specific Unit numbers in the standard FORTRAN language terminology.

2.2.1 Input Features

In the UNITGRPH input file (Unit 5), the following information is specified:

- Error convergence value and maximum number of iterations if the error convergence value is not reached
- Number of floods from which the unitgraph is derived
- Number and value of "LIST" ordinates of the unitgraph that are directly computed
- Basin drainage area
- Runoff input interval (equivalent to the unitgraph duration)
- The surface runoff hydrograph in units of 1000 cfs for each flood
- The runoff ordinates in inches for each flood

2.2.2 Output Features

The plotting output file (Unit 3) includes the following:

- Input surface runoff hydrograph and final computed surface runoff hydrograph for each flood

- Final computed unitgraph

The main output file (Unit 6) includes the following:

- The input surface runoff hydrograph and input runoff for each flood
- Results for each iteration including:
  - Starting unitgraph
  - Runoff, computed hydrograph, hydrograph error, adjusted runoff, computed hydrograph using the adjusted runoff, and the hydrograph error using the adjusted runoff for each flood

The following responses to valid and invalid inputs and responses to abnormal situations are produced by UNITGRPH. When UNITGRPH functions normally, the output file is created and ends with either "STOPPED BY CONVERGENCE TEST" or "STOPPED BY ITERATION TEST." However, UNITGRPH has no built-in safeguards to warn users when abnormal situations arise during operation of the program. Therefore, as long as values of the proper dimension are input for each expected variable, UNITGRPH will produce an output file, regardless of whether the input data are logical or not. Therefore, it is possible for UNITGRPH to appear to have functioned normally while using invalid input data. A few such cases are presented below:

- **Negative value input for flood hydrograph or runoff:**

  Physically, all flood hydrograph ordinates and runoff values should be greater than zero. However, UNITGRPH does not reject input values that are less than zero (although computed hydrograph ordinates and runoff values are required to be greater than zero). UNITGRPH still terminates normally without any warning or error message when negative flood hydrograph or runoff values are input.

- **Negative value input for "LIST" value or basin area:**

  When negative "LIST" values or a negative value for the basin area are input, UNITGRPH returns "NaN" for most of the computed values. Therefore, it is obvious to the user that UNITGRPH has not functioned properly. However, UNITGRPH accepts these negative input values and still terminates normally without any warning or error message.

In the cases presented in this section, UNITGRPH accepts invalid input data but does not warn the user that the data are invalid. In some cases UNITGRPH may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of UNITGRPH besides those presented above. Therefore, it is the responsibility of the user to confirm that the data in the input file are valid in order to ensure that the UNITGRPH output is also valid. Normal termination of UNITGRPH is a necessary but not sufficient condition for producing valid results.

2.3 Plan for Testing UNITGRPH Functionality

2.3.1 Overview of UNITGRPH Version 1.0 Test Plan

The UNITGRPH Test Plan consists of a comparison of the solution to test problems obtained with UNITGRPH to the solution of the same problems obtained through independent

calculations. The test plan serves to evaluate the program's capabilities and limitations as related to TVA design applications. The test problems, which are described in Section 2.3.2, were selected to be representative of typical TVA applications of the program.

The test problems must be re-run when UNITGRPH is run on a new computer, as well as in the event of major upgrades or total replacement of the computer operating system. Any modifications to the UNITGRPH computer program shall be documented. Whenever changes are made to the UNITGRPH computer code, an assessment should be made of the impact on the operation of UNITGRPH and the test problems specified below must be re-run.

The test problems specified here are intended to assess the extent of possible program features and options likely to be required for safety-related design analysis. These test problems were run using UNITGRPH Version 1.0. The results of these runs are documented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT Software Verification and Validation Report (SVVR) (Reference 4).

2.3.2 UNITGRPH Test Problems

2.3.2.1 Tests of the Implementation of the Newton and Vinyard Method

- **Test Problem 1:** Fort Loudoun Sub-basin

  This problem is intended to ensure that UNITGRPH properly calculates the unit hydrograph using the flood hydrograph from a single storm. This problem was taken from Reference 5.

- **Test Problem 2:** French Broad River, Newport to Asheville

  This problem is intended to ensure that UNITGRPH properly calculates the unitgraph using data from two floods. Rainfall, flood hydrograph data, and subbasin properties for this problem were taken from References 6 and 7.

- **Test Problem 3:** French Broad River at Rosman

  This problem demonstrates the program capability to recreate the unit hydrograph computed by Newton and Vinyard in Table 3 (List 1) of the paper "Computer-Determined Unit Hydrographs from Floods" (Reference 2).

- **Test Problem 4:** Triangular Unit Hydrograph

  This problem is intended to ensure that UNITGRPH properly solves for a known unitgraph from a given derived flood hydrograph and uniform rainfall rate. For this purpose a triangular unit hydrograph is combined with a uniform precipitation of 2 inches over a period of 6 hours to construct the flood hydrograph. This problem was developed to test UNITGRPH with a simple input file.

2.3.2.2 Tests of Specific Options Available in UNITGRPH

- **Test Problems 2a and 2b:** French Broad River, Newport to Asheville

  These test problems are identical to Test Problem 2 with the exception that Test Problems 2a and 2b use different calculated unit hydrograph ordinates, defined by user provided "LIST" values, than Test Problem 2. For Test Problem 2a, all unit hydrograph ordinates are directly computed, while the "LIST" values for Test Problem 2b are 3, 6, and 8.

These test problems are intended to show the importance of picking the ordinates of the unit hydrograph that will be directly computed and those between which linear interpolation will be used.

- **Test Problems 4a, 4b, and 4c:** Triangular Unit Hydrograph

  Test problems 4a and 4b use the same flood hydrograph as Test Problem 4 but they differ from Problem 4 in the time distribution of the excess rainfall. Problems 4a and 4b use different number of ordinates, defined by user provided "LIST" values. For Test Problem 4a, all unit hydrograph ordinates are directly computed, while the "LIST" values for Test Problem 4b are 4 and 13. These test problems are intended to show the importance of the choice of "LIST" values used to define the unit hydrograph.

  Problem 4c is designed to test how UNITGRPH deals with inconsistent data and show the importance of having agreement between the excess rainfall and outflow volumes. The inconsistency built in to these data is that the volume of the excess rainfall is 17.35 thousand acre-ft, while the volume of the flood hydrograph is 13.88 thousand acre-ft. All unit hydrograph ordinates are directly computed for Test Problem 4c.

- **Test Problems 5, and 5a:** Hiwassee River at Charleston Local

  This test problem uses multiple storms to calculate the unitgraph. These test problems are intended to explore whether or not the runoff values generated by UNITGRPH are realistic as well as to show the importance of the "LIST" variables. Rainfall, flood hydrograph data, and subbasin properties for this problem were taken from References 6 and 8.

The input data used in each of these test problems are presented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT Software Verification and Validation Report (SVVR) (Reference 4).

2.3.3 Results of the UNITGRPH Test Plans

The detailed results of the implementation of the UNITGRPH test plan are presented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT Software Verification and Validation Report (SVVR) (Reference 4).

3. FLDHYDRO

3.1 Theoretical basis

The FLDHYDRO code determines the runoff for specific storm events, as well as the flood hydrograph using as input the unit hydrograph and the rainfall distribution. The flood hydrograph flows computed with FLDHYDRO are combined with time sequencing or channel routing coefficients computed by the CHANROUT code to compute discharges from upstream unit areas using the TRBROUTE code.

FLDHYDRO computes the runoff from the rainfall data using the Antecedent Precipitation Index (API) as an estimate of initial moisture deficiency based on the method developed in the report "Predicting the Runoff from Storm Rainfall" Kohler and Linsley and the textbook "Hydrology for Engineers" by Linsley, Kohler, and Paulhus (References 9 and 10 respectively). The method developed from a study of storm records relates the amount of precipitation excess (and hence the precipitation loss) to the rainfall, the week of the year, the API, and the geographic location of the drainage basin. The method was first implemented graphically using coaxial relations between the API and runoff. An example of the original application of this method is found in References 9 and 10. In FLDHYDRO, the methodology is implemented using lookup tables developed specifically for the Tennessee River basin (Reference 11). The user also has the option to specify a known storm runoff depth. The tables are then referenced to find the RI (Runoff Index) value that best matches the known storm runoff depth. Once the runoff has been estimated the flood hydrograph is computed from the unit hydrograph and runoff.

The UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 3) presents the theoretical basis of the code FLDHYDRO in detail.

3.2 Input and Output Features

FLDHYDRO uses one user-specified input file and three input files containing tables developed by TVA specifically for the Tennessee River basin. FLDHYDRO produces one or two output files; an optional file which is formatted to be used as input to subsequent codes, and the main output file.

3.2.1 Input Features

In the FLDHYDRO input file (Unit 5), the following information is specified:

- Daily antecedent rainfall (optional),
- Hourly storm event rainfall,
- Thiessen weights (when needed)
- Base flow factor for each subwatershed and storm,
- Surface runoff volume at specified drainage points (optional), and
- Unit hydrographs for each subwatershed (optional, needed if the flood hydrograph is to be computed)
- Drainage area for each subwatershed

Also used as inputs to the program are three tables developed by TVA (Reference 11) specifically for the Tennessee River basin:

- APITBL – relates locality parameters (geographic region and week of the year) and Antecedent Precipitation Index (API) values to give RI values within the Tennessee River basin
- TV – relates RI and cumulative precipitation to effective precipitation for all Tennessee River basin runoff regions except the southeast (SE) region
- NonTV – relates RI and cumulative precipitation to effective precipitation for the SE runoff region of the Tennessee River basin.

3.2.2 Output Features

The optional plotting output file (Unit 3) contains the calculated flood hydrograph for each specified subwatershed. Flood hydrographs are generated in the order of subwatersheds listed in the input file.

The main output file (Unit 6) includes the following:

- An echo of the input data
- Results for each subwatershed including:
    - Thiessen factor, API value, RI value, and look-up table (NonTV or TV) used for each rain gage
    - Summation hourly rain and summation hourly runoff
    - Runoff hydrograph and flood hydrograph calculated using the input unit hydrograph (optional)

The following responses to valid and invalid inputs and responses to abnormal situations are produced by FLDHYDRO. When FLDHYDRO functions normally, the output file is created but no end message is printed. However, FLDHYDRO does have built-in safeguards to warn users when abnormal situations arise during operation of the program. A listing of these safeguards is provided below:

- After the second line of input data is read by FLDHYDRO, a check is done for input values out of range. If the number of runoff indices, number of stations, number of recorders, number of subwatersheds, or number of volume checks is invalid, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and one of the following messages:

    " (No. of Runoff Indices) IS INVALID AS NUMBER OF RI"S PER STATION; MAXIMUM IS 4"

    " (No. of Stations) IS INVALID AS NUMBER OF STATIONS; MAXIMUM IS 100"

    " (No. of Recorders) IS INVALID AS NUMBER OF RECORDERS; MAXIMUM IS 30"

    " (No. of Subwatersheds) IS INVALID AS NUMBER OF SUBWATERSHEDS; MAXIMUM IS 50"

    " (No. of Volume Checks) IS INVALID AS NUMBER OF VOLUME CHECKS; MAXIMUM IS NO. OF SUBWATERSHEDS"

- All non-recording stations (i.e. stations where no hourly rainfall data were recorded, but only daily totals are available) must be paired with a recording station (i.e. a station where hourly rainfall was recorded) that will be used to distribute the daily rainfall from the non-recording stations. If an invalid recording station is entered, the output file consists of an echo of the input data and the beginning of the output data up to the point of calculations with the ill-referenced non-recorder. The following message is inserted in the echo data:

  " (Non-Recording Station) IS NOT A VALID RECORDER NAME FOR STATION (Recording Station)"

- For FLDHYDRO runs where the RI value is input, the RI is required to be less than or equal to 55. If a value of RI greater than 55 is input, the following message is inserted in the echo data:

  " RI VALUE OF (RI Value) DETECTED; MAX. IS 55"

- FLDHYDRO only allows one subwatershed to use more than 25 stations and that subwatershed must be the last one referenced. If this rule is violated, the following message is inserted in the echo data:

  " ONLY ONE WATERSHED ALLOWED WITH >25 STATIONS AND THAT WATERSHED MUST BE THE LAST ONE"

- When assigning Thiessen factors for a subwatershed, the Thiessen factors must be applied to rain stations defined as either recorders or non-recorders. If a station name that does not match an input recorder or non-recorder is input, the following message is inserted in the echo data:

  "... ERROR...ORDER OF RAIN STATIONS NOT ESTABLISHED PROPERLY. MAKE SURE... THAT FOUR CHARACTER RAIN STATION NAMES IN BSNSTA(I,J) MATCH THOSE IN NAMSTA(I)"

- When calculating non-recorder hourly rain from recorders, two error messages can be generated. These error messages do not invalidate the output data. Rather, they serve as warnings to the user that abnormal situations have occurred and leave it up to the user whether to accept the data or not. These messages are printed in the output data where RI values are calculated and are reproduced below:

  " *** ERROR -- A DAILY RAIN OF ZERO FOR RECORDER (Recording Station) WILL PRODUCE A DAILY RAIN OF ZERO FOR GAGE (Non-Recording Station). INVALID COMPUTATIONS WILL RESULT."

  " WARNING...A DAILY RAIN OF (Non-Recorder Daily Rain) FOR GAGE (Non-Recording Station) IS WEIGHTED AGAINST A DAILY RAIN OF (Recorder Daily Rain) FOR RECORDER (Recording Station). THIS IS A WEIGHT RATIO OF (Ratio) WHICH MAY SIGNIFICANTLY AFFECT RESULTS."

If none of the above abnormal conditions occurs, FLDHYDRO is presumed to have functioned normally. In this case, the entire output file is created.

However, it is possible for FLDHYDRO to appear to have functioned normally while using invalid input data. A few such cases are presented below:

- **Input API value greater than 5:**

In FLDHYDRO, the look-up tables do not allow API values greater than 5. However, it is possible to assign an initial API value greater than 5. FLDHYDRO still terminates normally without any warning or error message when API values greater than 5 are input.

- **Negative value input for precipitation:**

  Physically, all precipitation values should be greater than zero. However, FLDHYDRO does not reject input values that are less than zero. FLDHYDRO still terminates normally without any warning or error message when negative precipitation values are input.

- **Thiessen weights do not sum to one:**

  When weighting rainfall with Thiessen weights, the sum of the Thiessen weights must be 1. However, FLDHYDRO does not check the sum of the Thiessen weights. Therefore, the sum of the Thiessen weights can be either greater than or less than one and FLDHYDRO still terminates normally without any warning or error message.

- **The *.hyd files created by FLDHYDRO do not include a time/date stamp:** The direct use or export of FLDHYDRO *.hyd data to TRBROUTE can combine hydrographs that have different starting times without the user's knowledge. The user should carefully check the *.out file for the time interval alignment prior to use or routing of the FLDHYDRO output data.

  For example, if a storm for a subwatershed with a unit hydrograph duration and time interval of 6 hours were to start at 3/15 0000 hours and the first non-zero hourly runoff value for the storm were to occur on 3/16 at 0100 hours (and thus, the first block of 6 hour runoff ends at 0600 hours) FLDHYDRO would insert into the .hyd file a runoff value of 0 cfs (assuming no baseflow) at 3/16 0000, 3/15 1800, 3/15 1200, 3/15 0600 and the starting runoff value of 0 cfs would be at 3/15 0000. If the same storm were to have the first-nonzero runoff value at 3/16 0500, FLDHYDRO would insert into the .hyd file a runoff value of 0 cfs (assuming no baseflow) at 3/16 0400, 3/15 2200, 3/15 1600, 3/15 1000 and the starting runoff value of 0 cfs would be at 3/15 0400.

In the cases presented in this section, FLDHYDRO accepts invalid input data, but does not warn the user that the data are invalid. In some cases FLDHYDRO may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of FLDHYDRO besides those presented above. Therefore, it is the responsibility of the user to confirm that the input data file is valid in order to ensure that the FLDHYDRO output is also valid. Normal termination of FLDHYDRO is a necessary but not sufficient condition for producing valid results.

3.3 Plan for Testing FLDHYDRO Functionality

3.3.1 Overview of FLDHYDRO Version 1.0 Test Plan

The FLDHYDRO Test Plan consists of a comparison of the solution to test problems obtained with FLDHYDRO to the solution obtained from independent calculations for the same problems. The test plan serves to evaluate the program's capabilities and limitations as

related to TVA design applications. The test problems, which are described in Section 3.3.2, were selected to be representative of typical TVA applications of the program.

The test problems must be re-run when FLDHYDRO is run on a new computer, as well as in the event of major upgrades or total replacement of the computer operating system. Any modifications to the FLDHYDRO computer program shall be documented. Whenever changes are made to the FLDHYDRO computer code, an assessment should be made of the impact on the operation of FLDHYDRO and the test problems specified below must be re-run.

The test problems specified here are intended to assess the extent of possible program features and options likely to be required for safety-related design analysis. These test problems were run using FLDHYDRO Version 1.0. The results of these runs are documented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT SVVR (Reference 4).

3.3.2 FLDHYDRO Test Problems

3.3.2.1 Tests of the Implementation of the FLDHYRO Methodology

- **Test Problem 1:** Nottely Dam

  This problem is intended to ensure that FLDHYDRO properly calculates runoff depths using the method outlined in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 3). The rainfall data and the basin characteristics for this problem were taken from References 6 and 12.

- **Test Problem 2:** Nottely Dam with CHKVOL Enabled

  This problem is identical to Test Problem 1, but with the CHKVOL option enabled. For this purpose the total runoff, represented in FLDHYDRO by the parameter CHKVOL is specified as equal to 0.9 inches. This problem is intended to ensure that FLDHYDRO properly calculates runoff depths when a total volume of runoff for the storm is specified.

- **Test Problem 3:** Nottely Dam with two Separate Storms and CHKVOL

  This problem is identical to Test Problem 2 with the exception that another storm is added prior to the storm used in Test Problems 1 and 2. The runoff volume of the first storm is 0.4 inches and that of the second storm is 0.9 inches, as in Test Problem 2. This problem is intended to ensure that FLDHYDRO properly calculates runoff depths for multiple storms.

- **Test Problem 4:** Cherokee Local

  This problem is intended to ensure that FLDHYDRO properly calculates runoff depths when multiple gages are used and CHKVOL is enabled. Test Problem 4 uses both hourly and daily rain gages from multiple stations as input. Stations where no hourly rainfall data were recorded, but only daily totals are available are referred to in FLDHYDRO as "nonrecorders". Each nonrecorder station is paired with a station for which hourly data are available. This problem was taken from Reference 11.

- **Test Problem 5:** Norris Dam

  This problem is intended to ensure that FLDHYDRO properly calculates runoff depths and the flood hydrograph for multiple storms from a single station. This problem was taken from Reference 11.

- **Test Problem 6:** Cherokee Watershed

  This problem is intended to ensure that FLDHYDRO properly calculates runoff depths and flood hydrographs when multiple gages and subbasins are used. This problem was taken from Reference 3.

3.3.2.2 Tests of the Specific Options Available in FLDHYRO

- **Test Problem 2a:** Nottely Dam with CHKVOL Enabled

  This problem is identical to Test Problem 2 with the exception that a CHKVOL value of 0.96 is used. This problem is intended to show the result when FLDHYDRO runs off the edge of the TV or NonTV table (the contents and the use of these tables are explained in Reference 4).

- **Test Problem 3a:** Nottely Dam Separated into Two Storms with CHKVOL

  This problem is identical to Test Problem 3 with the exception that the two storms are consecutive. This problem is intended to show that the summation of hourly runoff is not reset for the second storm when two consecutive storms are input.

- **Test Problems 7 and 7a:** Watts Bar Reservoir

  These test problems are intended to show how FLDHYDRO can generate erroneous zeros at the end of the runoff data when a gage with a long record of data is weighted at zero, and the way to set up the input file to avoid this problem. This problem was taken from Reference 13.

The input data used in each of these test problems are presented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT Software Verification and Validation Report (SVVR) (Reference 4).

3.3.3 Results of the FLDHYDRO Test Plans

The detailed results of the implementation of the FLDHYDRO test plan are presented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT Software Verification and Validation Report (SVVR) (Reference 4).

4. CHANROUT

4.1 Theoretical basis

The CHANROUT code computes the coefficients of an ARMA channel routing model of which the Muskingum routing equation is a special case. An ARMA(P,Q) channel routing model computes current outflow out of a river reach as a linear combination of the previous P outflows, plus the previous Q inflows and current inflow into a reach. ARMA(1,1) is equivalent to the Muskingum routing equation. Channel routing coefficients computed by CHANROUT are combined with flood hydrographs from FLDHYDRO to route flood hydrographs downstream using the TRBROUTE code.

The UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 3) presents the detailed theoretical basis for CHANROUT.

4.2 Input and Output Features

CHANROUT uses one user-specified input file for all the required data input and produces one output file.

4.2.1 Input Features

In the CHANROUT input file (Unit 5), the following information is specified:

- Number of previous inflows to be used in the ARMA routing model
- Number of previous outflows to be used in the ARAM routing model
- Flow time interval
- Routing period
- Inflows into and outflows out of the channel reach

4.2.2 Output Features

The CHANROUT output file (Unit 6) includes the following:

- An echo of the input data
- The channel routing coefficients
- Inflow, outflow, and computed outflow for each time period

The following responses to valid and invalid inputs and responses to abnormal situations are produced by CHANROUT. When CHANROUT functions normally, the output file is created but no end message is printed. However, CHANROUT does have built-in safeguards to warn users when abnormal situations arise during operation of the program. A listing of these safeguards is provided below.

- If the number of previous inflows or outflows to be used in the ARMA routing model is less than one, or if the total number of inflows and outflows to be used is greater than 20, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and the message:

" 1 – 10 BACK POINTS ALLOWED: IBKPTS = (No. Previous Inflows); OBKPTS = (No. Previous Outflows)"

- If the routing period is not a multiple of the time interval, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and the message:

  " ROUTING PERIOD MUST BE A MULTIPLE OF TIME INCREMENT: RP = (Routing Period); TIMINT = (Time Interval)"

- In order to perform the routing the number of inflows and outflows input must be at least as many as the larger of the number of previous inflows or outflows, times the routing period divided by the time interval (this term is the variable "SHIFT" in the CHANROUT program). If this is not true, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and the message:

  " AT LEAST (SHIFT) FLOWS MUST BE SPECIFIED FOR VIABLE COMPUTATIONS: NFLOWS = (No. Inflows/Outflows)"

- The maximum number of inflows/outflows input to CHANROUT is 300. If this number is exceeded the run terminates and the output file consists only of an echo of the first two lines of input data and the message:

  " MAX. NO. OF FLOWS IS 200: NFLOWS = (No. Inflows/Outflows)"

If none of the above abnormal conditions occurs, CHANROUT is presumed to have functioned normally. In this case, the entire output file is created.

However, it is possible for CHANROUT to appear to have functioned normally while using invalid input data. One such case is presented below:

- **Negative value input for inflow or outflow:**

  Physically, all inflow and outflow values should be greater than zero. However, CHANROUT does not reject input values that are less than zero. CHANROUT still terminates normally without any warning or error message when negative inflow or outflow values are input.

In the case presented above, CHANROUT accepts invalid input data but does not warn the user that the data are invalid. In some cases CHANROUT may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of CHANROUT besides that presented above. Therefore, it is the responsibility of the user to confirm that the input data file is valid in order to ensure that the CHANROUT output is also valid. Normal termination of CHANROUT is a necessary but not sufficient condition for producing valid results.

4.3 Plan for Testing CHANROUT Functionality

4.3.1 Overview of CHANROUT Version 1.0 Test Plan

The CHANROUT Test Plan consists of a comparison of the solution to test problems obtained with CHANROUT to those obtained from independent calculations for the same problems. The test plan serves to evaluate the program's capabilities and limitations as related to TVA

design applications. The test problems, which are described in Section 4.3.2, were selected to be representative of typical TVA applications of the program.

The test problems must be re-run when CHANROUT is run on a new computer, as well as in the event of major upgrades or total replacement of the computer operating system. Any modifications to the CHANROUT computer program shall be documented. Whenever changes are made to the CHANROUT computer code, an assessment should be made of the impact on the operation of CHANROUT and the test problems specified below must be re-run.

The test problems specified here are intended to assess the extent of possible program features and options likely to be required for safety-related design analysis. These test problems were run using CHANROUT Version 1.0. The results of these runs are documented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT SVVR (Reference 4).

4.3.2 CHANROUT Test Problems

- **Test Problem 1:** Yangtze River

  This problem is intended to ensure that CHANROUT properly calculates the routing coefficients for an ARMA(3,2) model using the equations presented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 3). This problem is taken from Reference 14.

- **Test Problem 2:** Muskingum Routing Example

  This problem recreates Example 3.6 from Reference 15 to demonstrate that CHANROUT properly calculates the routing coefficients for Muskingum routing (ARMA[1,1]).

- **Test Problem 3:** Flow Interval Different from Routing Period

  This is identical to Test Problem 2 with the exception that the routing period is doubled (to 2 hours). This problem is intended to ensure that CHANROUT properly solves for the routing coefficients when the flow interval is different than the routing period.

The input data used in each of these test problems are presented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT Software Verification and Validation Report (SVVR) (Reference 4).

4.3.3 Results of CHANROUT Test Plans

The detailed results of the implementation of the CHANROUT test plan are presented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT Software Verification and Validation Report (SVVR) (Reference 4).

5. TRBROUTE

5.1 Theoretical basis

TRBROUTE performs the channel and reservoir routings necessary to route flood hydrographs downstream to selected points (for input to the SOCH model). This includes routing through reservoirs with fixed discharge rating curves and the major tributary dam systems whose operations follow fixed rules. Discharge rating curves defining the fixed rules of the major tributary dams are handled by the program. TRBROUTE uses autoregressive moving average (ARMA) type channel routing coefficients computed by CHANROUT combined with flood hydrographs from FLDHYDRO to route flood hydrographs downstream.

The UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 3) presents the detailed theoretical basis for TRBROUTE.

5.2 Input and Output Features

TRBROUTE uses four pre-defined Tennessee River basis specific input files. These four input files, named STORAGES, QRATINGS, IMPRULES, and SGUIDES, contain reservoir storage data, rating curves, operation rules and seasonal elevation guidelines. The file names and content are in the TRBROUTE code. The four pre-defined input files must be located in the same folder with these exact names and no extensions as the TRBROUTE executable. Revisions to the four pre-defined input files are Version controlled and must adhere to SPP 2.6, Section 3.3.2 for revisions.

TRBROUTE uses up to two user-specified input files and produces two output files; one with the flood hydrograph data in the format required for their subsequent use by other codes, and the main output file.

5.2.1 Input Features

In the TRBROUTE main input file (Unit 5), the following information is specified:

- Inflow hydrographs from FLDHYDRO (if second input file is not used)
- Channel routing coefficients from CHANROUT
- Set of instruction codes that tell TRBROUTE how to route and combine the inputs
- Reservoir names
- Starting water surface elevation for each reservoir
- Starting discharge used for routing calculations for each reservoir (FOUT)
- Storage-elevation curves and discharge rating curves for reservoirs not defined in TVA tables (see below)

The second (optional) input file (Unit 2) is produced by FLDHYDRO and specifies the flood hydrographs, including hydrograph ordinates and the hydrograph interval (in hours).

Also used as inputs to the program are four files developed by TVA (Reference 16):

- STORAGES – look-up table with storage-elevation curves for reservoirs to be routed
- QRATINGS – look-up table with discharge rating curves for tributary dams to be routed using TRBROUTE
- IMPRULES – look-up table with reservoir operation guides for major tributary dams
- SGUIDES – look-up table with reservoir seasonal operation guidelines

5.2.2 Output Features

The main output file (Unit 6) includes the following:

- An echo of the input data
- Discharge and storage curves for all storms for each reservoir
- A printout depending on the combination of instruction codes
    - 1,6 – total hydrograph currently in the working location
    - 2,6 – inflow into and outflow from the reservoir
    - 3,6 – outflow out of the channel
    - 4,6 – not valid
    - 5,6 – combined flow

The output file with data formatted for use in subsequent codes (Unit 3) includes the ordinates of the most downstream flood hydrograph produced by TRBROUTE as well as the hydrograph interval (in hours).

The following responses to valid and invalid inputs and responses to abnormal situations are produced by TRBROUTE. When TRBROUTE functions normally, the output file is created but no end message is printed. However, TRBROUTE does have built-in safeguards to warn users when abnormal situations arise during the operation of the program. A listing of these safeguards is provided below.

- TRBROUTE checks some input parameters for values out of range. If the number of storms, instruction code value, or rating curve code value is out of range, the run terminates. In this case, the output file consists only of an echo of the input data already read and one of the following messages:

  " (No. Storms) IS INVALID AS NUMBER OF STORMS; MAXIMUM IS 9"

  " (Instruction Code) IS INVALID INSTRUCTION CODE; RANGE IS 1 TO 6"

  " (Rating Curve Code) IS INVALID CODE FOR RATING CURVES; RANGE IS 0 TO 2"

- When using the look up tables, the reservoir name given in the main input file must match one of the reservoir names in the look up tables. If the names do not match, the data for the last entry in the look-up table will be used for computations and the run will continue with the invalid data. In this case, the output file consists of an echo of the input data, and the output data. One or more of the following messages will be inserted before the output for the reservoir with the invalid name:

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN STORAGE CURVES FILE"

" RESERVOIR NAME (Reservoir Name) NOT FOUND IN DISCHARGE CURVES FILE"

" RESERVOIR NAME (Reservoir Name) NOT FOUND IN IMPROVED FIXED RULES FILE"

" RESERVOIR NAME (Reservoir Name) NOT FOUND IN SEASONAL GUIDES FILE"

If none of the above abnormal conditions occurs, TRBROUTE is presumed to have functioned normally. In this case, the entire output file is created.

However, it is possible for TRBROUTE to appear to have functioned normally while using invalid input data. A few such cases are presented below:

- **Negative value input in hydrograph input file:**

  Physically, all hydrograph values should be greater than zero. However, TRBROUTE does not reject input values that are less than zero. TRBROUTE still terminates normally without any warning or error message when negative hydrograph values are input to the hydrograph input file.

- **Initial Headwater elevation above the range of elevation values in the look-up table:**

  The QRATINGS and IMPRULES data input files in TRBROUTE contain discharge rating curves for specified TVA structures. When initial headwater elevation values are specified above the range given in the table, the discharge obtained from these tables is invalid. TRBROUTE still terminates normally without any warning or error message when initial headwater elevations are greater than the largest value in the look-up tables.

In the cases presented in this section, TRBROUTE accepts invalid input data but does not warn the user that the data are invalid. In some cases TRBROUTE may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of TRBROUTE besides those presented above. Therefore, it is the responsibility of the user to confirm that the input data file is valid in order to ensure that the TRBROUTE output is also valid. Normal termination of TRBROUTE is a necessary but not sufficient condition for producing valid results.

5.3 Plan for Testing TRBROUTE Functionality

5.3.1 Overview of TRBROUTE Version 1.1 Test Plan

The TRBROUTE Test Plan consists of a comparison of the solution to test problems obtained with TRBROUTE to solutions of the same problems obtained from independent calculations. The test plan serves to evaluate the program's capabilities and limitations as related to TVA design applications. The test problems, which are described in Section 5.3.2, were selected to be representative of typical TVA applications of the program.

The test problems must be re-run when TRBROUTE is run on a new computer, as well as in the event of major upgrades or total replacement of the computer operating system. Any modifications to the TRBROUTE computer program shall be documented. Whenever changes are made to the TRBROUTE computer code, an assessment should be made of the

impact on the operation of TRBROUTE and the test problems specified below must be re-run.

The test problems specified here are intended to assess the extent of possible program features and options likely to be required for safety-related design analysis. These test problems were run using TRBROUTE Version 1.1. The results of these runs are documented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT SVVR (Reference 4).

5.3.2 TRBROUTE Test Problems

- **Test Problem 1:** Holston River Above Cherokee Dam

  This problem is intended to ensure that TRBROUTE properly routes flows through channels and reservoirs. This problem consists of five reservoirs and three channel sections that are lag routed. The combined South Holston Dam and Watauga Dam flows are lagged 6 hours, the combined North Fork Holston River flows and flows out of Fort Patrick Henry Dam are lagged 12 hours, and the Holston River flows between Surgoinsville and Cherokee Dam are lagged 4 hours. This problem is taken from Reference 16.

- **Test Problem 2:** Muskingum Channel Routing Example

  This problem recreates the example whose answer is in Table 16.6 of the textbook Hydrology in Practice (Reference 17). It is intended to demonstrate that TRBROUTE properly performs Muskingum channel routing when given the routing coefficients.

- **Test Problem 3:** Muskingum Channel Routing Example

  This problem recreates the example from Table 9-3 of the textbook Hydrology for Engineers (Reference 10). It is intended to demonstrate that TRBROUTE properly performs Muskingum channel routing when given the routing coefficients.

- **Test Problem 4:** Muskingum Channel Routing Example

  This problem recreates Example 9.9 from the textbook Introduction to Hydrology (Reference 18). It is intended to demonstrate that TRBROUTE properly performs Muskingum channel routing when given the routing coefficients.

- **Test Problem 5:** Muskingum Channel Routing Example

  This problem recreates Example 10.1 from the textbook Hydrology: An Introduction to Hydrologic Science (Reference 19). It is intended to demonstrate that TRBROUTE properly performs Muskingum channel routing when given the routing coefficients.

The input data used in each of these test problems are presented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT Software Verification and Validation Report (SVVR) (Reference 4).

5.3.3 Results of the TRBROUTE Test Plan

The detailed results of the implementation of the TRBROUTE test plan are presented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT Software Verification and Validation Report (SVVR) (Reference 4).

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Tennessee Valley Authority

SOFTWARE DESIGN DOCUMENT

(SDD)

UNITGRPH Version 1.0
FLDHYRDO Version 1.0
TRBROUTE Version 1.1
CHANROUT Version 1.0

	R0	R1	R2	R3
Prepared	Lena Ireland	James Kelley		
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Reviewed	Angelos Findikakis	Eric King		
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Issue Date		~~12-22-09~~ 12-23-09		

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Tennessee Valley Authority

SOFTWARE DESIGN DOCUMENT

(SDD)

UNITGRPH Version 1.0
FLDHYRDO Version 1.0
TRBROUTE Version 1.0
CHANROUT Version 1.0

	R0	R1	R2	R3
Prepared	Lena Ireland			
Reviewed	Angelos Findikakis			
Approved	Kenneth Spates			
	PBSelman for KPS			
Issue Date	3/31/09			

	REVISION LOG	
Revision Number	**Description of Revision**	**Date Approved**
0	Initial Issue for UNITGRPH Version 1.0, FLDHYRDO Version 1.0, TRBROUTE Version 1.0, and CHANROUT Version 1.0	
1	• Revised FLDHYDRO Section 3.2.2 to add additional user warnings – Pages 8-9 • Revised TRBROUTE Section 5.2.2 (Page 14) to increase the maximum number of storms from three (3) to nine (9).	

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ACRONYMS

ANS	American National Standard
ANSI	American National Standards Institute
API	Antecedent Precipitation Index
ARMA	Autoregressive Moving Average
RI	Runoff Index
SOCH	Simulated Open Channel Hydraulics
SRS	Software Requirements Specification
TVA	Tennessee Valley Authority

1. INTRODUCTION

1.1 Background

The Tennessee Valley Authority (TVA) has developed and used the Simulated Open Channel Hydraulics (SOCH) code for flood routing calculations in the Tennessee River basin. In addition to this code, TVA has developed seven auxiliary programs to prepare the required inputs to SOCH. These computer programs are used to meet United States Nuclear Regulatory Commission guidance set forth in Nuclear Regulatory Guide 1.59 (American National Standards Institute [ANSI] ANSI/ANS-2.8-1992) and the requirements of TVA SPP-2.6, Computer Software Control (Reference 1).

This Software Design Description (SDD) pertains to four of the seven codes including UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT. UNITGRPH computes unit hydrographs from historical flood data. FLDHYDRO determines inflows from unit hydrographs and rainfall. TRBROUTE routes hydrographs from one point to another using different routing procedures (channel and reservoir) and CHANROUT determines channel routing method coefficients.

This SDD document presents the general overview and details of running the UNITGRPH, FLDHYDRO, TRBROUTE, CHANROUT codes and how these codes meet the requirements of Reference 2, UNITGRPH, FLDHYDRO, TRBROUTE, CHANROUT Software Requirements Specification (SRS).

1.2 Overview of Design

Inflow hydrographs at input points to the SOCH model are generated by the FLDHYDRO and TRBROUTE code with inputs from UNITGRPH and CHANROUT. The Tennessee River basin has been divided into watershed sub-basins (unit areas). Unit hydrographs as determined by the UNITGRPH code are used to compute flows from each unit area. These unit area flows computed by the flood hydrograph code (FLDHYDRO) are combined with appropriate channel routing coefficients (computed using CHANROUT) to compute inflows into the most upstream reservoirs which in turn are routed through the reservoirs using the TRBROUTE code. Resulting outflows are combined with additional local inflows and carried downstream using appropriate time sequencing or routing procedures (TRBROUTE code), including unsteady flow routing (SOCH code).

The four computer codes, UNITGRPH, FLDHYDRO, TRBROUTE, CHANROUT were developed and used by Tennessee Valley Authority (TVA). These codes were originally programmed to run on a mainframe computer and were later transferred to the personal computer (PC). The latest version of these codes has been compiled using the Compaq Visual FORTRAN compiler, Professional Edition 6.6A.

1.3 Design Constraint Limitations

There are no major limitations in the use of UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT related to the nature of the calculations performed by these codes. The primary limitations arise from the dimensions of arrays in these codes. These limitations can be addressed by editing the source code and creating a new executable. Source code revisions must adhere to Reference 1, Section 3.3.2.

2. UNITGRPH

2.1 Theoretical basis

The UNITGRPH code is used to develop unit hydrographs for the sub-basins of the Tennessee River basin. The highest historical floods for which data are available are used for this purpose. The historic flood information is obtained from recording stream gages, tributary dam headwater elevation, discharge and storage relationships which permitted calculation of the flood, and estimates on ungaged watersheds where historic flood information upstream and downstream of the watershed under consideration was available to make flow estimates.

The UNITGRPH code implements the method for unit hydrograph development described in "Computer-Determined Unit Hydrographs from Floods", by Newton and Vinyard (Reference 3), which uses matrix algebra and a least squares approach to iteratively solve for the unit hydrograph and precipitation excess values that provide the best fit to the observed flood or a series of floods.

The UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 4) presents the detailed theoretical basis of UNITGRPH in detail.

2.2 Input and Output Features

The UNITGRPH code consists of the main program and three subroutines:

- AVERAG, which performs averaging on the runoff matrix.
- XATEQ(A,B,N,M,DET) which solves a system of linear equations; A is the system matrix and B is the right hand side vector. The solution returned is in the array B.
- GRAFIT(U,UGD,NUGO,Q,CQ,NQ,NFLOOD,HEAD,HEAD2) writes the output data for facilitating the plotting of the unit hydrograph, and the measured and computed flood hydrograph.

UNITGRPH uses one user-specified input file for all the required data input and produces two output files; one with the data needed to plot the key results, and the main output file.

UNITGRPH input and output files are associated with specific Unit numbers in the standard FORTRAN language terminology.

2.2.1 Input Features

In the UNITGRPH input file (Unit 5), the following information is specified:

- Error convergence value and maximum number of iterations if the error convergence value is not reached
- Number of floods from which the unitgraph is derived
- Number and value of "LIST" ordinates of the unitgraph that are directly computed
- Basin drainage area
- Runoff input interval (equivalent to the unitgraph duration)

- The surface runoff hydrograph in units of 1000 cfs for each flood
- The runoff ordinates in inches for each flood

2.2.2 Output Features

The plotting output file (Unit 3) includes the following:

- Input surface runoff hydrograph and final computed surface runoff hydrograph for each flood
- Final computed unitgraph

The main output file (Unit 6) includes the following:

- The input surface runoff hydrograph and input runoff for each flood
- Results for each iteration including:
    - Starting unitgraph
    - Runoff, computed hydrograph, hydrograph error, adjusted runoff, computed hydrograph using the adjusted runoff, and the hydrograph error using the adjusted runoff for each flood

The following responses to valid and invalid inputs and responses to abnormal situations are produced by UNITGRPH. When UNITGRPH functions normally, the output file is created and ends with either "STOPPED BY CONVERGENCE TEST" or "STOPPED BY ITERATION TEST." However, UNITGRPH has no built-in safeguards to warn users when abnormal situations arise during the operation of the program. Therefore, as long as values of the proper dimension are input for each expected variable, UNITGRPH will produce an output file, regardless of whether the input data are logical or not. Therefore, it is possible for UNITGRPH to appear to have functioned normally while using invalid input data. A few such cases are presented below:

- **Negative value input for flood hydrograph or runoff:**

  Physically, all flood hydrograph ordinates and runoff values should be greater than zero. However, UNITGRPH does not reject input values that are less than zero (although computed hydrograph ordinates and runoff values are required to be greater than zero). UNITGRPH still terminates normally without any warning or error message when negative flood hydrograph or runoff values are input.

- **Negative value input for "LIST" value or basin area:**

  When negative "LIST" values or a negative value for the basin area are input, UNITGRPH returns "NaN" for most of the computed values. Therefore, it is obvious to the user that UNITGRPH has not functioned properly. However, UNITGRPH accepts these negative input values and still terminates normally without any warning or error message.

In the cases presented in this section, UNITGRPH accepts invalid input data but does not warn the user that the data are invalid. In some cases UNITGRPH may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of UNITGRPH besides those presented above. Therefore, it is the responsibility of the user to confirm that the data in the input file are valid in order to ensure that the UNITGRPH output is also valid. Normal

termination of UNITGRPH is a necessary but not sufficient condition for producing valid results.

3. FLDHYDRO

3.1 Theoretical basis

FLDHYDRO computes the runoff for specific storm events, as well as the flood hydrograph using as input the unit hydrograph and the rainfall distribution. The flood hydrograph flows computed with FLDHYDRO are combined with time sequencing or channel routing coefficients computed by the CHANROUT code to compute discharges from upstream unit areas using the TRBROUTE code.

FLDHYDRO computes the runoff from the rainfall data using the Antecedent Precipitation Index (API) as an estimate of initial moisture deficiency based on the method developed in the report "Predicting the Runoff from Storm Rainfall" by Kohler and Linsley and the textbook "Hydrology for Engineers" by Kohler, Linsley, and Paulhus (References 5 and 6 respectively). The method, developed from a study of storm records, relates the amount of precipitation excess (and hence the precipitation loss) to the rainfall, the week of the year, the API, and the geographic location of the drainage basin. The method was first implemented graphically using coaxial relations between the API and runoff. An example of the original application of this method can be found in References 5 and 6. In FLDHYDRO the method is implemented using lookup tables developed specifically for the Tennessee River basin (Reference **Error! Reference source not found.**). The user also has the option to specify a known storm runoff depth. The tables are then referenced to find the RI (Runoff Index) value that best matches the known storm runoff depth. Once the runoff has been estimated the flood hydrograph is computed from the unit hydrograph and runoff.

The UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 4) presents the detailed theoretical basis of the code FLDHYDRO in detail.

3.2 Input and Output Features

The FLDHYDRO code consists of the main program and several subroutines. The following subroutines were part of the original FLDHYDRO code developed on a mainframe computer:

- APIWK(WEEK) computes API values and week of the year
- VOLCHK(CHKVOL,NUMVOL) adjusts the RI's to obtain computed surface volumes that are nearest the check volumes input
- HYDROG computes flood hydrograph
- HYDRO(BSNIDX,YEAR,DAY,MONTH,TIME,YEARRO,DAYRO,MORO, IN, BHRAIN,NBLKS,NOFLOW,NFLOWS,BSNHRO,BLCKRO,FHCNT)
- RUNOFF(RI,RITYP,RAIN,RO,FACTOR) computes runoff
- CLOCK(DATE,INCRMT,DAY)

The following subroutines are used in the present PC version of FLDHYDRO to facilitate the interactive use of the code:

- DoDialog()
- UpdateFiles(dlg, control_name, callbacktype)

- UpdateButton(dlg, control_name, callbacktype)
- UpdateDat(dlg, control_name, static_file, button_control, dirname, ofile)
- SETFIL(dlg, static_file, datname, Output, xtension)

FLDHYDRO uses one user-specified input file and three input files containing tables developed by TVA specifically for the Tennessee River basin. FLDHYDRO produces one or two output files; an optional file which is formatted to be used as input to subsequent codes, and the main output file.

3.2.1 Input Features

In the FLDHYDRO input file (Unit 5), the following information is specified:

- Daily antecedent rainfall (optional),
- Hourly storm event rainfall,
- Thiessen weights (when needed)
- Base flow factor for each subwatershed and storm,
- Surface runoff volume at specified drainage points (optional), and
- Unit hydrographs for each subwatershed (optional, needed if the flood hydrograph is to be computed)
- Drainage area for each subwatershed

Also used as inputs to the program are three tables developed by TVA (Reference 7) specifically for the Tennessee River basin:

- APITBL – relates locality parameters (geographic region and week of the year) and Antecedent Precipitation Index (API) values to give RI values within the Tennessee River basin
- TV – relates RI and cumulative precipitation to effective precipitation for all Tennessee River basin runoff regions except the southeast (SE) region
- NonTV – relates RI and cumulative precipitation to effective precipitation for the SE runoff region of the Tennessee River basin.

3.2.2 Output Features

The optional plotting output file (Unit 3) contains the calculated flood hydrograph for each specified subwatershed. Flood hydrographs are generated in the order of subwatersheds listed in the input file.

The main output file (Unit 6) includes the following:

- An echo of the input data
- Results for each subwatershed including:
    - Thiessen factor, API value, RI value, and look-up table (NonTV or TV) used for each raingage
    - Summation hourly rain and summation hourly runoff

- Runoff hydrograph and flood hydrograph calculated using the input unit hydrograph (optional)

The following responses to valid and invalid inputs and responses to abnormal situations are produced by FLDHYDRO. When FLDHYDRO functions normally, the output file is created but no end message is printed. However, FLDHYDRO does have built-in safeguards to warn users when abnormal situations arise during the operation of the program. A listing of these safeguards is provided below:

- After the second line of input data is read by FLDHYDRO, a check is done for input values out of range. If the number of runoff indices, number of stations, number of recorders, number of subwatersheds, or number of volume checks is invalid, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and one of the following messages:

  " (No. of Runoff Indices) IS INVALID AS NUMBER OF RI"S PER STATION; MAXIMUM IS 4"

  " (No. of Stations) IS INVALID AS NUMBER OF STATIONS; MAXIMUM IS 100"

  " (No. of Recorders) IS INVALID AS NUMBER OF RECORDERS; MAXIMUM IS 30"

  " (No. of Subwatersheds) IS INVALID AS NUMBER OF SUBWATERSHEDS; MAXIMUM IS 50"

  " (No. of Volume Checks) IS INVALID AS NUMBER OF VOLUME CHECKS; MAXIMUM IS NO. OF SUBWATERSHEDS"

- All non-recording stations (i.e. stations where no hourly rainfall data were recorded, but only daily totals are available) must be paired with a recording station (i.e. a station where hourly rainfall was recorded) that will be used to distribute the daily rainfall from the non-recording stations. If an invalid recording station is entered, the output file consists of an echo of the input data and the beginning of the output data up to the point of calculations with the ill-referenced non-recorder. The following message is inserted in the echo data:

  " (Non-Recording Station) IS NOT A VALID RECORDER NAME FOR STATION (Recording Station)"

- For FLDHYDRO runs where the RI value is input, the RI is required to be less than or equal to 55. If a value of RI greater than 55 is input, the following message is inserted in the echo data:

  " RI VALUE OF (RI Value) DETECTED; MAX. IS 55"

- FLDHYDRO only allows one subwatershed to use more than 25 stations and that subwatershed must be the last one referenced. If this rule is violated, the following message is inserted in the echo data:

  " ONLY ONE WATERSHED ALLOWED WITH >25 STATIONS AND THAT WATERSHED MUST BE THE LAST ONE"

- When assigning Thiessen factors for a subwatershed, the Thiessen factors must be applied to rain stations defined as either recorders or non-recorders. If a station name that does not match an input recorder or non-recorder is input, the following message is inserted in the echo data:

"... ERROR...ORDER OF RAIN STATIONS NOT ESTABLISHED PROPERLY. MAKE SURE... THAT FOUR CHARACTER RAIN STATION NAMES IN BSNSTA(I,J) MATCH THOSE IN NAMSTA(I)"

- When calculating non-recorder hourly rain from recorders, two error messages can be generated. These error messages do not invalidate the output data. Rather, they serve as warnings to the user that abnormal situations have occurred and leave it up to the user whether to accept the data or not. These messages are printed in the output data where RI values are calculated and are reproduced below:

  " *** ERROR -- A DAILY RAIN OF ZERO FOR RECORDER (Recording Station) WILL PRODUCE A DAILY RAIN OF ZERO FOR GAGE (Non-Recording Station). INVALID COMPUTATIONS WILL RESULT."

  " WARNING...A DAILY RAIN OF (Non-Recorder Daily Rain) FOR GAGE (Non-Recording Station) IS WEIGHTED AGAINST A DAILY RAIN OF (Recorder Daily Rain) FOR RECORDER (Recording Station). THIS IS A WEIGHT RATIO OF (Ratio) WHICH MAY SIGNIFICANTLY AFFECT RESULTS."

If none of the above abnormal conditions occurs, FLDHYDRO is presumed to have functioned normally. In this case, the entire output file is created.

However, it is possible for FLDHYDRO to appear to have functioned normally while using invalid input data. A few such cases are presented below:

- **Input API value greater than 5:**

  In FLDHYDRO, the look-up tables do not allow API values greater than 5. However, it is possible to assign an initial API value greater than 5. FLDHYDRO still terminates normally without any warning or error message when API values greater than 5 are input.

- **Negative value input for precipitation:**

  Physically, all precipitation values should be greater than zero. However, FLDHYDRO does not reject input values that are less than zero. FLDHYDRO still terminates normally without any warning or error message when negative precipitation values are input.

- **Thiessen weights do not sum to one:**

  When weighting rainfall with Thiessen weights, the sum of the Thiessen weights must be 1. However, FLDHYDRO does not check the sum of the Thiessen weights. Therefore, the sum of the Thiessen weights can be either greater than or less than one and FLDHYDRO still terminates normally without any warning or error message.

- **The *.hyd files created by FLDHYDRO do not include a time/date stamp:** The direct use or export of FLDHYDRO *.hyd data to TRBROUTE can combine hydrographs that have different starting times without the user's knowledge. The user should carefully check the *.out file for the time interval alignment prior to use or routing of the FLDHYDRO output data.

  For example, if a storm for a subwatershed with a unit hydrograph duration and time interval of 6 hours were to start at 3/15 0000 hours and the first non-zero hourly runoff value for the storm were to occur on 3/16 at 0100 hours (and thus, the first block of 6 hour runoff ends at 0600 hours) FLDHYDRO would insert into the .hyd file

a runoff value of 0 cfs (assuming no baseflow) at 3/16 0000, 3/15 1800, 3/15 1200, 3/15 0600 and the starting runoff value of 0 cfs would be at 3/15 0000. If the same storm were to have the first-nonzero runoff value at 3/16 0500, FLDHYDRO would insert into the .hyd file a runoff value of 0 cfs (assuming no baseflow) at 3/16 0400, 3/15 2200, 3/15 1600, 3/15 1000 and the starting runoff value of 0 cfs would be at 3/15 0400.

In the cases presented in this section, FLDHYDRO accepts invalid input data but does not warn the user that the data are invalid. In some cases FLDHYDRO may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of FLDHYDRO besides those presented above. Therefore, it is the responsibility of the user to confirm that the input data file is valid in order to ensure that the FLDHYDRO output is also valid. Normal termination of FLDHYDRO is a necessary but not sufficient condition for producing valid results.

4. CHANROUT

4.1 Theoretical basis

The CHANROUT code computes the coefficients of an ARMA channel routing model of which the Muskingum routing equation is a special case. An ARMA(P,Q) channel routing model computes current outflow out of a river reach as a linear combination of the previous P outflows, plus the previous Q inflows and current inflow into a reach. ARMA(1,1) is equivalent to the Muskingum routing equation. Channel routing coefficients computed by CHANROUT are combined with flood hydrographs from FLDHYDRO to route flood hydrographs downstream using the TRBROUTE code.

The UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 4) presents the detailed theoretical basis for CHANROUT.

4.2 Input and Output Features

The CHANROUT code consists of the main program and the subroutine XATEQ(L,A,B,N,M) which solves a system of linear equations.

CHANROUT uses one user-specified input file for all the required data input and produces one output file.

4.2.1 Input Features

In the CHANROUT input file (Unit 5), the following information is specified:

- Number of previous inflows to be used in the ARMA routing model
- Number of previous outflows to be used in the ARAM routing model
- Flow time interval
- Routing period
- Inflows into and outflows out of the channel reach

4.2.2 Output Features

The CHANROUT output file (Unit 6) includes the following:

- An echo of the input data
- The channel routing coefficients
- Inflow, outflow, and computed outflow for each time period

The following responses to valid and invalid inputs and responses to abnormal situations are produced by CHANROUT. When CHANROUT functions normally, the output file is created but no end message is printed. However, CHANROUT does have built-in safeguards to warn users when abnormal situations arise during the operation of the program. A listing of these safeguards is provided below.

- If the number of previous inflows or outflows to be used in the ARMA routing model is less than one, or if the total number of inflows and outflows to be used is greater than 20, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and the message:

  " 1 – 10 BACK POINTS ALLOWED: IBKPTS = (No. Previous Inflows); OBKPTS = (No. Previous Outflows)"

- If the routing period is not a multiple of the time interval, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and the message:

  " ROUTING PERIOD MUST BE A MULTIPLE OF TIME INCREMENT: RP = (Routing Period); TIMINT = (Time Interval)"

- In order to perform the routing the number of inflows and outflows input must be at least as many as the larger of the number of previous inflows or outflows, times the routing period divided by the time interval (this term is the variable "SHIFT" in the CHANROUT program). If this is not true, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and the message:

  " AT LEAST (SHIFT) FLOWS MUST BE SPECIFIED FOR VIABLE COMPUTATIONS: NFLOWS = (No. Inflows/Outflows)"

- The maximum number of inflows/outflows input to CHANROUT is 300. If this number is exceeded the run terminates and the output file consists only of an echo of the first two lines of input data and the message:

  " MAX. NO. OF FLOWS IS 200: NFLOWS = (No. Inflows/Outflows)"

If none of the above abnormal conditions occurs, CHANROUT is presumed to have functioned normally. In this case, the entire output file is created.

However, it is possible for CHANROUT to appear to have functioned normally while using invalid input data. One such case is presented below:

- **Negative value input for inflow or outflow:**

  Physically, all inflow and outflow values should be greater than zero. However, CHANROUT does not reject input values that are less than zero. CHANROUT still terminates normally without any warning or error message when negative inflow or outflow values are input.

In the case presented above, CHANROUT accepts invalid input data but does not warn the user that the data are invalid. In some cases CHANROUT may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of CHANROUT besides that presented above. Therefore, it is the responsibility of the user to confirm that the input data file is valid in order to ensure that the CHANROUT output is also valid. Normal termination of CHANROUT is a necessary but not sufficient condition for producing valid results.

5. TRBROUTE

5.1 Theoretical basis

TRBROUTE performs the channel and reservoir routings necessary to route flood hydrographs downstream to selected points (for input to the SOCH model). This includes routing through reservoirs with fixed discharge rating curves and the major tributary dam systems whose operations follow fixed rules. Discharge rating curves defining the fixed rules of the major tributary dams can be handled by the program. TRBROUTE uses autoregressive moving average (ARMA) type channel routing coefficients computed by CHANROUT combined with flood hydrographs from FLDHYDRO to route flood hydrographs downstream.

The UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 4) presents the detailed theoretical basis for TRBROUTE.

5.2 Input and Output Features

The TRBROUTE code consists of the main program and several subroutines. The following subroutines were part of the original TRBROUTE code developed on a mainframe computer:

- ROUTE
- WRITE(PREVCD,PTR)
- OUTRAT(RSVRNM,STMPTR,ELEV,QRAT,STO,NUMPTS)
- GETSTO(RSVRNM,STO,NUMPTS,ELEV)
- GETRAT(RSVRNM,QRAT,NUMPTS,ELEV)
- GETIFR(RSVRNM,FEL,FOUT,NUMPTS,ELEV,QRAT,NUL,TOG,QEMPTY)
- SRTMRG(FROMX,FNUM,TOX,TNUM,FROMY,TOY)
- FRSTEL(RSVRNM,DATE,TIME,GUIDE,TOPZON)
- UPDATE(DELTAT,GUIDE,TOPZON)
- CHGHI(FLOWS,OLDHI,NEWHI,NUMORD,AVE)

The following subroutines are used in the present PC version of TRBROUTE to facilitate the interactive use of the code:

- DoDialog()
- UpdateFiles(dlg, control_name, callbacktype)
- UpdateButton(dlg, control_name, callbacktype)
- UpdateDat(dlg, control_name, static_file, button_control, dirname, ofile)
- SETFIL(dlg, static_file, datname, Output, xtension)

TRBROUTE uses up to two user-specified input files and four input files developed by TVA. These four input files are named STORAGES, QRATINGS, IMPRULES, and SGUIDES and they contain reservoir storage data, rating curves, operation rules and seasonal elevation

guidelines. The names of the files developed by TVA are "hardwired" in TRBROUTE and they must be located in the same folder with these exact names and no extensions as the TRBROUTE executable.

TRBROUTE produces two output files; one with the flood hydrograph data in the format required for their subsequent use by other codes, and the main output file.

5.2.1 Input Features

In the TRBROUTE main input file (Unit 5), the following information is specified:

- Inflow hydrographs from FLDHYDRO (if second input file is not used)
- Channel routing coefficients from CHANROUT
- Set of instruction codes that tell TRBROUTE how to route and combine the inputs
- Reservoir names
- Starting water surface elevation for each reservoir
- Starting discharge used for routing calculations for each reservoir (FOUT)
- Storage-elevation curves and discharge rating curves for reservoirs not defined in TVA tables (see below)

The second (optional) input file (Unit 2) is produced by FLDHYDRO and specifies the flood hydrographs, including hydrograph ordinates and the hydrograph interval (in hours).

Also used as inputs to the program are four files developed by TVA (Reference 8):

- STORAGES – look-up table with storage-elevation curves for reservoirs to be routed
- QRATINGS – look-up table with discharge rating curves for tributary dams to be routed using TRBROUTE
- IMPRULES – look-up table with reservoir operation guides for major tributary dams
- SGUIDES – look up table with reservoir seasonal operation guidelines

5.2.2 Output Features

The main output file (Unit 6) includes the following:

- An echo of the input data
- Discharge and storage curves for all storms for each reservoir
- A printout depending on the combination of instruction codes
    - 1,6 – total hydrograph currently in the working location
    - 2,6 – inflow into and outflow from the reservoir
    - 3,6 – outflow out of the channel
    - 4,6 – not valid
    - 5,6 – combined flow

The output file with data formatted for use in subsequent codes (Unit 3) includes the ordinates of the most downstream flood hydrograph produced by TRBROUTE as well as the hydrograph interval (in hours).

The following responses to valid and invalid inputs and responses to abnormal situations are produced by TRBROUTE. When TRBROUTE functions normally, the output file is created but no end message is printed. However, TRBROUTE does have built-in safeguards to warn users when abnormal situations arise during the operation of the program. A listing of these safeguards is provided below.

- TRBROUTE checks some input parameters for values out of range. If the number of storms, instruction code value, or rating curve code value is out of range, the run terminates. In this case, the output file consists only of an echo of the input data already read and one of the following messages:

  " (No. Storms) IS INVALID AS NUMBER OF STORMS; MAXIMUM IS 9"

  " (Instruction Code) IS INVALID INSTRUCTION CODE; RANGE IS 1 TO 6"

  " (Rating Curve Code) IS INVALID CODE FOR RATING CURVES; RANGE IS 0 TO 2"

- When using the look up tables, the reservoir name given in the main input file must match one of the reservoir names in the look up tables. If the names do not match, the data for the last entry in the look-up table will be used for computations and the run will continue with the invalid data. In this case, the output file consists of an echo of the input data, and the output data. One or more of the following messages will be inserted before the output for the reservoir with the invalid name:

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN STORAGE CURVES FILE"

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN DISCHARGE CURVES FILE"

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN IMPROVED FIXED RULES FILE"

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN SEASONAL GUIDES FILE"

If none of the above abnormal conditions occurs, TRBROUTE is presumed to have functioned normally. In this case, the entire output file is created.

However, it is possible for TRBROUTE to appear to have functioned normally while using invalid input data. A few such cases are presented below:

- **Negative value input in hydrograph input file:**

  Physically, all hydrograph values should be greater than zero. However, TRBROUTE does not reject input values that are less than zero. TRBROUTE still terminates normally without any warning or error message when negative hydrograph values are input to the hydrograph input file.

- **Initial Headwater elevation above the range of elevation values in the look-up table:**

  The QRATINGS and IMPRULES data input files in TRBROUTE contain discharge rating curves for specified TVA structures. When initial headwater elevation values are specified above the range given in the table, the discharge obtained from these tables is invalid. TRBROUTE still terminates normally without any warning or error

message when initial headwater elevations are greater than the largest value in the look-up tables.

In the cases presented in this section, TRBROUTE accepts invalid input data but does not warn the user that the data are invalid. In some cases TRBROUTE may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of TRBROUTE besides those presented above. Therefore, it is the responsibility of the user to confirm that the input data file is valid in order to ensure that the TRBROUTE output is also valid. Normal termination of TRBROUTE is a necessary but not sufficient condition for producing valid results.

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Tennessee Valley Authority

SOFTWARE VERIFICATION AND VALIDATION REPORT

(SVVR)

UNITGRPH Version 1.0
FLDHYDRO Version 1.0
TRBROUTE Version 1.1
CHANROUT Version 1.0

	R0	R1	R2	R3
Prepared	Lena Ireland	James Kelley		
		Steve Limback		
Reviewed	Angelos Findikakis	Eric King		
Approved		K.E. Spates		
		K.E. Spates		
Issue Date		~~12-22-09~~		

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Tennessee Valley Authority

SOFTWARE VERIFICATION AND VALIDATION REPORT

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UNITGRPH Version 1.0
FLDHYDRO Version 1.0
TRBROUTE Version 1.0
CHANROUT Version 1.0

	R0	R1	R2	R3
Prepared	Lena Ireland			
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Approved	K.R. Spates			
	PBselman for KRS			
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	REVISION LOG	
Revision Number	**Description of Revision**	**Date Approved**
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1	• Revised FLDHYDRO Section 3.2.4 to add additional user warnings – Page 83 • Revised TRBROUTE Section 5.2.2 (Page 114) to increase the maximum number of storms from three (3) to nine (9). • Revised to include Reference 21 associated with the SOCH Software Operability Procedure and Results – Page 117	

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ELECTRONIC ATTACHMENTS

1. UNITGRPH, FLDHYDRO, TRBROUTE, CHANROUT input data files in folder "UNITGPRH-FLDHYDRO-TRBROUTE-CHANROUT SVVR - Attachment 1 - Test_Problems_Input"
2. UNITGRPH, FLDHYDRO, TRBROUTE, CHANROUT output data files in folder "UNITGPRH-FLDHYDRO-TRBROUTE-CHANROUT SVVR - Attachment 2 - Test_Problems_Output"
3. UNITGRPH, FLDHYDRO, TRBROUTE, CHANROUT source code and executable used to perform the tests reported in this SVVR in folder "UNITGPRH-FLDHYDRO-TRBROUTE-CHANROUT SVVR - Attachment 3 - Source_&_Executable"
4. Independent calculation EXCEL files in folder "UNITGPRH-FLDHYDRO-TRBROUTE-CHANROUT SVVR - Attachment 4 - Independent_Calculations"

ABBREVIATIONS

cfs	cubic feet per second
ft	feet
hr	hour
hrs	hours
in	inches
in/hr	inches per hour
sq mi	square miles

ACRONYMS

API	Antecedent Precipitation Index
ARMA	Autoregressive Moving Average
CV	Check Volume
RI	Runoff Index
SE	Southeast
SOCH	Simulated Open Channel Hydraulics
SVVR	Software Validation and Verification Report
TVA	Tennessee Valley Authority

1. INTRODUCTION

1.1 Background

The four computer codes validated in the present manual were developed by the Tennessee Valley Authority (TVA) to develop part of the required input to the Simulated Open Channel Hydraulic (SOCH) code, which is used for flood routing calculations in the Tennessee River basin. Specifically the function of the four codes is:

UNITGRPH	Computes unit hydrographs from historical flood data.
FLDHYDRO	Determines inflows from unit hydrographs and rainfall.
CHANROUT	Determines channel routing method coefficients.
TRBROUTE	Routes hydrographs from one point to another using different routing procedures (channel & reservoir).

The Tennessee River basin has been divided into watershed sub-basins (unit areas). Unit hydrographs as determined by the UNITGRPH code are used to compute flows from each unit area. These unit area flows computed by the flood hydrograph code (FLDHYDRO) are combined with appropriate channel routing coefficients (computed using CHANROUT) to compute inflows into the most upstream reservoirs which in turn are routed through the reservoirs using the TRBROUTE code. Resulting outflows are combined with additional local inflows and carried downstream using appropriate time sequencing or routing procedures (TRBROUTE code), including unsteady flow routing (SOCH code).

1.2 Scope

The scope of this report is limited to verifying the numerical solutions of the equations used and solved by UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT. The theoretical basis of the codes and the equations they solve are described in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 1).

Section 2.1 of this document describes the plan for testing UNITGRPH functionality. Section 2.2 describes the results of the tests of the UNITGRPH code. Section 3.1 describes the plan for testing the FLDHYDRO functionality. Section 3.2 describes the results of the tests of the FLDHYDRO code. Section 4.1 of this document describes the plan for testing the CHANROUT functionality. Section 4.2 describes the results of the tests of the CHANROUT code. Section 5.1 of this document describes the plan for testing the TRBROUTE functionality. Section 5.2 describes the results of the tests of the TRBROUTE code. Section 6 gives the summary and conclusions of the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT functionality testing. References are listed in Section 7.

References to the source of the data used for the validation of the codes are given in the description of the test problems used in each case.

2. UNITGRPH

2.1 Plan for Testing UNITGRPH Functionality

2.1.1 Overview

The plan for testing the functionality of UNITGRPH is defined in Reference 2, Appendix G. The UNITGRPH Test Plan consists of a comparison of the solution of test problems obtained with UNITGRPH to independent calculations for the same problems. The test plan serves to evaluate the program's capabilities, limitations, and the validity of its results as related to TVA design applications. The test problems, which are described in Section 2.1.2, were selected to be representative of typical TVA applications of the program.

Revisions or modifications to the UNITGRPH computer program require documentation of the changes as required in Section 3.3 of Reference 2.

The test problems specified here are intended to assess the extent of possible program features and options likely to be required for safety-related design analysis. These test problems were run using UNITGRPH Version 1.0.

The UNITGRPH code implements the method for unit hydrograph development developed by Newton and Vinyard in 1969 and described in Reference 3. Two sets of test problems are used for the validation of UNITGRPH. The first set of tests is aimed at verifying that the code correctly implements the Newton and Vinyard method. The second set of problems is aimed at testing different options available in UNITGRPH which impact the shape of the unit hydrograph produced by the code.

In UNITGRPH, the user has the option to calculate only selected ordinates defining the unit hydrograph. This option is available in UNITGRPH by defining the ordinates of the unitgraph to be directly computed as the elements of the user-defined input array "LIST". Intermediate ordinates are found by interpolating between computed ordinates. This option was designed to provide a smoothing device usually used only in the recession of the unit hydrograph. The list begins with the last ordinate to be directly computed before interpolation begins, and ends on the last ordinate computed for that unit graph.

2.1.2 Tests of the Implementation of the Newton and Vinyard Method

- **Test Problem 1:** Fort Loudoun Sub-basin

  This problem is intended to ensure that UNITGRPH properly calculates the unit hydrograph using the flood hydrograph from a single storm. The flood hydrograph and the hyetograph used for this purpose are given in Figure 1. The drainage area for the watershed is 323 square miles. The user-defined "LIST" values are 3 and 5. This problem was taken from Reference 4.

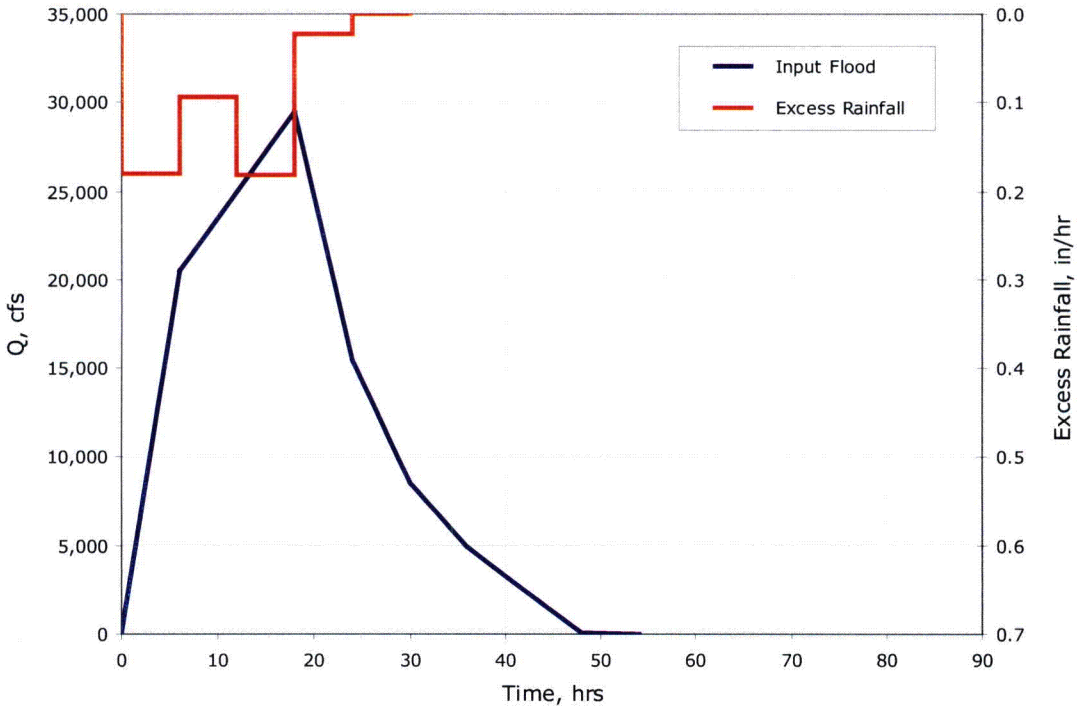


Figure 1. Flood Hydrograph and Hyetograph for Test Problem 1

- **Test Problem 2:** French Broad River, Newport to Asheville

  This problem is intended to ensure that UNITGRPH properly calculates the unitgraph using data from two floods. Figure 2 and Figure 3 show the flood hydrographs and the hyetograph for each of these two floods. The drainage area for the watershed is 913.1 square miles. The user-defined "LIST" values are 3, 5, and 8. Rainfall and flood hydrograph data, as well as the watershed area for this problem were taken from References 5 and 6.

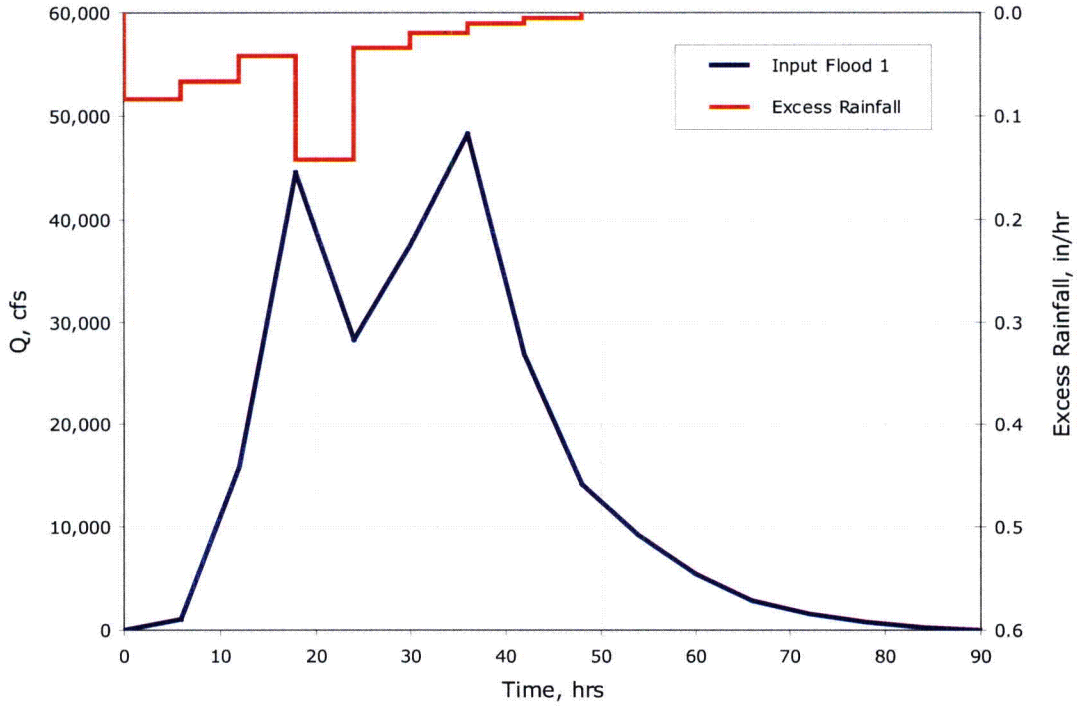


Figure 2. Flood Hydrograph and Hyetograph for First Event of Test Problem 2

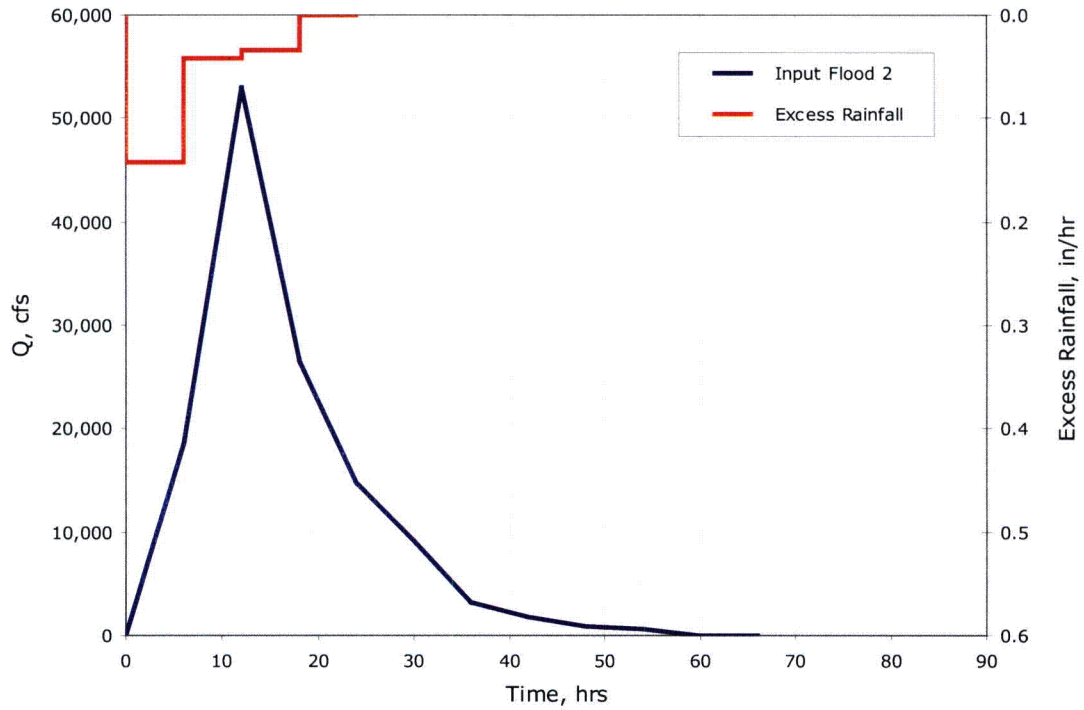


Figure 3. Flood Hydrograph and Hyetograph for Second Event of Test Problem 2

- **Test Problem 3:** French Broad River at Rosman

  This problem demonstrates the program's capability to recreate the unit hydrograph computed by Newton and Vinyard in Table 3 (List 1) of the paper "Computer-Determined Unit Hydrographs from Floods" (Reference 3). The flood hydrograph and the hyetograph used for this purpose are given in Figure 4. The drainage area for the watershed is 67.9 square miles. The user-defined "LIST" values are 2, 4, 6, 9, 16, and 22.

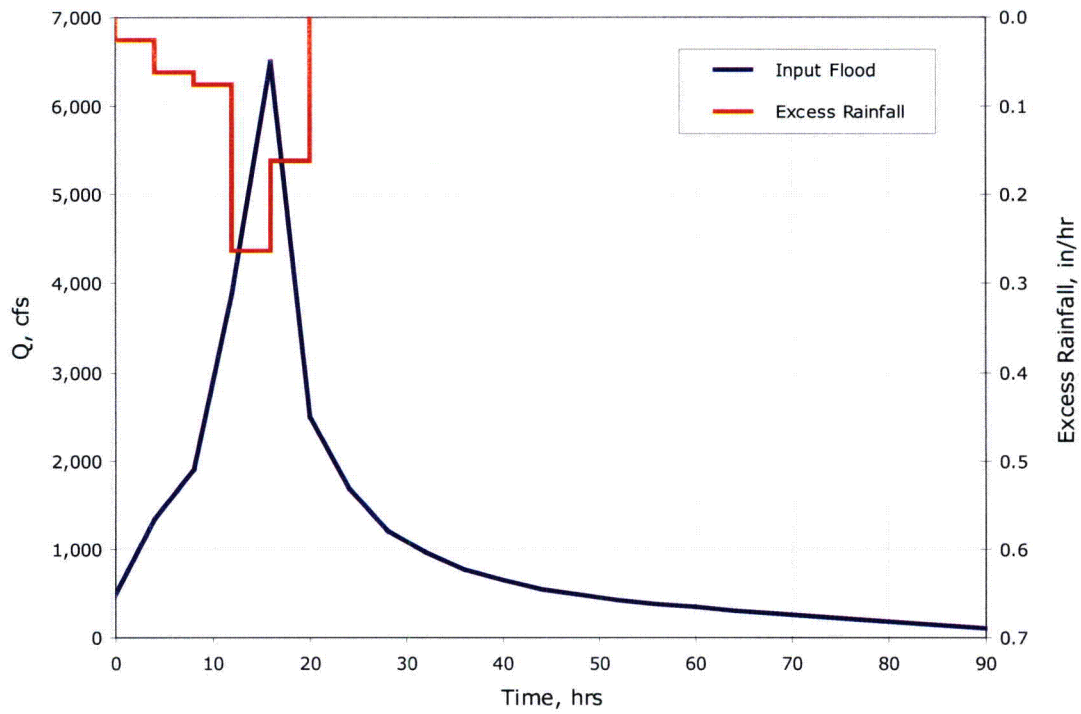


Figure 4. Flood Hydrograph and Hyetograph for Test Problem 3

- **Test Problem 4:** Triangular Unit Hydrograph

  This problem is intended to ensure that UNITGRPH properly solves for a known unitgraph from a given derived flood hydrograph and uniform rainfall rate. For this purpose the triangular unit hydrograph shown in Figure 5 is combined with a uniform precipitation of 2 inches over a period of 6 hours to construct the flood hydrograph shown in Figure 6. The drainage area for the watershed is 43.388 square miles. All ordinates of the unit hydrograph are computed by UNITGRPH. This problem was developed to test UNITGRPH with a simple input file.

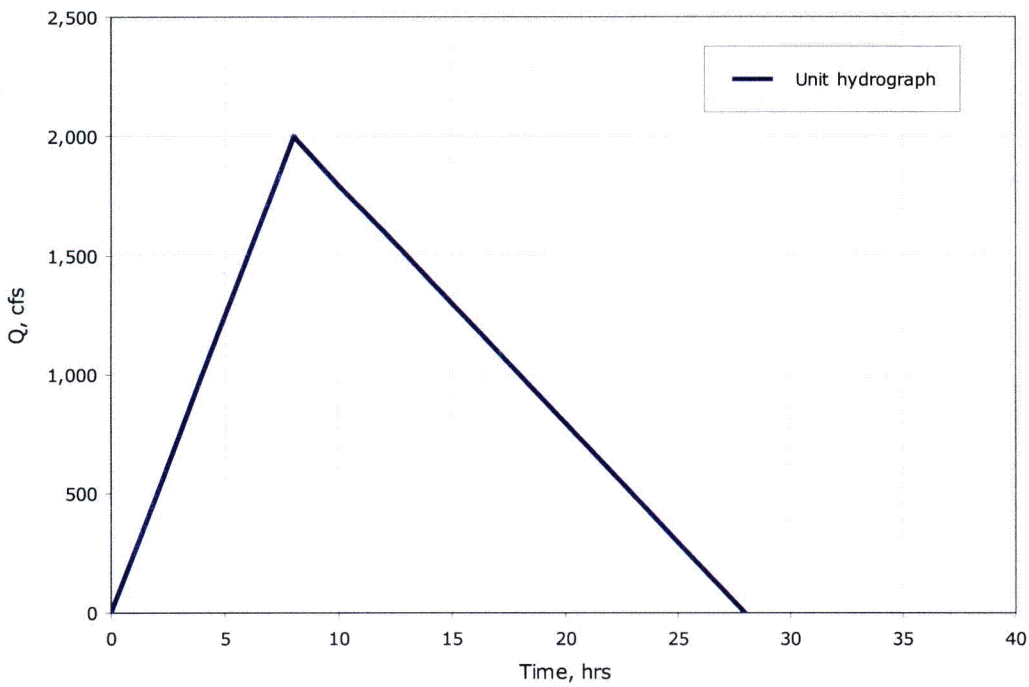


Figure 5. Triangular Unit Hydrograph

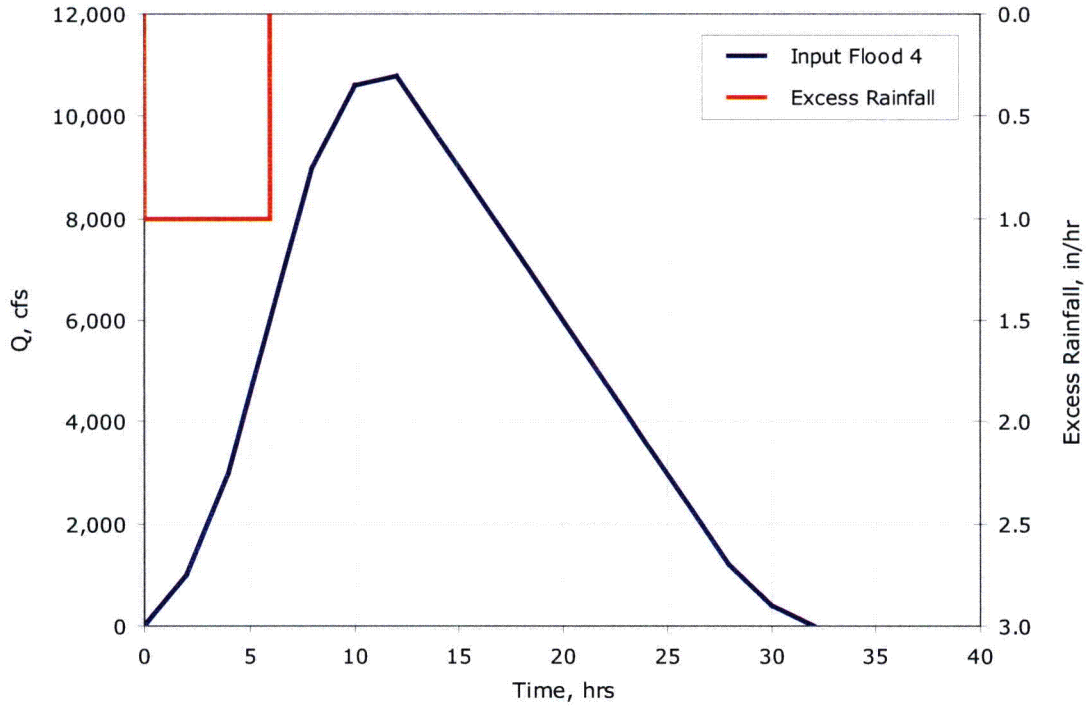


Figure 6. Flood Hydrograph and Hyetograph for Test Problem 4

2.1.3 Tests of Specific Options Available in UNITGRPH

- **Test Problems 2a and 2b:** French Broad River, Newport to Asheville

  These test problems are identical to Test Problem 2 with the exception that Test Problems 2a and 2b use different calculated unit hydrograph ordinates, defined by user provided "LIST" values, than Test Problem 2. For Test Problem 2a, all unit hydrograph ordinates are directly computed, while the "LIST" values for Test Problem 2b are 3, 6, and 8.

  These test problems are intended to show the importance of picking the ordinates of the unit hydrograph that will be directly computed and those between which where linear interpolation will be used.

- **Test Problems 4a, 4b, and 4c:** Triangular Unit Hydrograph

  Test problems 4a and 4b use the same flood hydrograph as Test Problem 4 but they differ from Problem 4 in the time distribution of the excess rainfall shown in Figure 7. Problems 4a and 4b use different number of ordinates, defined by user provided "LIST" values. For Test Problem 4a, all unit hydrograph ordinates are directly computed, while the "LIST" values for Test Problem 4b are 4 and 13. These test problems are intended to show the importance of the choice of "LIST" values used to define the unit hydrograph.

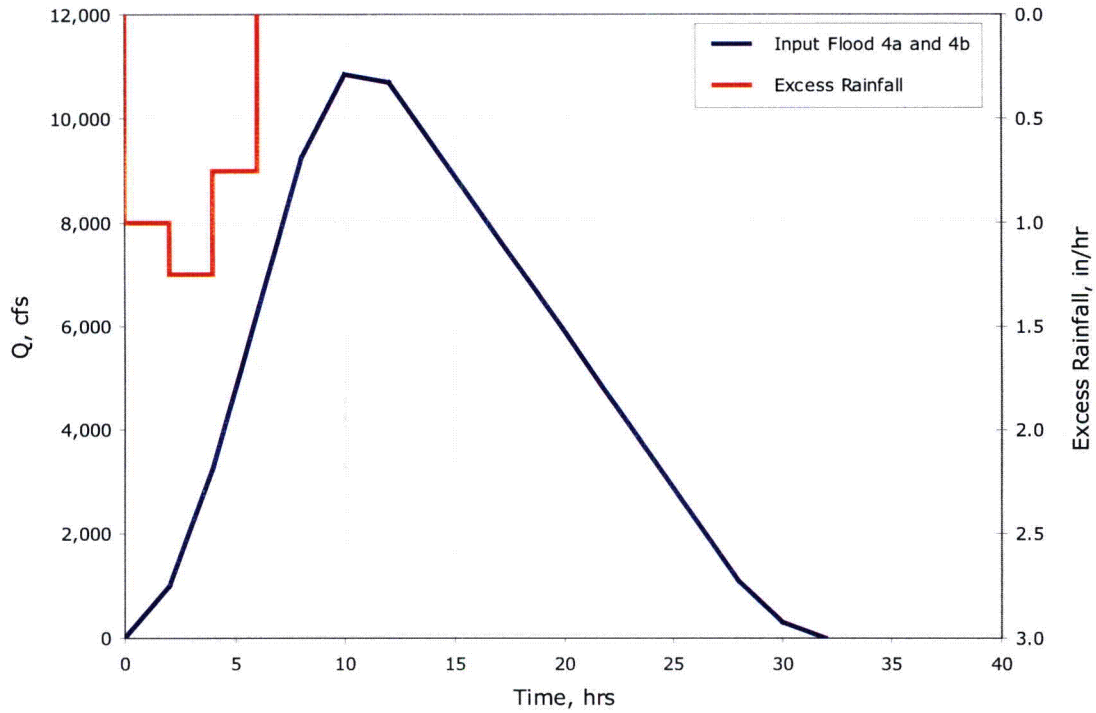


Figure 7. Flood Hydrograph and Hyetograph for Test Problems 4a and 4b

Problem 4c is designed to test how UNITGRPH deals with inconsistent data and show the importance of having agreement between the excess rainfall and outflow volumes. Figure 8 shows the hyetograph of the excess rainfall and the flood hydrograph defining problem 4c. The inconsistency built in these data is that the volume of the excess rainfall is 17.35 thousand acre-ft, while the volume of the flood hydrograph is 13.88 thousand acre-ft. All unit hydrograph ordinates are directly computed for Test Problem 4c.

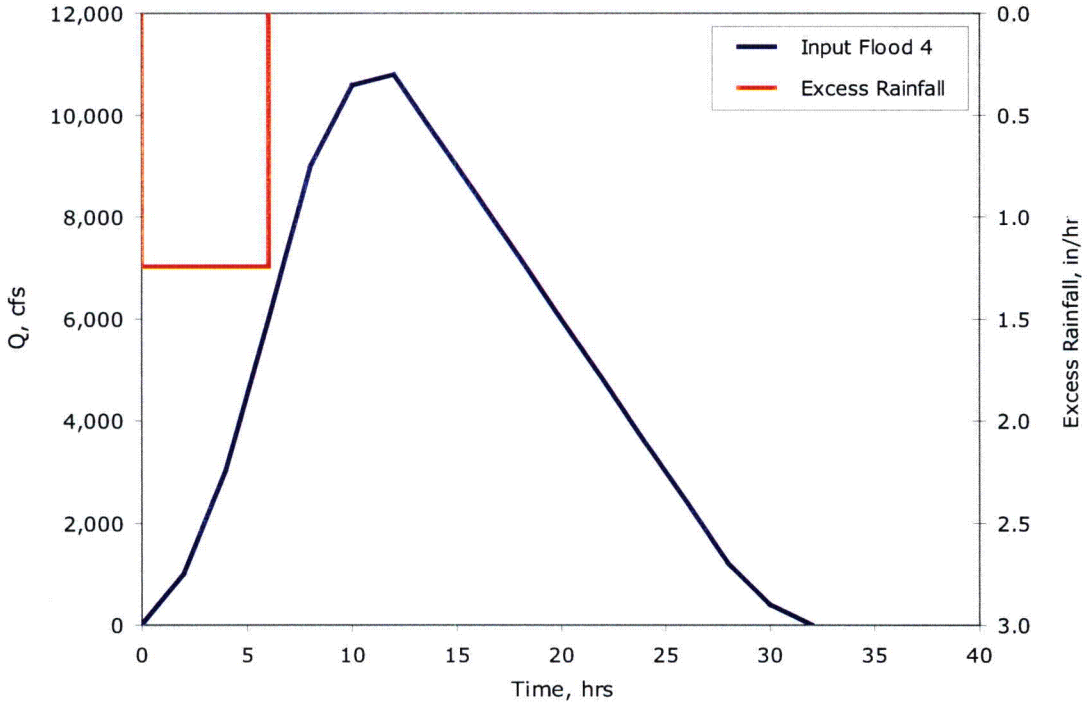


Figure 8. Flood Hydrograph and Hyetograph for Test Problem 4c

- **Test Problems 5, and 5a:** Hiwassee River at Charleston Local

  This test problem uses multiple storms to calculate the unitgraph. These test problems are intended to explore whether or not the runoff values generated by UNITGRPH are realistic as well as to show the importance of the "LIST" variables. The drainage area for the watershed is 685 square miles. The user-defined "LIST" values for Test Problem 5 are 1, 5, 9, and 17. The user-defined "LIST" values for Test Problem 5a are 1, 5, 10, and 17.

  Figure 9 shows the flood hydrograph and excess rainfall for the first flood of Test Problem 5, Figure 10 shows the flood hydrograph and excess rainfall for the second flood and Figure 11 shows the same data for the third flood of Test Problem 5. Rainfall and flood hydrograph data, as well as the watershed area for this problem were taken from References 5 and 7.

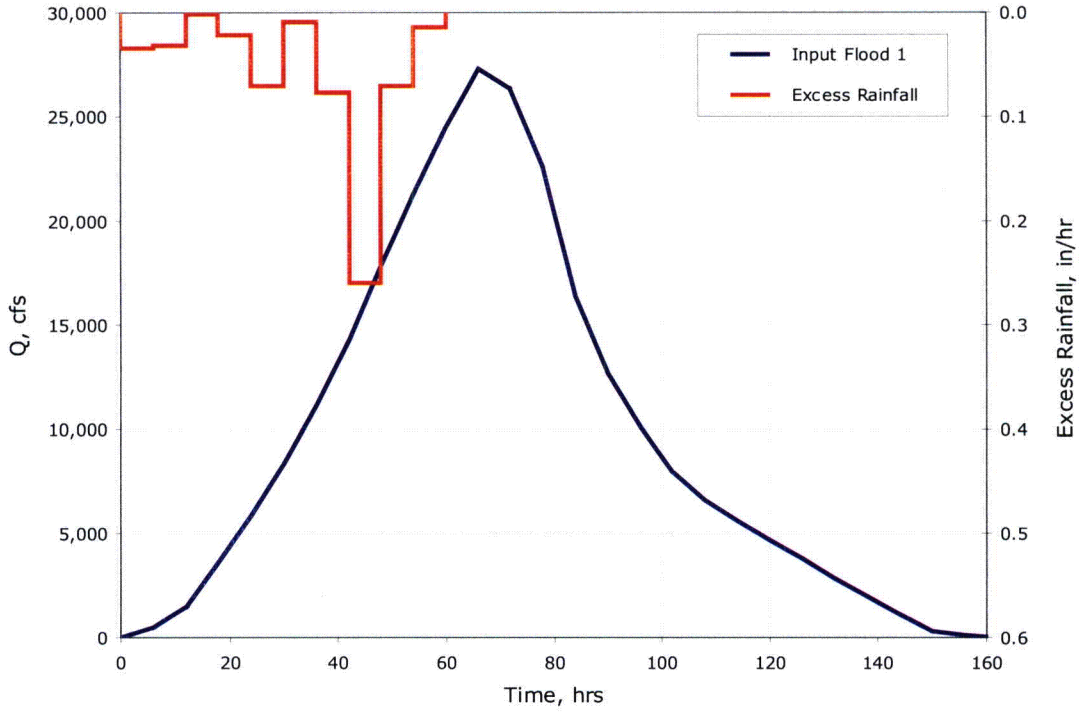


Figure 9. Flood Hydrograph and Hyetograph for Flood 1 of Test Problem 5

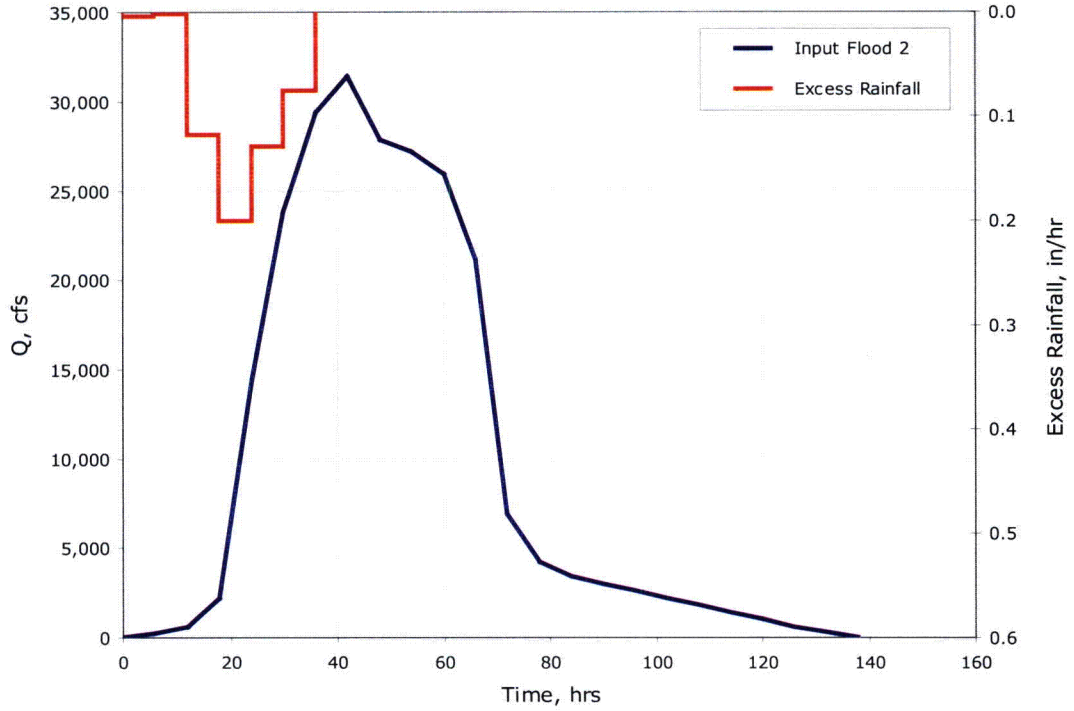


Figure 10. Flood Hydrograph and Hyetograph for Flood 2 of Test Problem 5

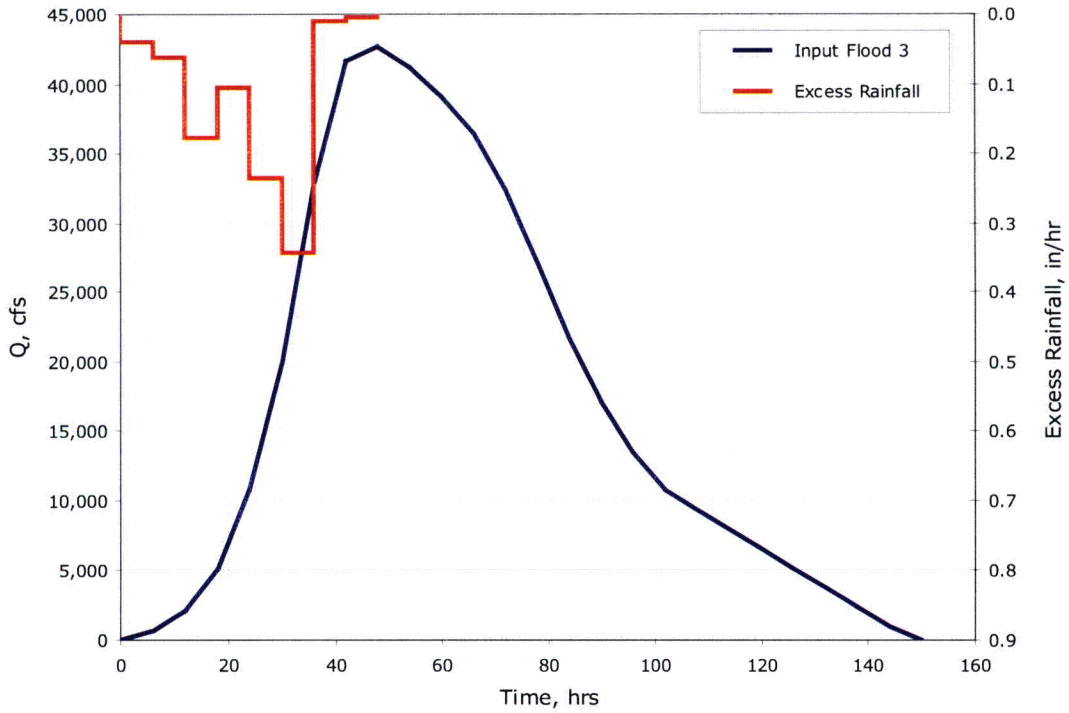


Figure 11. Flood Hydrograph and Hyetograph for Flood 3 of Test Problem 5

2.1.4 Solution Method Used in the Independent Calculations

The independent calculations used the same general method for calculating the unitgraph given in Reference 1, as described below.

The UNITGRPH code has been used to develop unit hydrographs for the sub-basins of the Tennessee River basin. The highest historical floods for which suitable data are available were used for this purpose. The historic flood information was obtained from recording stream gages, tributary dam headwater elevation, discharge and storage relationships which permitted calculation of the flood, and estimates on ungaged watersheds where historic flood information upstream and downstream of the watershed under consideration was available to make flow estimates.

The UNITGRPH code implements the method for unit hydrograph development described in Reference 3, which uses matrix algebra and a least squares approach to iteratively solve for the unit hydrograph and precipitation excess values that provide the best fit to the observed flood or a series of floods.

The method described in Reference 3 is based on the following equation which expresses how a series of runoff data can be combined with the unit hydrograph to produce the flood hydrograph:

$$\begin{bmatrix} r_1 & & & & \\ r_2 & r_1 & & & \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ r_i & r_{i-1} & \dots & r_1 & \\ & r_i & r_{i-1} & \dots & r_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ & & & & r_i \end{bmatrix} \cdot \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ \vdots \\ u_j \end{bmatrix} = \begin{bmatrix} q_1 \\ q_2 \\ \vdots \\ q_i \\ q_{i+1} \\ \vdots \\ q_n \end{bmatrix} \tag{1}$$

where

$[r_1 \;\; r_2 \;\; \dots \;\; r_{i-1} \;\; r_i]$ is the time series of runoff depths

$[u_1 \;\; u_2 \;\; \dots \;\; u_{j-1} \;\; u_j]$ is the unit hydrograph

$[q_1 \;\; q_2 \;\; \dots \;\; q_{n-1} \;\; q_n]$ is the flood hydrograph

i is the number of runoff depth (i.e., precipitation excess) ordinates

j is the number of ordinates of the unit hydrograph (excluding the first and last 0)

n is the number of flow ordinates of the flood hydrograph

j is related to i and n by the expression: $j = n-i+1$.

Equation (1) can be written also as:

$$(R) \cdot U = Q \tag{2}$$

where

(R) is the matrix of runoff values; (R) has j columns and n rows

U is the unit hydrograph vector; U has j values

Q is the flood hydrograph vector; Q has n values

Equation (2) is multiplied by the transpose of the matrix R, i.e.

$$\left[(R)^T \cdot (R)\right] \cdot U = (R)^T \cdot Q\,, \tag{3}$$

where

$(R)^T$ is the transpose of matrix (R).

The unit hydrograph is obtained by solving Equation (3). The solution of Equation (3) can be expressed as:

$$U = \left[(R)^T \cdot (R)\right]^{-1} \cdot (R)^T \cdot Q\,, \tag{4}$$

where the symbol $[\;]^{-1}$ denotes the inverse matrix.

As stated in Reference 3 the estimation of the unit hydrograph is subject to error due to the uncertainty in the runoff values. For this purpose Equation (2) can be modified by introducing an error term (E) and substituting (R) with $(R+E)$, leading to:

$$\left[(R+E)\right] \cdot U = (R) \cdot U + (E) \cdot U = Q \tag{5}$$

Equation (5) can be rewritten as:

$$\hat{Q} + (E) \cdot U = Q \tag{6}$$

where $\hat{Q} = (R) \cdot U$.

Equation (6) can be rewritten as:

$$\hat{Q} + (U) \cdot E = Q, \tag{7}$$

where (U) is an $n \times i$ matrix of unit hydrograph ordinates and E is the $i \times 1$ error vector, i.e.:

$$(U) = \begin{bmatrix} u_1 & & & & \\ u_2 & u_1 & & & \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ u_j & u_{j-1} & \dots & u_1 & \\ & u_j & u_{j-1} & \dots & u_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ & & & & u_j \end{bmatrix} \text{ and } E = \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ \vdots \\ e_i \end{bmatrix}.$$

The solution of Equation (7) for the error term can be expressed as:

$$E = \left[(U)^T \cdot (U)\right]^{-1} \cdot (U)^T \cdot \left[Q - \hat{Q}\right]. \tag{8}$$

2.2 UNITGRPH Test Results

Input files to UNITGRPH for each test problem are included in electronic form as Attachment 1. UNITGRPH output files for each test problem are included in electronic form as Attachment 2. The UNITGRPH source code and the executable that was used for these tests are included in the electronic Attachment 3. Solutions to the test problems using UNITGRPH were compared to the independent calculations performed with the same theoretical basis outlined in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 1) and using Microsoft Excel 2003 SP3. These Excel files used for independent calculation are included as Attachment 4. The results of these comparisons are presented below.

Table 1 gives the names of the Excel files used for the validation of UNITGRPH. All these files are included in the Electronic Attachment 4.

Table 1. List of Excel Files Used for the Validation of UNITGRPH

Test Problem	Excel File Name in Electronic Attachment 4
Test Problem 1	Unitgraph_sample1.xls
Test Problem 2	Unitgraph_sample2.xls
Test Problem 3	Unitgraph_sample3.xls
Test Problem 4	Unitgraph_sample4.xls

2.2.1 Tests of the Implementation of the Newton and Vinyard Method

2.2.1.1 Test Problem 1

A comparison of the unit hydrographs derived using the UNITGRPH code and the unit hydrographs derived through independent calculations for Test Problem 1 is presented in Table 2. The comparison of the unit hydrographs given in Table 2 is illustrated in Figure 12.

Table 2. Comparison of UNITGRPH and Independent Calculation Results for Test Problem 1

Time (hr)	UNITGRPH (cfs)	Independent Calculations (cfs)
6	18835	18835
12	8203	8203
18	2819	2819
24	2568	2568
30	2317	2317

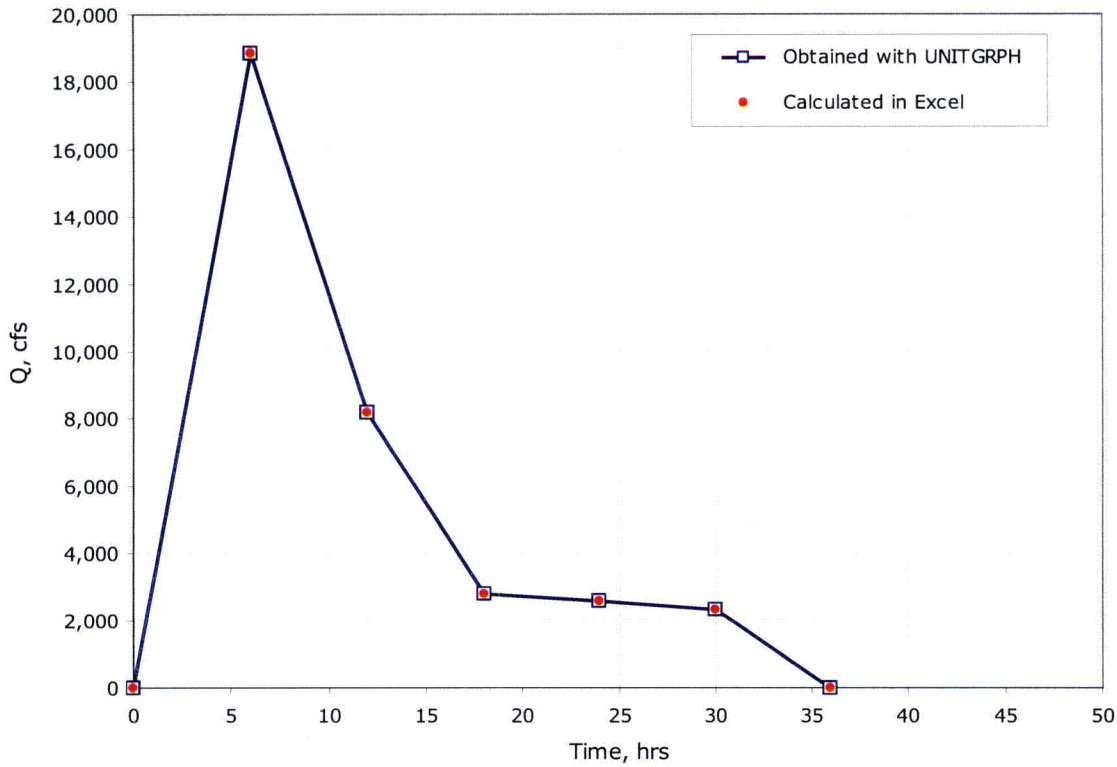


Figure 12. Comparison of Unit Hydrograph for Test Problem 1 Obtained with UNITGRPH and from Independent Calculations in Excel

2.2.1.2 Test Problem 2

Table 3 presents the results of UNITGRPH and those from the independent calculations in Excel for Test Problem 2. Figure 13 illustrates the comparison of the unit hydrographs given in Table 3.

Table 3. Comparison of UNITGRPH and Independent Calculation Results for Test Problem 2

Time (hr)	UNITGRPH (cfs)	Independent Calculations (cfs)
6	15374	15374
12	43114	43114
18	18839	18839
24	11712	11712
30	4585	4585
36	3057	3057
42	1528	1528
48	0	0

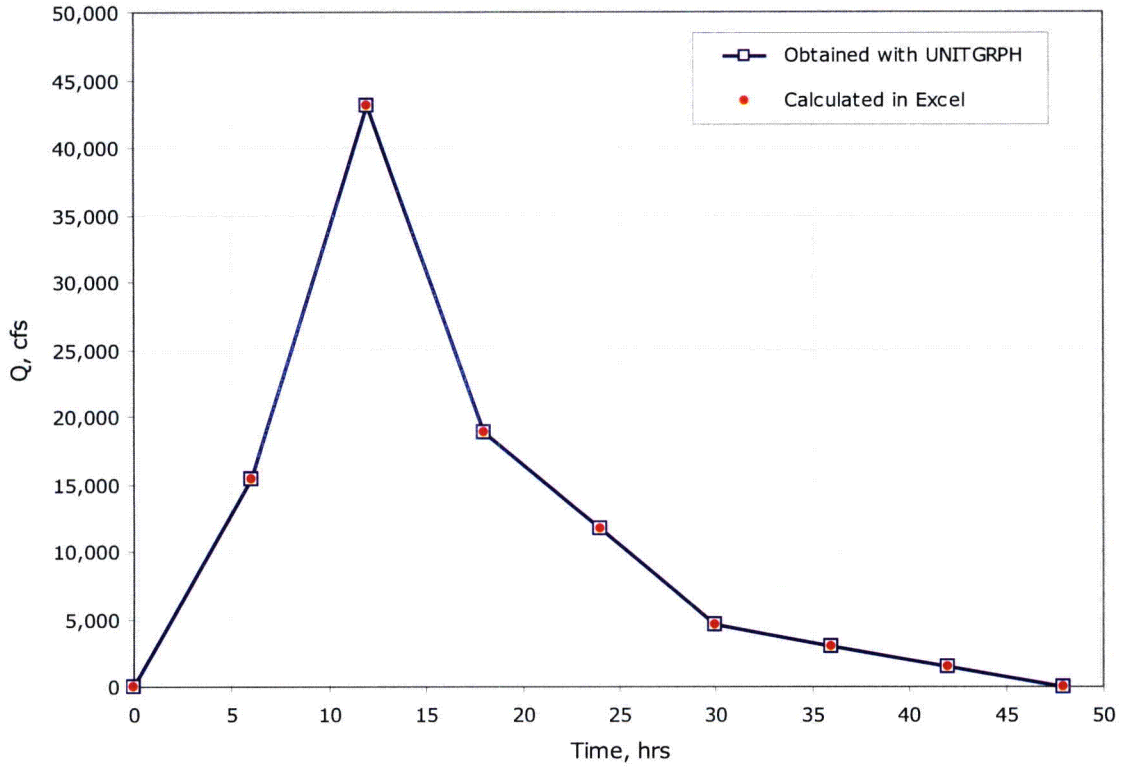


Figure 13. Comparison of Unit Hydrograph for Test Problem 2 Obtained with UNITGRPH and from Independent Calculations in Excel

2.2.1.3 Test Problem 3

Table 4 presents the results of UNITGRPH and those from the independent calculations in Excel for Test Problem 3. Figure 14 illustrates the comparison of the unit hydrographs given in Table 4.

Table 4. Comparison of UNITGRPH and Independent Calculation Results for Test Problem 3

Time (hr)	UNITGRPH (cfs)	Independent Calculations (cfs)
4	4828	4828
8	1413	1413
12	1008	1008
16	603	603
20	496	496
24	390	390
28	331	331
32	272	272
36	213	213
40	197	197
44	181	181
48	165	165
52	149	149
56	133	133
60	117	117
64	101	101
68	89	89
72	77	77
76	66	66
80	54	54
84	42	42
88	30	30

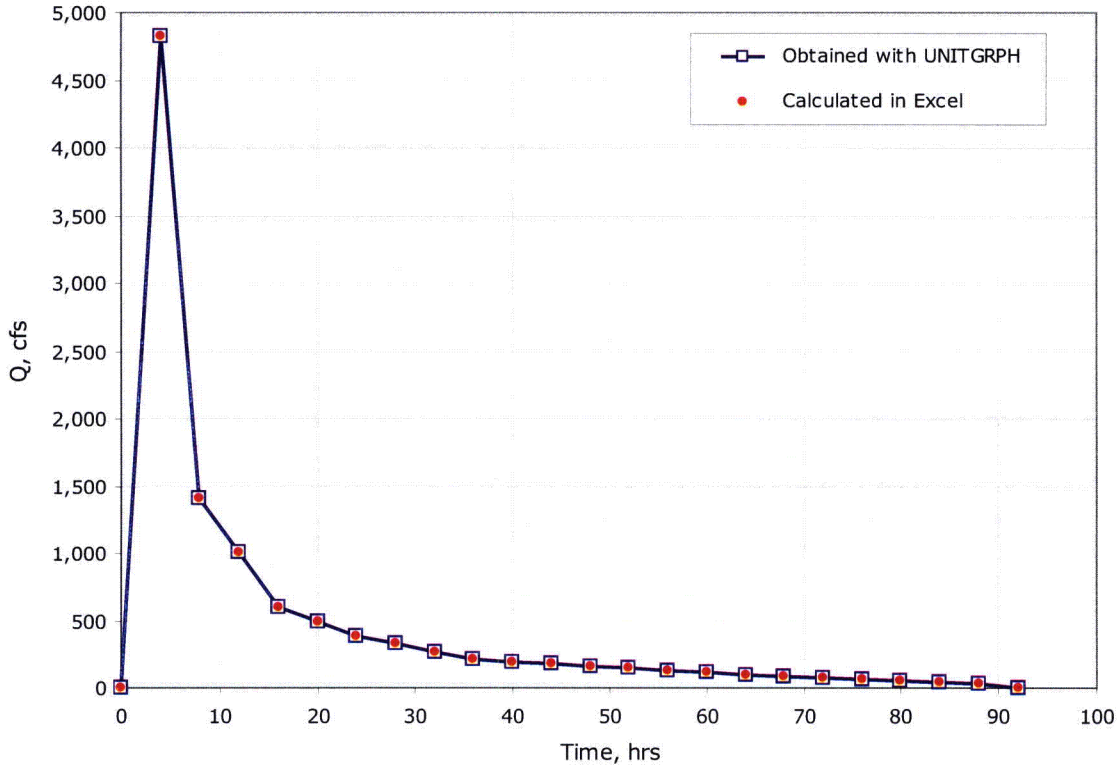


Figure 14. Comparison of Unit Hydrograph for Test Problem 3 Obtained with UNITGRPH and from Independent Calculations in Excel

2.2.1.4 Test Problem 4

Table 5 presents the results of UNITGRPH and those from the independent calculations in Excel for Test Problem 4. Figure 15 illustrates the comparison of the unit hydrographs given in Table 5.

Table 5. Comparison of UNITGRPH and Independent Calculation Results for Test Problem 4

Time (hr)	UNITGRPH (cfs)	Independent Calculations (cfs)
2	500	500
4	1000	1000
6	1500	1500
8	2000	2000
10	1800	1800
12	1600	1600
14	1400	1400
16	1200	1200
18	1000	1000
20	800	800
22	600	600
24	400	400
26	200	200

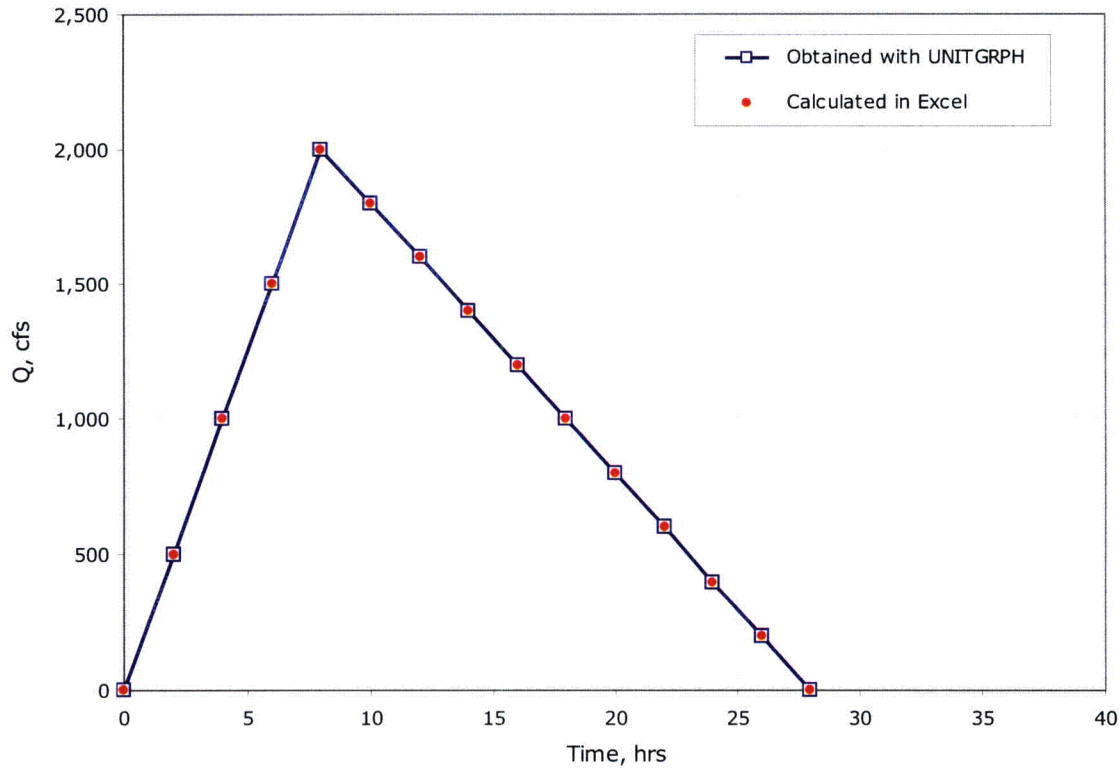


Figure 15. Comparison of Unit Hydrograph for Test Problem 4 Obtained with UNITGRPH and from Independent Calculations in Excel

2.2.1.5 Summary of Implementation Test Problems

For all four Test Problems there are no differences between the unit hydrographs derived from UNITGRPH and those obtained through independent calculation. The results of this analysis verify that the UNITGRPH code properly implements the method proposed by Newton and Vinyard outlined in Reference 3.

2.2.2 Tests of Specific Options Available in UNITGRPH

Section 2.1.2 verifies that the UNITGRPH code correctly implements the method proposed by Newton and Vinyard. This section explores the impact of different options available in UNITGRPH on the produced unit hydrographs and provides suggestions for ensuring that the derived results are hydrologically correct.

2.2.2.1 Test Problems 2a and 2b

First, the UNITGRPH option for defining the ordinates that define the unit hydrograph is evaluated. As stated in Section 2.1.3 this option is intended to provide smoothing and is used in the recession portion of the unit hydrograph. This option is implemented with the aid of the user-defined array "LIST". The following three problems illustrate the importance of selecting appropriate "LIST" values. The "LIST" variables determine which ordinates of the unit hydrograph will be directly computed. When an ordinate is included in the "LIST," the temporal variation in between listed ordinates is assumed to be linear. In other words, the "LIST" variables determine the shape of the unit hydrograph by defining certain

segments of the unit hydrograph as straight lines. Three different combinations of "LIST" variables were explored for Test Problem 2. The "LIST" variables used are given in Table 6.

Table 6. "LIST" Variables Used in Test Problem 2

	"LIST" Values	Meaning of "LIST" Variables
Test Problem 2	3, 5, 8	Straight lines between ordinates 3 and 5 and then 5 and 8
Test Problem 2a	8	All unitgraph ordinates are directly computed
Test Problem 2b	3, 6, 8	Straight lines between ordinates 3 and 6 and then 6 and 8

The three UNITGRPH runs described above produce different unitgraphs, as shown in Figure 16. The ordinates of these unit hydrographs are given in Table 7.

Table 7. Unit Hydrographs Generated by Test Problem 2

Test Problem 2 (cfs)	Test Problem 2a (cfs)	Test Problem 2b (cfs)
15374	17008	16559
43114	50971	45220
18839	21184	15455
11712	0	10907
4585	2645	6359
3057	4006	1810
1528	1987	1237
0	409	663

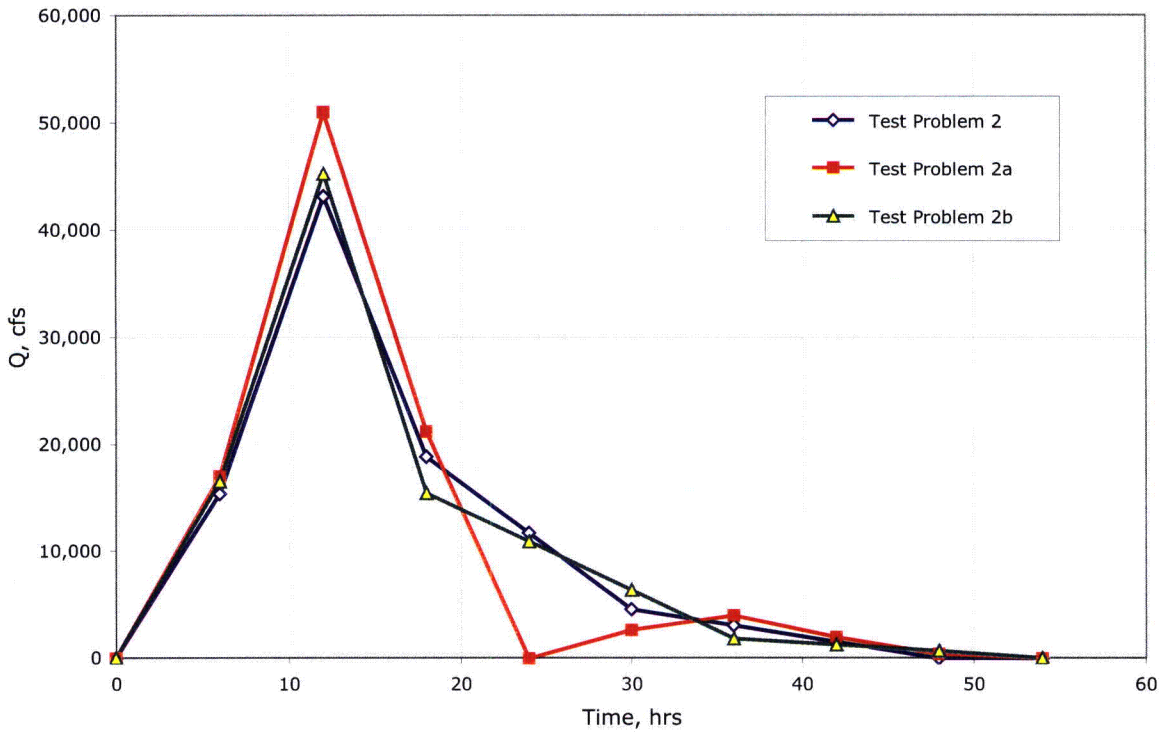


Figure 16. Unit Hydrographs for Test Problem 2

The outflow hydrographs generated by UNITGRPH for each Test Problem and the flood hydrograph input to UNITGRPH are shown in Figure 17 and Figure 18.

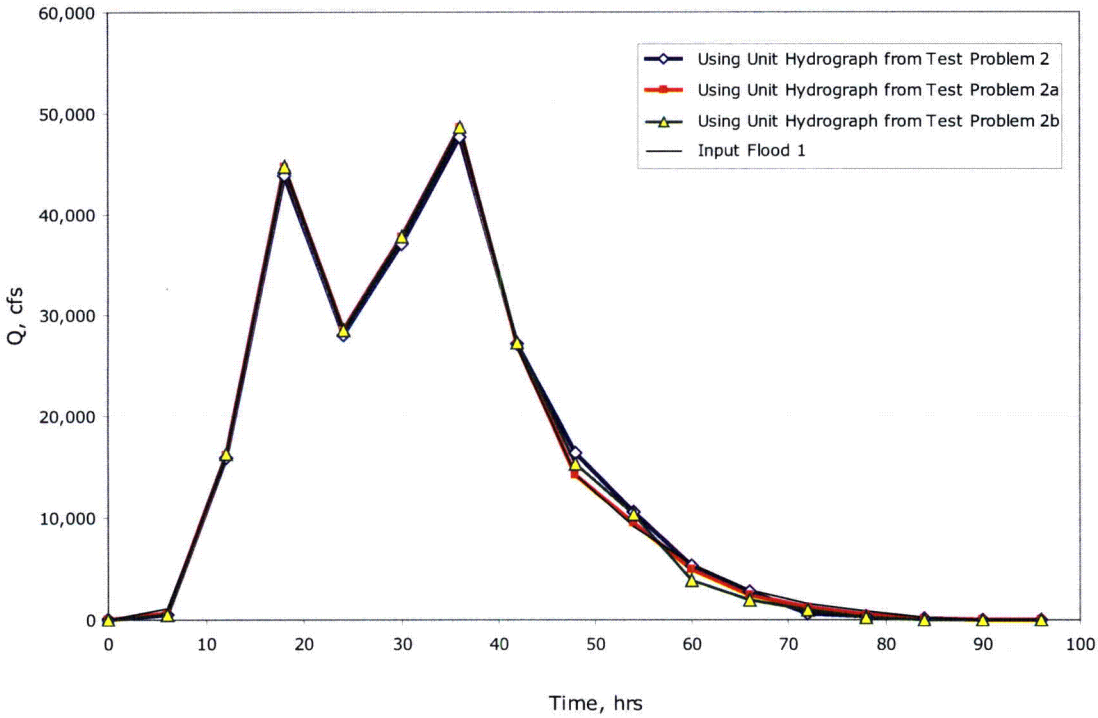


Figure 17. Outflow Hydrographs for First Event of Test Problem 2

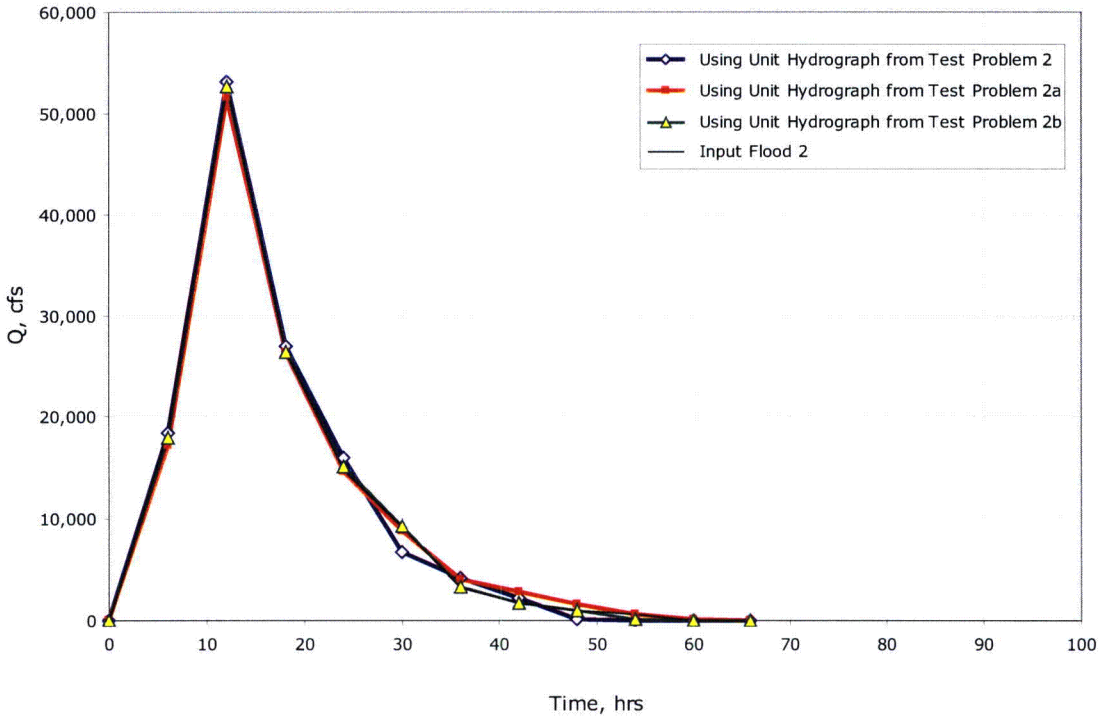


Figure 18. Outflow Hydrographs for Second Event of Test Problem 2

As can be seen in Figure 17 and Figure 18, the best match to both of the input flood hydrographs is obtained from Test Problem 2a. However, as seen in Figure 16, the unit hydrograph obtained from Test Problem 2a is not hydrologically logical, as its recession branch does not have a monotonic decline, instead going to zero and then rising again. This test problem suggests that care should be taken to select proper "LIST" values to produce a unit hydrograph that is hydrologically logical while still producing a good match to the flood hydrographs. With this in mind, both Test Problems 2 and 2b produce hydrologically logical unit hydrographs. As can be seen in Figure 17 and Figure 18, using the unit hydrographs developed in Test Problem 2 and Test Problem 2b produces an equally good match with Flood 1; however, the unit hydrograph from Test Problem 2b matches better Flood 2 than the unit hydrograph from Test Problem 2.

2.2.2.2 Test Problems 4a, 4b and 4c

Variations on Test Problem 4 were also used to explore the importance of the "LIST" variables as well as the importance of agreement between the rainfall excess and outflow volumes. Test problems 4a and 4b show the importance of the choice of "LIST" values for the definition of the unit hydrograph. The variables used Test Problems 4a, 4b, and 4c are given in Table 8.

Table 8. "LIST" Variables Used in Test Problem 4

	Input Rainfall Excess (in)	"List" Variables	Meaning of "LIST" Variables
Test Problem 4	2.0, 2.0, 2.0	13	All unitgraph ordinates are directly computed
Test Problem 4a	2.0, 2.5, 1.5	13	All unitgraph ordinates are directly computed
Test Problem 4b	2.0, 2.5, 1.5	4, 13	Straight line between ordinates 4 and 13
Test Problem 4c	2.5, 2.5, 2.5	13	All unitgraph ordinates are directly computed

The results of the UNITGRPH runs described above are given in Table 9.

Table 9. Unit Hydrographs Generated by Test Problem 4

Test Problem 4 (cfs)	Test Problem 4a (cfs)	Test Problem 4b (cfs)	Test Problem 4c (cfs)
500	516	467	500
1000	848	945	1000
1500	1565	1459	1500
2000	1894	2009	2000
1800	1745	1810	1800
1600	1806	1611	1600
1400	1213	1412	1400
1200	1355	1212	1200
1000	979	1013	1000
800	767	814	800
600	714	615	600
400	320	416	400
200	280	216	200

Figure 19 shows the unit hydrographs obtained for Problems 4a and 4b. As can be seen in Figure 19, the "LIST" values used in Test Problem 4a do not produce a hydrologically logical unit hydrograph, while the choice of "LIST" values in Test Problem 4b, which has exactly the same input rainfall excess distribution, returns a unit hydrograph similar to the expected unit hydrograph. It is also noted that Problem 4a uses the same "LIST" values as Problem 4, i.e. it computes directly all the ordinates of the unit hydrograph. The only difference between problems 4 and 4a is the time distribution of the excess rainfall. This test shows that the choice of the ordinates used to define the unit hydrograph ("LIST" values) that gives a hydrologically reasonable unit hydrograph is dependant on the accuracy of the time distribution of excess rainfall.

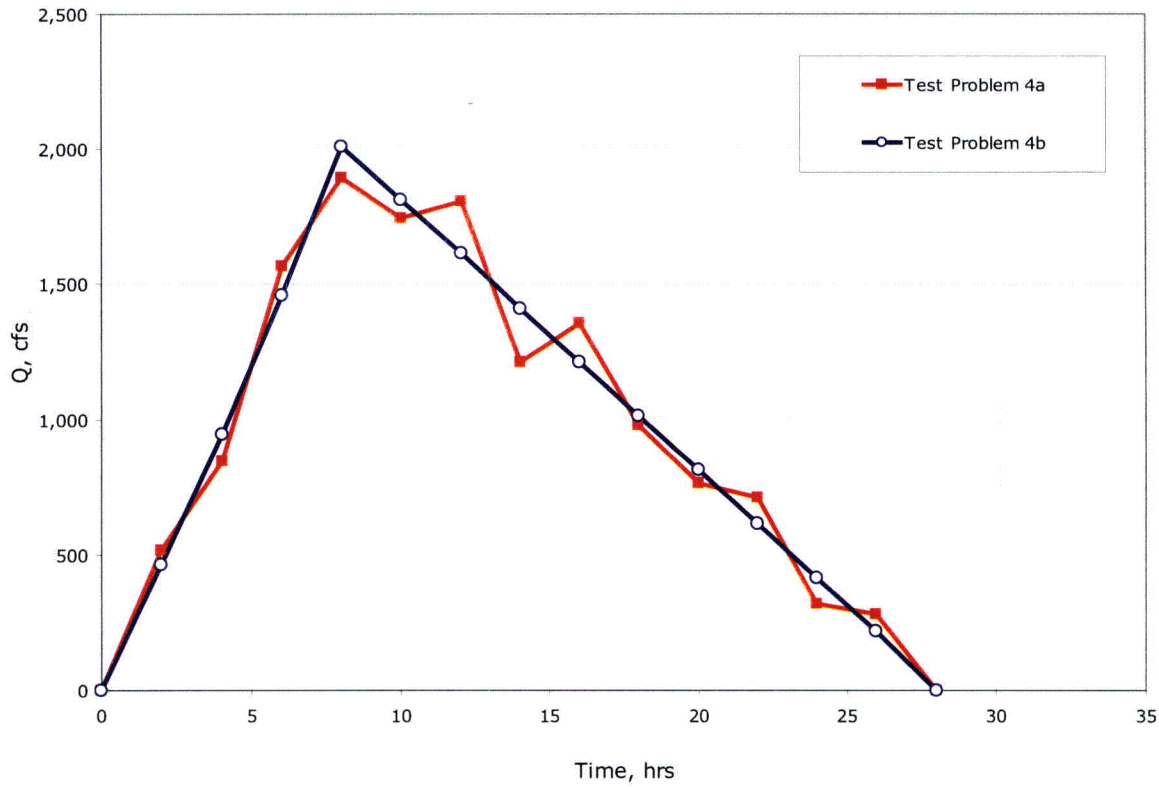


Figure 19. Unit Hydrographs for Test Problems 4a and 4b.

Problem 4c includes an apparent inconsistency in the data. As stated in Section 2.1.3 the volume of the excess rainfall in this problem is 17.35 thousand acre-ft, while the volume of the flood hydrograph is 13.88 thousand acre-ft. UNITGRPH apparently did not detect this inconsistency and produced the UNITGRPH listed in Table 9 using the volume of the flood hydrograph. This unit hydrograph is in perfect agreement with the postulated triangular unit hydrograph used to define this problem. However, when the code uses the derived unit hydrograph to calculate the flood hydrograph and compare it with the input flood hydrograph the discrepancy in the data becomes evident (see Figure 20).

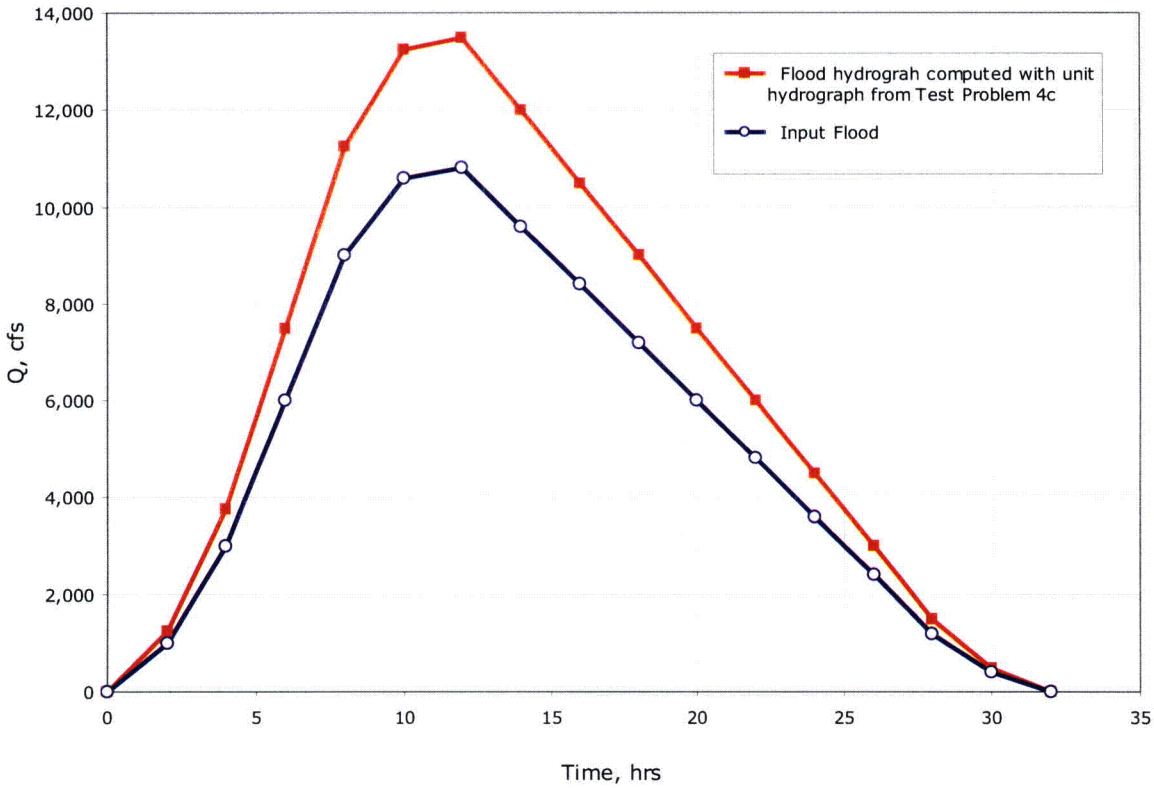


Figure 20. Flood Hydrographs for Test Problem 4

2.2.2.3 Test Problem 5

UNITGRPH uses as input the time distribution of the excess rainfall or runoff, which it uses as is, to estimate the unit hydrograph. This estimate is referred to as Iteration 1 in the estimation of the unit hydrograph.

UNITGRPH includes the option to improve the agreement between measured flows and the flood hydrograph produced by the unit hydrograph, by using an iterative process where the distribution of the excess rainfall in time is adjusted, preserving the total runoff volume. This adjustment is based on the Newton & Vinyard method described in Section 2.1.4. The underlying assumption of this method is that the hydrologic response of a basin is linear and that rainfall is spatially uniform and of constant intensity within each time step, consistent with unit hydrograph theory. The methodology therefore treats the runoff values, in addition to the unit hydrograph ordinates, as parameters to be estimated in the optimization process. This adjustment does not include any particular constraint regarding the relationship between excess rainfall, or runoff, and total rainfall during each period. In fact, the total rainfall is not part of the input data used by UNITGRPH. Consequently, the runoff values obtained through the iterative optimization process implanted in UNITGRPH can exceed the total rainfall during a particular time period.

Test Problem 5 shows the difference between the unit hydrographs obtained by adjusting the time distribution of the excess rainfall and explores the implications of this adjustment.

In addition it illustrates further the importance of the choice of the "LIST" values that define the parts of the unit hydrograph where its ordinates are not calculated directly by UNITGRPH, which was also discussed in Section 2.2.2.2.

Test Problem 5 uses three floods that occurred in March 1963, March 1965, and March 1973 to create a unit hydrograph for the Hiwassee River at Charleston local. For Test Problem 5 two different combinations of "LIST" variables were explored. The "LIST" variables used are given in Table 10.

Table 10. "LIST" Variables Used in Test Problem 5

	"List" Variables	Meaning of "LIST" Variables
Test Problem 5	1, 5, 9, 17	Straight lines between ordinates 1 and 5, 5 and 9, and 9 and 17
Test Problem 5a	1, 5, 10, 17	Straight lines between ordinates 1 and 5, 5 and 10, and 10 and 17

The UNITGRPH runs described above produce different unit graphs, as shown in Table 11.

Table 11. Unit Hydrographs Generated by Test Problem 5

Test Problem 5, Iteration 1 (cfs)	Test Problem 5, Iteration 5 (cfs)	Test Problem 5a, Iteration 1 (cfs)	Test Problem 5a, Iteration 5 (cfs)
4971	2597	5092	5354
6121	4946	6150	6496
7272	7294	7209	7638
8422	9643	8267	8779
9573	11991	9325	9921
8035	9632	7988	8328
6497	7273	6651	6735
4959	4914	5315	5142
3421	2555	3978	3548
3061	2343	2642	1955
2701	2132	2376	1816
2341	1921	2111	1676
1981	1710	1845	1537
1621	1498	1580	1397
1261	1287	1314	1258
901	1076	1049	1118
541	864	783	979

These unit hydrographs are plotted in Figure 21.

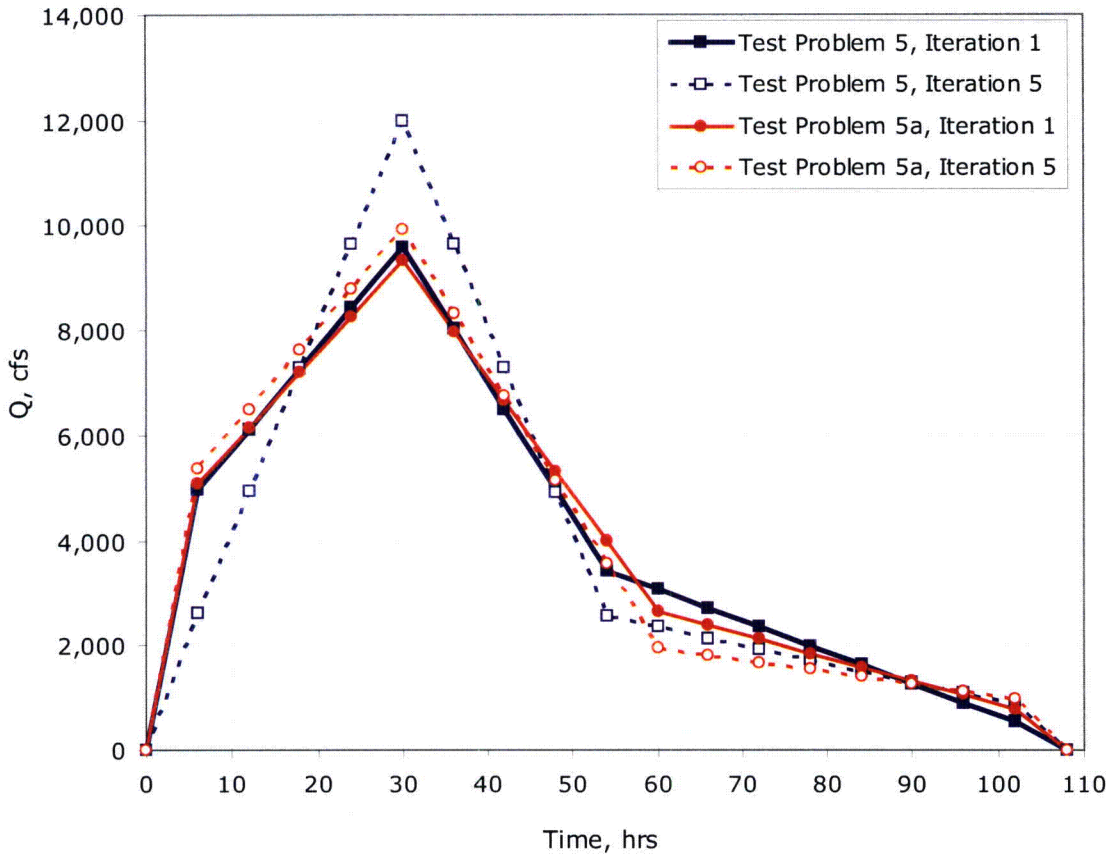


Figure 21. Unit Hydrographs for Test Problem 5

The outflow hydrographs generated by UNITGRPH for each Test Problem as well as the flood hydrograph input to UNITGRPH are shown in Figure 22, Figure 23, and Figure 24.

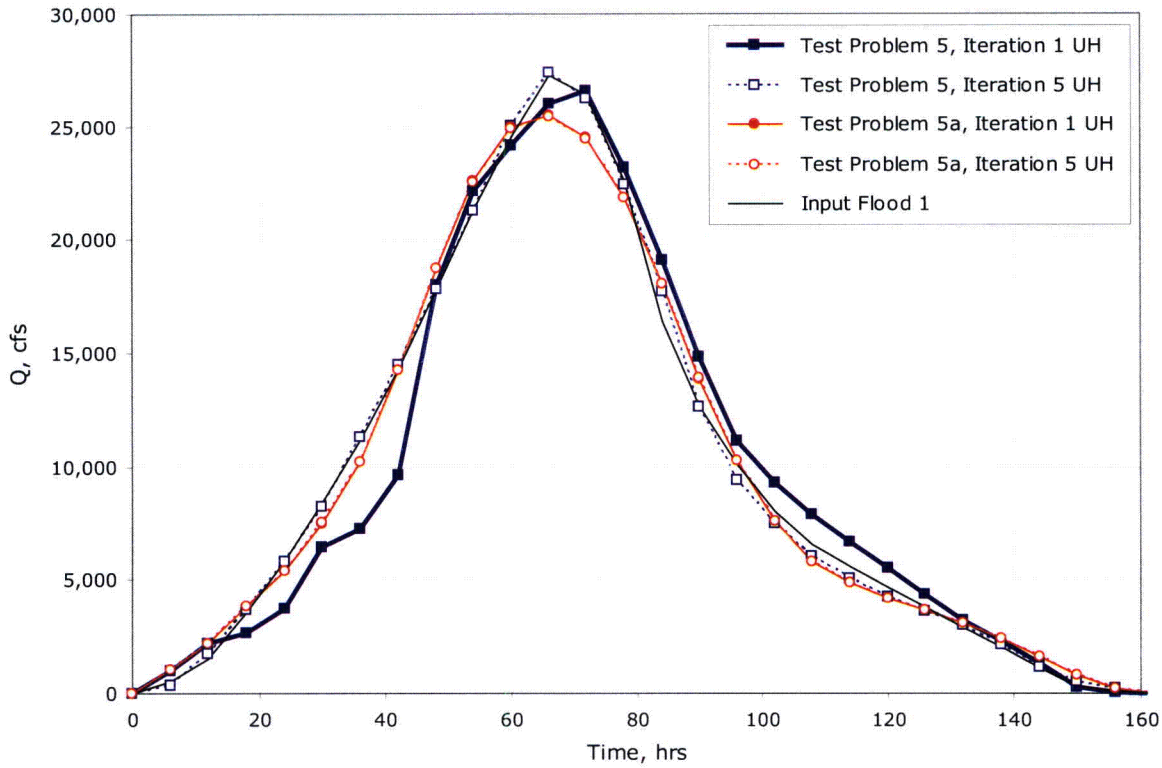


Figure 22. Outflow Hydrographs for First Event of Test Problem 5

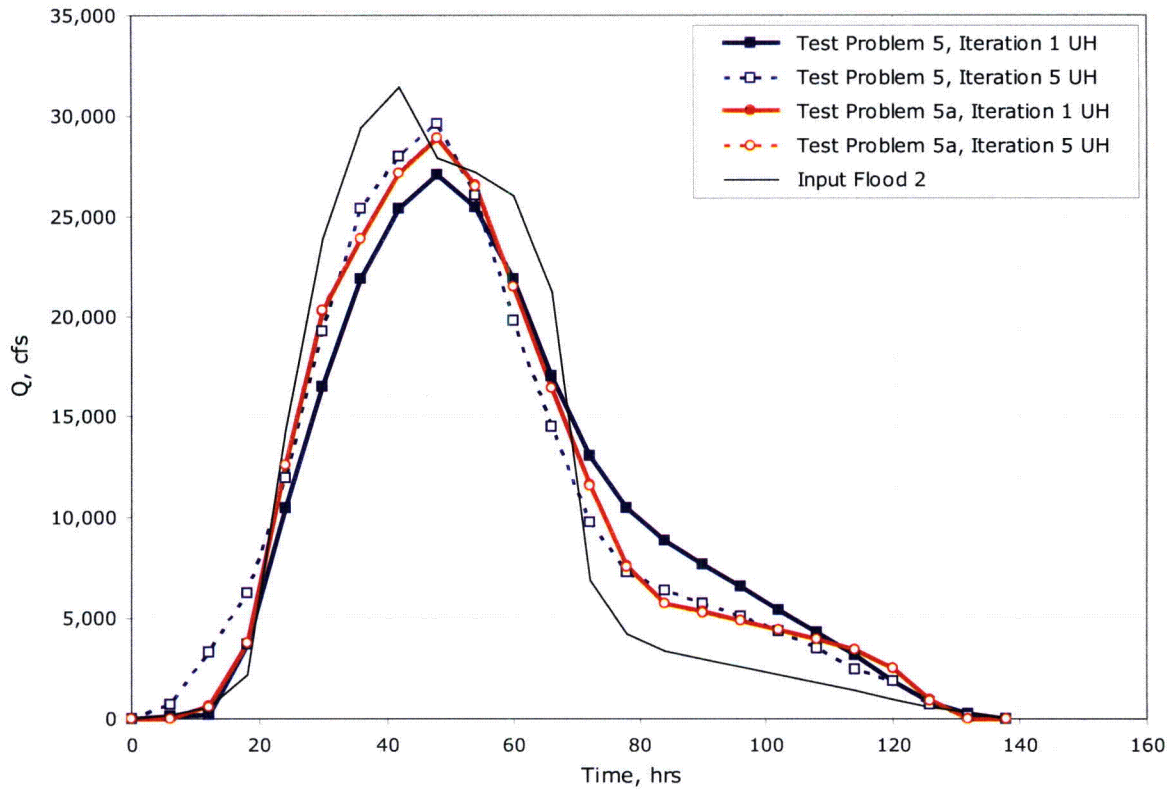


Figure 23. Outflow Hydrographs for Second Event of Test Problem 5

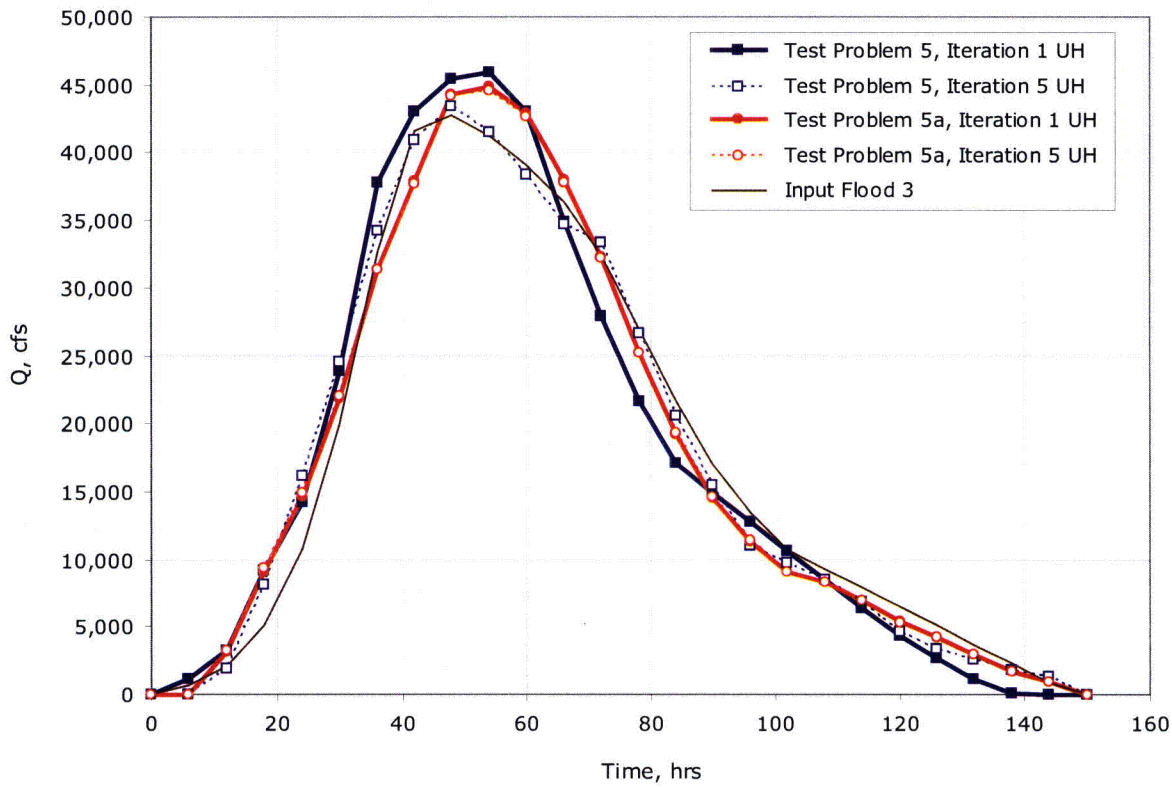


Figure 24. Outflow Hydrographs for Third Event of Test Problem 5

As can be seen in the outflow hydrographs generated by UNITGRPH in Figure 22 through Figure 24, Test Problem 5, Iteration 5 matches best the flood hydrograph peak for all three floods while, Test Problem 5, Iterations 1 and 5 provide better overall matching over the entire flood hydrograph for all three floods. However, runoff values calculated by UNITGRPH and used to compute the flood hydrographs for Test Problem 5, Iteration 5 are not physically possible; as explored below.

It is noted that UNITGRPH uses as input the time distribution of the excess rainfall or runoff (which it uses as is) to estimate the first iteration of the unit hydrograph. In subsequent iterations it adjusts the distribution of the excess rainfall to better match calculated flood hydrograph to the input flood hydrograph.

Each upper panel of Figure 25, Figure 26 and Figure 27 shows the rainfall, the excess rainfall, or runoff (estimated with FLDHYDRO and used as input to UNITGRPH), and the adjusted excess rainfall by UNITGRPH for each of the three storms of Test Problem 5. The lower panel of each of these figures shows cumulative values. In the upper panel of these figures each point represents the total rainfall or excess rainfall during a 6-hour period. As already stated, UNITGRPH uses only the excess rainfall (not the total rainfall) as input. The precipitation losses shown in these three figures were calculated outside UNITGRPH by subtracting the excess rainfall from the total precipitation. As can be seen in these figures sometimes the adjusted runoff by UNITGRPH exceeds the observed precipitation, sometimes greatly.

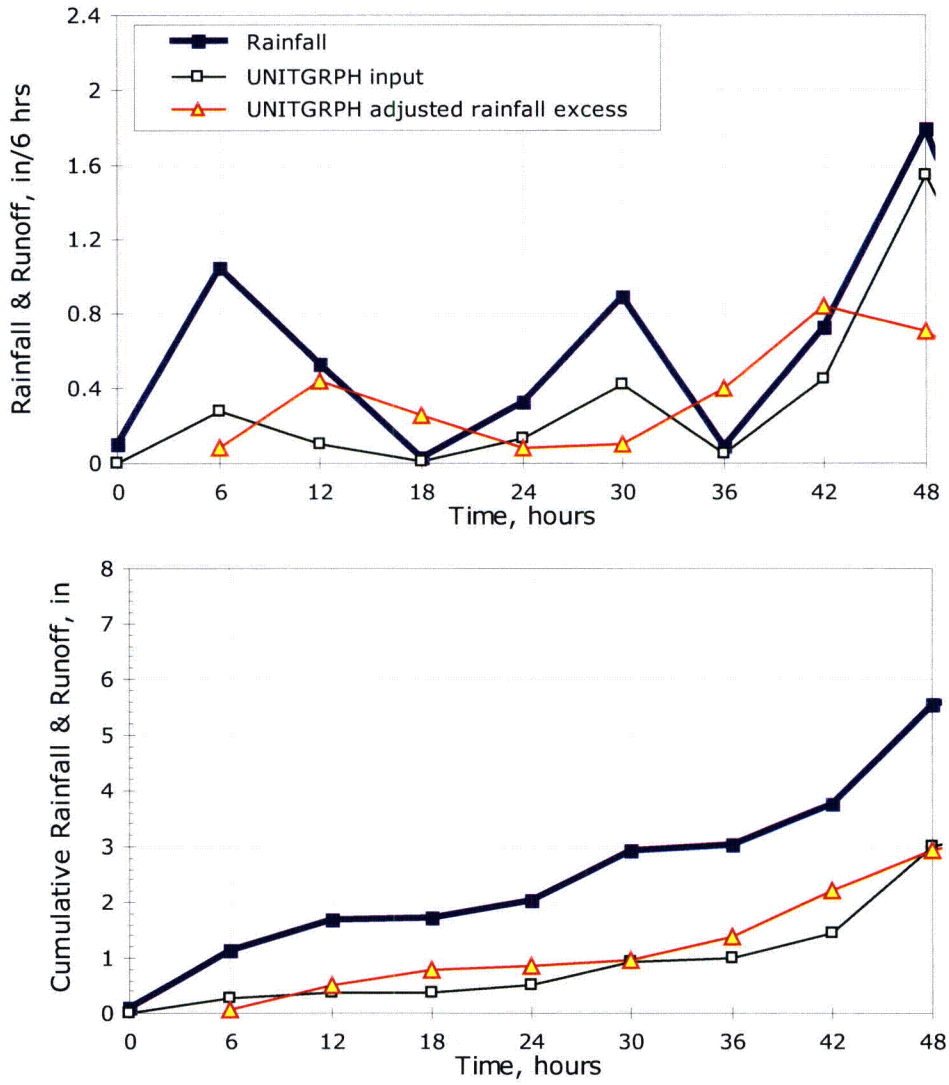


Figure 25. Rainfall, excess rainfall input obtained from FLDHYDRO, and adjusted excess rainfall distribution by UNITGRPH for the first event of Test Problem 5

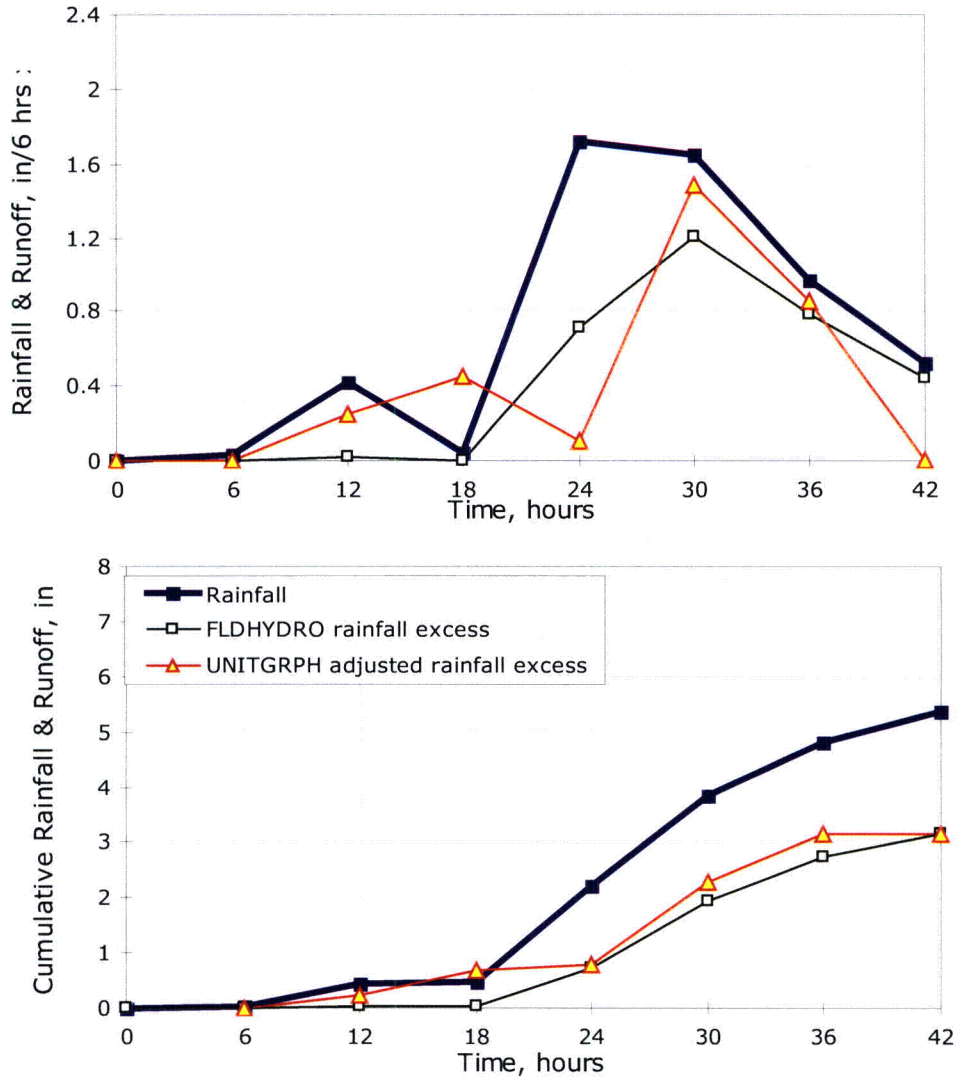


Figure 26. Rainfall, excess rainfall input obtained from FLDHYDRO, and adjusted excess rainfall distribution by UNITGRPH for the second event of Test Problem 5

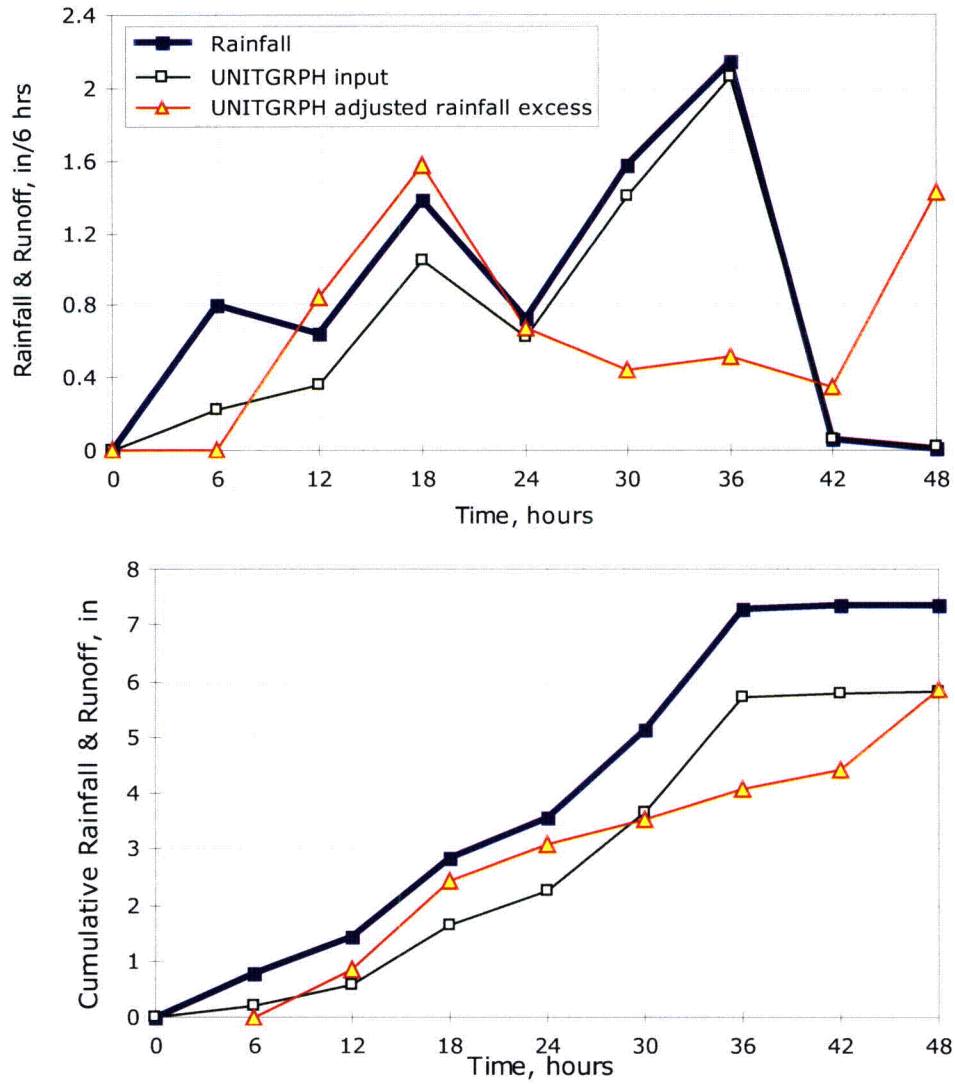


Figure 27. Rainfall, excess rainfall input obtained from FLDHYDRO, and adjusted excess rainfall distribution by UNITGRPH for third event of Test Problem 5

Figure 27 shows clearly that in this case UNITGRPH adjusted the excess rainfall upwards during the first half of the storm and downwards during the second half. As can be seen in the upper panel of Figure 27, at some 6-hour time periods the adjusted excess rainfall in UNITGRPH exceeds the total rainfall during the same time period. However, the cumulative excess rainfall shown in the lower panel of the same figure is always less than the total rainfall.

The observation that UNITGRPH adjusts the excess rainfall in a manner that during some time periods the excess rainfall is higher than the total rainfall during the same time period raises a fundamental question, namely whether such an adjustment is consistent with unit hydrograph theory.

Such an adjustment might be acceptable if the unit hydrograph did not account for the time between the incidence of rainfall and the time at which such rainfall becomes excess. In other words, if the excess rainfall during a particular time period was the result of rainfall at earlier times, this would explain why excess rainfall exceeded the direct rainfall during that time period. However, the unit hydrograph itself accounts for the distribution of travel times throughout the basin for excess rainfall. Therefore, the adjustment in the excess rainfall performed by UNITGRPH can be only justified if there is considerable uncertainty in the estimation of the excess rainfall. In this case the excess rainfall that contributes to streamflow during a time period should still be part of the total rainfall during the same period. In other words, the excess rainfall during a particular period cannot exceed the total rainfall for the same period. Other time-related effects (such as the time lag between the occurrence of rainfall and the time at which the volume of water contributed by this rainfall manifests itself at the downstream end of the basin), are accounted for in the unit hydrograph. For example, the high excess rainfall produced by UNITGRPH in the two last time steps of the case presented in Figure 27 (0.4 inches at time 42 and 1.4 inches at time 48 hours) when the total rainfall is practically zero seems inconsistent with unit hydrograph theory.

It is noted that the flood hydrographs produced by UNITGRPH based on the estimated unit hydrograph are based on the redistributed excess rainfall. If the same unit hydrograph were to be combined with the original excess rainfall time distribution shown in Figure 9, Figure 10 and Figure 11 for Floods 1, 2 and 3 respectively, the computed flood hydrographs would have been different.

Figure 28, Figure 29, and Figure 30 show the computed flood hydrographs for the three floods of Test Problem 5 obtained by combining the input runoff values, i.e. those computed with FLDHYDRO, with the output unit hydrographs.

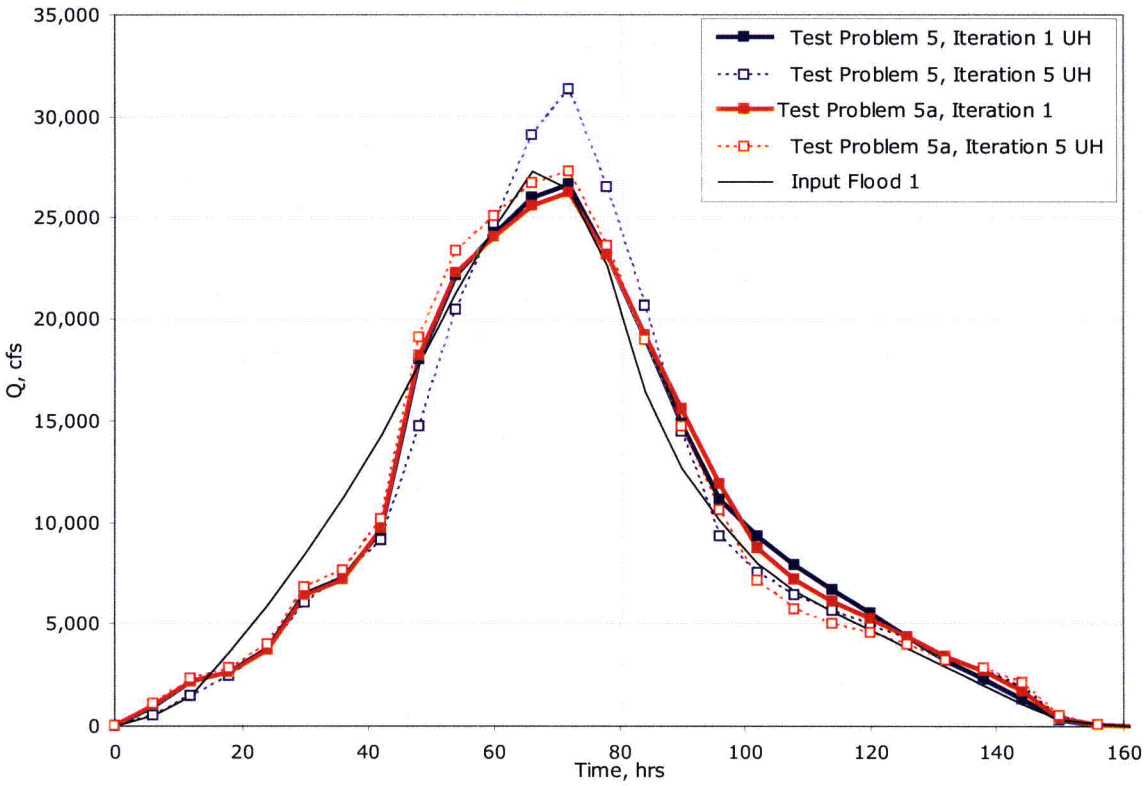


Figure 28. Outflow Hydrographs Using Input Runoff for First Event of Test Problem 5

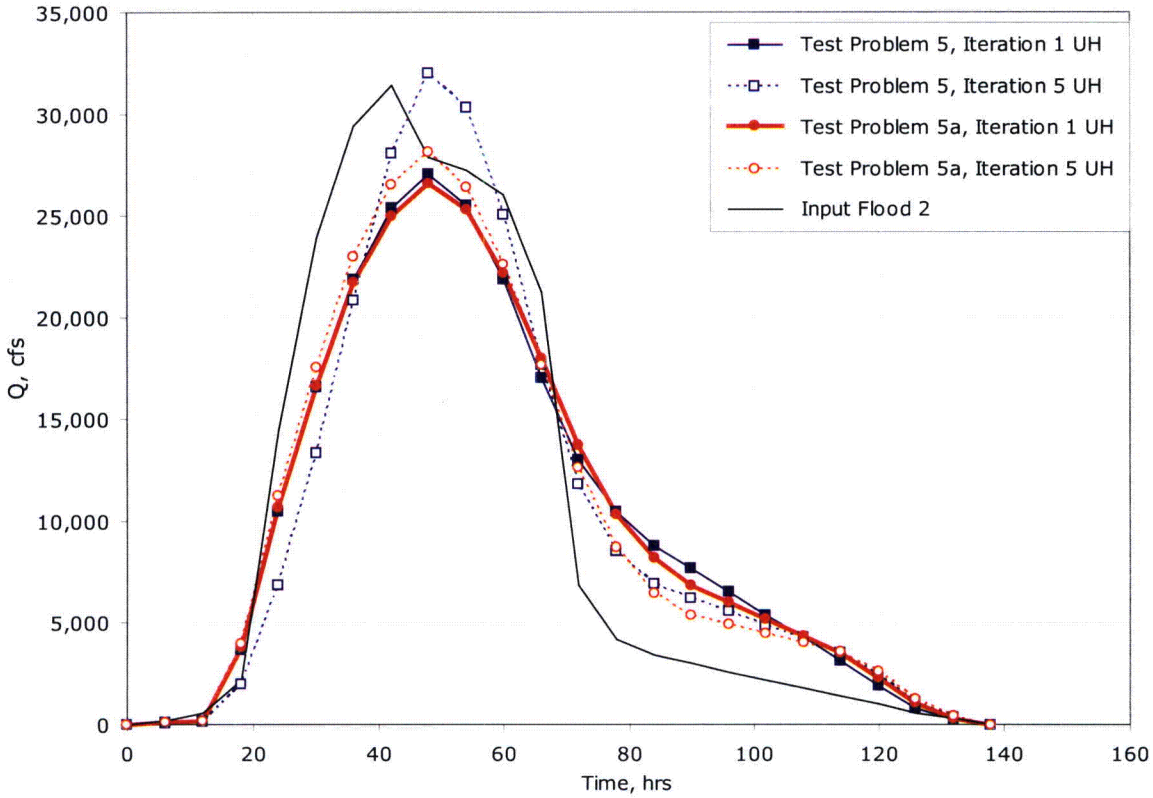


Figure 29. Outflow Hydrographs Using Input Runoff for Second Event of Test Problem 5

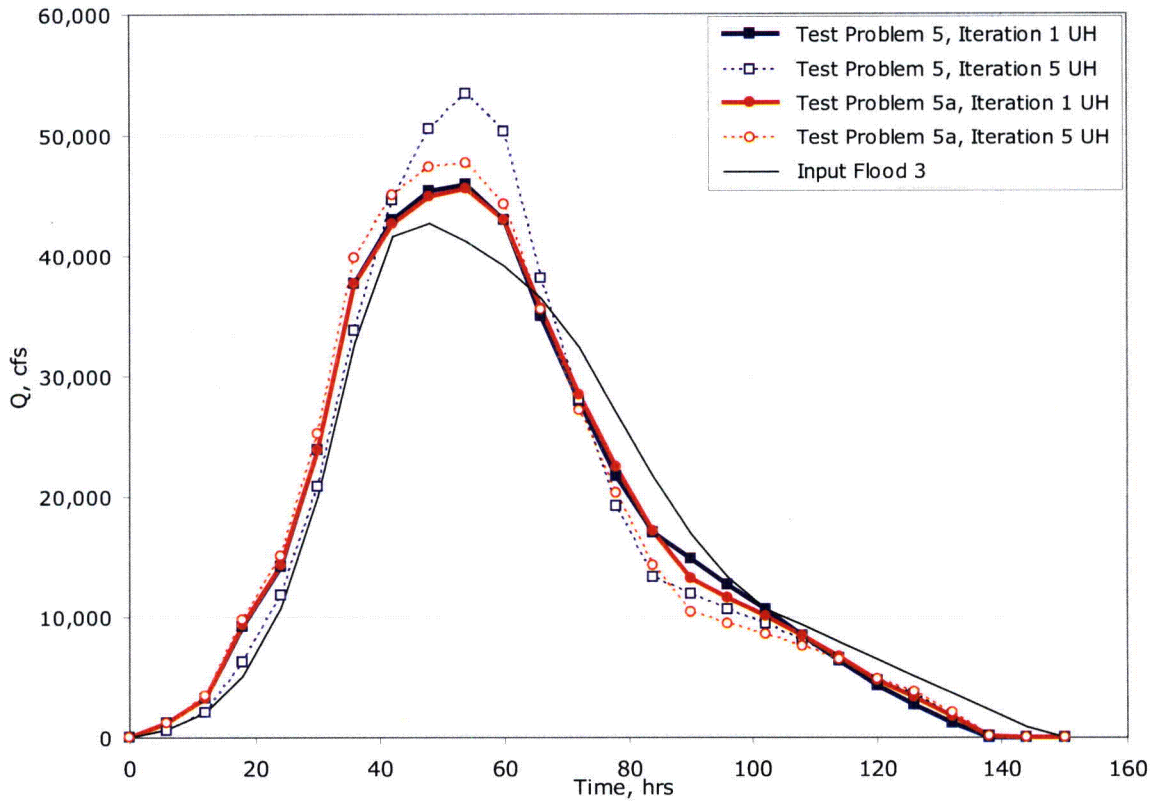


Figure 30. Outflow Hydrographs Using Input Runoff for Third Event of Test Problem 5

As can be seen in Figure 28, Figure 29, and Figure 30, when the flood hydrographs are re-calculated using the input runoff values, the unit hydrograph derived from Test Problem 5, Iteration 5 overestimates the peak for all three floods. The other three unit hydrographs perform similarly in recreating the input floods. The fact that the unit hydrograph from Test Problem 5a, Iteration 5 performs fairly well highlights the importance of the "LIST" values, as the only difference between Test Problem 5 and Test Problem 5a is changing one "LIST" variable from 9 to 10.

Considering these results, it is recommended that the user should carefully evaluate the UNITGRPH output before accepting it, taking also into account the accuracy of the discharge data. If the data are uncertain or are of poor quality, the runoff values should not be "corrected" to fit suspect flow values and only one iteration should be used. This applies to flood hydrographs obtained from extensive manipulation (e.g., reverse reservoir routing, hydrograph and base flow separation).

When using multiple iterations, check UNITGRPH adjusted runoff values to see if:

1. They exceed the precipitation values, or
2. They imply loss rates that exhibit large, inexplicable variations.

If there are substantial violations of either of these two checks, the precipitation data accuracy should be considered. For example, are there many gages in or near the basin? If not, the gridded NWS data may be less accurate than in a heavily gauged basin. Significant

violations of the two checks for well gauged basins may indicate problems with the flood hydrograph and/or unit hydrograph assumptions that cannot be addressed by manipulating rainfall excess values. If the data are considered reliable, then the iteration 1 unit hydrograph could be used to simulate other flood events as part of the unit hydrograph validation.

2.2.3 Response of UNITGRPH to Abnormal Input Data

UNITGRPH has no built-in safeguards to warn users when abnormal situations arise during operation of the program. Therefore, as long as values of the proper dimension are input for each expected variable, UNITGRPH will produce an output file, regardless of whether the input data are logical or not. Therefore, it is possible for UNITGRPH to appear to have functioned normally while using invalid input data. A few such cases are presented below:

- **Negative value input for flood hydrograph or runoff:**

  Physically, all flood hydrograph ordinates and runoff values should be greater than zero. However, UNITGRPH does not reject input values that are less than zero (although computed hydrograph ordinates and runoff values are required to be greater than zero). UNITGRPH still terminates normally without any warning or error message when negative flood hydrograph or runoff values are input.

- **Negative value input for "LIST" value or basin area:**

  When negative "LIST" values or a negative value for the basin area are input, UNITGRPH returns "NaN" for most of the computed values. Therefore, it is obvious to the user that UNITGRPH has not functioned properly. However, UNITGRPH accepts these negative input values and still terminates normally without any warning or error message.

In the cases presented in this section, UNITGRPH accepts invalid input data but does not warn the user that the data are invalid. In some cases UNITGRPH may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of UNITGRPH besides those presented above. Therefore, it is the responsibility of the user to confirm that the data in the input file are valid in order to ensure that the UNITGRPH output is also valid. Normal termination of UNITGRPH is a necessary but not sufficient condition for producing valid results.

3. FLDHYDRO

3.1 Plan for Testing FLDHYDRO Functionality

3.1.1 Overview

The plan for testing the functionality of FLDHYDRO is defined in Reference 2, Appendix G. The FLDHYDRO Test Plan consists of a comparison of the solution of test problems obtained with FLDHYDRO to independent calculations for the same problems. The test plan serves to evaluate the program's capabilities and limitations as related to TVA design applications. The test problems, which are described in Section 3.1.2, were selected to be representative of typical TVA applications of the program.

Revisions or modifications to the FLDHYDRO computer program requires documentation of the changes as required in Section 3.3 of Reference 2.

The test problems specified here are intended to assess the extent of possible program features and options likely to be required for safety-related design analysis. These test problems were run using FLDHYDRO Version 1.0.

3.1.2 Tests of the Implementation of the FLDHYDRO Methodology

- **Test Problem 1:** Nottely Dam

  This problem is intended to ensure that FLDHYDRO properly calculates runoff depths using the method outlined in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 1). The rainfall data from a single station used for this purpose are given in Figure 31.

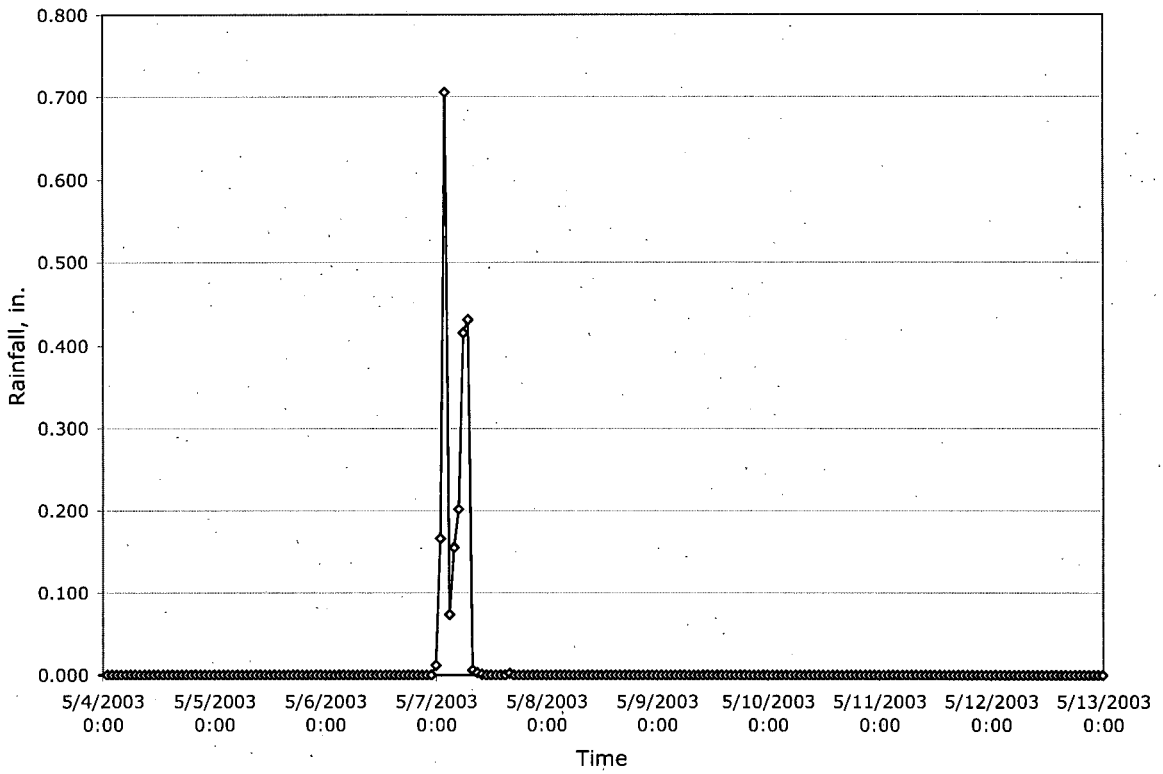


Figure 31. Input Hourly Rainfall for Test Problems 1 and 2

For the purposes of the API-RI table, Nottely Dam is located in the SE region of the Tennessee River basin (see Figure 42). The drainage area of the Nottely Dam watershed is 214.3 square miles. 30 days of antecedent rainfall data are used to calculate the API. Figure 32 shows the daily rainfall for the 30 days prior to the start of the hourly rainfall record shown in Figure 31. The API value at the beginning of this 30-day period is assumed to be equal to 1.0. The rainfall data and the basin characteristics for this problem were taken from References 5 and 8.

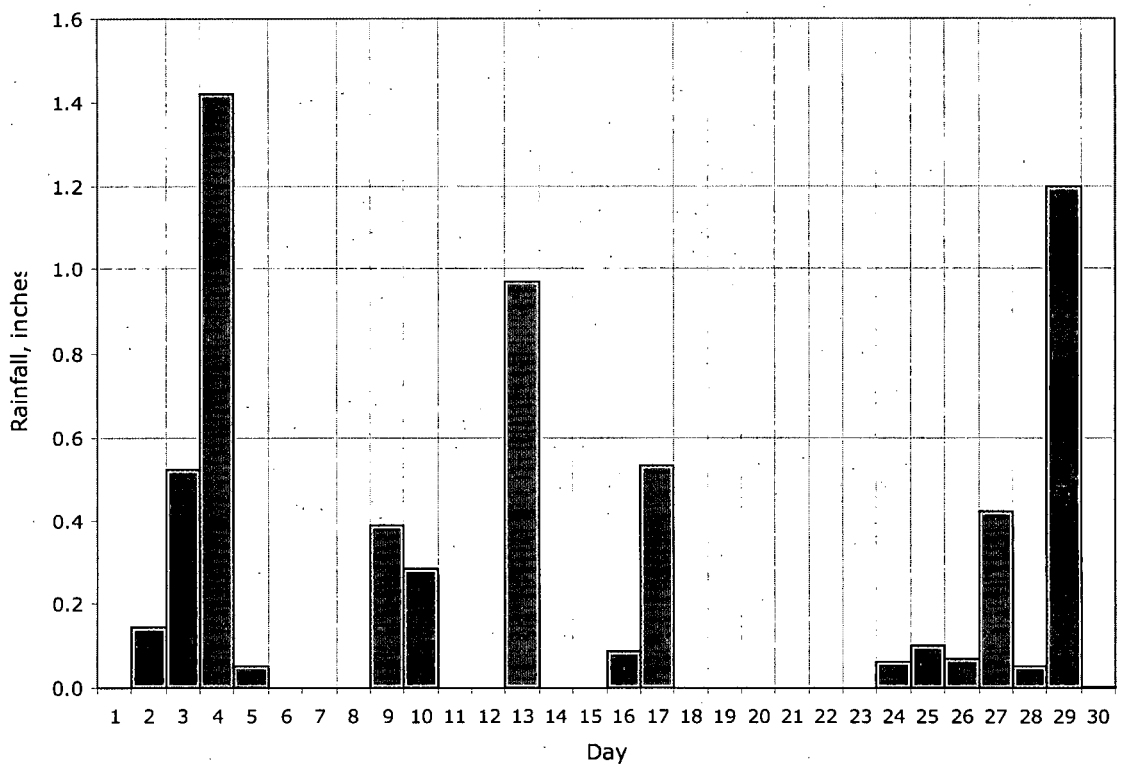


Figure 32. Daily rainfall 30 days prior to event used in Test Problem 1

- **Test Problem 2:** Nottely Dam with CHKVOL Enabled

  This problem is identical to Test Problem 1, but with the CHKVOL (Reference 1) option enabled. For this purpose the total runoff, represented in FLDHYDRO by the parameter CHKVOL is specified as equal to 0.9 inches. This problem is intended to ensure that FLDHYDRO properly calculates runoff depths when a total volume of runoff for the storm is specified. The rainfall data for this problem are identical to Test Problem 1 and are given in Figure 31 and Figure 32.

- **Test Problem 3:** Nottely Dam with two Separate Storms and CHKVOL

  This problem is identical to Test Problem 2 with the exception that another storm is added prior to the storm used in Test Problems 1 and 2. The runoff volume of the first storm is 0.4 inches and that of the second storm is 0.9 inches, as in Test Problem 2. This problem is intended to ensure that FLDHYDRO properly calculates runoff depths for multiple storms. The rainfall data from a single station used for this purpose are given in Figure 33.

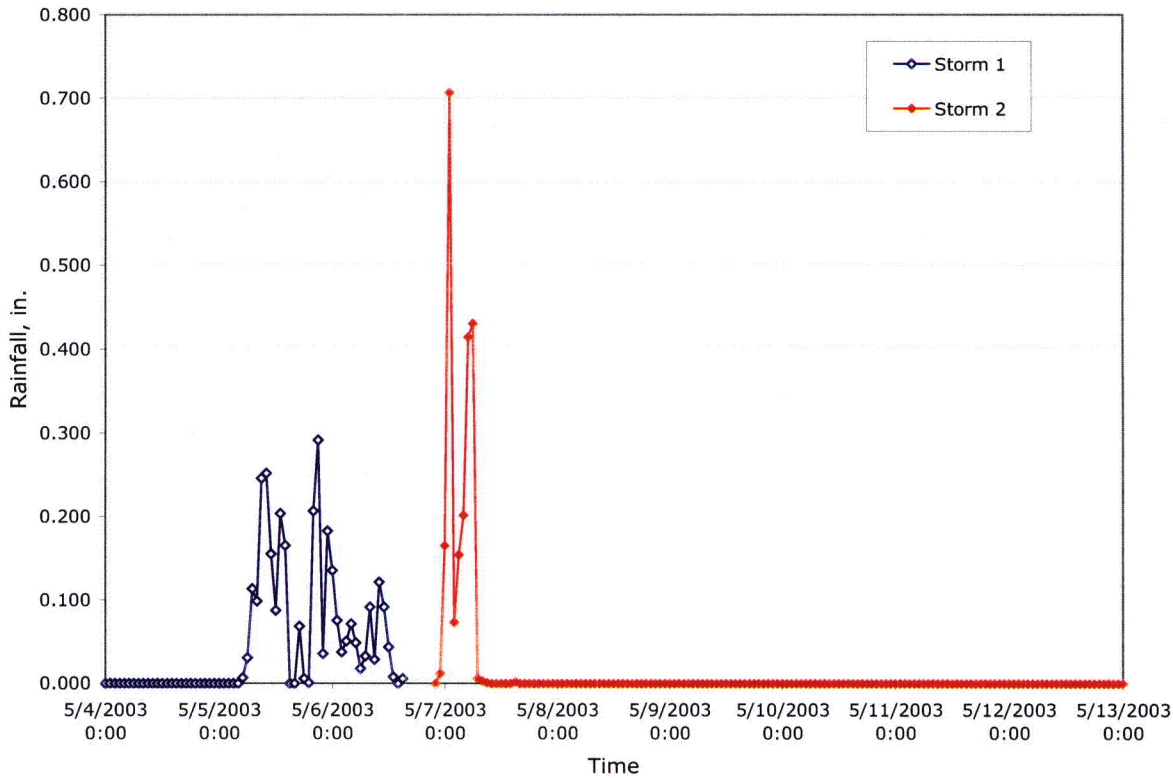


Figure 33. Input Hourly Rainfall for Test Problem 3

- **Test Problem 4:** Cherokee Local

  This problem is intended to ensure that FLDHYDRO properly calculates runoff depths when multiple gages are used and CHKVOL is enabled. Test Problem 4 uses both hourly and daily rain gages from multiple stations as input. Hourly data from four rain gages are shown in Figure 34. Stations where no hourly rainfall data were recorded, but only daily totals are available are referred to in FLDHYDRO as "nonrecorders". Each nonrecorder station is paired with a station for which hourly data are available. The pairing of stations as well as the daily rainfall data for 13 nonrecorders is given in Table 12. Table 13 gives the Thiessen weights of the rainfall stations used in Test Problem 4.

  For the purposes of the API-RI table, Cherokee Dam is located in the NE region of the Tennessee River basin (see Figure 42). The drainage area of the local watershed upstream of Cherokee Dam is 1022 square miles. 29 days of antecedent rainfall data are used to calculate the API. Figure 35 shows the daily rainfall at all 17 stations for the 29 days prior to the start of the hourly rainfall record shown in Figure 34. The API value at the beginning of this 29-day period is assumed to be equal to 1.0 at all rainfall stations. This problem was taken from Reference 9.

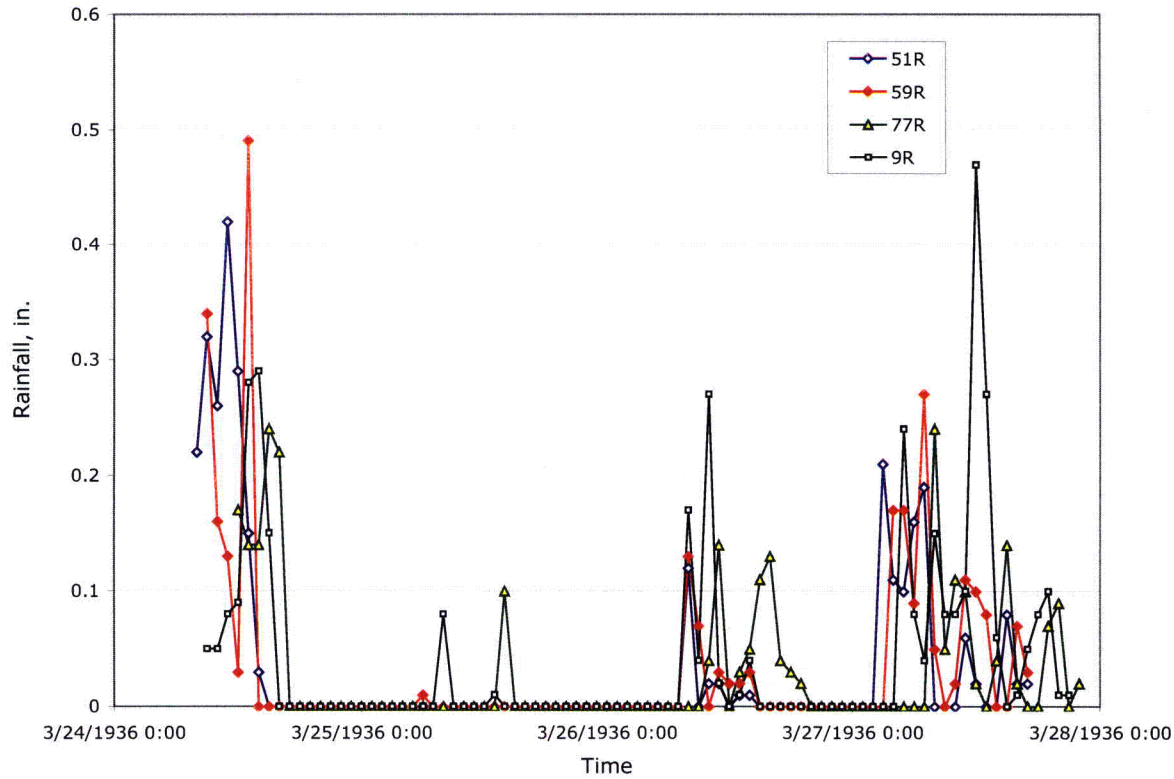


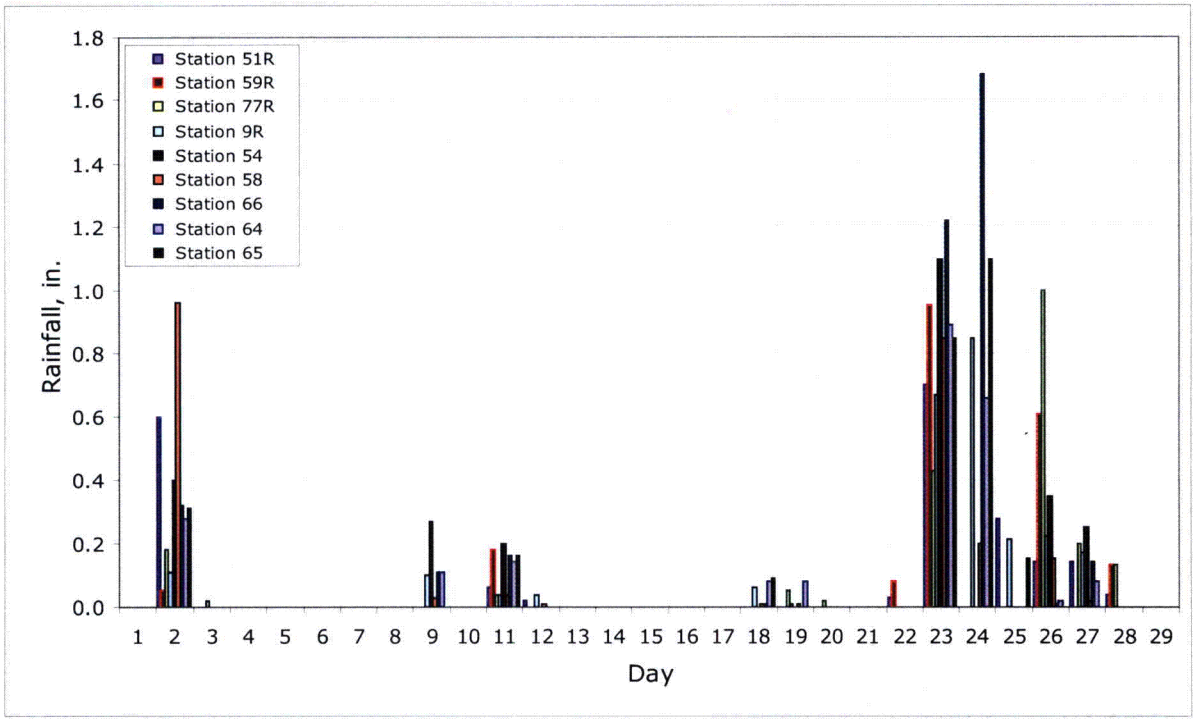
Figure 34. Input Hourly Rainfall for Test Problem 4

Table 12. Daily Rainfall Data and Paring of Nonrecorders and Hourly Data Stations

Daily Rain Gage Station	Daily Total Rainfall (in)				Pairing with Hourly Data Station
	3/24/1936	3/25/1936	3/26/1936	3/27/1936	
54	1.51	0.90	0.80	0.80	51R
58	1.98	0.45	0.55	0.98	59R
66	1.45	0.05	1.01	0.69	59R
64	1.80	0.21	0.73	0.96	9R
65	1.42	0.22	1.15	0.51	9R
1	1.33	0.05	0.68	0.58	77R
2	2.00	0.25	0.50	2.25	9R
4	0.23	0.22	0.22	1.02	9R
32	1.50	0.30	0.20	1.15	9R
72	1.31	0.02	0.78	0.87	77R
63	1.54	0.25	1.20	0.63	59R
57	2.38	0.46	1.01	1.20	51R
55	2.45	1.13	0.55	0.99	59R

Table 13. Thiessen Weights used in Test Problem 4

Station	Thiessen Weight
51R	0.00
59R	0.00
77R	0.00
9R	0.03
54	0.20
58	0.18
66	0.07
64	0.09
65	0.15
1	0.01
2	0.01
4	0.04
32	0.02
72	0.03
63	0.09
57	0.03
55	0.02



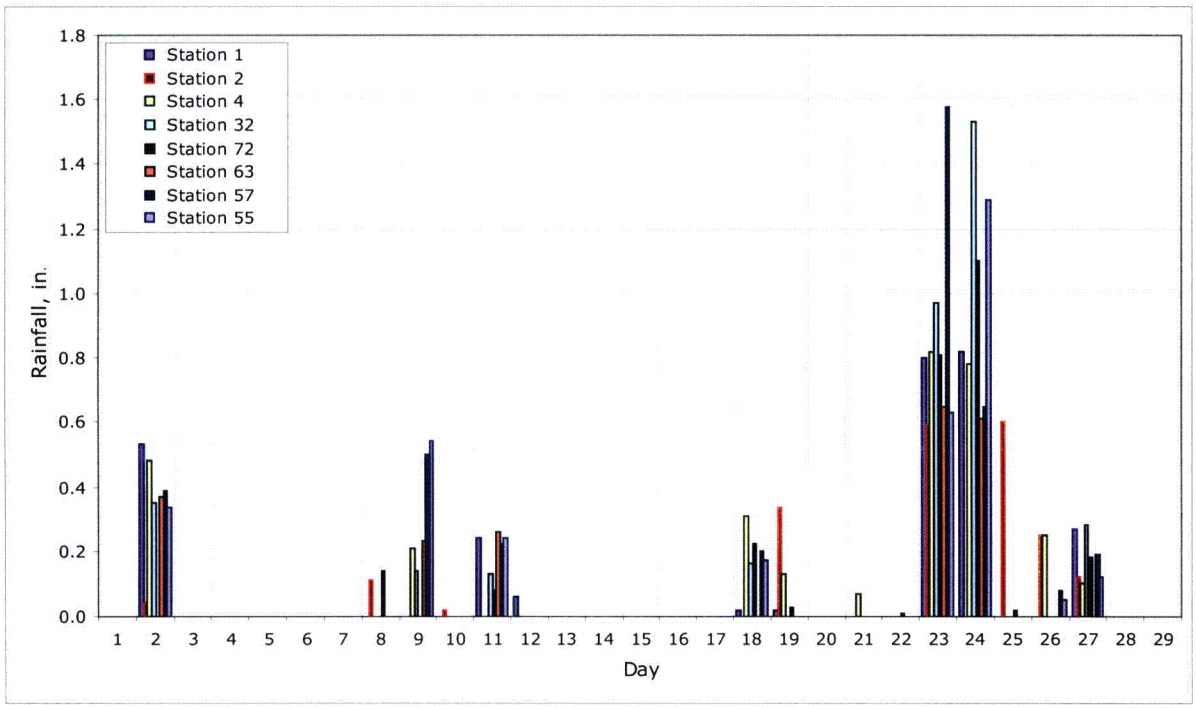


Figure 35. Daily rainfall 30 days prior to event used in Test Problem 4

- **Test Problem 5:** Norris Dam

  This problem is intended to ensure that FLDHYDRO properly calculates runoff depths and the flood hydrograph for multiple storms from a single station and the option to calculate the flood hydrograph is enabled. The rainfall data used in this problem are 6-hour totals. The rainfall used for this purpose is given in Figure 36. The 6-hour unit hydrograph for the Norris Dam basin is given in Figure 37.

  The drainage area upstream of Norris Dam is 2,912 square miles. For the purposes of the API-RI table, Norris Dam is located in the NE region of the Tennessee River basin (see Figure 42). This problem was taken from Reference 9.

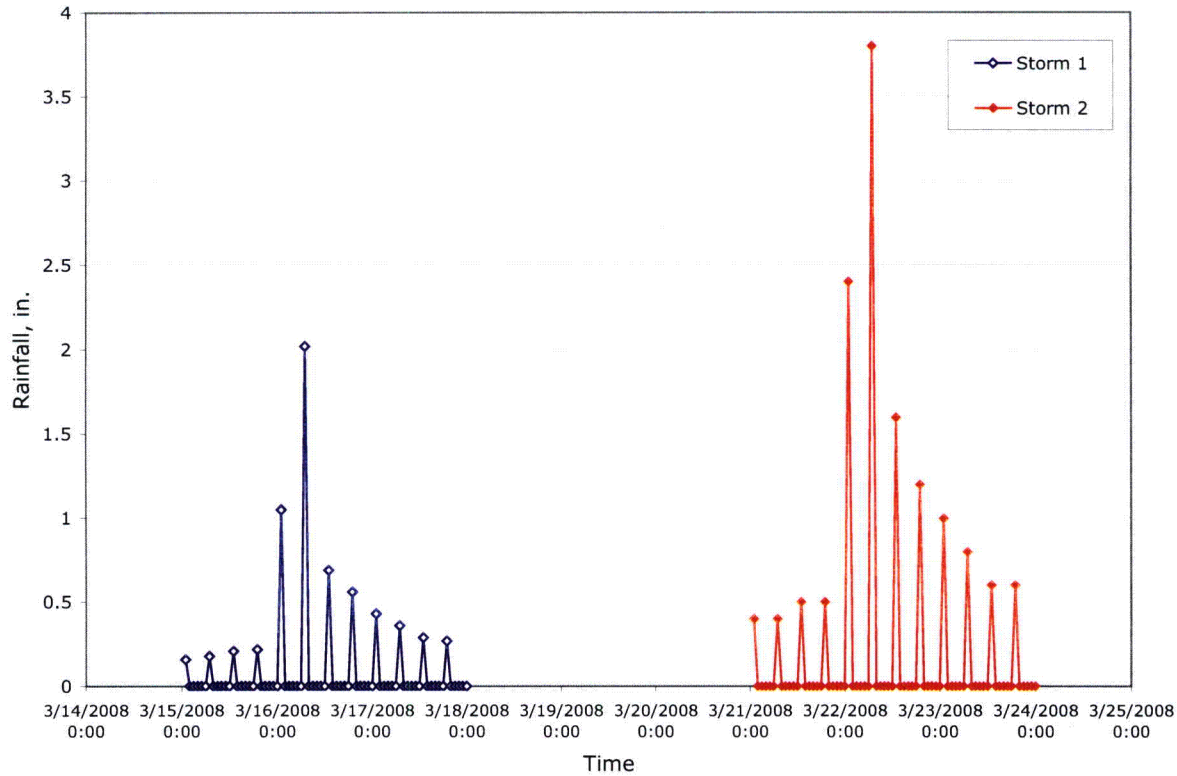


Figure 36. Input Hourly Rainfall for Test Problem 5

As can be seen in Figure 36, the rain gage used for this problem recorded every six hours. Since FLDHYDRO requires hourly data, the 6-hour rainfall values are input as-is at the time recorded and hours when data were not recorded are input as zero. This ensures that the runoff values calculated by FLDHYDRO are correct for every sixth hour. The intermediate values are erroneous and can be discarded when examining the results. In this particular problem this becomes irrelevant because the hydrograph duration is 6 hours, which means that what matters for FLDHYDRO is the cumulative rainfall every 6 hours, regardless of its distribution within each 6-hour interval. Since rainfall was recorded every 6 hours, the actual distribution of rainfall within its 6-hour interval is not known. A better presentation of the rainfall data, consistent with the nature of these data, would have been to show these data in the form of histogram of the total rainfall in every 6-hour period. Figure 36 is presented the way it is, in order to show the rainfall data exactly as they are entered in

FLDHYDRO in typical TVA applications. The same data could also have been entered by distributing each 6-hour rainfall total uniformly within the preceding 6 hours. The effects of using a 6-hr rain gage instead of an hourly rain gage are discussed further in Section 3.2.1.7.

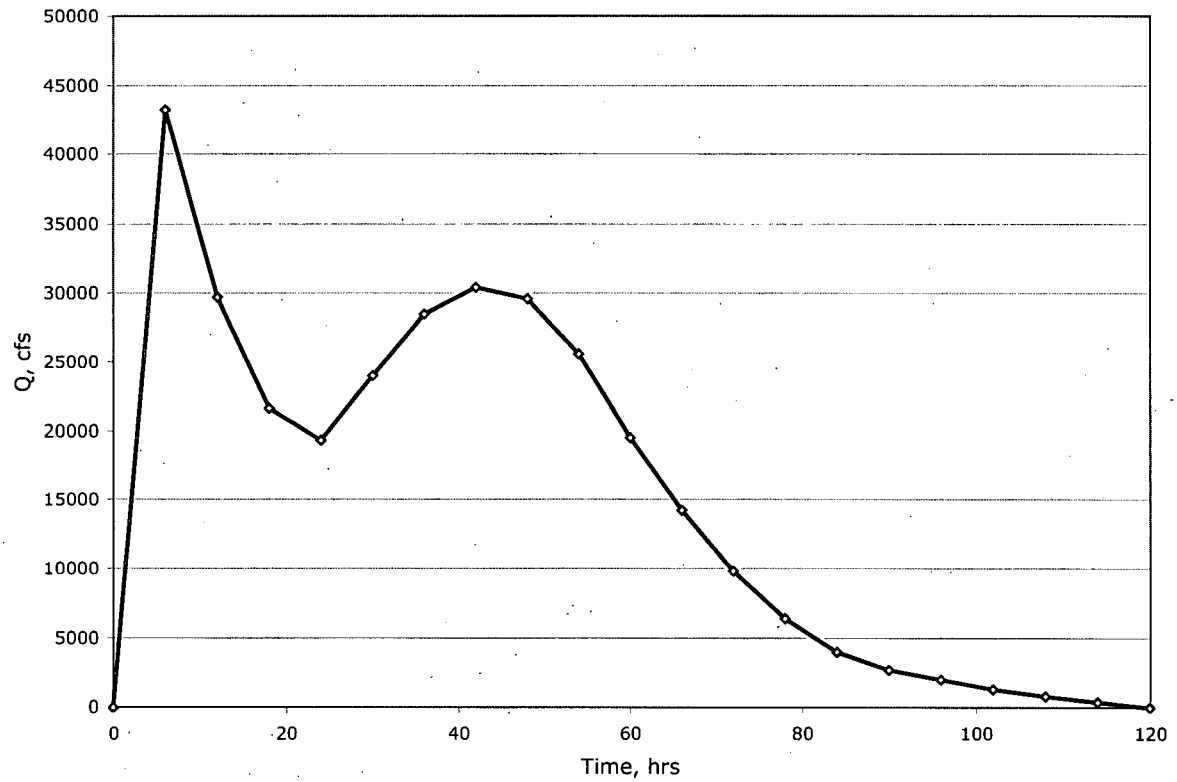


Figure 37. Input Unit Hydrograph for Test Problem 5

- **Test Problem 6:** Cherokee Watershed

  This problem is intended to ensure that FLDHYDRO properly calculates runoff depths and flood hydrographs when multiple gages and subbasins are used and the option to calculate the flood hydrograph is enabled. The watershed upstream of Cherokee Dam is divided into the seven subbasins listed in Table 14 along with their drainage areas.

  Table 14. Subbasins and drainage areas upstream of Cherokee Dam

Subbasin	Drainage Area (square miles)	Rainfall Station for Storm 2 (see Figure 39)
South Holston	708	Station 1
Wautaga	468	Station 2
Boone local	669	Station 3
Fort Patrick Henry local	63	Station 4
North Fork Holston at Gate City	672	Station 5
Holston at Surgoinsville	299	Station 6
Cherokee	554	Station 7

  The rainfall input data used are available every 6 hours. Rainfall data for storm 1 are available only from a single station, which is assumed to be representative of all seven subbasins. The rainfall data for storm 1 are plotted in Figure 38. For storm 2 data are available at seven different stations every 6 hours. The name of the rainfall station in each subbasin is given in Table 14. The rainfall data at these seven stations used for storm 2 is given in Figure 39.

  All subbasins have 6-hour unit hydrographs. It is noted that the Holston River at Surgoinsville 6-hour unit hydrograph has a 2-hour time interval (flow values are given every two hours). The unit hydrographs of all subbasins are plotted in Figure 40. This problem was taken from Reference 1.

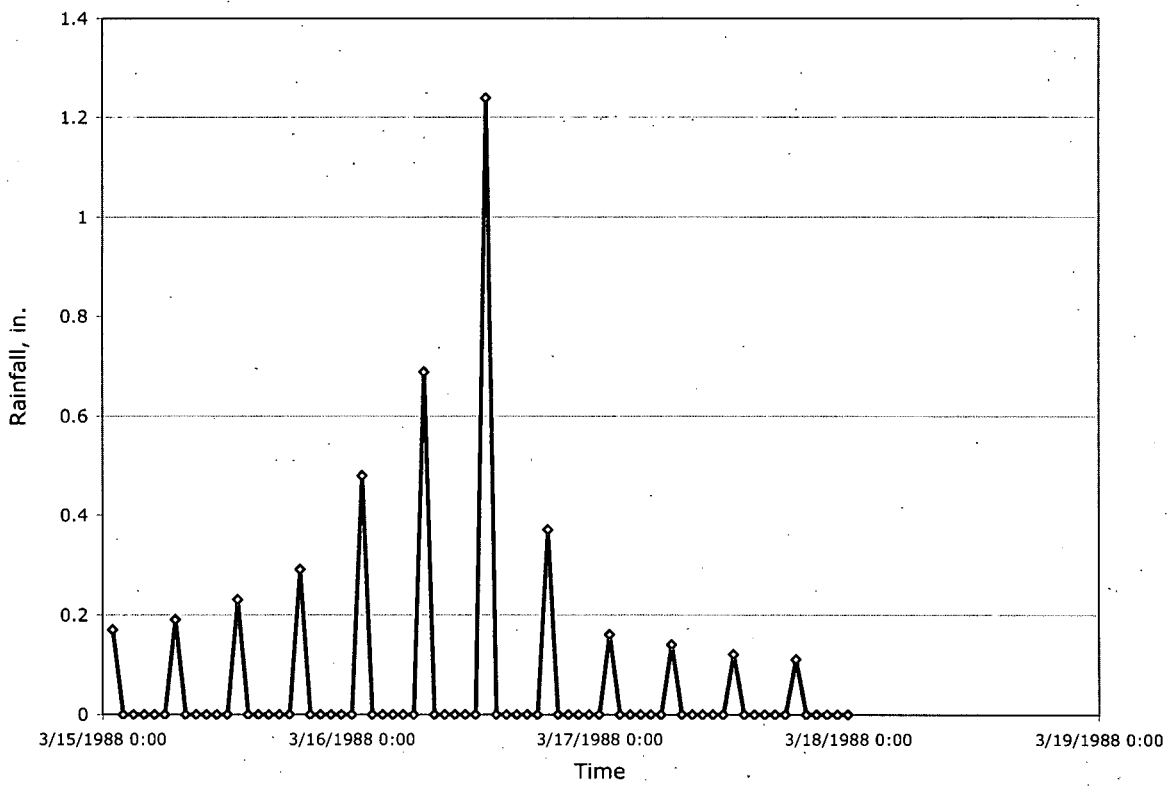


Figure 38. Input Hourly Rainfall for Storm 1, Test Problem 6

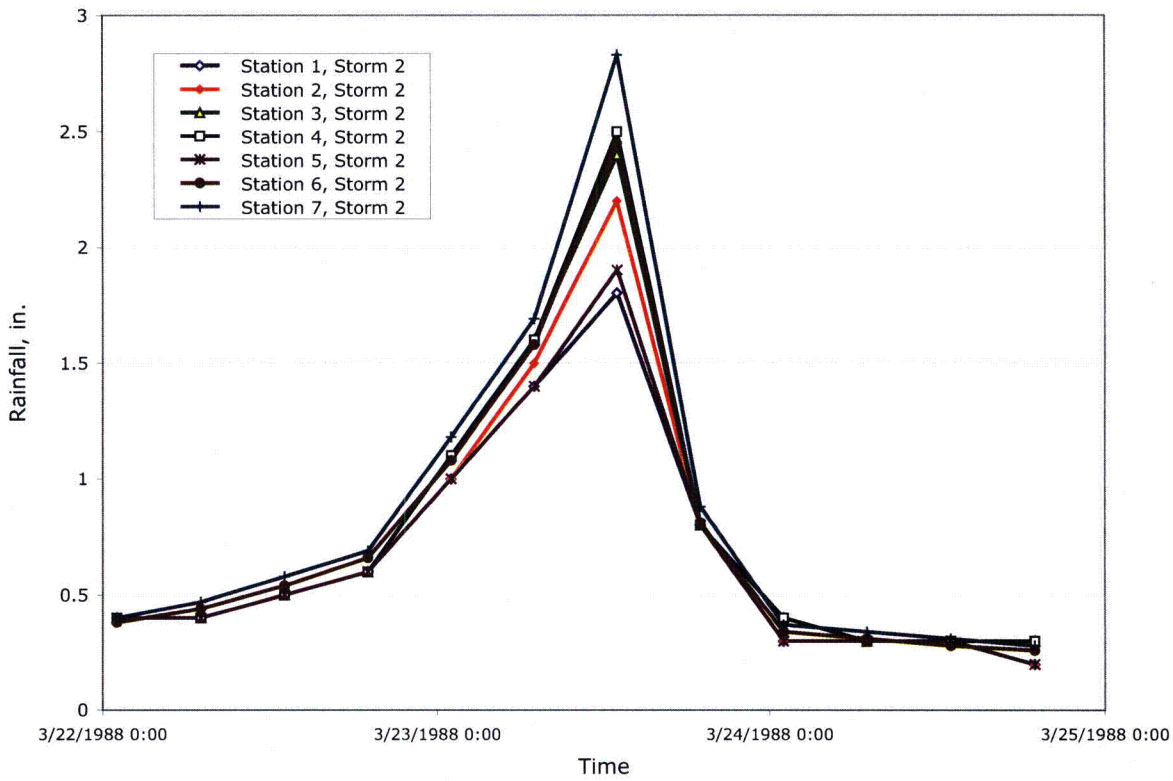


Figure 39. Input 6-Hourly Rainfall for Storm 2, Test Problem 6

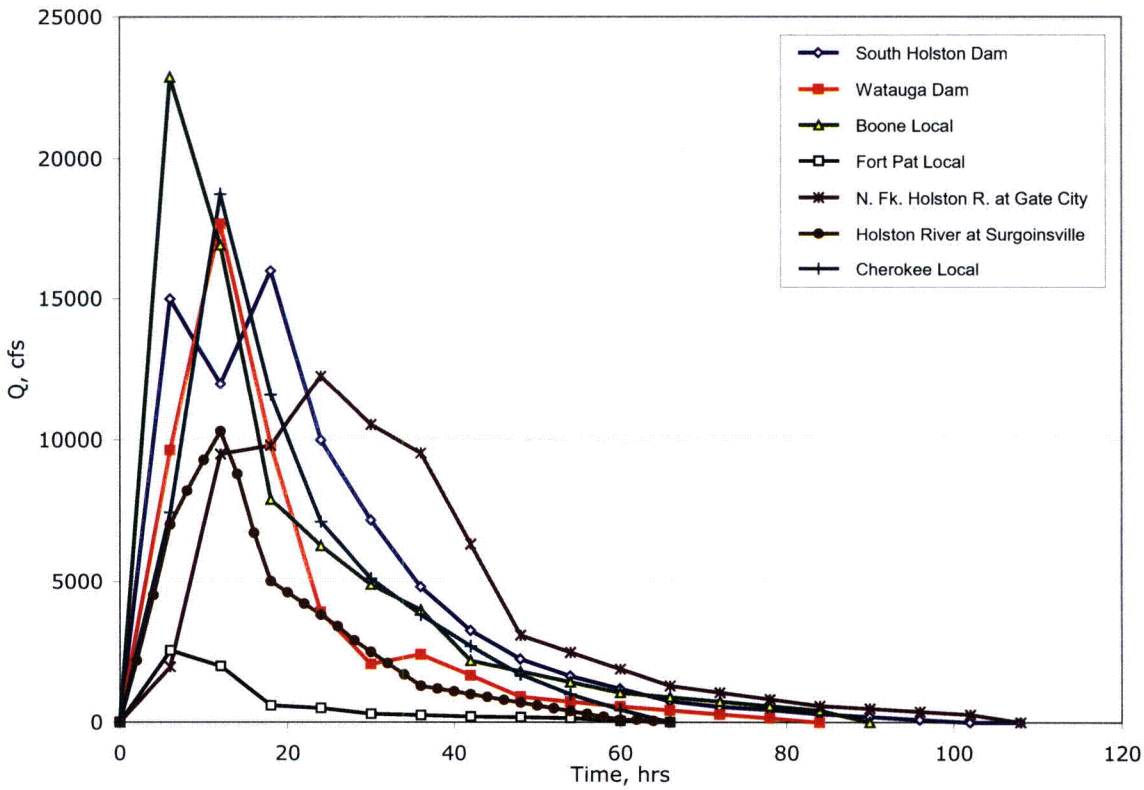


Figure 40. Input Unit Hydrographs for Test Problem 6

3.1.3 Tests of Specific Options Available in FLDHYDRO

- **Test Problem 2a:** Nottely Dam with CHKVOL Enabled

  This problem is identical to Test Problem 2 with the exception that a CHKVOL value of 0.96 is used. This problem is intended to show the result when FLDHYDRO runs off the edge of the TV or NonTV table (The contents and the use of these tables are explained in Section 3.1.4). The rainfall data for this problem are identical to Test Problems 1 and 2 and is given in Figure 31.

- **Test Problem 3a:** Nottely Dam Separated into Two Storms with CHKVOL

  This problem is identical to Test Problem 3 with the exception that the two storms are consecutive (the second begins one time step after the first stops, i.e. at time 22:00 on 5/6/03). This problem is intended to show that the summation of hourly runoff is not reset for the second storm when two consecutive storms are input. The rainfall data for this problem are identical to Test Problems 1 and 2 and is given in Figure 33.

- **Test Problems 7 and 7a:** Watts Bar Reservoir

  These test problems are intended to show how FLDHYDRO can generate erroneous zeros at the end of the runoff data when a gage with a long record of data is weighted at zero, and the way to set up the input file to avoid this problem. The

rainfall used for this purpose is given in Figure 41. This problem was taken from Reference 10.

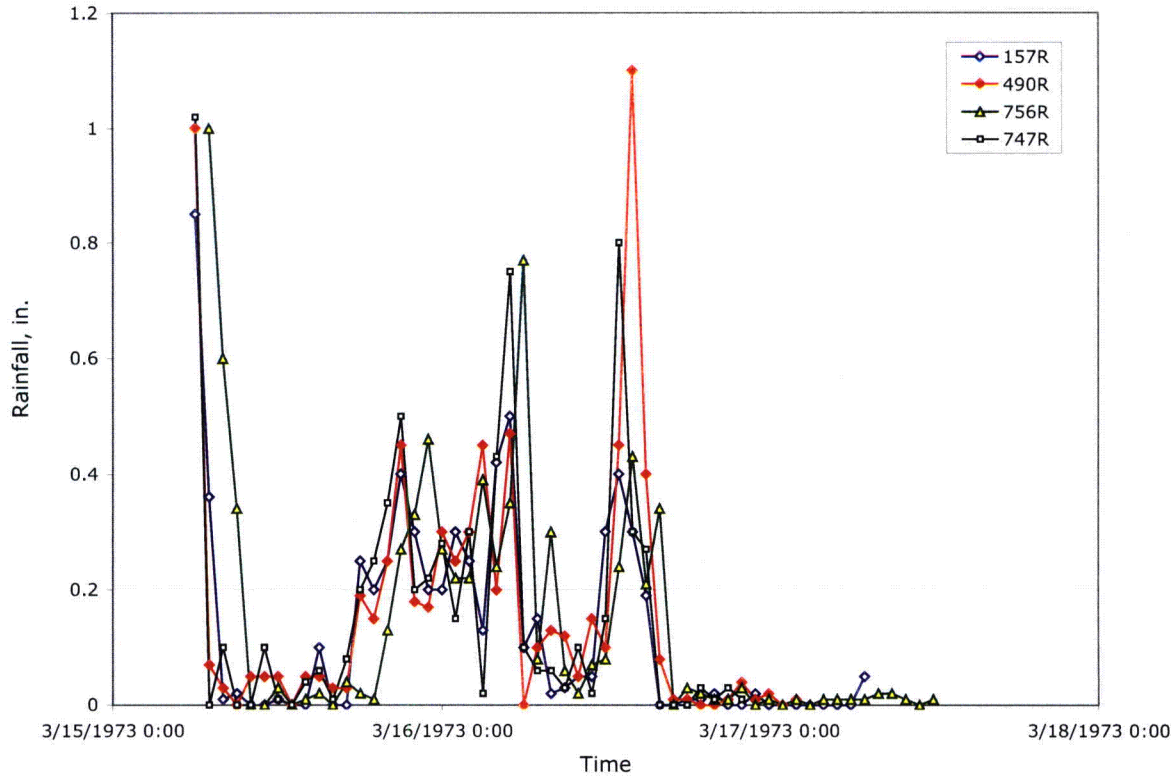


Figure 41. Input Hourly Rainfall for Test Problem 7

3.1.4 Solution Method Used in the Independent Calculations

The independent calculations used the same general method for calculating the flood hydrograph for a subbasin as FLDHYDRO which is described in Reference 1, and summarized below.

FLDHYDRO computes the runoff (also referred to as effective precipitation/rainfall or excess precipitation/rainfall) for specific storm events, and has the option to compute flood hydrographs using as input the unit hydrograph and the rainfall distribution.

User inputs to the program include:

- Daily antecedent rainfall (optional),
- Hourly storm event rainfall,
- Thiessen weights (when needed)
- Base flow factor for each subwatershed and storm,
- Surface runoff volume at specified drainage points (optional), and
- Unit hydrographs for each subwatershed (optional, needed if the flood hydrograph is to be computed)

- Drainage area for each subwatershed

Also used as inputs to the program are three tables developed by TVA specifically for the Tennessee River basin (Reference 9):

- APITBL – relates locality parameters (geographic region [as defined in Figure 42] and week of the year) and Antecedent Precipitation Index (API) values to give Runoff Index (RI) values within the Tennessee River basin
- TV – relates RI and cumulative precipitation to effective precipitation for all Tennessee River basin runoff regions except the southeast (SE) region
- NonTV – relates RI and cumulative precipitation to effective precipitation for the SE runoff region of the Tennessee River basin

FLDHYDRO computes the runoff from rainfall data using the API as an estimate of initial moisture deficiency based on the method developed by Kohler and Linsley (References 11 and 12). The API for a given day is calculated from the following equation:

$$API_i = K*API_{i-1} + P_i \quad (9)$$

API_i indicates the API value at time increment i and P_i the precipitation at the same time. K is a recession constant which the literature gives as normally having values in the range of 0.85 to 0.90 (Reference 11) or 0.85 to 0.98 (Reference 12). In FLDHYDRO is programmed such that K is always equal to 0.90 and API values can range from 0 to 5. The API is used to obtain a Runoff Index (RI) that has been determined for the Tennessee River Valley region as a function of location and season. The RI is then used to obtain precipitation losses for each increment of rainfall. This method developed from a study of storm records, relates the amount of precipitation excess (and hence the precipitation loss) to the rainfall, the week of the year, the API, and the geographic location of the drainage basin. It was first implemented graphically using coaxial relations between the API and runoff. In FLDHYDRO the method is implemented using lookup tables developed specifically for the Tennessee River basin.

The solution technique used by FLDHYDRO is similar to, but varies in implementation from the method proposed by Kohler and Linsley (Reference 11 and 12). In addition, FLDHYDRO gives the option of two different methods to compute the time sequence of excess precipitation, the antecedent rainfall method and the check volume method. These two methods are described in detail in Sections 3.1.4.1 and 3.1.4.2. Regardless of the method used, FLDHYDRO requires a region specification in order to provide excess precipitation for a storm event.

3.1.4.1 Antecedent Rainfall Method

The Antecedent Rainfall method, which is referred to also as the API method, calculates the total volume of runoff using the rainfall data for a specific storm and information or data on rainfall for a period prior to the storm event under consideration. When antecedent rainfall values are used, a starting API value for each rainfall event is either specified as input or calculated for each rain gage using Equation (9).

In order to use this equation, an API value at the start of the antecedent rainfall is needed. Usually, TVA uses a starting value of 1. The value of the index on any day theoretically depends on precipitation over an infinite antecedent period, but if a reasonable initial value is assumed, the computed index will closely approach the true value within a few weeks. Usually a month of antecedent rain is sufficient to define the API value.

Once a starting API value is obtained for the rainfall event, the APITBL is referenced (Figure 43). The week of the year and location of the runoff region are located across the top of the

table. The RI values are located down the left side of the table. This table is used to find the RI value by first identifying the column with the proper locality parameters (region and week). This column is then followed down to the calculated API value. From the API value, the row is followed to the column of RI values and the corresponding RI value is read from the table.

Next, the TV or NonTV table is referenced. Which table is used depends on the runoff region. These tables have the RI value across the top of the table and effective precipitation down the left side of the table (Figure 44). These tables are used by first identifying the appropriate column for the RI value obtained from the APITBL. The column where this value is located is then followed down to the first cumulative rainfall value for the referenced storm. For each cumulative rainfall value, the row is followed over to the accumulative effective precipitation value for that time. This process is repeated for all time increments of the storm.

The use of these tables is illustrated also in Figure 45 where the plotted curves are based on data from the two tables shown in Figure 43 and Figure 44. Figure 46 shows the relationship between runoff and precipitation for different values of RI (data from the Table TV).

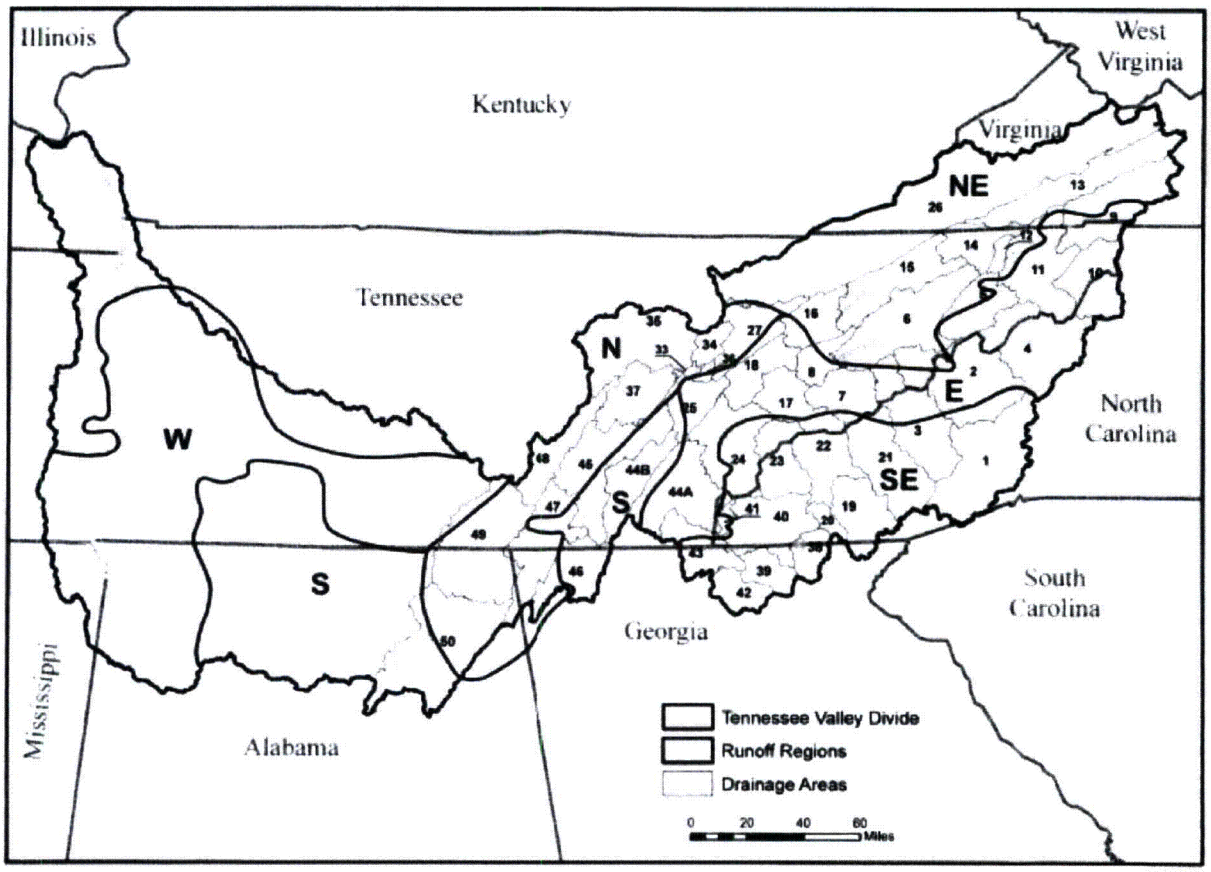
From the effective precipitation values, the runoff hydrograph is determined. If desired, these runoff values along with the unit hydrograph can then be used to compute the flood hydrograph using Equations (1) and (2) described in Section 2.1.4.

3.1.4.2 Check Volume Method

The Check Volume (CV) method is identical to the Antecedent Rainfall Method, with one exception. After the effective rainfall values are obtained from the TV or NonTV table, the total runoff volume for each specified drainage point is calculated. These values are then compared with the input surface runoff volumes (check volumes) at these specified drainage points. If the values are not equal, the RI value is adjusted and new effective rainfall values are computed. This process is repeated until the calculated runoff volumes equal the check volumes. By using this method, antecedent rainfall input to the model is rendered moot as the RI value is used as a calibration parameter instead of a look-up value. The exception is when the check volume option is being used over more than one subwatershed where it is important to preserve each subwatershed's unique antecedent conditions. For instance, take the example of a run with 2 subwatersheds whose initial RI values computed from their individual API values are 24 and 26, respectively. If those RI's produce a composite storm volume for the 2 subwatersheds less than the check volume, then both "initial" RI values are reduced to 23 and 25, respectively, and another volume check is performed until the check volume value is matched. In this way, the different antecedent conditions between the 2 subwatersheds are preserved.

The check volume method distributes and scales excess precipitation, independently of antecedent precipitation, so that the total volume of excess precipitation approximately matches the calculated direct runoff volume. The direct runoff volume comes from the baseflow separation calculations and is provided to the program with the CHKVOL variable. The time distribution of rainfall excess within the storm interval occurs according to the API region and season of the year provided to the FLDHYDRO model.

Figure 42. Six Different Regions Determining RI from API



	API																																	
Region	SE																																	
Week	1	2	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	41	42	43	44	45	46	47	48	49	50	51	52
RI 70																																	
69																																	
68																																	
67																																	
66																																	
65																																	
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52																																	
51																																	
50																																	
49																					0.05												
48																					0.14												
47																				0.09	0.23	0.03											
46																			0.04	0.19	0.33	0.14											
45																			0.15	0.29	0.43	0.24											
44																		0.11	0.26	0.40	0.53	0.34	0.08										
43																	0.06	0.22	0.37	0.51	0.53	0.44	0.20										
42																	0.18	0.34	0.48	0.62	0.73	0.54	0.31	0.04									
41																0.13	0.31	0.46	0.60	0.72	0.84	0.66	0.43	0.17									
40															0.13	0.26	0.43	0.58	0.72	0.83	0.96	0.77	0.55	0.29									
39														0.13	0.27	0.39	0.57	0.72	0.84	0.95	1.07	0.88	0.67	0.41	0.09								
38													0.13	0.28	0.42	0.53	0.71	0.85	0.97	1.08	1.20	1.01	0.81	0.55	0.24								
37												0.14	0.30	0.43	0.57	0.68	0.85	1.00	1.12	1.22	1.33	1.14	0.94	0.69	0.39								
36										0.06	0.16	0.27	0.47	0.59	0.73	0.84	1.01	1.15	1.27	1.37	1.48	1.28	1.09	0.84	0.54	0.15							
35								0.04	0.13	0.24	0.33	0.50	0.64	0.77	0.91	1.02	1.18	1.32	1.42	1.54	1.64	1.45	1.25	0.99	0.72	0.33	0.17						
34							0.13	0.23	0.33	0.43	0.52	0.69	0.84	0.97	1.10	1.22	1.37	1.51	1.61	1.72	1.82	1.62	1.42	1.18	0.89	0.52	0.35	0.18					
33						0.22	0.34	0.44	0.54	0.64	0.74	0.91	1.07	1.19	1.32	1.46	1.58	1.71	1.81	1.92	2.02	1.83	1.62	1.38	1.10	0.74	0.56	0.38	0.18				
32					0.21	0.44	0.56	0.67	0.77	0.88	0.98	1.16	1.30	1.43	1.57	1.71	1.82	1.93	2.04	2.16	2.26	2.07	1.84	1.62	1.33	0.98	0.78	0.59	0.39	0.20			
31				0.17	0.46	0.70	0.81	0.92	1.03	1.14	1.27	1.42	1.58	1.71	1.85	1.99	2.09	2.21	2.33	2.45	2.59	2.36	2.10	1.88	1.58	1.27	1.04	0.83	0.62	0.43	0.19		
30			0.12	0.43	0.72	0.98	1.09	1.22	1.32	1.45	1.57	1.74	1.88	2.02	2.17	2.28	2.42	2.55	2.69	2.82	2.97	2.71	2.43	2.18	1.88	1.57	1.34	1.10	0.87	0.68	0.43	0.17	
29	0.12	0.12	0.40	0.72	1.02	1.28	1.42	1.55	1.67	1.80	1.92	2.09	2.24	2.37	2.54	2.68	2.77	2.96	3.11	3.25	3.45	3.12	2.82	2.53	2.25	1.91	1.67	1.43	1.18	0.94	0.71	0.42	0.12
28	0.38	0.38	0.69	1.03	1.35	1.64	1.77	1.91	2.03	2.17	2.32	2.51	2.67	2.82	2.98	3.14	3.31	3.46	3.62	3.81	4.00	3.65	3.29	2.95	2.66	2.32	2.05	1.78	1.52	1.25	1.02	0.70	0.38
27	0.68	0.68	1.02	1.38	1.73	2.03	2.18	2.32	2.47	2.63	2.79	2.97	3.15	3.34	3.53	3.70	3.89	4.07	4.23	4.42	4.62	4.23	3.85	3.47	3.12	2.78	2.49	2.20	1.92	1.67	1.38	1.02	0.68
26	1.04	1.04	1.38	1.78	2.15	2.48	2.65	2.82	2.97	3.15	3.30	3.52	3.73	3.93	4.15	4.35	4.56	4.75	4.92	5.00	5.00	4.90	4.50	4.08	3.68	3.30	3.00	2.67	2.35	2.04	1.78	1.38	1.04
25	1.50	1.50	1.87	2.28	2.65	3.00	3.20	3.39	3.57	3.77	3.93	4.17	4.40	4.64	4.85	5.00	5.00	5.00	5.00			5.00	5.00	4.79	4.35	3.92	3.61	3.26	2.90	2.56	2.28	1.86	1.50
24	2.07	2.07	2.47	2.86	3.24	3.64	3.85	4.06	4.27	4.51	4.67	4.90	5.00	5.00	5.00									5.00	5.00	4.65	4.30	3.93	3.56	3.21	2.85	2.47	2.07
23	2.75	2.75	3.24	3.62	3.98	4.37	4.60	4.82	5.00	5.00	5.00	5.00														5.00	5.00	4.73	4.30	3.94	3.52	3.20	2.75
22	3.60	3.60	4.13	4.50	4.83	5.00	5.00	5.00																				5.00	5.00	4.78	4.36	4.03	3.60
21	4.60	4.60	5.00	5.00	5.00																									5.00	5.00	4.95	4.60
20	5.00	5.00																														5.00	5.00
Week	1	2	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	41	42	43	44	45	46	47	48	49	50	51	52
Region	SE																																

Figure 43. Table APITBL to Determine API Values as a Function of the Week of the Year and API (Data for SE Region)

RI \ Precipitation, inches	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.00	0.42	0.44	0.46	0.48	0.5	0.52	0.54	0.56	0.58	0.6	0.62	0.64	0.67	0.69	0.71	0.73	0.75	0.77	0.78	0.8	0.81	0.83	0.85	0.87	0.88	0.92	0.96	1.01	1.05	1.1	1.22	1.34
0.05	0.54	0.56	0.59	0.62	0.65	0.68	0.73	0.77	0.78	0.84	0.89	0.92	0.94	0.97	1	1.03	1.06	1.09	1.12	1.15	1.2	1.25	1.3	1.35	1.4	1.48	1.56	1.65	1.73	1.82	1.98	2.14
0.10	0.65	0.68	0.72	0.75	0.8	0.84	0.9	0.96	0.98	1.04	1.1	1.14	1.18	1.21	1.26	1.31	1.36	1.39	1.44	1.49	1.54	1.62	1.69	1.76	1.88	1.9	2	2.11	2.23	2.35	2.51	2.67
0.15	0.76	0.8	0.85	0.89	0.95	1	1.07	1.13	1.17	1.23	1.29	1.34	1.4	1.44	1.5	1.57	1.64	1.68	1.74	1.8	1.87	1.97	2.04	2.12	2.2	2.28	2.41	2.55	2.68	2.8	2.97	3.14
0.20	0.87	0.92	0.98	1.02	1.09	1.16	1.23	1.3	1.35	1.42	1.48	1.54	1.6	1.66	1.72	1.81	1.89	1.95	2.01	2.08	2.18	2.29	2.36	2.44	2.55	2.64	2.78	2.97	3.05	3.2	3.36	3.52
0.25	0.98	1.04	1.11	1.15	1.23	1.31	1.39	1.46	1.52	1.6	1.66	1.73	1.8	1.86	1.93	2.04	2.13	2.2	2.27	2.34	2.47	2.58	2.65	2.74	2.86	2.98	3.12	3.29	3.39	3.55	3.72	3.86
0.30	1.09	1.15	1.23	1.28	1.37	1.46	1.54	1.61	1.68	1.78	1.84	1.92	1.99	2.06	2.13	2.25	2.35	2.43	2.51	2.59	2.73	2.84	2.92	3.03	3.15	3.28	3.42	3.58	3.7	3.85	4.01	4.17
0.35	1.19	1.26	1.35	1.41	1.5	1.6	1.68	1.76	1.84	1.95	2.02	2.11	2.17	2.26	2.33	2.45	2.55	2.65	2.74	2.83	2.97	3.08	3.18	3.3	3.41	3.55	3.69	3.85	3.98	4.12	4.28	4.45
0.40	1.29	1.37	1.47	1.53	1.63	1.73	1.82	1.91	2.01	2.12	2.19	2.29	2.35	2.45	2.53	2.65	2.75	2.85	2.96	3.06	3.19	3.3	3.42	3.54	3.65	3.79	3.94	4.08	4.22	4.37	4.55	4.72
0.45	1.39	1.48	1.59	1.65	1.76	1.86	1.96	2.06	2.16	2.28	2.35	2.46	2.53	2.63	2.72	2.84	2.94	3.05	3.17	3.28	3.4	3.51	3.65	3.76	3.87	4.02	4.17	4.3	4.45	4.62	4.8	4.98
0.50	1.49	1.59	1.71	1.77	1.88	1.99	2.1	2.2	2.31	2.43	2.51	2.62	2.7	2.8	2.9	3.02	3.13	3.24	3.37	3.48	3.6	3.71	3.85	3.96	4.08	4.23	4.39	4.52	4.68	4.85	5.03	5.22
0.55	1.59	1.69	1.82	1.89	2	2.12	2.23	2.34	2.45	2.58	2.66	2.78	2.86	2.97	3.07	3.19	3.31	3.43	3.56	3.67	3.78	3.9	4.03	4.15	4.28	4.43	4.58	4.73	4.9	5.06	5.25	5.44
0.60	1.69	1.79	1.93	2	2.12	2.24	2.36	2.47	2.58	2.72	2.8	2.93	3.02	3.13	3.23	3.35	3.48	3.61	3.73	3.85	3.96	4.08	4.21	4.33	4.47	4.61	4.77	4.93	5.1	5.27	5.46	5.65
0.65	1.78	1.89	2.04	2.12	2.24	2.36	2.48	2.6	2.71	2.86	2.96	3.07	3.17	3.28	3.38	3.51	3.64	3.78	3.89	4.02	4.13	4.25	4.39	4.51	4.65	4.8	4.96	5.12	5.3	5.48	5.66	5.85
0.70	1.87	1.99	2.14	2.23	2.35	2.47	2.6	2.72	2.84	2.99	3.08	3.21	3.32	3.42	3.52	3.67	3.79	3.94	4.04	4.18	4.29	4.42	4.56	4.69	4.82	4.98	5.14	5.31	5.49	5.67	5.85	6.04
0.75	1.96	2.09	2.24	2.33	2.46	2.58	2.71	2.84	2.96	3.11	3.22	3.34	3.46	3.56	3.66	3.82	3.93	4.09	4.19	4.34	4.45	4.58	4.73	4.86	4.98	5.15	5.31	5.49	5.67	5.85	6.03	6.22
0.80	2.05	2.18	2.34	2.44	2.57	2.69	2.82	2.96	3.08	3.23	3.35	3.46	3.59	3.69	3.8	3.96	4.07	4.23	4.34	4.49	4.6	4.73	4.89	5.02	5.14	5.31	5.48	5.66	5.85	6.03	6.2	6.39
0.85	2.14	2.27	2.44	2.55	2.68	2.8	2.93	3.07	3.2	3.35	3.47	3.58	3.71	3.82	3.93	4.09	4.2	4.36	4.48	4.63	4.75	4.88	5.04	5.17	5.3	5.47	5.64	5.83	6.02	6.2	6.37	6.56
0.90	2.23	2.36	2.53	2.65	2.78	2.91	3.04	3.18	3.31	3.46	3.58	3.7	3.83	3.94	4.05	4.21	4.33	4.48	4.62	4.77	4.9	5.03	5.19	5.32	5.45	5.62	5.8	5.99	6.18	6.36	6.53	6.72
0.95	2.31	2.45	2.62	2.74	2.88	3.01	3.15	3.29	3.42	3.57	3.69	3.82	3.94	4.05	4.17	4.33	4.46	4.6	4.75	4.91	5.04	5.18	5.33	5.47	5.6	5.77	5.96	6.14	6.33	6.51	6.69	6.88
1.00	2.39	2.54	2.71	2.84	2.98	3.11	3.25	3.39	3.53	3.67	3.79	3.93	4.05	4.16	4.28	4.45	4.58	4.72	4.88	5.04	5.17	5.32	5.46	5.61	5.75	5.92	6.11	6.29	6.48	6.66	6.84	7.03
1.05	2.47	2.62	2.8	2.93	3.07	3.2	3.35	3.49	3.64	3.77	3.89	4.03	4.15	4.27	4.39	4.56	4.7	4.84	5	5.17	5.3	5.45	5.59	5.75	5.89	6.06	6.26	6.44	6.63	6.81	6.99	7.18
1.10	2.55	2.7	2.88	3.02	3.16	3.29	3.44	3.58	3.74	3.87	3.99	4.12	4.25	4.37	4.5	4.67	4.81	4.96	5.12	5.29	5.42	5.58	5.72	5.88	6.03	6.2	6.4	6.58	6.78	6.95	7.14	7.33
1.15	2.63	2.78	2.96	3.11	3.25	3.38	3.53	3.67	3.83	3.97	4.09	4.21	4.34	4.47	4.6	4.77	4.92	5.08	5.24	5.41	5.54	5.7	5.85	6	6.16	6.34	6.54	6.72	6.92	7.09	7.28	7.47
1.20	2.7	2.86	3.04	3.2	3.34	3.47	3.62	3.76	3.92	4.06	4.17	4.3	4.43	4.57	4.7	4.87	5.03	5.2	5.36	5.52	5.66	5.82	5.97	6.12	6.29	6.47	6.67	6.86	7.05	7.23	7.42	7.6
1.25	2.77	2.94	3.12	3.28	3.42	3.56	3.7	3.85	4	4.15	4.26	4.39	4.53	4.66	4.8	4.97	5.14	5.31	5.48	5.63	5.78	5.94	6.09	6.24	6.42	6.6	6.8	7	7.18	7.36	7.55	7.74
1.30	2.84	3.01	3.19	3.36	3.5	3.64	3.78	3.94	4.08	4.24	4.35	4.48	4.62	4.75	4.9	5.07	5.24	5.42	5.59	5.74	5.9	6.06	6.21	6.36	6.54	6.72	6.92	7.13	7.31	7.49	7.68	7.87
1.35	2.91	3.08	3.26	3.43	3.57	3.72	3.86	4.02	4.17	4.32	4.44	4.57	4.71	4.84	5	5.17	5.34	5.52	5.7	5.85	6.01	6.17	6.33	6.48	6.66	6.84	7.04	7.25	7.43	7.62	7.81	8
1.40	2.98	3.15	3.33	3.5	3.64	3.8	3.94	4.1	4.25	4.4	4.52	4.66	4.8	4.93	5.09	5.26	5.44	5.62	5.8	5.96	6.12	6.28	6.44	6.6	6.77	6.96	7.16	7.36	7.55	7.74	7.93	8.12
1.45	3.04	3.22	3.4	3.57	3.71	3.87	4.01	4.18	4.33	4.48	4.6	4.75	4.88	5.02	5.18	5.35	5.53	5.72	5.9	6.07	6.23	6.39	6.55	6.71	6.88	7.07	7.27	7.47	7.66	7.86	8.05	8.25
1.50	3.1	3.28	3.46	3.63	3.77	3.94	4.08	4.25	4.4	4.56	4.68	4.83	4.96	5.1	5.26	5.43	5.62	5.81	6	6.17	6.33	6.5	6.66	6.82	6.99	7.18	7.38	7.58	7.77	7.97	8.17	8.37
1.55	3.16	3.34	3.52	3.69	3.84	4	4.15	4.32	4.47	4.63	4.76	4.91	5.04	5.18	5.34	5.51	5.71	5.9	6.09	6.27	6.43	6.6	6.77	6.93	7.1	7.29	7.49	7.69	7.88	8.08	8.28	8.48
1.60	3.22	3.4	3.58	3.75	3.91	4.06	4.22	4.39	4.54	4.7	4.83	4.99	5.12	5.26	5.42	5.59	5.79	5.99	6.18	6.37	6.53	6.7	6.87	7.04	7.2	7.39	7.59	7.79	7.99	8.19	8.39	8.59
1.65	3.28	3.46	3.64	3.81	3.97	4.12	4.28	4.45	4.6	4.77	4.9	5.07	5.2	5.34	5.5	5.68	5.87	6.07	6.27	6.46	6.63	6.79	6.97	7.14	7.3	7.49	7.69	7.89	8.1	8.29	8.5	8.7
1.70	3.33	3.51	3.69	3.87	4.03	4.18	4.34	4.51	4.66	4.84	4.97	5.14	5.28	5.42	5.57	5.76	5.95	6.15	6.36	6.55	6.72	6.88	7.06	7.23	7.4	7.59	7.79	7.99	8.2	8.39	8.6	8.8
1.75	3.38	3.56	3.74	3.92	4.09	4.24	4.4	4.57	4.73	4.9	5.04	5.21	5.35	5.5	5.65	5.84	6.03	6.23	6.45	6.64	6.81	6.97	7.15	7.33	7.5	7.69	7.89	8.09	8.3	8.49	8.7	8.9
1.80	3.43	3.61	3.79	3.97	4.15	4.3	4.46	4.63	4.79	4.96	5.1	5.28	5.42	5.57	5.72	5.92	6.11	6.31	6.53	6.72	6.89	7.06	7.24	7.43	7.6	7.79	7.99	8.19	8.4	8.59	8.8	9
1.85	3.48	3.66	3.84	4.02	4.2	4.36	4.52	4.69	4.85	5.02	5.16	5.35	5.49	5.65	5.8	6	6.19	6.39	6.61	6.8	6.97	7.15	7.33	7.52	7.7	7.89	8.09	8.29	8.5	8.69	8.9	9.1
1.90	3.53	3.71	3.89	4.07	4.25	4.42	4.58	4.75	4.91	5.08	5.22	5.41	5.56	5.72	5.87	6.08	6.27	6.47	6.69	6.88	7.05	7.24	7.42	7.61	7.8	7.99	8.19	8.39	8.59	8.78	8.99	9.2
1.95	3.58	3.76	3.94	4.12	4.3	4.48	4.63	4.8	4.97	5.14	5.28	5.47	5.63	5.79	5.95	6.16	6.35	6.55	6.77	6.96	7.13	7.32	7.51	7.7	7.89	8.08	8.28	8.48	8.68	8.88	9.09	9.3
2.00	3.63	3.81	3.99	4.17	4.35	4.53	4.69	4.86	5.03	5.2	5.34	5.53	5.7	5.86	6.02	6.24	6.43	6.63	6.84	7.04	7.21	7.4	7.6	7.78	7.98	8.17	8.37	8.57	8.77	8.98	9.18	9.4
2.05	3.68	3.86	4.04	4.22	4.4	4.58	4.73	4.91	5.09	5.26	5.4	5.59	5.77	5.93	6.1	6.31	6.51	6.7	6.91	7.11	7.29	7.48	7.68	7.87	8.07	8.26	8.46	8.66	8.86	9.07	9.28	9.49
2.10	3.73	3.91	4.09	4.27	4.45	4.63	4.78	4.96	5.15	5.32	5.46	5.65	5.83	6	6.18	6.39	6.58	6.77	6.98	7.18	7.37	7.56	7.76	7.95	8.15	8.35	8.55	8.75	8.95	9.16	9.37	9.58
2.15	3.78	3.96	4.14	4.32	4.5	4.68	4.83	5.01	5.21	5.38	5.52	5.71	5.89	6.07	6.25	6.45	6.65	6.84	7.05	7.25	7.44	7.64	7.84	8.03	8.23	8.43	8.64	8.84	9.04	9.25	9.46	9.67
2.20	3.83	4.01	4.19	4.37	4.55	4.73	4.88	5.06	5.27	5.44	5.58	5.77	5.95	6.14	6.32	6.52	6.72	6.91	7.12	7.32	7.51	7.72	7.91	8.11	8.31	8.51	8.72	8.92	9.13	9.34	9.55	9.76
2.25	3.88	4.06	4.24	4.42	4.6	4.78	4.93	5.11	5.32	5.5	5.64	5.83	6.02	6.21	6.39	6.59	6.79	6.98	7.19	7.39	7.58	7.79	7.99	8.19	8.39	8.59	8.8	9	9.22	9.43	9.63	9.85
2.30	3.93	4.11	4.29	4.47	4.65	4.83	4.98	5.16	5.37	5.56	5.7	5.89	6.08	6.27	6.46	6.66	6.86	7.05	7.26	7.46	7.65	7.86	8.06	8.27	8.46	8.67	8.88	9.08	9.3	9.51	9.71	9.93
2.35	3.98	4.16	4.34	4.52	4.7	4.88	5.03	5.21	5.42	5.62	5.76	5.95	6.15	6.34	6.53	6.73	6.93	7.12	7.33	7.53	7.72	7.93	8.14	8.34	8.54	8.75	8.96	9.16	9.38	9.59	9.8	10.02
2.40	4.03	4.21	4.39	4.57	4.75	4.93	5.08	5.26	5.47	5.67	5.82	6.01	6.21	6.41	6.6	6.8	7	7.19	7.4	7.6	7.79	8	8.21	8.41	8.61	8.82	9.04	9.24	9.46	9.67	9.89	10.1
2.45	4.08	4.26	4.44	4.62	4.8	4.98	5.13	5.31	5.52	5.72	5.88	6.07	6.27	6.48	6.67	6.87	7.06	7.25	7.46	7.66	7.86	8.07	8.28	8.48	8.68	8.9	9.11	9.32	9.54	9.75	9.97	10.19
2.50	4.13	4.31	4.49	4.67	4.85	5.03	5.18	5.36	5.57	5.77	5.94	6.13	6.33	6.54	6.73	6.93	7.12	7.31	7.52	7.72	7.93	8.14	8.35	8.55	8.76	8.97	9.18	9.4	9.61	9.82	10.05	10.27
2.55	4.18	4.36	4.54	4.72	4.9	5.08	5.23	5.41	5.62	5.82	6	6.19	6.39	6.6	6.79	6.99	7.18	7.37	7.59	7.78	8	8.21	8.42	8.62	8.83	9.04	9.25	9.47	9.68	9.9	10.13	10.35
2.60	4.23	4.41	4.59	4.77	4.95	5.13	5.28	5.46	5.67	5.87	6.05	6.25	6.45	6.66	6.85	7.05	7.24	7.43	7.64	7.84	8.07	8.27	8.49	8.69	8.9	9.11	9.32	9.54	9.75	9.97	10.2	10.43
2.65	4.28	4.46	4.64	4.82	5	5.18	5.33	5.51	5.72	5.92	6.1	6.31	6.51	6.72	6.91	7.11	7.31	7.49	7.7	7.9	8.13	8.33	8.56	8.76	8.97	9.18	9.39	9.61	9.82	10.05	10.28	10.51
2.70	4.33	4.51	4.69	4.87	5.05	5.23	5.38	5.56	5.77	5.97	6.15	6.37	6.57	6.78	6.97	7.17	7.37	7.55	7.76	7.96	8.19	8.39	8.62	8.83	9.04	9.25	9.46	9.69	9.89	10.12	10.35	10.58
2.75	4.38	4.56	4.74	4.92	5.1	5.28	5.43	5.61	5.82	6.02	6.2	6.42	6.63	6.84	7.03	7.23	7.43	7.61	7.82	8.02	8.25	8.45	8.68	8.9	9.11	9.32	9.54	9.76	9.96	10.19	10.43	10.66

Figure 44. Table NonTV to Determine Runoff as a Function of the RI Value and Precipitation (Data for SE Region)

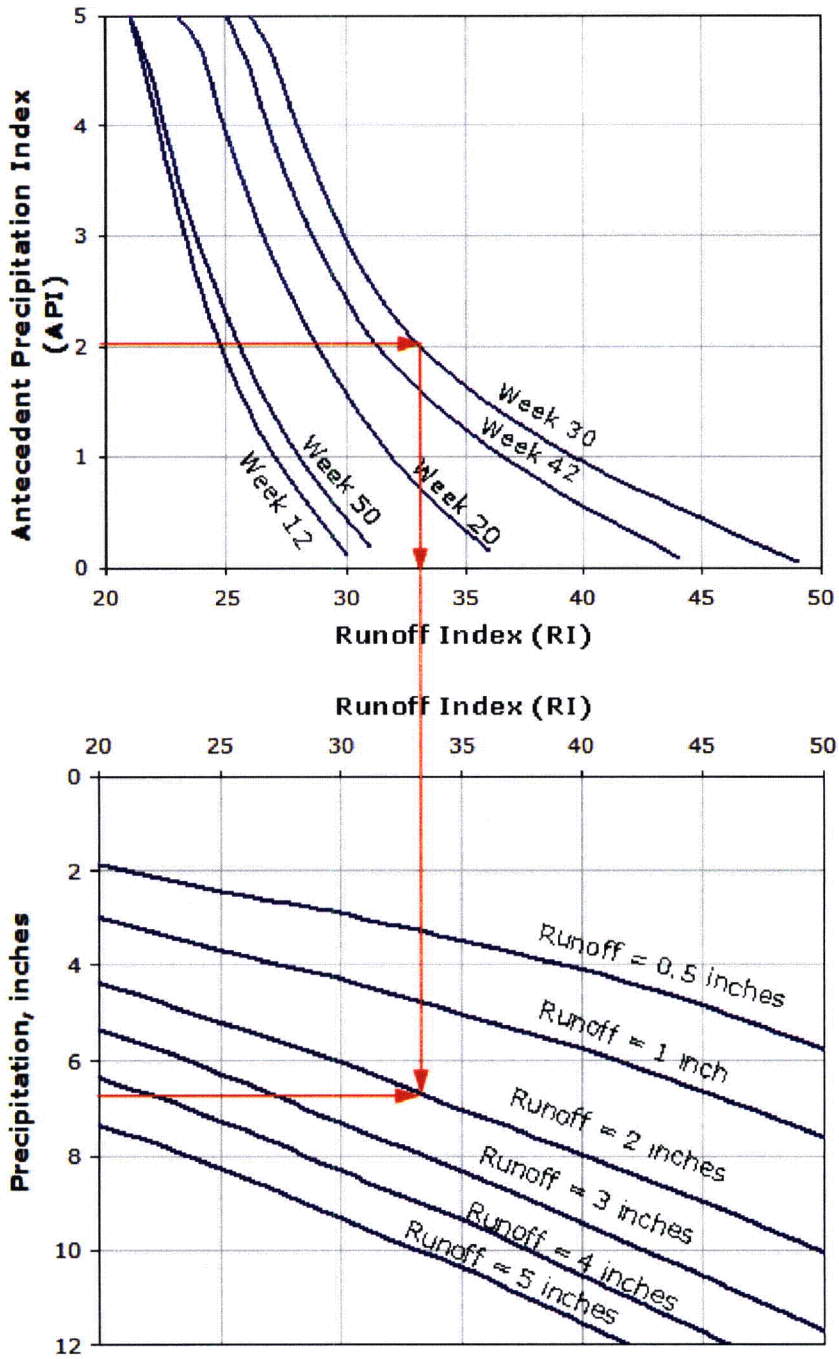

Figure 45. Illustration of Runoff Estimation (Data for SE Region)

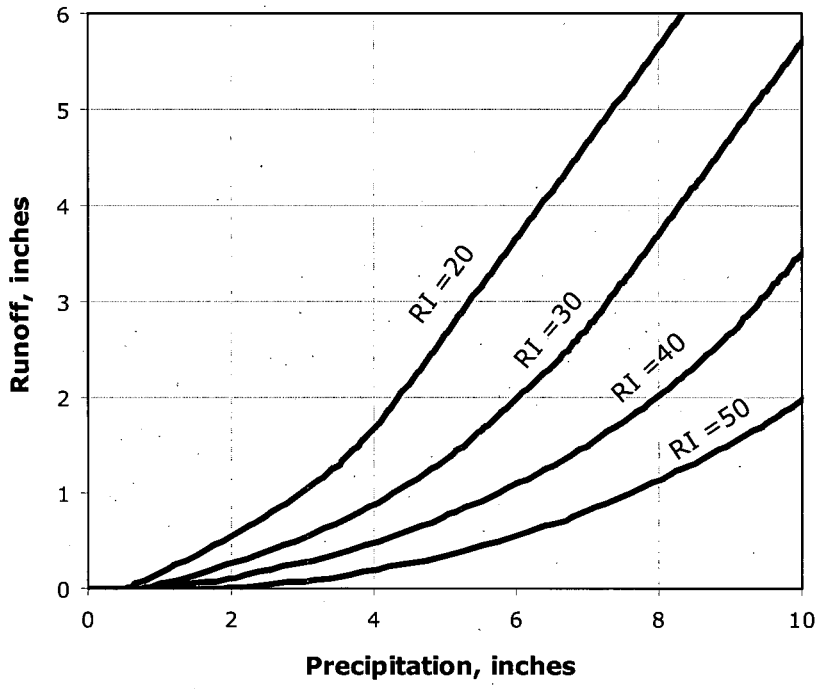

Figure 46. Runoff as a Function of Precipitation for Different RI values, Plotted from Data from the Table NonTV (Data for SE Region)

3.1.5 Assessment of Runoff Estimates produced by FLDHYDRO

To assess the ability of FLDHYDRO to estimate the runoff volume for a storm event in the absence of recorded flow data, FLDHYDRO is applied to several historic storms and its estimates are compared with runoff volumes obtained from recorded flood hydrographs. Data from 42 storms in 20 different subbasins are used for this purpose. Table 15 gives the date, rainfall depth, and runoff depth for these events. Each of the basins listed in Table 15 is defined by a number that is used in Figure 42 to show its location.

Table 15. Storms used to assess FLDHYDRO's runoff predictive ability

Basin		Starting Date of Storm Event	Rainfall depth	Runoff depth
Number	Area			
	sq mi		in	in
1	944.42	5-3-03	5.66	1.40
1	944.42	9-14-04	6.25	2.21
2	913.08	5-3-03	5.84	1.48
2	913.08	9-14-04	3.82	1.32
3	667.14	5-3-03	7.18	2.68
3	667.14	9-14-04	4.71	2.23
4	804.85	11-16-03	3.29	1.22
4	804.85	9-14-04	4.59	2.58
5	378.71	3-16-02	4.48	0.92

Basin		Starting Date of Storm Event	Rainfall depth	Runoff depth
Number	Area			
	sq mi		in	in
5	378.71	11-16-03	3.15	0.81
6	855.04	5-3-03	2.82	1.13
6	855.04	9-14-04	2.62	0.64
7	352.06	3-17-02	4.03	3.45
7	352.06	5-4-03	6.20	3.85
9	703.25	3-16-02	4.60	1.55
9	703.25	11-18-03	3.85	1.44
10	468.25	11-18-03	3.63	1.47
10	468.25	9-16-04	3.71	2.36
11	667.67	3-16-02	4.10	1.04
11	667.67	11-18-03	3.45	1.04
13	668.88	3-17-02	4.81	3.46
13	668.88	11-18-03	3.91	2.02
15	552.21	3-17-02	4.35	3.37
15	552.21	11-18-03	2.56	1.29
35	868.78	2-14-03	6.26	4.53
35	868.78	9-16-04	5.63	3.31
38	189.08	5-5-03	4.77	1.68
38	189.08	9-15-04	5.68	2.84
39	214.29	5-4-03	5.20	1.26
39	214.29	9-16-04	3.95	1.53
39	214.29	9-16-04	5.89	1.53
39	214.29	7-28-05	2.71	0.96
40	565.06	5-5-03	5.94	3.05
40	565.06	12-5-04	3.02	1.17
41	49.82	4-18-98	2.22	1.46
42	231.61	9-16-04	4.54	1.42
42	231.61	7-1-05	4.40	0.94
43	362.63	5-5-03	6.28	2.98
43	362.63	9-15-04	4.11	1.73
43	362.63	4-17-98	2.27	1.88
44A	686.61	5-4-03	9.41	6.85
44A	686.61	9-16-04	5.20	1.99

3.2 FLDHYDRO Test Results

Input files to FLDHYDRO for each test problem are included in electronic form as Attachment 1. FLDHYDRO output files for each test problem are included in electronic form as Attachment 2. The FLDHYDRO source code and the executable that was used for these tests are included in the electronic Attachment 3. Solutions to the test problems using FLDHYDRO were compared to the independent calculations performed with the same theoretical basis outlined in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 1) and using Microsoft Excel 2003 SP3. These Excel files used for independent calculation are included as Attachment 4. The results of these comparisons are presented in below.

Table 16 gives the names of the Excel files used for the validation of FLDHYDRO. All these files are included in the Electronic Attachment 4.

Table 16. List of Excel Files Used for the Validation of FLDHYDRO

Test Problem	Excel File Name in Electronic Attachment 4
Test Problem 1	Fldhydro_sample1.xls
Test Problem 2	Fldhydro_sample2.xls
Test Problem 3	Fldhydro_sample3.xls
Test Problem 4	Fldhydro_sample4.xls
Test Problem 5	Fldhydro_sample5.xls
Test Problem 6	Fldhydro_sample6.xls

3.2.1 Tests of the Implementation of the FLDHYDRO Methodology

3.2.1.1 Test problem 1

A comparison of the API, RI, and runoff calculated with the FLDHYDRO code and those derived through independent calculations for Test Problem 1 is presented in Table 17. A comparison of the cumulative rainfall and runoff from the two methods is presented in Figure 47.

Table 17. Comparison of FLDHYDRO and Independent Calculations for Test Problem 1

	FLDHYDRO	Independent Calculations
API	2.14	2.14
RI (Initial)	27SE	27SE
RI (Used)	27SE	27SE
Basin Rainfall (in)	2.17	2.17
Basin Runoff (in)	0.37	0.37

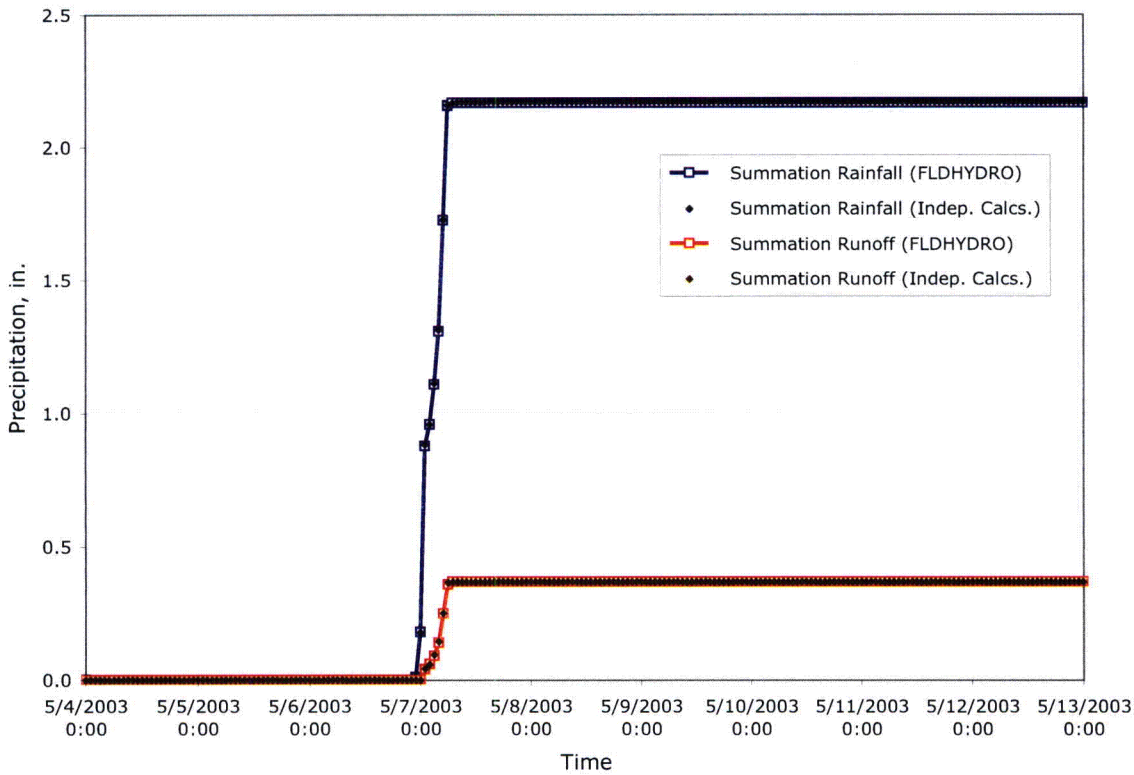

Figure 47. Comparison of Rainfall and Runoff for Test Problem 1 Obtained with FLDHYDRO and from Independent Calculations in Excel

As can be seen in Table 17 and Figure 47 the results of FLDHYDRO for Test Problem 1 are identical to those of the independent calculations for the same problem.

3.2.1.2 Test Problem 2

Table 18 compares the API, RI, and runoff calculated with FLDHYDRO and those obtained from the independent calculations for Test Problem 2. Figure 48 presents the results of the two methods for the cumulative rainfall and runoff for the same problem.

Table 18. Comparison of FLDHYDRO and Independent Calculations for Test Problem 2

	FLDHYDRO	Independent Calculations
API	2.14	2.14
RI (Initial)	27SE	27SE
RI (Used)	16SE	16SE
Basin Rainfall (in)	2.17	2.17
Basin Runoff (in)	0.87	0.87

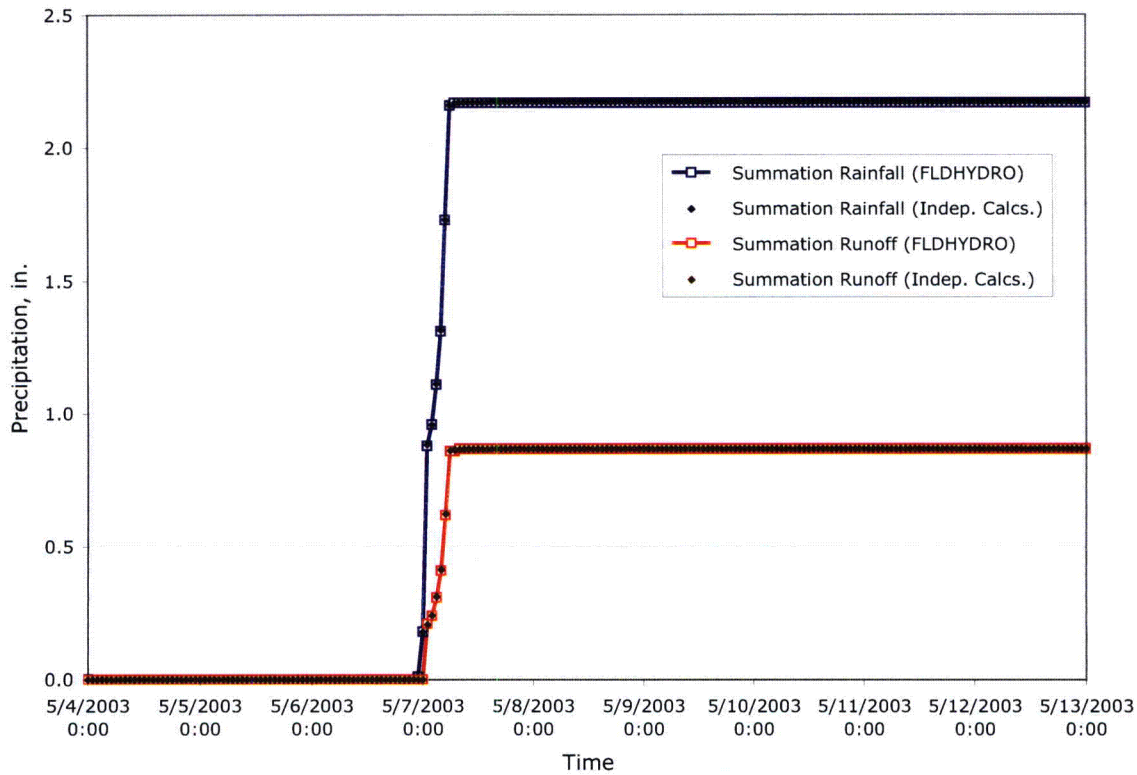

Figure 48. Comparison of Rainfall and Runoff for Test Problem 2 Obtained with FLDHYDRO and from Independent Calculations in Excel

As can be seen in Table 18 and Figure 48 the results of FLDHYDRO for Test problem 2 are identical to those of the independent calculations for the same problem.

3.2.1.3 Test Problem 3

Table 19 compares the API, RI, and runoff calculated with FLDHYDRO and those obtained from the independent calculations for Test Problem 3. Figure 49 presents the results of the two methods for the cumulative rainfall and runoff for the same problem.

Table 19. Comparison of FLDHYDRO and Independent Calculations for Test Problem 3

		FLDHYDRO	Independent Calculations
API	Flood 1	2.14	2.14
	Flood 2	3.85	3.85
RI (Initial)	Flood 1	27SE	27SE
	Flood 2	24SE	24SE
RI (Used)	Flood 1	35SE	16SE
	Flood 2	35SE	16SE
Basin Rainfall (in)		5.20	5.20
Basin Runoff (in)		1.26	1.26

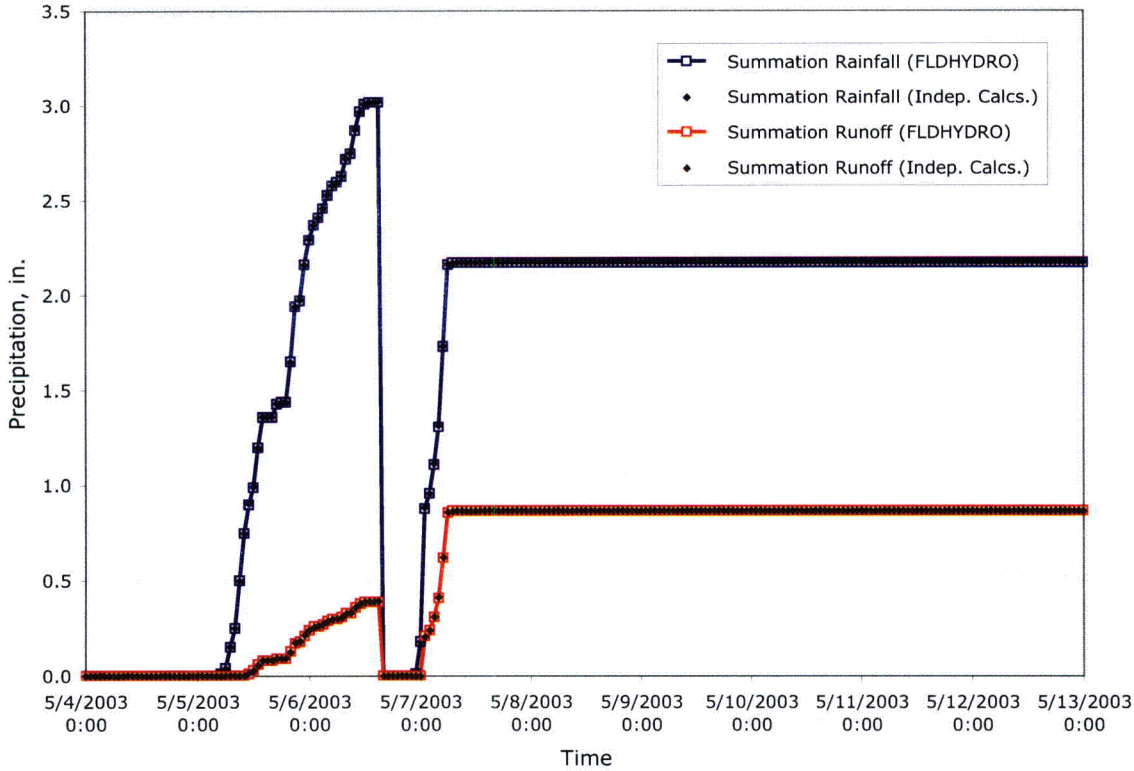

Figure 49. Comparison of Rainfall and Runoff for Test Problem 3 Obtained with FLDHYDRO and from Independent Calculations in Excel

As can be seen in Table 19 and Figure 49 the results of FLDHYDRO for Test problem 3 are identical to those of the independent calculations for the same problem.

3.2.1.4 Test Problem 4

Table 20 compares the API, RI, and runoff calculated with FLDHYDRO and those obtained from the independent calculations for Test Problem 4. Figure 50 presents the results of the two methods for the cumulative rainfall and runoff for the same problem.

Table 20. Comparison of FLDHYDRO and Independent Calculations for Test Problem 4

		FLDHYDRO	Independent Calculations
API		2.14	2.14
RI (Initial) by Rain gage	Station 51R	23TV	23TV
	Station 59R	22TV	22TV
	Station 77R	22TV	22TV
	Station 9R	22TV	22TV
	Station 54	22TV	22TV
	Station 58	23TV	23TV
	Station 66	21TV	21TV
	Station 64	22TV	22TV
	Station 65	22TV	22TV
	Station 1	22TV	22TV
	Station 2	22TV	22TV
	Station 4	22TV	22TV
	Station 32	21TV	21TV
	Station 72	22TV	22TV
	Station 63	23TV	23TV
	Station 57	21TV	21TV
	Station 55	22TV	22TV
RI (Used) by Rain gage	Station 51R	25TV	25TV
	Station 59R	24TV	24TV
	Station 77R	24TV	24TV
	Station 9R	24TV	24TV
	Station 54	24TV	24TV
	Station 58	25TV	25TV
	Station 66	23TV	23TV
	Station 64	24TV	24TV
	Station 65	24TV	24TV
	Station 1	24TV	24TV
	Station 2	24TV	24TV
	Station 4	24TV	24TV
	Station 32	23TV	23TV
	Station 72	24TV	24TV
	Station 63	25TV	25TV
	Station 57	23TV	23TV
	Station 55	24TV	24TV
Basin Rainfall (in)		3.22	3.22
Basin Runoff (in)		1.71	1.71

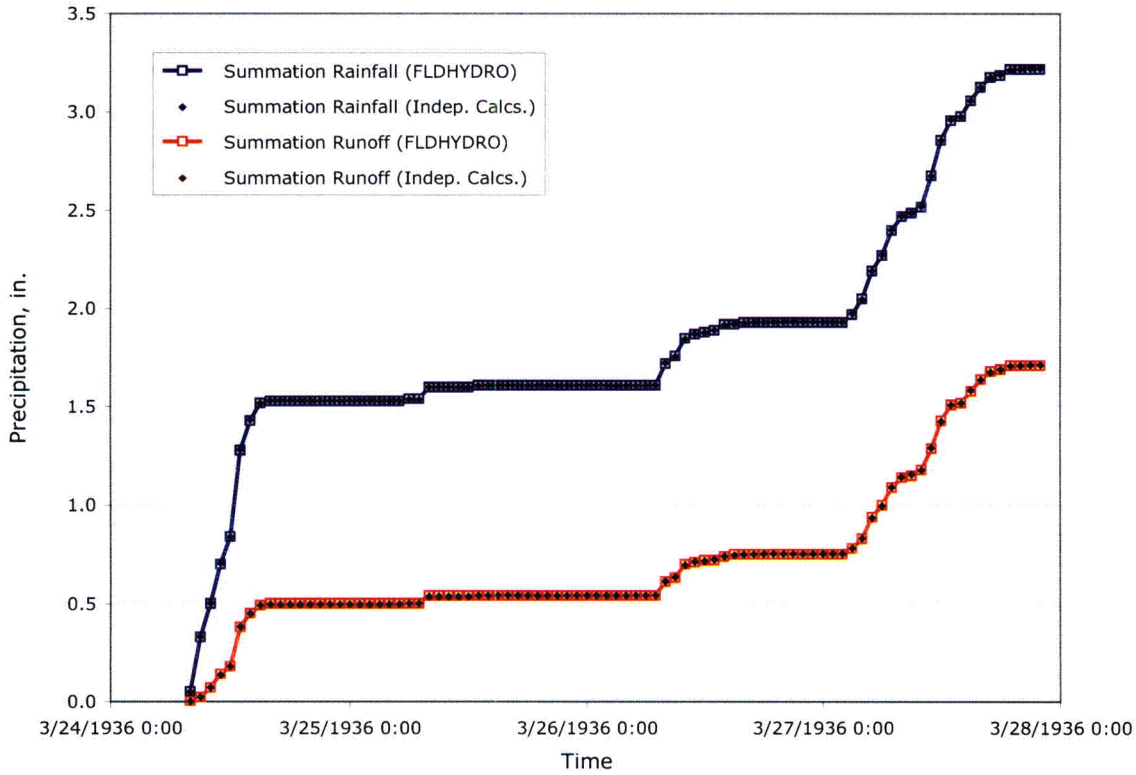

Figure 50. Comparison of Rainfall and Runoff for Test Problem 4 Obtained with FLDHYDRO and from Independent Calculations in Excel

As can be seen in Table 20 and Figure 50 the results of FLDHYDRO for Test problem 4 are identical to those of the independent calculations for the same problem.

3.2.1.5 Test Problem 5

Table 21 compares the API, RI, and runoff calculated with FLDHYDRO and those obtained from the independent calculations for Test Problem 5. Figure 51 presents the results of the two methods for the cumulative rainfall and runoff for the same problem. Figure 52 plots the flood hydrograph for Test Problem 5 obtained with FLDHYDRO and that obtained from the independent calculations for the same problem.

Table 21. Comparison of FLDHYDRO and Independent Calculations for Test Problem 5

		FLDHYDRO	Independent Calculations
API	Flood 1	1.00	1.00
	Flood 2	3.64	3.65
RI (Initial)	Flood 1	22TV	22TV
	Flood 2	20TV	20TV
RI (Used)	Flood 1	22TV	22TV
	Flood 2	20TV	20TV
Basin Rainfall (in)		20.24	20.24
Basin Runoff (in)		17.44	17.44

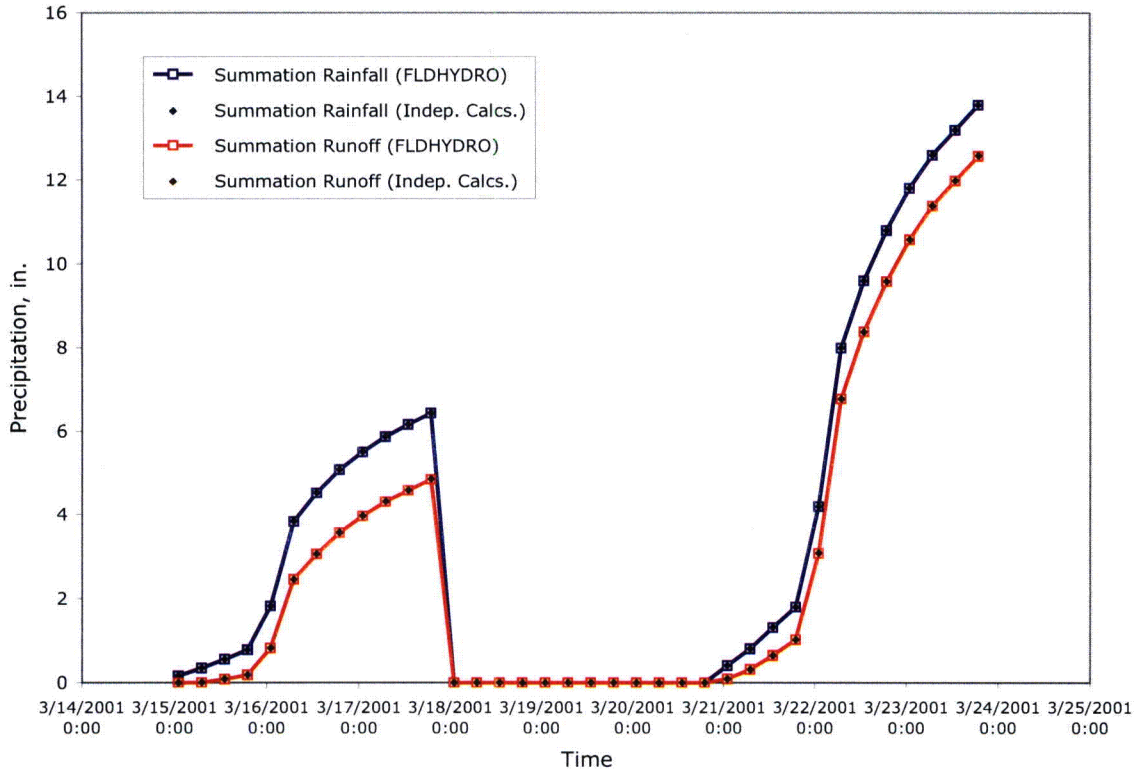

Figure 51. Comparison of Rainfall and Runoff for Test Problem 5 Obtained with FLDHYDRO and from Independent Calculations in Excel

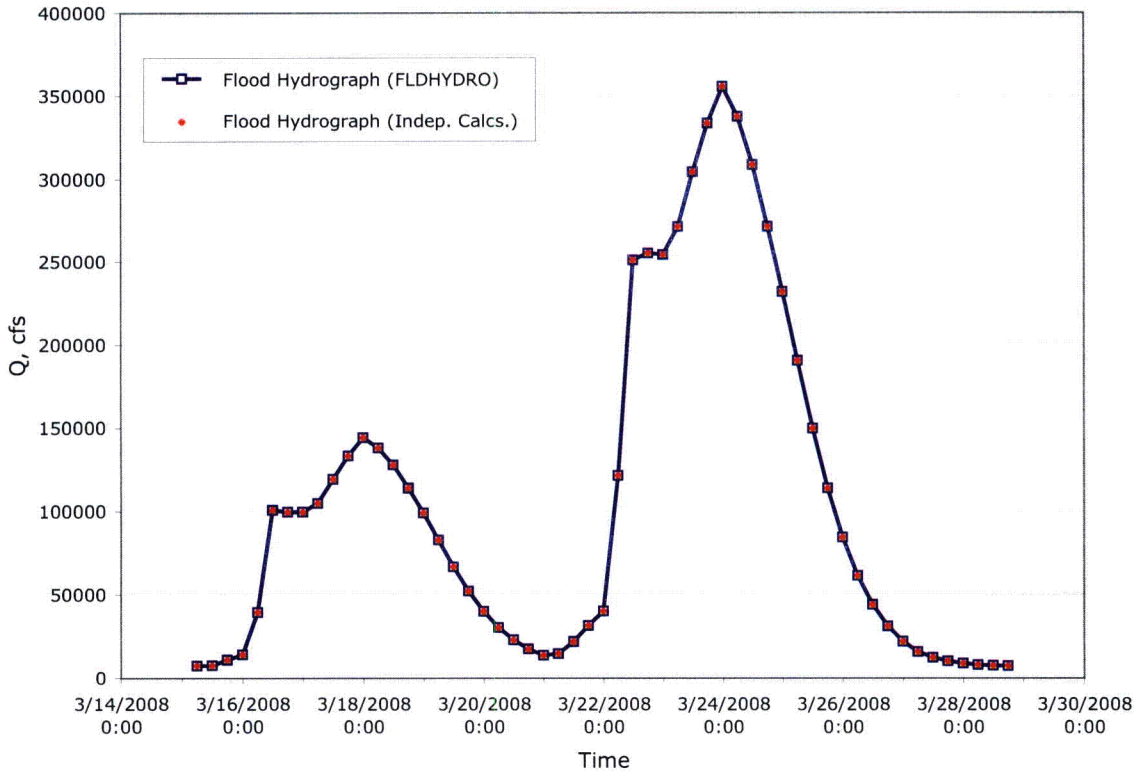

Figure 52. Comparison of Flood Hydrograph for Test Problem 5 Obtained with FLDHYDRO and from Independent Calculations in Excel

As can be seen in Table 21, Figure 51 and Figure 52 the results of FLDHYDRO for Test Problem 5 are practically identical to those of the independent calculations for the same problem. The only difference in the results obtained with FLDHYDRO and the independent calculations was in the calculated value of the API for the second storm.

3.2.1.6 Test Problem 6

Table 22 compares the API, RI and runoff for each subbasin calculated with FLDHYDRO and those obtained from the independent calculations for Test Problem 6. Figure 53 and Figure 54 present the cumulative rainfall and runoff respectively for the same problem. Figure 55 plots the flood hydrographs for the seven subbasins of Test Problem 6 obtained with FLDHYDRO and that obtained from the independent calculations for the same problem.

Table 22. Comparison of FLDHYDRO and Independent Calculations for Test Problem 6

			FLDHYDRO	Independent Calculations
API (for all Subbasins)	Flood 1		0.50	0.50
	Flood 2		2.70	2.70
RI (by Subbasin)	Flood 1	South Holston Dam	24TV	24TV
		Watauga Dam	29TV	29TV
		Boone Local	29TV	29TV
		Fort Patrick Henry Local	24TV	24TV
		N. Fk. Holston R. at Gate City	24TV	24TV
		Holston River at Surgoinsville	24TV	24TV
		Cherokee Local	24TV	24TV
	Flood 2	South Holston Dam	21TV	21TV
		Watauga Dam	25TV	25TV
		Boone Local	25TV	25TV
		Fort Patrick Henry Local	21TV	21TV
		N. Fk. Holston R. at Gate City	21TV	21TV
		Holston River at Surgoinsville	21TV	21TV
		Cherokee Local	21TV	21TV
Basin Rainfall (in) by Subbasin		South Holston Dam	12.19	12.19
		Watauga Dam	12.69	12.69
		Boone Local	13.29	13.29
		Fort Patrick Henry Local	13.39	13.39
		N. Fk. Holston R. at Gate City	12.29	12.29
		Holston River at Surgoinsville	13.32	13.32
		Cherokee Local	14.21	14.21
Basin Runoff (in) by Subbasin		South Holston Dam	9.08	9.08
		Watauga Dam	8.24	8.24
		Boone Local	8.84	8.84
		Fort Patrick Henry Local	10.28	10.28
		N. Fk. Holston R. at Gate City	9.18	9.18
		Holston River at Surgoinsville	10.21	10.21
		Cherokee Local	11.10	11.10

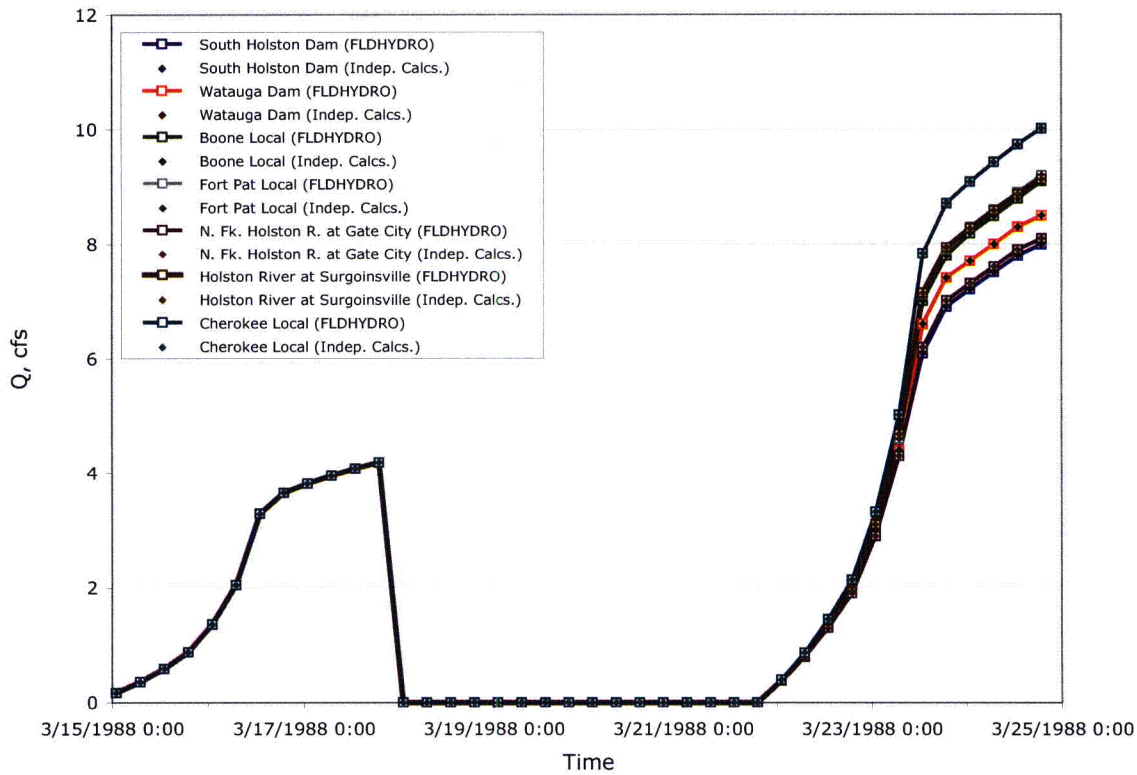

Figure 53. Comparison of Rainfall for Test Problem 6 Obtained with FLDHYDRO and from Independent Calculations in Excel

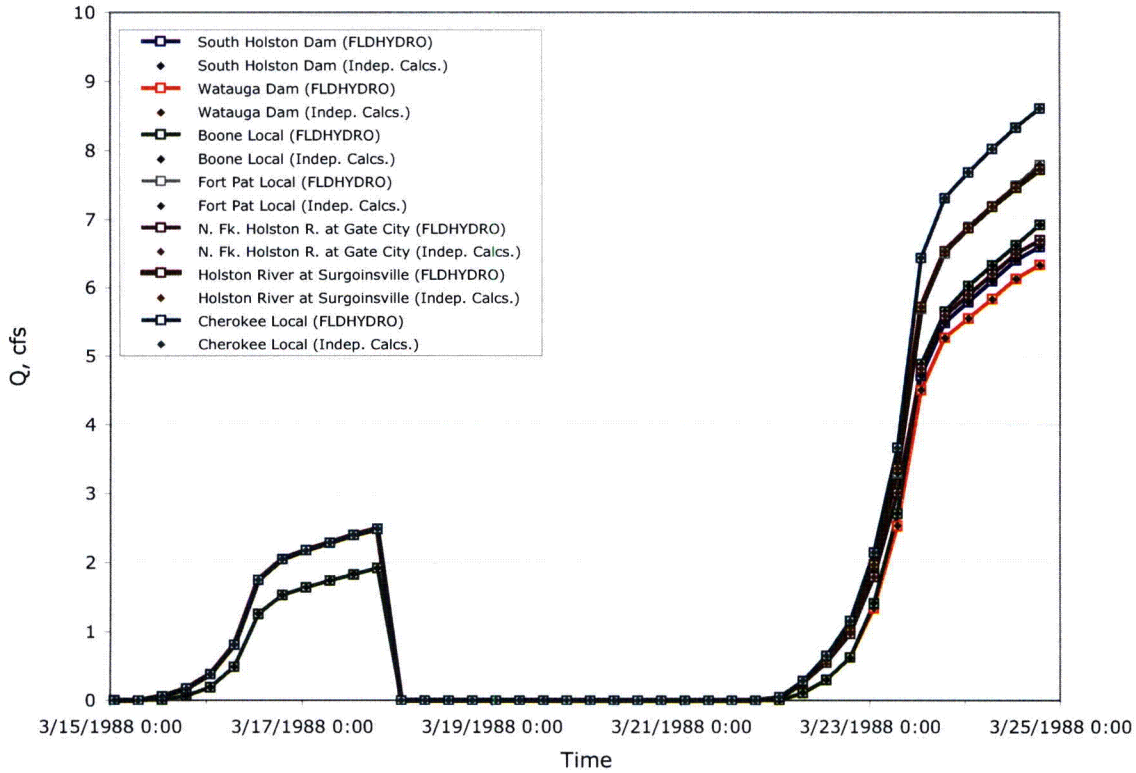

Figure 54. Comparison of Runoff for Test Problem 6 Obtained with FLDHYDRO and from Independent Calculations in Excel

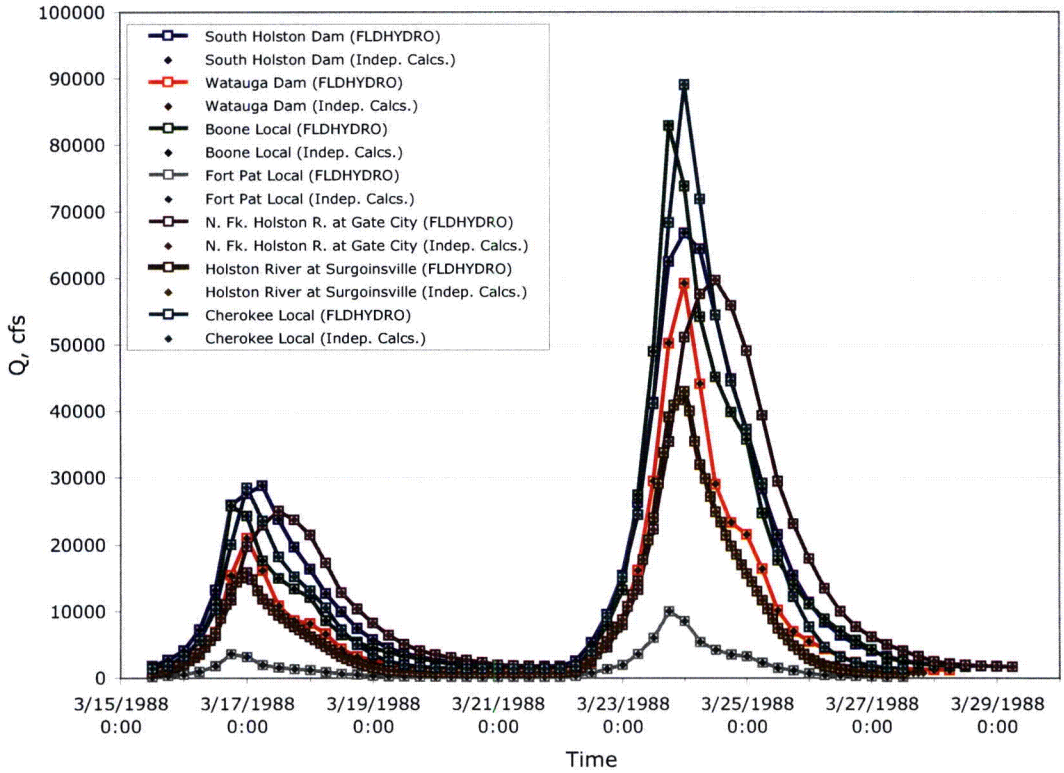

Figure 55. Comparison of Flood Hydrographs for Test Problem 6 Obtained with FLDHYDRO and from Independent Calculations in Excel

As can be seen in Table 22, Figure 53, Figure 54, and Figure 55 the results of FLDHYDRO for Test problem 6 are practically identical to those of the independent calculations for the same problem. The only results where there is a small difference are in the flow values of the flood hydrographs. The maximum difference between computed flow values is about 0.03 percent in the Holston River at Surgoinsville flood hydrograph.

3.2.1.7 Summary of Implementation Test Problems

As can be seen in Table 17 through Table 22 and Figure 47 through Figure 55, the results obtained through the two different methods are almost identical. However, for Test Problem 5 the API for the second storm obtained from FLDHYDRO and the API obtained through independent calculation differs slightly (as can be seen in Table 21). In addition, the flood hydrographs obtained from FLDHYDRO and those obtained through independent calculations also differ slightly. These differences can be attributed to differences in rounding between the two methods.

As can be seen in Figure 49 and Figure 51 when more than one storm is input, the cumulative rainfall and runoff values return to zero between the storms.

Also, Test Problems 5 and 6 use 6-hour rainfall input data instead of hourly data. In order to accommodate 6-hour data in FLDHYDRO, the user inputs the 6-hour rainfall data into FLDHYDRO as is, and places zeros for the hours when data is not collected. In this way, the cumulative runoff calculated every sixth hour is correct, while the cumulative runoff

calculated for the intermediate hours is erroneous. Therefore, only every sixth line of output is used when plotting the rainfall and runoff output in Figure 51, Figure 53, and Figure 54. As can be seen in Figure 52 and Figure 55, because the input unit hydrograph duration is also 6 hours, the erroneous values in the runoff data do not affect the 6-hour runoff values used to calculate the flood hydrograph.

Based on the results of this analysis, it is verified that the FLDHYDRO code properly implements the method proposed by Kohler and Linsley and outlined in Reference 1.

3.2.2 Tests of Specific Options Available in FLDHYDRO

Section 3.2.1 focused on demonstrating that the FLDHYDRO code correctly implements the method for estimating runoff proposed by Kohler and Linsley. This section tests specific options available in FLDHYDRO and suggests where the user should be cautious in the use of the code.

First, the ability of FLDHYDRO to go off the TV or NonTV table when using CHKVOL is explored. If a CHKVOL value is picked such that the expected runoff is larger than the largest possible runoff volume provided in the TV or NonTV table, FLDHYDRO will return the rainfall as the runoff. This is demonstrated by Test Problem 2a and shown in Table 23.

Table 23. Comparison of FLDHYDRO Results for Test Problem 2 and 2a

	Test Problem 2	Test Problem 2a
CHKVOL (in)	0.90	0.96
API	2.14	2.14
RI (Initial)	27SE	27SE
RI (Used)	16SE	15SE
Basin Rainfall (in)	2.17	2.17
Basin Runoff (in)	0.87	2.17

As can be seen in Table 23, the rainfall and runoff calculated by FLDHYDRO for Test Problem 2a are identical. In this case FLDHYDRO went off the edge of the NonTV table. The RI (Used) value for Test Problem 2a is given as 15SE, but there is no such column in the NonTV table. Therefore, users of FLDHYDRO need to check their output when using CHKVOL to make sure the program did not run off the tables.

Next, Test Problem 3a was devised to show what happens when FLDHYDRO is run for two consecutive storms (the second storm begins one time step after the first storm ends). In this case, the runoff is not reset to zero for the second storm while the rainfall values do reset, as can be seen in Figure 56.

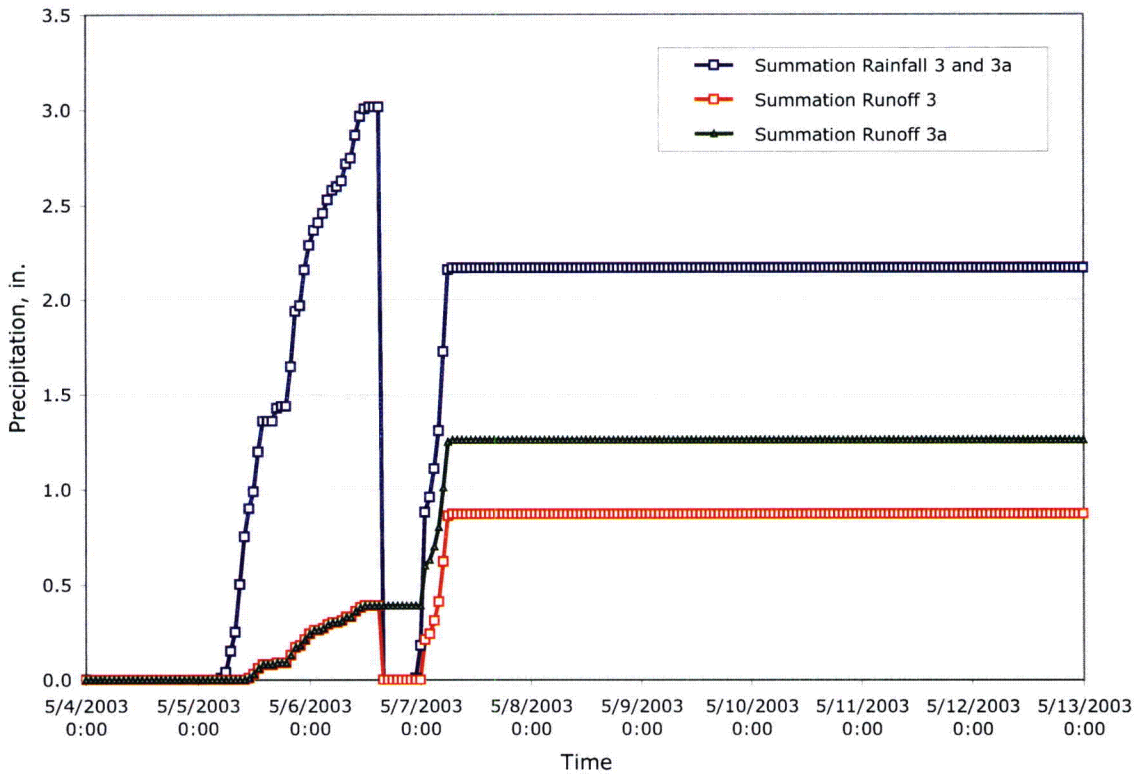

Figure 56. Comparison of Rainfall and Runoff from FLDHYDRO for Test Problems 3 and 3a

A can be seen in Figure 56, when storms are consecutive the runoff does not reset for the second storm while the rainfall does. Therefore, when using FLDHYDRO with more than one storm, the user should be sure to allow at least one time step off between storms. Also, it is important for the user to note that the value of CHKVOL input for the second storm in FLDHYDRO is cumulative with the first storm. Therefore in Test Problem 3, the second CHKVOL of 1.30 implies an expected volume of 0.90 (=1.30-0.40) for the second storm.

Finally, Test Problem 7 explores the behavior of FLDHYDRO when an hourly gage outside of the watershed is used to estimate the average rainfall together with the gages inside the watershed. If a gage with a zero Thiessen weight has a rainfall record longer than the other gages, FLDHYDRO can give erroneous zeros at the end of the computed runoff values. A solution to this is to exclude this gage in the Thiessen weightings, as in Test Problem 7a. The runoff values for these two problems are shown in Table 24.

Table 24. Comparison of FLDHYDRO Results for Test Problem 7 and 7a

Date	Time	Summation Rainfall (in)	Test Problem 7 Runoff (in)	Test Problem 7a Runoff (in)
3/15/73	600	0.64	0.24	0.24
3/15/73	700	1.09	0.53	0.53
3/15/73	800	1.18	0.59	0.59
3/15/73	900	1.21	0.61	0.61
3/15/73	1000	1.22	0.62	0.62

Date	Time	Summation Rainfall (in)	Test Problem 7 Runoff (in)	Test Problem 7a Runoff (in)
3/15/73	1100	1.25	0.63	0.63
3/15/73	1200	1.26	0.64	0.64
3/15/73	1300	1.26	0.64	0.64
3/15/73	1400	1.28	0.65	0.65
3/15/73	1500	1.34	0.69	0.69
3/15/73	1600	1.36	0.71	0.71
3/15/73	1700	1.39	0.73	0.73
3/15/73	1800	1.56	0.84	0.84
3/15/73	1900	1.72	0.96	0.96
3/15/73	2000	1.97	1.15	1.15
3/15/73	2100	2.36	1.46	1.46
3/15/73	2200	2.63	1.70	1.70
3/15/73	2300	2.87	1.90	1.90
3/15/73	2400	3.13	2.12	2.12
3/16/73	100	3.35	2.32	2.32
3/16/73	200	3.63	2.57	2.57
3/16/73	300	3.80	2.72	2.72
3/16/73	400	4.15	3.04	3.04
3/16/73	500	4.60	3.46	3.46
3/16/73	600	4.85	3.69	3.69
3/16/73	700	4.96	3.80	3.80
3/16/73	800	5.04	3.87	3.87
3/16/73	900	5.08	3.91	3.91
3/16/73	1000	5.12	3.95	3.95
3/16/73	1100	5.16	3.99	3.99
3/16/73	1200	5.33	4.15	4.15
3/16/73	1300	5.75	4.56	4.56
3/16/73	1400	6.17	4.96	4.96
3/16/73	1500	6.41	5.20	5.20
3/16/73	1600	6.45	5.23	5.23
3/16/73	1700	6.45	5.24	5.24
3/16/73	1800	6.45	5.24	5.24
3/16/73	1900	6.46	5.25	5.25
3/16/73	2000	6.47	5.26	5.26
3/16/73	2100	6.48	5.27	5.27
3/16/73	2200	6.49	5.27	5.27
3/16/73	2300	6.49	5.28	5.28
3/16/73	2400	6.50	5.28	5.28
3/17/73	100	6.50	5.28	5.28
3/17/73	200	6.50	5.28	5.28
3/17/73	300	6.50	5.28	5.28
3/17/73	400	6.50	5.28	5.28
3/17/73	500	6.50	5.28	5.28
3/17/73	600	6.50	5.28	5.28

Date	Time	Summation Rainfall (in)	Test Problem 7 Runoff (in)	Test Problem 7a Runoff (in)
3/17/73	700	6.52	5.30	5.30
3/17/73	800	6.52	0.00	
3/17/73	900	6.52	0.00	
3/17/73	1000	6.52	0.00	
3/17/73	1100	6.52	0.00	
3/17/73	1200	6.52	0.00	

A can seen in Table 24, if the gage with the long record is given a Thiessen weight of zero, erroneous zeros results at the end of the runoff calculation. However, if this gage is omitted from the Thiessen weighting, the erroneous zeros are not present. Therefore, it is recommended that when setting up FLDHYDRO input files, gages outside the watershed should be omitted from the Thiessen weighting instead of being assigned a zero value.

3.2.3 Assessment of Runoff Estimates produced by FLDHYDRO

Table 25 summarizes the runoff estimates obtained by running FLDHYDRO for the 42 storms listed in Table 15. For each of these runs of FLDHYDRO Table 25 gives the runoff computed with FLDHYDRO using the Antecedent Rainfall method (see Section 3.1.4.1) and with the Check Volume method (see Section 3.1.4.2), as well as the runoff estimated from flow data. The latter was estimated from the flood hydrograph after separating the base flow from the starting point of the rising limb of the hydrograph to a point on the receding limb of the hydrograph N hours after the time of peak discharge, where N is the area of the watershed in square miles, raised to the one-fifth power as described in Reference 12.

Table 25 gives also the difference between the runoff obtained with FLDHYDRO and that estimated from the flood hydrograph, as well as the difference between the originally computed runoff by the API method and the value obtained with the CV method. The runoff given in Table 25 is expressed as depth, obtained by dividing the total runoff volume by the area of the basin. It should also be noted that in some bases the flood hydrograph used to estimate directly the runoff volume was based on streamgage data. These basins are referred to as headwater basins and are marked with an (H) in Table 25. In the remaining basins the flood hydrograph was obtained through calculations on data from gages outside these basins. Therefore, these runoff estimates are subject to greater uncertainty.

Figure 57 plots the FLDHYDRO runoff vs. the runoff estimated from the flood hydrograph. As can be seen in this figure there is significant spread around the 45-degree line which represents the perfect match between the FLDHYDRO and the runoff estimates from the flood hydrographs. Figure 58 plots the ratio of the computed over the measured runoff vs. the runoff volume. As can be seen in Table 25 and Figure 58 the difference between the runoff estimated from the flood hydrographs and the runoff obtained with FLDHYDRO ranges from -72 percent to 136 percent. Figure 58 suggests that the difference in the estimation of the runoff is getting smaller for larger runoff volumes. This is to be expected as for larger runoff volumes the effect of the losses estimated with the API method becomes less important as the losses represent an increasingly smaller fraction of the total precipitation volume. It should also be noted that the set of 42 applications of FLDHYDRO does not include many large storms. It includes only one large storm, the May 4, 2003 storm in basin 44A (Hiwassee at Charleston) which produced 6.85 inches of runoff. The second largest storm (the February 14, 2003 in basin 35, Emory at Mouth) produced 4.53 inches of runoff.

Table 25 Comparison of FLDHYDRO Runoff Estimates with Measured Data

Basin		Storm Event Starting Date	Rainfall depth	Runoff			Percent Difference	
Number	Area			Runoff from flow data	Computed with FLDHYDRO		Runoff from flow data – FLDHYDRO by API	Computed by API – FLDHYDRO by CV
					API method	CV method		
	sq mi		inches	inches	inches	inches	percent	percent
1 (H)	944.42	5-3-03	5.66	1.40	1.97	1.42	40.7	38.7
1 (H)	944.42	9-14-04	6.25	2.21	2.15	2.15	-2.7	0.0
2	913.08	5-3-03	5.84	1.48	3.10	1.39	109.5	123.0
2	913.08	9-14-04	3.82	1.32	1.06	1.29	-19.7	17.8
3 (H)	667.14	5-3-03	7.18	2.68	3.51	2.71	31.0	29.5
3 (H)	667.14	9-14-04	4.71	2.23	1.12	2.18	-49.8	48.6
4 (H)	804.85	11-16-03	3.29	1.22	0.56	1.18	-54.1	52.5
4 (H)	804.85	9-14-04	4.59	2.58	2.01	2.57	-22.1	21.8
5	378.71	3-16-02	4.46	0.92	2.12	0.90	130.4	135.6
5	378.71	11-16-03	3.15	0.81	0.81	0.81	0.0	0.0
6	855.04	5-3-03	2.82	1.13	1.19	1.11	5.3	7.2
6	855.04	9-14-04	2.62	0.64	0.32	0.63	-50.0	49.2
7 (H)	352.06	3-17-02	4.03	3.45	2.01	3.37	-41.7	40.4
7 (H)	352.06	5-4-03	6.20	3.85	3.13	3.82	-18.7	18.1
9 (H)	703.25	3-16-02	4.60	1.55	2.71	1.53	74.8	77.1
9 (H)	703.25	11-18-03	3.85	1.44	1.76	1.48	22.2	18.9
10 (H)	468.25	11-18-03	3.63	1.47	1.09	1.51	-25.9	27.8
10 (H)	468.25	9-16-04	3.71	2.36	0.92	2.34	-61.0	60.7
11	667.67	3-16-02	4.10	1.04	1.85	1.07	77.9	72.9
11	667.67	11-18-03	3.45	1.04	1.12	1.05	7.7	6.7
13 (H)	668.88	3-17-02	4.81	3.46	3.32	3.48	-4.0	4.6
13 (H)	668.88	11-18-03	3.91	2.02	0.74	2.02	-63.4	63.4
15	552.21	3-17-02	4.35	3.37	2.76	3.36	-18.1	17.9
15	552.21	11-18-03	2.56	1.29	0.85	1.28	-34.1	33.6
35 (H)	868.78	2-14-03	6.26	4.53	3.32	4.51	-26.7	26.4
35 (H)	868.78	9-16-04	5.63	3.31	1.90	3.32	-42.6	42.8
38 (H)	189.08	5-5-03	4.77	1.68	1.55	1.65	-7.7	6.1
38 (H)	189.08	9-15-04	5.68	2.84	1.27	2.82	-55.3	55.0
39 (H)	214.29	5-4-03	5.20	1.26	1.74	1.36	38.1	27.9
39 (H)	214.29	9-16-04	3.95	1.53	0.67	1.51	-56.2	55.6
39 (H)	214.29	9-16-04	5.89	1.53	1.45	1.55	-5.2	6.5
39 (H)	214.29	7-28-05	2.71	0.96	0.53	0.93	-44.8	43.0
40	565.06	5-5-03	5.94	3.05	2.34	3.08	-23.3	24.0
40	565.06	12-5-04	3.02	1.17	0.63	1.19	-46.2	47.1
41	49.82	4-18-98	2.22	1.46	0.40	1.45	-72.6	72.4
42 (H)	231.61	9-16-04	4.54	1.42	0.78	1.41	-45.1	44.7
42 (H)	231.61	7-1-05	4.40	0.94	1.25	0.93	33.0	34.4
43	362.63	5-5-03	6.28	2.98	3.61	2.95	21.1	22.4
43	362.63	9-15-04	4.11	1.73	1.07	1.76	-38.2	39.2
43	362.63	4-17-98	2.27	1.88	0.51	1.82	-72.9	72.0
44A	686.61	5-4-03	9.41	6.85	6.34	6.87	-7.4	7.7
44A	686.61	9-16-04	5.20	1.99	1.46	2.04	-26.6	28.4

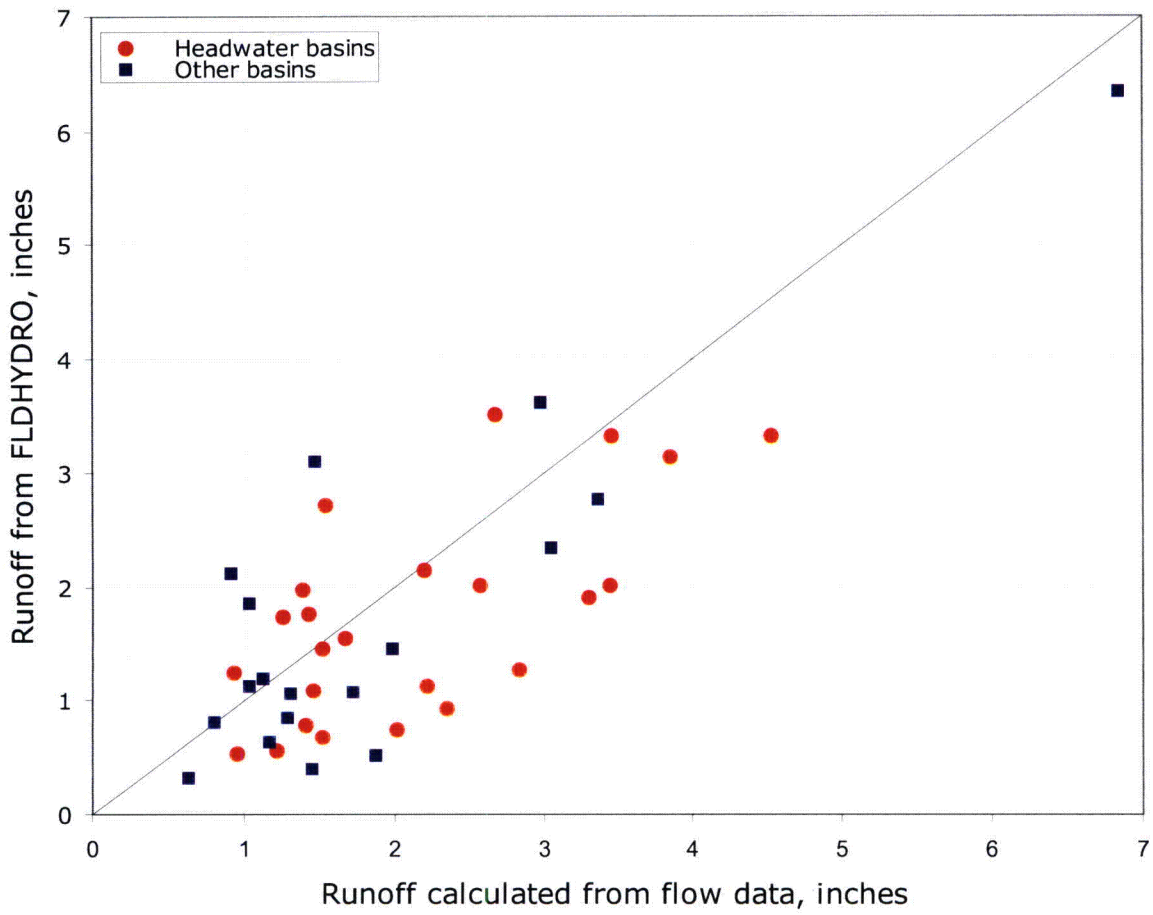

Figure 57 Computed vs. measured runoff

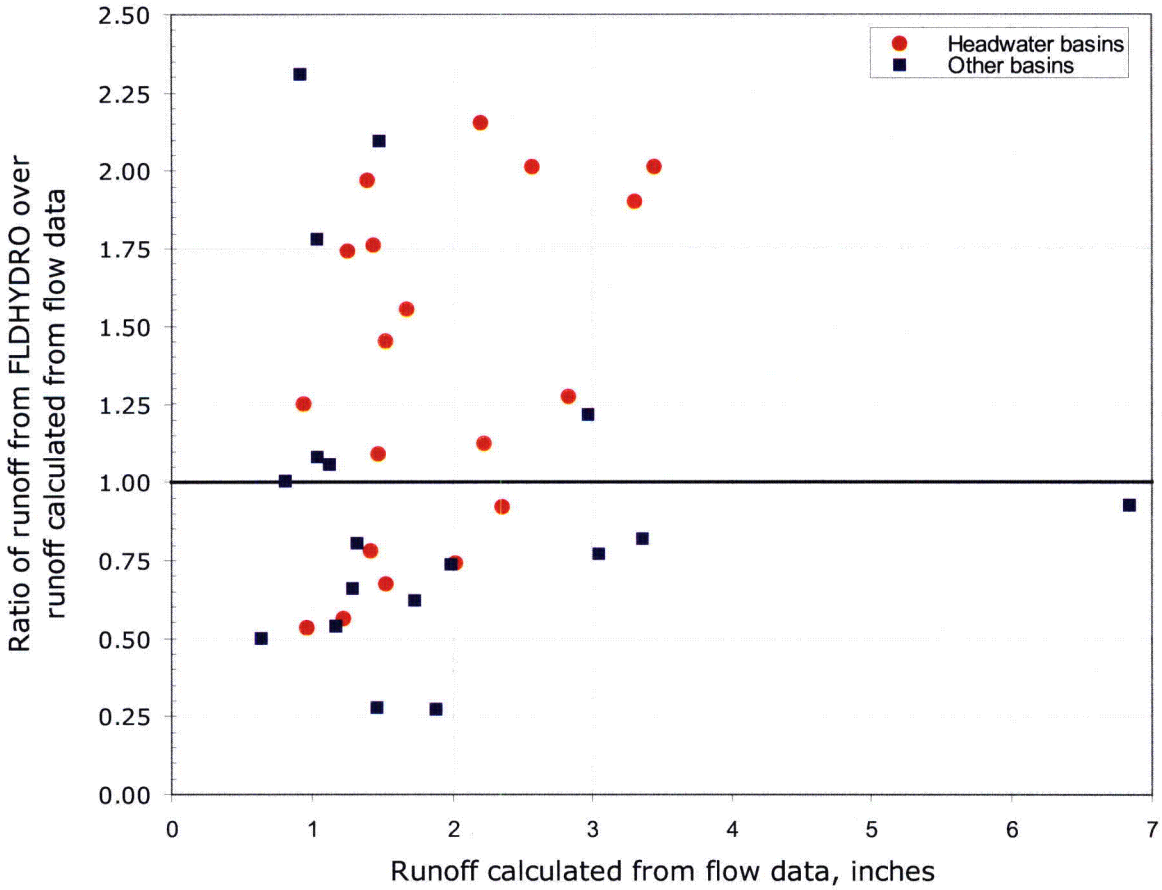

Figure 58. Ratio of the computed over measured runoff vs. measured runoff

3.2.4 Response of FLDHYDRO to Abnormal Input Data

FLDHYDRO has built-in safeguards to warn users when abnormal situations arise during operation of the program. A listing of these safeguards is provided below.

- After the second line of input data is read by FLDHYDRO, a check is done for input values out of range. If the number of runoff indices, number of stations, number of recorders, number of subwatersheds, or number of volume checks is invalid, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and one of the following messages:

  " (No. of Runoff Indices) IS INVALID AS NUMBER OF RI"S PER STATION; MAXIMUM IS 4"

  " (No. of Stations) IS INVALID AS NUMBER OF STATIONS; MAXIMUM IS 100"

  " (No. of Recorders) IS INVALID AS NUMBER OF RECORDERS; MAXIMUM IS 30"

  " (No. of Subwatersheds) IS INVALID AS NUMBER OF SUBWATERSHEDS; MAXIMUM IS 50"

" (No. of Volume Checks) IS INVALID AS NUMBER OF VOLUME CHECKS; MAXIMUM IS NO. OF SUBWATERSHEDS"

- All non-recording stations (i.e. stations where no hourly rainfall data were recorded, but only daily totals are available) must be paired with a recording station (i.e. a station where hourly rainfall was recorded) that will be used to distribute the daily rainfall from the non-recording stations. If an invalid recording station is entered, the output file consists of an echo of the input data and the beginning of the output data up to the point of calculations with the ill-referenced non-recorder. The following message is inserted in the echo data:

  " (Non-Recording Station) IS NOT A VALID RECORDER NAME FOR STATION (Recording Station)"

- For FLDHYDRO runs where the RI value is input, the RI is required to be less than or equal to 55. If a value of RI greater than 55 is input, the following message is inserted in the echo data:

  " RI VALUE OF (RI Value) DETECTED; MAX. IS 55"

- FLDHYDRO only allows one subwatershed to use more than 25 stations and that subwatershed must be the last one referenced. If this rule is violated, the following message is inserted in the echo data:

  " ONLY ONE WATERSHED ALLOWED WITH >25 STATIONS AND THAT WATERSHED MUST BE THE LAST ONE"

- When assigning Thiessen factors for a subwatershed, the Thiessen factors must be applied to rain stations defined as either recorders or non-recorders. If a station name that does not match an input recorder or non-recorder is input, the following message is inserted in the echo data:

  "... ERROR...ORDER OF RAIN STATIONS NOT ESTABLISHED PROPERLY. MAKE SURE... THAT FOUR CHARACTER RAIN STATION NAMES IN BSNSTA(I,J) MATCH THOSE IN NAMSTA(I)"

- When calculating non-recorder hourly rain from recorders, two error messages can be generated. These error messages do not invalidate the output data. Rather, they serve as warnings to the user that abnormal situations have occurred and leave it up to the user whether to accept the data or not. These messages are printed in the output data where RI values are calculated and are reproduced below:

  " *** ERROR -- A DAILY RAIN OF ZERO FOR RECORDER (Recording Station) WILL PRODUCE A DAILY RAIN OF ZERO FOR GAGE (Non-Recording Station). INVALID COMPUTATIONS WILL RESULT."

  " WARNING...A DAILY RAIN OF (Non-Recorder Daily Rain) FOR GAGE (Non-Recording Station) IS WEIGHTED AGAINST A DAILY RAIN OF (Recorder Daily Rain) FOR RECORDER (Recording Station). THIS IS A WEIGHT RATIO OF (Ratio) WHICH MAY SIGNIFICANTLY AFFECT RESULTS."

If none of the above abnormal conditions occurs, FLDHYDRO is presumed to have functioned normally. In this case, the entire output file is created.

However, it is possible for FLDHYDRO to appear to have functioned normally while using invalid input data. A few such cases are presented below:

- **Input API value greater than 5:**

  In FLDHYDRO, the look-up tables do not allow API values greater than 5. However, it is possible to assign an initial API value greater than 5. FLDHYDRO still terminates normally without any warning or error message when API values greater than 5 are input.

- **Negative value input for precipitation:**

  Physically, all precipitation values should be greater than zero. However, FLDHYDRO does not reject input values that are less than zero. FLDHYDRO still terminates normally without any warning or error message when negative precipitation values are input.

- **Thiessen weights do not sum to one:**

  When weighting rainfall with Thiessen weights, the sum of the Thiessen weights must be 1. However, FLDHYDRO does not check the sum of the Thiessen weights. Therefore, the sum of the Thiessen weights can be either greater than or less than one and FLDHYDRO still terminates normally without any warning or error message.

- **The *.hyd files created by FLDHYDRO do not include a time/date stamp:** The direct use or export of FLDHYDRO *.hyd data to TRBROUTE can combine hydrographs that have different starting times without the user's knowledge. The user should carefully check the *.out file for the time interval alignment prior to use or routing of the FLDHYDRO output data.

  For example, if a storm for a subwatershed with a unit hydrograph duration and time interval of 6 hours were to start at 3/15 0000 hours and the first non-zero hourly runoff value for the storm were to occur on 3/16 at 0100 hours (and thus, the first block of 6 hour runoff ends at 0600 hours) FLDHYDRO would insert into the .hyd file a runoff value of 0 cfs (assuming no baseflow) at 3/16 0000, 3/15 1800, 3/15 1200, 3/15 0600 and the starting runoff value of 0 cfs would be at 3/15 0000. If the same storm were to have the first-nonzero runoff value at 3/16 0500, FLDHYDRO would insert into the .hyd file a runoff value of 0 cfs (assuming no baseflow) at 3/16 0400, 3/15 2200, 3/15 1600, 3/15 1000 and the starting runoff value of 0 cfs would be at 3/15 0400.

In the cases presented in this section, FLDHYDRO accepts invalid input data but does not warn the user that the data are invalid. In some cases FLDHYDRO may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of FLDHYDRO besides those presented above. Therefore, it is the responsibility of the user to confirm that the input data file is valid in order to ensure that the FLDHYDRO output is also valid. Normal termination of FLDHYDRO is a necessary but not sufficient condition for producing valid results.

4. CHANROUT

4.1 Plan for Testing CHANROUT Functionality

4.1.1 Overview

The plan for testing the functionality of CHANROUT is defined in Reference 2, Appendix G. The CHANROUT Test Plan consists of a comparison of the solution of test problems obtained with CHANROUT to independent calculations for the same problems. The test plan serves to evaluate the program's capabilities and limitations as related to TVA design applications. The test problems, which are described in Section 4.1.2, were selected to be representative of typical TVA applications of the program.

Revisions or modifications to the CHANROUT computer program requires documentation of the changes as required in Section 3.3 of Reference 2.

The test problems specified here are intended to assess the extent of possible program features and options likely to be required for safety-related design analysis. These test problems were run using CHANROUT Version 1.0.

4.1.2 Test of the Implementation of the CHANROUT Methodology

- **Test Problem 1:** Yangtze River

  This problem is intended to ensure that CHANROUT properly calculates the routing coefficients for an ARMA(3,2) model using the equations presented in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 1). The inflow and outflow hydrographs used for this purpose are given in Figure 59. The inflow/outflow time interval and the routing period are both 24 hours. This problem is taken from Reference 14.

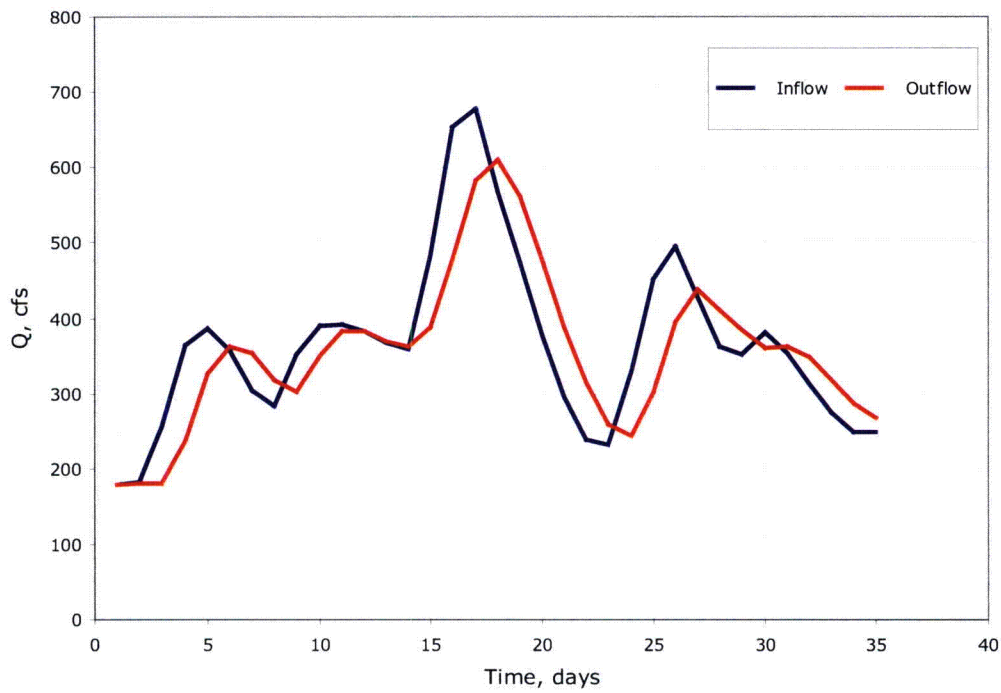

Figure 59. Inflow and Outflow Hydrographs for Test Problem 1

- **Test Problem 2:** Muskingum Routing Example

  This problem recreates Example 3.6 from Reference 16 to demonstrate that CHANROUT properly calculates the routing coefficients for Muskingum routing (ARMA[1,1]). The inflow and outflow hydrographs used for this purpose are given in Figure 60. The inflow/outflow time interval and the routing period are both 1 hour.

- **Test Problem 3:** Flow Interval Different from Routing Period

  This is identical to Test Problem 2 with the exception that the routing period is doubled (to 2 hours). This problem is intended to ensure that CHANROUT properly solves for the routing coefficients when the flow interval is different than the routing period. The inflow and outflow hydrographs are identical to those for Test Problem 2 show in Figure 60.

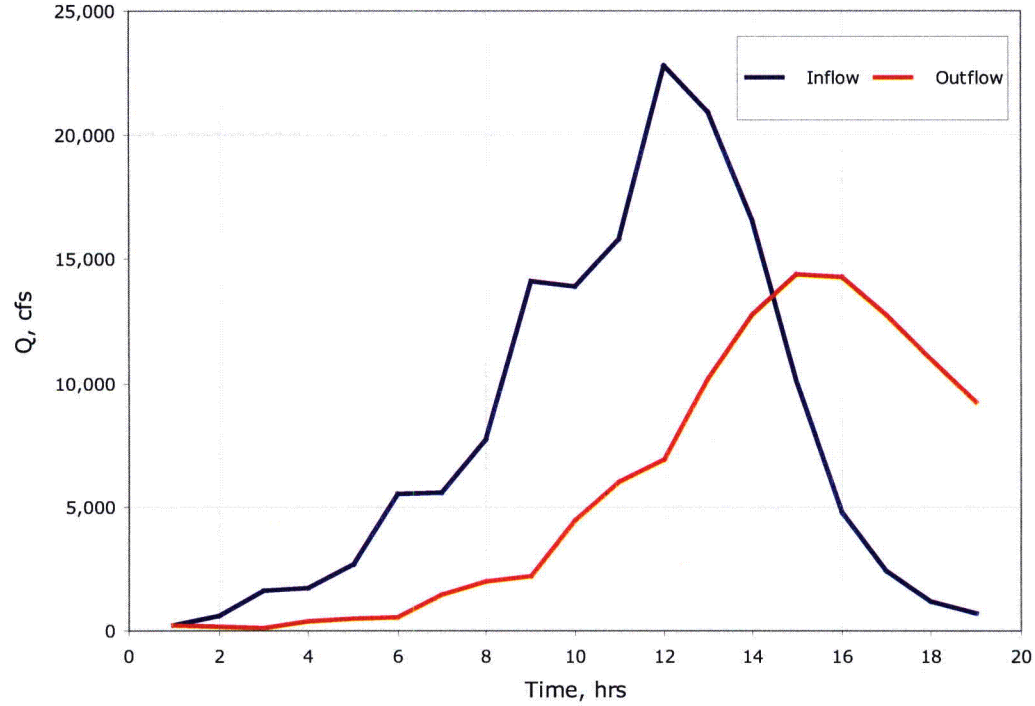

Figure 60. Inflow and Outflow Hydrographs for Test Problems 2 and 3

4.1.3 Solution Method Used in the Independent Calculations

The independent calculations used the same general method for calculating the coefficients for channel routing given in Reference 1, as described below.

The CHANROUT code computes the coefficients of an ARMA (autoregressive moving average) channel routing model of which the Muskingum routing equation is a special case. Equations (10) and (11) below utilize ARMA mathematical solution techniques as applied to hydrological data. Additional information regarding the use of ARMA in hydrological applications can be found in Reference 13. An ARMA(p,q) channel routing model computes current outflow out of a river reach as a linear combination of the previous p outflows, the previous q inflows, and current inflow into a reach, as shown in Equation (10) below. ARMA(1,1) is equivalent to the Muskingum routing equation. The governing equations for ARMA(p,q) channel routing (Reference 14) are given below:

$$\begin{aligned} O_t = {} & a_1 O_{t-r} + a_2 O_{t-2r} + a_3 O_{t-3r} + \ldots + a_p O_{t-pr} + \\ & b_0 I_t + b_1 I_{t-r} + b_2 I_{t-2r} + b_3 I_{t-3r} + \ldots + b_q I_{t-qr} \end{aligned} \tag{10}$$

The variables p and q that define the order of the ARMA(p,q) method, define also the number of outflow and inflow terms in Equation (10).

The basic equations for the ARMA(p,q) method are described in different hydrology textbooks (see for example Reference 15). The most common description of these equations in textbooks such as Reference 15 is in the context of their use for precipitation and outflow models, not for channel flow routing. The coefficients a_1, a_2, a_3, ... a_p and b_1, b_2, b_3, ... b_p are subject to the constraint:

$$a_1 + a_2 + a_3 + \ldots + a_p + b_0 + b_1 + b_2 + b_3 + \ldots + b_q = 1 \tag{11}$$

Equation (11) can be derived by expressing the mass balance condition for steady-state flow in flow in a prismatic channel.

Equations (10) and (11) can be expressed in matrix form for (m-t) time steps as:

$$D \cdot C = Q \tag{12}$$

$$U \cdot C = 1 \tag{13}$$

where:

$$D = \begin{bmatrix} O_{t-r} & O_{t-2r} & \ldots & O_{t-pr} & I_t & I_{t-r} & \ldots & I_{t-qr} \\ O_{t-r+1} & O_{t-2r+1} & \ldots & O_{t-pr+1} & I_{t+1} & I_{t-r+1} & \ldots & I_{t-qr+1} \\ O_{t-r+2} & O_{t-2r+2} & \ldots & O_{t-pr+2} & I_{t+2} & I_{t-r+2} & \ldots & I_{t-qr+2} \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ O_{m-r} & O_{m-2r} & \ldots & O_{m-pr} & I_m & I_{m-r} & \ldots & I_{m-qr} \end{bmatrix} \tag{14}$$

$$C = \begin{bmatrix} a_1 \\ a_2 \\ \ldots \\ a_p \\ b_0 \\ b_1 \\ \ldots \\ b_q \end{bmatrix} \tag{15}$$

$$Q = \begin{bmatrix} O_t \\ O_{t+1} \\ \ldots \\ O_m \end{bmatrix} \tag{16}$$

$$U = [1 \;\; 1 \;\; \ldots \;\; 1]_{p+q+1} \tag{17}$$

where:

r is the routing period divided by the flow interval

O_{t-pr} is the first outflow if $p \geq q$

O_{t-pr} is the ((q-p)*r+1)th outflow if $p < q$

I_{t-qr} is the ((p-q)*r+1)th inflow if $p \geq q$

I_{t-qr} is the first inflow if $p < q$

I_m is the last inflow

The set of equations is solved using the Lagrangian equation:

$$D^T \cdot D \cdot C = L + D^T \cdot Q \tag{18}$$

where:

D^T is the transpose matrix of D,

$L = U^T \cdot \lambda$ is a Lagrangian multiplier and

$$C = C_1 + C_2 \cdot \lambda \tag{19}$$

The Lagrangian equations are solved by rewriting Equation (18) as:

$$D^T \cdot D \cdot (C_1 + C_2 \cdot \lambda) = U^T \cdot \lambda + D^T \cdot Q \tag{20}$$

This can be broken into the following two equations:

$$D^T \cdot D \cdot C_1 = D^T \cdot Q \tag{21}$$

$$D^T \cdot D \cdot C_2 \cdot \lambda = U^T \cdot \lambda \tag{22}$$

Equations (21) and (22) are solved for C_1 and C_2 as follows:

$$C_1 = (D^T \cdot D)^{-1} \cdot D^T \cdot Q \tag{23}$$

$$C_2 = (D^T \cdot D)^{-1} \cdot U^T \tag{24}$$

Next, Equations (13) and (19) are combined to find a solution for λ:

$$\lambda = \frac{1 - U \cdot C_1}{U \cdot C_2} \tag{25}$$

Finally, the routing coefficients, C, are found by solving Equation (19).

The degree of the ARMA(p,q) model is specified in the CHANROUT input file. For the Muskingum routing equation to be properly applied, the routing period must be at least as long as the approximate travel time through the reach. Also, sudden surges or increases in inflows do not attenuate correctly downstream if the flow interval does not equal the routing period. A higher degree ARMA channel routing model (e.g. ARMA(3,2)) may eliminate these "timing" problems, as well as be more accurate than the simple Muskingum routing equation. Therefore, care must be taken when deciding on the values of p and q to be used by CHANROUT.

4.2 CHANROUT Test Results

4.2.1 Tests of the Implementation of the CHANROUT Methodology

Input files to CHANROUT for each test problem are included in electronic form as Attachment 1. CHANROUT output files for each test problem are included in electronic form as Attachment 2. The CHANROUT source code and the executable that was used for these tests are included in the electronic Attachment 3. Solutions to the test problems using CHANROUT were compared to the independent calculations performed with the same theoretical basis outlined in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 1) and using Microsoft Excel 2003 SP3. These Excel files used for independent calculation are included as Attachment 4. The results of these comparisons are presented below.

Table 26 gives the names of the Excel files used for the validation of CHANROUT. All these files are included in the Electronic Attachment 4.

Table 26. List of Excel Files Used for the Validation of CHANROUT

Test Problem	Excel File Name in Electronic Attachment 4
Test Problem 1	Chanrout_sample1.xls
Test Problem 2	Chanrout_sample2.xls
Test Problem 3	Chanrout_sample3.xls

4.2.1.1 Test Problem 1

Table 27 compares the channel routing coefficients for Test Problem 1 obtained with CHANROUT with those derived through independent calculations for the same problem. A comparison of the input inflows and outflows and the computed outflows from each method is presented in Table 28. Figure 61 presents plots of the hydrographs given in Table 28.

Table 27. Comparison of Routing Coefficients from CHANROUT and Independent Calculations for Test Problem 1

	CHANROUT	Independent Calculations
O(T-1)	0.9275	0.9275
O(T-2)	-0.2494	-0.2494
O(T-3)	0.0217	0.0217
I(T)	0.1860	0.1860
I(T-1)	0.3292	0.3292
I(T-2)	-0.2150	-0.2150

Table 28. Comparison of Inputs with Outputs from CHANROUT and Independent Calculations for Test Problem 1

Time (days)	Input Inflow (cfs)	Input Outflow (cfs)	CHANROUT Outflow (cfs)	Independent Calculations Outflow (cfs)
1	179	179	179	179
2	182	180	180	180
3	257	181	195	195
4	365	237	253	253
5	387	327	327	327
6	357	363	360	360
7	305	354	349	349
8	284	318	317	317
9	353	302	309	309
10	391	351	343	343
11	392	383	373	373
12	383	384	384	384
13	368	370	381	381
14	360	363	371	371
15	483	388	387	387
16	654	479	478	478
17	677	584	592	592
18	568	610	626	626
19	475	563	573	573
20	378	478	493	493
21	296	389	405	405
22	239	315	326	326
23	232	260	270	270
24	331	245	265	265
25	452	303	328	328
26	495	395	414	414
27	429	438	453	453
28	363	412	427	427
29	353	386	385	385
30	382	361	369	369
31	355	363	372	372
32	313	349	354	354
33	275	318	322	322
34	250	287	288	288
35	250	268	264	264

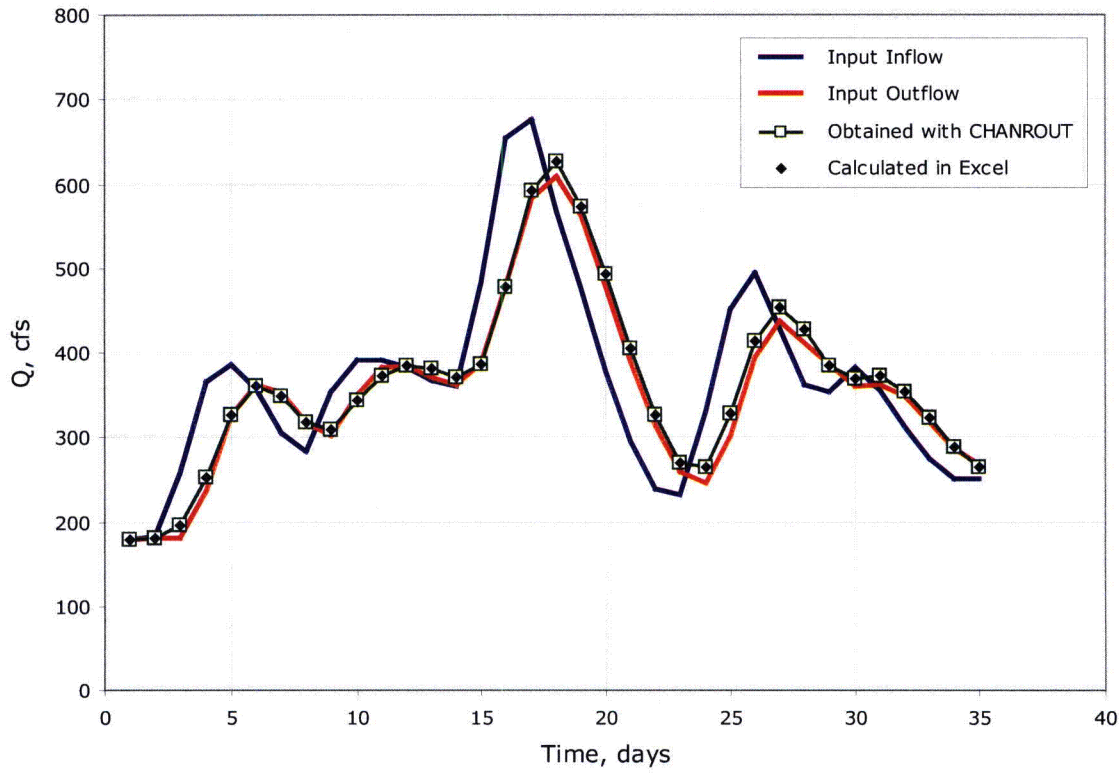

Figure 61. Comparison of Inputs with Outputs from CHANROUT and Independent Calculations in Excel for Test Problem 1

4.2.1.2 Test Problem 2

Table 29 compares the routing coefficients calculated for Test Problem 2 calculated with CHANROUT with those presented in Reference 16. Table 30 compares the outflow hydrograph computed with CHANROUT with that from the independent Excel calculation for the same problem. Figure 62 presents plots of the hydrographs given in Table 30.

Table 29. Comparison of Routing Coefficients from Reference 16, CHANROUT, and Independent Calculations for Test Problem 2

	Reference 16	CHANROUT	Independent Calculations
O(T-1)	0.8113	0.8110	0.8110
I(T)	-0.1320	-0.1322	-0.1322
I(T-1)	0.3208	0.3211	0.3211

Table 30. Comparison of Inputs with Outputs from CHANROUT and Independent Calculations for Test Problem 2

Time (hrs)	Input Inflow (cfs)	Input Outflow (cfs)	CHANROUT Outflow (cfs)	Independent Calculations Outflow (cfs)
1	200	200	200	200
2	600	147.3	147	147
3	1600	100.8	101	101
4	1700	370.7	371	371
5	2700	489.8	490	490
6	5500	537.6	537	537
7	5600	1461.4	1462	1462
8	7700	1965.7	1966	1966
9	14100	2203.8	2204	2204
10	13900	4476.4	4478	4478
11	15800	6005.2	6007	6007
12	22800	6931.0	6932	6932
13	20900	10187.5	10182	10182
14	16600	12778.6	12775	12775
15	10100	14359.4	14357	14357
16	4800	14256.3	14253	14253
17	2400	12778.1	12784	12784
18	1200	10986.9	10981	10981
19	700	9206.2	9199	9199

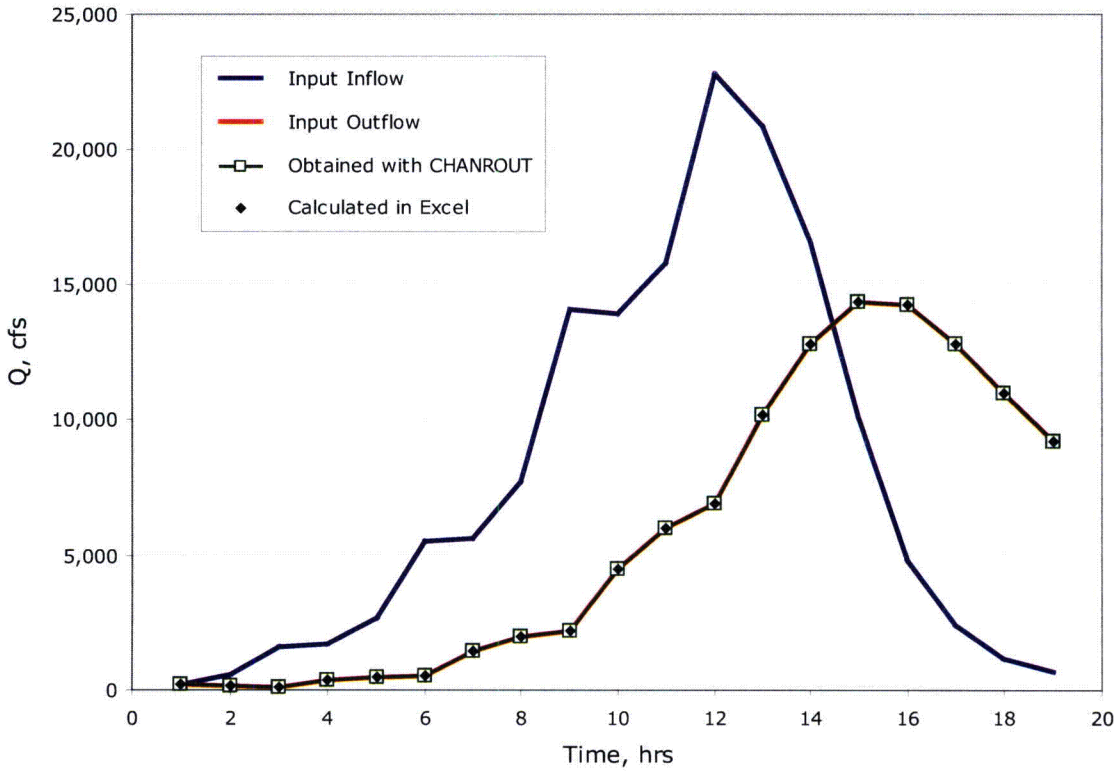

Figure 62. Comparison of Inputs with Outputs from CHANROUT and Independent Calculations in Excel for Test Problem 2

As can be seen in Table 29 the results of CHANROUT for the routing coefficients of Test Problem 2 are very close to those presented in Reference 16. Table 30 and Figure 62 show that the outflow hydrograph for Test Problem 2 obtained with CHANROUT is practically identical to that obtained from independent calculations in Excel using the routing coefficients given in Reference 16.

4.2.1.3 Test Problem 3

Table 31 compares the routing coefficients calculated for Test Problem 3 calculated with CHANROUT with those obtained from independent calculations. Table 32 compares the outflow hydrograph computed with CHANROUT with that from the independent Excel calculation for the same problem. Figure 63 presents plots of the hydrographs given in Table 32.

Table 31. Comparison of Routing Coefficients from CHANROUT and Independent Calculations for Test Problem 3

	CHANROUT	Independent Calculations
O(T-2)	0.6455	0.6455
I(T)	-0.0267	-0.0267
I(T-2)	0.3811	0.3811

Table 32. Comparison of Inputs with Outputs from CHANROUT and Independent Calculations for Test Problem 3

Time (hrs)	Input Inflow (cfs)	Input Outflow (cfs)	CHANROUT Outflow (cfs)	Independent Calculations Outflow (cfs)
1	200	200	200	200
2	600	147.3	189	189
3	1600	100.8	163	163
4	1700	370.7	306	306
5	2700	489.8	643	643
6	5500	537.6	699	699
7	5600	1461.4	1295	1295
8	7700	1965.7	2342	2342
9	14100	2203.8	2594	2594
10	13900	4476.4	4076	4076
11	15800	6005.2	6628	6628
12	22800	6931.0	7321	7321
13	20900	10187.5	9743	9743
14	16600	12778.6	12973	12973
15	10100	14359.4	13986	13986
16	4800	14256.3	14574	14574
17	2400	12778.1	12814	12814
18	1200	10986.9	11205	11205
19	700	9206.2	9168	9168

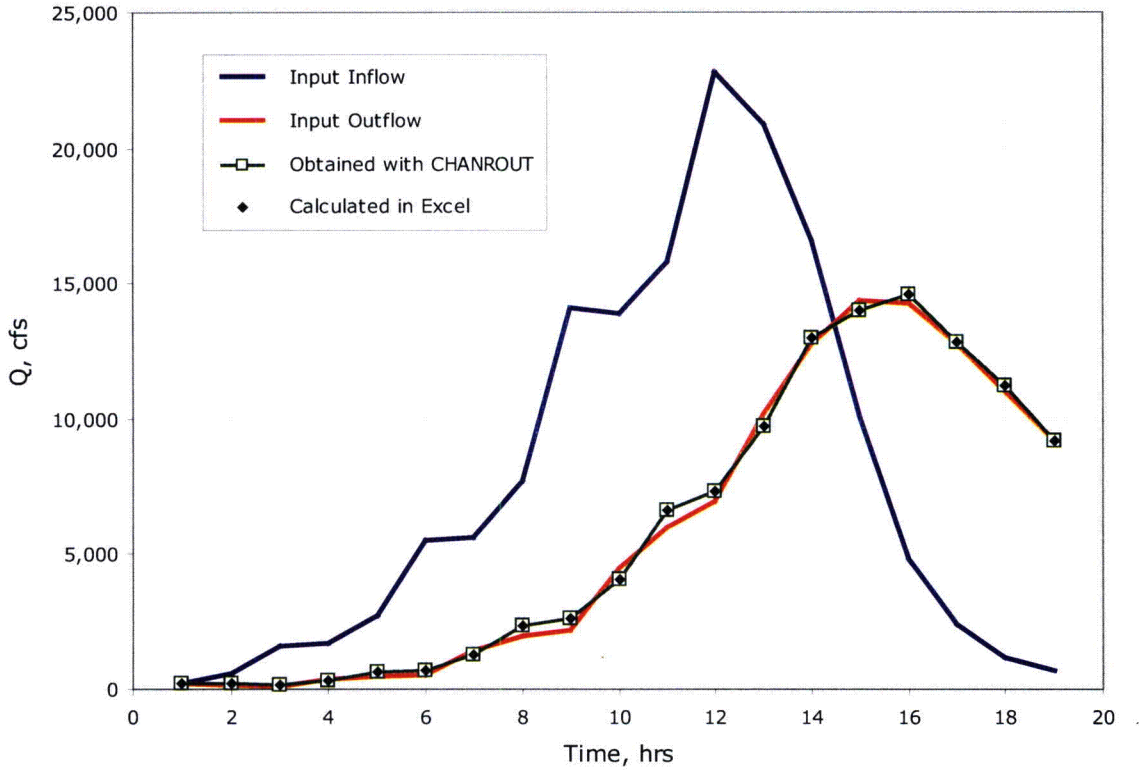

Figure 63. Comparison of Inputs with Outputs from CHANROUT and Independent Calculations in Excel for Test Problem 3

For all three Test Problems there are no differences between the channel routing coefficients or outflows calculated by CHANROUT and those obtained through independent calculation.

For Test Problem 2 where the outflows and Muskingum routing coefficients are known, the results from CHANROUT are not significantly different from the known values. These variations can be attributed to the differences in the methods used to calculate the routing coefficients. This demonstrates that CHANROUT properly implements the Muskingum routing method. For Test Problem 3, CHANROUT properly calculates the outflows based on the method outlined in Section 4.1.3, as verified by the independent calculations, but the calculated outflows do not match the input outflows as well as in Test Problem 2. This shows the importance of using the proper routing period for the channel reach. The results of this analysis verify that the CHANROUT code properly implements the channel routing method outlined in Section 4.1.3.

4.2.2 Response of CHANROUT to Abnormal Input Data

CHANROUT has built-in safeguards to warn users when abnormal situations arise during operation of the program. A listing of these safeguards is provided below.

- If the number of previous inflows or outflows to be used in the ARMA routing model is less than one, or if the total number of inflows and outflows to be used

is greater than 20, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and the message:

" 1 - 10 BACK POINTS ALLOWED: IBKPTS = (No. Previous Inflows); OBKPTS = (No. Previous Outflows)"

- If the routing period is not a multiple of the time interval, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and the message:

  " ROUTING PERIOD MUST BE A MULTIPLE OF TIME INCREMENT: RP = (Routing Period); TIMINT = (Time Interval)"

- In order to perform the routing the number of inflows and outflows input must be at least as many as the larger of the number of previous inflows or outflows, times the routing period divided by the time interval (this term is the variable "SHIFT" in the CHANROUT program). If this is not true, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and the message:

  " AT LEAST (SHIFT) FLOWS MUST BE SPECIFIED FOR VIABLE COMPUTATIONS: NFLOWS = (No. Inflows/Outflows)"

- The maximum number of inflows/outflows input to CHANROUT is 300. If this number is exceeded the run terminates and the output file consists only of an echo of the first two lines of input data and the message:

  " MAX. NO. OF FLOWS IS 200: NFLOWS = (No. Inflows/Outflows)"

If none of the above abnormal conditions occurs, CHANROUT is presumed to have functioned normally. In this case, the entire output file is created.

However, it is possible for CHANROUT to appear to have functioned normally while using invalid input data. One such case is presented below:

- **Negative value input for inflow or outflow:**

  Physically, all inflow and outflow values should be greater than zero. However, CHANROUT does not reject input values that are less than zero. CHANROUT still terminates normally without any warning or error message when negative inflow or outflow values are input.

In the case presented above, CHANROUT accepts invalid input data but does not warn the user that the data are invalid. In some cases CHANROUT may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of CHANROUT besides that presented above. Therefore, it is the responsibility of the user to confirm that the input data file is valid in order to ensure that the CHANROUT output is also valid. Normal termination of CHANROUT is a necessary but not sufficient condition for producing valid results.

5. TRBROUTE

5.1 Plan for Testing TRBROUTE Functionality

5.1.1 Overview

The plan for testing the functionality of TRBROUTE is defined in Reference 2, Appendix G. The TRBROUTE Test Plan consists of a comparison of the solution of test problems obtained with TRBROUTE to independent calculations for the same problems. The test plan serves to evaluate the program's capabilities and limitations as related to TVA design applications. The test problems, which are described in Section 5.1.2, were selected to be representative of typical TVA applications of the program.

Revisions or modifications to the TRBROUTE computer program requires documentation of the changes as required in Section 3.3 of Reference 2.

The test problems specified here are intended to assess the extent of possible program features and options likely to be required for safety-related design analysis. These test problems were run using TRBROUTE Version 1.1.

5.1.2 Test of the Implementation of the TRBROUTE Methodology

- **Test Problem 1:** Holston River Above Cherokee Dam

  This problem is intended to ensure that TRBROUTE properly routes flows through channels and reservoirs. This problem consists of five reservoirs and three channel sections that are lag routed. A schematic of the system modeled in this Test Problem is shown in Figure 64. Inflow hydrographs used as input for Test Problem 1 are those obtained from FLDHYDRO Test Problem 6 and are shown in Figure 55. Initial reservoir elevations and outflows are given in Table 33.

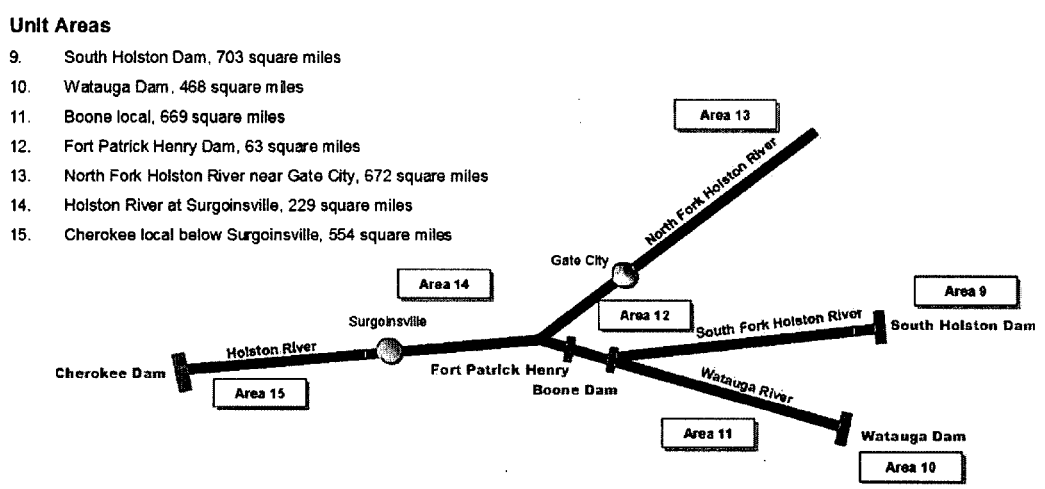

Figure 64. Flow schematic for Test Problem 1

The combined South Holston Dam and Watauga Dam flows are lagged 6 hours, the combined North Fork Holston River flows and flows out of Fort Patrick Henry Dam are

lagged 12 hours, and the Holston River flows between Surgoinsville and Cherokee Dam are lagged 4 hours. This problem is taken from Reference 17.

Table 33. Initial Reservoir Elevations and Discharge Used for Routing for Test Problem 1

Reservoir	Initial W.S. Elevation (ft)	Initial Discharge for Routing (cfs)
South Holston	1713.0	3000
Watauga	1945.0	3000
Boone	1368.5	17500
Fort Patrick Henry	1261.0	158
Cherokee	1042.5	0

- **Test Problem 2:** Muskingum Channel Routing Example

  This problem recreates the example whose answer is in Table 16.6 of the textbook Hydrology in Practice (Reference 18). It is intended to demonstrate that TRBROUTE properly performs Muskingum channel routing when given the routing coefficients.

  For the Muskingum routing equation $O_t = c_0 I_t + c_1 I_{t-1} + c_2 O_{t-1}$, this Test Problem uses c_0=-0.29, c_1=0.74, c_2=0.55 with a routing period of 12 hours. The inflow hydrograph used is shown in Figure 65.

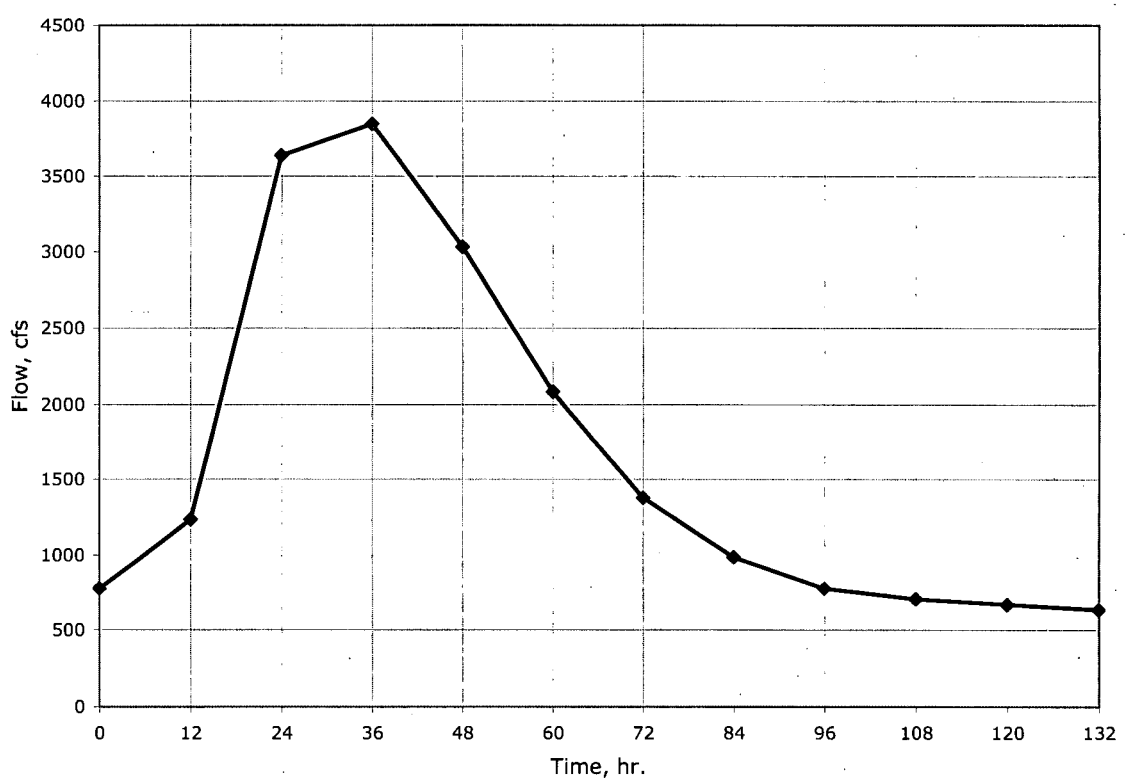

Figure 65. Inflow Hydrograph for Test Problem 2

- **Test Problem 3:** Muskingum Channel Routing Example

  This problem recreates the example from Table 9-3 of the textbook Hydrology for Engineers (Reference 12). It is intended to demonstrate that TRBROUTE properly performs Muskingum channel routing when given the routing coefficients. This Test Problem uses Muskingum routing coefficients c_0=0.124, c_1=0.353, c_2=0.523 with a routing period of 6 hours. The inflow hydrograph used is shown in Figure 66.

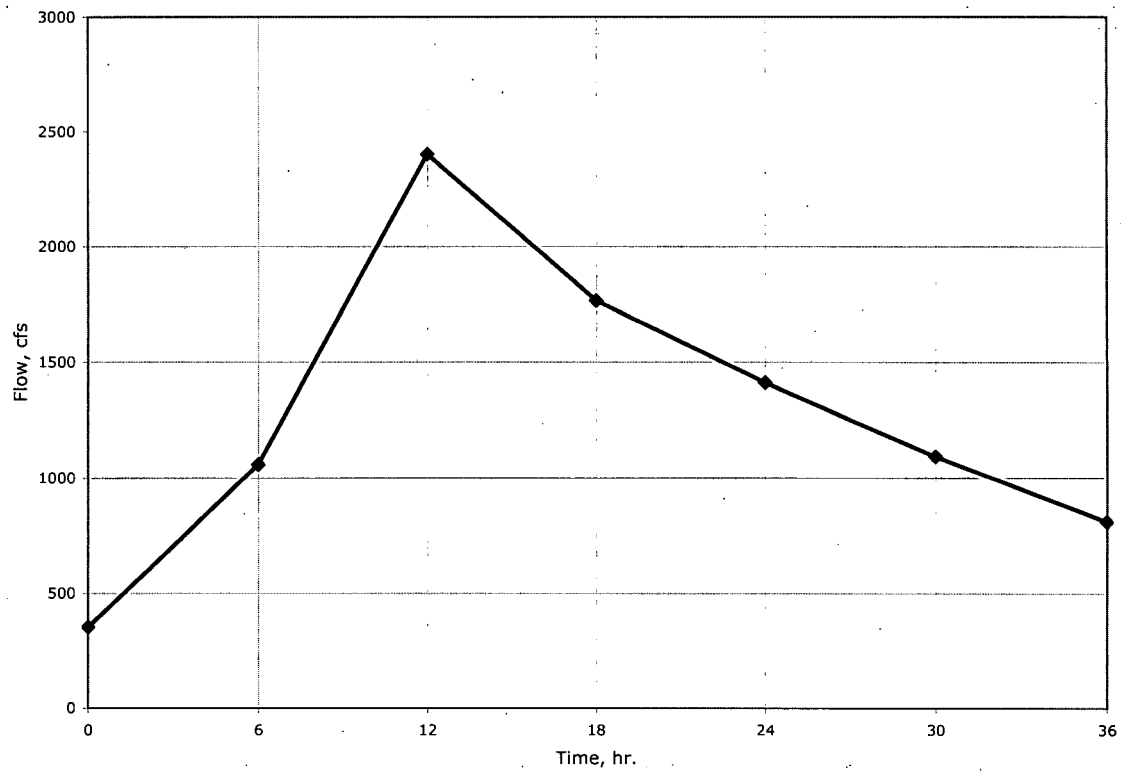

Figure 66. Inflow Hydrograph for Test Problem 3

- **Test Problem 4:** Muskingum Channel Routing Example

  This problem recreates Example 9.9 from the textbook Introduction to Hydrology (Reference 19). It is intended to demonstrate that TRBROUTE properly performs Muskingum channel routing when given the routing coefficients. This Test Problem uses Muskingum routing coefficients c_0=0.048, c_1=0.428, c_2=0.524 with a routing period of 24 hours. The inflow hydrograph used is shown in Figure 67.

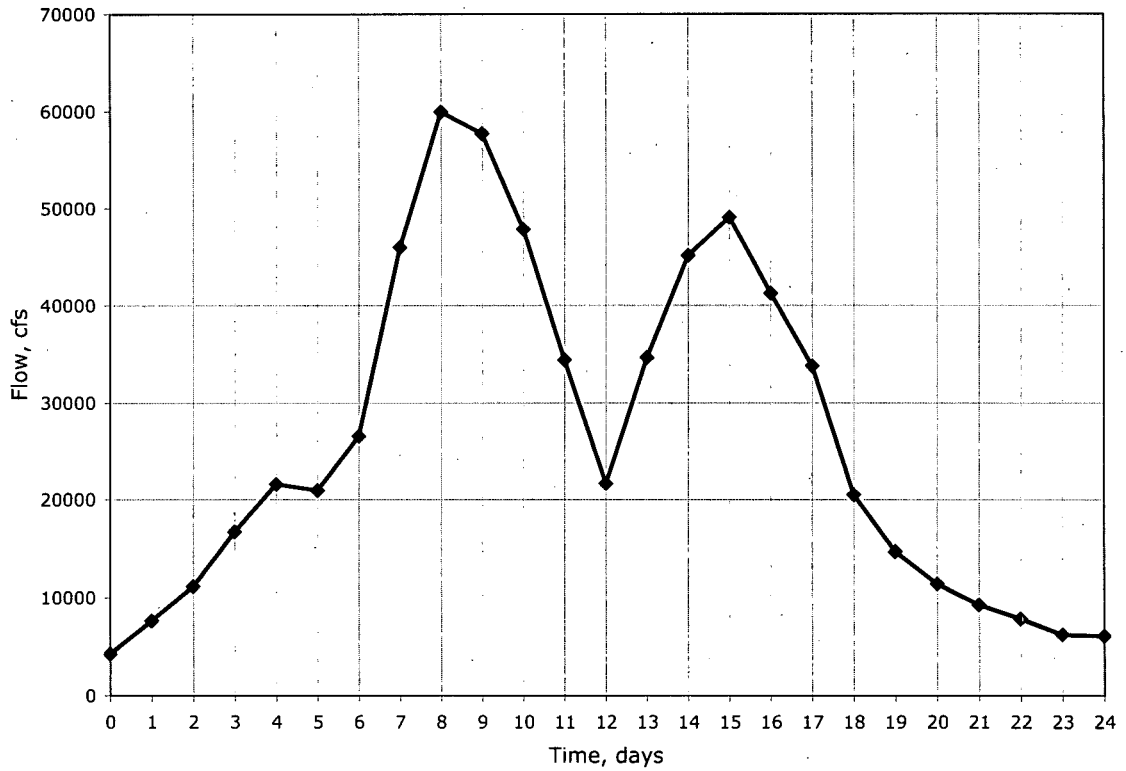

Figure 67. Inflow Hydrograph for Test Problem 4

- **Test Problem 5:** Muskingum Channel Routing Example

  This problem recreates Example 10.1 from the textbook Hydrology: An Introduction to Hydrologic Science (Reference 20). It is intended to demonstrate that TRBROUTE properly performs Muskingum channel routing when given the routing coefficients. This Test Problem uses Muskingum routing coefficients c_0=0.097, c_1=0.548, c_2=0.355 with a routing period of 6 hours. The inflow hydrograph used is shown in Figure 68.

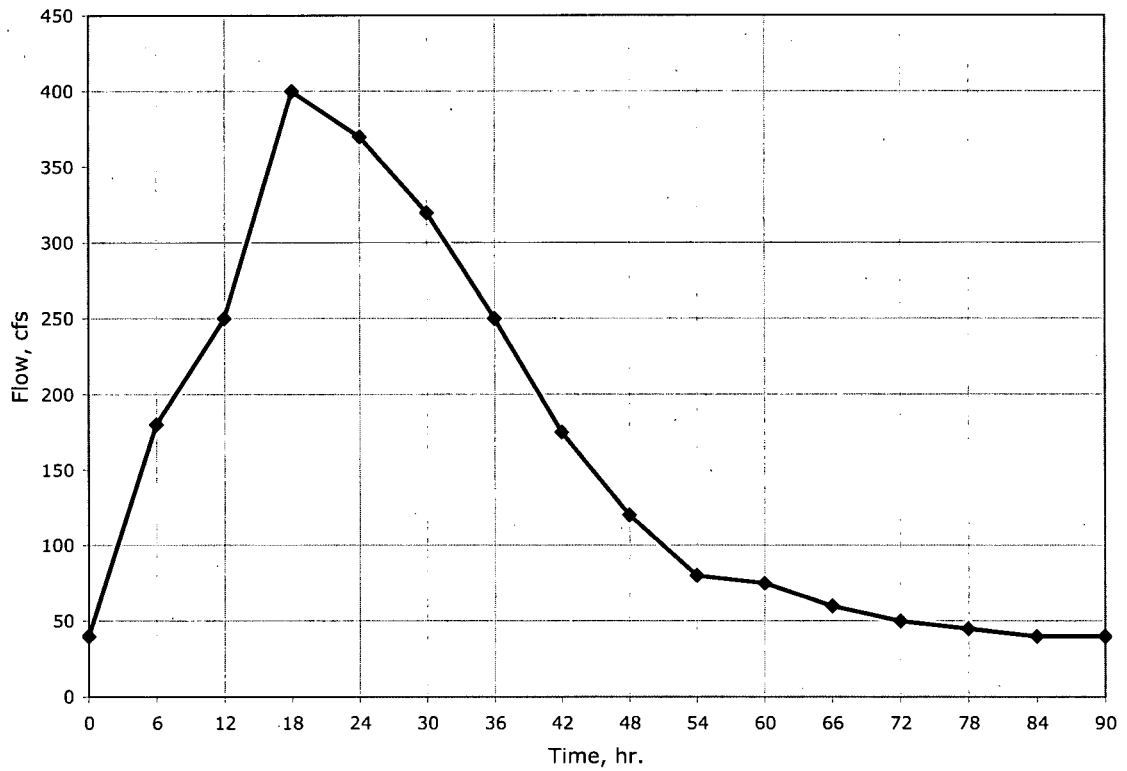

Figure 68. Inflow Hydrograph for Test Problem 5

5.1.3 Solution Method Used in the Independent Calculations

The independent calculations used the same general method for routing flood hydrographs downstream given in Reference 1, as described below.

TRBROUTE performs the channel and reservoir routings necessary to route flood hydrographs downstream to selected points (for input to the SOCH model). This includes routing through reservoirs with fixed discharge rating curves as well as the major tributary dam systems whose operations follow fixed rules. Discharge rating curves defining the fixed rules of the major tributary dams can be handled by the program. Flows are routed through channels in TRBROUTE by using the autoregressive moving average (ARMA) type channel routing coefficients calculated using CHANROUT.

TRBROUTE performs reservoir and channel routing to compute outflow at specified locations using as input inflow hydrographs calculated by FLDHYDRO, and channel routing coefficients calculated by CHANROUT.

User inputs to the program include:

- Inflow hydrographs from FLDHYDRO (can either be specified in the main input file or in a second input file)
- Channel routing coefficients from CHANROUT
- Set of instruction codes that tell TRBROUTE how to route and combine the inputs

- Reservoir names
- Starting water surface elevation for each reservoir
- Starting discharge used for routing calculations for each reservoir (FOUT)
- Storage-elevation curves and discharge rating curves for reservoirs not defined in TVA tables (see below)

Also used as inputs to the program are four tables developed by TVA (Reference 17):

- STORAGES – look up table with storage-elevation curves for reservoirs to be routed
- QRATINGS – look up table with discharge rating curves for tributary dams to be routed using TRBROUTE
- IMPRULES – look up table with reservoir operation guides for major tributary dams
- SGUIDES – look up table with reservoir seasonal elevation operation guidelines.

Reservoir routings are made assuming flat pool storage conditions. Routing through reservoirs is performed with the storage equation:

$$I - O = \frac{dS}{dt} \tag{26}$$

where:

I is the inflow rate

O is the outflow rate

S is the storage volume, and

t is the routing period

Equation (26) is more commonly expressed as:

$$\bar{I} - \bar{O} = \frac{\Delta S}{\Delta t} \tag{27}$$

If the average rate of flow during a given time period is equal to the average of the flows at the beginning and end of the period, then Equation (27) can be written as:

$$\frac{I_1 + I_2}{2}\Delta t - \frac{O_1 + O_2}{2}\Delta t = S_2 - S_1 \tag{28}$$

where the subscripts 1 and 2 refer the beginning and end of the period Δt, respectively.

Solving Equation (28) for the unknowns yields:

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

where:

I_1 and I_2 are input to TRBROUTE from FLDHYDRO

For the first time step TRBROUTE assumes that O_1 is equal to I_1 and S_1 is the storage corresponding to the initial elevation. O_1 and S_1 are calculated using Equation (29) for all other time steps.

Using the solution to Equation (29), S_2 and O_2 are determined by referencing the relations in the TVA tables or user input values (for reservoirs not in the tables).

If the inflow is less than the discharge used for routing calculations (FOUT) then routing is not performed and outflow equals inflow.

5.2 TRBROUTE Test Results

5.2.1 Tests of the Implementation of the TRBROUTE Methodology

Input files to TRBROUTE for each test problem are included in electronic form as Attachment 1. TRBROUTE output files for each test problem are included in electronic form as Attachment 2. The TRBROUTE source code and the executable that was used for these tests are included in the electronic Attachment 3. Solutions to the test problems using TRBROUTE were compared to the independent calculations performed with the same theoretical basis outlined in the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT User's Manual (Reference 1) and using Microsoft Excel 2003 SP3. These Excel files used for independent calculation are included as Attachment 4. The results of these comparisons are presented below.

Table 34 gives the names of the Excel files used for the validation of TRBROUTE. All these files are included in the Electronic Attachment 4.

Table 34. List of Excel Files Used for the Validation of TRBROUTE

Test Problem	Excel File Name in Electronic Attachment 4
Test Problem 1	Trbroute_sample1.xls
Test Problem 2	Trbroute_sample2-5.xls
Test Problem 3	Trbroute_sample2-5.xls
Test Problem 4	Trbroute_sample2-5.xls
Test Problem 5	Trbroute_sample2-5.xls

5.2.1.1 Test Problem 1

A comparison of the inflows and outflows at specified locations derived using the TRBROUTE code and those derived through independent calculations for Test Problem 1 are presented in Figure 69 through Figure 73.

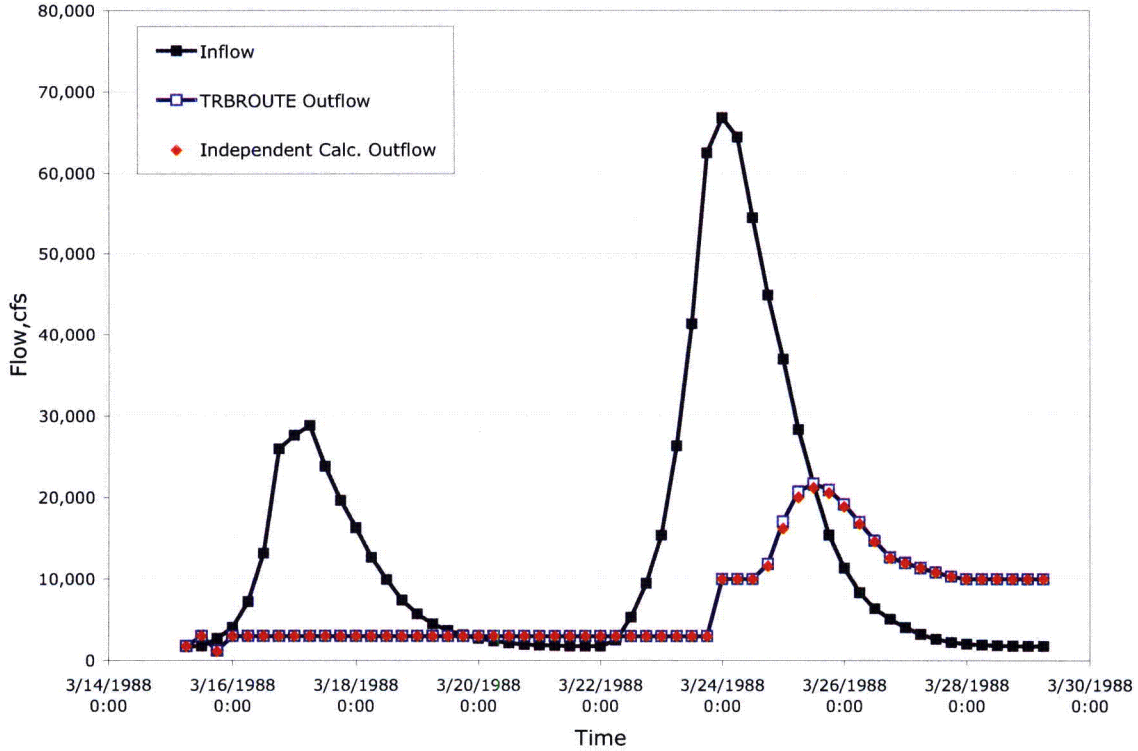

Figure 69. Comparison of Outputs from TRBROUTE and Independent Calculations in Excel for Test Problem 1, South Holston Dam

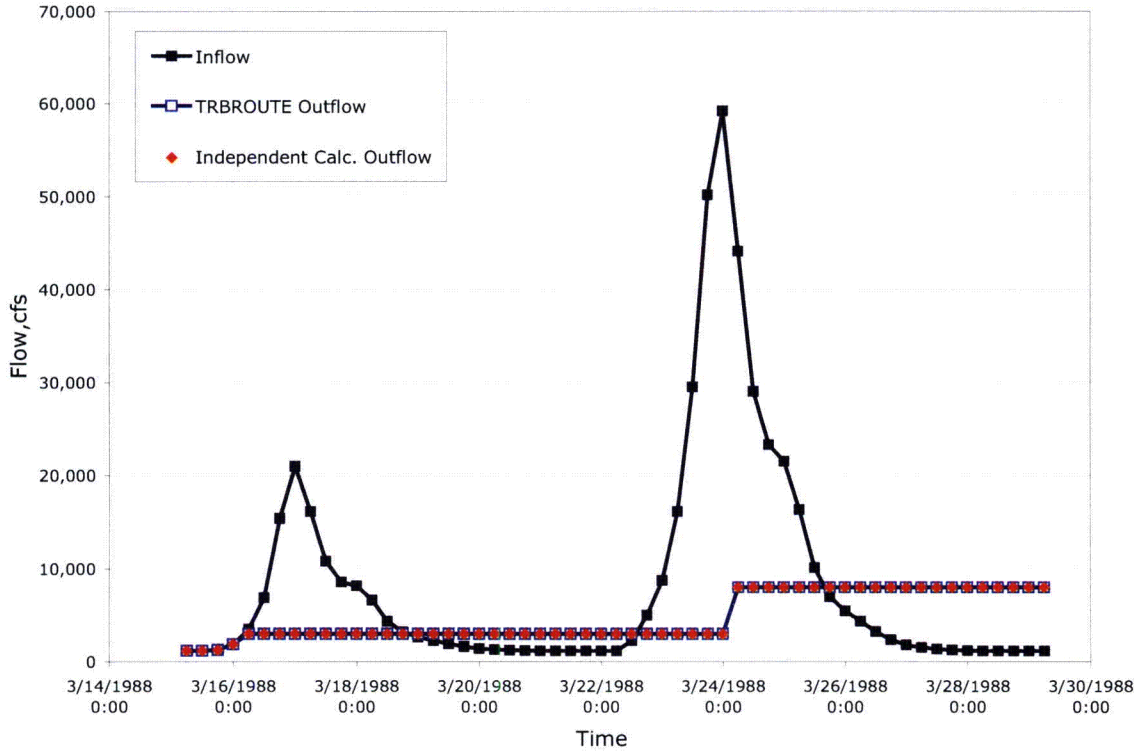

Figure 70. Comparison of Outputs from TRBROUTE and Independent Calculations in Excel for Test Problem 1, Watauga Dam

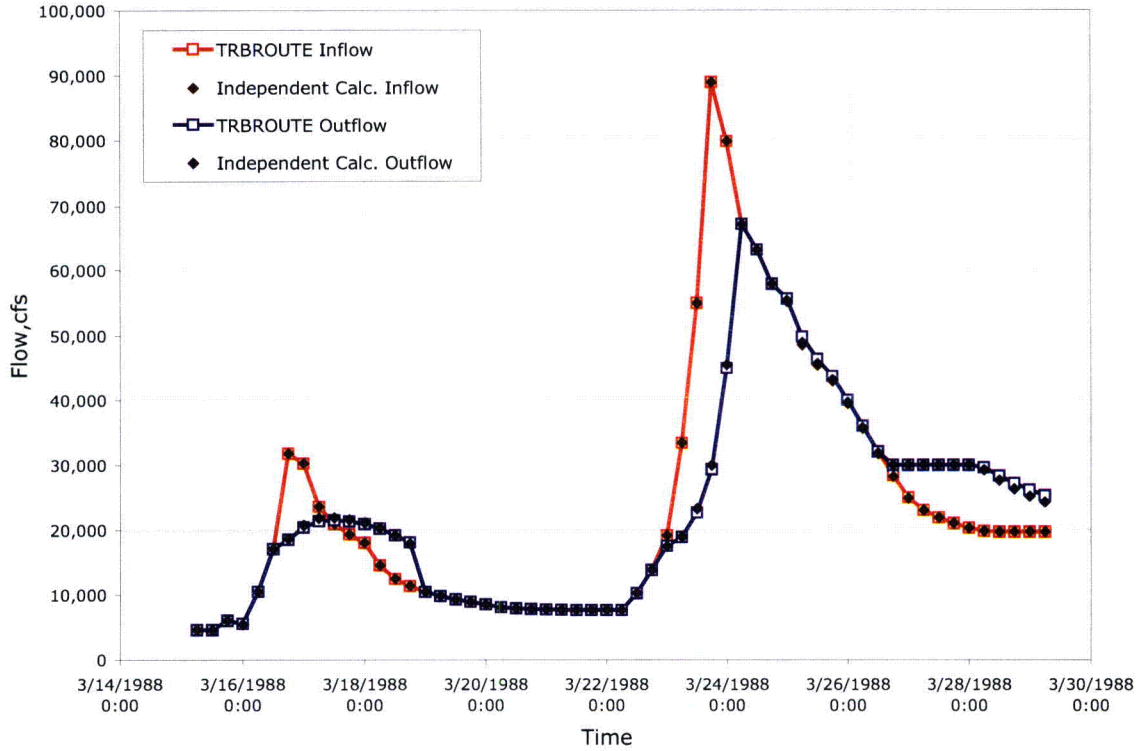

Figure 71. Comparison of Outputs from TRBROUTE and Independent Calculations in Excel for Test Problem 1, Boone Dam

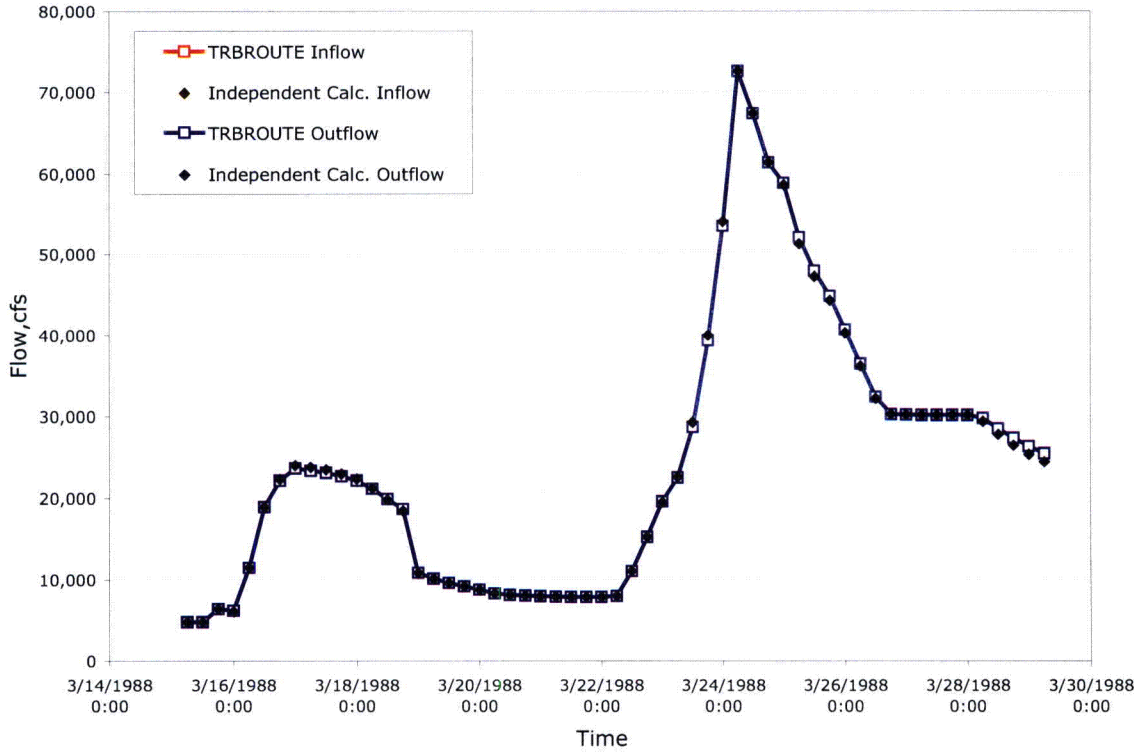

Figure 72. Comparison of Outputs from TRBROUTE and Independent Calculations in Excel for Test Problem 1, Fort Patrick Henry Dam

All flows through Fort Patrick Henry Dam are less than the smallest flow for Fort Patrick Henry in the QRATINGS table. Therefore, reservoir routing is not performed and inflow equals outflow for all time steps. Thus, the outflow values in Figure 72 plot directly on top of the inflow values.

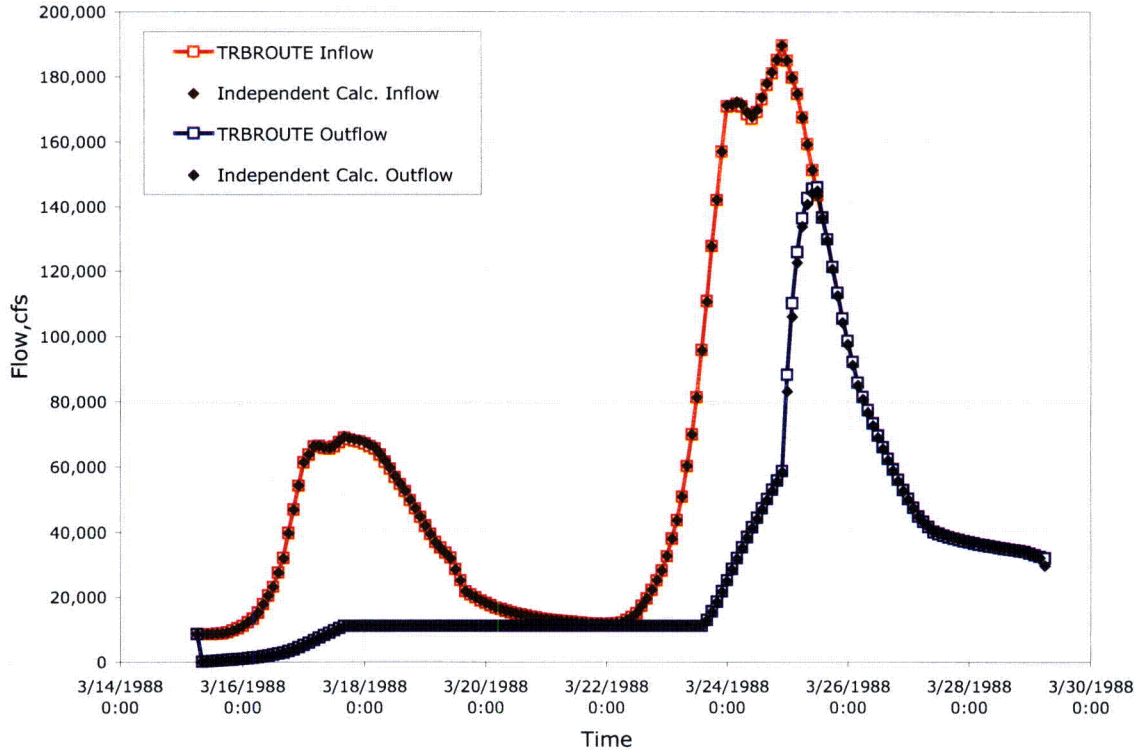

Figure 73. Comparison of Outputs from TRBROUTE and Independent Calculations in Excel for Test Problem 1, Cherokee Dam

5.2.1.2 Test Problem 2

A comparison of the outflows from the Muskingum routing using the TRBROUTE code and those derived through independent calculations for Test Problem 2 are presented in Figure 74.

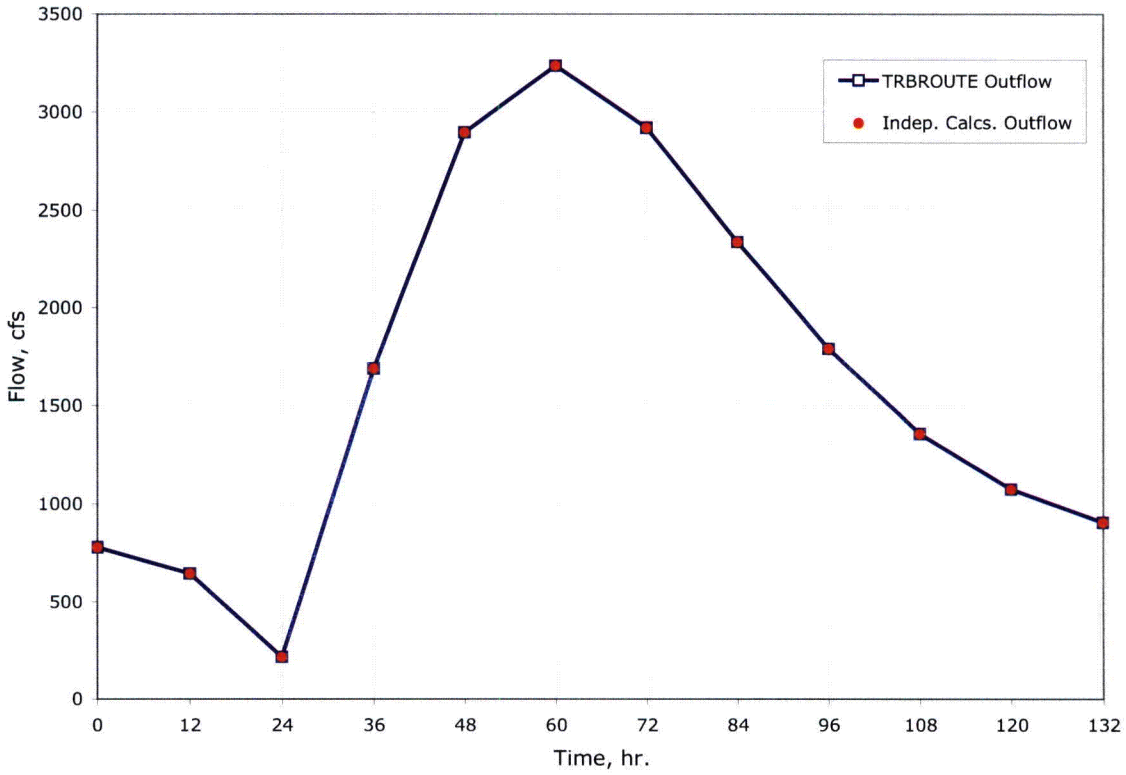

Figure 74. Comparison of Outflows from TRBROUTE and Independent Calculations in Excel for Test Problem 2

5.2.1.3 Test Problem 3

A comparison of the outflows from the Muskingum routing using the TRBROUTE code and those derived through independent calculations for Test Problem 3 are presented in Figure 75.

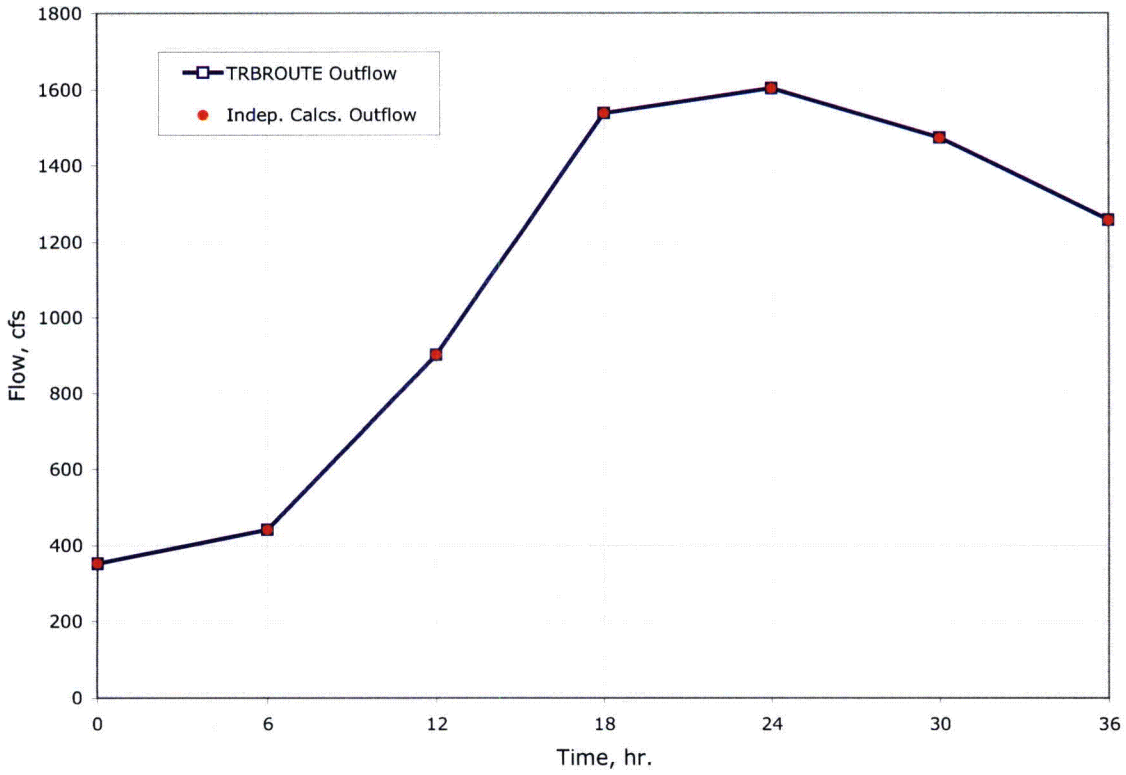

Figure 75. Comparison of Outflows from TRBROUTE and Independent Calculations in Excel for Test Problem 3

5.2.1.4 Test Problem 4

A comparison of the outflows from the Muskingum routing using the TRBROUTE code and those derived through independent calculations for Test Problem 4 are presented in Figure 76.

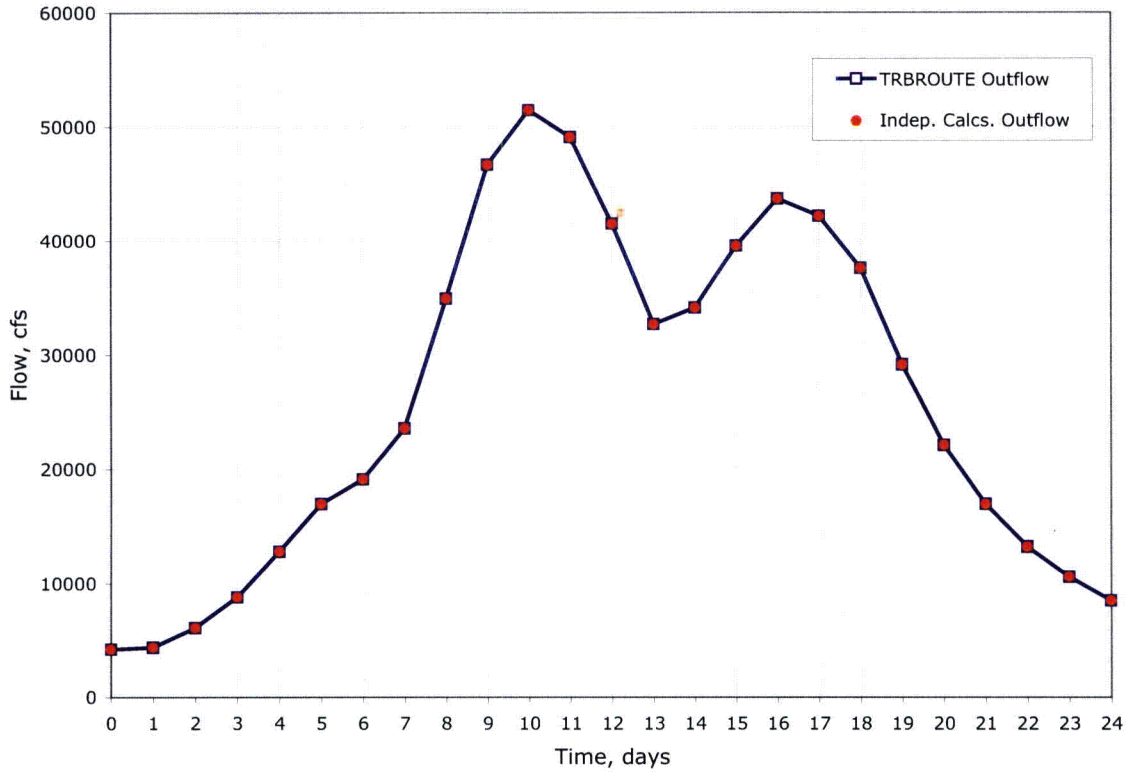

Figure 76. Comparison of Outflows from TRBROUTE and Independent Calculations in Excel for Test Problem 4

5.2.1.5 Test Problem 5

A comparison of the outflows from the Muskingum routing using the TRBROUTE code and those derived through independent calculations for Test Problem 5 are presented in Figure 77.

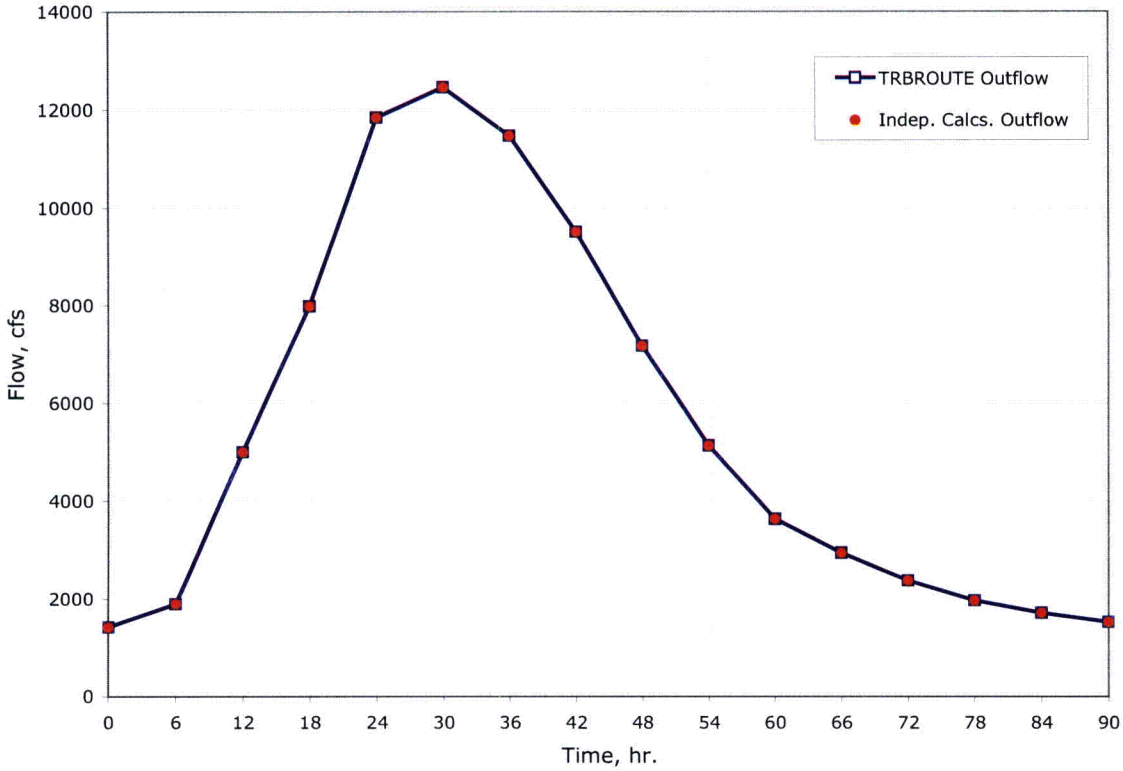

Figure 77. Comparison of Outflows from TRBROUTE and Independent Calculations in Excel for Test Problem 5

5.2.1.6 Summary of Implementation Test Problems

As can be seen in Figure 69 through Figure 73, the results from the independent calculations and those obtained through independent calculation are similar, but do not match exactly for Test Problem 1. This can be attributed to differences in the seasonal guide elevations used. TRBROUTE interpolates the seasonal guide elevation for each routing time step while average daily seasonal guide elevation was used in the independent calculation. As can be seen in Figure 74 through Figure 77, for Test Problems 2 through 5 the results are practically identical. Differences in calculated outflows can be attributed to the rounding of input flow values when converting from cubic meters per second to cfs for FLDHYRO whereas exact values were used in the independent calculations. The results of this analysis verify that the TRBROUTE code properly implements reservoir and channel routing.

5.2.2 Response of TRBROUTE to Abnormal Input Data

TRBROUTE has built-in safeguards to warn users when abnormal situations arise during operation of the program. A listing of these safeguards is provided below.

- TRBROUTE checks some input parameters for values out of range. If the number of storms, instruction code value, or rating curve code value is out of range, the run terminates. In this case, the output file consists only of an echo of the input data already read and one of the following messages:

" (No. Storms) IS INVALID AS NUMBER OF STORMS; MAXIMUM IS 9"

" (Instruction Code) IS INVALID INSTRUCTION CODE; RANGE IS 1 TO 6"

" (Rating Curve Code) IS INVALID CODE FOR RATING CURVES; RANGE IS 0 TO 2"

- When using the look up tables, the reservoir name given in the main input file must match one of the reservoir names in the look up tables. If the names do not match, the data for the last entry in the look-up table will be used for computations and the run will continue with the invalid data. In this case, the output file consists of an echo of the input data, and the output data. One or more of the following messages will be inserted before the output for the reservoir with the invalid name:

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN STORAGE CURVES FILE"

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN DISCHARGE CURVES FILE"

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN IMPROVED FIXED RULES FILE"

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN SEASONAL GUIDES FILE"

If none of the above abnormal conditions occurs, TRBROUTE is presumed to have functioned normally. In this case, the entire output file is created.

However, it is possible for TRBROUTE to appear to have functioned normally while using invalid input data. A few such cases are presented below:

- **Negative value input in hydrograph input file:**

  Physically, all hydrograph values should be greater than zero. However, TRBROUTE does not reject input values that are less than zero. TRBROUTE still terminates normally without any warning or error message when negative hydrograph values are input to the hydrograph input file.

- **Initial Headwater elevation above the range of elevation values in the look-up table:**

  The QRATINGS and IMPRULES data input files in TRBROUTE contain discharge rating curves for specified TVA structures. When initial headwater elevation values are specified above the range given in the table, the discharge obtained from these tables is invalid. TRBROUTE still terminates normally without any warning or error message when initial headwater elevations are greater than the largest value in the look-up tables.

In the cases presented in this section, TRBROUTE accepts invalid input data but does not warn the user that the data are invalid. In some cases TRBROUTE may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of TRBROUTE besides those presented above. Therefore, it is the responsibility of the user to confirm that the input data file is valid in order to ensure that the TRBROUTE output is also valid. Normal termination of TRBROUTE is a necessary but not sufficient condition for producing valid results.

6. SUMMARY AND CONCLUSIONS

Several test problems were used to check the functionality of UNITGRPH, FLDHYDRO, CHANROUT, TRBROUTE and verify that the hydrologic theory used by each of these computer programs is implemented correctly in the code. Specifically four test problems were employed to test the implementation of the UNITGRPH theory and six additional problems were used to test specific options available in the code. Six problems were used to test the implementation of the theory that FLDHYDRO is based on, and three additional problems were used to test specific options available in the code. Three problems were used to test the implementation of the theory of CHANROUT and five problems to test the theory of TRBROUTE.

In addition to these problems numerous test runs were made with each of these codes to test their response to abnormal input data, i.e. to data values out of the expected range of values for specific parameters, sequential data out of order, etc.

All the test problems were solved with each of the codes under validation and by performing independent calculations implementing the theory of each code in an Excel spreadsheet. In all the test problems the results of the four codes were in good agreement with the results of the independent calculations. In most cases the results were identical. In cases where there were small differences, these differences were attributed to round-off errors.

Even though some of the codes produce error messages when abnormal data are used as input, in most cases such abnormal data are not detected and the codes may terminate normally. Normal termination of these codes is a necessary but not sufficient condition for producing valid results. Therefore, it is recommended that the user of these codes checks thoroughly the input data to confirm that they are valid and ensure that the output of these codes is also valid.

Based on the results of all the test problems, the computer codes UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT are considered validated and verified for use.

7. REFERENCES

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SVVR

UNITGRPH
Version 1.0

FLDHYDRO
Version 1.0

TRBROUTE
Version 1.0

CHANROUTE
Version 1.0

Attachment 1

Test Problem Input

SVVR

UNITGRPH
Version 1.0

Test Problem Input

SVVR

FLDHYDRO
Version 1.0

Test Problem Input

SVVR

TRBROUTE
Version 1.0

Test Problem Input

SVVR

CHANROUTE
Version 1.0

Test Problem Input

SVVR

UNITGRPH
Version 1.0

FLDHYDRO
Version 1.0

TRBROUTE
Version 1.0

CHANROUTE
Version 1.0

Attachment 2

Test Problem Output

SVVR

UNITGRPH
Version 1.0

Test Problem Output

SVVR

FLDHYDRO
Version 1.0

Test Problem Output

SVVR

TRBROUTE
Version 1.0

Test Problem Output

SVVR

CHANROUTE
Version 1.0

Test Problem Output

SVVR

UNITGRPH
Version 1.0

FLDHYDRO
Version 1.0

TRBROUTE
Version 1.1

CHANROUTE
Version 1.0

Attachment 3

Source & Executable

SVVR
Attachment 3

CHANROUTE Version 1

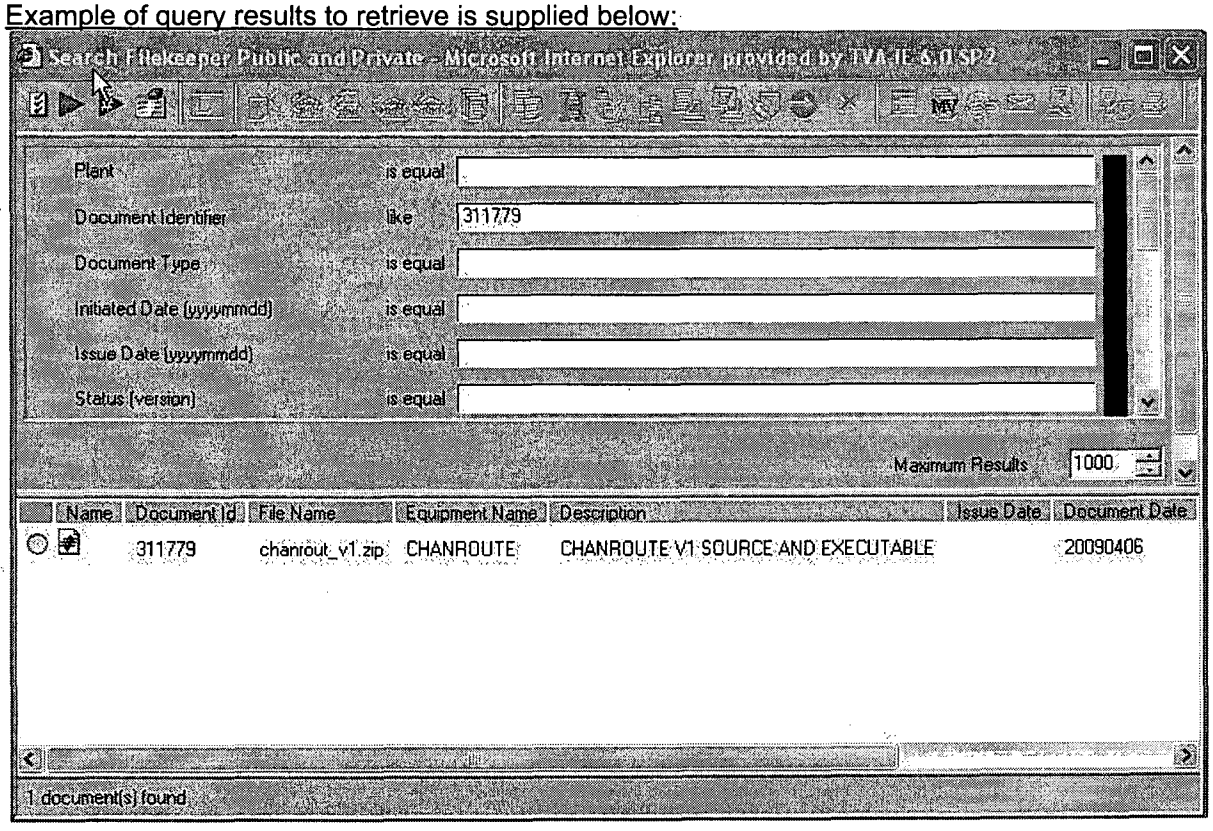
TVA Storage of CHANROUTE Source Code and Executable provided by Bechtel.

CHANROUTE V1 Source and compiled executable delivered by Bechtel has was compressed by TVA into ZIP file chanrout_v1.zip and stored in BSL-FileKeeper (Private).

COC BSL
NUC Corporate Library (BSL-FileKeeper)
Document Class: FileKeeper-Private, Nuclear)

BSL FileKeeper Unique Document Identifier: 311779

Example of query results to retrieve is supplied below:



SVVR
Attachment 3

FLDHYDRO Version 1

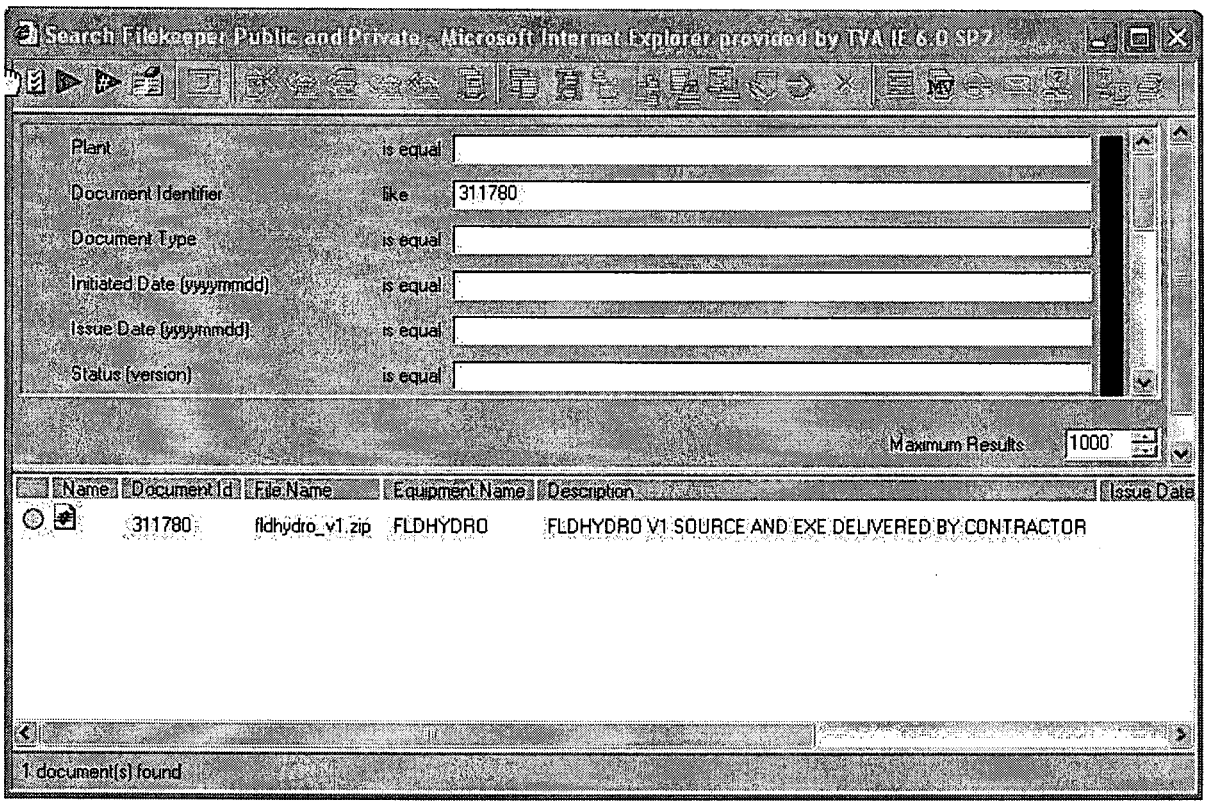
TVA Storage of FLDHYDRO Source Code and Executable provided by Bechtel.

FLDHYDRO V1 Source and compiled executable delivered by Bechtel has was compressed by TVA into ZIP file **fldhydro_v1.zip** and stored in BSL-FileKeeper (Private).

COC BSL
NUC Corporate Library (BSL-FileKeeper)
Document Class: FileKeeper-Private, Nuclear)

BSL FileKeeper Unique Document Identifier: 311780

Example of query results to retrieve is supplied below:



SVVR
Attachment 3

TRBROUTE Version 1.1

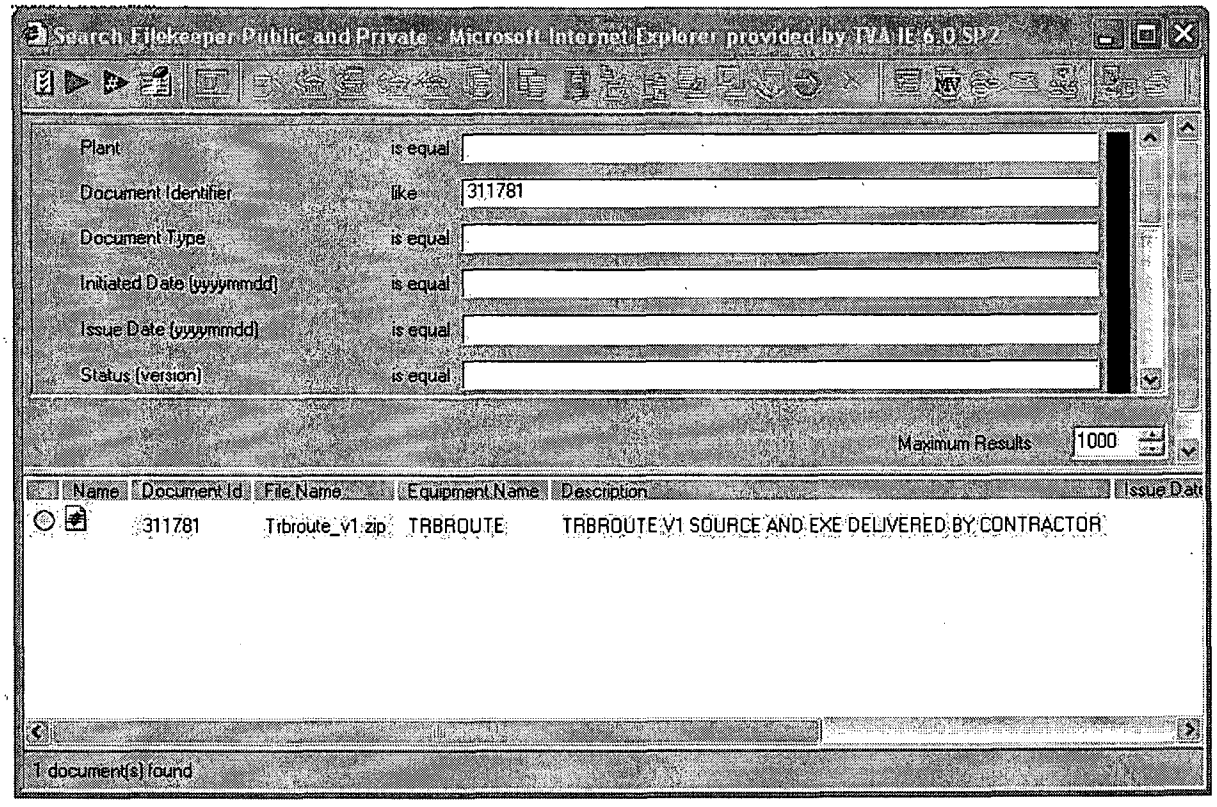
TVA Storage of TRBROUTE Source Code and Executable provided by TVA-River Operations.

TRBROUTE V1.1 Source and compiled executable delivered by Bechtel has was compressed by TVA into ZIP file **trbroute_v1.zip** and stored in BSL-FileKeeper (Private).

COC BSL
NUC Corporate Library (BSL-FileKeeper)
Document Class: FileKeeper-Private, Nuclear)

BSL FileKeeper Unique Document Identifier: 311781

Example of query results to retrieve is supplied below:



SVVR
Attachment 3

UNITGRPH Version 1

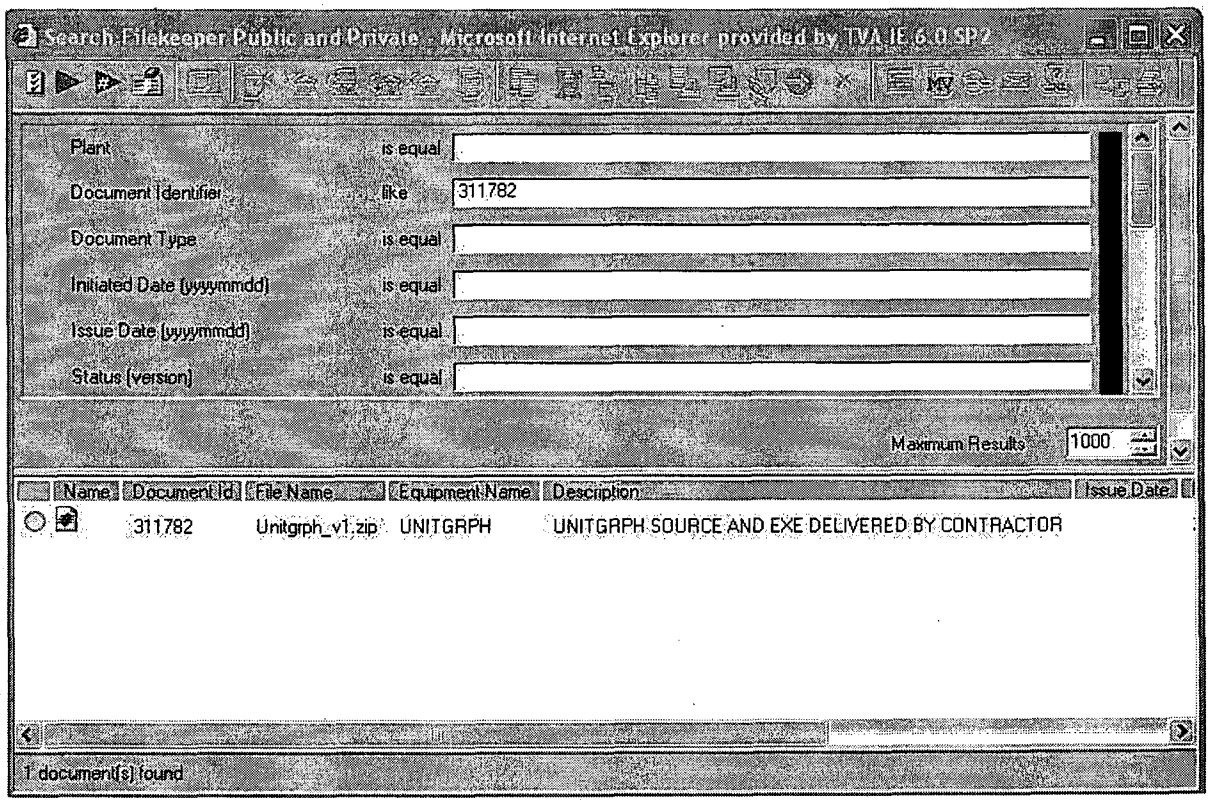
TVA Storage of UNITGRPH Source Code and Executable provided by Bechtel.

UNITGRPH V1 Source and compiled executable delivered by Bechtel has was compressed by TVA into ZIP file **unitgrph_v1.zip** and stored in BSL-FileKeeper (Private).

COC BSL
NUC Corporate Library (BSL-FileKeeper)
Document Class: FileKeeper-Private, Nuclear)

BSL FileKeeper Unique Document Identifier: 311782

Example of query results to retrieve is supplied below:



SVVR

UNITGRPH
Version 1.0

FLDHYDRO
Version 1.0

TRBROUTE
Version 1.0

CHANROUTE
Version 1.0

Attachment 4

Independent Calculations

SVVR

UNITGRPH
Version 1.0

Independent Calculations

SVVR

FLDHYDRO
Version 1.0

Independent Calculations

SVVR

TRBROUTE
Version 1.0

Independent Calculations

SVVR

CHANROUTE
Version 1.0

Independent Calculations

L58 091223 001

Tennessee Valley Authority

USER'S MANUAL

UNITGRPH Version 1.0
FLDHYRDO Version 1.0
TRBROUTE Version 1.1
CHANROUT Version 1.0

	R0	R1	R2	R3
Prepared	Angelos Findikakis	James Kelley		
		Steve Limback		
Reviewed	Lena Ireland	Eric King		
Approved		K.R. Gates		
Issue Date		~~12-22-09~~ 12-23-09		

L58 090325 001

Tennessee Valley Authority

USER'S MANUAL

UNITGRPH
FLDHYRDO
TRBROUTE
CHANROUT

Version 1.0

	R0	R1	R2	R3
Prepared	Angelos Findikakis			
Reviewed	Lena Ireland			
Approved	K.R. Spates			
Issue Date	3-25-09			

	REVISION LOG	
Revision Number	**Description of Revision**	**Date Approved**
0	Original Issue - Issued in support of the UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT computer codes used to prepare input data for the SOCH computer code, Version SOCH90PC	
1	• Revised FLDHYDRO Section 3.3.3 to add additional user warnings – Pages 33 • Revised TRBROUTE Section 5.21 (Page 41), Table 5 (Page 45) and Section 5.3.4 (Page 53) to increase the maximum number of storms from three (3) to nine (9). • Replaced TRBROUTE source code in Appendix L with TRBROUTE Version 1.1 (Note: This revision does not change the functionality of the program and will provide the same results as in Appendix O. Appendix O is unchanged)	

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ABBREVIATIONS

cfs	cubic feet per second
dsf	day-second-feet
mi^2	square mile

ACRONYMS

API	Antecedent Precipitation Index
ARMA	Autoregressive Moving Average
BLN	Bellefonte Nuclear Plant
CV	Check Volume
PC	Personal computer
RI	Runoff Index
SE	Southeast
SOCH	Simulated Open Channel Hydraulics
TVA	Tennessee Valley Authority

1. INTRODUCTION

1.1 The TVA SOCH Suite of Computer Codes

The Tennessee Valley Authority (TVA) has developed and used the Simulated Open Channel Hydraulics (SOCH) code for flood routing calculations in the Tennessee River basin. In addition to this code, TVA has developed seven auxiliary codes to prepare the required inputs to SOCH. These codes are: UNITGRPH, FLDHYDRO, TRBROUTE, CHANROUT, DBREACH, CONVEY, and WWIDTH. Table 1 gives a brief description of the seven codes used together with SOCH.

These codes are being used to develop, calibrate, and verify the runoff and stream course models needed to compute elevations and discharges at the Bellefonte Nuclear Plant (BLN) site.

This manual provides instructions for the use of four of these codes, UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT.

These programs were originally developed and run on a mainframe computer. Later they were transferred to the personal computer (PC).

Table 1. Summary of TVA's Flood Analysis Codes

Computer Code	Description
UNITGRPH	Computes unit hydrographs from historical flood data.
FLDHYDRO	Determines inflows from unit hydrographs and rainfall.
TRBROUTE	Routes hydrographs from one point to another using different routing procedures (channel & reservoir).
CHANROUT	Determines channel routing method coefficients.
DBREACH	Determines time of failure of an overtopped earth embankment based on soil type and time and depth of overtopping during a flood.
WWIDTH	Determines equivalent weighted width (B) to account for reservoir volume in SOCH geometry.
CONVEY	Determines cross sectional area (A) and composite conveyance for SOCH geometry.
SOCH	One dimensional unsteady flow model that computes elevation, discharge, and average velocity at selected locations.

Figure 1 illustrates the sequence of use of the codes described in Table 1.

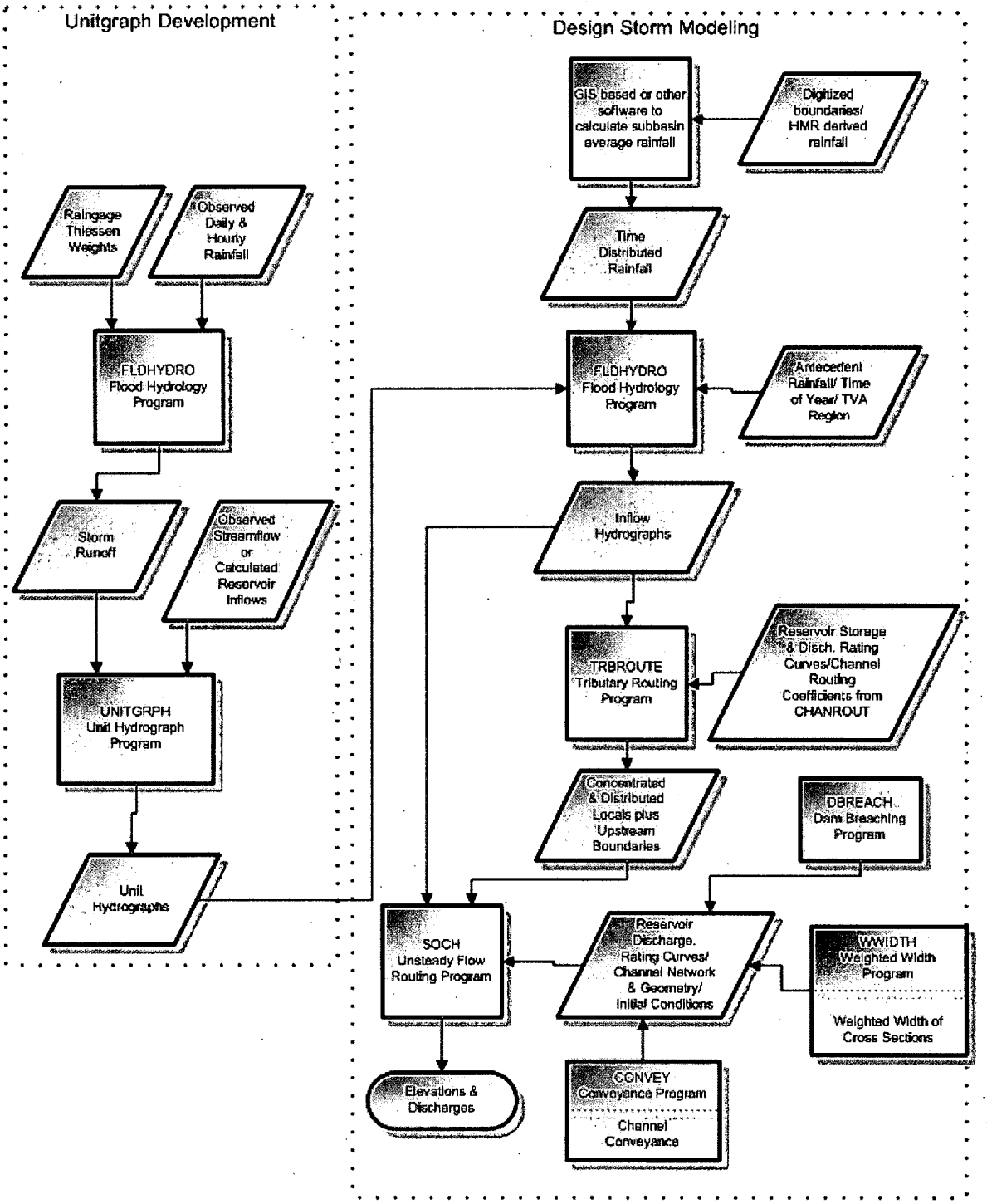


Figure 1. TVA's Flood Analysis Computer Codes.

Inflow hydrographs at input points to the SOCH model are generated by the FLDHYDRO and TRBROUTE codes with inputs from UNITGRPH and CHANROUT. The Tennessee River basin has been divided into watershed sub-basins (unit areas). Unit hydrographs as determined by the UNITGRPH code are used to compute flows from each unit area. These unit area flows computed by the flood hydrograph code (FLDHYDRO) are combined with appropriate channel routing coefficients (computed using CHANROUT) to compute inflows into the most upstream reservoirs which in turn are routed through the reservoirs using the TRBROUTE code. Resulting outflows are combined with additional local inflows and carried downstream using appropriate time sequencing or routing procedures (TRBROUTE code), including unsteady flow routing (SOCH code).

1.2 Scope

Section 2 of this document describes the theoretical basis, input parameters, and gives examples of input and output files of the UNITGRPH code. FLDHYDRO, CHANROUT, and TRBROUTE, are described in Sections 3, 4, and 5 respectively. References are presented in Section 6. Appendices A through D provide a listing of the FORTRAN source code and sample input and output files for UNITGRPH. Appendices E through H provide the same information for FLDHYDRO, Appendices I through K for CHANROUT, and Appendices L through P for TRBROUTE.

1.3 Limitations on Use

There are no major limitations in the use of UNITGRPH, FLDHYDRO, TRBROUTE, and CHANROUT related to the calculations performed by these codes. The primary limitations arise from the dimensions of arrays in these codes. These limitations can be addressed by editing the source code to create a new executable. Source code revisions must adhere to Reference 1, Section 3.3.2.

Limitations in the range of parameter values that are used as input to the four codes described in this manual are discussed for UNITGRPH in Section 2.3.1, for FLDHYDRO in Section 3.3.1, for CHANROUT in Section 4.3.1, and for TRBROUTE in Section 5.3.1. The response of each program to abnormal input data is discussed for UNITGRPH in Section 2.3.3, for FLDHYDRO in Section 3.3.3, for CHANROUT in Section 4.3.3, and for TRBROUTE in Section 5.3.4.

1.4 Maintenance and User Support

The application owner is Nuclear Power Group (NPG) Corporate Civil Engineering. User support needs will be arranged through the NPG Corporate Civil Engineering with the technically cognizant TVA organization or vendor. Any problems identified with the software should be reported to NPG Corporate Civil Engineering.

2. UNITGRPH

2.1 Theoretical Basis

The UNITGRPH code has been used to develop unit hydrographs for the sub-basins of the Tennessee River basin. The highest historical floods for which suitable data are available were used for this purpose. The historic flood information was obtained from recording stream gages, tributary dam headwater elevation, discharge and storage relationships which permitted calculation of the flood, and estimates on ungaged watersheds where historic flood information upstream and downstream of the watershed under consideration was available to make flow estimates.

The UNITGRPH code implements the method for unit hydrograph development described in Reference 2, which uses matrix algebra and a least squares approach to iteratively solve for the unit hydrograph and precipitation excess values that provide the best fit to the observed flood or a series of floods.

The method described in Reference 2 is based on the following equation which expresses how a series of runoff data can be combined with the unit hydrograph to produce the flood hydrograph:

$$\begin{bmatrix} r_1 & & & & \\ r_2 & r_1 & & & \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ r_i & r_{i-1} & \cdots & r_1 & \\ & r_i & r_{i-1} & \cdots & r_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ & & & & r_i \end{bmatrix} \cdot \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ \vdots \\ u_j \end{bmatrix} = \begin{bmatrix} q_1 \\ q_2 \\ \vdots \\ q_i \\ q_{i+1} \\ \vdots \\ q_n \end{bmatrix} \tag{1}$$

where

$[r_1 \;\; r_2 \;\; \ldots \;\; r_{i-1} \;\; r_i]$ is the time series of runoff depths

$[u_1 \;\; u_2 \;\; \ldots \;\; u_{j-1} \;\; u_j]$ is the unit hydrograph

$[q_1 \;\; q_2 \;\; \ldots \;\; q_{n-1} \;\; q_n]$ is the flood hydrograph

i is the number of runoff depth (i.e. precipitation excess ordinates)

j is the number of ordinates of the unit hydrograph (excluding the first and last 0)

n is the number of flow ordinates of the flood hydrograph

j is related to i and n by the expression: $j = n-i+1$.

Equation (1) can be written also as

$$(R) \cdot U = Q \tag{2}$$

where

(R) is the matrix of runoff values; (R) has j columns and n rows

U is the unit hydrograph vector; U has j values

Q is the flood hydrograph vector; Q has n values

Equation (2) is multiplied by the transpose of the matrix R, i.e.

$$\left[(R)^T \cdot (R)\right] \cdot U = (R)^T \cdot Q \tag{3}$$

where

$(R)^T$ is the transpose of matrix (R)

The unit hydrograph is obtained by solving Equation (3). The solution of Equation (3) can be expressed as:

$$U = \left[(R)^T \cdot (R)\right]^{-1} \cdot (R)^T \cdot Q \tag{4}$$

As stated in Reference 2 the estimation of the unit hydrograph is subject to error due to the uncertainty in the runoff values. For this purpose Equation (2) can be modified by introducing an error term (E) and substituting (R) with $(R+E)$, leading to:

$$\left[(R+E)\right] \cdot U = (R) \cdot U + (E) \cdot U = Q \tag{5}$$

Equation (5) can be rewritten as:

$$\hat{Q} + (E) \cdot U = Q \tag{6}$$

where $\hat{Q} = (R) \cdot U$

Equation (6) can be rewritten as:

$$\hat{Q} + (U) \cdot E = Q \tag{7}$$

where (U) is an $n \times i$ matrix of unit hydrograph ordinates and E is the $i \times 1$ error vector, i.e.:

$$(U) = \begin{bmatrix} u_1 & & & & \\ u_2 & u_1 & & & \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ u_j & u_{j-1} & \dots & u_1 & \\ & u_j & u_{j-1} & \dots & u_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ & & & & uj \end{bmatrix} \text{ and } E = \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ \vdots \\ e_i \end{bmatrix}$$

The solution of Equation (7) for the error term can be expressed as:

$$E = \left[(U)^T \cdot (U)\right]^{-1} \cdot (U)^T \cdot \left[Q - \hat{Q}\right] \tag{8}$$

2.2 The UNITGRPH code and How to Run it

The method for the derivation of the unit hydrograph described in Section 2.1 has been implemented in a FORTRAN code, originally developed by TVA in April 1967 and programmed to run on a mainframe computer. The code was later transferred to the

personal computer (PC). The latest version of the code has been compiled using the Compaq Visual FORTRAN, Professional Edition 6.6A.

The UNITGRPH code consists of the main program and three subroutines:

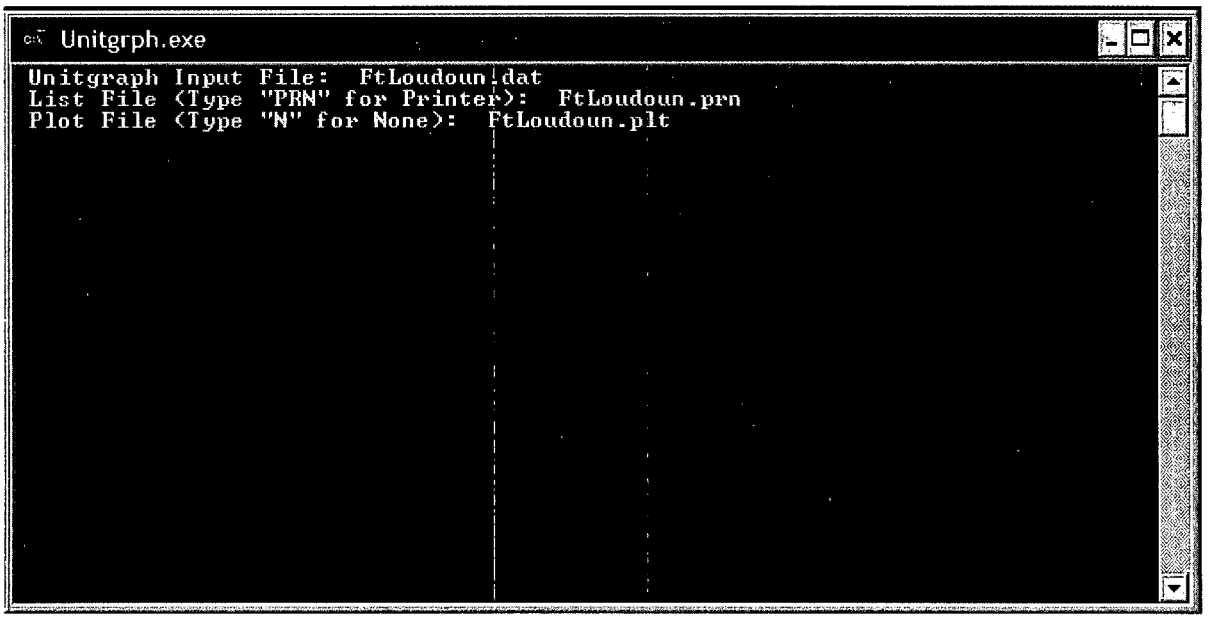
- AVERAG, which performs averaging on the runoff matrix.
- XATEQ(A,B,N,M,DET) which solves a system of linear equations; A is the system matrix and B is the right hand side vector. The solution returned is in the array B.
- GRAFIT(U,UGD,NUGO,Q,CQ,NQ,NFLOOD,HEAD,HEAD2) writes the output data for facilitating the plotting of the unit hydrograph, and the measured and computed flood hydrograph.

A complete listing of the main program and the subroutines of UNITGRPH is given in Appendix A.

To run UNITGRPH on a Windows PC go through the following steps:

1. Create a shortcut of the executable UNITGRPH.EXE, by placing the cursor on the file UNITGRPH.EXE, right clicking the mouse and from the open menu selecting "Create Shortcut".
2. Copy the shortcut to the Desktop.
3. Right button click the shortcut icon and choose "properties".
4. Change the "Start in:" folder to the folder containing the UNITGRPH input data file(s). If the input data file is in the same folder as the executable, there is no need to perform this step.
5. Double click on the UNITGRPH shortcut icon
6. When prompted, provide the name of the input and the output files.

An example of the interactive session for running UNITGRPH is given below:



When the execution window disappears, UNITGRPH has run and produced the output files FtLoudoun.prn and FtLoudoun.plt, which are located in the same folder as the input data file. The contents of the input and output files are discussed in detail in Sections 2.3 and 2.4.

2.3 Input Data

2.3.1 Description of Input Variables

UNITGRPH uses one input file and creates two output files, which are associated with specific Unit numbers in the standard FORTRAN language terminology.

Input:

- Unit 5: INFIL – The main input file where the input parameters are provided.

Output:

- Unit 6: OUTFIL – The standard file for printed output.
- Unit 3: PLTFIL – Output file with key output data in format for easy plotting

Table 2 gives the structure and format of the input file to UNITGRPH. The designations used to describe the format of the input data in Table 2 are the standard designations used in FORTRAN. The designations "F" and "I" are used to indicate floating point and integer numbers respectively. They are followed by a number that indicates the number of characters in each field, and preceded by a number indicating how many times a field is repeated, i.e. how many such numbers are entered sequentially in the same line. For example, 8I9 indicates 8 fields, each of which contains an integer number 9 characters long. An integer number should be placed at the right end of the corresponding field. Blanks after any numbers are interpreted as zeros. For example, if the format is I9, and the data file contains the number 55 preceded by 7 blanks, the program will read it correctly. If,

however, the number 55 is shifted within the 9-character field in such a way as it is preceded by 6 blanks and followed by a blank, then the program will read it as 550, because it will interpret the last blank as zero. The floating point number designation indicates also how many significant decimal digits follow the decimal point. For example, the format 8F9.2 indicates that they are 8 numbers, each of which can be as long as 9 characters, the last two of which are decimal digits. The letter "A" is the format designation of a single character alphanumeric variable. If the letter "A" is followed by number, this number indicates the number of characters in the alphanumeric variable. For example the format 80A1 indicates 80 variable each consisting of a single character and together forming a 80-character title line.

Table 2. Structure and Format of UNITGRPH Input

No	Name	Definition	Format
1	NRUNS	Number of complete runs (when plotting option was available, this allowed for multiple unit graph plots – Now obsolete, so specify 1).	I3, F5.0
	ERROR	Error convergence value. Convergence factor equal to the average allowable percent error between computed and observed flood hydrograph. A value of 0.05 or 5 percent has been used with satisfactory results. The program will continue to adjust the rainfall excess and the unit graph until an error of 0.05 has been obtained or until a specified number of iterations has been completed. (The number of iterations is specified later in the data).	
2	HEAD(I) I = 1, 80	First title line.	80A1
	HEAD2(I) I = 1, 80	Second title line.	
3	NFLOOD	Number of floods from which the unit graph is derived. It is 1 when a unit graph is made from a single flood or equals the number of flood hydrographs used in determining a "composite" unit graph. NFLOOD cannot exceed 10.	3I12, 2F10.0
	ITERS	Maximum number of iterations desired if the ERROR factor of 0.05 is not reached. Experience has shown that improvement is small after about five iterations.	
	NLIST	Number of LIST(I) ordinates used to define the number of directly computed unit graph ordinates. NLIST cannot exceed 20.	
	AD	Drainage area (in thousand square miles).	

No	Name	Definition	Format
	UGD	Runoff input interval and unit graph duration (in hours).	
4	LIST(I) I = 1, NLIST	List of ordinates of the unit graph to be directly computed, including the first LIST(1) ordinates. LIST(NLIST) must equal total number of unit graph ordinates (j), which is calculated from the number of input hydrograph ordinates (n) and excess rainfall ordinates (i) by the equation j=n-i+1, as shown in Section 2.1. Intermediate ordinates are found by interpolating between computed ordinates. This is a smoothing device usually used only in the recession of the unit graph. The list begins with the last ordinate to be directly computed before interpolation begins, and ends on the last ordinate computed for that unit graph. The maximum LIST value is 50.	20I4
5	IORD(I) I = 1, NFLOOD	First significant ordinate of input hydrograph.	20I4
	LORD(I) I = 1, NFLOOD	Last significant ordinate of input hydrograph. IORD and LORD are the ordinate numbers of the input hydrograph between which most of the hydrograph volume is contained. This is used in the error computation.	
6	NQ(K) K = 1, NFLOOD	Number of ordinates of input hydrograph, excluding leading or ending zeros. The maximum value of NQ(K) is 90.	20I4
7	NRO(K) K = 1, NFLOOD	Number of ordinates of the runoff, or rainfall excess, data. The time period for these ordinates must be equal to the duration of the computed unit graph. The maximum value of NRO(K) is 50. For all K storms, the following relation must hold true: LIST(NLIST)=NQ(K)-NRO(K)+1.	20I4
Note: Lines 8 and 9 must be repeated for each flood K, where K varies from 1 to NFLOOD, i.e. there should be NFLOOD sets of the data in lines 8 and 9.			
8	Q(I,K) I = 1, NQ(K)	Surface runoff hydrograph ordinates in units of thousands cubic feet per second (1000 cfs).	8F10.0
9	RO(I,K) I = 1, NRO(K)	Runoff ordinates (inches).	8F10.0

2.3.2 Example of Input Data File

An example of a typical UNITGRPH input data file is presented in Appendix B. It is for the derivation of the 6-hour unit hydrograph in the Ft. Loudoun subbasin.

2.3.3 Response of UNITGRPH to Abnormal Input Data

UNITGRPH has no built-in safeguards to warn users when abnormal situations arise during operation of the program. Therefore, as long as values of the proper dimension are input for each expected variable, UNITGRPH will produce an output file, regardless of whether the input data are logical or not. Therefore, it is possible for UNITGRPH to appear to have functioned normally while using invalid input data. A few such cases are presented below:

- **Negative value input for flood hydrograph or runoff:**

  Physically, all flood hydrograph ordinates and runoff values should be greater than zero. However, UNITGRPH does not reject input values that are less than zero (although computed hydrograph ordinates and runoff values are required to be greater than zero). UNITGRPH still terminates normally without any warning or error message when negative flood hydrograph or runoff values are input.

- **Negative value input for "LIST" value or basin area:**

  When negative "LIST" values or a negative value for the basin area are input, UNITGRPH returns "NaN" for most of the computed values. Therefore, it is obvious to the user that UNITGRPH has not functioned properly. However, UNITGRPH accepts these negative input values and still terminates normally without any warning or error message.

In the cases presented in this section, UNITGRPH accepts invalid input data but does not warn the user that the data are invalid. In some cases UNITGRPH may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of UNITGRPH besides those presented above. Therefore, it is the responsibility of the user to confirm that the data in the input file are valid in order to ensure that the UNITGRPH output is also valid. Normal termination of UNITGRPH is a necessary but not sufficient condition for producing valid results.

2.4 Output Data

UNITGRPH produces two output files, one with the data needed to plot key results, written out in Unit 3, and the main output file written out in Unit 6. Appendices C and D list these two files produced by running UNITGRPH with the input data given in the example presented in Appendix B.

The data in the plotting output file can be imported into Excel to produce plots of the unit and flood hydrographs. Figure 2 is a plot of the unit hydrograph produced by UNITGRPH for the example in Appendix B. Figure 3 is a plot of the measured flood hydrograph from the same example together with the computed flood hydrograph using the unit hydrograph shown in Figure 2.

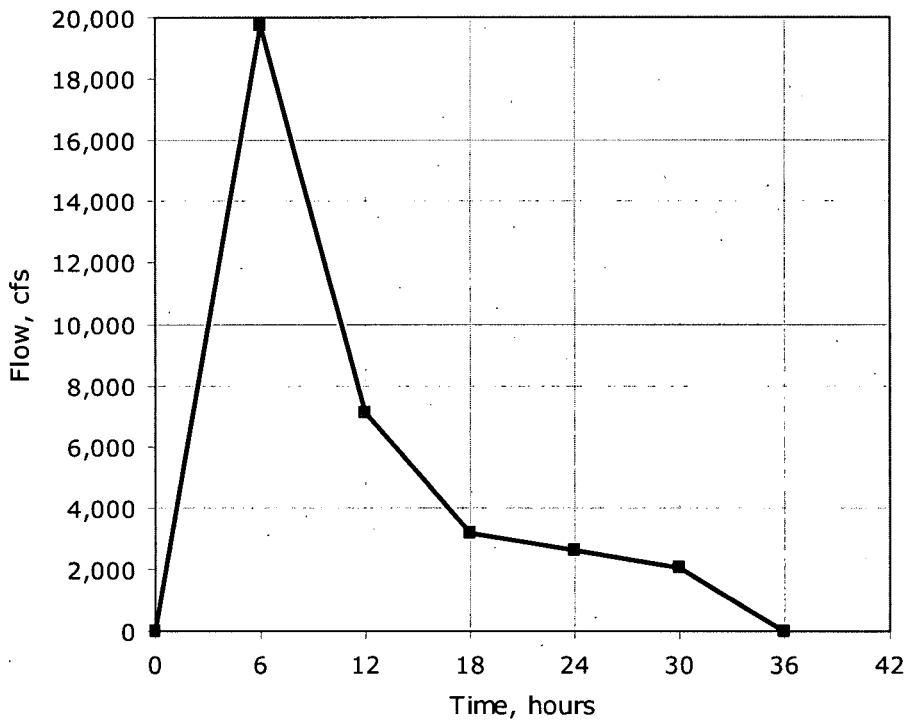


Figure 2. Computed unit hydrograph for the example described in Appendix B

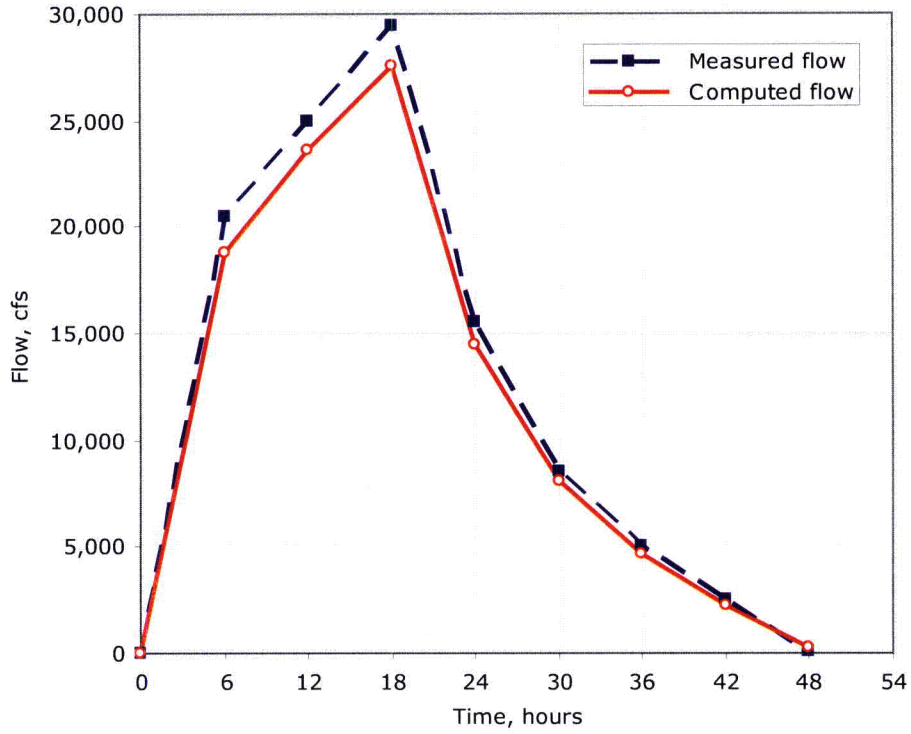


Figure 3. Computed and measured flood hydrograph for the example described in Appendix B

3. FLDHYDRO

3.1 Theoretical Basis

FLDHYDRO computes the runoff (also referred to as effective precipitation/rainfall or excess precipitation/rainfall) for specific storm events, as well as the flood hydrograph using as input the unit hydrograph and the rainfall distribution. The flood hydrograph flows computed with FLDHYDRO are either input directly into SOCH or by using the TRBROUTE code (Section 5) are combined using time sequencing or channel routing coefficients (computed by the CHANROUT code [Section 4]) and appropriately flat pool reservoir routed through the upper tributary system before being input to SOCH.

User inputs to the program include:

- Daily antecedent rainfall (optional),
- Hourly storm event rainfall,
- Thiessen weights (when needed)
- Base flow factor for each subwatershed and storm,
- Surface runoff volume at specified drainage points (optional), and
- Unit hydrographs for each subwatershed (optional, needed if the flood hydrograph is to be computed)
- Drainage area for each subwatershed

Also used as inputs to the program are three tables developed by TVA specifically for the Tennessee River basin (Reference 3):

- APITBL – relates locality parameters (geographic region [as defined in Figure 4] and week of the year) and Antecedent Precipitation Index (API) values to give Runoff Index (RI) values within the Tennessee River basin
- TV – relates RI and cumulative precipitation to effective precipitation for all Tennessee River basin runoff regions except the southeast (SE) region
- NonTV – relates RI and cumulative precipitation to effective precipitation for the SE runoff region of the Tennessee River basin

FLDHYDRO computes the runoff from rainfall data using the API as an estimate of initial moisture deficiency based on the method developed by Kohler and Linsley (References 4 and 5). The API for a given day is calculated from the following equation:

$$API_i = K*API_{i-1} + P_i \qquad (9)$$

API_i indicates the API value at time increment i and P_i the precipitation at the same time. K is a recession constant which the literature gives as normally having values in the range of 0.85 to 0.90 (Reference 4) or 0.85 to 0.98 (Reference 5). FLDHYDRO is programmed such that K is always equal to 0.90 and API values can range from 0 to 5. The API is used to obtain a Runoff Index (RI) that has been determined for the Tennessee River Valley region as a function of location and season. The RI is then used to obtain precipitation losses for each increment of rainfall. This method developed from a study of storm records, relates the amount of precipitation excess (and hence the precipitation loss) to the rainfall, the week of the year, the API, and the geographic location of the drainage basin. It was first

implemented graphically using coaxial relations between the API and runoff. In FLDHYDRO the method is implemented using lookup tables developed specifically for the Tennessee River basin.

The solution technique used by FLDHYDRO is similar to, but varies in implementation from the method proposed by Kohler and Linsley (Reference 4 and 5). In addition, FLDHYDRO gives the option of two different methods to compute the time sequence of excess precipitation, the antecedent rainfall method and the check volume method. These two methods are described in detail in Sections 3.1.1 and 3.1.2. Regardless of the method used, FLDHYDRO requires a region specification in order to provide excess precipitation for a storm event.

3.1.1 Antecedent Rainfall Method

The Antecedent Rainfall method, which is referred to also as the API method, calculates the total volume of runoff using the rainfall data for a specific storm and information or data on rainfall for a period prior to the storm event under consideration. When antecedent rainfall values are used, a starting API value for each rainfall event is either specified as input or calculated for each rain gage using Equation (9).

In order to use this equation, an API value at the start of the antecedent rainfall is needed. Usually, TVA uses a starting value of 1. The value of the index on any day theoretically depends on precipitation over an infinite antecedent period, but if a reasonable initial value is assumed, the computed index will closely approach the true value within a few weeks. Usually a month of antecedent rain is sufficient to define the API value.

Once a starting API value is obtained for the rainfall event, the APITBL is referenced (Figure 5). The week of the year and location of the runoff region are located across the top of the table. The RI values are located down the left side of the table. This table is used to find the RI value by first identifying the column with the proper locality parameters (region and week). This column is then followed down to the calculated API value. From the API value, the row is followed to the column of RI values and the corresponding RI value is read from the table.

Next, the TV or NonTV table is referenced. Which table is used depends on the runoff region. These tables have the RI value across the top of the table and effective precipitation down the left side of the table (Figure 6). These tables are used by first identifying the appropriate column for the RI value obtained from the APITBL. The column where this value is located is then followed down to the first cumulative rainfall value for the referenced storm. For each cumulative rainfall value, the row is followed over to the accumulative effective precipitation value for that time. This process is repeated for all time increments of the storm.

The use of these tables is illustrated also in Figure 7 where the plotted curves are based on data from the two tables shown in Figure 5 and Figure 6. Figure 8 shows the relationship between runoff and precipitation for different values of RI (data from the Table TV).

From the effective precipitation values, the runoff hydrograph is determined. If desired, these runoff values along with the unit hydrograph can then be used to compute the flood hydrograph using Equations (1) and (2) described in Section 2.1.

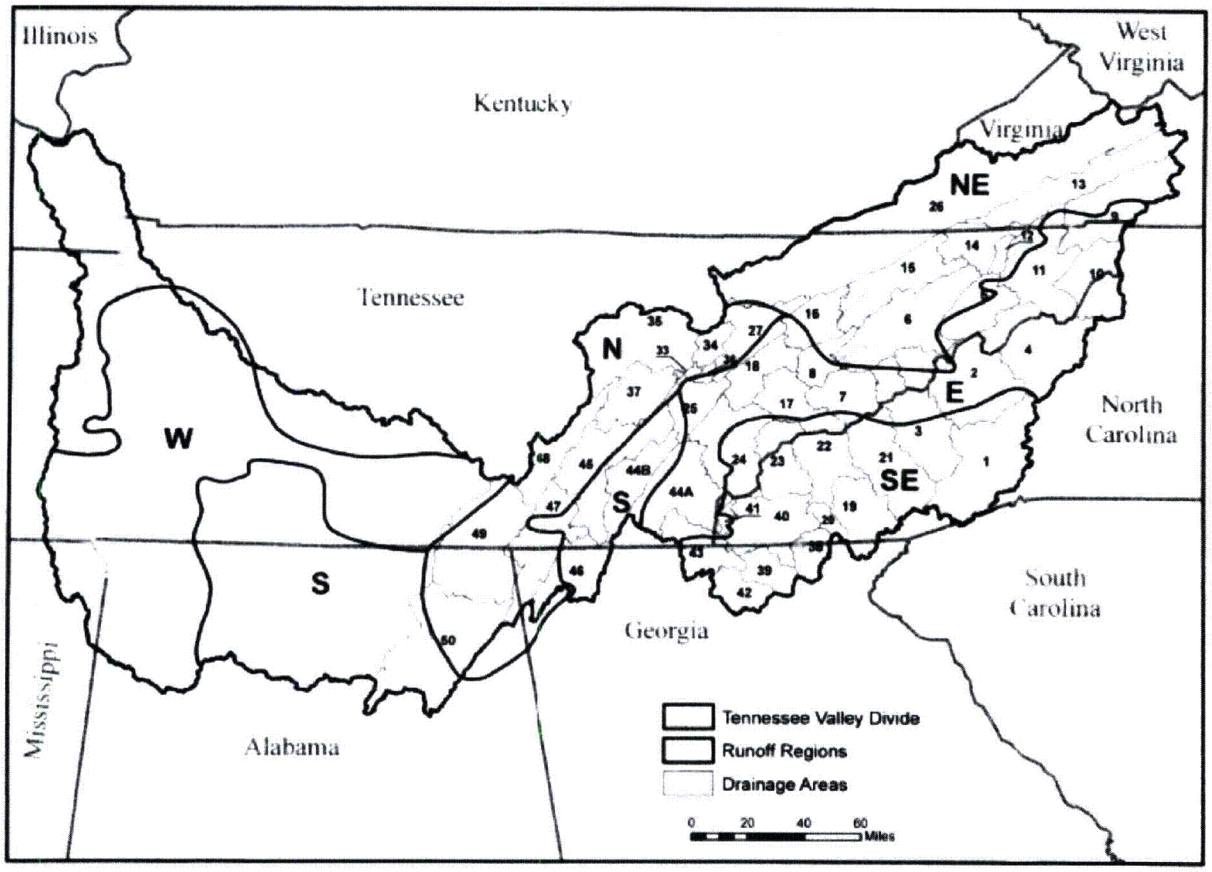
3.1.2 Check Volume Method

The Check Volume (CV) method is identical to the Antecedent Rainfall Method, with one exception. After the effective rainfall values are obtained from the TV or NonTV table, the

total runoff volume for each specified drainage point is calculated. These values are then compared with the input surface runoff volumes (check volumes) at these specified drainage points. If the values are not equal, the RI value is adjusted and new effective rainfall values are computed. This process is repeated until the calculated runoff volumes equal the check volumes. By using this method, antecedent rainfall input to the model is rendered moot as the RI value is used as a calibration parameter instead of a look-up value. The exception is when the check volume option is being used over more than one subwatershed where it is important to preserve each subwatershed's unique antecedent conditions. For instance, take the example of a run with 2 subwatersheds whose initial RI values computed from their individual API values are 24 and 26, respectively. If those RI's produce a composite storm volume for the 2 subwatersheds less than the check volume, then both "initial" RI values are reduced to 23 and 25, respectively, and another volume check is performed until the check volume value is matched. In this way, the different antecedent conditions between the 2 subwatersheds are preserved.

The check volume method distributes and scales excess precipitation, independently of antecedent precipitation, so that the total volume of excess precipitation approximately matches the calculated direct runoff volume. The direct runoff volume comes from the base flow separation calculations and is provided to the program with the CHKVOL variable. The time distribution of rainfall excess within the storm interval occurs according to the API region and season of the year provided to the FLDHYDRO model.

Figure 4. Six Regions for Determining RI from API



API

Region: SE

RI \ Week	1	2	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	41	42	43	44	45	46	47	48	49	50	51	52
70																																	
69																																	
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50																																	
49																					0.05												
48																					0.14												
47																				0.09	0.23	0.03											
46																			0.04	0.19	0.33	0.14											
45																			0.15	0.29	0.43	0.24											
44																		0.11	0.26	0.40	0.53	0.34	0.08										
43																	0.06	0.22	0.37	0.51	0.53	0.44	0.20										
42																	0.18	0.34	0.48	0.62	0.73	0.54	0.31	0.04									
41																0.13	0.31	0.46	0.60	0.72	0.84	0.66	0.43	0.17									
40															0.13	0.26	0.43	0.58	0.72	0.83	0.96	0.77	0.55	0.29									
39														0.13	0.27	0.39	0.57	0.72	0.84	0.95	1.07	0.88	0.67	0.41	0.09								
38													0.13	0.28	0.42	0.53	0.71	0.85	0.97	1.08	1.20	1.01	0.81	0.55	0.24								
37												0.14	0.30	0.43	0.57	0.68	0.85	1.00	1.12	1.22	1.33	1.14	0.94	0.69	0.39								
36										0.06	0.16	0.27	0.47	0.59	0.73	0.84	1.01	1.15	1.27	1.37	1.48	1.28	1.09	0.84	0.54	0.15							
35								0.04	0.13	0.24	0.33	0.50	0.64	0.77	0.91	1.02	1.18	1.32	1.42	1.54	1.64	1.45	1.25	0.99	0.72	0.33	0.17						
34							0.13	0.23	0.33	0.43	0.52	0.69	0.84	0.97	1.10	1.22	1.37	1.51	1.61	1.72	1.82	1.62	1.42	1.18	0.89	0.52	0.35	0.18					
33						0.22	0.34	0.44	0.54	0.64	0.74	0.91	1.07	1.19	1.32	1.46	1.58	1.71	1.81	1.92	2.02	1.83	1.62	1.38	1.10	0.74	0.56	0.38	0.18				
32					0.21	0.44	0.56	0.67	0.77	0.88	0.98	1.16	1.30	1.43	1.57	1.71	1.82	1.93	2.04	2.16	2.26	2.07	1.84	1.62	1.33	0.98	0.78	0.59	0.39	0.20			
31				0.17	0.46	0.70	0.81	0.92	1.03	1.14	1.27	1.42	1.58	1.71	1.85	1.99	2.09	2.21	2.33	2.45	2.59	2.36	2.10	1.88	1.58	1.27	1.04	0.83	0.62	0.43	0.19		
30			0.12	0.43	0.72	0.98	1.09	1.22	1.32	1.45	1.57	1.74	1.88	2.02	2.17	2.28	2.42	2.55	2.69	2.82	2.97	2.71	2.43	2.18	1.88	1.57	1.34	1.10	0.87	0.68	0.43	0.17	
29	0.12	0.12	0.40	0.72	1.02	1.28	1.42	1.55	1.67	1.80	1.92	2.09	2.24	2.37	2.54	2.68	2.77	2.96	3.11	3.25	3.45	3.12	2.82	2.53	2.25	1.91	1.67	1.43	1.18	0.94	0.71	0.42	0.12
28	0.38	0.38	0.69	1.03	1.35	1.64	1.77	1.91	2.03	2.17	2.32	2.51	2.67	2.82	2.98	3.14	3.31	3.46	3.62	3.81	4.00	3.65	3.29	2.95	2.66	2.32	2.05	1.78	1.52	1.25	1.02	0.70	0.38
27	0.68	0.68	1.02	1.38	1.73	2.03	2.18	2.32	2.47	2.63	2.79	2.97	3.15	3.34	3.53	3.70	3.89	4.07	4.23	4.42	4.62	4.23	3.85	3.47	3.12	2.78	2.49	2.20	1.92	1.67	1.38	1.02	0.68
26	1.04	1.04	1.38	1.78	2.15	2.48	2.65	2.82	2.97	3.15	3.30	3.52	3.73	3.93	4.15	4.35	4.56	4.75	4.92	5.00	5.00	4.90	4.50	4.08	3.68	3.30	3.00	2.67	2.35	2.04	1.78	1.38	1.04
25	1.50	1.50	1.87	2.28	2.65	3.00	3.20	3.39	3.57	3.77	3.93	4.17	4.40	4.64	4.85	5.00	5.00	5.00	5.00			5.00	5.00	4.79	4.35	3.92	3.61	3.26	2.90	2.56	2.28	1.86	1.50
24	2.07	2.07	2.47	2.86	3.24	3.64	3.85	4.06	4.27	4.51	4.67	4.90	5.00	5.00	5.00									5.00	5.00	4.65	4.30	3.93	3.56	3.21	2.85	2.47	2.07
23	2.75	2.75	3.24	3.62	3.98	4.37	4.60	4.82	5.00	5.00	5.00	5.00														5.00	5.00	4.73	4.30	3.94	3.52	3.20	2.75
22	3.60	3.60	4.13	4.50	4.83	5.00	5.00	5.00																				5.00	5.00	4.78	4.36	4.03	3.60
21	4.60	4.60	5.00	5.00	5.00																									5.00	5.00	4.95	4.60
20	5.00	5.00																														5.00	5.00

Region: SE

Figure 5. Table APITBL to Determine RI Values as a Function of the Week of the Year and API (SE Region)

RI \ Precipitation, inches	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
Runoff 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.05	0.42	0.44	0.46	0.48	0.5	0.52	0.54	0.56	0.58	0.6	0.62	0.64	0.67	0.69	0.71	0.73	0.75	0.77	0.78	0.8	0.81	0.83	0.85	0.87	0.88	0.92	0.96	1.01	1.05	1.1	1.22	1.34
0.10	0.54	0.56	0.59	0.62	0.65	0.68	0.73	0.77	0.78	0.84	0.89	0.92	0.94	0.97	1	1.03	1.06	1.09	1.12	1.15	1.2	1.25	1.3	1.35	1.4	1.48	1.56	1.65	1.73	1.82	1.98	2.14
0.15	0.65	0.68	0.72	0.75	0.8	0.84	0.9	0.96	0.98	1.04	1.1	1.14	1.18	1.21	1.26	1.31	1.36	1.39	1.44	1.49	1.54	1.62	1.69	1.76	1.88	1.9	2	2.11	2.23	2.35	2.51	2.67
0.20	0.76	0.8	0.85	0.89	0.95	1	1.07	1.13	1.17	1.23	1.29	1.34	1.4	1.44	1.5	1.57	1.64	1.68	1.74	1.8	1.87	1.97	2.04	2.12	2.2	2.28	2.41	2.55	2.68	2.8	2.97	3.14
0.25	0.87	0.92	0.98	1.02	1.09	1.16	1.23	1.3	1.35	1.42	1.48	1.54	1.6	1.66	1.72	1.81	1.89	1.95	2.01	2.08	2.18	2.29	2.35	2.44	2.55	2.64	2.78	2.97	3.05	3.2	3.36	3.52
0.30	0.98	1.04	1.11	1.15	1.23	1.31	1.39	1.46	1.52	1.6	1.66	1.73	1.8	1.86	1.93	2.04	2.13	2.2	2.27	2.34	2.47	2.58	2.65	2.74	2.86	2.98	3.12	3.29	3.39	3.55	3.72	3.88
0.35	1.09	1.15	1.23	1.28	1.37	1.46	1.54	1.61	1.68	1.78	1.84	1.92	1.99	2.06	2.13	2.25	2.35	2.43	2.51	2.59	2.73	2.84	2.92	3.03	3.15	3.28	3.42	3.58	3.7	3.85	4.01	4.17
0.40	1.19	1.26	1.35	1.41	1.5	1.6	1.68	1.76	1.84	1.95	2.02	2.11	2.17	2.26	2.33	2.45	2.55	2.65	2.74	2.83	2.97	3.08	3.18	3.3	3.41	3.55	3.69	3.85	3.98	4.12	4.28	4.45
0.45	1.29	1.37	1.47	1.53	1.63	1.73	1.82	1.91	2.01	2.12	2.19	2.29	2.35	2.45	2.53	2.65	2.76	2.86	2.96	3.06	3.19	3.3	3.42	3.54	3.65	3.79	3.94	4.08	4.22	4.37	4.55	4.72
0.50	1.39	1.48	1.59	1.65	1.76	1.86	1.96	2.06	2.16	2.28	2.35	2.46	2.53	2.63	2.72	2.84	2.94	3.05	3.17	3.28	3.4	3.51	3.65	3.76	3.87	4.02	4.17	4.3	4.45	4.62	4.8	4.98
0.55	1.49	1.59	1.71	1.77	1.88	1.99	2.1	2.2	2.31	2.43	2.51	2.62	2.7	2.8	2.9	3.02	3.13	3.24	3.37	3.48	3.6	3.71	3.85	3.96	4.08	4.23	4.38	4.52	4.68	4.85	5.03	5.22
0.60	1.59	1.69	1.82	1.89	2	2.12	2.23	2.34	2.45	2.58	2.66	2.78	2.86	2.97	3.07	3.19	3.31	3.43	3.56	3.67	3.78	3.9	4.03	4.15	4.28	4.43	4.58	4.73	4.9	5.06	5.25	5.44
0.65	1.69	1.79	1.93	2	2.12	2.24	2.36	2.47	2.58	2.72	2.8	2.93	3.02	3.13	3.23	3.35	3.48	3.61	3.73	3.85	3.96	4.08	4.21	4.33	4.47	4.61	4.77	4.93	5.1	5.27	5.46	5.65
0.70	1.78	1.89	2.04	2.12	2.24	2.36	2.48	2.6	2.71	2.86	2.96	3.07	3.17	3.28	3.38	3.51	3.64	3.78	3.89	4.02	4.13	4.25	4.39	4.51	4.65	4.8	4.96	5.12	5.3	5.48	5.66	5.85
0.75	1.87	1.99	2.14	2.23	2.35	2.47	2.6	2.72	2.84	2.99	3.08	3.21	3.32	3.42	3.52	3.67	3.79	3.94	4.04	4.18	4.29	4.42	4.56	4.69	4.82	4.98	5.14	5.31	5.49	5.67	5.85	6.04
0.80	1.96	2.09	2.24	2.33	2.46	2.58	2.71	2.84	2.96	3.11	3.22	3.34	3.46	3.56	3.66	3.82	3.93	4.09	4.19	4.34	4.45	4.58	4.73	4.86	4.98	5.15	5.31	5.49	5.67	5.85	6.03	6.22
0.85	2.05	2.18	2.34	2.44	2.57	2.69	2.82	2.96	3.08	3.23	3.35	3.46	3.59	3.69	3.8	3.96	4.07	4.23	4.34	4.49	4.6	4.73	4.89	5.02	5.14	5.31	5.48	5.66	5.85	6.03	6.2	6.39
0.90	2.14	2.27	2.44	2.55	2.68	2.8	2.93	3.07	3.2	3.35	3.47	3.58	3.71	3.82	3.93	4.09	4.2	4.36	4.48	4.63	4.75	4.88	5.04	5.17	5.3	5.47	5.64	5.83	6.02	6.2	6.37	6.56
0.95	2.23	2.36	2.53	2.65	2.78	2.91	3.04	3.18	3.31	3.46	3.58	3.7	3.83	3.94	4.05	4.21	4.33	4.48	4.62	4.77	4.9	5.03	5.19	5.32	5.45	5.62	5.8	5.99	6.18	6.36	6.53	6.72
1.00	2.31	2.45	2.62	2.74	2.88	3.01	3.15	3.29	3.42	3.57	3.69	3.82	3.94	4.05	4.17	4.33	4.46	4.6	4.75	4.91	5.04	5.18	5.33	5.47	5.6	5.77	5.96	6.14	6.33	6.51	6.69	6.88
1.05	2.39	2.54	2.71	2.84	2.98	3.11	3.25	3.39	3.53	3.67	3.79	3.93	4.05	4.16	4.28	4.45	4.58	4.72	4.88	5.04	5.17	5.32	5.46	5.61	5.75	5.92	6.11	6.29	6.48	6.66	6.84	7.03
1.10	2.47	2.62	2.8	2.93	3.07	3.2	3.35	3.49	3.64	3.77	3.89	4.03	4.15	4.27	4.39	4.56	4.7	4.84	5	5.17	5.3	5.45	5.59	5.75	5.89	6.06	6.26	6.44	6.63	6.81	6.99	7.18
1.15	2.55	2.7	2.88	3.02	3.16	3.29	3.44	3.58	3.74	3.87	3.99	4.12	4.25	4.37	4.5	4.67	4.81	4.96	5.12	5.29	5.42	5.58	5.72	5.88	6.03	6.2	6.4	6.58	6.78	6.95	7.14	7.33
1.20	2.63	2.78	2.96	3.11	3.25	3.38	3.53	3.67	3.83	3.97	4.08	4.21	4.34	4.47	4.6	4.77	4.92	5.08	5.24	5.41	5.54	5.7	5.85	6	6.16	6.34	6.54	6.72	6.92	7.09	7.28	7.47
1.25	2.7	2.86	3.04	3.2	3.34	3.47	3.62	3.76	3.92	4.06	4.17	4.3	4.43	4.57	4.7	4.87	5.03	5.2	5.36	5.52	5.66	5.82	5.97	6.12	6.29	6.47	6.67	6.86	7.05	7.23	7.42	7.6
1.30	2.77	2.94	3.12	3.28	3.42	3.56	3.7	3.85	4	4.15	4.26	4.39	4.53	4.66	4.8	4.97	5.14	5.31	5.48	5.63	5.78	5.94	6.09	6.24	6.42	6.6	6.8	7	7.18	7.36	7.55	7.74
1.35	2.84	3.01	3.19	3.36	3.5	3.64	3.78	3.94	4.08	4.24	4.35	4.48	4.62	4.75	4.9	5.07	5.24	5.42	5.59	5.74	5.9	6.06	6.21	6.36	6.54	6.72	6.92	7.13	7.31	7.49	7.68	7.87
1.40	2.91	3.08	3.26	3.43	3.57	3.72	3.86	4.02	4.17	4.32	4.44	4.57	4.71	4.84	5	5.17	5.34	5.52	5.7	5.85	6.01	6.17	6.33	6.48	6.66	6.84	7.04	7.25	7.43	7.62	7.81	8
1.45	2.98	3.15	3.33	3.5	3.64	3.8	3.94	4.1	4.25	4.4	4.52	4.66	4.8	4.93	5.09	5.26	5.44	5.62	5.8	5.96	6.12	6.28	6.44	6.6	6.77	6.96	7.16	7.36	7.55	7.74	7.93	8.12
1.50	3.04	3.22	3.4	3.57	3.71	3.87	4.01	4.18	4.33	4.48	4.6	4.75	4.88	5.02	5.18	5.35	5.53	5.72	5.9	6.07	6.23	6.39	6.55	6.71	6.88	7.07	7.27	7.47	7.66	7.86	8.05	8.25
1.55	3.1	3.28	3.46	3.63	3.77	3.94	4.08	4.25	4.4	4.56	4.68	4.83	4.96	5.1	5.26	5.43	5.62	5.81	6	6.17	6.33	6.5	6.66	6.82	6.99	7.18	7.38	7.58	7.77	7.97	8.17	8.37
1.60	3.16	3.34	3.52	3.69	3.84	4	4.15	4.32	4.47	4.63	4.76	4.91	5.04	5.18	5.34	5.51	5.71	5.9	6.09	6.27	6.43	6.6	6.77	6.93	7.1	7.29	7.49	7.69	7.88	8.08	8.28	8.48
1.65	3.22	3.4	3.58	3.75	3.91	4.06	4.22	4.39	4.54	4.7	4.83	4.99	5.12	5.26	5.42	5.59	5.79	5.99	6.18	6.37	6.53	6.7	6.87	7.04	7.2	7.39	7.59	7.79	7.98	8.19	8.39	8.59
1.70	3.28	3.46	3.64	3.81	3.97	4.12	4.28	4.45	4.6	4.77	4.9	5.07	5.2	5.34	5.5	5.68	5.87	6.07	6.27	6.46	6.63	6.79	6.97	7.14	7.3	7.49	7.69	7.89	8.1	8.29	8.5	8.7
1.75	3.33	3.51	3.69	3.87	4.03	4.18	4.34	4.51	4.66	4.84	4.97	5.14	5.28	5.42	5.57	5.76	5.95	6.15	6.36	6.55	6.72	6.88	7.06	7.23	7.4	7.59	7.79	7.99	8.2	8.39	8.6	8.8
1.80	3.38	3.56	3.74	3.92	4.09	4.24	4.4	4.57	4.73	4.9	5.04	5.21	5.35	5.5	5.65	5.84	6.03	6.23	6.45	6.64	6.81	6.97	7.15	7.33	7.5	7.69	7.89	8.09	8.3	8.49	8.7	8.9
1.85	3.43	3.61	3.79	3.97	4.15	4.3	4.46	4.63	4.79	4.96	5.1	5.28	5.42	5.57	5.72	5.92	6.11	6.31	6.53	6.72	6.89	7.06	7.24	7.43	7.6	7.79	7.99	8.19	8.4	8.59	8.8	9
1.90	3.48	3.66	3.84	4.02	4.2	4.36	4.52	4.69	4.85	5.02	5.16	5.35	5.49	5.65	5.8	6	6.19	6.39	6.61	6.8	6.97	7.15	7.33	7.52	7.7	7.89	8.09	8.29	8.5	8.69	8.9	9.1
1.95	3.53	3.71	3.89	4.07	4.25	4.42	4.58	4.75	4.91	5.08	5.22	5.41	5.56	5.72	5.87	6.08	6.27	6.47	6.69	6.88	7.05	7.24	7.42	7.61	7.8	7.99	8.19	8.39	8.59	8.78	8.99	9.2
2.00	3.58	3.76	3.94	4.12	4.3	4.48	4.63	4.8	4.97	5.14	5.28	5.47	5.63	5.79	5.95	6.16	6.35	6.55	6.77	6.96	7.13	7.32	7.51	7.7	7.89	8.08	8.28	8.48	8.68	8.88	9.09	9.3
2.05	3.63	3.81	3.99	4.17	4.35	4.53	4.68	4.85	5.02	5.2	5.34	5.53	5.7	5.86	6.02	6.24	6.43	6.63	6.84	7.04	7.21	7.4	7.6	7.78	7.98	8.17	8.37	8.57	8.77	8.98	9.18	9.4
2.10	3.68	3.86	4.04	4.22	4.4	4.58	4.73	4.91	5.09	5.26	5.4	5.59	5.77	5.93	6.1	6.31	6.51	6.71	6.91	7.11	7.29	7.48	7.68	7.87	8.07	8.26	8.46	8.66	8.86	9.07	9.28	9.49
2.15	3.73	3.91	4.09	4.27	4.45	4.63	4.78	4.96	5.15	5.32	5.46	5.65	5.83	6	6.18	6.39	6.58	6.77	6.98	7.18	7.37	7.56	7.76	7.95	8.15	8.35	8.55	8.75	8.95	9.16	9.37	9.58
2.20	3.78	3.96	4.14	4.32	4.5	4.68	4.83	5.01	5.21	5.38	5.52	5.71	5.89	6.07	6.25	6.45	6.65	6.84	7.05	7.25	7.44	7.64	7.84	8.03	8.23	8.43	8.64	8.84	9.04	9.25	9.46	9.67
2.25	3.83	4.01	4.19	4.37	4.55	4.73	4.88	5.06	5.27	5.44	5.58	5.77	5.95	6.14	6.32	6.52	6.72	6.91	7.12	7.32	7.51	7.72	7.91	8.11	8.31	8.51	8.72	8.92	9.13	9.34	9.55	9.76
2.30	3.88	4.06	4.24	4.42	4.6	4.78	4.93	5.11	5.32	5.5	5.64	5.83	6.02	6.21	6.39	6.59	6.79	6.98	7.19	7.39	7.58	7.79	7.99	8.19	8.39	8.59	8.8	9	9.22	9.43	9.63	9.85
2.35	3.93	4.11	4.29	4.47	4.65	4.83	4.98	5.16	5.37	5.56	5.7	5.89	6.08	6.27	6.46	6.66	6.86	7.05	7.26	7.46	7.65	7.86	8.06	8.27	8.46	8.67	8.88	9.08	9.3	9.51	9.71	9.93
2.40	3.98	4.16	4.34	4.52	4.7	4.88	5.03	5.21	5.42	5.62	5.76	5.95	6.15	6.34	6.53	6.73	6.93	7.12	7.33	7.53	7.72	7.93	8.14	8.34	8.54	8.75	8.96	9.16	9.38	9.59	9.8	10.02
2.45	4.03	4.21	4.39	4.57	4.75	4.93	5.08	5.26	5.47	5.67	5.82	6.01	6.21	6.41	6.6	6.8	7	7.19	7.4	7.6	7.79	8	8.21	8.41	8.61	8.82	9.04	9.24	9.46	9.67	9.89	10.1
2.50	4.08	4.26	4.44	4.62	4.8	4.98	5.13	5.31	5.52	5.72	5.88	6.07	6.27	6.48	6.67	6.87	7.06	7.25	7.46	7.66	7.86	8.07	8.28	8.48	8.68	8.9	9.11	9.32	9.54	9.75	9.97	10.19
2.55	4.13	4.31	4.49	4.67	4.85	5.03	5.18	5.36	5.57	5.77	5.94	6.13	6.33	6.54	6.73	6.93	7.12	7.31	7.52	7.72	7.93	8.14	8.35	8.55	8.76	8.97	9.18	9.4	9.61	9.82	10.05	10.27
2.60	4.18	4.36	4.54	4.72	4.9	5.09	5.23	5.41	5.62	5.82	6	6.19	6.39	6.6	6.79	6.99	7.18	7.37	7.58	7.78	8	8.21	8.42	8.62	8.83	9.04	9.25	9.47	9.68	9.9	10.13	10.35
2.65	4.23	4.41	4.59	4.77	4.95	5.13	5.28	5.46	5.67	5.87	6.05	6.25	6.45	6.66	6.85	7.05	7.24	7.43	7.64	7.84	8.07	8.27	8.49	8.69	8.9	9.11	9.32	9.54	9.75	9.97	10.2	10.43
2.70	4.28	4.46	4.64	4.82	5	5.18	5.33	5.51	5.72	5.92	6.1	6.31	6.51	6.72	6.91	7.11	7.31	7.49	7.7	7.9	8.13	8.33	8.56	8.76	8.97	9.18	9.39	9.61	9.82	10.05	10.28	10.51
2.75	4.33	4.51	4.69	4.87	5.05	5.23	5.38	5.56	5.77	5.97	6.15	6.37	6.57	6.78	6.97	7.17	7.37	7.55	7.76	7.96	8.19	8.39	8.62	8.83	9.04	9.25	9.46	9.69	9.89	10.12	10.35	10.58
2.80	4.38	4.56	4.74	4.92	5.1	5.28	5.43	5.61	5.82	6.02	6.2	6.42	6.63	6.84	7.03	7.23	7.43	7.61	7.82	8.02	8.25	8.45	8.68	8.9	9.11	9.32	9.54	9.76	9.96	10.19	10.43	10.66

Figure 6. Table NonTV to Determine Runoff as a Function of the RI Value and Precipitation (Data for SE Region)

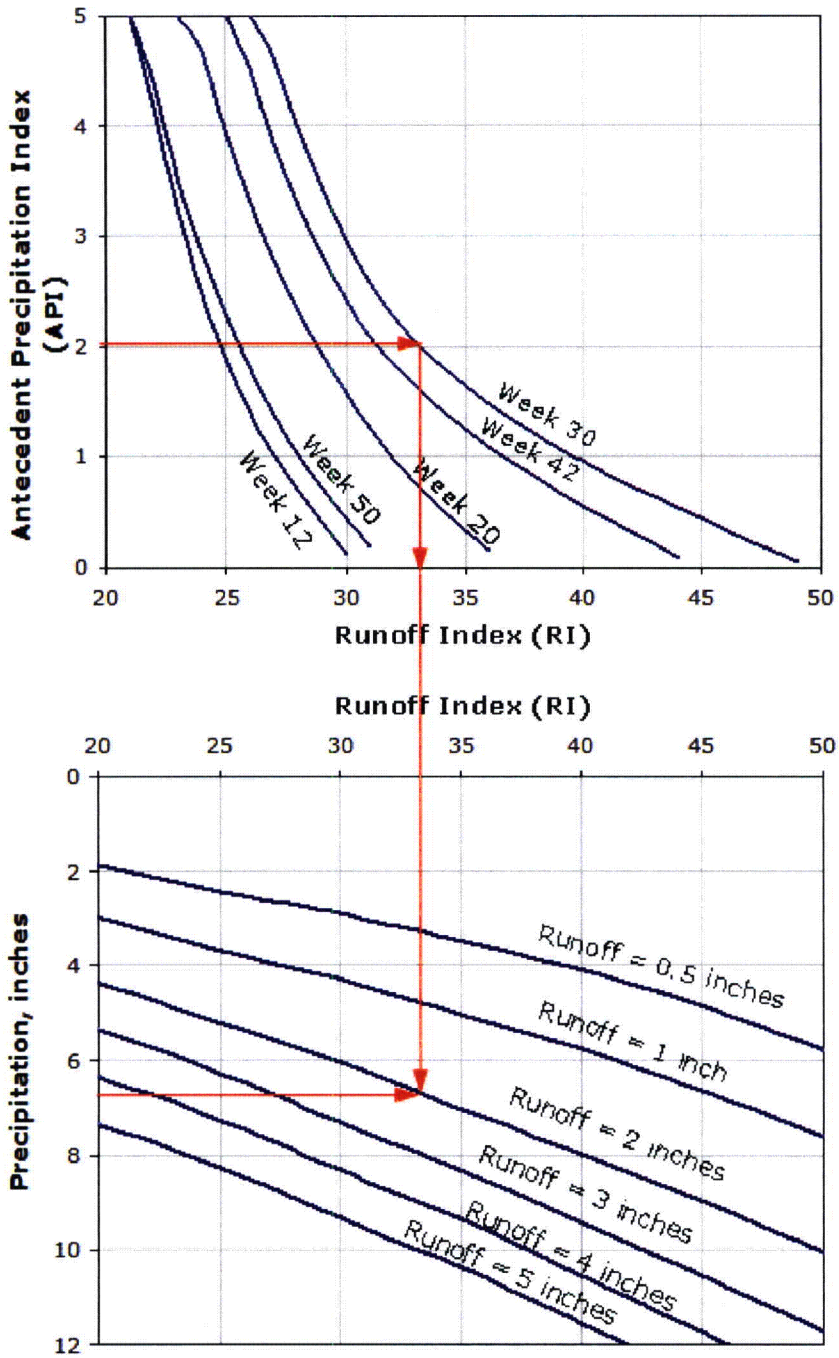


Figure 7. Illustration of Runoff Estimation (Data for SE Region)

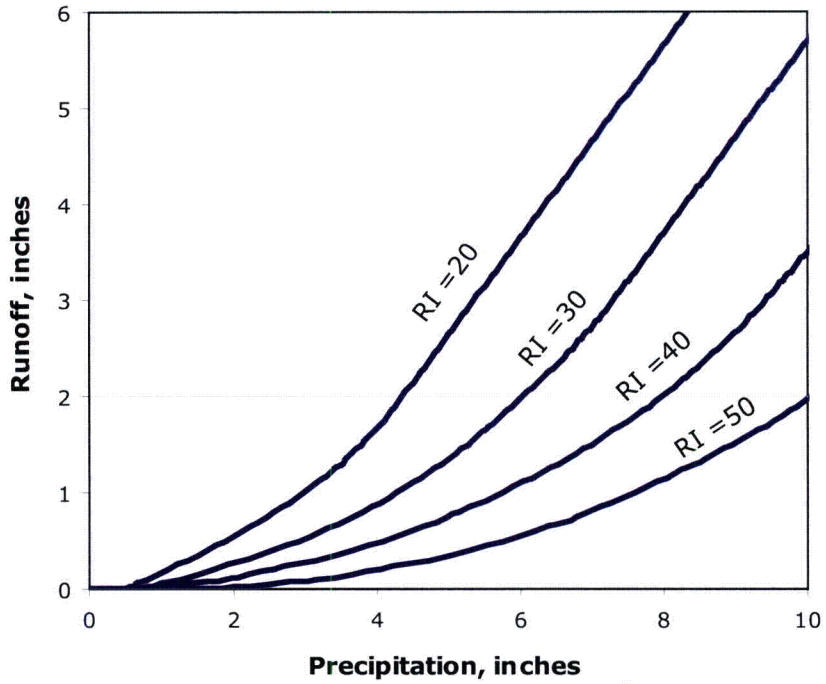


Figure 8. Runoff as a Function of Precipitation for Different RI values, Plotted from Data from the Table NonTV (Data for SE Region)

3.2 The FLDHYDRO code and How to Run it

FLDHYDRO was originally programmed to run on a mainframe computer and was later transferred to the personal computer (PC). The latest version of the code has been compiled using the Compaq Visual FORTRAN, Professional Edition 6.6A.

The FLDHYDRO code consists of the main program and several subroutines. The following subroutines were part of the original FLDHYDRO code developed on a mainframe computer:

- APIWK(WEEK) computes API values and week of the year
- VOLCHK(CHKVOL,NUMVOL) adjusts the RIs to obtain computed surface volumes that are nearest to the check volumes input
- HYDROG computes average rainfall/runoff for each subwatershed and if flood hydrograph computation specified, calls HYDRO subroutine.
- HYDRO(BSNIDX,YEAR,DAY,MONTH,TIME,YEARRO,DAYRO,MORO, IN, BHRAIN,NBLKS,NOFLOW,NFLOWS,BSNHRO,BLCKRO,FHCNT) computes and outputs flood hydrographs
- RUNOFF(RI,RITYP,RAIN,RO,FACTOR) computes runoff
- CLOCK(DATE,INCRMT,DAY) increments the time step

The following subroutines are used in the present PC version of FLDHYDRO to facilitate the interactive use of the code:

- DoDialog()

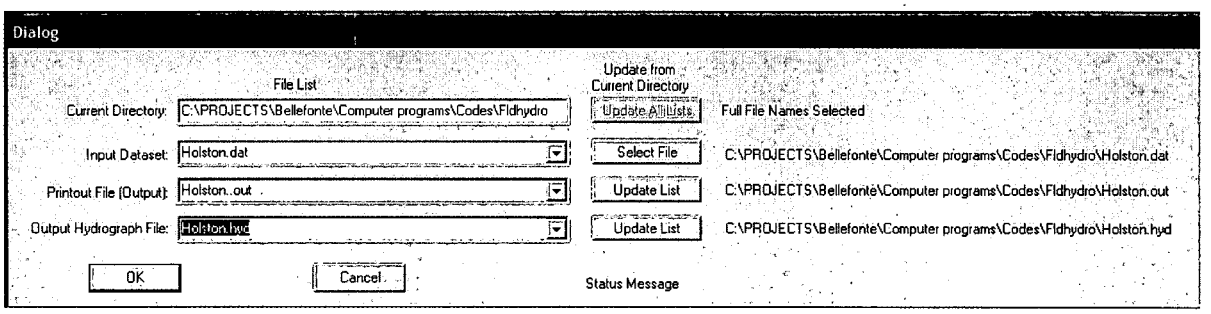
- UpdateFiles(dlg, control_name, callbacktype)
- UpdateButton(dlg, control_name, callbacktype)
- UpdateDat(dlg, control_name, static_file, button_control, dirname, ofile)
- SETFIL(dlg, static_file, datname, Output, xtension)

A complete listing of the main program and the subroutines of FLDHYDRO is given in Appendix E.

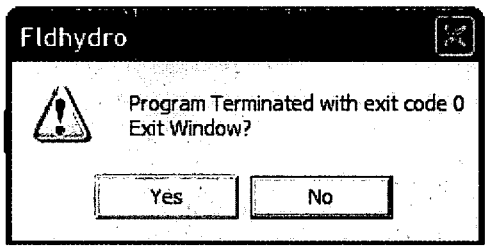
To run FLDHYDRO using the executable file on a Windows PC go through the following steps:

1. Create a shortcut of the executable FLDHYDRO.EXE, by placing the cursor on the file FLDHYDRO.EXE, right clicking the mouse and from the open menu selecting "Create Shortcut".
2. Copy the shortcut to the Desktop.
3. Double click on the FLDHYDRO shortcut icon. This will launch the code and open a dialog window for entering the names of the input and output files.
4. In the dialog window the "Current Directory" field defaults to the location of the executable. If the FLDHYDRO input data files are stored in a different location, the "Current Directory" needs to be changed to the location of the input files.

Enter the file names of the up to three files requested, as shown in the example below:



After the files names are entered, press the button "Update List", and then the button "OK". Then FLDHYDRO will run and will come back with the following message:



Exit code 0 means normal termination, i.e. successful execution of the code. Press the button "Yes". The two output files will have been written in the same directory as the input data file.

To run FLDHYDRO, the files APITBL, TV and NONTV must be in the folder chosen in the dialog window as the current directory.

3.3 Input Data

3.3.1 Description of Input Variables

Table 3 gives the structure and format of the main input files to FLDHYDRO. FLDHYDRO uses up to four input files and two output files, which are associated with specific Unit numbers in the standard FORTRAN language terminology.

Input:

- Unit 4: FILNAM – APITBL; the antecedent precipitation index (API)/runoff indexes (RI) tables.
- Unit 5: DATFIL – The main input file where the input parameters are provided.
- Unit 7: FILNAM – TV; RUNOFF table for all Tennessee River basin runoff regions except the SE
- Unit 8: FILNAM – NONTV; RUNOFF table for the SE runoff region

Output:

- Unit 6: OUTFIL – The standard file for printed output.
- Unit 3: HYDFIL – Hydrograph output file (optional)

The FORTRAN format designations in Table 3 are the same as those used in Table 2 and explained in Section 2.3.1.

Table 3. Structure and Format of FLDHYDRO Input

No	Name	Definition	Format
1	BSNAME(51)	Name of the watershed and title output at top of each hydrograph printout.	A80
2	NARFE ..... = 0	Use when average rain and runoff are desired.	16I5
	NARFE ..... = 1	Use when only a printout of flood hydrographs is desired.	
	NARFE ..... = 2	Use when hydrographs are also to be saved on disk.	
	NRI	Number of runoff indexes (RIs) per station, i.e., number of floods (maximum is 4).	
	NCPTS	Number of locations within the watershed for surface runoff volume checks (maximum is NSUBW).	
	NSUBW	Number of watersheds (maximum is 50).	

No	Name	Definition	Format
	NREC	Number of recording rain stations, i.e., stations with hourly precipitation (maximum is 30).	
	NSTNS	Total number of stations including nonrecorders (maximum is 100).	
	STAB	API variance parameter to determine which API area the rain stations are in; NDA = number of API areas input. The following codes are used to designate the different regions within the Tennessee River basin: Area Code SE 1 E 2 NE 3 N 4 W 5 S 6 Figure 4 shows the boundaries of these six regions.	
	STAB ..... = 1	Use if all stations are in the same API area (NDA = 1).	
	STAB ..... = 2	Use if API areas vary with subwatershed; (NDA = NSUBW).	
	STAB ..... = 3	Use if all stations are in the same API area (NDA = NSTNS).	
	ITDGR	Time (hour) when daily stations are read every day.	
3	NAMSTA(I) I = 1, NREC	Label for each recorder (4 characters long). The order of input must agree with the order in which hourly rain is input.	20A4
4	BEGDR(I,J) I = 1, NRI J = 1, NREC	Beginning date of each storm for each recorder (given as MMDDYY).	10I8
5	BEGTR(I,J) I = 1, NRI J = 1, NREC	Time at which first hour of rainfall has been recorded (2 digit number from 01 to 24 [military time]).	10I8
6	NHR(I,J) I = 1, NRI J = 1, NREC	Number of hours of rainfall for each storm (maximum of 240 hours total for any recorder).	16I5
7	SHRAIN(K,RECIDX)	Hourly rain for each storm for each recorder (start each storm on a new line).	10F8.0

No	Name	Definition	Format
	K = START, END		
Note: Lines 8 - 10 needed only if NSTNS > NREC			
8	NAMSTA(I) I = NREC+1, NSTNS	Label for each nonrecorder (4 characters long). Order of input must agree with the order in which daily rain is input.	20A4
9	NAMREC(I) I = NREC+1, NSTNS	The 4 character label (as given on line 3) of the recorder to be used for each nonrecorder for converting daily totals into hourly distributions.	20A4
10	DYRAIN(I, STNIDX) I = 1, NDRTOT(RECIDX)	Daily rainfall totals for each nonrecorder. This is rainfall for the 24 hour period between ITDGR of one day and ITDGR of the next, and includes the period between storms. The number of days input must correspond to that of the total storm period of the associated recorder (start a new line for each nonrecorder).	10F8.0
11	NDRAPI(I) I = 1, NSTNS	Number of days of antecedent rain before the first storm for each station (both recorders and nonrecorders, with recorders input first) for use in computing API & RI values (maximum is 30 days).	16I5
12	API(1,I) I = 1, NSTNS	Initial API either at start of first storm (if NDRAPI(I)=0) or at beginning of antecedent rain (if NDRAPI(I) > 0). If both NDRAPI(I) & API(1,I) are 0, the RI's must be input for the Ith station.	10F8.0
Note: Line 13 needed only if at least one NDRAPI() > 0.			
13	APRAIN(I, STNIDX) I = 1, NDRAPI(STNIDX)	Daily antecedent rainfall totals for all stations with antecedent rain to be used for computing initial API's. Only stations with NDRAPI() > 0 have antecedent rainfall input (start a new line for each station with antecedent rain).	10F8.0
Note: Line 14 needed only if NSWRI > 0.			
14	ORIGRI(I,J) I = 1, NRI J = 1, NSWRI	RI's for each storm for each station whose RI's values are known (NSWRI is the number of stations with both NDRAPI() & API(1,) equal 0).	16I5
15	BSNAME(J) J = 1, NSUBW	Title heading for each subwatershed printout. Use only one line for each printout.	A80
16	BAREA(I) I = 1, NSUBW	Drainage area of each subwatershed.	10F8.0
17	APITYP(I) I = 1, NDA	API area code where NDA = 1, NSUBW, or NSTNS, depending on the value of STAB (see line 2	16I5

No	Name	Definition	Format
		description).	
18	NSPW (I) I = 1, NSUBW	Number of rainfall stations (i.e., Thiessen factors) for each subwatershed.	16I5
19	BSNSTA(I,J) I = 1, NSPW(J), J = 1, NSUBW	Station label (4 characters long) identifying station defined on line 3 or 8 with the Jth subwatershed.	A4,F5.0
	THIESN(I,J) I = 1, NSPW(J), J = 1, NSUBW	The Thiessen factor of the station for the subwatershed.	
Note: Lines 20 & 21 needed only if NCPTS > 0.			
20	NUMVOL(I) I = 1, NCPTS	Number of subwatersheds above each surface runoff volume check point.	16I5
21	CHKVOL(I,J) I = 1, NRI J = 1, NCPTS	Surface runoff volume in inches at corresponding point of drainage (check volume).	10F8.0
Note: Lines 22 - 26 needed only if NARFE > 0.			
22	BBSFLW(I,J) I=1,NRI J=1,NSUBW	Beginning base flow for each storm for each subwatershed in cfs per mi^2 (cfs/mi^2) of drainage area.	10F8.0
	EBSFLW(I,J) I = 1, NRI J = 1 ,NSUBW	Ending base flow for each storm for each subwatershed (in cfs/mi^2 of drainage area).	
23	HYDINT(K) K = 1, NSUBW	Hydrograph interval (in hours) (i.e., unit graph increment) for each subwatershed.	16I5
24	UGDUR(I) I = 1, NSUBW	Unit graph duration (in hours) for each subwatershed.	16I5
25	NUGORD(I) I = 1, NSUBW	Number of unit graph ordinates for each subwatershed.	16I5
26	UGORD(I,J) I = 1, NUGORD(J) J = 1, NSUBW	Unit graph ordinates for each unit graph including beginning and ending 0's (start each unit graph on a new line).	10F8.0
Note: Lines 27 - 29 needed only if NARFE = 2.			
27	BEGD	Beginning date of the hydrographs to be stored on a disk file.	I7, I5
	BEGT	Beginning time of the hydrographs to be stored on a disk file.	
28	NUMHYD	Number of hydrographs to be stored on disk.	16I5

No	Name	Definition	Format
29	FHORDR(I) I=1,NUMHYD	Ordinal number of each hydrograph to be stored on disk (must be in ascending order).	16I5

3.3.2 Example of Input Data File

An example of a typical FLDHYDRO input data file is presented in Appendix F. The data are for the Holston basin and it is the file "Holston.dat" entered in the dialog box described in Section 3.2.

3.3.3 Response of FLDHYDRO to Abnormal Input Data

FLDHYDRO has built-in safeguards to warn users when abnormal situations arise during operation of the program. A listing of these safeguards is provided below.

- After the second line of input data is read by FLDHYDRO, a check is done for input values out of range. If the number of runoff indices, number of stations, number of recorders, number of subwatersheds, or number of volume checks is invalid, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and one of the following messages:

  " (No. of Runoff Indices) IS INVALID AS NUMBER OF RI"S PER STATION; MAXIMUM IS 4"

  " (No. of Stations) IS INVALID AS NUMBER OF STATIONS; MAXIMUM IS 100"

  " (No. of Recorders) IS INVALID AS NUMBER OF RECORDERS; MAXIMUM IS 30"

  " (No. of Subwatersheds) IS INVALID AS NUMBER OF SUBWATERSHEDS; MAXIMUM IS 50"

  " (No. of Volume Checks) IS INVALID AS NUMBER OF VOLUME CHECKS; MAXIMUM IS NO. OF SUBWATERSHEDS"

- All non-recording stations (i.e. stations where no hourly rainfall data were recorded, but only daily totals are available) must be paired with a recording station (i.e. a station where hourly rainfall was recorded) that will be used to distribute the daily rainfall from the non-recording stations. If an invalid recording station is entered, the output file consists of an echo of the input data and the beginning of the output data up to the point of calculations with the ill-referenced non-recorder. The following message is inserted in the echo data:

  " (Non-Recording Station) IS NOT A VALID RECORDER NAME FOR STATION (Recording Station)"

- For FLDHYDRO runs where the RI value is input, the RI is required to be less than or equal to 55. If a value of RI greater than 55 is input, the following message is inserted in the echo data:

  " RI VALUE OF (RI Value) DETECTED; MAX. IS 55"

- FLDHYDRO only allows one subwatershed to use more than 25 stations and that subwatershed must be the last one referenced. If this rule is violated, the following message is inserted in the echo data:

  " ONLY ONE WATERSHED ALLOWED WITH >25 STATIONS AND THAT WATERSHED MUST BE THE LAST ONE"

- When assigning Thiessen factors for a subwatershed, the Thiessen factors must be applied to rain stations defined as either recorders or non-recorders. If a station name that does not match an input recorder or non-recorder is input, the following message is inserted in the echo data:

  "... ERROR...ORDER OF RAIN STATIONS NOT ESTABLISHED PROPERLY. MAKE SURE... THAT FOUR CHARACTER RAIN STATION NAMES IN BSNSTA(I,J) MATCH THOSE IN NAMSTA(I)"

- When calculating non-recorder hourly rain from recorders, two error messages can be generated. These error messages do not invalidate the output data. Rather, they serve as warnings to the user that abnormal situations have occurred and leave it up to the user whether to accept the data or not. These messages are printed in the output data where RI values are calculated and are reproduced below:

  " *** ERROR -- A DAILY RAIN OF ZERO FOR RECORDER (Recording Station) WILL PRODUCE A DAILY RAIN OF ZERO FOR GAGE (Non-Recording Station). INVALID COMPUTATIONS WILL RESULT."

  " WARNING...A DAILY RAIN OF (Non-Recorder Daily Rain) FOR GAGE (Non-Recording Station) IS WEIGHTED AGAINST A DAILY RAIN OF (Recorder Daily Rain) FOR RECORDER (Recording Station). THIS IS A WEIGHT RATIO OF (Ratio) WHICH MAY SIGNIFICANTLY AFFECT RESULTS."

If none of the above abnormal conditions occurs, FLDHYDRO is presumed to have functioned normally. In this case, the entire output file is created.

However, it is possible for FLDHYDRO to appear to have functioned normally while using invalid input data. A few such cases are presented below:

- **Input API value greater than 5:**

  In FLDHYDRO, the look-up tables do not allow API values greater than 5. However, it is possible to assign an initial API value greater than 5. FLDHYDRO still terminates normally without any warning or error message when API values greater than 5 are input.

- **Negative value input for precipitation:**

  Physically, all precipitation values should be greater than zero. However, FLDHYDRO does not reject input values that are less than zero. FLDHYDRO still terminates normally without any warning or error message when negative precipitation values are input.

- **Thiessen weights do not sum to one:**

  When weighting rainfall with Thiessen weights, the sum of the Thiessen weights must be 1. However, FLDHYDRO does not check the sum of the Thiessen weights. Therefore, the sum of the Thiessen weights can be either greater than or less than one and FLDHYDRO still terminates normally without any warning or error message.

- **The *.hyd files created by FLDHYDRO do not include a time/date stamp:** The direct use or export of FLDHYDRO *.hyd data to TRBROUTE can combine hydrographs that have different starting times without the user's knowledge. The user should carefully check the *.out file for the time interval alignment prior to use or routing of the FLDHYDRO output data.

  For example, if a storm for a subwatershed with a unit hydrograph duration and time interval of 6 hours were to start at 3/15 0000 hours and the first non-zero hourly runoff value for the storm were to occur on 3/16 at 0100 hours (and thus, the first block of 6 hour runoff ends at 0600 hours) FLDHYDRO would insert into the .hyd file a runoff value of 0 cfs (assuming no baseflow) at 3/16 0000, 3/15 1800, 3/15 1200, 3/15 0600 and the starting runoff value of 0 cfs would be at 3/15 0000. If the same storm were to have the first-nonzero runoff value at 3/16 0500, FLDHYDRO would insert into the .hyd file a runoff value of 0 cfs (assuming no baseflow) at 3/16 0400, 3/15 2200, 3/15 1600, 3/15 1000 and the starting runoff value of 0 cfs would be at 3/15 0400.

In the cases presented in this section, FLDHYDRO accepts invalid input data but does not warn the user that the data are invalid. In some cases FLDHYDRO may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of FLDHYDRO besides those presented above. Therefore, it is the responsibility of the user to confirm that the input data file is valid in order to ensure that the FLDHYDRO output is also valid. Normal termination of FLDHYDRO is a necessary but not sufficient condition for producing valid results.

3.4 Output Data

FLDHYDRO produces one or two output files; an optional file which is formatted to be used as input to subsequent codes (written out in Unit 3), and the main output file (written out in Unit 6). Appendices G and H list these two files produced by running FLDHYDRO with the input data given in the example presented in Appendix F.

4. CHANROUT CODE

4.1 Theoretical Basis

The CHANROUT code computes the coefficients of an ARMA (autoregressive moving average) channel routing model of which the Muskingum routing equation is a special case. Equations (10) and (11) below utilize ARMA mathematical solution techniques as applied to hydrological data. Additional information regarding the use of ARMA in hydrological applications can be found in Reference 6. An ARMA(p,q) channel routing model computes current outflow out of a river reach as a linear combination of the previous p outflows, plus the previous q inflows and current inflow into a reach, as shown in Equation (10) below. ARMA(1,1) is equivalent to the Muskingum routing equation. The governing equations for ARMA(p,q) channel routing (Reference 7) are given below:

$$\begin{aligned} O_t = {} & a_1 O_{t-r} + a_2 O_{t-2r} + a_3 O_{t-3r} + \ldots + a_p O_{t-pr} + \\ & b_0 I_t + b_1 I_{t-r} + b_2 I_{t-2r} + b_3 I_{t-3r} + \ldots + b_q I_{t-qr} \end{aligned} \tag{10}$$

The variables p and q that define the order of the ARMA(p,q) method, define also the number of outflow and inflow terms in Equation (10).

The basic equations for the ARMA(p,q) method are described in different hydrology textbooks (see for example Reference 8). The most common description of these equations in textbooks such as Reference 8 is in the context of their use for precipitation and outflow models, not for channel flow routing. The coefficients a_1, a_2, a_3, ... a_p and b_1, b_2, b_3, ... b_p are subject to the constraint:

$$a_1 + a_2 + a_3 + \ldots + a_p + b_0 + b_1 + b_2 + b_3 + \ldots + b_q = 1 \tag{11}$$

Equation (11) can be derived by expressing the mass balance condition for steady-state flow in flow in a prismatic channel.

Equations (10) and (11) can be expressed in matrix form for (m-t) time steps as:

$$D \cdot C = Q \tag{12}$$

$$U \cdot C = 1 \tag{13}$$

where:

$$D = \begin{bmatrix} O_{t-r} & O_{t-2r} & \ldots & O_{t-pr} & I_t & I_{t-r} & \ldots & I_{t-qr} \\ O_{t-r+1} & O_{t-2r+1} & \ldots & O_{t-pr+1} & I_{t+1} & I_{t-r+1} & \ldots & I_{t-qr+1} \\ O_{t-r+2} & O_{t-2r+2} & \ldots & O_{t-pr+2} & I_{t+2} & I_{t-r+2} & \ldots & I_{t-qr+2} \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ O_{m-r} & O_{m-2r} & \ldots & O_{m-pr} & I_m & I_{m-r} & \ldots & I_{m-qr} \end{bmatrix} \tag{14}$$

$$C = \begin{bmatrix} a_1 \\ a_2 \\ \dots \\ a_p \\ b_0 \\ b_1 \\ \dots \\ b_q \end{bmatrix} \tag{15}$$

$$Q = \begin{bmatrix} O_t \\ O_{t+1} \\ \dots \\ O_m \end{bmatrix} \tag{16}$$

$$U = [1 \;\; 1 \;\; \dots \;\; 1]_{p+q+1} \tag{17}$$

where:

r is the routing period divided by the flow interval

O_{t-pr} is the first outflow if $p \geq q$

O_{t-pr} is the ((q-p)*r+1)th outflow if $p < q$

I_{t-qr} is the ((p-q)*r+1)th inflow if $p \geq q$

I_{t-qr} is the first inflow if $p < q$

I_m is the last inflow

The set of equations is solved using the Lagrangian equation:

$$D^T \cdot D \cdot C = L + D^T \cdot Q \tag{18}$$

where:

D^T is the transpose matrix of D,

$L = U^T \cdot \lambda$ is a Lagrangian multiplier and

$$C = C_1 + C_2 \cdot \lambda \tag{19}$$

The Lagrangian equations are solved by rewriting Equation (18) as:

$$D^T \cdot D \cdot (C_1 + C_2 \cdot \lambda) = U^T \cdot \lambda + D^T \cdot Q \tag{20}$$

This can be broken into the following two equations:

$$D^T \cdot D \cdot C_1 = D^T \cdot Q \tag{21}$$

$$D^T \cdot D \cdot C_2 \cdot \lambda = U^T \cdot \lambda \tag{22}$$

Equations (21) and (22) are solved for C_1 and C_2 as follows:

$$C_1 = (D^T \cdot D)^{-1} \cdot D^T \cdot Q \tag{23}$$

$$C_2 = (D^T \cdot D)^{-1} \cdot U^T \tag{24}$$

Next, Equations (13) and (19) are combined to find a solution for λ:

$$\lambda = \frac{1 - U \cdot C_1}{U \cdot C_2} \tag{25}$$

Finally, the routing coefficients, C, are found by solving Equation (19).

The degree of the ARMA(p,q) model is specified in the CHANROUT input file. For the Muskingum routing equation to be properly applied, the routing period must be at least as long as the approximate travel time through the reach. Also, sudden surges or increases in inflows do not attenuate correctly downstream if the flow interval does not equal the routing period. A higher degree ARMA channel routing model (e.g. ARMA(3,2)) may eliminate these "timing" problems, as well as be more accurate than the simple Muskingum routing equation. Therefore, care must be taken when deciding on the values of p and q to be used by CHANROUT.

4.2 The CHANROUT code and How to Run it

CHANROUT was originally programmed to run on a mainframe computer and was later transferred to the personal computer (PC). The latest version of the code has been compiled using the Compaq Visual FORTRAN, Professional Edition 6.6A.

The CHANROUT code consists of the main program and the subroutine XATEQ(L,A,B,N,M) which solves a system of linear equations. A complete listing of the CHANROUT source code is given in Appendix I.

To run CHANROUT on a Windows PC go through the following steps:

1. Create a shortcut of the executable CHANROUT.EXE, by placing the cursor on the file CHANROUT.EXE, right clicking the mouse and from the open menu selecting "Create Shortcut".
2. Copy the shortcut to the Desktop.
3. Right button click the shortcut icon and choose "properties".
4. Change the "Start in:" folder to the folder containing the CHANROUT input data file(s). If the input data file is in the same folder as the executable, there is no need to perform this step.
5. Double click on the CHANROUT shortcut icon
6. When prompted, provide the name of the input and the output files.

An example of the interactive session for running CHANROUT is given below:

When the execution window disappears, CHANROUT has run and produced the output file Yangtze.out, which is located in the same folder as the input data file. The content of this file as well as the contents of the user-provided input file Yangtze.dat are discussed in detail in Sections 2.3.2 and 2.4.

4.3 Input Data

4.3.1 Description of Input Variables

Table 4 gives the structure and format of the main input files to CHANROUT. The FORTRAN format designations in Table 4 are the same as those used in Table 2 and explained in Section 2.3.1.

Table 4. Structure and Format of CHANROUT Input

No	Name	Definition	Format
1	TITLE	Description of channel reach.	A80
2	IBKPTS	Number of previous inflows to be used in the ARMA routing model (maximum is 20 – OKPTS).	3I8, 2F8.0
	OBKPTS	Number of previous outflows to be used in the ARMA routing model (maximum is 20 – IBKPTS).	
	NFLOWS	Number of inflows/outflows to be input for computing the coefficients of the ARMA model (maximum is 300).	
	TIMINT	Inflows/outflow time interval (in hours).	
	RP	Routing period (in hours).	
3	INFLO(I), I = 1, NFLOWS	Inflows into the channel reach; NFLOWS is the number of inflows to be input for computing the coefficients of the ARMA model (maximum is 300).	10F8.0
4	OUTFLO(I) I = 1, NFLOWS	Outflows out of the channel reach.	10F8.0

4.3.2 Example of Input Data File

An example of a typical CHANROUT input data file is presented in Appendix J. It is for the Yangtze River.

4.3.3 Response of CHANROUT to Abnormal Input Data

CHANROUT has built-in safeguards to warn users when abnormal situations arise during operation of the program. A listing of these safeguards is provided below.

- If the number of previous inflows or outflows to be used in the ARMA routing model is less than one, or if the total number of inflows and outflows to be used is greater than 20, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and the message:

  " 1 - 10 BACK POINTS ALLOWED: IBKPTS = (No. Previous Inflows); OBKPTS = (No. Previous Outflows)"

- If the routing period is not a multiple of the time interval, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and the message:

  " ROUTING PERIOD MUST BE A MULTIPLE OF TIME INCREMENT: RP = (Routing Period); TIMINT = (Time Interval)"

- In order to perform the routing the number of inflows and outflows input must be at least as many as the larger of the number of previous inflows or outflows, times the routing period divided by the time interval (this term is the variable "SHIFT" in the CHANROUT program). If this is not true, the run terminates. In this case, the output file consists only of an echo of the first two lines of input data and the message:

  " AT LEAST (SHIFT) FLOWS MUST BE SPECIFIED FOR VIABLE COMPUTATIONS: NFLOWS = (No. Inflows/Outflows)"

- The maximum number of inflows/outflows input to CHANROUT is 300. If this number is exceeded the run terminates and the output file consists only of an echo of the first two lines of input data and the message:

  " MAX. NO. OF FLOWS IS 200: NFLOWS = (No. Inflows/Outflows)"

If none of the above abnormal conditions occurs, CHANROUT is presumed to have functioned normally. In this case, the entire output file is created.

However, it is possible for CHANROUT to appear to have functioned normally while using invalid input data. One such case is presented below:

- **Negative value input for inflow or outflow:**

  Physically, all inflow and outflow values should be greater than zero. However, CHANROUT does not reject input values that are less than zero. CHANROUT still terminates normally without any warning or error message when negative inflow or outflow values are input.

In the case presented above, CHANROUT accepts invalid input data but does not warn the user that the data are invalid. In some cases CHANROUT may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of CHANROUT besides that presented above. Therefore, it is the responsibility of the user to confirm that the input data file is valid in order to ensure that the CHANROUT output is also valid. Normal termination of CHANROUT is a necessary but not sufficient condition for producing valid results.

4.4 Output Data

CHANROUT produces one output file, written out in Unit 6. Appendix K lists the file produced by running CHANROUT with the input data given in the example presented in Appendix J.

5. TRBROUTE

5.1 Theoretical Basis

TRBROUTE performs the channel and reservoir routings necessary to route flood hydrographs downstream to selected points (for input to the SOCH model). This includes routing through reservoirs with fixed discharge rating curves as well as the major tributary dam systems whose operations follow fixed rules. Discharge rating curves defining the fixed rules of the major tributary dams can be handled by the program. Flows are routed through channels in TRBROUTE by using the autoregressive moving average (ARMA) type channel routing coefficients calculated using CHANROUT.

TRBROUTE performs reservoir and channel routing to compute outflow at specified locations using as input inflow hydrographs calculated by FLDHYDRO, and channel routing coefficients calculated by CHANROUT.

User inputs to the program include:

- Inflow hydrographs from FLDHYDRO (can either be specified in the main input file or in a second input file)
- Channel routing coefficients from CHANROUT
- Set of instruction codes that tell TRBROUTE how to route and combine the inputs
- Reservoir names
- Starting water surface elevation for each reservoir
- Starting discharge used for routing calculations for each reservoir (FOUT)
- Storage-elevation curves and discharge rating curves for reservoirs not defined in TVA tables (see below)

Also used as inputs to the program are four tables developed by TVA (Reference 9):

- STORAGES – look up table with storage-elevation curves for reservoirs to be routed
- QRATINGS – look up table with discharge rating curves for tributary dams to be routed using TRBROUTE
- IMPRULES – look up table with reservoir operation guides for major tributary dams
- SGUIDES – look up table with reservoir seasonal elevation operation guidelines.

Reservoir routings are made assuming flat pool storage conditions. Routing through reservoirs is performed with the storage equation:

$$I - O = \frac{dS}{dt} \tag{26}$$

where:

I is the inflow rate

O is the outflow rate

S is the storage volume, and

t is the routing period

Equation (26) is more commonly expressed as:

$$\bar{I} - \bar{O} = \frac{\Delta S}{\Delta t} \tag{27}$$

If the average rate of flow during a given time period is equal to the average of the flows at the beginning and end of the period, then Equation (27) can be written as:

$$\frac{I_1 + I_2}{2}\Delta t - \frac{O_1 + O_2}{2}\Delta t = S_2 - S_1 \tag{28}$$

where the subscripts 1 and 2 refer the beginning and end of the period Δt, respectively.

Solving Equation (28) for the unknowns yields:

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

where:

I_1 and I_2 are input to TRBROUTE from FLDHYDRO

For the first time step TRBROUTE assumes that O_1 is equal to I_1 and S_1 is the storage corresponding to the initial elevation. O_1 and S_1 are calculated using Equation (29) for all other time steps.

Using the solution to Equation (29), S_2 and O_2 are determined by referencing the relations in the TVA tables or user input values (for reservoirs not in the tables).

If the inflow is less than the discharge used for routing calculations (FOUT) then routing is not performed and outflow equals inflow.

5.2 The TRBROUTE code and How to Run it

5.2.1 Evolution of TRBROUTE

TRBROUTE was originally programmed to run on a mainframe computer and was later transferred to the personal computer (PC). The latest version of the code has been compiled using the Compaq Visual FORTRAN, Professional Edition 6.6A.

The following list of improvements (since 1988) have been made to increase the flexibility of this program.

- Fixed rule discharge rating curves for the major tributary dams are automatically computed by the program.
- Storage curves and dams with fixed discharge rating curves can be stored on a separate disk file for access by the program.
- The program can handle multiple storm sequences (up to 9 storms) with multiple starting reservoir elevations for applying fixed rules, or a different discharge rating curve for each storm.
- The most downstream (i.e., final) output hydrograph can be stored on a disk file for later processing (option).
- Seasonal guides for most reservoirs can be computed by the program (optional).

This allows the following implementations.

- The initial elevation can be automatically computed by the program.
- For non-major tributary dams, at the start of a flood, reservoirs will fill to the guide elevation.
- For all dams, the reservoirs will not fall below the seasonal guide
- For major tributary dams, the reservoirs will discharge at a "user-defined" rate (e.g., 1/2 turbine) while operating in the regulating zone during flood recession.

- An end-of-routing date and time can be specified to define a routing period beyond the length of the longest input hydrograph (option).
- Input hydrograph intervals and channel routing periods need to be integer multiples of each other. Linear interpolation will be used to combine hydrographs.
- Inputting the reservoir routing period is optional. If not specified, the current hydrograph interval is used.
- If for a major tributary dam, the emptying rate is greater than the most recent release before the emptying rate is to go into effect then the "most recent release" becomes the emptying rate.
- If for a major tributary dam, the headwater crests above top-of-gates, then discharge will follow the rating curve until top-of-gates is reached, at which time the top-of-gates elevation will be held until discharge recedes to the emptying rate.
- If for a major tributary dam, maximum inflow occurs before the normal upper limit elevation is reached, and holding discharge until headwater crests brings the headwater to top-of-gates, then discharge at maximum inflow will be held only until the normal upper limit elevation is reached, at which time, discharge will be increased until the normal upper discharge is reached. The discharge will then follow the rating curve.
- For a major tributary dam with a multiple storm sequence, the discharge used at the end of the first (second) storm will be used as the initial discharge (until the rating curve is "reached") at the beginning of the second (third) storm.
- Channel routing allows multiple back points via an ARMA(p,q) model where p is the number of outflow back points and q is the number of inflow back points (ARMA(1,1) is the Muskingum routing model).

5.2.2 The TRBROUTE code

The TRBROUTE code consists of the main program and several subroutines. The following subroutines were part of the original TRBROUTE code developed on a mainframe computer:

- ROUTE routes hydrographs
- RROUTE performs reservoir routing
- WRITE(PREVCD,PTR) outputs hydrograph routing
- OUTRAT(RSVRNM,STMPTR,ELEV,QRAT,STO,NUMPTS) outputs rating curve for current storm and reservoir
- GETSTO(RSVRNM,STO,NUMPTS,ELEV) searches storage curve file for storage

curve using reservoir name

- GETRAT(RSVRNM,QRAT,NUMPTS,ELEV) searches rating curve file for rating curve using reservoir name
- GETIFR(RSVRNM,FEL,FOUT,NUMPTS,ELEV,QRAT,NUL,TOG,QEMPTY) computes fixed rules rating curve
- SRTMRG(FROMX,FNUM,TOX,TNUM,FROMY,TOY) performs a sort/merge of 2 sets of ordered pairs
- FRSTEL(RSVRNM,DATE,TIME,GUIDE,TOPZON) computes seasonal guide elevations and top of regulating zone elevations
- UPDATE(DELTAT,GUIDE,TOPZON) updates elevations
- CHGHI(FLOWS,OLDHI,NEWHI,NUMORD,AVE) changes the hydrograph interval from OLDHI to NEWHI.

The following subroutines are used in the present PC version of TRBROUTE to facilitate the interactive use of the code:

- DoDialog()
- UpdateFiles(dlg, control_name, callbacktype)
- UpdateButton(dlg, control_name, callbacktype)
- UpdateDat(dlg, control_name, static_file, button_control, dirname, ofile)
- SETFIL(dlg, static_file, datname, Output, xtension)

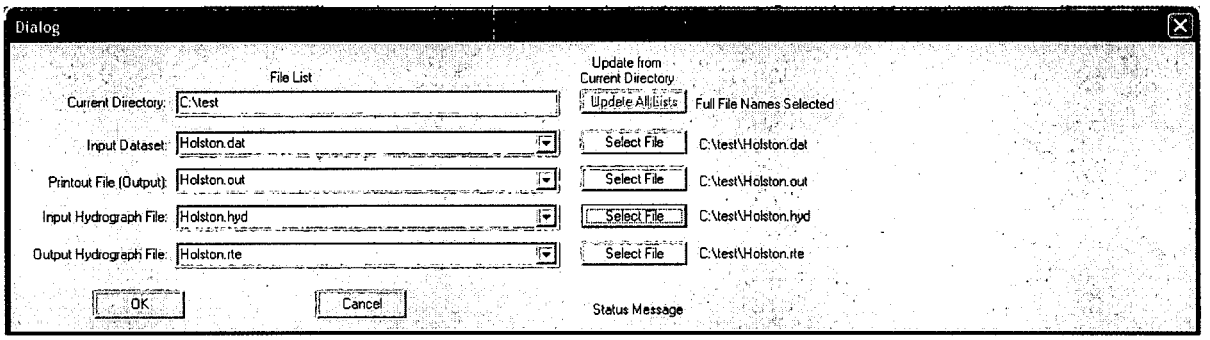
A complete listing of the main program and the subroutines of TRBROUTE is given in Appendix L.

5.2.3 How to run TRBROUTE

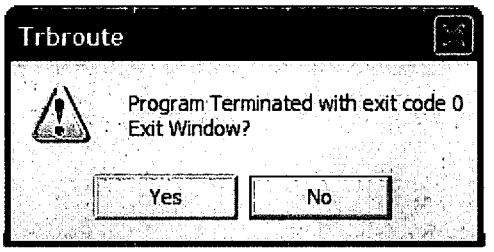
To run TRBROUTE on a Windows PC go through the following steps:

1. Create a shortcut of the executable TRBROUTE.EXE, by placing the cursor on the file TRBROUTE.EXE, right clicking the mouse and from the open menu selecting "Create Shortcut".
2. Copy the shortcut to the Desktop.
3. Double click on the TRBROUTE shortcut icon. This will launch the code and open a dialog window for entering the names of the input and output files.
4. In the dialog window the "Current Directory" field defaults to the location of the executable. If the TRBROUTE input data files are stored in a different location, the "Current Directory" needs to be changed to the location of the input files.

Enter the file names of the up to four required files:



After the files names are entered, press the button "Update List", and then the button "OK". Then TRBROUTE will run and will come back with the following message:



Exit code 0 means normal termination, i.e. successful execution of the code. Press the button "Yes". The output files will have been written in the same directory as the input data file.

To run TRBROUTE, the files STORAGES, QRATINGS, IMPRULES, and SGUIDES must be in the folder chosen with these exact names and no extensions in the dialog window as the current directory.

5.3 Input Data

5.3.1 Description of Input Variables

Table 5 gives the structure and format of the main input data file to TRBROUTE. TRBROUTE uses up to six input files and two output files, which are associated with specific Unit numbers in the standard FORTRAN language terminology.
Input:

- Unit 2: IHGFIL – Hydrograph input file (see Table 6, optional).
- Unit 5: INFIL – The main input file where the input parameters are provided (see Table 5).
- Unit 8: TBFIL – STORAGES look up table with storage-elevation curves for reservoirs to be routed using TRBROUTE (see Table 7).
- Unit 9: TBFIL – QRATINGS look up table with discharge rating curves for tributary dams to be routed using TRBROUTE (see Table 8).
- Unit 10: TBFIL – IMPRULES look up table with reservoir operation guides (see Table 9)

- Unit 11: TBFIL – SGUIDES look up table with reservoir seasonal elevation operation guidelines (see Table 10).

Output:

- Unit 6: OUTFIL – The standard file for printed output.
- Unit 3: OHGFIL – Hydrograph output file (optional).

The FORTRAN format designations in Table 5 through Table 10 are the same as those used in Table 2 and explained in Section 2.3.1.

Table 5. Structure and Format of the TRBROUTE Main Input File (read from Unit 5)

No	Name	Definition	Format
1	TITLE	Title output at top of listing.	A80
2	NSTRMS	Number of storms (i.e., number of separate starting elevations from which to begin an fixed rule operation on a major tributary dam, or the number of different rating curves to apply) (maximum is 9).	20I4
	INHYD	If not zero, all input hydrographs are to be input from a file generated by the flood hydrology program (i.e., input hydrograph flag, e.g. FLDHYDRO output file)	
	OUTHYD	If not zero, the final downstream hydrograph is output in an application specific format to a disk file (i.e., output hydrograph flag).	
	ENDATE	If not zero, the final downstream hydrograph will end at a date and time specified by the user. Otherwise, the routing period is determined by the length of the longest input hydrograph (i.e., ending date flag).	
3	SDATES(I) I = 1, NSTRMS	The beginning date of each separate fixed rule operation or rating curve application (starting date of each storm) (6 digit number: MMDDYY).	10I8
	EDATE	Ending date of the last storm, optional (6 digit number: MMDDYY).	
4	STIMES(I) I = 1, NSTRMS	The corresponding beginning time of each separate fixed rule operation or rating curve application (starting time of each storm) (4 digit number: HHMM).	
	ETIME	Ending time of the last storm, optional (4 digit	

No	Name	Definition	Format
		number: HHMM).	
Note: Line 5, valid instruction codes are 1 through 6; other codes are invalid.			
5	NIC	Number of instruction codes.	20I4
	IC(I) I = 1, NIC	Instruction codes (1 - 6) which dictate the operations to be made on each hydrograph.	
	IC..... = 1	An input hydrograph is read and added to the hydrograph in the working location (i.e., current hydrograph).	
	IC ..... = 2	The current hydrograph is to be reservoir routed and the resulting outflow hydrograph is placed in the working location.	
	IC ..... = 3	The current hydrograph is to be channel routed and the resulting outflow hydrograph is placed in the working location.	
	IC ..... = 4	The current hydrograph is to be stored in another location for later use. Zeroes are placed in the working location.	
	IC ..... = 5	The most recently stored hydrograph and not previously combined is to be added to the current hydrograph.	
	IC ..... = 6	This will generate a printout that depends on the previous instruction code. 1,6 -- total hydrograph generated by 1. 2,6 -- inflow into & outflow from the reservoir. 3,6 -- outflow out of the channel. 4,6 -- not valid. 5,6 -- combined flow.	
6	ANAMES(I) I = 1, NPRINS	Title for each printout one title per line (NPRINS is the number of 6's in array IC).	A80
Note: Repeat lines 7 & 8 for each channel routing (3 in array IC) .			
7	IBKPTS(I)	No. of previous inflows to be used in the ARMA routing model (maximum is 20-OBKPTS(I)).	2I8, F8.0
	OBKPTS(I)	No. of previous outflows to be used in the ARMA routing model (maximum is 20-IBKPTS(I)).	
	CRP(I)	Routing period of ARMA routing model in hours.	

No	Name	Definition	Format
8	C(J,I) J = 1, IBKPTS(I)+ OBKPTS(I) + 1	Coefficients for the IBKPTS+1 most recent inflows starting with the current inflow, followed by coefficients for the OBKPTS most recent outflows starting with the outflow CRP hours before the current one (Muskingum coefficients if IBKPTS = OBKPTS = 1).	10F8.0
Note: For each reservoir (2 in array IC) repeat lines 9 thru 15.			
9	RSVRNM(RRPTR)	Reservoir name (16 characters long). The name is predefined if the reservoir's discharge and/or storage curve is to be accessed from disk.	A16
Note: Line 10, reservoir parameters.			
10	RATCRV	Code defining method by which dam discharges will be specified.	3I8, 4F8.0, 2I8
	RATCRV ..... = 0	Discrete discharges defined completely by user.	
	RATCRV ..... = 1	Discharge rating curve(s).	
	STOCOD	Code specifying location of storage curve.	
	STOCOD ..... = 0	Defined by user.	
	STOCOD ..... = 1	Stored on disk.	
	SGUIDE(RRPTR)	If not zero, this reservoir cannot be drawn down below its seasonal guide elevation, and if a non-major tributary dam, this reservoir will fill to its seasonal guide.	
	FEL(RRPTR)	Initial headwater elevation. If FEL = 0.0, then seasonal guide elevation will be used.	
	FOUT(RRPTR)	If RATCOD(1,RRPTR) = 2 (see Line 11 below) initial discharge rate to be used before "climbing" fixed rule curve of the first storm. In most cases this is 1/2 turbine discharge.	
	RP(RRPTR)	Optional reservoir rating period in hours. If RP <= 0, the current hydrograph interval is used.	
	DSCHTM(RRPTR)	Time period for individual discharges (in hours) (defined only if RATCRV = 0).	
	NDSCHR(RRPTR)	Number of individual discharges to be specified for this reservoir. If the period over which discharges is defined is less than the routing period then the last discharge input is used over the rest of the period (defined only if RATCRV = 0).	

No	Name	Definition	Format
	SVNPTS	Number of points on user defined rating and/or storage curve(s) (needed only if STOCOD or at least one RATCOD(I) = 0).	
Note: If RATCRV > 0 use line 11, otherwise use Line 12.			
11	RATCOD(I,RRPTR) I = 1, NSTRMS	Code(s) defining type of rating curve(s) (required if RATCRV = 1, or RATCRV = 0 & FOUT > 0)	10I8
	RATCOD..... = 0	Rating curves defined completely by user (no fixed rules).	
	RATCOD..... = 1	Fixed rating curves stored on disk (no fixed rules).	
	RATCOD..... = 2	Fixed rules defined on disk (RATCRV = 1).	
12	DSCHRG(I,RRPTR) I = 1, NDSCHR(RRPTR)	Average discharge over each period of discharge (DSCHTM) hours. The first discharge is the average discharge over the period prior to the first inflow (required if RATCRV = 0).	10F8.0
13	SVELEV(I) I = 1, SVNNPTS	Elevations (in feet above mean sea level) used to define storage and/or rating curves for this reservoir (needed only if STOCOD or at least one RATCOD(I) = 0).	10F8.0
14	STO(I,RRPTR) I = 1, SVNNPTS	Storages (in dsf) corresponding to the elevations defined above (needed only if STOCOD = 0).	10F8.0
15	QRAT(I,STMPTR,RRPTR) I = 1, SVNNPTS	Discharges (in cfs) corresponding to the elevations defined above for each user defined rating curve (i.e., for each RATCOD(I) = 0). Start a new line for each rating curve.	
Note: If hydrographs in input data set use lines 16 through 18 (INHYD = 0 [user defined]).			
16	HI(I) I = 1, NTH	Hydrograph interval in hours for each input hydrograph (NTH is the number of 1's in array IC).	10F8.0
17	NORD(I) I = 1, NTH	The number of ordinates of each input hydrograph (in the input data set).	10I8
18	Q(J) J = 1, NORD(I)	Ordinates for each input hydrograph.	10F8.0

Table 6. Structure and Format of Input Hydrograph File (read from Unit 2)

No	Name	Definition	Format
Note: Lines 1 and 2 are repeated for each "1: in the array IC			

No	Name	Definition	Format
1	NORD(I) I = 1, NTH	The no. of ordinates of the next hydrograph.	2I8
	HI(I) I = 1, NTH	Hydrograph interval in hours of the next input hydrograph.	
2	OUT(J) J=1, NORD(I)	Ordinates for the next input hydrograph.	10F8.0

Table 7. Structure and Format of Input File STORAGES (read from Unit 8)

No	Name	Definition	Format
1	NAME	Name of reservoir.	A16
2	NUMPTS	Number of points defined on storage curve.	I4
3	ELEV(I) I=1,NUMPTS	Elevations (in feet above msl) used to define storage curves for each reservoir.	10F8.0
4	STO(I) I=1,NUMPTS	Storages (in dsf) corresponding to the elevations defined above.	10F8.0

Table 8. Structure and Format of Input File QRATINGS (read from Unit 9)

No	Name	Definition	Format
1	NAME	Name of reservoir.	A16
2	NUMPTS	Number of points defined on rating curve.	I4
3	ELEV(I) I=1,NUMPTS	Elevations (in feet above msl) used to define rating curves for each reservoir.	10F8.0
4	QRAT(I) I=1,NUMPTS	Discharges (in cfs) corresponding to the elevations defined above.	10F8.0

Table 9. Structure and Format of Input File IMPRULES (read from Unit 10)

No	Name	Definition	Format
1	NAME	Name of reservoir.	A16
2	NPTS1	Number of elevations used to define the fixed rule guides.	2I8,3F8.0
	NPTS2	Number of points used to define the uncontrolled	

No	Name	Definition	Format
		portion of the rating curve.	
	ZERFLO	Zero flow elevation.	
	TOG	Top of gates elevation.	
	QEMPTY	Emptying rate in cfs.	
Note: The data for data item 3 are given for I=1, NPTS1, i.e. there should be NPTS1 lines with these data.			
3	EL(I)	Initial elevation.	4F8.0
	NULEL(I),	Associated Normal Upper Limit elevation.	
	NULQ(I),	Associated Normal Upper Limit discharge.	
	TOGQ(I)	Associated Top of Gate discharge.	
4	ELEV(I) I=1,NPTS2	Elevations used to define uncontrolled portion of rating curve.	10F8.0
5	QRAT(I) I=1,NPTS2	Discharges corresponding to the elevations defined above.	10F8.0

Note on units: All elevations Table 9 are given in feet above mean sea level, and all discharges in cfs.

Table 10. Structure and Format of Input File SGUIDES (read from Unit 11)

No	Name	Definition	Format
1	NAME	Name of reservoir.	A16
2	GNMPTS	Number of seasonal guide elevations to be input.	I8,F8.0
	ZELEVS(1)	The top of the regulating zone elevation on the first date specified below. The top of the regulating zone is defined by a line connecting this elevation to the seasonal guide elevation on March 16. If ZELEVS(1) equals 0.0, then there is no regulating zone.	
3	GDATES(I) I=1,GNMPTS	The 4 digit dates (MMDD) corresponding to the seasonal guide elevations defined on line 4. The dates should be in ascending order (i.e. earliest calendar date first).	10F8.0
4	GELEVS(I) I=1,GNMPTS	The elevations of the seasonal guide on the respective dates above. Straight line guides are assumed between dates.	10F8.0

5.3.2 Example of Input Data File

TRBROUTE uses up to two user-specified input files. The first user-specified input file is the main input file read from in Unit 5. An example of a typical main input file is presented in Appendix M. The data are for the Holston basin and it is the file "Holston.dat" entered in the dialog box described in Section 5.2.3.

The second user-specified input file is optional. It contains the flood hydrographs for the basin. This is the file "Holston.hyd" which is produced by FLDHYDRO and an example of this input file is the FLDHYDRO output file presented in Appendix H.

5.3.3 Input Files Developed by TVA

TRBROUTE also uses four files developed by TVA. These four files are named STORAGES, QRATINGS, IMPRULES, SGUIDES and they contain reservoir storage data, rating curves, and operation guides and seasonal elevation guidelines. The names of these files are "hardwired" in TRBROUTE. These files must be verified to be reflective of current data and placed in the folder chosen in the dialog window as the current directory (see Section 5.2.3). A brief description and a listing of the contents of these files are given below.

5.3.3.1 File STORAGES: Storage Capacity Curves

The file STORAGES gives the storage-elevation curves for the reservoirs to be routed. The parameters given in the file STORAGES are described in Table 7. For each reservoir this file gives first the name of the dam, the number of points defining the storage-elevation curve, the elevations where the storage is defined, and the storage values at these elevations. Elevations are in feet and storage volumes in thousand dsf.

A complete listing of an example of the file STORAGES is given in Appendix N.

5.3.3.2 File SGUIDES: Seasonal Reservoir Operation Guidelines

The file SGUIDES gives reservoir seasonal operation elevation guidelines. The SGUIDES file is ignored if the SGUIDES parameter is 0 (Line 10 in main input file described in Table 5) and is only used in special studies, but not in flood routing studies such as those in support of PMF flood calculations.

The parameters given in the file SGUIDES are described in Table 10. For each reservoir the data are in the form of a series of dates and reservoir elevations representing the minimum level at which the reservoir must be maintained after each date. The dates are given as four digit numbers, with the first two digits representing the month and the last two the day of the month. The reservoir elevations are in feet.

A complete listing of an example of the file SGUIDES is given in Appendix N.

5.3.3.3 File QRATINGS: Rating Curves

The file QRATINGS gives the rating curves for the dams to be routed. The parameters given in the file QRATINGS are described in Table 8. For each dam this file gives first the name of the dam, the number of points defining the rating curve, the elevations where the discharge is provided, and the total discharge values at these elevations. Elevations are in feet and discharges in cubic feet per second (cfs).

A complete listing of an example of the file QRATINGS is given in Appendix N. The discharge data in this QRATINGS file is historical. However, new rating curves are in development by TVA and will be used in future calculations.

5.3.3.4 File IMPRULES: Reservoir Operation Guides

The file IMPRULES gives reservoir operation guides. The parameters given in the file IMPRULES are described in Table 9. A complete listing of an example of the file IMPRULES is given in Appendix N. Figure 9 illustrates the operation rule curves defined in the file below for the Cherokee reservoir.

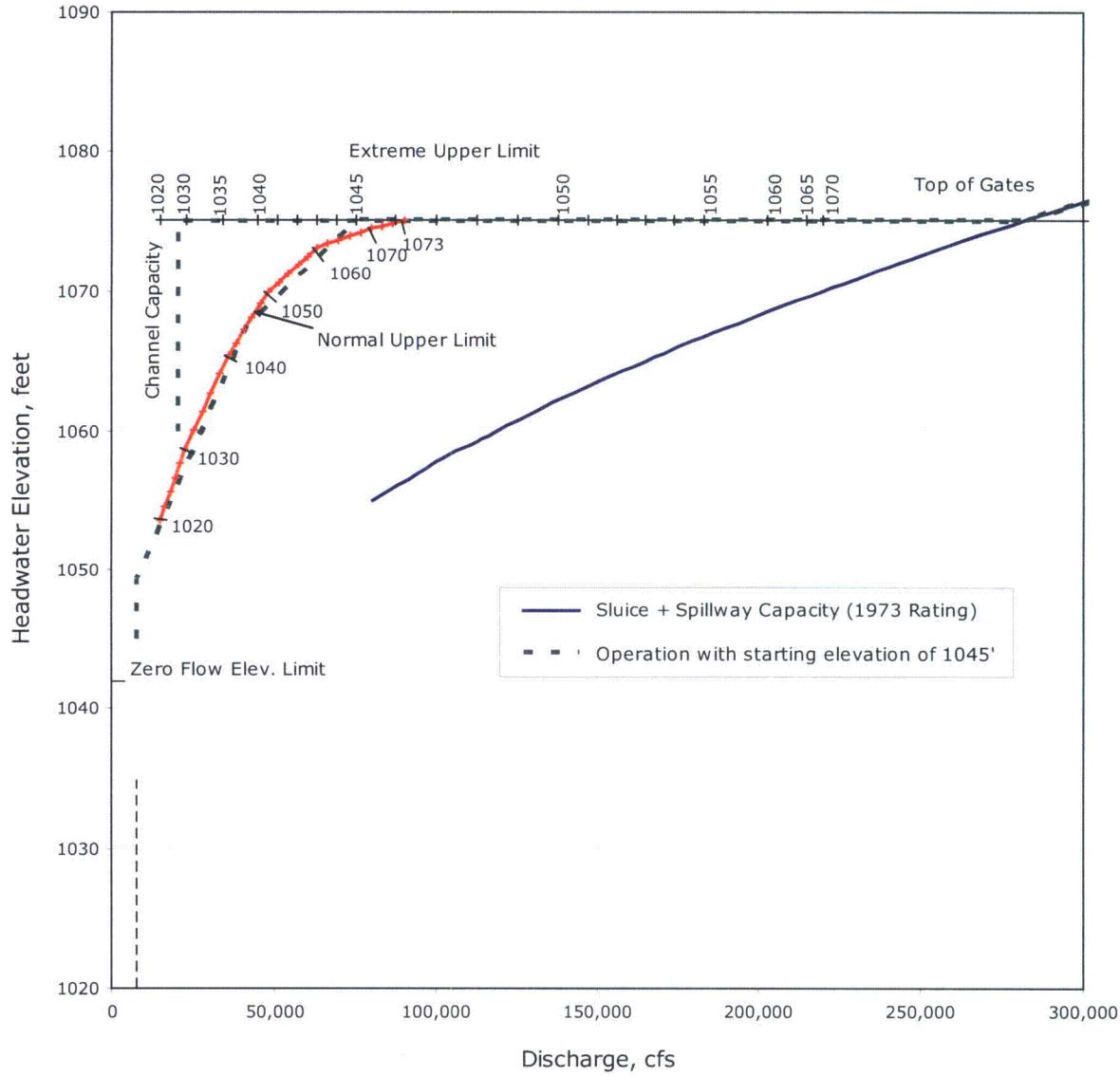


Figure 9. Illustration of the operation rule curves for the Cherokee reservoir

5.3.4 Response of TRBROUTE to Abnormal Input Data

TRBROUTE has built-in safeguards to warn users when abnormal situations arise during operation of the program. A listing of these safeguards is provided below.

- TRBROUTE checks some input parameters for values out of range. If the number of storms, instruction code value, or rating curve code value is out of range, the run terminates. In this case, the output file consists only of an echo of the input data already read and one of the following messages:

  " (No. Storms) IS INVALID AS NUMBER OF STORMS; MAXIMUM IS 9"

  " (Instruction Code) IS INVALID INSTRUCTION CODE; RANGE IS 1 TO 6"

  " (Rating Curve Code) IS INVALID CODE FOR RATING CURVES; RANGE IS 0 TO 2"

- When using the look up tables, the reservoir name given in the main input file must match one of the reservoir names in the look up tables. If the names do not match, the data for the last entry in the look-up table will be used for computations and the run will continue with the invalid data. In this case, the output file consists of an echo of the input data, and the output data. One or more of the following messages will be inserted before the output for the reservoir with the invalid name:

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN STORAGE CURVES FILE"

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN DISCHARGE CURVES FILE"

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN IMPROVED FIXED RULES FILE"

  " RESERVOIR NAME (Reservoir Name) NOT FOUND IN SEASONAL GUIDES FILE"

If none of the above abnormal conditions occurs, TRBROUTE is presumed to have functioned normally. In this case, the entire output file is created.

However, it is possible for TRBROUTE to appear to have functioned normally while using invalid input data. A few such cases are presented below:

- **Negative value input in hydrograph input file:**

  Physically, all hydrograph values should be greater than zero. However, TRBROUTE does not reject input values that are less than zero. TRBROUTE still terminates normally without any warning or error message when negative hydrograph values are input to the hydrograph input file.

- **Initial Headwater elevation above the range of elevation values in the look-up table:**

  The QRATINGS and IMPRULES data input files in TRBROUTE contain discharge rating curves for specified TVA structures. When initial headwater elevation values are specified above the range given in the table, the discharge obtained from these tables is invalid. TRBROUTE still terminates normally without any warning or error message when initial headwater elevations are greater than the largest value in the look-up tables.

In the cases presented in this section, TRBROUTE accepts invalid input data but does not warn the user that the data are invalid. In some cases TRBROUTE may produce correct results with invalid data, but in other cases it may not. In addition, there may be more examples of invalid data which result in normal termination of TRBROUTE besides those presented above. Therefore, it is the responsibility of the user to confirm that the input data file is valid in order to ensure that the TRBROUTE output is also valid. Normal termination of TRBROUTE is a necessary but not sufficient condition for producing valid results.

5.4 Output Data

TRBROUTE produces two output files, one with the flood hydrograph data in the format required for their subsequent use by other codes, written out in Unit 3 and the main output file, written out in Unit 6. Appendices O and P list these two files produced by running TRBROUTE with the input data given in the example presented in Appendices M and H.

6. REFERENCES

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8. Shaw, Elizabeth M., Hydrology in Practice, Third Edition, Chapman & Hall, 1994.
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APPENDIX A – LISTING OF THE UNITGRPH SOURCE CODE

```
C         ***********************************************************************
C         *
C         *        UNITGRPH - QA REV1.0 - 11/18/2008
C         *
C         ***********************************************************************
C
C      SOURCE PROGRAM COPIED FROM CARDS TO SOURCE LIBRARY AS
C      WMG10.FCB.EB321311.SOURCE(UGNEW)      SOURCE DECK LABELED 321094
C      UNIT GRAPH PROGRAM
C      ROSE ANN HATCHER, 713 UB, KNOXVILLE
C      APRIL 1967
       REAL *8 DET
       CHARACTER*1 HEAD,HEAD2
       DIMENSION HEAD(80),HEAD2(80),LIST(20),NQ(10),NRO(10),Q(90,10),RO(5
     10,10),TRO(10),SS(60,60),ROM(90,60),U(60),CQ(90,10),ERR(90),
     2IORD(20),LORD(20)
       COMMON/AVG/NLIST,KLIST,NQS,LIST,ROM
       CHARACTER*80 INFILE,OUTFIL,PLTFIL
       LOGICAL PLTFLG
C
       WRITE (*,'('' Unitgraph Input File:  ''\)')
       READ (*,'(A)') INFILE
       WRITE (*,'('' List File (Type "PRN" for Printer):  ''\)')
       READ (*,'(A)') OUTFIL
       WRITE (*,'('' Plot File (Type "N" for None):  ''\)')
       READ (*,'(A)') PLTFIL
       PLTFLG = PLTFIL .NE. 'N' .AND. PLTFIL .NE. 'n'
       OPEN (5,FILE=INFILE)
       OPEN (6,FILE=OUTFIL)
C
C************* Change Revision Number Here *******************
       WRITE (6,111)
  111 FORMAT (" UNITGRPH - QA REV1.0 - 11/18/2008"/)
C*************************************************************
       READ(5,1)NRUNS,ERROR
     1 FORMAT(I3,F5.0)
     2 NRUNS=NRUNS-1
       ITER=0
       READ(5,3)(HEAD(I),I=1,80)
       READ(5,3)(HEAD2(I),I=1,80)
     3 FORMAT(80A1)
       WRITE(6,4)(HEAD(I),I=1,80)
     4 FORMAT(' "',80A1,'"')
       WRITE(6,5)(HEAD2(I),I=1,80)
     5 FORMAT(' "',80A1,'"'//)
       READ(5,6)NFLOOD,ITERS,NLIST,AD,UGD
     6 FORMAT(3I2,2F10.0)
       READ(5,7)(LIST(I),I=1,NLIST)
     7 FORMAT(20I4)
       READ(5,7)(IORD(I),LORD(I),I=1,NFLOOD)
       AUGT=((5280.**2)/(12.0*3600.0*UGD))*AD
       DO 8 K=1,NFLOOD
     8 TRO(K)=0.0
       READ(5,7)(NQ(K),K=1,NFLOOD)
       READ(5,7)(NRO(K),K=1,NFLOOD)
       DO 15 K=1,NFLOOD
```

```
      NQS=NQ(K)
      READ(5,9)(Q(I,K),I=1,NQS)
    9 FORMAT(8F10.0)
      WRITE(6,10)K
   10 FORMAT(/T9,'"FLOOD',I2,'"')
      WRITE(6,11)
   11 FORMAT(T3,'"INPUT HYDROGRAPH"')
      WRITE(6,12)(Q(I,K),I=1,NQS)
   12 FORMAT(3P8F9.0)
      NROS=NRO(K)
      READ(5,9)(RO(I,K),I=1,NROS)
      WRITE(6,13)
   13 FORMAT(/T3,'"INPUT RUNOFF"')
      WRITE(6,14)(RO(I,K),I=1,NROS)
   14 FORMAT(8F9.4)
      DO 15 I=1,NROS
   15 TRO(K)=TRO(K)+RO(I,K)
      NUGS=LIST(1)+NLIST-1
      NUGO=NQS-NROS+1
      MD=NUGS+1
   16 ITER=ITER+1
      DO 17 J=1,MD
      DO 17 I=1,NUGS
   17 SS(I,J)=0.0
C     SOLVE FOR UNIT GRAPH ORDINATES
      DO 22 K=1,NFLOOD
      NQS=NQ(K)
      DO 18 I=1,NQS
      DO 18 J=1,NUGO
   18 ROM(I,J)=0.0
      NROS=NRO(K)
      DO 19 J=1,NUGO
      I=J
      DO 19 II=1,NROS
      ROM(I,J)=RO(II,K)
   19 I=I+1
      IF(NLIST.EQ.1)GO TO 191
      CALL AVERAG
  191 DO 21 I=1,NUGS
      DO 21 J=I,NUGS
      DO 20 II=1,NQS
   20 SS(I,J)=SS(I,J)+ROM(II,I)*ROM(II,J)
   21 SS(J,I)=SS(I,J)
      DO 22 I=1,NUGS
      DO 22 II=1,NQS
   22 SS(I,MD)=SS(I,MD)+ROM(II,I)*Q(II,K)
      CALL XATEQ(SS(1,1),SS(1,MD),NUGS,1,DET)
      DO 23 I=1,NUGS
      IF(SS(I,MD).LT.0.0)SS(I,MD)=0.0
   23 CONTINUE
      I1=LIST(1)
      DO 24 I=1,I1
   24 U(I)=SS(I,MD)
      IF(NLIST.EQ.1)GO TO 261
      DO 25 I2=2,NLIST
      I=LIST(I2)
      I1=I1+1
   25 U(I)=SS(I1,MD)
      DO 26 II=1,KLIST
      I1=LIST(II)
```

```
      I2=LIST(II+1)
      IJ=I2-I1
      A=(U(I2)-U(I1))/IJ
      IJ=IJ-1
      DO 26 I=1,IJ
      I3=I+I1
   26 U(I3)=U(I3-1)+A
  261 UGT=0.0
      DO 27 I=1,NUGO
   27 UGT=UGT+U(I)
      G=AUGT/UGT
      DO 28 I=1,NUGO
   28 U(I)=G*U(I)
      WRITE(6,29)ITER
   29 FORMAT(//T14,'"ITERATION',I3,'"'/)
      WRITE(6,30)
   30 FORMAT(T3,'"UNIT GRAPH"')
      WRITE(6,12)(U(I),I=1,NUGO)
      WRITE(6,31)DET
   31 FORMAT(/T3,'"DETERMINANT IS',D14.7,'"')
C     SOLVE FOR RUNOFF CORRECTIONS
      NUM=0
      DO 50 K=1,NFLOOD
      ASSIGN 44 TO N1
      NROS=NRO(K)
      NR=NROS+1
      DO 32 J=1,NR
      DO 32 I=1,NROS
   32 SS(I,J)=0.0
      DO 33 J=1,NROS
      DO 33 JJ=J,NUGO
      II=JJ-J+1
   33 SS(1,J)=SS(1,J)+U(JJ)*U(II)
      DO 34 I=2,NROS
      II=I-1
      DO 34 J=I,NROS
      SS(I,J)=SS(II,J-1)
   34 SS(J,I)=SS(I,J)
      DO 341 I=2,NROS
  341 SS(I,1)=SS(1,I)
      WRITE(6,10)K
      WRITE(6,35)
   35 FORMAT(T3,'"RUNOFF"')
   36 WRITE(6,37)(RO(I,K),I=1,NROS)
   37 FORMAT(8F9.4)
      NQS=NQ(K)
      J1=1
      DO 39 I=1,NQS
      CQ(I,K)=0.0
      IF(I.GT.NROS)J1=J1+1
      J2=I
      IF(J2.GT.NUGO)J2=NUGO
      DO 38 J=J1,J2
      J3=I-J+1
   38 CQ(I,K)=CQ(I,K)+RO(J3,K)*U(J)
   39 ERR(I)=Q(I,K)-CQ(I,K)
      WRITE(6,40)
   40 FORMAT(/T3,'"COMPUTED HYDROGRAPH"')
      WRITE(6,12)(CQ(I,K),I=1,NQS)
      WRITE(6,41)
```

```
 41 FORMAT(/T3,'"HYDROGRAPH ERROR"')
    WRITE(6,12)(ERR(I),I=1,NQS)
    TERR=0.0
    PTERR=0.0
    NQSP=0
    DO 42 I=1,NQS
    IF(I.LE.IORD(K).OR.I.GE.LORD(K))GO TO 42
    PTERR=PTERR+ABS(ERR(I)/Q(I,K))
    NQSP=NQSP+1
 42 TERR=TERR+ABS(ERR(I)/Q(I,K))
    TERR=TERR/NQS
    PTERR=PTERR/NQSP
    WRITE(6,43)TERR,PTERR
 43 FORMAT(/T3,'"AVERAGE PERCENT HYDROGRAPH ERROR IS',
   1        2PF7.2,5X,2PF7.2,'"')
    GO TO N1,(49,44)
44  DO 45 I=1,NROS
    JJ=I
    DO 45 J=1,NUGO
    SS(I,NR)=SS(I,NR)+ERR(JJ)*U(J)
 45 JJ=JJ+1
    CALL XATEQ(SS(1,1),SS(1,NR),NROS,1,DET)
    TCRO=0.0
    DO 46 I=1,NROS
    RO(I,K)=RO(I,K)+SS(I,NR)
    IF(RO(I,K).LT.0.0)RO(I,K)=0.0
    TCRO=TCRO+RO(I,K)
 46 CONTINUE
    ROVC=TRO(K)/TCRO
    DO 47 I=1,NROS
 47 RO(I,K)=RO(I,K)*ROVC
    WRITE(6,48)
 48 FORMAT(/T3,'"ADJUSTED RUNOFF"')
    ASSIGN 49 TO N1
    GO TO 36
49  WRITE(6,31)DET
    IF(TERR.LE.ERROR)NUM=NUM+1
 50 CONTINUE
    IF(NUM.EQ.NFLOOD)GO TO 51
    IF(ITER.EQ.ITERS)GO TO 53
    GO TO 16
 51 WRITE(6,52)
 52 FORMAT(/T2,'"STOPPED BY CONVERGENCE"')
    GO TO 55
 53 WRITE(6,54)
 54 FORMAT(/T2,'"STOPPED BY ITERATION TEST"')
 55 IF ( PLTFLG ) OPEN (3,FILE=PLTFIL)
    IF ( PLTFLG ) CALL GRAFIT(U,UGD,NUGO,Q,CQ,NQ,NFLOOD,HEAD,HEAD2)
    IF(NRUNS.NE.0)GO TO 2
    STOP
    END
    SUBROUTINE AVERAG
    REAL *4 K1,K2,KON
    DIMENSION ROM(90,60),LIST(20)
    COMMON/AVG/NLIST,KLIST,NQS,LIST,ROM
    KLIST=NLIST-1
    DO 2 K=1,KLIST
    I1=LIST(K)
    I2=LIST(K+1)
    KON=I2-I1
```

```
      JJ=KON-1
      IF(JJ.NE.0)GO TO 1
      JJ=1
    1 DO 2 J=1,JJ
      C=J
      K1=(KON-C)/KON
      K2=C/KON
      K3=I1+J
      DO 2 I=1,NQS
      ROM(I,I1)=ROM(I,I1)+K1*ROM(I,K3)
    2 ROM(I,I2)=ROM(I,I2)+K2*ROM(I,K3)
      J=LIST(1)
      DO 3 K=1,KLIST
      J=J+1
      JJ=LIST(K+1)
      DO 3 I=1,NQS
    3 ROM(I,J)=ROM(I,JJ)
    4 RETURN
      END
      SUBROUTINE XATEQ(A,B,N,M,DET)
      REAL*8 DET
      DIMENSION A(60,60),B(60,1)
      IFLG=0
      I1=1
      DET=1.0
  100 XFACT=0.0
      DO 10 I=I1,N
      DO 10 J=1,N
      IF(A(I,J)-XFACT)10,10,1
    1 XFACT=A(I,J)
      IB=I
      JB=J
   10 CONTINUE
      DET=DET*XFACT
      IF(IFLG) 1701,1701,17
 1701 DO 11 J=1,N
      STOR=A(I1,J)
      A(I1,J)=A(IB,J)
      A(IB,J)=STOR
   11 CONTINUE
      IF(M) 201,201,200
  200 DO 12 J=1,M
      STOR=B(I1,J)
      B(I1,J)=B(IB,J)
      B(IB,J)=STOR
   12 CONTINUE
  201 I1=I1+1
      DO 16 I=I1,N
      XFACT=-(A(I,JB)/A(I1-1,JB))
      DO 14 J=1,N
      A(I,J)=A(I,J)+A(I1-1,J)*XFACT
   14 CONTINUE
      IF(M) 203,203,202
  202 DO 15 J=1,M
      B(I,J)=B(I,J)+B(I1-1,J)*XFACT
   15 CONTINUE
  203 A(I,JB)=0.0
   16 CONTINUE
      IF(I1-N)100,1700,1700
 1700 IFLG=1
```

```
      GO TO 100
   17 IF(M) 290,290,170
  170 N1=N
   23 DO 18 J=1,N
      IF(A(N1,J))19,18,19
   18 CONTINUE
   19 N2=N1-1
      DO 21 J1=1,M
      XFACT=B(N1,J1)/A(N1,J)
      B(N1,J1)=XFACT
      IF(N2) 21,21,210
  210 DO 20 I=1,N2
      B(I,J1)=B(I,J1)-XFACT*A(I,J)
   20 CONTINUE
   21 CONTINUE
      IF(N2  ) 25,25,220
  220 DO 22 I=1,N2
      A(I,J)=0.0
   22 CONTINUE
      N1=N1-1
      GO TO 23
   25 continue
      DO 29 I1=1,N
   28 DO 30 I=I1,N
      IF( ABS(A(I,I1))) 30,30,26
   30 CONTINUE
   26 DO 27 J=1,M
      STOR=B(I,J)
      B(I,J)=B(I1,J)
      B(I1,J)=STOR
   27 CONTINUE
      DO 300 J=1,N
      STOR=A(I,J)
      A(I,J)=A(I1,J)
      A(I1,J)=STOR
  300 CONTINUE
   29 CONTINUE
  290 RETURN
      END
      SUBROUTINE GRAFIT(U,UGD,NUGO,Q,CQ,NQ,NFLOOD,HEAD,HEAD2)
      REAL U(60),UGD,Q(90,10),CQ(90,10),TIME,ZERO
      INTEGER NUGO,NQ(10),NFLOOD,HGINT,UGINT,INT,LSTCHR
      CHARACTER*1 HEAD(80),HEAD2(80),BLANK,QUOTE
      DATA ZERO/0.0/,BLANK/' '/,QUOTE/'"'/
C
      DO 50 LSTCHR = 80,1,-1
   50 IF ( HEAD(LSTCHR) .NE. BLANK ) GO TO 80
   80 IF ( LSTCHR .EQ. 80 ) THEN
         WRITE (3,100) (HEAD(I),I=1,80),QUOTE
  100    FORMAT (1H",81A1)
      ELSE
         HEAD(LSTCHR+1) = QUOTE
         WRITE (3,100) (HEAD(I),I=1,LSTCHR+1)
      END IF
      DO 150 LSTCHR = 80,1,-1
  150 IF ( HEAD2(LSTCHR) .NE. BLANK ) GO TO 180
  180 IF ( LSTCHR .EQ. 80 ) THEN
         WRITE (3,100) (HEAD2(I),I=1,80),QUOTE
      ELSE
         HEAD2(LSTCHR+1) = QUOTE
```

```
         WRITE (3,100) (HEAD2(I),I=1,LSTCHR+1)
      END IF
      HGINT = NQ(1) / 10
      IF ( HGINT .EQ. 0 ) HGINT = 1
      DO 600 I = 1,NFLOOD
      WRITE (3,200) I
  200 FORMAT (6H"FLOOD,I2,1H")
      TIME = 0.0
      INT = 1
      WRITE (3,300) TIME,ZERO,ZERO
  300 FORMAT (F5.1,3X,3P2F8.0)
      DO 500 J = 1,NQ(I)
      TIME = TIME + UGD
      IF ( INT .EQ. HGINT ) THEN
         INT = 0
         WRITE (3,300) TIME,Q(J,I),CQ(J,I)
      ELSE
         WRITE (3,400) Q(J,I),CQ(J,I)
  400    FORMAT (3H" ",5X,3P2F8.0)
      END IF
      INT = INT + 1
  500 CONTINUE
      TIME = TIME + UGD
      IF ( INT .EQ. HGINT ) THEN
         WRITE (3,300) TIME,ZERO,ZERO
      ELSE
         WRITE (3,400) ZERO,ZERO
      END IF
  600 CONTINUE
C
      WRITE (3,700) UGD
  700 FORMAT (1H",F3.1,14H-HR UNITGRAPH")
      UGINT = NUGO / 10
      IF ( UGINT .EQ. 0 ) UGINT = 1
      TIME = 0.0
      INT = 1
      WRITE (3,300) TIME,ZERO
      DO 800 I = 1,NUGO
      TIME = TIME + UGD
      IF ( INT .EQ. UGINT ) THEN
         INT = 0
         WRITE (3,300) TIME,U(I)
      ELSE
         WRITE (3,400) U(I)
      END IF
      INT = INT + 1
  800 CONTINUE
      TIME = TIME + UGD
      IF ( INT .EQ. UGINT ) THEN
         WRITE (3,300) TIME,ZERO
      ELSE
         WRITE (3,400) ZERO
      ENDIF
      RETURN
      END
```

APPENDIX B – EXAMPLE UNITGRPH INPUT FILE

An example of a typical UNITGRPH input data file is presented below. It is for the derivation of the 6-hour unit hydrograph in the Ft Loudoun subbasin.

```
  1  .05
Ft Loudoun Local 6 Hr Synthetic Unit Graph Development; From March, 1973
Hydrographs Obtained From Unsteady Flow Reverse Routing
 1 5 2      .323        6.
   3   5
   2   6
   8
   4
      20.5      25.0      29.5      15.5       8.5       5.0       2.5       .05
      1.08      0.56      1.09      0.14
```

APPENDIX C – EXAMPLE UNITGRPH MAIN OUTPUT FILE

The main output file (written out in Unit 6) produced by running UNITGRPH for the example presented in Appendix B is listed below.

```
UNITGRPH - QA REV1.0 - 11/18/2008

 "Ft Loudoun Local 6 Hr Synthetic Unit Graph Development; From March, 1973        "
 "Hydrographs Obtained From Unsteady Flow Reverse Routing                          "



       "FLOOD 1"
  "INPUT HYDROGRAPH"
   20500.   25000.   29500.   15500.    8500.    5000.    2500.      50.

  "INPUT RUNOFF"
   1.0800   0.5600   1.0900   0.1400


            "ITERATION  1"

  "UNIT GRAPH"
   18576.   10255.    1113.    1970.    2827.

  "DETERMINANT IS 0.3511540D+02"

       "FLOOD 1"
  "RUNOFF"
   1.0800   0.5600   1.0900   0.1400

  "COMPUTED HYDROGRAPH"
   20062.   21478.   27193.   16530.    6805.    3886.    3357.     396.

  "HYDROGRAPH ERROR"
      438.    3522.    2307.   -1030.    1695.    1114.    -857.    -346.

  "AVERAGE PERCENT HYDROGRAPH ERROR IS  99.83       11.47"

  "ADJUSTED RUNOFF"
   1.0330   0.7137   1.0155   0.1078

  "COMPUTED HYDROGRAPH"
   19189.   23852.   27333.   15245.    6561.    4138.    3083.     305.

  "HYDROGRAPH ERROR"
    1311.    1148.    2167.     255.    1939.     862.    -583.    -255.

  "AVERAGE PERCENT HYDROGRAPH ERROR IS  74.06       10.60"

  "DETERMINANT IS 0.2141990D+11"


            "ITERATION  2"

  "UNIT GRAPH"
   18738.    9033.    2011.    2323.    2635.
```

```
"DETERMINANT IS 0.2863404D+02"

      "FLOOD 1"
"RUNOFF"
 1.0330   0.7137   1.0155   0.1078

"COMPUTED HYDROGRAPH"
 19357.   22705.   27554.   15028.    7396.    4456.    2926.     284.

"HYDROGRAPH ERROR"
  1143.    2295.    1946.     472.    1104.     544.    -426.    -234.

"AVERAGE PERCENT HYDROGRAPH ERROR IS  66.64        7.55"

"ADJUSTED RUNOFF"
 1.0222   0.7595   0.9897   0.0986

"COMPUTED HYDROGRAPH"
 19155.   23465.   27461.   14690.    7339.    4498.    2837.     260.

"HYDROGRAPH ERROR"
  1345.    1535.    2039.     810.    1161.     502.    -337.    -210.

"AVERAGE PERCENT HYDROGRAPH ERROR IS  60.22        8.60"

"DETERMINANT IS 0.2064895D+11"


           "ITERATION  3"

"UNIT GRAPH"
 18797.    8565.    2450.    2460.    2469.

"DETERMINANT IS 0.2709043D+02"

      "FLOOD 1"
"RUNOFF"
 1.0222   0.7595   0.9897   0.0986

"COMPUTED HYDROGRAPH"
 19215.   23031.   27612.   14705.    7661.    4551.    2686.     244.

"HYDROGRAPH ERROR"
  1285.    1969.    1888.     795.     839.     449.    -186.    -194.

"AVERAGE PERCENT HYDROGRAPH ERROR IS  54.89        7.13"

"ADJUSTED RUNOFF"
 1.0187   0.7806   0.9756   0.0950

"COMPUTED HYDROGRAPH"
 19150.   23399.   27521.   14559.    7639.    4560.    2643.     235.

"HYDROGRAPH ERROR"
  1350.    1601.    1979.     941.     861.     440.    -143.    -185.

"AVERAGE PERCENT HYDROGRAPH ERROR IS  52.43        7.64"

"DETERMINANT IS 0.2047773D+11"
```

```
          "ITERATION  4"

"UNIT GRAPH"
 18824.    8330.    2686.    2529.    2372.

"DETERMINANT IS 0.2639470D+02"

      "FLOOD 1"
"RUNOFF"
 1.0187   0.7806   0.9756   0.0950

"COMPUTED HYDROGRAPH"
 19177.   23181.   27604.   14587.    7802.    4574.    2554.     225.

"HYDROGRAPH ERROR"
  1323.    1819.    1896.     913.     698.     426.     -54.    -175.

"AVERAGE PERCENT HYDROGRAPH ERROR IS  49.44        6.84"

"ADJUSTED RUNOFF"
 1.0173   0.7919   0.9680   0.0928

"COMPUTED HYDROGRAPH"
 19150.   23381.   27550.   14510.    7789.    4576.    2531.     220.

"HYDROGRAPH ERROR"
  1350.    1619.    1950.     990.     711.     424.     -31.    -170.

"AVERAGE PERCENT HYDROGRAPH ERROR IS  48.06        7.12"

"DETERMINANT IS 0.2041496D+11"


          "ITERATION  5"

"UNIT GRAPH"
 18835.    8203.    2819.    2568.    2317.

"DETERMINANT IS 0.2607597D+02"

      "FLOOD 1"
"RUNOFF"
 1.0173   0.7919   0.9680   0.0928

"COMPUTED HYDROGRAPH"
 19161.   23260.   27595.   14532.    7880.    4582.    2481.     215.

"HYDROGRAPH ERROR"
  1339.    1740.    1905.     968.     620.     418.      19.    -165.

"AVERAGE PERCENT HYDROGRAPH ERROR IS  46.59        6.67"

"ADJUSTED RUNOFF"
 1.0168   0.7982   0.9637   0.0914

"COMPUTED HYDROGRAPH"
 19151.   23374.   27564.   14486.    7871.    4581.    2467.     212.

"HYDROGRAPH ERROR"
```

```
  1349.    1626.    1936.    1014.     629.     419.      33.    -162.

 "AVERAGE PERCENT HYDROGRAPH ERROR IS  45.83        6.84"

 "DETERMINANT IS 0.2036731D+11"

"STOPPED BY ITERATION TEST"
```

APPENDIX D – EXAMPLE UNITGRPH PLOTTING OUTPUT FILE

This file contains the information that facilitates the plotting of the computed unit hydrograph and the observed and computed flood hydrographs. The plotting data file produced by running UNITGRPH with the input data given in the example presented in Appendix B is listed below.

```
"Ft Loudoun Local 6 Hr Synthetic Unit Graph Development; From March, 1973"
"Hydrographs Obtained From Unsteady Flow Reverse Routing"
"FLOOD 1"
  0.0         0.      0.
  6.0     20500.  19151.
 12.0     25000.  23374.
 18.0     29500.  27564.
 24.0     15500.  14486.
 30.0      8500.   7871.
 36.0      5000.   4581.
 42.0      2500.   2467.
 48.0        50.    212.
 54.0         0.      0.
"6.0-HR UNITGRAPH"
  0.0         0.
  6.0     18835.
 12.0      8203.
 18.0      2819.
 24.0      2568.
 30.0      2317.
 36.0         0.
```

APPENDIX E – LISTING OF THE FLDHYDRO SOURCE CODE

```
C         ***********************************************************************
C         *
C         *        FLDHYDRO - QA REV1.0 - 11/04/2008
C         *
C         ***********************************************************************
C
      BLOCK DATA
      COMMON /TABLES/ MODAYS(12)
      INTEGER MODAYS
C
      COMMON /PARMS/ NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
      INTEGER NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
C
      COMMON /GAGES/ APITYP(100),RITYP(100),NAMSTA(100),NAMREC(100),
     1               RECSTA(100)
      INTEGER APITYP,RITYP,RECSTA
      CHARACTER NAMSTA*4,NAMREC*4
C
      COMMON /TIMES/ BEGTR(4,30),BEGT,BEGTA,BEGD,BEGDR(4,30)
      INTEGER BEGTR,BEGT,BEGTA,BEGD,BEGDR
C
      COMMON /UNTGPH/ UGDUR(50),HYDINT(50),NUGORD(50),UGORD(200,50)
      INTEGER UGDUR,HYDINT,NUGORD
      REAL UGORD
C
      COMMON /HYDGPH/ NUMHYD,FHORDR(50),BBSFLW(4,50),EBSFLW(4,50)
      INTEGER NUMHYD,FHORDR
      REAL BBSFLW,EBSFLW
C
      COMMON /STATRO/ ORIGRI(4,100),ADJRI(4,100),API(4,100),
     1                NDRAPI(100),APRAIN(30,100),FACTOR(4,100),NSWRI
      REAL API,APRAIN,FACTOR
      INTEGER ORIGRI,ADJRI,NDRAPI,NSWRI
C
      COMMON /BASIN/ BAREA(50),BSNAME(51),NSPW(50),BSNSTA(25,50),
     1               THIESN(25,50),ORDSTA(25,50)
      REAL BAREA,THIESN
      INTEGER NSPW,ORDSTA
      CHARACTER BSNAME*80,BSNSTA*4
C
      COMMON /PRECIP/ SHRAIN(240,31),NHR(4,30),NHRBS(3,30),NDBS(3,30),
     1                DYRAIN(20,100),NDR(4,30),NDRTOT(30),TRAIN(4,100)
      REAL SHRAIN,DYRAIN,TRAIN
      INTEGER NHR,NHRBS,NDBS,NDR,NDRTOT
C
      DATA MODAYS/31,28,31,30,31,30,31,31,30,31,30,31/,FACTOR/400*1.0/
      END
      COMMON /TABLES/ MODAYS(12)
      INTEGER MODAYS
C
      COMMON /PARMS/ NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
      INTEGER NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
C
      COMMON /GAGES/ APITYP(100),RITYP(100),NAMSTA(100),NAMREC(100),
     1               RECSTA(100)
      INTEGER APITYP,RITYP,RECSTA
```

```
      CHARACTER NAMSTA*4,NAMREC*4
C
      COMMON /TIMES/ BEGTR(4,30),BEGT,BEGTA,BEGD,BEGDR(4,30)
      INTEGER BEGTR,BEGT,BEGTA,BEGD,BEGDR
C
      COMMON /UNTGPH/ UGDUR(50),HYDINT(50),NUGORD(50),UGORD(200,50)
      INTEGER UGDUR,HYDINT,NUGORD
      REAL UGORD
C
      COMMON /HYDGPH/ NUMHYD,FHORDR(50),BBSFLW(4,50),EBSFLW(4,50)
      INTEGER NUMHYD,FHORDR
      REAL BBSFLW,EBSFLW
C
      COMMON /STATRO/ ORIGRI(4,100),ADJRI(4,100),API(4,100),
     1                NDRAPI(100),APRAIN(30,100),FACTOR(4,100),NSWRI
      REAL API,APRAIN,FACTOR
      INTEGER ORIGRI,ADJRI,NDRAPI,NSWRI
C
      COMMON /BASIN/ BAREA(50),BSNAME(51),NSPW(50),BSNSTA(25,50),
     1               THIESN(25,50),ORDSTA(25,50)
      REAL BAREA,THIESN
      INTEGER NSPW,ORDSTA
      CHARACTER BSNAME*80,BSNSTA*4
C
      COMMON /PRECIP/ SHRAIN(240,31),NHR(4,30),NHRBS(3,30),NDBS(3,30),
     1                DYRAIN(20,100),NDR(4,30),NDRTOT(30),TRAIN(4,100)
      REAL SHRAIN,DYRAIN,TRAIN
      INTEGER NHR,NHRBS,NDBS,NDR,NDRTOT
C
      COMMON /FILES/DATFIL,OUTFIL,HYDFIL
      CHARACTER*240 DATFIL,OUTFIL,HYDFIL
C
C     LOCAL VARIABLES IN THE MAIN PROGRAM
C
      INTEGER TEMPRI(4,100),NUMVOL(50),WEEK(4,30),WORKWK(53)
      INTEGER TIME,NDAYS1,NDAYS2,RECNO
      INTEGER STNIDX,RECIDX,RIIDX,DAYIDX,SPWIDX,HRIDX,APIIDX,SRIIDX
      INTEGER START,END,STNCNT,APICNT,STRTRI,NUMAPI,BSNIDX
      INTEGER*2 ARGONE,LTH,LENGTH
      REAL APITBL(50),APITMP(100),CHKVOL(4,50)
      CHARACTER*240 FILNAM
      LOGICAL ERROR
      INTEGER NDAYS
C
      DATA WORKWK/ 1, 2, 2, 2, 2, 2, 2, 2, 2, 2,
     1             2, 3, 4, 5, 6, 7, 8, 9,10,11,
     2            12,13,14,15,16,17,18,19,20,21,
     3            21,21,21,21,21,21,21,21,21,21,
     4            22,23,24,25,26,27,28,29,30,31,
     5            32,33,33/
      DATA ERROR/.FALSE./
C
      ARGONE = 1
      CALL GETARG (ARGONE, FILNAM, LTH)
C
C     OPEN RI/RUNOFF TABLES
C
      IF ( LTH .LT. 0 ) THEN
        WRITE (FILNAM(1:2),'("TV")')
      ELSE
```

```
          WRITE (FILNAM(LTH+1:LTH+3),'("\TV")')
        END IF
       OPEN(UNIT=7,FILE=FILNAM,STATUS='OLD',ACCESS='DIRECT',RECL=121)
        IF ( LTH .LT. 0 ) THEN
          WRITE (FILNAM(1:5),'("NONTV")')
        ELSE
          WRITE (FILNAM(LTH+1:LTH+6),'("\NONTV")')
        END IF
       OPEN(UNIT=8,FILE=FILNAM,STATUS='OLD',ACCESS='DIRECT',RECL=121)
C
C      OPEN API/RI TABLES AND DETERMINE RI
C
        IF ( LTH .LT. 0 ) THEN
          WRITE (FILNAM(1:6),'("APITBL")')
        ELSE
          WRITE (FILNAM(LTH+1:LTH+7),'("\APITBL")')
        END IF
        OPEN(UNIT=4,FILE=FILNAM,STATUS='OLD',ACCESS='DIRECT',RECL=47)

       IF ( NARGS() .LE. 2 ) THEN
              CALL DoDialog( )
        ELSE
              ARGONE = 2
              CALL GETARG(ARGONE,DATFIL,LENGTH)
        END IF
       IF ( NARGS() .GT. 2 ) THEN
              WRITE (*,'('' List File (Type "PRN" for Printer):  ''\)')
              READ (*,'(A)') OUTFIL
        END IF
       OPEN (5,FILE=DATFIL)
       OPEN (6,FILE=OUTFIL)
C************* Change Revision Number Here *******************
        WRITE (6,1)
    1 FORMAT (" FLDHYDRO - QA REV1.0 - 11/04/2008"/)
C*************************************************************
C
C      BSNAME  =  NAME OF THE WATERSHED UNDER CONSIDERATION
C
       READ(5,10) BSNAME(51)
   10  FORMAT(A80)
       WRITE(6,20) BSNAME(51)
   20  FORMAT(1X,A80)
C
       READ(5,30) NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
   30  FORMAT(16I5)
       WRITE(6,40) NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
   40  FORMAT(1X,16I5)
C
C  NARFE OPTION =0,1, OR 2 WHEN CERTAIN OUTPUT IS TO BE SENT TO THE
C                 NARFE PROGRAM
C             = 0 MEANS THAT AVERAGE RAIN AND RUNOFF ARE DESIRED BY
C               THE PROGRAM WITH NO INPUT TO GO TO NARFE
C             = 1 MEANS THAT NONE OF THE COMPUTED FLOODS WILL BE INPUTED
C                TO THE NARFE PROGRAM
C             = 2 MEANS THAT SOME OR ALL OF THE COMPUTED FLOOD HYDROGRAPH
C                WILL BE SENT TO THE NARFE PROGRAM DEPENDING ON THE FLOOD
C                HYDROGRAPH ORDER (FHORDR)
C  NRI OPTION = NUMBER OF FLOODS OR RUNOFF INDEXES FOR EACH STATION
C  NCPTS OPTION =  NUMBER OF LOCATIONS WITHIN THE WATERSHED WHEN SURFACE
C                  RUNOFF VOLUME CHECKS ARE DESIRED
```

```
C  NSUBW OPTION = NUMBER OF SUBWATERSHEDS
C  NREC OPTION = NUMBER OF RECORDING RAIN STATIONS
C  NSTNS OPTION = NUMBER OF RAIN STATIONS INCLUDING NONRECORDERS
C  STAB OPTION = 1,2, OR 3 TO DETERMINE WHICH API AREA THE RAIN
C                STATIONS ARE IN
C              = 1 MEANS ALL STATIONS ARE IN THE SAME API AREA
C                (NDA=1)
C              = 2 MEANS API AREAS VARY WITH DIFFERENT SUBWATERSHEDS
C                (NDA=NSUBW)
C              = 3 MEANS API AREAS VARY WITH DIFFERENT STATIONS
C                (NDA=NSTNS)
C              * NDA = NUMBER OF DIFFERENT API AREAS
C  ITDGR OPTION = HOUR WHEN DAILY STATIONS ARE READ
C
      IF ( NRI .LT. 1 .OR. NRI .GT. 4 ) THEN
         WRITE(6,50) NRI
   50    FORMAT(//1X,I3,' IS INVALID AS NUMBER OF RI''S PER STATION; ',
     1          'MAXIMUM IS 4'//)
         ERROR = .TRUE.
      END IF
      IF ( NSTNS .LT. 1 .OR. NSTNS .GT. 100 ) THEN
         WRITE(6,60) NSTNS
   60    FORMAT(//1X,I3,' IS INVALID AS NUMBER OF STATIONS; ',
     1          'MAXIMUM IS 100'//)
         ERROR = .TRUE.
      END IF
      IF ( NREC .LT. 1 .OR. NREC .GT. 30 ) THEN
         WRITE(6,70) NREC
   70    FORMAT(//1X,I3,' IS INVALID AS NUMBER OF RECORDERS; ',
     1          'MAXIMUM IS 30'//)
         ERROR = .TRUE.
      END IF
      IF ( NSUBW .LT. 1 .OR. NSUBW .GT. 50 ) THEN
         WRITE(6,80) NSUBW
   80    FORMAT(//1X,I3,' IS INVALID AS NUMBER OF SUBWATERSHEDS; ',
     1          'MAXIMUM IS 50'//)
         ERROR = .TRUE.
      END IF
      IF ( NCPTS .GT. NSUBW ) THEN
         WRITE(6,100) NCPTS
  100    FORMAT(//1X,I3,' IS INVALID AS NUMBER VOLUME CHECKS; ',
     1          'MAXIMUM IS NO. OF SUBWATERSHEDS'//)
         ERROR = .TRUE.
      END IF
      IF ( ERROR ) STOP 4
C
C     SEE IF DISK FILE NEEDED FOR OUTPUT OF FLOOD HYDROGRAPHS
C
      IF ( NARFE .EQ. 2 ) THEN
          IF ( NARGS() .GT. 2 ) THEN
             WRITE (*,'('' Hydrograph Output File:  ''\)')
            READ (*,'(A)') HYDFIL
         END IF
         OPEN(UNIT=3,FILE=HYDFIL,STATUS='UNKNOWN')
      END IF
C
C     THIS ORDER MUST AGREE WITH THE ORDER IN WHICH THE HOURLY RAIN
C     IS INPUT.
C
      READ(5,110) (NAMSTA(I),I=1,NREC)
```

```
  110 FORMAT(20A4)
      WRITE(6,120) (NAMSTA(I),I=1,NREC)
  120 FORMAT(1X,20A4)
C
C     BEGDR(I,J)=BEGINNING DATE OF STORM RAINFALL (6 DIGIT NUMBER:
C     MONTH,DAY,YEAR)
C
      READ(5,130) ((BEGDR(I,J),I=1,NRI),J=1,NREC)
  130 FORMAT(10I8)
      WRITE(6,140) ((BEGDR(I,J),I=1,NRI),J=1,NREC)
  140 FORMAT(1X,10I8)
C
C   BEGTR = BEGINNING TIME OF STORM RAIN; THIS IS INPUTED AS A 2-DIGIT
C           NUMBER FROM 1-24 REFLECTING MILITARY TIME
C
      READ(5,130) ((BEGTR(I,J),I=1,NRI),J=1,NREC)
      WRITE(6,140) ((BEGTR(I,J),I=1,NRI),J=1,NREC)
C
C     NHR = NUMBER OF HOURS OF STORM RAINFALL.
C
      READ(5,30) ((NHR(I,J),I=1,NRI),J=1,NREC)
      WRITE(6,40) ((NHR(I,J),I=1,NRI),J=1,NREC)
C
C     SHRAIN = HOURLY RAIN FOR THE STORM PERIOD
C
      DO 180 RECIDX = 1,NREC
        END = 0
        DO 170 RIIDX = 1,NRI
           START = END + 1
           END = END + NHR(RIIDX,RECIDX)
           READ(5,150) (SHRAIN(K,RECIDX),K=START,END)
  150      FORMAT(10F8.0)
           WRITE(6,160) (SHRAIN(K,RECIDX),K=START,END)
  160      FORMAT(1X,10F8.2)
  170   CONTINUE
  180 CONTINUE
C
C     FOR EACH RECORDER ...
C
      DO 220 RECIDX = 1,NREC
C
C        DETERMINE DAILY TOTALS AND NO. OF DAYS OF EACH STORM
C
         DAYIDX = 0
         END = 0
         DO 210 RIIDX = 1,NRI
            DAYIDX = DAYIDX + 1
            START = END + 2
            END = END + NHR(RIIDX,RECIDX)
            NDR(RIIDX,RECIDX) = 1
            TIME = BEGTR(RIIDX,RECIDX)
            DYRAIN(DAYIDX,RECIDX) = SHRAIN(START-1,RECIDX)
            DO 190 HRIDX = START,END
               TIME = MOD(TIME,24) + 1
               IF ( TIME-ITDGR .EQ. 1 .OR. ITDGR-TIME .EQ. 23 ) THEN
                  NDR(RIIDX,RECIDX) = NDR(RIIDX,RECIDX) + 1
                  DAYIDX = DAYIDX + 1
                  DYRAIN(DAYIDX,RECIDX) = SHRAIN(HRIDX,RECIDX)
               ELSE
                  DYRAIN(DAYIDX,RECIDX) = DYRAIN(DAYIDX,RECIDX) +
```

```
     1                                    SHRAIN(HRIDX,RECIDX)
              END IF
  190       CONTINUE
C
C        AND IF MORE THAN ONE STORM...
C
            IF ( RIIDX .LT. NRI ) THEN
C
C           THE NO. OF HOURS BETWEEN STORMS
C
              NDAYS1 = NDAYS(BEGDR(RIIDX,RECIDX),IDUM,IDUM,IDUM)
              NDAYS2 = NDAYS(BEGDR(RIIDX+1,RECIDX),IDUM,IDUM,IDUM)
              NHRBS(RIIDX,RECIDX) = 24 * ( NDAYS2 - NDAYS1 ) +
     1                              BEGTR(RIIDX+1,RECIDX) -
     2                              BEGTR(RIIDX,RECIDX) -
     3                              NHR(RIIDX,RECIDX)
C
C           AND THE NO. OF DAYS BETWEEN STORMS
C
              NDBS(RIIDX,RECIDX) = -1
              DO 200 I = 1,NHRBS(RIIDX,RECIDX)+1
                IF ( TIME .EQ. ITDGR .OR. TIME-ITDGR .EQ. 24 ) THEN
                  NDBS(RIIDX,RECIDX) = NDBS(RIIDX,RECIDX) + 1
                  IF ( NDBS(RIIDX,RECIDX) .GT. 0 ) THEN
                    DAYIDX = DAYIDX + 1
                    DYRAIN(DAYIDX,RECIDX) = 0.0
                  END IF
                END IF
                TIME = MOD(TIME,24) + 1
  200         CONTINUE
            END IF
  210     CONTINUE
C
C        COMPUTE TOTAL LENGTH OF STORM STORM PERIOD
C
         NDRTOT(RECIDX) = DAYIDX
  220 CONTINUE
C
C     INPUT THE NAMES OF ANY NONRECORDERS, THE RECORDERS TO BE
C     USED FOR ESTIMATING HOURLY DISTRIBUTION OF DAILY TOTALS, AND
C     THE DAILY RAINFALL TOTALS FOR EACH NONRECORDER (INCLUDING AMOUNTS
C     BETWEEN STORMS)
C
      IF ( NSTNS .GT. NREC ) THEN
         READ(5,110) (NAMSTA(I),I=NREC+1,NSTNS)
         WRITE(6,120) (NAMSTA(I),I=NREC+1,NSTNS)
         READ(5,110) (NAMREC(I),I=NREC+1,NSTNS)
         WRITE(6,120) (NAMREC(I),I=NREC+1,NSTNS)
         DO 260 STNIDX = NREC+1,NSTNS
            DO 230 RECIDX = 1,NREC
              IF ( NAMREC(STNIDX) .EQ. NAMSTA(RECIDX) ) THEN
                RECSTA(STNIDX) = RECIDX
                GO TO 250
              END IF
  230       CONTINUE
            WRITE(6,240) NAMREC(STNIDX),NAMSTA(STNIDX)
  240       FORMAT(//1X,A4,' IS NOT A VALID RECORDER NAME FOR STATION ',
     1            A4//)
            RECIDX = 1
  250       CONTINUE
```

```
            READ(5,150) (DYRAIN(I,STNIDX),I=1,NDRTOT(RECIDX))
            WRITE(6,160) (DYRAIN(I,STNIDX),I=1,NDRTOT(RECIDX))
  260    CONTINUE
      END IF
      DO 270 RECIDX = 1,NREC
         NAMREC(RECIDX) = NAMSTA(RECIDX)
         RECSTA(RECIDX) = RECIDX
  270 CONTINUE
C
C     INPUT NUMBER OF DAYS OF ANTECEDENT RAINFALL AND STARTING API
C     FOR EACH STATION
C
      READ(5,30) (NDRAPI(I),I=1,NSTNS)
      WRITE(6,40) (NDRAPI(I),I=1,NSTNS)
      READ(5,150) (API(1,I),I=1,NSTNS)
      WRITE(6,160) (API(1,I),I=1,NSTNS)
C
C     READ IN ANY ANTECEDENT RAINFALL
C
      APICNT = 0
      DO 280 STNIDX = 1,NSTNS
         IF ( NDRAPI(STNIDX) .GT. 0 ) THEN
            READ(5,150) (APRAIN(I,STNIDX),I=1,NDRAPI(STNIDX))
            WRITE(6,160) (APRAIN(I,STNIDX),I=1,NDRAPI(STNIDX))
            APICNT = APICNT + 1
         ELSE
            IF ( API(1,STNIDX) .GT. 0.0 ) APICNT = APICNT + 1
         END IF
  280 CONTINUE
      NSWRI = NSTNS - APICNT
C
C     STATIONS WITH RI VALUES INPUT ARE THOSE WITH 0 FOR BOTH
C     NDRAPI() AND API(1,)
C
      IF ( NSWRI .GT. 0 ) THEN
         READ(5,30) ((ORIGRI(I,J),I=1,NRI),J=1,NSWRI)
         WRITE(6,40) ((ORIGRI(I,J),I=1,NRI),J=1,NSWRI)
         IF ( NSWRI .LT. NSTNS ) THEN
            DO 310 SRIIDX = 1,NSWRI
            DO 310 RIIDX = 1,NRI
               IF ( ORIGRI(RIIDX,SRIIDX) .GT. 55 )
     1            WRITE(6,300) ORIGRI(RIIDX,SRIIDX)
  300               FORMAT(//' RI VALUE OF ',I4,' DETECTED; MAX. IS 55'//)
               TEMPRI(RIIDX,SRIIDX) = ORIGRI(RIIDX,SRIIDX)
  310       CONTINUE
            SRIIDX = 1
            DO 330 STNIDX = 1,NSTNS
               IF ( NDRAPI(STNIDX) .LE. 0 .AND. API(1,STNIDX) .LE. 0.0 )
     1         THEN
                  DO 320 RIIDX = 1,NRI
                     ORIGRI(RIIDX,STNIDX) = TEMPRI(RIIDX,SRIIDX)
                     ADJRI(RIIDX,STNIDX) = TEMPRI(RIIDX,SRIIDX)
  320             CONTINUE
                  SRIIDX = SRIIDX + 1
               END IF
  330       CONTINUE
         ELSE
            DO 335 STNIDX = 1,NSTNS
            DO 335 RIIDX = 1,NRI
               ADJRI(RIIDX,STNIDX) = ORIGRI(RIIDX,STNIDX)
```

```
  335       CONTINUE
          END IF
        END IF
C
C       BSNAME = TITLE FOR EACH PRINTOUT. USE ONLY ONE LINE FOR EACH
C       PRINTOUT TITLE.
C
        READ(5,10) (BSNAME(J),J=1,NSUBW)
        WRITE(6,20) (BSNAME(J),J=1,NSUBW)
C
C       BAREA = DRAINAGE AREA OF EACH WATERSHED
C
        READ(5,150) (BAREA(I),I=1,NSUBW)
        WRITE(6,160) (BAREA(I),I=1,NSUBW)
C
C       APITYP = AREA CODES
C
        NDA = NSTNS
        IF ( STAB .EQ. 1 ) NDA = 1
        IF ( STAB .EQ. 2 ) NDA = NSUBW
        READ(5,30) (APITYP(I),I=1,NDA)
        WRITE(6,40) (APITYP(I),I=1,NDA)
C
C       NUMBER OF RAINFALL STATIONS FOR EACH SUBWATERSHED
C
        READ(5,30) (NSPW(I),I=1,NSUBW)
        WRITE(6,40) (NSPW(I),I=1,NSUBW)
C
C       IF ANY WATERSHED HAS MORE THAN 25 STATIONS, INSURE THAT
C       IT IS THE LAST WATERSHED TO PREVENT FORTRAN ARRAY WIPE OUT
C
        DO 350 J = 1,NSUBW
          IF ( NSPW(J) .GT. 25 .AND. ( J .NE. NSUBW .OR. J .EQ. 50 ) )
     1    THEN
            WRITE (6,340)
  340       FORMAT (//' ONLY ONE WATERSHED ALLOWED WITH > 25 STATIONS,',
     1                ' AND THAT WATERSHED MUST BE THE LAST ONE'//)
            STOP 4
          END IF
  350 CONTINUE
C
C       BSNSTA = RAINFALL STATIONS NUMBER PER SUBWATERSHED
C       THIESN = THIESSEN FACTOR FOR EACH STATION
C
        DO 380 J = 1,NSUBW
          READ(5,360) (BSNSTA(I,J),THIESN(I,J),I=1,NSPW(J))
  360     FORMAT(A4,F5.0)
          WRITE(6,370) (BSNSTA(I,J),THIESN(I,J),I=1,NSPW(J))
  370     FORMAT(1X,A4,F5.2)
  380 CONTINUE
C
C       NUMVOL = NUMBER OF SUBWATERSHEDS BEFORE EACH VOLUME CHECK POINT.
C       CHKVOL = CHECK VOLUME (SRO ONLY)
C
        IF ( NCPTS .GT. 0 ) THEN
          READ(5,30) (NUMVOL(I),I=1,NCPTS)
          WRITE(6,40) (NUMVOL(I),I=1,NCPTS)
          READ(5,150) ((CHKVOL(I,J),I=1,NRI),J=1,NCPTS)
          WRITE(6,160) ((CHKVOL(I,J),I=1,NRI),J=1,NCPTS)
        END IF
```

```
C
      IF ( NARFE .GT. 0 ) THEN
C
C     FBSFLW = BEGIN BASE FLOW IN CFS/MI*2
C     EBSFLW = END BASE FLOW IN CFS/MI*2
C     HYDINT = UNIT GRAPH INTERVAL FOR EACH SUBWATERSHEAD
C     UGDUR = UNIT GRAPH DURATION FOR EACH SUBWATERSHED
C     NUGORD = NUMBER OF UNIT GRAPH ORDINATES FOR EACH SUBWATERSHED
C     UGORD = UNIT GRAPH ORDINATES
C
         READ(5,150) ((BBSFLW(I,J),EBSFLW(I,J),I=1,NRI),J=1,NSUBW)
         WRITE(6,160) ((BBSFLW(I,J),EBSFLW(I,J),I=1,NRI),J=1,NSUBW)
         READ(5,30) (HYDINT(K),K=1,NSUBW)
         WRITE(6,40) (HYDINT(K),K=1,NSUBW)
         READ(5,30) (UGDUR(I),I=1,NSUBW)
         WRITE(6,40) (UGDUR(I),I=1,NSUBW)
         READ(5,30) (NUGORD(I),I=1,NSUBW)
         WRITE(6,40) (NUGORD(I),I=1,NSUBW)
         DO 400 J=1,NSUBW
            READ(5,150) (UGORD(I,J),I=1,NUGORD(J))
            WRITE(6,390) (UGORD(I,J),I=1,NUGORD(J))
  390       FORMAT(1X,10F8.0)
  400    CONTINUE
C
         IF ( NARFE .EQ. 2 ) THEN
C
C        BEGD = BEGINNING DATE OF HYDROGRAPHS WHEN SENT TO NARFE.
C        MUST BE SAME AS THE DIRECT INPUT HYDROGRAPHS INTO NARFE
C
C        BEGT = BEGINNING TIME OF HYDROGRAPH WHEN SENT TO NARFE.
C        MUST BE SAME AS THE DIRECT INPUT HYDROGRAPHS INTO NARFE.
C
C        NFHO = THE NUMBER OF HYDROGRAPHS TO BE SENT TO NARFE
C
C        FHORDR = NO. OF EACH HYDROGRAPH IN THE ORDER OF COMPUTATIONAL
C        USE THE NARFE PROGRAM
C
            READ(5,410) BEGD,BEGT
  410       FORMAT(I7,I5)
            WRITE(6,420) BEGD,BEGT
  420       FORMAT(1X,I7,I5)
            BEGT = BEGT / 100
            READ(5,30) NUMHYD
            WRITE(6,40) NUMHYD
            READ(5,30) (FHORDR(I),I=1,NUMHYD)
            WRITE(6,40) (FHORDR(I),I=1,NUMHYD)
         END IF
      END IF
C
C     COMPUTE STORM RAINFALL
C
      DO 450 STNIDX = 1,NSTNS
         START = 1
         END = 0
         RECIDX = RECSTA(STNIDX)
         DO 440 RIIDX = 1,NRI
            END = END + NDR(RIIDX,RECIDX)
            DO 430 DAYIDX = START,END
               TRAIN(RIIDX,STNIDX) = TRAIN(RIIDX,STNIDX) +
     1                               DYRAIN(DAYIDX,STNIDX)
```

```
  430       CONTINUE
            END = END + NDBS(RIIDX,RECIDX)
            START = END + 1
  440    CONTINUE
  450 CONTINUE
C
C     DETERMINE RI AREA FOR EACH STATION
C
      IF ( STAB .EQ. 1 ) THEN
         DO 460 STNIDX = 2,NSTNS
            APITYP(STNIDX) = APITYP(1)
  460    CONTINUE
      ELSE IF ( STAB .EQ. 2 ) THEN
         DO 470 STNIDX = 1,NSUBW
            APITMP(STNIDX) = APITYP(STNIDX)
  470    CONTINUE
         DO 490 STNIDX = 1,NSTNS
         DO 490 BSNIDX = 1,NSUBW
            DO 480 SPWIDX = 1,NSPW(BSNIDX)
               IF ( NAMSTA(STNIDX) .EQ. BSNSTA(SPWIDX,BSNIDX) ) THEN
                  APITYP(STNIDX) = APITMP(BSNIDX)
                  GO TO 490
               END IF
  480       CONTINUE
  490    CONTINUE
      END IF
      DO 500 STNIDX = 1,NSTNS
         RITYP(STNIDX) = 1
         IF ( APITYP(STNIDX) .EQ. 1 ) RITYP(STNIDX) = 2
  500 CONTINUE
C
C     IF SOME STATIONS REQUIRE API COMPUTATIONS
C
      IF ( APICNT .GT. 0 ) THEN
C
C        SUBROUTINE APIWK COMPUTES API VALUES AND WEEK OF THE YEAR
C
         CALL APIWK(WEEK)
C
         DO 530 STNIDX = 1,NSTNS
         DO 530 RIIDX = 1,NRI
            IF ( NDRAPI(STNIDX) .GT. 0 .OR. API(1,STNIDX) .GT. 0.0 )
     1      THEN
               RECIDX = RECSTA(STNIDX)
               RECNO = ( APITYP(STNIDX) - 1 ) * WORKWK(53) +
     1                 WORKWK(WEEK(RIIDX,RECIDX))
               READ(4,REC=RECNO) NUMAPI,STRTRI,(APITBL(I),I=1,NUMAPI)
               DO 510 APIIDX = 1,NUMAPI
                  IF ( API(RIIDX,STNIDX) .LE. APITBL(APIIDX) ) THEN
                     ORIGRI(RIIDX,STNIDX) = STRTRI - APIIDX + 1
                     ADJRI(RIIDX,STNIDX) = ORIGRI(RIIDX,STNIDX)
                     GO TO 520
                  END IF
  510          CONTINUE
  520          CONTINUE
            END IF
  530    CONTINUE
      END IF
C
C     ESTABLISH THE ORDER OF THE RAINFALL STATIONS
```

```
C
      STNCNT = 0
      DO 550 STNIDX = 1,NSTNS
      DO 550 BSNIDX = 1,NSUBW
         DO 540 SPWIDX = 1,NSPW(BSNIDX)
            IF ( NAMSTA(STNIDX) .EQ. BSNSTA(SPWIDX,BSNIDX) ) THEN
               ORDSTA(SPWIDX,BSNIDX) = STNIDX
               STNCNT = STNCNT + 1
               GO TO 550
            END IF
  540    CONTINUE
  550 CONTINUE
C
C          CHECK TO SEE IF NO. OF STATION ORDERS FIXED MATCHES
C          SUM OF NO. OF STATIONS PER SUBWATERSHED (NSTWF).
C
      NSTWF = 0
      DO 560 J = 1,NSUBW
         NSTWF = NSTWF + NSPW(J)
  560 CONTINUE
      IF ( STNCNT .NE. NSTWF ) WRITE(6,570)
  570 FORMAT(/1X,'ERROR...ORDER OF RAIN STATIONS NOT ESTABLISHED',1X,
     1        'PROPERLY.  MAKE SURE'/1X,'THAT FOUR CHARACTER RAIN',1X,
     2        'STATION NAMES IN BSNSTA(I,J) MATCH THOSE IN NAMSTA(I).')
C
C     SUBROUTINE VOLCHK ADJUSTS THE RI'S TO OBTAIN COMPUTED
C     SURFACE VOLUMES THAT ARE NEAREST THE CHECK VOLUMES INPUT
C
      IF ( NCPTS .GT. 0 ) CALL VOLCHK(CHKVOL,NUMVOL)
C
C     COMPUTE AVERAGE RAINFALL/RUNOFF FOR EACH SUBWATERSHED AND IF
C     NARFE > 0, COMPUTE FLOOD HYDROGRAPH
C
      CALL HYDROG
C
      STOP
      END
      SUBROUTINE APIWK(WEEK)
      INTEGER WEEK(4,30)
C
C     COMPUTE API AND WEEK
C
      COMMON /TABLES/ MODAYS(12)
      INTEGER MODAYS
C
      COMMON /PARMS/ NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
      INTEGER NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
C
      COMMON /GAGES/ APITYP(100),RITYP(100),NAMSTA(100),NAMREC(100),
     1               RECSTA(100)
      INTEGER APITYP,RITYP,RECSTA
      CHARACTER NAMSTA*4,NAMREC*4
C
      COMMON /TIMES/ BEGTR(4,30),BEGT,BEGTA,BEGD,BEGDR(4,30)
      INTEGER BEGTR,BEGT,BEGTA,BEGD,BEGDR
C
      COMMON /STATRO/ ORIGRI(4,100),ADJRI(4,100),API(4,100),
     1                NDRAPI(100),APRAIN(30,100),FACTOR(4,100),NSWRI
      REAL API,APRAIN,FACTOR
      INTEGER ORIGRI,ADJRI,NDRAPI,NSWRI
```

```
C
      COMMON /PRECIP/ SHRAIN(240,31),NHR(4,30),NHRBS(3,30),NDBS(3,30),
     1                DYRAIN(20,100),NDR(4,30),NDRTOT(30),TRAIN(4,100)
      REAL SHRAIN,DYRAIN,TRAIN
      INTEGER NHR,NHRBS,NDBS,NDR,NDRTOT
C
      INTEGER DAY,YEAR,MONTH,STNIDX,DAYIDX,RIIDX,MOIDX,RECIDX,START,END
      INTEGER NDAYS,DUMMY
C
      DO 300 STNIDX = 1,NSTNS
         IF ( NDRAPI(STNIDX) .GT. 0 .OR. API(1,STNIDX) .GT. 0.0 ) THEN
            END = 0
            DO 200 RIIDX = 1,NRI
               IF ( RIIDX .EQ. 1 ) THEN
                  IF ( NDRAPI(STNIDX) .GT. 0 ) THEN
                     DO 50 DAYIDX = 1,NDRAPI(STNIDX)
                        API(1,STNIDX) = MIN(5.0,API(1,STNIDX)*.9+
     1                                          APRAIN(DAYIDX,STNIDX))
   50                CONTINUE
                  END IF
               ELSE
                  RECIDX = RECSTA(STNIDX)
                  START = END + 1
                  END = END + NDBS(RIIDX-1,RECIDX) + NDR(RIIDX-1,RECIDX)
                  API(RIIDX,STNIDX) = API(RIIDX-1,STNIDX)
                  DO 100 DAYIDX = START,END
                     API(RIIDX,STNIDX) = MIN(5.0,API(RIIDX,STNIDX)*.9+
     1                                           DYRAIN(DAYIDX,STNIDX))
  100             CONTINUE
               END IF
  200       CONTINUE
         END IF
  300 CONTINUE
      DO 400 RECIDX = 1,NREC
      DO 400 RIIDX = 1,NRI
         DUMMY = NDAYS(BEGDR(RIIDX,RECIDX),YEAR,MONTH,DAY)
         IF ( MONTH .GT. 1 ) THEN
            DO 350 MOIDX = 1,MONTH-1
               WEEK(RIIDX,RECIDX) = MODAYS(MOIDX) + WEEK(RIIDX,RECIDX)
  350       CONTINUE
         END IF
         WEEK(RIIDX,RECIDX) = ( WEEK(RIIDX,RECIDX) + DAY + 6 ) / 7
  400 CONTINUE
      RETURN
      END
      SUBROUTINE VOLCHK(CHKVOL,NUMVOL)
      REAL CHKVOL(4,50)
      INTEGER NUMVOL(50)
C
      COMMON /PARMS/ NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
      INTEGER NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
C
      COMMON /GAGES/ APITYP(100),RITYP(100),NAMSTA(100),NAMREC(100),
     1               RECSTA(100)
      INTEGER APITYP,RITYP,RECSTA
      CHARACTER NAMSTA*4,NAMREC*4
C
      COMMON /STATRO/ ORIGRI(4,100),ADJRI(4,100),API(4,100),
     1                NDRAPI(100),APRAIN(30,100),FACTOR(4,100),NSWRI
      REAL API,APRAIN,FACTOR
```

```
      INTEGER ORIGRI,ADJRI,NDRAPI,NSWRI
C
      COMMON /BASIN/ BAREA(50),BSNAME(51),NSPW(50),BSNSTA(25,50),
     1               THIESN(25,50),ORDSTA(25,50)
      REAL BAREA,THIESN
      INTEGER NSPW,ORDSTA
      CHARACTER BSNAME*80,BSNSTA*4
C
      COMMON /PRECIP/ SHRAIN(240,31),NHR(4,30),NHRBS(3,30),NDBS(3,30),
     1                DYRAIN(20,100),NDR(4,30),NDRTOT(30),TRAIN(4,100)
      REAL SHRAIN,DYRAIN,TRAIN
      INTEGER NHR,NHRBS,NDBS,NDR,NDRTOT
C
      INTEGER COR,START,END,CPTIDX,BSNIDX,RIIDX,STNIDX,SPWIDX,MAXRI
      REAL SWRO(50),VOL(4,50),TBAREA(50),INITDF,NEWDIF,OLDDIF
      REAL TOTRO(4,100)
      LOGICAL DONSTN(100)
C
      DATA INITDF/1.E10/, DONSTN/100*.FALSE./
C
C     COMPUTE SUM OF DRAINAGE AREAS BEFORE EACH VOLUME CHECK POINT
C
      TBAREA(1) = 0.0
      END = 0
      DO 100 CPTIDX = 1,NCPTS
         START = END + 1
         END = NUMVOL(CPTIDX)
         DO 50 BSNIDX = START,END
            TBAREA(CPTIDX) = TBAREA(CPTIDX) + BAREA(BSNIDX)
   50    CONTINUE
         TBAREA(CPTIDX+1) = TBAREA(CPTIDX)
  100 CONTINUE
      END = 0
      FACVOL = CHKVOL(1,1)
C
C     FOR EACH CHECK POINT AND RI VALUE ...
C
      DO 900 CPTIDX = 1,NCPTS
         START = END + 1
         END = NUMVOL(CPTIDX)
         DO 850 RIIDX = 1,NRI
            NEWDIF = INITDF
            OLDDIF = INITDF
            SAVVOL = 0.0
C
C           COMPUTE FACVOL FOR ADJUSTING RUNOFF WHEN RUNOFF GT RAIN
C
            IF ( CPTIDX .EQ. 1 ) THEN
               FACVOL = CHKVOL(RIIDX,CPTIDX)
               INITVL = 0.0
            ELSE
               FACVOL = ( CHKVOL(RIIDX,CPTIDX) * TBAREA(CPTIDX) -
     1                  CHKVOL(RIIDX,CPTIDX-1) * TBAREA(CPTIDX-1) ) /
     2                  ( TBAREA(CPTIDX) - TBAREA(CPTIDX-1) )
               INITVL = CHKVOL(RIIDX,CPTIDX-1) * TBAREA(CPTIDX-1)
            END IF
C
            MAXRI = 16
  200       CONTINUE
C
```

```
C           ADJUST RI'S UNTIL CHECK VOLUME IS REACHED
C
            IF ( NEWDIF*OLDDIF .GT. 1.E-5 .AND. MAXRI .GE. 16 ) THEN
               VOL(RIIDX,CPTIDX) = INITVL
               DO 300 BSNIDX = START,END
                  SWRO(BSNIDX) = 0.0
                  DO 250 SPWIDX = 1,NSPW(BSNIDX)
                     STNIDX = ORDSTA(SPWIDX,BSNIDX)
                     IF ( ADJRI(RIIDX,STNIDX) .LT. 16 )
     1                  FACTOR(RIIDX,STNIDX) = FACVOL /
     2                                         TRAIN(RIIDX,STNIDX)
                     CALL RUNOFF(ADJRI(RIIDX,STNIDX),RITYP(STNIDX),
     1                   TRAIN(RIIDX,STNIDX),TOTRO(RIIDX,STNIDX),
     2                   FACTOR(RIIDX,STNIDX))
                     SWRO(BSNIDX) = SWRO(BSNIDX) + THIESN(SPWIDX,BSNIDX)
     1                                           * TOTRO(RIIDX,STNIDX)
  250                CONTINUE
                     VOL(RIIDX,CPTIDX) = VOL(RIIDX,CPTIDX) +
     1                                   SWRO(BSNIDX) * BAREA(BSNIDX)
  300          CONTINUE
C
               VOL(RIIDX,CPTIDX) = VOL(RIIDX,CPTIDX) / TBAREA(CPTIDX)
C
               NEWDIF = VOL(RIIDX,CPTIDX) - CHKVOL(RIIDX,CPTIDX)
               IF ( OLDDIF .EQ. INITDF ) THEN
                  OLDDIF = NEWDIF
                  COR = INT(SIGN(1.,NEWDIF))
               END IF
               IF ( NEWDIF*OLDDIF .GT. 1.E-5 ) THEN
                  OLDDIF = NEWDIF
                  SAVVOL = VOL(RIIDX,CPTIDX)
                  MAXRI = 0
                  DO 500 BSNIDX = START,END
                  DO 500 SPWIDX = 1,NSPW(BSNIDX)
                     STNIDX = ORDSTA(SPWIDX,BSNIDX)
                     IF ( ORIGRI(RIIDX,STNIDX) .NE. 0 .AND.
     1                    .NOT. DONSTN(STNIDX) ) ADJRI(RIIDX,STNIDX) =
     2                                           ADJRI(RIIDX,STNIDX) + COR
                     MAXRI = MAX(MAXRI,ADJRI(RIIDX,STNIDX))
  500                CONTINUE
               END IF
            GO TO 200
            END IF
C
            IF ( ABS(NEWDIF) .GT. ABS(OLDDIF) ) THEN
               DO 800 BSNIDX = START,END
               DO 800 SPWIDX = 1,NSPW(BSNIDX)
                  STNIDX = ORDSTA(SPWIDX,BSNIDX)
                  IF ( ORIGRI(RIIDX,STNIDX) .NE. 0 .AND.
     1                 .NOT. DONSTN(STNIDX) ) ADJRI(RIIDX,STNIDX) =
     2                                        ADJRI(RIIDX,STNIDX) - COR
  800          CONTINUE
            END IF
  850    CONTINUE
         DO 880 BSNIDX = START,END
         DO 880 SPWIDX = 1,NSPW(BSNIDX)
            STNIDX = ORDSTA(SPWIDX,BSNIDX)
            DONSTN(STNIDX) = .TRUE.
  880    CONTINUE
  900 CONTINUE
```

```
      RETURN
      END
      SUBROUTINE HYDROG
      COMMON /TABLES/ MODAYS(12)
      INTEGER MODAYS
C
      COMMON /PARMS/ NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
      INTEGER NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
C
      COMMON /GAGES/ APITYP(100),RITYP(100),NAMSTA(100),NAMREC(100),
     1               RECSTA(100)
      INTEGER APITYP,RITYP,RECSTA
      CHARACTER NAMSTA*4,NAMREC*4
C
      COMMON /TIMES/ BEGTR(4,30),BEGT,BEGTA,BEGD,BEGDR(4,30)
      INTEGER BEGTR,BEGT,BEGTA,BEGD,BEGDR
C
      COMMON /UNTGPH/ UGDUR(50),HYDINT(50),NUGORD(50),UGORD(200,50)
      INTEGER UGDUR,HYDINT,NUGORD
      REAL UGORD
C
      COMMON /STATRO/ ORIGRI(4,100),ADJRI(4,100),API(4,100),
     1                NDRAPI(100),APRAIN(30,100),FACTOR(4,100),NSWRI
      REAL API,APRAIN,FACTOR
      INTEGER ORIGRI,ADJRI,NDRAPI,NSWRI
C
      COMMON /BASIN/ BAREA(50),BSNAME(51),NSPW(50),BSNSTA(25,50),
     1               THIESN(25,50),ORDSTA(25,50)
      REAL BAREA,THIESN
      INTEGER NSPW,ORDSTA
      CHARACTER BSNAME*80,BSNSTA*4
C
      COMMON /PRECIP/ SHRAIN(240,31),NHR(4,30),NHRBS(3,30),NDBS(3,30),
     1                DYRAIN(20,100),NDR(4,30),NDRTOT(30),TRAIN(4,100)
      REAL SHRAIN,DYRAIN,TRAIN
      INTEGER NHR,NHRBS,NDBS,NDR,NDRTOT
C
      INTEGER EMONTH(4),EDAY(4),EYEAR(4),ETIME(4),ENDAYS(4)
      INTEGER CMONTH(4),CDAY(4),CYEAR(4),CTIME(4),CNDAYS(4)
      INTEGER MORO,DAYRO,YEARRO
      INTEGER DURUG,NOFLOW,NFLOWS(4),NBLKS,IBLKS(4),FHCNT
      INTEGER ID(4)
      INTEGER BSNIDX,SPWIDX,RECIDX,STNIDX,BLKIDX,RIIDX,DAYIDX,HRIDX
      INTEGER HRIDX2,STRTDY,LASTDY,DAYDIF,STRTHR,ENDHR,HRSHFT
      INTEGER TIMERO,APINUM,OETIME,START,END
      REAL BHRAIN(480,4),STNHRO(720),BSNHRO(720),SFRAIN(4)
      REAL SFRO(4),BLCKRO(720),TBRAIN,TBRO,TBAREA
      CHARACTER*2 CODE(2),KODE
      CHARACTER*24 APILST,BLANK
      LOGICAL DRY
      INTEGER NDAYS
      DATA CODE /'SE','TV'/, BLANK /' '/
C
C     INITIALIZE EARLIEST RAIN AND RUNOFF,ETC PREPARE TO COMPUTE
C     HYDROGRAPH FOR EACH SUBWATERSHED
C
C     TBRAIN = TOTAL BASIN (SUBWATERSHED) RAIN
C     TBRO = TOTAL BASIN (SUBWATERSHED) RUNOFF
C     TBAREA = TOTAL BASIN (SUBWATERSHED) AREA
C
```

```
      TBRAIN = 0.0
      TBRO = 0.0
      TBAREA = 0.0
      FHCNT = 1
C
C     FOR EACH SUBWATERSHED...
C
      DO 900 BSNIDX = 1,NSUBW
         TBAREA = TBAREA + BAREA(BSNIDX)
         DO 60 RIIDX = 1,NRI
            DO 50 I = 1,480
               BHRAIN(I,RIIDX) = 0.0
   50       CONTINUE
            SFRAIN(RIIDX) = 0.0
            SFRO(RIIDX) = 0.0
   60    CONTINUE
         DO 70 I = 1,720
            BSNHRO(I) = 0.0
   70    CONTINUE
         WRITE(6,80) BSNAME(51)
   80    FORMAT(1H1,A80)
         WRITE(6,90) BSNAME(BSNIDX),BAREA(BSNIDX)
   90    FORMAT(/1X,A80,/,' DRAINAGE AREA = ',F7.2,' SQUARE MILES',/,
     1           95X,'RI',/,'  RAIN STATION',4X,'THIESSEN FACTOR',4X,
     2           'RECORDER',14X,'API',14X,'INITIAL USED  INITIAL USED',
     3           '  INITIAL USED  INITIAL USED')
C
C        FOR EACH STATION WITHIN THE CURRENT SUBWATERSHED...
C
         DO 400 SPWIDX = 1,NSPW(BSNIDX)
C
            STNIDX = ORDSTA(SPWIDX,BSNIDX)
            APILST = BLANK
            IF ( API(1,STNIDX) .NE. 0.0 )
     1         WRITE(APILST,100) (API(K,STNIDX),K=1,NRI)
  100          FORMAT (4(F4.2,2X))
C
            APINUM = STNIDX
            IF ( STAB .EQ. 1 ) APINUM = 1
            IF ( STAB .EQ. 2 ) APINUM = BSNIDX
            KODE = CODE(1)
            IF ( APITYP(APINUM) .NE. 1 ) KODE = CODE(2)
            WRITE(6,110) BSNSTA(SPWIDX,BSNIDX),THIESN(SPWIDX,BSNIDX),
     1                   NAMREC(STNIDX),APILST,(ORIGRI(L,STNIDX),
     2                   KODE,ADJRI(L,STNIDX),KODE,L=1,NRI)
  110       FORMAT (4X,A4,14X,F4.2,12X,A4,10X,A,8(I2,A2,3X))
C
            THSFCT = THIESN(SPWIDX,BSNIDX)
            RECIDX = RECSTA(STNIDX)
            DO 120 RIIDX = 1,NRI
               CNDAYS(RIIDX) = NDAYS(BEGDR(RIIDX,RECIDX),CYEAR(RIIDX),
     1                               CMONTH(RIIDX),CDAY(RIIDX))
               CTIME(RIIDX) = BEGTR(RIIDX,RECIDX)
  120       CONTINUE
C
            IF ( STNIDX .NE. RECIDX ) THEN
C
C           COMPUTE HOURLY RAIN FOR NONRECORDER
C
               STRTDY = 1
```

```
                LASTDY = 0
                LASTHR = 0
                STRTHR = 1
                ENDHR = 0
                DO 160 RIIDX = 1,NRI
                   LASTHR = LASTHR + NHR(RIIDX,RECIDX)
                   LASTDY = LASTDY + NDR(RIIDX,RECIDX)
                   ENDHR = ENDHR + ITDGR - BEGTR(RIIDX,RECIDX) + 1
                   IF ( BEGTR(RIIDX,RECIDX) .GT. ITDGR ) ENDHR =
     1                                                  ENDHR + 24
                   DO 150 DAYIDX = STRTDY,LASTDY
                      IF ( DYRAIN(DAYIDX,RECIDX) .EQ. 0.0 ) THEN
                         ADJ = 1.E10
                         WRITE (6,125) NAMREC(STNIDX),
     1                                 BSNSTA(SPWIDX,BSNIDX)
  125                    FORMAT(/' *** ERROR -- A DAILY RAIN OF ZERO',
     1                        ' FOR RECORDER ',A4/14X,'WILL PRODUCE ',
     2                        ' A DAILY RAIN OF ZERO FOR GAGE ',A4,'.'/
     3                        14X,'INVALID COMPUTATIONS WILL RESULT.'/)
                      ELSE
                         ADJ = DYRAIN(DAYIDX,STNIDX) /
     1                        DYRAIN(DAYIDX,RECIDX)
                      END IF
C
C               CHECK FOR UNREASONABLE ADJ AND FLAG WARNING TO USER.
C
                      IF ( ( ADJ .GT. 1.5 .OR. ADJ .LT. 0.5 ) .AND.
     1                   DYRAIN(DAYIDX,STNIDX) .GT. 1.0 )
     2                   WRITE(6,130) DYRAIN(DAYIDX,STNIDX),
     3                      BSNSTA(SPWIDX,BSNIDX),DYRAIN(DAYIDX,RECIDX),
     4                      NAMREC(STNIDX),ADJ
  130                    FORMAT(/' WARNING...A DAILY RAIN OF ',F5.2,
     1                        ' FOR GAGE ',A4,' IS WEIGHTED AGAINST'/
     2                        ' A DAILY RAIN OF ',F5.2,' FOR RECORDER ',
     3                        A4,'.  THIS IS A WEIGHT RATIO OF ',F5.1,
     4                        ' WHICH'/' MAY SIGNIFICANTLY AFFECT ',
     5                        'RESULTS.')
C
                      ENDHR = MIN0(ENDHR,LASTHR)
                      DO 140 HRIDX = STRTHR,ENDHR
                        SHRAIN(HRIDX,NREC+1) = ADJ * SHRAIN(HRIDX,RECIDX)
  140                 CONTINUE
                      STRTHR = ENDHR + 1
                      ENDHR = ENDHR + 24
  150              CONTINUE
                   ENDHR = ENDHR - 24
                   STRTDY = LASTDY + NDBS(RIIDX,RECIDX) + 1
                   LASTDY = LASTDY + NDBS(RIIDX,RECIDX)
  160           CONTINUE
             END IF
C
             OETIME = 0
             ENDHR = 0
C
C            FOR EACH STORM...
C
             DO 220 RIIDX = 1,NRI
C
C               COMPUTE ACCUMULATED RAINFALL AND RUNOFF (SHRAIN & STNHRO)
C
```

```
                STRTHR = ENDHR + 1
                IF ( STNIDX .EQ. RECIDX ) SHRAIN(STRTHR,NREC+1) =
     1                                    SHRAIN(STRTHR,RECIDX)
                CALL RUNOFF(ADJRI(RIIDX,STNIDX),RITYP(STNIDX),
     1                    SHRAIN(STRTHR,NREC+1),STNHRO(STRTHR),
     2                    FACTOR(RIIDX,STNIDX))
                ENDHR = ENDHR + NHR(RIIDX,RECIDX)
C
                DO 170 HRIDX = STRTHR+1,ENDHR
                   IF ( STNIDX .EQ. RECIDX ) SHRAIN(HRIDX,NREC+1) =
     1                                       SHRAIN(HRIDX,RECIDX)
                   SHRAIN(HRIDX,NREC+1) = SHRAIN(HRIDX,NREC+1) +
     1                                  SHRAIN(HRIDX-1,NREC+1)
                   CALL RUNOFF(ADJRI(RIIDX,STNIDX),RITYP(STNIDX),
     1                        SHRAIN(HRIDX,NREC+1),STNHRO(HRIDX),
     2                        FACTOR(RIIDX,STNIDX))
  170           CONTINUE
C
C               STORE TOTALS
C
                SFRAIN(RIIDX) = SFRAIN(RIIDX) + SHRAIN(ENDHR,NREC+1) *
     1                         THSFCT
                SFRO(RIIDX) = SFRO(RIIDX) + STNHRO(ENDHR) * THSFCT
                TBRAIN = TBRAIN + SHRAIN(ENDHR,NREC+1) * THSFCT *
     1                  BAREA(BSNIDX)
                TBRO = TBRO + STNHRO(ENDHR) * THSFCT * BAREA(BSNIDX)
C
                IF ( SPWIDX .EQ. 1 ) THEN
C
C                  INITIALIZE EARLIEST STORM TO THAT OF 1ST STATION
C
                   EDAY(RIIDX) = CDAY(RIIDX)
                   EMONTH(RIIDX) = CMONTH(RIIDX)
                   EYEAR(RIIDX) = CYEAR(RIIDX)
                   ETIME(RIIDX) = CTIME(RIIDX)
                   ENDAYS(RIIDX) = CNDAYS(RIIDX)
                END IF
                DAYDIF = CNDAYS(RIIDX) - ENDAYS(RIIDX)
C
                IF ( DAYDIF .GT. 0 ) THEN
C
C                  THIS STATION'S STORM BEGINS AT A LATER DATE;
C                  ADD 24 HOURS TIMES NO. OF DAYS TO THE TIME
C                  OF THIS STATION
C
                   CTIME(RIIDX) = CTIME(RIIDX) + 24 * DAYDIF
C
                ELSE IF ( DAYDIF .LT. 0 ) THEN
C
C                  THIS STATION'S STORM BEGINS AT AN EARLIER DATE;
C                  UPDATE THE EARLIEST STORM DATE FOR SUBWATERSHED
C
                   EYEAR(RIIDX) = CYEAR(RIIDX)
                   EMONTH(RIIDX) = CMONTH(RIIDX)
                   EDAY(RIIDX) = CDAY(RIIDX)
                   OETIME = ETIME(RIIDX)
                   ETIME(RIIDX) = CTIME(RIIDX)
C
C                  ADJUST THE HOURLY RAIN AND SURFACE RUNOFF MATRICES
C                  TO TAKE INTO ACCOUNT THE NEWER DATE
```

```
C
                  HRSHFT = -DAYDIF * 24
                  OETIME = OETIME + HRSHFT
                  DO 180 HRIDX = 480,OETIME,-1
                     BHRAIN(HRIDX,RIIDX) = BHRAIN(HRIDX-HRSHFT,RIIDX)
  180             CONTINUE
                  IF ( RIIDX .EQ. 1 ) THEN
                     DO 185 HRIDX = 720,OETIME,-1
                        BSNHRO(HRIDX) = BSNHRO(HRIDX-HRSHFT)
  185                CONTINUE
                  END IF
                  DO 190 HRIDX = 1,OETIME-1
                     BHRAIN(HRIDX,RIIDX) = 0.0
  190             CONTINUE
                  IF ( RIIDX .EQ. 1 ) THEN
                     DO 191 HRIDX = 1,OETIME-1
                        BSNHRO(HRIDX) = 0.0
  191                CONTINUE
                  END IF
                  ENDAYS(RIIDX) = CNDAYS(RIIDX)
C
               ELSE
C
C                 THIS STATION'S STORM BEGINS AT EARLIEST DATE SO FAR
C                 CHECK FOR A DIFFERENT TIME
C
                  IF ( CTIME(RIIDX) .LT. ETIME(RIIDX) ) THEN
                     OETIME = ETIME(RIIDX)
                     ETIME(RIIDX) = CTIME(RIIDX)
                  END IF
               END IF
C
C              EXPAND SUBWATERSHED PRECIPITATION ARRAY BHRAIN
C
               START = CTIME(RIIDX)
               END = CTIME(RIIDX) + ENDHR - STRTHR
               HRIDX2 = STRTHR
               IF ( OETIME .LT. START .AND. OETIME .NE. 0 ) THEN
  193             CONTINUE
                  IF ( BHRAIN(START,RIIDX) .EQ. 0.0 ) THEN
                     START = START - 1
                  GO TO 193
                  END IF
               END IF
C
               DO 196 HRIDX = START,END
                  IF ( BHRAIN(HRIDX,RIIDX) .EQ. 0.0 .AND. HRIDX .NE. 1 )
     1               BHRAIN(HRIDX,RIIDX) = BHRAIN(HRIDX-1,RIIDX)
  196          CONTINUE
C
C              COMBINE HOURLY RAIN FOR ENTIRE SUBWATERSHED
C
               DO 200 HRIDX = CTIME(RIIDX),END
                  BHRAIN(HRIDX,RIIDX) = SHRAIN(HRIDX2,NREC+1) * THSFCT +
     1                                  BHRAIN(HRIDX,RIIDX)
                  HRIDX2 = HRIDX2 + 1
  200          CONTINUE
C
               HRIDX = END + 1
  210          CONTINUE
```

```
                IF ( BHRAIN(HRIDX,RIIDX) .GT. 0. .OR. HRIDX .LE. OETIME )
     1             THEN
                   BHRAIN(HRIDX,RIIDX) = SHRAIN(HRIDX2-1,NREC+1) * THSFCT
     1                                 + BHRAIN(HRIDX,RIIDX)
                   HRIDX = HRIDX + 1
                GO TO 210
                END IF
C
  220        CONTINUE
C
C            CONVERT FROM CUMULATIVE TO INCREMENTAL RUNOFF;
C            THEN MULTIPLY BY THIESSEN FACTOR
C
             DO 240 RIIDX = NRI,1,-1
                STRTHR = ENDHR - NHR(RIIDX,RECIDX) + 2
                DO 230 HRIDX = ENDHR,STRTHR,-1
                   STNHRO(HRIDX) = ( STNHRO(HRIDX) - STNHRO(HRIDX-1) ) *
     1                             THSFCT
                   IF ( STNHRO(HRIDX) .EQ. 0.0 ) STNHRO(HRIDX) = 1.E-6
  230           CONTINUE
                STRTHR = STRTHR - 1
                STNHRO(STRTHR) = STNHRO(STRTHR) * THSFCT
                IF ( STNHRO(STRTHR) .EQ. 0.0 ) STNHRO(STRTHR) = 1.E-6
                ENDHR = ENDHR - NHR(RIIDX,RECIDX)
  240        CONTINUE
             ENDHR = 0
             DO 245 RIIDX = 1,NRI
                ENDHR = ENDHR + NHR(RIIDX,RECIDX)
  245        CONTINUE
C
             IF ( NRI .GT. 1 ) THEN
C
C               FILL IN ZERO HOURLY RUNOFF ORDINATES
C
                STRTHR = NHR(1,RECIDX) + 1
                DO 270 RIIDX = 2,NRI
                   NHBS = NHRBS(RIIDX-1,RECIDX)
                   DO 250 HRIDX = ENDHR,STRTHR,-1
                      STNHRO(HRIDX+NHBS) = STNHRO(HRIDX)
  250              CONTINUE
                   DO 260 HRIDX = STRTHR,STRTHR+NHBS-1
                      STNHRO(HRIDX) = 0.0
  260              CONTINUE
                   STRTHR = STRTHR + NHBS + NHR(RIIDX,RECIDX)
                   ENDHR = ENDHR + NHBS
  270           CONTINUE
             END IF
C
C            FIND START OF RUNOFF FOR THIS STATION
C
             DO 280 HRIDX = 1,ENDHR
                IF ( STNHRO(HRIDX) .GT. 1.E-6 ) GO TO 290
  280        CONTINUE
  290        CONTINUE
C
C            ADD STATION'S COMPUTED RUNOFF TO CURRENT SUBWATERSHED
C
             DO 300 HRIDX2 = CTIME(1)+HRIDX-1,CTIME(1)+ENDHR-1
                BSNHRO(HRIDX2) = STNHRO(HRIDX) + BSNHRO(HRIDX2)
                HRIDX = HRIDX + 1
```

```
  300       CONTINUE
C
  400    CONTINUE
C
C        WATERSHED RUNOFF COMPUTATIONS COMPLETED; DETERMINE FIRST
C        HOUR OF RUNOFF FOR SUBWATERSHED
C
         DO 410 TIMERO = 1,720
            IF ( BSNHRO(TIMERO) .GT. 1.E-6 ) GO TO 420
  410    CONTINUE
         TIMERO = 1
  420    CONTINUE
C
C        START HYDROGRAPH AT HOUR BEFORE FIRST RUNOFF
C
         BEGTA = TIMERO - 1
C
C        SAVE RUNOFF FOR BLOCKING BY UNIT GRAPH DURATION;
C        SAVE LENGTH OF EACH STORM'S RUNOFF IN IBLKS( )
C
         DO 430 RIIDX = 1,NRI
            IBLKS(RIIDX) = 0
  430    CONTINUE
         RIIDX = 1
         DRY = .FALSE.
         DO 440 HRIDX = TIMERO,720
            IF ( BSNHRO(HRIDX) .EQ. 0.0 ) THEN
               IF ( RIIDX .EQ. NRI ) GO TO 445
               DRY = .TRUE.
            ELSE
               IF ( DRY ) THEN
                  DRY = .FALSE.
                  RIIDX = RIIDX + 1
               END IF
               IBLKS(RIIDX) = IBLKS(RIIDX) + 1
            END IF
            BLCKRO(HRIDX-TIMERO+1) = BSNHRO(HRIDX)
  440    CONTINUE
  445    CONTINUE
         NHRO = HRIDX - TIMERO
C
C        OBTAIN CUMULATIVE RUNOFF FOR EACH STORM PERIOD
C
         DO 450 HRIDX = TIMERO,TIMERO+NHRO-1
            IF (BSNHRO(HRIDX+1) .GT. 0.0 ) BSNHRO(HRIDX+1) =
     1                                     BSNHRO(HRIDX) + BSNHRO(HRIDX+1)
  450    CONTINUE
C
C        COMPUTE STARTING DATE OF FIRST HYDROGRAPH ORDINATE
C
         DAYRO = EDAY(1)
         MORO = EMONTH(1)
         YEARRO = EYEAR(1)
  460    CONTINUE
         IF ( BEGTA .GT. 24 ) THEN
            MODAY = MODAYS(MORO)
            IF ( MORO .EQ. 2 .AND. MOD(YEARRO,4) .EQ. 0 ) MODAY =
     1                                                    MODAY + 1
            BEGTA = BEGTA - 24
            DAYRO = DAYRO + 1
```

```
            IF ( DAYRO .GT. MODAY ) THEN
               DAYRO = 1
               MORO = MORO + 1
               IF ( MORO .GT. 12 ) THEN
                  MORO = 1
                  YEARRO = YEARRO + 1
               END IF
            END IF
         GO TO 460
         END IF
C
         IF ( NARFE .GT. 0 ) THEN
C
C           BLOCK RUNOFF ACCORDING TO UNIT GRAPH DURATION
C
            DURUG = UGDUR(BSNIDX)
            DO 470 RIIDX = 1,NRI
               NUMBLK = IBLKS(RIIDX)
               IBLKS(RIIDX) = NUMBLK / DURUG
               IF ( IBLKS(RIIDX)*DURUG .NE. NUMBLK ) IBLKS(RIIDX) =
     1                                                IBLKS(RIIDX) + 1
  470       CONTINUE
            NBLKS = NHRO / DURUG
            IF ( DURUG .NE. 1 ) THEN
               IF ( NBLKS*DURUG .NE. NHRO ) NBLKS = NBLKS + 1
               START = 1
               END = DURUG
               DO 490 BLKIDX = 1,NBLKS
                  BLCKRO(BLKIDX) = BLCKRO(START)
                  IF ( START .LT. NHRO ) THEN
                     START = START + 1
                     DO 480 HRIDX = START,END
                        BLCKRO(BLKIDX) = BLCKRO(BLKIDX) + BLCKRO(HRIDX)
  480                CONTINUE
                     START = END + 1
                     END = MIN0(END+DURUG,NHRO)
                  END IF
  490          CONTINUE
            END IF
C
C           OUTPUT HEADINGS
C
            WRITE(6,500) (K,SFRAIN(K),SFRO(K),K=1,NRI)
  500       FORMAT(/' AVERAGE SUBWATERSHED RAINFALL',4X,'SUBWATERSHED',
     1              ' RUNOFF',/,(1H ,2X,'FLOOD',I2,3X,F6.2,22X,F6.2))
            WRITE(6,510) UGDUR(BSNIDX),HYDINT(BSNIDX)
  510       FORMAT(/' UNIT GRAPH ORDINATES',19X,
     1             'SUMMATION',3X,'SUMMATION',/,1H ,
     2             2X,'DURATION - ',I2,' HRS.',21X,
     3             'HOURLY',6X,'HOURLY',4X,'RUNOFF',
     4             22X, 'SRO',20X,'FLOOD',/,1H ,
     5             1X,'TIME INCR - ',I2,' HRS.',3X,
     6             'DATE',4X,'TIME',7X,'RAIN',7X,'RUNOFF',
     7             4X,'BLOCKED',4X,'DATE',3X,'TIME',3X,
     8             'HYDROGRAPH',3X,'BASEFLOW',3X,'HYDROGRAPH'/)
C
C           GET PARAMETERS FOR FLOOD HYDROGRAPH COMPUTATIONS
C
            NOFLOW = ( ( NUGORD(BSNIDX) - 1 ) * HYDINT(BSNIDX) +
     1              ( NBLKS - 1 ) * UGDUR(BSNIDX) ) / HYDINT(BSNIDX) + 1
```

```
            IF ( NBLKS .EQ. 0 ) NOFLOW = 1
C
            DO 520 RIIDX = 1,NRI
               NFLOWS(RIIDX) = ( ( NUGORD(BSNIDX) - 1 ) * HYDINT(BSNIDX)
     1         + ( IBLKS(RIIDX) - 1 ) * UGDUR(BSNIDX) ) / HYDINT(BSNIDX)
     2         + 1
               IF ( IBLKS(RIIDX) .EQ. 0 ) NFLOWS(RIIDX) = 1
  520       CONTINUE
C
C           COMPUTE AND OUTPUT FLOOD HYDROGRAPHS
C
            CALL HYDRO(BSNIDX,EYEAR,EDAY,EMONTH,ETIME,YEARRO,DAYRO,MORO,
     *                 BHRAIN,NBLKS,NOFLOW,NFLOWS,BSNHRO,BLCKRO,FHCNT)
         ELSE
C
C           NARFE = 0, PRINT OUT ONLY HOURLY RAIN AND RUNOFF
C
            WRITE(6,530)
  530       FORMAT(/45X,'SUMMATION',3X,'SUMMATION',/,1H ,
     1             45X,'HOURLY',6X,'HOURLY'/1H ,24X,
     2             'DATE',7X,'TIME',7X,'RAIN',7X,'RUNOFF',/)
            ID(1) = EMONTH(1)
            ID(2) = EDAY(1)
            ID(3) = ETIME(1) * 100
            ID(4) = EYEAR(1)
C
            HRIDX = ETIME(1)
            DO 560 RIIDX = 1,NRI
               DO 550 HRIDX2 = ETIME(RIIDX),720
                  WRITE(6,540) ID(1),ID(2),ID(4),ID(3),
     1                         BHRAIN(HRIDX2,RIIDX),BSNHRO(HRIDX)
  540             FORMAT(23X,I2,'-',I2,'-',I2,5X,I4,6X,F6.2,6X,F6.2)
                  CALL CLOCK(ID,1,MODAYS)
                  HRIDX = HRIDX + 1
                  IF ( RIIDX .EQ. NRI ) THEN
                     IF ( BHRAIN(HRIDX2+1,RIIDX) .LT.
     1                    BHRAIN(HRIDX2,RIIDX) ) GO TO 570
                  ELSE
                     IF ( ETIME(RIIDX+1)*100 .EQ. ID(3) .AND.
     1                    ID(2) .EQ. EDAY(RIIDX+1) .AND.
     2                    ID(1) .EQ. EMONTH(RIIDX+1) .AND.
     3                    ID(4) .EQ. EYEAR(RIIDX+1) ) GO TO 560
                  END IF
  550          CONTINUE
  560       CONTINUE
  570       CONTINUE
         END IF
  900 CONTINUE
C
      TBRO = TBRO / TBAREA
      TBRAIN = TBRAIN / TBAREA
      WRITE(6,950) TBRAIN,TBRO
  950 FORMAT(/'   BASIN AVERAGE'/' RAINFALL RUNOFF'//1X,2F7.2)
      RETURN
      END
      SUBROUTINE HYDRO(BSNIDX,YEAR,DAY,MONTH,TIME,YEARRO,DAYRO,MORO,     IN,
     1                 BHRAIN,NBLKS,NOFLOW,NFLOWS,BSNHRO,BLCKRO,FHCNT)
      INTEGER YEAR(4),DAY(4),MONTH(4),YEARRO,DAYRO,MORO,NBLKS
      INTEGER NOFLOW,NFLOWS(4),TIME(4),FHCNT,BSNIDX
      REAL BHRAIN(480,4),BSNHRO(720),BLCKRO(720)
```

```
C
      COMMON /TABLES/ MODAYS(12)
      INTEGER MODAYS
C
      COMMON /PARMS/ NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
      INTEGER NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
C
      COMMON /TIMES/ BEGTR(4,30),BEGT,BEGTA,BEGD,BEGDR(4,30)
      INTEGER BEGTR,BEGT,BEGTA,BEGD,BEGDR
C
      COMMON /UNTGPH/ UGDUR(50),HYDINT(50),NUGORD(50),UGORD(200,50)
      INTEGER UGDUR,HYDINT,NUGORD
      REAL UGORD
C
      COMMON /HYDGPH/ NUMHYD,FHORDR(50),BBSFLW(4,50),EBSFLW(4,50)
      INTEGER NUMHYD,FHORDR
      REAL BBSFLW,EBSFLW
C
      COMMON /BASIN/ BAREA(50),BSNAME(51),NSPW(50),BSNSTA(25,50),
     1               THIESN(25,50),ORDSTA(25,50)
      REAL BAREA,THIESN
      INTEGER NSPW,ORDSTA
      CHARACTER BSNAME*80,BSNSTA*4
C
      REAL TOTFLW(400),FLOW(8),BASFLW(400,4),BASFIL,HYDORD
      INTEGER DUG,INCRMT,JDUR,ORDCNT,BLKCNT,HROFST,START,END,REM
      INTEGER PDATE(4),PHOUR(4),RDATE(4),RHOUR(4),CPDATE(4),CRDATE(4)
      INTEGER BFIDX,RIIDX,HYDIDX,PRIIDX,RRIIDX,HRIDX,UGIDX,ROIDX
      INTEGER ROHR,NARFHR
      INTEGER NDAYS
C
C     COMPUTE BASEFLOWS:
C     FLOW(1),FLOW(2) - BEG & END BASEFLOW FOR FLOOD 1
C     FLOW(3),FLOW(4) - BEG & END BASEFLOW FOR FLOOD 2
C     FLOW(5),FLOW(6) - BEG & END BASEFLOW FOR FLOOD 3
C     FLOW(7),FLOW(8) - BEG & END BASEFLOW FOR FLOOD 4
C
      BFIDX = 1
      DO 10 RIIDX = 1,NRI
         FLOW(BFIDX) = BBSFLW(RIIDX,BSNIDX) * BAREA(BSNIDX)
         FLOW(BFIDX+1) = EBSFLW(RIIDX,BSNIDX) * BAREA(BSNIDX)
         BFIDX = BFIDX + 2
   10 CONTINUE
C
      BFIDX = 1
      DO 40 RIIDX = 1,NRI
         BASFLW(1,RIIDX) = FLOW(BFIDX)
         DO 20 HYDIDX = 2,NFLOWS(RIIDX)
         BASFLW(HYDIDX,RIIDX) = BASFLW(HYDIDX-1,RIIDX) + ( FLOW(BFIDX+1)
     1                        - FLOW(BFIDX) ) / FLOAT(NFLOWS(RIIDX)-1)
   20    CONTINUE
         DO 30 HYDIDX = NFLOWS(RIIDX)+1,400
            BASFLW(HYDIDX,RIIDX) = FLOW(BFIDX+1)
   30    CONTINUE
         BFIDX = BFIDX + 2
   40 CONTINUE
C
C     INITIALIZE CURRENT PRECIP. AND RUNOFF DATES FOR OUTPUT
C
      CPDATE(1) = MONTH(1)
```

```
      CPDATE(2) = DAY(1)
      CPDATE(3) = TIME(1) * 100
      CPDATE(4) = YEAR(1)
      CRDATE(1) = MORO
      CRDATE(2) = DAYRO
      CRDATE(3) = BEGTA * 100
      CRDATE(4) = YEARRO
C
C     SETUP STARTING DATE & HOUR OF EACH STORM
C
      IF ( NRI .GT. 1 ) THEN
         DO 50 RIIDX = 1,NRI
            PDATE(RIIDX) = ( MONTH(RIIDX) * 100 + DAY(RIIDX) ) * 100 +
     1                     YEAR(RIIDX)
            RDATE(RIIDX) = PDATE(RIIDX)
            PHOUR(RIIDX) = NDAYS(PDATE(RIIDX),IDUMMY,IDUMMY,IDUMMY) *
     1                     24 + TIME(RIIDX)
            RHOUR(RIIDX) = PHOUR(RIIDX)
   50    CONTINUE
      END IF
      RDATE(1) = ( MORO * 100 + DAYRO ) * 100 + YEARRO
      RHOUR(1) = NDAYS(RDATE(1),IDUMMY,IDUMMY,IDUMMY) * 24 + BEGTA
C
C     INITIALIZE FOR FLOOD HYDROGRAPH COMPUTATION
C
      RRIIDX = 1
      PRIIDX = 1
      BFIDX = 1
      HRIDX = TIME(1)
      HROFST = TIME(1) - 1
      ORDCNT = NUGORD(BSNIDX)
      NUMORD = ORDCNT
      BLKCNT = NBLKS
      DUG = UGDUR(BSNIDX)
      INCRMT = HYDINT(BSNIDX)
      JDUR = DUG / INCRMT
C
C     FLOOD HYDROGRAPH = UNIT GRAPH * RUNOFF + BASEFLOW
C
      START = 1
      END = 1
      DO 200 HYDIDX = 1,NOFLOW
         END = MIN0((HYDIDX-1)/JDUR+1,NBLKS)
         IF ( HYDIDX .GT. NUMORD ) THEN
            REM = MOD(HYDIDX-NUMORD-1,JDUR)
            UGIDX = NUMORD - JDUR + REM + 1
            IF ( REM .EQ. 0 ) START = MIN0(START+1,NBLKS)
         ELSE
            UGIDX = HYDIDX
         END IF
         HYDORD = 0.0
         DO 60 ROIDX = START,END
            HYDORD = BLCKRO(ROIDX) * UGORD(UGIDX,BSNIDX) +
     1                     HYDORD
            UGIDX = UGIDX - JDUR
            IF ( UGIDX .LE. 0 ) GO TO 70
   60    CONTINUE
   70    CONTINUE
         TOTFLW(HYDIDX) = BASFLW(BFIDX,RRIIDX) + HYDORD
C
```

```
C         OUTPUT ONE LINE OF PRECIP/ RUNOFF
C
          IF ( BLKCNT .GT. 0 ) THEN
             IF ( ORDCNT .EQ. 0 ) THEN
                WRITE(6,100) CPDATE(1),CPDATE(2),CPDATE(4),CPDATE(3),
     1                       BHRAIN(HRIDX,PRIIDX),BSNHRO(HYDIDX+HROFST),
     2                       BLCKRO(HYDIDX),(CRDATE(I),I=1,3),HYDORD,
     3                       BASFLW(BFIDX,RRIIDX),TOTFLW(HYDIDX)
  100           FORMAT(21X,2(I2,'-'),I2,3X,I4,4X,F7.2,5X,F7.2,4X,
     1                 F8.5,3X,I2,'-',I2,3X,I4,4X,F7.0,6X,F6.0,5X,F7.0)
             ELSE
                WRITE(6,110) UGORD(HYDIDX,BSNIDX),CPDATE(1),CPDATE(2),
     1                       CPDATE(4),CPDATE(3),BHRAIN(HRIDX,PRIIDX),
     2                       BSNHRO(HYDIDX+HROFST),BLCKRO(HYDIDX),
     3                       (CRDATE(I),I=1,3),HYDORD,BASFLW(BFIDX,RRIIDX)
     4                       ,TOTFLW(HYDIDX)
  110           FORMAT(4X,F7.0,10X,2(I2,'-'),I2,3X,I4,4X,F7.2,5X,F7.2,
     1                 4X,F8.5,3X,I2,'-',I2,3X,I4,4X,F7.0,6X,F6.0,5X,
     2                 F7.0)
                ORDCNT = ORDCNT - 1
             END IF
             BLKCNT = BLKCNT - 1
          ELSE
             IF ( ORDCNT .EQ. 0 ) THEN
                IF ( BHRAIN(HRIDX,PRIIDX) .EQ. 0. .AND. PRIIDX .EQ. NRI )
     1          THEN
                   WRITE(6,120) (CRDATE(L),L=1,3),HYDORD,
     1                          BASFLW(BFIDX,RRIIDX),TOTFLW(HYDIDX)
  120              FORMAT(74X,I2,'-',I2,3X,I4,4X,F7.0,6X,F6.0,5X,F7.0)
                ELSE
                   WRITE(6,130) CPDATE(1),CPDATE(2),CPDATE(4),CPDATE(3),
     1                        BHRAIN(HRIDX,PRIIDX),BSNHRO(HYDIDX+HROFST),
     2                          (CRDATE(I),I=1,3),HYDORD,
     3                          BASFLW(BFIDX,RRIIDX),TOTFLW(HYDIDX)
  130              FORMAT(21X,2(I2,'-'),I2,3X,I4,4X,F7.2,5X,F7.2,15X,
     X                   I2,'-',I2,3X,I4,4X,F7.0,6X,F6.0,5X,F7.0)
                END IF
             ELSE
                IF ( BHRAIN(HRIDX,PRIIDX) .EQ. 0. .AND. PRIIDX .EQ. NRI )
     1          THEN
                   WRITE(6,140) UGORD(HYDIDX,BSNIDX),(CRDATE(I),I=1,3),
     1                          HYDORD,BASFLW(BFIDX,RRIIDX),
     2                          TOTFLW(HYDIDX)
  140              FORMAT(4X,F7.0,63X,I2,'-',I2,3X,I4,4X,F7.0,6X,F6.0,
     1                   5X,F7.0)
                ELSE
                   WRITE(6,150) UGORD(HYDIDX,BSNIDX),CPDATE(1),CPDATE(2),
     1                          CPDATE(4),CPDATE(3),BHRAIN(HRIDX,PRIIDX),
     2                          BSNHRO(HYDIDX+HROFST),(CRDATE(I),I=1,3),
     3                          HYDORD,BASFLW(BFIDX,RRIIDX),
     4                          TOTFLW(HYDIDX)
  150              FORMAT(4X,F7.0,10X,2(I2,'-'),I2,3X,I4,4X,F7.2,5X,
     1                    F7.2,15X,I2,'-',I2,3X,I4,4X,F7.0,6X,F6.0,5X,
     2                    F7.0)
                END IF
                ORDCNT = ORDCNT - 1
             END IF
          END IF
C
C         SEE IF NEXT STORM FOR PRECIPITATION OUTPUT
```

```
C
         HRIDX = HRIDX + 1
         CALL CLOCK(CPDATE,1,MODAYS)
         IF ( PRIIDX .LT. NRI ) THEN
            PHOUR(PRIIDX) = PHOUR(PRIIDX) + 1
            IF ( PHOUR(PRIIDX) .EQ. PHOUR(PRIIDX+1) ) THEN
               PRIIDX = PRIIDX + 1
               HRIDX = TIME(PRIIDX)
            END IF
         END IF
C
C        SEE IF NEXT STORM FOR FLOOD HYDROGRAPH OUTPUT
C
         BFIDX = BFIDX + 1
         CALL CLOCK(CRDATE,INCRMT,MODAYS)
         IF ( RRIIDX .LT. NRI ) THEN
            RHOUR(RRIIDX) = RHOUR(RRIIDX) + INCRMT
            IF ( RHOUR(RRIIDX) .GE. RHOUR(RRIIDX+1) ) THEN
               RHOUR(RRIIDX+1) = RHOUR(RRIIDX)
               RRIIDX = RRIIDX + 1
               BFIDX = 1
            END IF
         END IF
  200 CONTINUE
C
C     NO MORE FLOWS; SEE IF MORE PRECIPITATION TO OUTPUT
C
      DO 300 HYDIDX = NOFLOW+1,480
         IF ( PRIIDX .EQ. NRI ) THEN
            IF ( BHRAIN(HRIDX,PRIIDX) .EQ. 0.0 ) GO TO 350
         ELSE
            IF ( PHOUR(PRIIDX) .EQ. PHOUR(PRIIDX+1) ) THEN
               PRIIDX = PRIIDX + 1
               HRIDX = TIME(PRIIDX)
            END IF
         END IF
         WRITE(6,250) CPDATE(1),CPDATE(2),CPDATE(4),CPDATE(3),
     1                BHRAIN(HRIDX,PRIIDX),BSNHRO(HYDIDX+HROFST)
  250    FORMAT(21X,2(I2,'-'),I2,3X,I4,4X,F7.2,5X,F7.2)
         HRIDX = HRIDX + 1
         CALL CLOCK(CPDATE,1,MODAYS)
         PHOUR(PRIIDX) = PHOUR(PRIIDX) + 1
  300 CONTINUE
  350 CONTINUE
C
C     SEE IF FLOOD HYDROGRAPH IS TO BE OUTPUT TO DISK
C
      IF ( NARFE .EQ. 2 .AND. FHCNT .LE. NUMHYD .AND.
     1     BSNIDX .EQ. FHORDR(FHCNT) ) THEN
         FHCNT = FHCNT + 1
         ROHR = NDAYS(RDATE(1),IDUMMY,IDUMMY,IDUMMY) * 24 + BEGTA
         NARFHR = NDAYS(BEGD,IDUMMY,IDUMMY,IDUMMY) * 24 + BEGT
         IF ( ROHR .EQ. NARFHR ) THEN
            WRITE(3,400) NOFLOW,INCRMT
  400       FORMAT (2I9)
            WRITE(3,450) (TOTFLW(I),I=1,NOFLOW)
  450       FORMAT (8F9.0)
         ELSE IF ( ROHR .LT. NARFHR ) THEN
            NB = ( NARFHR - ROHR ) / INCRMT + 1
            IN = NOFLOW - NB + 1
```

```
            WRITE(3,400) IN,INCRMT
            WRITE(3,450) (TOTFLW(I),I=NB,NOFLOW)
         ELSE
            NB = ( ROHR - NARFHR ) / INCRMT
            IF ( NB*INCRMT .NE. ROHR-NARFHR ) NB = NB + 1
            IN = NB + NOFLOW
            BASFIL = BBSFLW(1,BSNIDX) * BAREA(BSNIDX)
            WRITE(3,400) IN,INCRMT
            WRITE(3,450) (BASFIL,I=1,NB),(TOTFLW(I),I=1,NOFLOW)
         END IF
      END IF
      RETURN
      END
      SUBROUTINE RUNOFF(RI,RITYP,RAIN,RO,FACTOR)
      REAL RAIN,RO,FACTOR
      INTEGER RI,RITYP
C
      REAL RITBL(121)
      INTEGER DSUNIT,RECNO,TBLIDX
C
      RECNO = RI - 15
      IF ( RECNO .GE. 1 ) THEN
         DSUNIT = RITYP + 6
         READ(DSUNIT,REC=RECNO) RITBL
         IF ( RAIN .GE. RITBL(121) ) THEN
            RO = 6.0 + RAIN - RITBL(121)
         ELSE
            IF ( RAIN .GT. RITBL(1) ) THEN
               DO 10 TBLIDX = 2,121
                  IF ( RAIN .LE. RITBL(TBLIDX) ) THEN
                     RO = 0.05 * ( ( RAIN - RITBL(TBLIDX-1) ) / (
     1                    RITBL(TBLIDX) - RITBL(TBLIDX-1) ) + TBLIDX
     2                    - 2 )
                     GO TO 20
                  END IF
   10          CONTINUE
   20          CONTINUE
            ELSE
               RO = 0.0
            END IF
         END IF
      ELSE
         RO = FACTOR * RAIN
      END IF
      RETURN
      END
      INTEGER FUNCTION NDAYS(DATE,YEAR,MONTH,DAY)
      INTEGER DATE,YEAR,MONTH,DAY
C
      COMMON /TABLES/ MODAYS(12)
      INTEGER MODAYS
C
      INTEGER YR,MO,DY
C
      YR = MOD(DATE,100)
      MO = DATE / 10000
      DY = DATE / 100 - MO * 100
      NDAYS = DY
      IF ( MO .GT. 1 ) THEN
         DO 100 I = 1,MO-1
```

```
            NDAYS = NDAYS + MODAYS(I)
  100     CONTINUE
      END IF
      NDAYS = NDAYS + YR * 365 + YR / 4
      IF ( MOD(YR,4) .EQ. 0 .AND. MO .LE. 2 ) NDAYS = NDAYS - 1
      YEAR = YR
      MONTH = MO
      DAY = DY
      RETURN
      END
      SUBROUTINE CLOCK(DATE,INCRMT,DAY)
      INTEGER DATE(4),DAY(12),INCRMT
C
      DATE(3) = DATE(3) + 100 * INCRMT
      IF ( DATE(3) .GT. 2400) DATE(2)=DATE(2) + 1
      IF ( MOD(DATE(4),4) .EQ. 0 ) DAY(2) = 29
C
      IF ( DATE(2) .GT. DAY(DATE(1)) .AND. DATE(3) .GT. 2400 ) THEN
         DATE(2) = 1
         DATE(1) = MOD(DATE(1),12) + 1
         IF ( DATE(1) .EQ. 1 ) DATE(4) = DATE(4) + 1
      END IF
C
      IF ( DATE(3) .GT. 2400) DATE(3) = DATE(3) - 2400
C
      RETURN
      END

      SUBROUTINE DoDialog()
      USE DIALOGM
      IMPLICIT NONE
      INCLUDE 'Fldhydro.fd'

      CHARACTER*240 DATFIL,OUTFIL,HYDFIL
         COMMON /FILES/DATFIL,OUTFIL,HYDFIL
C
      INTEGER retint
      LOGICAL retlog, enable
      TYPE (dialog) dlg
      character*240 dirname
      integer istat
       EXTERNAL UpdateFiles, UpdateButton
       INTEGER GETCWD
!      Initialize
       DATFIL = "*.dat"
       OUTFIL = "*.out"
       HYDFIL = "*.hyd"
       IF ( .not. DlgInit( IDD_FLDHYDRO, dlg ) ) THEN
              WRITE (*,*) "Error: dialog not found"
       ELSE
!      variable dirname must be long enough to hold entire string
              enable = .false.
              retlog = DlgSet( dlg, IDOK, .false., dlg_enable )
              retlog = DlgSet( dlg, IDC_BUTTON_PWD, enable, dlg_enable )
              retlog = DlgSet( dlg, IDC_BUTTON_OUT, enable, dlg_enable )
              retlog = DlgSet( dlg, IDC_BUTTON_HYD, enable, dlg_enable )
              ISTAT = GETCWD (dirname)
              IF (ISTAT == 0)
     1        retlog = DlgSet( dlg, IDC_FLDHYDRO_PWD, dirname )
              retlog = DlgSet( dlg, IDC_FLDHYDRO_DAT, DATFIL, 1 )
```

```
            retlog = DlgSet( dlg, IDC_FLDHYDRO_OUT, OUTFIL, 1 )
            retlog = DlgSet( dlg, IDC_FLDHYDRO_HYD, HYDFIL, 1 )
            retlog = DlgSetSub( dlg, IDC_FLDHYDRO_DAT, UpdateButton,
     1                                   dlg_selchange )
            retlog = DlgSetSub( dlg, IDC_FLDHYDRO_DAT, UpdateButton,
     1                                   dlg_update )
            call UpdateButton( dlg, IDC_FLDHYDRO_DAT, dlg_update )
            retlog = DlgSetSub( dlg, IDC_BUTTON_DAT, UpdateFiles )
            retlog = DlgSetSub( dlg, IDC_BUTTON_OUT, UpdateFiles )
            retlog = DlgSetSub( dlg, IDC_BUTTON_HYD, UpdateFiles )
            call UpdateFiles( dlg, IDC_BUTTON_PWD, dlg_clicked )
            call UpdateFiles( dlg, IDC_BUTTON_DAT, dlg_clicked )
            call UpdateFiles( dlg, IDC_BUTTON_OUT, dlg_clicked )
            call UpdateFiles( dlg, IDC_BUTTON_HYD, dlg_clicked )
!           Activate the dialog.
            retint = DlgModal( dlg )
            IF ( retint .eq. IDOK ) THEN
                  retlog = DlgGet( dlg, IDC_STATIC_DAT, DATFIL )
                  retlog = DlgGet( dlg, IDC_STATIC_OUT, OUTFIL )
                  retlog = DlgGet( dlg, IDC_STATIC_HYD, HYDFIL )
            ELSE
                  STOP
            END IF
!           Release dialog resources.
            CALL DlgUninit( dlg )
      END IF
      END SUBROUTINE DoDialog

      SUBROUTINE UpdateFiles( dlg, control_name, callbacktype )
      USE DIALOGM
      IMPLICIT NONE
      INCLUDE 'FLDHYDRO.fd'
      TYPE (dialog) dlg
      INTEGER control_name
      INTEGER callbacktype
      INTEGER local_callbacktype, numcalls
      character*240 dirname
      LOGICAL retlog
       LOGICAL input,output
       LOGICAL UpdateDir
       DATA numcalls/0/
       DATA input/.false./,output/.true./
      numcalls = numcalls + 1
       local_callbacktype = callbacktype
       IF ( numcalls .gt. 4 ) THEN
          retlog = DlgSet( dlg, IDC_STATIC_MSG, "Status Message" )
          IF ( UpdateDir( dlg, IDC_FLDHYDRO_PWD, dirname )   ) THEN
             IF ( control_name .eq. IDC_BUTTON_PWD ) THEN
               CALL UpdateDat( dlg, IDC_FLDHYDRO_DAT, IDC_STATIC_DAT,
     1                         IDC_BUTTON_DAT, dirname, input )
               CALL UpdateDat( dlg, IDC_FLDHYDRO_OUT, IDC_STATIC_OUT,
     1                         IDC_BUTTON_DAT, dirname, output )
               CALL UpdateDat( dlg, IDC_FLDHYDRO_HYD, IDC_STATIC_HYD,
     1                         IDC_BUTTON_DAT, dirname, output )
             ELSE
                SELECT CASE ( control_name )
                  CASE ( IDC_BUTTON_DAT )
                     CALL UpdateDat( dlg, IDC_FLDHYDRO_DAT,
     1                               IDC_STATIC_DAT, IDC_BUTTON_DAT,
     2                               dirname, input )
```

```
              CASE ( IDC_BUTTON_OUT )
                 CALL UpdateDat( dlg, IDC_FLDHYDRO_OUT,
1                                IDC_STATIC_OUT, IDC_BUTTON_OUT,
2                                dirname, output )
              CASE ( IDC_BUTTON_HYD )
                 CALL UpdateDat( dlg, IDC_FLDHYDRO_HYD,
1                                IDC_STATIC_HYD, IDC_BUTTON_HYD,
2                                dirname, output )
           END SELECT
        END IF
     END IF
  END IF
  RETURN
   END SUBROUTINE UpdateFiles

  SUBROUTINE UpdateButton( dlg, control_name, callbacktype )
  USE DIALOGM
  IMPLICIT NONE
  INCLUDE 'FLDHYDRO.fd'
  TYPE (dialog) dlg
  INTEGER control_name
  INTEGER callbacktype
  INTEGER local_callbacktype, button_control
  LOGICAL retlog
  character*240 filename,blank
   character*11 button_title
   INTEGER SCAN
   CHARACTER star
   DATA star/"*"/,blank/" "/
   local_callbacktype = callbacktype
  retlog = DlgGet( dlg, control_name, filename, 1 )
  IF ( SCAN(filename,star) .ne. 0 .or. filename .eq. blank ) THEN
      button_title = "Update List"
   ELSE
      button_title = "Select File"
   END IF
   SELECT CASE ( control_name )
     CASE ( IDC_FLDHYDRO_DAT )
        button_control = IDC_BUTTON_DAT
     CASE ( IDC_FLDHYDRO_OUT )
        button_control = IDC_BUTTON_OUT
     CASE ( IDC_FLDHYDRO_HYD )
        button_control = IDC_BUTTON_HYD
  END SELECT
  retlog = DlgSet( dlg, button_control, button_title, dlg_title )
  RETURN
   END SUBROUTINE UpdateButton

  LOGICAL FUNCTION UpdateDir( dlg, control_name, curname )
  USE DIALOGM
  USE MSFLIB
  IMPLICIT NONE
  TYPE (dialog) dlg
  INTEGER control_name
  CHARACTER*240 curname
   INTEGER istat
  CHARACTER*240 dirname
  LOGICAL retlog
   INTEGER GETCWD
   INTEGER CHDIR
```

```
      retlog = DlgGet( dlg, control_name, dirname )
      IF ( CHDIR(dirname) .eq. 0 ) THEN
         UpdateDir = .TRUE.
          curname = dirname
      ELSE
         UpdateDir = .FALSE.
         ISTAT = GETCWD (curname)
          UpdateDir = dirname .eq. curname
         IF (ISTAT == 0 .and. .not. UpdateDir )
     1      retlog = DlgSet( dlg, control_name, curname )
       END IF
      RETURN
      END FUNCTION UpdateDir

      SUBROUTINE UpdateDat( dlg, control_name, static_file,
       1                      button_control, dirname, ofile )
      USE DIALOGM
      USE MSFLIB
      IMPLICIT NONE
      INCLUDE 'FLDHYDRO.fd'
      TYPE (dialog) dlg
      INTEGER control_name, static_file, button_control
      CHARACTER*240 dirname

      CHARACTER*240 DATFIL,OUTFIL,HYDFIL
         COMMON /FILES/DATFIL,OUTFIL,HYDFIL
       LOGICAL ofile
      INTEGER index,numfiles
      CHARACTER*240 datname,blank,required,stardot,na
       CHARACTER*11 update,select
      CHARACTER*240 datlist(100)
       CHARACTER*4 xtension
      CHARACTER*80 CARD
      INTEGER NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
      LOGICAL retlog
       LOGICAL input,output,enable,disable
      INTEGER  handle, length
      TYPE  (FILE$INFO)  info
       DATA blank/" "/,stardot/"*.*"/,required/"Required"/,na/"NA"/
       DATA update/"Update List"/,select/"Select File"/
       DATA input/.false./,output/.true./,enable/.true./,disable/.false./

      retlog = DlgGet( dlg, control_name, datname )
       IF ( datname .eq. blank ) datname = stardot
      handle = FILE$FIRST
       numfiles = 1
      DO WHILE (.TRUE.)
         length = GETFILEINFOQQ(datname, info, handle)
         IF ((handle .EQ. FILE$LAST) .OR.
     1       (handle .EQ. FILE$ERROR)) THEN
            IF ( numfiles .gt. 1 ) THEN
                 numfiles = numfiles - 1
            ELSE
                IF ( ofile ) THEN
                   OPEN (6,FILE=datname,ERR=100,STATUS='NEW')
                   CLOSE(6,STATUS='DELETE')
                   numfiles = 1
                   datlist(1) = datname
                   GO TO 200
  100              CONTINUE
```

```
                 retlog = DlgSet( dlg, IDC_STATIC_MSG,
     1                          "Invalid filename" )
                datlist(1) = stardot
                 retlog = DlgSet( dlg, button_control, update,
     1                            dlg_title )
 200            CONTINUE
              ELSE
                 retlog = DlgSet( dlg, IDC_STATIC_MSG,
     1                            "File does not exist" )
                datlist(1) = stardot
                 retlog = DlgSet( dlg, button_control, update,
     1                            dlg_title )
              END IF
           END IF
           EXIT
        ELSE
           IF ( info.permit .eq. 32 ) THEN
              datlist(numfiles) = info.name
              numfiles = min(numfiles + 1, 100)
           END IF
        END IF
     END DO
     IF ( datlist(1) .ne. stardot )
     1   retlog = DlgSet( dlg, button_control, select, dlg_title )
     retlog = DlgSet( dlg, control_name, numfiles )
     DO index = 1,numfiles
        retlog = DlgSet( dlg, control_name, datlist(index), index )
     END DO
     IF ( numfiles .eq. 1 .and. datlist(1) .ne. stardot ) THEN
        datname = TRIM(dirname)//"\"//datlist(1)
        IF ( control_name .eq. IDC_FLDHYDRO_DAT ) THEN
           OPEN (5,FILE=datname,ERR=900)
           READ(5,250) CARD
 250       FORMAT(A)
           READ(5,300) NARFE,NRI,NCPTS,NSUBW,NREC,NSTNS,STAB,ITDGR
 300       FORMAT(16I5)
           CLOSE(5)

           CALL SETFIL( dlg, IDC_STATIC_DAT, datname, input, Blank  )

           retlog = DlgSet( dlg, IDC_BUTTON_OUT, enable, dlg_enable )
           xtension = OUTFIL(2:5)
           CALL SETFIL( dlg, IDC_STATIC_OUT, required, output,
     1                  xtension )

           IF ( NARFE .EQ. 2 ) THEN
              retlog = DlgSet( dlg, IDC_BUTTON_HYD, enable, dlg_enable)
              xtension = HYDFIL(2:5)
              CALL SETFIL( dlg, IDC_STATIC_HYD, required, output,
     1                     xtension )
           ELSE
              retlog = DlgSet( dlg, IDC_BUTTON_HYD, disable, dlg_enable)
              CALL SETFIL( dlg, IDC_STATIC_HYD, na, output, Blank )
           END IF
        ELSE
           CALL SETFIL( dlg, static_file, datname, ofile, Blank )
        END IF
     END IF
     RETURN
 900 CONTINUE
```

```
      retlog = DlgSet( dlg, IDC_STATIC_MSG,
      1                "Error in Input File; not updated" )

      END SUBROUTINE UpdateDat

      SUBROUTINE SETFIL( dlg, static_file, datname, Output, xtension )
      USE DIALOGM
      USE MSFLIB
      IMPLICIT NONE
      INCLUDE 'FLDHYDRO.fd'
      TYPE (dialog) dlg
      INTEGER static_file
      CHARACTER*240 datname
      LOGICAL Output
      CHARACTER*4 xtension
      CHARACTER*240 oldname,newname,required,na,qmark
      INTEGER numreq,oldnum
      LOGICAL retlog
      INTEGER  handle, length, i
      CHARACTER dot
      LOGICAL back, enable, disable
      TYPE  (FILE$INFO)  info
      INTEGER SCAN,LEN
      DATA numreq/2/,dot/'.'/
      DATA back/.true./,enable/.true./,disable/.false./
      DATA required/'Required'/,na/'NA'/,qmark/'?'/

      newname = datname
      retlog = DlgGet( dlg, static_file, oldname )
      IF ( newname .eq. required ) THEN
         IF ( oldname .eq. na .or.
      1        oldname .eq. qmark .or. oldname .eq. required ) THEN
            retlog = DlgGet( dlg, IDC_STATIC_DAT, newname, dlg_title )
           i = SCAN(newname, dot, back) - 1
            if ( i .lt. 1 ) i = LEN(TRIM(newname))
            newname = newname(1:i)//xtension
           handle = FILE$FIRST
           length = GETFILEINFOQQ(newname, info, handle)
           IF ( handle .EQ. FILE$LAST ) THEN
               IF ( output ) THEN
                  OPEN (6,FILE=datname,ERR=100,STATUS='NEW')
                  CLOSE(6,STATUS='DELETE')
                  GO TO 200
100              CONTINUE
                  newname = required
200              CONTINUE
              ELSE
                  newname = required
               END IF
            END IF
         ELSE
            newname = oldname
         END IF
      END IF
      retlog = DlgSet( dlg, static_file, newname )
      oldnum = numreq
      IF ( oldname .eq. required ) numreq = numreq - 1
      IF ( newname .eq. required ) numreq = numreq + 1
      IF ( oldnum .eq. 0 .and. numreq .gt. 0 )
      1   retlog = DlgSet( dlg, IDOK, disable, dlg_enable )
```

```
IF ( oldnum .gt. 0 .and. numreq .eq. 0 )
 1   retlog = DlgSet( dlg, IDOK, enable, dlg_enable )
 RETURN
 END SUBROUTINE SETFIL
```

APPENDIX F – EXAMPLE FLDHYDRO INPUT FILE

The following example illustrates the structure of a FLDHYDRO input data file. The data are for the Holston basin. This is the file "Holston.dat" entered in the dialog box described in Section 3.2.

```
MARCH 21400 SQ. MI. TVA & ANTECEDENT ON CHEROKEE WSHD
    2    2    0    7    7    7    2    0
   1   2   3   4   5   6   7
  031588  032288  031588  032288  031588  032288  031588  032288  031588  032288
  031588  032288  031588  032288
      01      01      01      01      01      01      01      01      01      01
      01      01      01      01
   72   72   72   72   72   72   72   72   72   72   72   72   72   72
    0.17    0.00    0.0     0.00    0.0     0.00    0.19    0.00    0.0     0.00
    0.0     0.00    0.23    0.00    0.0     0.00    0.00    0.00    0.29    0.00
    0.00    0.00    0.00    0.00    0.48    0.00    0.00    0.00    0.00    0.00
    0.69    0.00    0.00    0.00    0.00    0.00    1.24    0.00    0.00    0.00
    0.00    0.00    0.37    0.00    0.00    0.00    0.00    0.00    0.16    0.00
    0.00    0.00    0.00    0.00    0.14    0.00    0.00    0.00    0.00    0.00
    0.12    0.00    0.00    0.00    0.00    0.00    0.11    0.00    0.00    0.00
    0.00    0.00
    0.40    0.00    0.00    0.00    0.00    0.00    0.40    0.00    0.00    0.00
    0.00    0.00    0.50    0.00    0.00    0.00    0.00    0.00    0.60    0.00
    0.00    0.00    0.00    0.00    1.00    0.00    0.00    0.00    0.00    0.00
    1.40    0.00    0.00    0.00    0.00    0.00    1.80    0.00    0.00    0.00
    0.00    0.00    0.80    0.00    0.00    0.00    0.00    0.00    0.30    0.00
    0.00    0.00    0.00    0.00    0.30    0.00    0.00    0.00    0.00    0.00
    0.30    0.00    0.00    0.00    0.00    0.00    0.20    0.00    0.00    0.00
    0.00    0.00
    0.17    0.00    0.00    0.00    0.00    0.00    0.19    0.00    0.00    0.00
    0.00    0.00    0.23    0.00    0.00    0.00    0.00    0.00    0.29    0.00
    0.00    0.00    0.00    0.00    0.48    0.00    0.00    0.00    0.00    0.00
    0.69    0.00    0.00    0.00    0.00    0.00    1.24    0.00    0.00    0.00
    0.00    0.00    0.37    0.00    0.00    0.00    0.00    0.00    0.16    0.00
    0.00    0.00    0.00    0.00    0.14    0.00    0.00    0.00    0.00    0.00
    0.12    0.00    0.00    0.00    0.00    0.00    0.11    0.00    0.00    0.00
    0.00    0.00
    0.40    0.00    0.00    0.00    0.00    0.00    0.40    0.00    0.00    0.00
    0.00    0.00    0.50    0.00    0.00    0.00    0.00    0.00    0.60    0.00
    0.00    0.00    0.00    0.00    1.00    0.00    0.00    0.00    0.00    0.00
    1.50    0.00    0.00    0.00    0.00    0.00    2.20    0.00    0.00    0.00
    0.00    0.00    0.80    0.00    0.00    0.00    0.00    0.00    0.30    0.00
    0.00    0.00    0.00    0.00    0.30    0.00    0.00    0.00    0.00    0.00
    0.30    0.00    0.00    0.00    0.00    0.00    0.20    0.00    0.00    0.00
    0.00    0.00
    0.17    0.00    0.00    0.00    0.00    0.00    0.19    0.00    0.00    0.00
    0.00    0.00    0.23    0.00    0.00    0.00    0.00    0.00    0.29    0.00
    0.00    0.00    0.00    0.00    0.48    0.00    0.00    0.00    0.00    0.00
    0.69    0.00    0.00    0.00    0.00    0.00    1.24    0.00    0.00    0.00
    0.00    0.00    0.37    0.00    0.00    0.00    0.00    0.00    0.16    0.00
    0.00    0.00    0.00    0.00    0.14    0.00    0.00    0.00    0.00    0.00
    0.12    0.00    0.00    0.00    0.00    0.00    0.11    0.00    0.00    0.00
    0.00    0.00
    0.40    0.00    0.00    0.00    0.00    0.00    0.40    0.00    0.00    0.00
    0.00    0.00    0.50    0.00    0.00    0.00    0.00    0.00    0.60    0.00
    0.00    0.00    0.00    0.00    1.10    0.00    0.00    0.00    0.00    0.00
    1.60    0.00    0.00    0.00    0.00    0.00    2.40    0.00    0.00    0.00
```

0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.40	0.00
0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
0.30	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00
0.00	0.00								
0.17	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00
0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.29	0.00
0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00
0.69	0.00	0.00	0.00	0.00	0.00	1.24	0.00	0.00	0.00
0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.16	0.00
0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00
0.12	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00
0.00	0.00								
0.40	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00
0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.60	0.00
0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.00	0.00
1.60	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.00	0.00
0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.40	0.00
0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
0.30	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00
0.00	0.00								
0.17	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00
0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.29	0.00
0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00
0.69	0.00	0.00	0.00	0.00	0.00	1.24	0.00	0.00	0.00
0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.16	0.00
0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00
0.12	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00
0.00	0.00								
0.40	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00
0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.60	0.00
0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
1.40	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00
0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.30	0.00
0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
0.30	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
0.00	0.00								
0.17	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00
0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.29	0.00
0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00
0.69	0.00	0.00	0.00	0.00	0.00	1.24	0.00	0.00	0.00
0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.16	0.00
0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00
0.12	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00
0.00	0.00								
0.38	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00
0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.66	0.00
0.00	0.00	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00
1.58	0.00	0.00	0.00	0.00	0.00	2.45	0.00	0.00	0.00
0.00	0.00	0.81	0.00	0.00	0.00	0.00	0.00	0.34	0.00
0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00
0.28	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00
0.00	0.00								
0.17	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00
0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.29	0.00
0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00
0.69	0.00	0.00	0.00	0.00	0.00	1.24	0.00	0.00	0.00
0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.16	0.00
0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00
0.12	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00
0.00	0.00								

```
    0.40    0.00    0.00    0.00    0.00    0.00    0.47    0.00    0.00    0.00
    0.00    0.00    0.58    0.00    0.00    0.00    0.00    0.00    0.69    0.00
    0.00    0.00    0.00    0.00    1.18    0.00    0.00    0.00    0.00    0.00
    1.69    0.00    0.00    0.00    0.00    0.00    2.83    0.00    0.00    0.00
    0.00    0.00    0.88    0.00    0.00    0.00    0.00    0.00    0.37    0.00
    0.00    0.00    0.00    0.00    0.34    0.00    0.00    0.00    0.00    0.00
    0.31    0.00    0.00    0.00    0.00    0.00    0.28    0.00    0.00    0.00
    0.00    0.00
    0    0    0    0    0    0    0
     0.5     0.5     0.5     0.5     0.5     0.5     0.5
SOUTH HOLSTON DAM
WATAUGA DAM
BOONE LOCAL
FORT PAT LOCAL
N.FK. HOLSTON R AT GATE CITY
HOLSTON RIVER AT SURGOINSVILLE
CHEROKEE LOCAL
    708.    468.    669.     63.    672.    299.    554.
    3    2    2    3    3    3    3
    1    1    1    1    1    1    1
   1   1.
   2   1.
   3   1.
   4   1.
   5   1.
   6   1.
   7   1.
     2.5     2.5     2.5     2.5     2.5     2.5     2.5     2.5     2.5     2.5
     2.5     2.5     2.5     2.5     2.5     2.5     2.5     2.5     2.5     2.5
     2.5     2.5     2.5     2.5     2.5     2.5     2.5     2.5
    6    6    6    6    6    2    6
    6    6    6    6    6    6    6
   18   15   16   12   19   34   12
      0.  15000.  12000.  16000.  10000.   7150.   4800.   3250.   2250.   1650.
   1200.    750.    550.    450.    300.    200.    100.      0.      0.
      0.   9641.  17708.   9825.   3899.   2073.   2416.   1676.    915.    739.
    564.    429.    293.    158.      0.
      0.  22886.  16935.   7897.   6257.   4883.   3979.   2192.   1812.   1433.
   1054.    892.    736.    577.    418.      0.
      0.   2550.   2000.    600.    500.    300.    250.    200.    180.    150.
     50.      0.
      0.   1967.   9510.   9808.  12265.  10528.   9535.   6305.   3076.   2484.
   1892.   1300.   1061.    823.    584.    482.    380.    278.      0.
      0.   2200.   4500.   7000.   8200.   9300.  10300.   8800.   6700.   5000.
   4600.   4200.   3800.   3400.   2900.   2500.   2100.   1700.   1300.   1200.
   1100.   1000.    900.    800.    700.    600.    500.    400.    300.    200.
    100.    100.     50.      0.
      0.   7425.  18750.  11595.   7100.   5100.   3800.   2700.   1700.   1000.
    450.      0.
 031588 0600
    7
    1    2    3    4    5    6    7
```

APPENDIX G – EXAMPLE FLDHYDRO MAIN OUTPUT FILE

The main output file (written out in Unit 6) produced by running FLDHYDRO for the example presented in Appendix F is listed below. This is the file "Holston.out" entered in the dialog box described in Section 3.2

```
FLDHYDRO - QA REV1.0 - 11/04/2008

 MARCH 21400 SQ. MI. TVA & ANTECEDENT ON CHEROKEE WSHD
     2    2    0    7    7    7    2    0
    1   2   3   4   5   6   7
    31588   32288   31588   32288   31588   32288   31588   32288   31588   32288
    31588   32288   31588   32288
        1       1       1       1       1       1       1       1       1       1
        1       1       1       1
    72   72   72   72   72   72   72   72   72   72   72   72   72
     0.17    0.00    0.00    0.00    0.00    0.00    0.19    0.00    0.00    0.00
     0.00    0.00    0.23    0.00    0.00    0.00    0.00    0.00    0.29    0.00
     0.00    0.00    0.00    0.00    0.48    0.00    0.00    0.00    0.00    0.00
     0.69    0.00    0.00    0.00    0.00    0.00    1.24    0.00    0.00    0.00
     0.00    0.00    0.37    0.00    0.00    0.00    0.00    0.00    0.16    0.00
     0.00    0.00    0.00    0.00    0.14    0.00    0.00    0.00    0.00    0.00
     0.12    0.00    0.00    0.00    0.00    0.00    0.11    0.00    0.00    0.00
     0.00    0.00
     0.40    0.00    0.00    0.00    0.00    0.00    0.40    0.00    0.00    0.00
     0.00    0.00    0.50    0.00    0.00    0.00    0.00    0.00    0.60    0.00
     0.00    0.00    0.00    0.00    1.00    0.00    0.00    0.00    0.00    0.00
     1.40    0.00    0.00    0.00    0.00    0.00    1.80    0.00    0.00    0.00
     0.00    0.00    0.80    0.00    0.00    0.00    0.00    0.00    0.30    0.00
     0.00    0.00    0.00    0.00    0.30    0.00    0.00    0.00    0.00    0.00
     0.30    0.00    0.00    0.00    0.00    0.00    0.20    0.00    0.00    0.00
     0.00    0.00
     0.17    0.00    0.00    0.00    0.00    0.00    0.19    0.00    0.00    0.00
     0.00    0.00    0.23    0.00    0.00    0.00    0.00    0.00    0.29    0.00
     0.00    0.00    0.00    0.00    0.48    0.00    0.00    0.00    0.00    0.00
     0.69    0.00    0.00    0.00    0.00    0.00    1.24    0.00    0.00    0.00
     0.00    0.00    0.37    0.00    0.00    0.00    0.00    0.00    0.16    0.00
     0.00    0.00    0.00    0.00    0.14    0.00    0.00    0.00    0.00    0.00
     0.12    0.00    0.00    0.00    0.00    0.00    0.11    0.00    0.00    0.00
     0.00    0.00
     0.40    0.00    0.00    0.00    0.00    0.00    0.40    0.00    0.00    0.00
     0.00    0.00    0.50    0.00    0.00    0.00    0.00    0.00    0.60    0.00
     0.00    0.00    0.00    0.00    1.00    0.00    0.00    0.00    0.00    0.00
     1.50    0.00    0.00    0.00    0.00    0.00    2.20    0.00    0.00    0.00
     0.00    0.00    0.80    0.00    0.00    0.00    0.00    0.00    0.30    0.00
     0.00    0.00    0.00    0.00    0.30    0.00    0.00    0.00    0.00    0.00
     0.30    0.00    0.00    0.00    0.00    0.00    0.20    0.00    0.00    0.00
```

```
0.00    0.00
0.17    0.00    0.00    0.00    0.00    0.00    0.19    0.00    0.00    0.00
0.00    0.00    0.23    0.00    0.00    0.00    0.00    0.00    0.29    0.00
0.00    0.00    0.00    0.00    0.48    0.00    0.00    0.00    0.00    0.00
0.69    0.00    0.00    0.00    0.00    0.00    1.24    0.00    0.00    0.00
0.00    0.00    0.37    0.00    0.00    0.00    0.00    0.00    0.16    0.00
0.00    0.00    0.00    0.00    0.14    0.00    0.00    0.00    0.00    0.00
0.12    0.00    0.00    0.00    0.00    0.00    0.11    0.00    0.00    0.00
0.00    0.00
0.40    0.00    0.00    0.00    0.00    0.00    0.40    0.00    0.00    0.00
0.00    0.00    0.50    0.00    0.00    0.00    0.00    0.00    0.60    0.00
0.00    0.00    0.00    0.00    1.10    0.00    0.00    0.00    0.00    0.00
1.60    0.00    0.00    0.00    0.00    0.00    2.40    0.00    0.00    0.00
0.00    0.00    0.80    0.00    0.00    0.00    0.00    0.00    0.40    0.00
0.00    0.00    0.00    0.00    0.30    0.00    0.00    0.00    0.00    0.00
0.30    0.00    0.00    0.00    0.00    0.00    0.30    0.00    0.00    0.00
0.00    0.00
0.17    0.00    0.00    0.00    0.00    0.00    0.19    0.00    0.00    0.00
0.00    0.00    0.23    0.00    0.00    0.00    0.00    0.00    0.29    0.00
0.00    0.00    0.00    0.00    0.48    0.00    0.00    0.00    0.00    0.00
0.69    0.00    0.00    0.00    0.00    0.00    1.24    0.00    0.00    0.00
0.00    0.00    0.37    0.00    0.00    0.00    0.00    0.00    0.16    0.00
0.00    0.00    0.00    0.00    0.14    0.00    0.00    0.00    0.00    0.00
0.12    0.00    0.00    0.00    0.00    0.00    0.11    0.00    0.00    0.00
0.00    0.00
0.40    0.00    0.00    0.00    0.00    0.00    0.40    0.00    0.00    0.00
0.00    0.00    0.50    0.00    0.00    0.00    0.00    0.00    0.60    0.00
0.00    0.00    0.00    0.00    1.10    0.00    0.00    0.00    0.00    0.00
1.60    0.00    0.00    0.00    0.00    0.00    2.50    0.00    0.00    0.00
0.00    0.00    0.80    0.00    0.00    0.00    0.00    0.00    0.40    0.00
0.00    0.00    0.00    0.00    0.30    0.00    0.00    0.00    0.00    0.00
0.30    0.00    0.00    0.00    0.00    0.00    0.30    0.00    0.00    0.00
0.00    0.00
0.17    0.00    0.00    0.00    0.00    0.00    0.19    0.00    0.00    0.00
0.00    0.00    0.23    0.00    0.00    0.00    0.00    0.00    0.29    0.00
0.00    0.00    0.00    0.00    0.48    0.00    0.00    0.00    0.00    0.00
0.69    0.00    0.00    0.00    0.00    0.00    1.24    0.00    0.00    0.00
0.00    0.00    0.37    0.00    0.00    0.00    0.00    0.00    0.16    0.00
0.00    0.00    0.00    0.00    0.14    0.00    0.00    0.00    0.00    0.00
0.12    0.00    0.00    0.00    0.00    0.00    0.11    0.00    0.00    0.00
0.00    0.00
0.40    0.00    0.00    0.00    0.00    0.00    0.40    0.00    0.00    0.00
0.00    0.00    0.50    0.00    0.00    0.00    0.00    0.00    0.60    0.00
0.00    0.00    0.00    0.00    1.00    0.00    0.00    0.00    0.00    0.00
1.40    0.00    0.00    0.00    0.00    0.00    1.90    0.00    0.00    0.00
0.00    0.00    0.80    0.00    0.00    0.00    0.00    0.00    0.30    0.00
0.00    0.00    0.00    0.00    0.30    0.00    0.00    0.00    0.00    0.00
0.30    0.00    0.00    0.00    0.00    0.00    0.20    0.00    0.00    0.00
0.00    0.00
```

```
    0.17    0.00    0.00    0.00    0.00    0.00    0.19    0.00    0.00    0.00
    0.00    0.00    0.23    0.00    0.00    0.00    0.00    0.00    0.29    0.00
    0.00    0.00    0.00    0.00    0.48    0.00    0.00    0.00    0.00    0.00
    0.69    0.00    0.00    0.00    0.00    0.00    1.24    0.00    0.00    0.00
    0.00    0.00    0.37    0.00    0.00    0.00    0.00    0.00    0.16    0.00
    0.00    0.00    0.00    0.00    0.14    0.00    0.00    0.00    0.00    0.00
    0.12    0.00    0.00    0.00    0.00    0.00    0.11    0.00    0.00    0.00
    0.00    0.00
    0.38    0.00    0.00    0.00    0.00    0.00    0.44    0.00    0.00    0.00
    0.00    0.00    0.54    0.00    0.00    0.00    0.00    0.00    0.66    0.00
    0.00    0.00    0.00    0.00    1.08    0.00    0.00    0.00    0.00    0.00
    1.58    0.00    0.00    0.00    0.00    0.00    2.45    0.00    0.00    0.00
    0.00    0.00    0.81    0.00    0.00    0.00    0.00    0.00    0.34    0.00
    0.00    0.00    0.00    0.00    0.31    0.00    0.00    0.00    0.00    0.00
    0.28    0.00    0.00    0.00    0.00    0.00    0.26    0.00    0.00    0.00
    0.00    0.00
    0.17    0.00    0.00    0.00    0.00    0.00    0.19    0.00    0.00    0.00
    0.00    0.00    0.23    0.00    0.00    0.00    0.00    0.00    0.29    0.00
    0.00    0.00    0.00    0.00    0.48    0.00    0.00    0.00    0.00    0.00
    0.69    0.00    0.00    0.00    0.00    0.00    1.24    0.00    0.00    0.00
    0.00    0.00    0.37    0.00    0.00    0.00    0.00    0.00    0.16    0.00
    0.00    0.00    0.00    0.00    0.14    0.00    0.00    0.00    0.00    0.00
    0.12    0.00    0.00    0.00    0.00    0.00    0.11    0.00    0.00    0.00
    0.00    0.00
    0.40    0.00    0.00    0.00    0.00    0.00    0.47    0.00    0.00    0.00
    0.00    0.00    0.58    0.00    0.00    0.00    0.00    0.00    0.69    0.00
    0.00    0.00    0.00    0.00    1.18    0.00    0.00    0.00    0.00    0.00
    1.69    0.00    0.00    0.00    0.00    0.00    2.83    0.00    0.00    0.00
    0.00    0.00    0.88    0.00    0.00    0.00    0.00    0.00    0.37    0.00
    0.00    0.00    0.00    0.00    0.34    0.00    0.00    0.00    0.00    0.00
    0.31    0.00    0.00    0.00    0.00    0.00    0.28    0.00    0.00    0.00
    0.00    0.00
    0    0    0    0    0    0    0
    0.50    0.50    0.50    0.50    0.50    0.50    0.50
SOUTH HOLSTON DAM
WATAUGA DAM
BOONE LOCAL
FORT PAT LOCAL
N.FK. HOLSTON R AT GATE CITY
HOLSTON RIVER AT SURGOINSVILLE
CHEROKEE LOCAL
  708.00  468.00  669.00   63.00  672.00  299.00  554.00
    3    2    2    3    3    3    3
    1    1    1    1    1    1    1
   1 1.00
   2 1.00
   3 1.00
   4 1.00
   5 1.00
```

```
 6 1.00
 7 1.00
  2.50    2.50    2.50    2.50    2.50    2.50    2.50    2.50    2.50    2.50
  2.50    2.50    2.50    2.50    2.50    2.50    2.50    2.50    2.50    2.50
  2.50    2.50    2.50    2.50    2.50    2.50    2.50    2.50
  6    6    6    6    6    2    6
  6    6    6    6    6    6    6
 18   15   16   12   19   34   12
    0.  15000.  12000.  16000.  10000.   7150.   4800.   3250.   2250.   1650.
 1200.    750.    550.    450.    300.    200.    100.      0.
    0.   9641.  17708.   9825.   3899.   2073.   2416.   1676.    915.    739.
  564.    429.    293.    158.      0.
    0.  22886.  16935.   7897.   6257.   4883.   3979.   2192.   1812.   1433.
 1054.    892.    736.    577.    418.      0.
    0.   2550.   2000.    600.    500.    300.    250.    200.    180.    150.
   50.      0.
    0.   1967.   9510.   9808.  12265.  10528.   9535.   6305.   3076.   2484.
 1892.   1300.   1061.    823.    584.    482.    380.    278.      0.
    0.   2200.   4500.   7000.   8200.   9300.  10300.   8800.   6700.   5000.
 4600.   4200.   3800.   3400.   2900.   2500.   2100.   1700.   1300.   1200.
 1100.   1000.    900.    800.    700.    600.    500.    400.    300.    200.
  100.    100.     50.      0.
    0.   7425.  18750.  11595.   7100.   5100.   3800.   2700.   1700.   1000.
  450.      0.
31588  600
  7
  1    2    3    4    5    6    7
```

1MARCH 21400 SQ. MI. TVA & ANTECEDENT ON CHEROKEE WSHD

SOUTH HOLSTON DAM
DRAINAGE AREA = 708.00 SQUARE MILES

RAIN STATION	THIESSEN FACTOR	RECORDER	API		INITIAL USED		RI INITIAL USED		INITIAL USED	INITIAL USED
1	1.00	1	0.50	2.70	24TV	24TV	21TV	21TV		

AVERAGE SUBWATERSHED RAINFALL		SUBWATERSHED RUNOFF
FLOOD 1	4.19	2.49
FLOOD 2	8.00	6.59

UNIT GRAPH ORDINATES
DURATION - 6 HRS.
TIME INCR - 6 HRS.

	DATE	TIME	SUMMATION HOURLY RAIN	SUMMATION HOURLY RUNOFF	RUNOFF BLOCKED	DATE	TIME	SRO HYDROGRAPH	BASEFLOW	FLOOD HYDROGRAPH
0.	3-15-88	100	0.17	0.00	0.06072	3-15	1200	0.	1770.	1770.
15000.	3-15-88	200	0.17	0.00	0.10468	3-15	1800	911.	1770.	2681.
12000.	3-15-88	300	0.17	0.00	0.21462	3-15	2400	2299.	1770.	4069.
16000.	3-15-88	400	0.17	0.00	0.43429	3-16	600	5447.	1770.	7217.
10000.	3-15-88	500	0.17	0.00	0.93572	3-16	1200	11372.	1770.	13142.
7150.	3-15-88	600	0.17	0.00	0.30000	3-16	1800	24162.	1770.	25932.
4800.	3-15-88	700	0.36	0.00	0.12858	3-16	2400	25863.	1770.	27633.
3250.	3-15-88	800	0.36	0.00	0.11310	3-17	600	27077.	1770.	28847.
2250.	3-15-88	900	0.36	0.00	0.10834	3-17	1200	22009.	1770.	23779.
1650.	3-15-88	1000	0.36	0.00	0.09167	3-17	1800	17848.	1770.	19618.
1200.	3-15-88	1100	0.36	0.00	0.00000	3-17	2400	14547.	1770.	16317.
750.	3-15-88	1200	0.36	0.00	0.00000	3-18	600	10867.	1770.	12637.
550.	3-15-88	1300	0.59	0.06	0.00000	3-18	1200	8142.	1770.	9912.
450.	3-15-88	1400	0.59	0.06	0.00000	3-18	1800	5638.	1770.	7408.
300.	3-15-88	1500	0.59	0.06	0.00000	3-18	2400	3959.	1770.	5729.
200.	3-15-88	1600	0.59	0.06	0.00000	3-19	600	2700.	1770.	4470.
100.	3-15-88	1700	0.59	0.06	0.00000	3-19	1200	1909.	1770.	3679.
0.	3-15-88	1800	0.59	0.06	0.00000	3-19	1800	1387.	1770.	3157.
	3-15-88	1900	0.88	0.17	0.00000	3-19	2400	961.	1770.	2731.
	3-15-88	2000	0.88	0.17	0.00000	3-20	600	632.	1770.	2402.
	3-15-88	2100	0.88	0.17	0.00000	3-20	1200	371.	1770.	2141.
	3-15-88	2200	0.88	0.17	0.00000	3-20	1800	189.	1770.	1959.
	3-15-88	2300	0.88	0.17	0.00000	3-20	2400	109.	1770.	1879.
	3-15-88	2400	0.88	0.17	0.00000	3-21	600	60.	1770.	1830.
	3-16-88	100	1.36	0.38	0.00000	3-21	1200	29.	1770.	1799.
	3-16-88	200	1.36	0.38	0.00000	3-21	1800	9.	1770.	1779.
	3-16-88	300	1.36	0.38	0.05000	3-21	2400	0.	1770.	1770.
	3-16-88	400	1.36	0.38	0.19500	3-22	600	750.	1770.	2520.
	3-16-88	500	1.36	0.38	0.30501	3-22	1200	3525.	1770.	5295.
	3-16-88	600	1.36	0.38	0.42143	3-22	1800	7715.	1770.	9485.
	3-16-88	700	2.05	0.81	0.81858	3-22	2400	13602.	1770.	15372.
	3-16-88	800	2.05	0.81	1.22000	3-23	600	24524.	1770.	26294.
	3-16-88	900	2.05	0.81	1.70001	3-23	1200	39550.	1770.	41320.

3-16-88	1000	2.05	0.81	0.78001
3-16-88	1100	2.05	0.81	0.30001
3-16-88	1200	2.05	0.81	0.30001
3-16-88	1300	3.29	1.75	0.30001
3-16-88	1400	3.29	1.75	0.20000
3-16-88	1500	3.29	1.75	
3-16-88	1600	3.29	1.75	
3-16-88	1700	3.29	1.75	
3-16-88	1800	3.29	1.75	
3-16-88	1900	3.66	2.05	
3-16-88	2000	3.66	2.05	
3-16-88	2100	3.66	2.05	
3-16-88	2200	3.66	2.05	
3-16-88	2300	3.66	2.05	
3-16-88	2400	3.66	2.05	
3-17-88	100	3.82	2.18	
3-17-88	200	3.82	2.18	
3-17-88	300	3.82	2.18	
3-17-88	400	3.82	2.18	
3-17-88	500	3.82	2.18	
3-17-88	600	3.82	2.18	
3-17-88	700	3.96	2.29	
3-17-88	800	3.96	2.29	
3-17-88	900	3.96	2.29	
3-17-88	1000	3.96	2.29	
3-17-88	1100	3.96	2.29	
3-17-88	1200	3.96	2.29	
3-17-88	1300	4.08	2.40	
3-17-88	1400	4.08	2.40	
3-17-88	1500	4.08	2.40	
3-17-88	1600	4.08	2.40	
3-17-88	1700	4.08	2.40	
3-17-88	1800	4.08	2.40	
3-17-88	1900	4.19	2.49	
3-17-88	2000	4.19	2.49	
3-17-88	2100	4.19	2.49	
3-17-88	2200	4.19	2.49	
3-17-88	2300	4.19	2.49	
3-17-88	2400	4.19	2.49	
3-18-88	100	0.00	0.00	
3-18-88	200	0.00	0.00	
3-18-88	300	0.00	0.00	
3-18-88	400	0.00	0.00	
3-18-88	500	0.00	0.00	
3-18-88	600	0.00	0.00	
3-18-88	700	0.00	0.00	
3-18-88	800	0.00	0.00	
3-18-88	900	0.00	0.00	
3-18-88	1000	0.00	0.00	

3-23	1800	60731.	1770.	62501.
3-23	2400	65030.	1770.	66800.
3-24	600	62649.	1770.	64419.
3-24	1200	52670.	1770.	54440.
3-24	1800	43095.	1770.	44865.
3-24	2400	35179.	1770.	36949.
3-25	600	26574.	1770.	28344.
3-25	1200	19727.	1770.	21497.
3-25	1800	13636.	1770.	15406.
3-25	2400	9537.	1770.	11307.
3-26	600	6562.	1770.	8332.
3-26	1200	4609.	1770.	6379.
3-26	1800	3296.	1770.	5066.
3-26	2400	2267.	1770.	4037.
3-27	600	1461.	1770.	3231.
3-27	1200	866.	1770.	2636.
3-27	1800	473.	1770.	2243.
3-27	2400	270.	1770.	2040.
3-28	600	150.	1770.	1920.
3-28	1200	70.	1770.	1840.
3-28	1800	20.	1770.	1790.
3-28	2400	0.	1770.	1770.

3-18-88	1100	0.00	0.00
3-18-88	1200	0.00	0.00
3-18-88	1300	0.00	0.00
3-18-88	1400	0.00	0.00
3-18-88	1500	0.00	0.00
3-18-88	1600	0.00	0.00
3-18-88	1700	0.00	0.00
3-18-88	1800	0.00	0.00
3-18-88	1900	0.00	0.00
3-18-88	2000	0.00	0.00
3-18-88	2100	0.00	0.00
3-18-88	2200	0.00	0.00
3-18-88	2300	0.00	0.00
3-18-88	2400	0.00	0.00
3-19-88	100	0.00	0.00
3-19-88	200	0.00	0.00
3-19-88	300	0.00	0.00
3-19-88	400	0.00	0.00
3-19-88	500	0.00	0.00
3-19-88	600	0.00	0.00
3-19-88	700	0.00	0.00
3-19-88	800	0.00	0.00
3-19-88	900	0.00	0.00
3-19-88	1000	0.00	0.00
3-19-88	1100	0.00	0.00
3-19-88	1200	0.00	0.00
3-19-88	1300	0.00	0.00
3-19-88	1400	0.00	0.00
3-19-88	1500	0.00	0.00
3-19-88	1600	0.00	0.00
3-19-88	1700	0.00	0.00
3-19-88	1800	0.00	0.00
3-19-88	1900	0.00	0.00
3-19-88	2000	0.00	0.00
3-19-88	2100	0.00	0.00
3-19-88	2200	0.00	0.00
3-19-88	2300	0.00	0.00
3-19-88	2400	0.00	0.00
3-20-88	100	0.00	0.00
3-20-88	200	0.00	0.00
3-20-88	300	0.00	0.00
3-20-88	400	0.00	0.00
3-20-88	500	0.00	0.00
3-20-88	600	0.00	0.00
3-20-88	700	0.00	0.00
3-20-88	800	0.00	0.00
3-20-88	900	0.00	0.00
3-20-88	1000	0.00	0.00
3-20-88	1100	0.00	0.00

3-20-88	1200	0.00	0.00
3-20-88	1300	0.00	0.00
3-20-88	1400	0.00	0.00
3-20-88	1500	0.00	0.00
3-20-88	1600	0.00	0.00
3-20-88	1700	0.00	0.00
3-20-88	1800	0.00	0.00
3-20-88	1900	0.00	0.00
3-20-88	2000	0.00	0.00
3-20-88	2100	0.00	0.00
3-20-88	2200	0.00	0.00
3-20-88	2300	0.00	0.00
3-20-88	2400	0.00	0.00
3-21-88	100	0.00	0.00
3-21-88	200	0.00	0.00
3-21-88	300	0.00	0.00
3-21-88	400	0.00	0.00
3-21-88	500	0.00	0.00
3-21-88	600	0.00	0.00
3-21-88	700	0.00	0.00
3-21-88	800	0.00	0.00
3-21-88	900	0.00	0.00
3-21-88	1000	0.00	0.00
3-21-88	1100	0.00	0.00
3-21-88	1200	0.00	0.00
3-21-88	1300	0.00	0.00
3-21-88	1400	0.00	0.00
3-21-88	1500	0.00	0.00
3-21-88	1600	0.00	0.00
3-21-88	1700	0.00	0.00
3-21-88	1800	0.00	0.00
3-21-88	1900	0.00	0.00
3-21-88	2000	0.00	0.00
3-21-88	2100	0.00	0.00
3-21-88	2200	0.00	0.00
3-21-88	2300	0.00	0.00
3-21-88	2400	0.00	0.00
3-22-88	100	0.40	0.05
3-22-88	200	0.40	0.05
3-22-88	300	0.40	0.05
3-22-88	400	0.40	0.05
3-22-88	500	0.40	0.05
3-22-88	600	0.40	0.05
3-22-88	700	0.80	0.25
3-22-88	800	0.80	0.25
3-22-88	900	0.80	0.25
3-22-88	1000	0.80	0.25
3-22-88	1100	0.80	0.25
3-22-88	1200	0.80	0.25

3-22-88	1300	1.30	0.55
3-22-88	1400	1.30	0.55
3-22-88	1500	1.30	0.55
3-22-88	1600	1.30	0.55
3-22-88	1700	1.30	0.55
3-22-88	1800	1.30	0.55
3-22-88	1900	1.90	0.97
3-22-88	2000	1.90	0.97
3-22-88	2100	1.90	0.97
3-22-88	2200	1.90	0.97
3-22-88	2300	1.90	0.97
3-22-88	2400	1.90	0.97
3-23-88	100	2.90	1.79
3-23-88	200	2.90	1.79
3-23-88	300	2.90	1.79
3-23-88	400	2.90	1.79
3-23-88	500	2.90	1.79
3-23-88	600	2.90	1.79
3-23-88	700	4.30	3.01
3-23-88	800	4.30	3.01
3-23-88	900	4.30	3.01
3-23-88	1000	4.30	3.01
3-23-88	1100	4.30	3.01
3-23-88	1200	4.30	3.01
3-23-88	1300	6.10	4.71
3-23-88	1400	6.10	4.71
3-23-88	1500	6.10	4.71
3-23-88	1600	6.10	4.71
3-23-88	1700	6.10	4.71
3-23-88	1800	6.10	4.71
3-23-88	1900	6.90	5.49
3-23-88	2000	6.90	5.49
3-23-88	2100	6.90	5.49
3-23-88	2200	6.90	5.49
3-23-88	2300	6.90	5.49
3-23-88	2400	6.90	5.49
3-24-88	100	7.20	5.79
3-24-88	200	7.20	5.79
3-24-88	300	7.20	5.79
3-24-88	400	7.20	5.79
3-24-88	500	7.20	5.79
3-24-88	600	7.20	5.79
3-24-88	700	7.50	6.09
3-24-88	800	7.50	6.09
3-24-88	900	7.50	6.09
3-24-88	1000	7.50	6.09
3-24-88	1100	7.50	6.09
3-24-88	1200	7.50	6.09
3-24-88	1300	7.80	6.39

3-24-88	1400	7.80	6.39
3-24-88	1500	7.80	6.39
3-24-88	1600	7.80	6.39
3-24-88	1700	7.80	6.39
3-24-88	1800	7.80	6.39
3-24-88	1900	8.00	6.59
3-24-88	2000	8.00	6.59
3-24-88	2100	8.00	6.59
3-24-88	2200	8.00	6.59
3-24-88	2300	8.00	6.59
3-24-88	2400	8.00	6.59

1MARCH 21400 SQ. MI. TVA & ANTECEDENT ON CHEROKEE WSHD

WATAUGA DAM
DRAINAGE AREA = 468.00 SQUARE MILES

RAIN STATION	THIESSEN FACTOR	RECORDER	API		INITIAL	USED	RI INITIAL	USED	INITIAL	USED	INITIAL	USED
2	1.00	2	0.50	2.70	29TV	29TV	25TV	25TV				

AVERAGE SUBWATERSHED RAINFALL		SUBWATERSHED RUNOFF
FLOOD 1	4.19	1.92
FLOOD 2	8.50	6.32

UNIT GRAPH ORDINATES
DURATION - 6 HRS.
TIME INCR - 6 HRS.

	DATE	TIME	SUMMATION HOURLY RAIN	SUMMATION HOURLY RUNOFF	RUNOFF BLOCKED	DATE	TIME	SRO HYDROGRAPH	BASEFLOW	FLOOD HYDROGRAPH
0.	3-15-88	100	0.17	0.00	0.00962	3-15	1200	0.	1170.	1170.
9641.	3-15-88	200	0.17	0.00	0.05706	3-15	1800	93.	1170.	1263.
17708.	3-15-88	300	0.17	0.00	0.12709	3-15	2400	720.	1170.	1890.
9825.	3-15-88	400	0.17	0.00	0.29626	3-16	600	2330.	1170.	3500.
3899.	3-15-88	500	0.17	0.00	0.77429	3-16	1200	5705.	1170.	6875.
2073.	3-15-88	600	0.17	0.00	0.26429	3-16	1800	14202.	1170.	15372.
2416.	3-15-88	700	0.36	0.00	0.11429	3-16	2400	19807.	1170.	20977.
1676.	3-15-88	800	0.36	0.00	0.10001	3-17	600	14962.	1170.	16132.
915.	3-15-88	900	0.36	0.00	0.09048	3-17	1200	9629.	1170.	10799.
739.	3-15-88	1000	0.36	0.00	0.08810	3-17	1800	7390.	1170.	8560.
564.	3-15-88	1100	0.36	0.00	0.00000	3-17	2400	6959.	1170.	8129.
429.	3-15-88	1200	0.36	0.00	0.00000	3-18	600	5413.	1170.	6583.
293.	3-15-88	1300	0.59	0.01	0.00000	3-18	1200	3171.	1170.	4341.
158.	3-15-88	1400	0.59	0.01	0.00000	3-18	1800	2018.	1170.	3188.
0.	3-15-88	1500	0.59	0.01	0.00000	3-18	2400	1479.	1170.	2649.
	3-15-88	1600	0.59	0.01	0.00000	3-19	600	1129.	1170.	2299.
	3-15-88	1700	0.59	0.01	0.00000	3-19	1200	756.	1170.	1926.
	3-15-88	1800	0.59	0.01	0.00000	3-19	1800	453.	1170.	1623.
	3-15-88	1900	0.88	0.07	0.00000	3-19	2400	234.	1170.	1404.
	3-15-88	2000	0.88	0.07	0.00000	3-20	600	136.	1170.	1306.
	3-15-88	2100	0.88	0.07	0.00000	3-20	1200	80.	1170.	1250.
	3-15-88	2200	0.88	0.07	0.00000	3-20	1800	40.	1170.	1210.
	3-15-88	2300	0.88	0.07	0.00000	3-20	2400	14.	1170.	1184.
	3-15-88	2400	0.88	0.07	0.00000	3-21	600	0.	1170.	1170.
	3-16-88	100	1.36	0.19	0.00000	3-21	1200	0.	1170.	1170.
	3-16-88	200	1.36	0.19	0.00000	3-21	1800	0.	1170.	1170.
	3-16-88	300	1.36	0.19	0.00001	3-21	2400	0.	1170.	1170.
	3-16-88	400	1.36	0.19	0.11334	3-22	600	0.	1170.	1170.
	3-16-88	500	1.36	0.19	0.18667	3-22	1200	1093.	1170.	2263.
	3-16-88	600	1.36	0.19	0.32501	3-22	1800	3807.	1170.	4977.
	3-16-88	700	2.05	0.49	0.71786	3-22	2400	7553.	1170.	8723.
	3-16-88	800	2.05	0.49	1.19048	3-23	600	14952.	1170.	16122.
	3-16-88	900	2.05	0.49	1.96667	3-23	1200	28345.	1170.	29515.

3-16-88	1000	2.05	0.49	0.76667	3-23	1800	49023.	1170.	50193.
3-16-88	1100	2.05	0.49	0.28334	3-23	2400	58027.	1170.	59197.
3-16-88	1200	2.05	0.49	0.27501	3-24	600	42962.	1170.	44132.
3-16-88	1300	3.29	1.26	0.29500	3-24	1200	27871.	1170.	29041.
3-16-88	1400	3.29	1.26	0.20000	3-24	1800	22142.	1170.	23312.
3-16-88	1500	3.29	1.26		3-24	2400	20346.	1170.	21516.
3-16-88	1600	3.29	1.26		3-25	600	15165.	1170.	16335.
3-16-88	1700	3.29	1.26		3-25	1200	8951.	1170.	10121.
3-16-88	1800	3.29	1.26		3-25	1800	5790.	1170.	6960.
3-16-88	1900	3.66	1.53		3-25	2400	4296.	1170.	5466.
3-16-88	2000	3.66	1.53		3-26	600	3177.	1170.	4347.
3-16-88	2100	3.66	1.53		3-26	1200	2061.	1170.	3231.
3-16-88	2200	3.66	1.53		3-26	1800	1213.	1170.	2383.
3-16-88	2300	3.66	1.53		3-26	2400	636.	1170.	1806.
3-16-88	2400	3.66	1.53		3-27	600	365.	1170.	1535.
3-17-88	100	3.82	1.64		3-27	1200	216.	1170.	1386.
3-17-88	200	3.82	1.64		3-27	1800	105.	1170.	1275.
3-17-88	300	3.82	1.64		3-27	2400	32.	1170.	1202.
3-17-88	400	3.82	1.64		3-28	600	0.	1170.	1170.
3-17-88	500	3.82	1.64						
3-17-88	600	3.82	1.64						
3-17-88	700	3.96	1.74						
3-17-88	800	3.96	1.74						
3-17-88	900	3.96	1.74						
3-17-88	1000	3.96	1.74						
3-17-88	1100	3.96	1.74						
3-17-88	1200	3.96	1.74						
3-17-88	1300	4.08	1.83						
3-17-88	1400	4.08	1.83						
3-17-88	1500	4.08	1.83						
3-17-88	1600	4.08	1.83						
3-17-88	1700	4.08	1.83						
3-17-88	1800	4.08	1.83						
3-17-88	1900	4.19	1.92						
3-17-88	2000	4.19	1.92						
3-17-88	2100	4.19	1.92						
3-17-88	2200	4.19	1.92						
3-17-88	2300	4.19	1.92						
3-17-88	2400	4.19	1.92						
3-18-88	100	0.00	0.00						
3-18-88	200	0.00	0.00						
3-18-88	300	0.00	0.00						
3-18-88	400	0.00	0.00						
3-18-88	500	0.00	0.00						
3-18-88	600	0.00	0.00						
3-18-88	700	0.00	0.00						
3-18-88	800	0.00	0.00						
3-18-88	900	0.00	0.00						
3-18-88	1000	0.00	0.00						

3-18-88	1100	0.00	0.00
3-18-88	1200	0.00	0.00
3-18-88	1300	0.00	0.00
3-18-88	1400	0.00	0.00
3-18-88	1500	0.00	0.00
3-18-88	1600	0.00	0.00
3-18-88	1700	0.00	0.00
3-18-88	1800	0.00	0.00
3-18-88	1900	0.00	0.00
3-18-88	2000	0.00	0.00
3-18-88	2100	0.00	0.00
3-18-88	2200	0.00	0.00
3-18-88	2300	0.00	0.00
3-18-88	2400	0.00	0.00
3-19-88	100	0.00	0.00
3-19-88	200	0.00	0.00
3-19-88	300	0.00	0.00
3-19-88	400	0.00	0.00
3-19-88	500	0.00	0.00
3-19-88	600	0.00	0.00
3-19-88	700	0.00	0.00
3-19-88	800	0.00	0.00
3-19-88	900	0.00	0.00
3-19-88	1000	0.00	0.00
3-19-88	1100	0.00	0.00
3-19-88	1200	0.00	0.00
3-19-88	1300	0.00	0.00
3-19-88	1400	0.00	0.00
3-19-88	1500	0.00	0.00
3-19-88	1600	0.00	0.00
3-19-88	1700	0.00	0.00
3-19-88	1800	0.00	0.00
3-19-88	1900	0.00	0.00
3-19-88	2000	0.00	0.00
3-19-88	2100	0.00	0.00
3-19-88	2200	0.00	0.00
3-19-88	2300	0.00	0.00
3-19-88	2400	0.00	0.00
3-20-88	100	0.00	0.00
3-20-88	200	0.00	0.00
3-20-88	300	0.00	0.00
3-20-88	400	0.00	0.00
3-20-88	500	0.00	0.00
3-20-88	600	0.00	0.00
3-20-88	700	0.00	0.00
3-20-88	800	0.00	0.00
3-20-88	900	0.00	0.00
3-20-88	1000	0.00	0.00
3-20-88	1100	0.00	0.00

3-20-88	1200	0.00	0.00
3-20-88	1300	0.00	0.00
3-20-88	1400	0.00	0.00
3-20-88	1500	0.00	0.00
3-20-88	1600	0.00	0.00
3-20-88	1700	0.00	0.00
3-20-88	1800	0.00	0.00
3-20-88	1900	0.00	0.00
3-20-88	2000	0.00	0.00
3-20-88	2100	0.00	0.00
3-20-88	2200	0.00	0.00
3-20-88	2300	0.00	0.00
3-20-88	2400	0.00	0.00
3-21-88	100	0.00	0.00
3-21-88	200	0.00	0.00
3-21-88	300	0.00	0.00
3-21-88	400	0.00	0.00
3-21-88	500	0.00	0.00
3-21-88	600	0.00	0.00
3-21-88	700	0.00	0.00
3-21-88	800	0.00	0.00
3-21-88	900	0.00	0.00
3-21-88	1000	0.00	0.00
3-21-88	1100	0.00	0.00
3-21-88	1200	0.00	0.00
3-21-88	1300	0.00	0.00
3-21-88	1400	0.00	0.00
3-21-88	1500	0.00	0.00
3-21-88	1600	0.00	0.00
3-21-88	1700	0.00	0.00
3-21-88	1800	0.00	0.00
3-21-88	1900	0.00	0.00
3-21-88	2000	0.00	0.00
3-21-88	2100	0.00	0.00
3-21-88	2200	0.00	0.00
3-21-88	2300	0.00	0.00
3-21-88	2400	0.00	0.00
3-22-88	100	0.40	0.00
3-22-88	200	0.40	0.00
3-22-88	300	0.40	0.00
3-22-88	400	0.40	0.00
3-22-88	500	0.40	0.00
3-22-88	600	0.40	0.00
3-22-88	700	0.80	0.11
3-22-88	800	0.80	0.11
3-22-88	900	0.80	0.11
3-22-88	1000	0.80	0.11
3-22-88	1100	0.80	0.11
3-22-88	1200	0.80	0.11

3-22-88	1300	1.30	0.30
3-22-88	1400	1.30	0.30
3-22-88	1500	1.30	0.30
3-22-88	1600	1.30	0.30
3-22-88	1700	1.30	0.30
3-22-88	1800	1.30	0.30
3-22-88	1900	1.90	0.63
3-22-88	2000	1.90	0.63
3-22-88	2100	1.90	0.63
3-22-88	2200	1.90	0.63
3-22-88	2300	1.90	0.63
3-22-88	2400	1.90	0.63
3-23-88	100	2.90	1.34
3-23-88	200	2.90	1.34
3-23-88	300	2.90	1.34
3-23-88	400	2.90	1.34
3-23-88	500	2.90	1.34
3-23-88	600	2.90	1.34
3-23-88	700	4.40	2.53
3-23-88	800	4.40	2.53
3-23-88	900	4.40	2.53
3-23-88	1000	4.40	2.53
3-23-88	1100	4.40	2.53
3-23-88	1200	4.40	2.53
3-23-88	1300	6.60	4.50
3-23-88	1400	6.60	4.50
3-23-88	1500	6.60	4.50
3-23-88	1600	6.60	4.50
3-23-88	1700	6.60	4.50
3-23-88	1800	6.60	4.50
3-23-88	1900	7.40	5.27
3-23-88	2000	7.40	5.27
3-23-88	2100	7.40	5.27
3-23-88	2200	7.40	5.27
3-23-88	2300	7.40	5.27
3-23-88	2400	7.40	5.27
3-24-88	100	7.70	5.55
3-24-88	200	7.70	5.55
3-24-88	300	7.70	5.55
3-24-88	400	7.70	5.55
3-24-88	500	7.70	5.55
3-24-88	600	7.70	5.55
3-24-88	700	8.00	5.83
3-24-88	800	8.00	5.83
3-24-88	900	8.00	5.83
3-24-88	1000	8.00	5.83
3-24-88	1100	8.00	5.83
3-24-88	1200	8.00	5.83
3-24-88	1300	8.30	6.12

3-24-88	1400	8.30	6.12
3-24-88	1500	8.30	6.12
3-24-88	1600	8.30	6.12
3-24-88	1700	8.30	6.12
3-24-88	1800	8.30	6.12
3-24-88	1900	8.50	6.32
3-24-88	2000	8.50	6.32
3-24-88	2100	8.50	6.32
3-24-88	2200	8.50	6.32
3-24-88	2300	8.50	6.32
3-24-88	2400	8.50	6.32

1MARCH 21400 SQ. MI. TVA & ANTECEDENT ON CHEROKEE WSHD

BOONE LOCAL
DRAINAGE AREA = 669.00 SQUARE MILES

RAIN STATION	THIESSEN FACTOR	RECORDER	API		INITIAL USED		RI INITIAL USED		INITIAL USED	INITIAL USED
3	1.00	3	0.50	2.70	29TV	29TV	25TV	25TV		

AVERAGE SUBWATERSHED RAINFALL		SUBWATERSHED RUNOFF
FLOOD 1	4.19	1.92
FLOOD 2	9.10	6.92

UNIT GRAPH ORDINATES
DURATION - 6 HRS.
TIME INCR - 6 HRS.

	DATE	TIME	SUMMATION HOURLY RAIN	SUMMATION HOURLY RUNOFF	RUNOFF BLOCKED	DATE	TIME	SRO HYDROGRAPH	BASEFLOW	FLOOD HYDROGRAPH
0.	3-15-88	100	0.17	0.00	0.00962	3-15	1200	0.	1672.	1672.
22886.	3-15-88	200	0.17	0.00	0.05706	3-15	1800	220.	1672.	1893.
16935.	3-15-88	300	0.17	0.00	0.12709	3-15	2400	1469.	1672.	3141.
7897.	3-15-88	400	0.17	0.00	0.29626	3-16	600	3951.	1672.	5623.
6257.	3-15-88	500	0.17	0.00	0.77429	3-16	1200	9443.	1672.	11116.
4883.	3-15-88	600	0.17	0.00	0.26429	3-16	1800	24145.	1672.	25818.
3979.	3-15-88	700	0.36	0.00	0.11429	3-16	2400	22613.	1672.	24285.
2192.	3-15-88	800	0.36	0.00	0.10001	3-17	600	15928.	1672.	17601.
1812.	3-15-88	900	0.36	0.00	0.09048	3-17	1200	13251.	1672.	14923.
1433.	3-15-88	1000	0.36	0.00	0.08810	3-17	1800	11676.	1672.	13348.
1054.	3-15-88	1100	0.36	0.00	0.00000	3-17	2400	10396.	1672.	12069.
892.	3-15-88	1200	0.36	0.00	0.00000	3-18	600	6927.	1672.	8599.
736.	3-15-88	1300	0.59	0.01	0.00000	3-18	1200	4804.	1672.	6476.
577.	3-15-88	1400	0.59	0.01	0.00000	3-18	1800	3703.	1672.	5376.
418.	3-15-88	1500	0.59	0.01	0.00000	3-18	2400	2806.	1672.	4479.
0.	3-15-88	1600	0.59	0.01	0.00000	3-19	600	2178.	1672.	3851.
	3-15-88	1700	0.59	0.01	0.00000	3-19	1200	1651.	1672.	3323.
	3-15-88	1800	0.59	0.01	0.00000	3-19	1800	1262.	1672.	2934.
	3-15-88	1900	0.88	0.07	0.00000	3-19	2400	871.	1672.	2544.
	3-15-88	2000	0.88	0.07	0.00000	3-20	600	424.	1672.	2096.
	3-15-88	2100	0.88	0.07	0.00000	3-20	1200	251.	1672.	1923.
	3-15-88	2200	0.88	0.07	0.00000	3-20	1800	159.	1672.	1831.
	3-15-88	2300	0.88	0.07	0.00000	3-20	2400	89.	1672.	1761.
	3-15-88	2400	0.88	0.07	0.00000	3-21	600	37.	1672.	1709.
	3-16-88	100	1.36	0.19	0.00000	3-21	1200	0.	1672.	1672.
	3-16-88	200	1.36	0.19	0.00000	3-21	1800	0.	1672.	1672.
	3-16-88	300	1.36	0.19	0.00001	3-21	2400	0.	1672.	1672.
	3-16-88	400	1.36	0.19	0.11334	3-22	600	0.	1672.	1673.
	3-16-88	500	1.36	0.19	0.18667	3-22	1200	2594.	1672.	4266.
	3-16-88	600	1.36	0.19	0.32501	3-22	1800	6192.	1672.	7864.
	3-16-88	700	2.05	0.49	0.78929	3-22	2400	11494.	1672.	13167.
	3-16-88	800	2.05	0.49	1.29405	3-23	600	25751.	1672.	27424.
	3-16-88	900	2.05	0.49	2.17167	3-23	1200	47270.	1672.	48943.

3-16-88	1000	2.05	0.49	0.77001	3-23	1800	81245.	1672.	82917.
3-16-88	1100	2.05	0.49	0.37000	3-23	2400	72136.	1672.	73808.
3-16-88	1200	2.05	0.49	0.30001	3-24	600	52516.	1672.	54189.
3-16-88	1300	3.29	1.26	0.30001	3-24	1200	43473.	1672.	45146.
3-16-88	1400	3.29	1.26	0.30001	3-24	1800	38146.	1672.	39818.
3-16-88	1500	3.29	1.26		3-24	2400	34062.	1672.	35735.
3-16-88	1600	3.29	1.26		3-25	600	23026.	1672.	24699.
3-16-88	1700	3.29	1.26		3-25	1200	15985.	1672.	17658.
3-16-88	1800	3.29	1.26		3-25	1800	12316.	1672.	13989.
3-16-88	1900	3.66	1.53		3-25	2400	9380.	1672.	11052.
3-16-88	2000	3.66	1.53		3-26	600	7218.	1672.	8890.
3-16-88	2100	3.66	1.53		3-26	1200	5383.	1672.	7055.
3-16-88	2200	3.66	1.53		3-26	1800	3980.	1672.	5653.
3-16-88	2300	3.66	1.53		3-26	2400	2638.	1672.	4311.
3-16-88	2400	3.66	1.53		3-27	600	1340.	1672.	3012.
3-17-88	100	3.82	1.64		3-27	1200	816.	1672.	2489.
3-17-88	200	3.82	1.64		3-27	1800	519.	1672.	2192.
3-17-88	300	3.82	1.64		3-27	2400	299.	1672.	1971.
3-17-88	400	3.82	1.64		3-28	600	125.	1672.	1798.
3-17-88	500	3.82	1.64		3-28	1200	0.	1672.	1672.
3-17-88	600	3.82	1.64						
3-17-88	700	3.96	1.74						
3-17-88	800	3.96	1.74						
3-17-88	900	3.96	1.74						
3-17-88	1000	3.96	1.74						
3-17-88	1100	3.96	1.74						
3-17-88	1200	3.96	1.74						
3-17-88	1300	4.08	1.83						
3-17-88	1400	4.08	1.83						
3-17-88	1500	4.08	1.83						
3-17-88	1600	4.08	1.83						
3-17-88	1700	4.08	1.83						
3-17-88	1800	4.08	1.83						
3-17-88	1900	4.19	1.92						
3-17-88	2000	4.19	1.92						
3-17-88	2100	4.19	1.92						
3-17-88	2200	4.19	1.92						
3-17-88	2300	4.19	1.92						
3-17-88	2400	4.19	1.92						
3-18-88	100	0.00	0.00						
3-18-88	200	0.00	0.00						
3-18-88	300	0.00	0.00						
3-18-88	400	0.00	0.00						
3-18-88	500	0.00	0.00						
3-18-88	600	0.00	0.00						
3-18-88	700	0.00	0.00						
3-18-88	800	0.00	0.00						
3-18-88	900	0.00	0.00						
3-18-88	1000	0.00	0.00						

3-18-88	1100	0.00	0.00
3-18-88	1200	0.00	0.00
3-18-88	1300	0.00	0.00
3-18-88	1400	0.00	0.00
3-18-88	1500	0.00	0.00
3-18-88	1600	0.00	0.00
3-18-88	1700	0.00	0.00
3-18-88	1800	0.00	0.00
3-18-88	1900	0.00	0.00
3-18-88	2000	0.00	0.00
3-18-88	2100	0.00	0.00
3-18-88	2200	0.00	0.00
3-18-88	2300	0.00	0.00
3-18-88	2400	0.00	0.00
3-19-88	100	0.00	0.00
3-19-88	200	0.00	0.00
3-19-88	300	0.00	0.00
3-19-88	400	0.00	0.00
3-19-88	500	0.00	0.00
3-19-88	600	0.00	0.00
3-19-88	700	0.00	0.00
3-19-88	800	0.00	0.00
3-19-88	900	0.00	0.00
3-19-88	1000	0.00	0.00
3-19-88	1100	0.00	0.00
3-19-88	1200	0.00	0.00
3-19-88	1300	0.00	0.00
3-19-88	1400	0.00	0.00
3-19-88	1500	0.00	0.00
3-19-88	1600	0.00	0.00
3-19-88	1700	0.00	0.00
3-19-88	1800	0.00	0.00
3-19-88	1900	0.00	0.00
3-19-88	2000	0.00	0.00
3-19-88	2100	0.00	0.00
3-19-88	2200	0.00	0.00
3-19-88	2300	0.00	0.00
3-19-88	2400	0.00	0.00
3-20-88	100	0.00	0.00
3-20-88	200	0.00	0.00
3-20-88	300	0.00	0.00
3-20-88	400	0.00	0.00
3-20-88	500	0.00	0.00
3-20-88	600	0.00	0.00
3-20-88	700	0.00	0.00
3-20-88	800	0.00	0.00
3-20-88	900	0.00	0.00
3-20-88	1000	0.00	0.00
3-20-88	1100	0.00	0.00

3-20-88	1200	0.00	0.00
3-20-88	1300	0.00	0.00
3-20-88	1400	0.00	0.00
3-20-88	1500	0.00	0.00
3-20-88	1600	0.00	0.00
3-20-88	1700	0.00	0.00
3-20-88	1800	0.00	0.00
3-20-88	1900	0.00	0.00
3-20-88	2000	0.00	0.00
3-20-88	2100	0.00	0.00
3-20-88	2200	0.00	0.00
3-20-88	2300	0.00	0.00
3-20-88	2400	0.00	0.00
3-21-88	100	0.00	0.00
3-21-88	200	0.00	0.00
3-21-88	300	0.00	0.00
3-21-88	400	0.00	0.00
3-21-88	500	0.00	0.00
3-21-88	600	0.00	0.00
3-21-88	700	0.00	0.00
3-21-88	800	0.00	0.00
3-21-88	900	0.00	0.00
3-21-88	1000	0.00	0.00
3-21-88	1100	0.00	0.00
3-21-88	1200	0.00	0.00
3-21-88	1300	0.00	0.00
3-21-88	1400	0.00	0.00
3-21-88	1500	0.00	0.00
3-21-88	1600	0.00	0.00
3-21-88	1700	0.00	0.00
3-21-88	1800	0.00	0.00
3-21-88	1900	0.00	0.00
3-21-88	2000	0.00	0.00
3-21-88	2100	0.00	0.00
3-21-88	2200	0.00	0.00
3-21-88	2300	0.00	0.00
3-21-88	2400	0.00	0.00
3-22-88	100	0.40	0.00
3-22-88	200	0.40	0.00
3-22-88	300	0.40	0.00
3-22-88	400	0.40	0.00
3-22-88	500	0.40	0.00
3-22-88	600	0.40	0.00
3-22-88	700	0.80	0.11
3-22-88	800	0.80	0.11
3-22-88	900	0.80	0.11
3-22-88	1000	0.80	0.11
3-22-88	1100	0.80	0.11
3-22-88	1200	0.80	0.11

3-22-88	1300	1.30	0.30
3-22-88	1400	1.30	0.30
3-22-88	1500	1.30	0.30
3-22-88	1600	1.30	0.30
3-22-88	1700	1.30	0.30
3-22-88	1800	1.30	0.30
3-22-88	1900	1.90	0.63
3-22-88	2000	1.90	0.63
3-22-88	2100	1.90	0.63
3-22-88	2200	1.90	0.63
3-22-88	2300	1.90	0.63
3-22-88	2400	1.90	0.63
3-23-88	100	3.00	1.41
3-23-88	200	3.00	1.41
3-23-88	300	3.00	1.41
3-23-88	400	3.00	1.41
3-23-88	500	3.00	1.41
3-23-88	600	3.00	1.41
3-23-88	700	4.60	2.71
3-23-88	800	4.60	2.71
3-23-88	900	4.60	2.71
3-23-88	1000	4.60	2.71
3-23-88	1100	4.60	2.71
3-23-88	1200	4.60	2.71
3-23-88	1300	7.00	4.88
3-23-88	1400	7.00	4.88
3-23-88	1500	7.00	4.88
3-23-88	1600	7.00	4.88
3-23-88	1700	7.00	4.88
3-23-88	1800	7.00	4.88
3-23-88	1900	7.80	5.65
3-23-88	2000	7.80	5.65
3-23-88	2100	7.80	5.65
3-23-88	2200	7.80	5.65
3-23-88	2300	7.80	5.65
3-23-88	2400	7.80	5.65
3-24-88	100	8.20	6.02
3-24-88	200	8.20	6.02
3-24-88	300	8.20	6.02
3-24-88	400	8.20	6.02
3-24-88	500	8.20	6.02
3-24-88	600	8.20	6.02
3-24-88	700	8.50	6.32
3-24-88	800	8.50	6.32
3-24-88	900	8.50	6.32
3-24-88	1000	8.50	6.32
3-24-88	1100	8.50	6.32
3-24-88	1200	8.50	6.32
3-24-88	1300	8.80	6.62

3-24-88	1400	8.80	6.62
3-24-88	1500	8.80	6.62
3-24-88	1600	8.80	6.62
3-24-88	1700	8.80	6.62
3-24-88	1800	8.80	6.62
3-24-88	1900	9.10	6.92
3-24-88	2000	9.10	6.92
3-24-88	2100	9.10	6.92
3-24-88	2200	9.10	6.92
3-24-88	2300	9.10	6.92
3-24-88	2400	9.10	6.92

1MARCH 21400 SQ. MI. TVA & ANTECEDENT ON CHEROKEE WSHD

FORT PAT LOCAL
DRAINAGE AREA = 63.00 SQUARE MILES

RAIN STATION	THIESSEN FACTOR	RECORDER	API		INITIAL USED		RI INITIAL USED		INITIAL USED	INITIAL USED
4	1.00	4	0.50	2.70	24TV	24TV	21TV	21TV		

AVERAGE SUBWATERSHED RAINFALL		SUBWATERSHED RUNOFF
FLOOD 1	4.19	2.49
FLOOD 2	9.20	7.79

UNIT GRAPH ORDINATES
DURATION - 6 HRS.
TIME INCR - 6 HRS.

	DATE	TIME	SUMMATION HOURLY RAIN	SUMMATION HOURLY RUNOFF	RUNOFF BLOCKED	DATE	TIME	SRO HYDROGRAPH	BASEFLOW	FLOOD HYDROGRAPH
0.	3-15-88	100	0.17	0.00	0.06072	3-15	1200	0.	158.	158.
2550.	3-15-88	200	0.17	0.00	0.10468	3-15	1800	155.	158.	312.
2000.	3-15-88	300	0.17	0.00	0.21462	3-15	2400	388.	158.	546.
600.	3-15-88	400	0.17	0.00	0.43429	3-16	600	793.	158.	951.
500.	3-15-88	500	0.17	0.00	0.93572	3-16	1200	1630.	158.	1787.
300.	3-15-88	600	0.17	0.00	0.30000	3-16	1800	3454.	158.	3611.
250.	3-15-88	700	0.36	0.00	0.12858	3-16	2400	3051.	158.	3208.
200.	3-15-88	800	0.36	0.00	0.11310	3-17	600	1809.	158.	1967.
180.	3-15-88	900	0.36	0.00	0.10834	3-17	1200	1409.	158.	1567.
150.	3-15-88	1000	0.36	0.00	0.09167	3-17	1800	1190.	158.	1347.
50.	3-15-88	1100	0.36	0.00	0.00000	3-17	2400	1051.	158.	1208.
0.	3-15-88	1200	0.36	0.00	0.00000	3-18	600	721.	158.	879.
	3-15-88	1300	0.59	0.06	0.00000	3-18	1200	480.	158.	637.
	3-15-88	1400	0.59	0.06	0.00000	3-18	1800	348.	158.	506.
	3-15-88	1500	0.59	0.06	0.00000	3-18	2400	192.	158.	350.
	3-15-88	1600	0.59	0.06	0.00000	3-19	600	99.	158.	257.
	3-15-88	1700	0.59	0.06	0.00000	3-19	1200	61.	158.	219.
	3-15-88	1800	0.59	0.06	0.00000	3-19	1800	38.	158.	196.
	3-15-88	1900	0.88	0.17	0.00000	3-19	2400	19.	158.	177.
	3-15-88	2000	0.88	0.17	0.00000	3-20	600	5.	158.	162.
	3-15-88	2100	0.88	0.17	0.00000	3-20	1200	0.	158.	158.
	3-15-88	2200	0.88	0.17	0.00000	3-20	1800	0.	158.	158.
	3-15-88	2300	0.88	0.17	0.00000	3-20	2400	0.	158.	158.
	3-15-88	2400	0.88	0.17	0.00000	3-21	600	0.	158.	158.
	3-16-88	100	1.36	0.38	0.00000	3-21	1200	0.	158.	158.
	3-16-88	200	1.36	0.38	0.00000	3-21	1800	0.	158.	158.
	3-16-88	300	1.36	0.38	0.05000	3-21	2400	0.	158.	158.
	3-16-88	400	1.36	0.38	0.19500	3-22	600	128.	158.	285.
	3-16-88	500	1.36	0.38	0.30501	3-22	1200	597.	158.	755.
	3-16-88	600	1.36	0.38	0.42143	3-22	1800	1198.	158.	1355.
	3-16-88	700	2.05	0.81	0.90858	3-22	2400	1827.	158.	1984.
	3-16-88	800	2.05	0.81	1.41000	3-23	600	3455.	158.	3613.
	3-16-88	900	2.05	0.81	2.40000	3-23	1200	5889.	158.	6047.

3-16-88	1000	2.05	0.81	0.80001	3-23	1800	9846.	158.	10004.
3-16-88	1100	2.05	0.81	0.40001	3-23	2400	8391.	158.	8548.
3-16-88	1200	2.05	0.81	0.30001	3-24	600	5247.	158.	5404.
3-16-88	1300	3.29	1.75	0.30001	3-24	1200	4066.	158.	4224.
3-16-88	1400	3.29	1.75	0.30001	3-24	1800	3391.	158.	3548.
3-16-88	1500	3.29	1.75		3-24	2400	3109.	158.	3267.
3-16-88	1600	3.29	1.75		3-25	600	2141.	158.	2299.
3-16-88	1700	3.29	1.75		3-25	1200	1369.	158.	1526.
3-16-88	1800	3.29	1.75		3-25	1800	970.	158.	1127.
3-16-88	1900	3.66	2.05		3-25	2400	537.	158.	695.
3-16-88	2000	3.66	2.05		3-26	600	289.	158.	447.
3-16-88	2100	3.66	2.05		3-26	1200	179.	158.	337.
3-16-88	2200	3.66	2.05		3-26	1800	114.	158.	272.
3-16-88	2300	3.66	2.05		3-26	2400	60.	158.	218.
3-16-88	2400	3.66	2.05		3-27	600	15.	158.	173.
3-17-88	100	3.82	2.18		3-27	1200	0.	158.	158.
3-17-88	200	3.82	2.18						
3-17-88	300	3.82	2.18						
3-17-88	400	3.82	2.18						
3-17-88	500	3.82	2.18						
3-17-88	600	3.82	2.18						
3-17-88	700	3.96	2.29						
3-17-88	800	3.96	2.29						
3-17-88	900	3.96	2.29						
3-17-88	1000	3.96	2.29						
3-17-88	1100	3.96	2.29						
3-17-88	1200	3.96	2.29						
3-17-88	1300	4.08	2.40						
3-17-88	1400	4.08	2.40						
3-17-88	1500	4.08	2.40						
3-17-88	1600	4.08	2.40						
3-17-88	1700	4.08	2.40						
3-17-88	1800	4.08	2.40						
3-17-88	1900	4.19	2.49						
3-17-88	2000	4.19	2.49						
3-17-88	2100	4.19	2.49						
3-17-88	2200	4.19	2.49						
3-17-88	2300	4.19	2.49						
3-17-88	2400	4.19	2.49						
3-18-88	100	0.00	0.00						
3-18-88	200	0.00	0.00						
3-18-88	300	0.00	0.00						
3-18-88	400	0.00	0.00						
3-18-88	500	0.00	0.00						
3-18-88	600	0.00	0.00						
3-18-88	700	0.00	0.00						
3-18-88	800	0.00	0.00						
3-18-88	900	0.00	0.00						
3-18-88	1000	0.00	0.00						

3-18-88	1100	0.00	0.00
3-18-88	1200	0.00	0.00
3-18-88	1300	0.00	0.00
3-18-88	1400	0.00	0.00
3-18-88	1500	0.00	0.00
3-18-88	1600	0.00	0.00
3-18-88	1700	0.00	0.00
3-18-88	1800	0.00	0.00
3-18-88	1900	0.00	0.00
3-18-88	2000	0.00	0.00
3-18-88	2100	0.00	0.00
3-18-88	2200	0.00	0.00
3-18-88	2300	0.00	0.00
3-18-88	2400	0.00	0.00
3-19-88	100	0.00	0.00
3-19-88	200	0.00	0.00
3-19-88	300	0.00	0.00
3-19-88	400	0.00	0.00
3-19-88	500	0.00	0.00
3-19-88	600	0.00	0.00
3-19-88	700	0.00	0.00
3-19-88	800	0.00	0.00
3-19-88	900	0.00	0.00
3-19-88	1000	0.00	0.00
3-19-88	1100	0.00	0.00
3-19-88	1200	0.00	0.00
3-19-88	1300	0.00	0.00
3-19-88	1400	0.00	0.00
3-19-88	1500	0.00	0.00
3-19-88	1600	0.00	0.00
3-19-88	1700	0.00	0.00
3-19-88	1800	0.00	0.00
3-19-88	1900	0.00	0.00
3-19-88	2000	0.00	0.00
3-19-88	2100	0.00	0.00
3-19-88	2200	0.00	0.00
3-19-88	2300	0.00	0.00
3-19-88	2400	0.00	0.00
3-20-88	100	0.00	0.00
3-20-88	200	0.00	0.00
3-20-88	300	0.00	0.00
3-20-88	400	0.00	0.00
3-20-88	500	0.00	0.00
3-20-88	600	0.00	0.00
3-20-88	700	0.00	0.00
3-20-88	800	0.00	0.00
3-20-88	900	0.00	0.00
3-20-88	1000	0.00	0.00
3-20-88	1100	0.00	0.00

3-20-88	1200	0.00	0.00
3-20-88	1300	0.00	0.00
3-20-88	1400	0.00	0.00
3-20-88	1500	0.00	0.00
3-20-88	1600	0.00	0.00
3-20-88	1700	0.00	0.00
3-20-88	1800	0.00	0.00
3-20-88	1900	0.00	0.00
3-20-88	2000	0.00	0.00
3-20-88	2100	0.00	0.00
3-20-88	2200	0.00	0.00
3-20-88	2300	0.00	0.00
3-20-88	2400	0.00	0.00
3-21-88	100	0.00	0.00
3-21-88	200	0.00	0.00
3-21-88	300	0.00	0.00
3-21-88	400	0.00	0.00
3-21-88	500	0.00	0.00
3-21-88	600	0.00	0.00
3-21-88	700	0.00	0.00
3-21-88	800	0.00	0.00
3-21-88	900	0.00	0.00
3-21-88	1000	0.00	0.00
3-21-88	1100	0.00	0.00
3-21-88	1200	0.00	0.00
3-21-88	1300	0.00	0.00
3-21-88	1400	0.00	0.00
3-21-88	1500	0.00	0.00
3-21-88	1600	0.00	0.00
3-21-88	1700	0.00	0.00
3-21-88	1800	0.00	0.00
3-21-88	1900	0.00	0.00
3-21-88	2000	0.00	0.00
3-21-88	2100	0.00	0.00
3-21-88	2200	0.00	0.00
3-21-88	2300	0.00	0.00
3-21-88	2400	0.00	0.00
3-22-88	100	0.40	0.05
3-22-88	200	0.40	0.05
3-22-88	300	0.40	0.05
3-22-88	400	0.40	0.05
3-22-88	500	0.40	0.05
3-22-88	600	0.40	0.05
3-22-88	700	0.80	0.25
3-22-88	800	0.80	0.25
3-22-88	900	0.80	0.25
3-22-88	1000	0.80	0.25
3-22-88	1100	0.80	0.25
3-22-88	1200	0.80	0.25

3-22-88	1300	1.30	0.55
3-22-88	1400	1.30	0.55
3-22-88	1500	1.30	0.55
3-22-88	1600	1.30	0.55
3-22-88	1700	1.30	0.55
3-22-88	1800	1.30	0.55
3-22-88	1900	1.90	0.97
3-22-88	2000	1.90	0.97
3-22-88	2100	1.90	0.97
3-22-88	2200	1.90	0.97
3-22-88	2300	1.90	0.97
3-22-88	2400	1.90	0.97
3-23-88	100	3.00	1.88
3-23-88	200	3.00	1.88
3-23-88	300	3.00	1.88
3-23-88	400	3.00	1.88
3-23-88	500	3.00	1.88
3-23-88	600	3.00	1.88
3-23-88	700	4.60	3.29
3-23-88	800	4.60	3.29
3-23-88	900	4.60	3.29
3-23-88	1000	4.60	3.29
3-23-88	1100	4.60	3.29
3-23-88	1200	4.60	3.29
3-23-88	1300	7.10	5.69
3-23-88	1400	7.10	5.69
3-23-88	1500	7.10	5.69
3-23-88	1600	7.10	5.69
3-23-88	1700	7.10	5.69
3-23-88	1800	7.10	5.69
3-23-88	1900	7.90	6.49
3-23-88	2000	7.90	6.49
3-23-88	2100	7.90	6.49
3-23-88	2200	7.90	6.49
3-23-88	2300	7.90	6.49
3-23-88	2400	7.90	6.49
3-24-88	100	8.30	6.89
3-24-88	200	8.30	6.89
3-24-88	300	8.30	6.89
3-24-88	400	8.30	6.89
3-24-88	500	8.30	6.89
3-24-88	600	8.30	6.89
3-24-88	700	8.60	7.19
3-24-88	800	8.60	7.19
3-24-88	900	8.60	7.19
3-24-88	1000	8.60	7.19
3-24-88	1100	8.60	7.19
3-24-88	1200	8.60	7.19
3-24-88	1300	8.90	7.49

3-24-88	1400	8.90	7.49
3-24-88	1500	8.90	7.49
3-24-88	1600	8.90	7.49
3-24-88	1700	8.90	7.49
3-24-88	1800	8.90	7.49
3-24-88	1900	9.20	7.79
3-24-88	2000	9.20	7.79
3-24-88	2100	9.20	7.79
3-24-88	2200	9.20	7.79
3-24-88	2300	9.20	7.79
3-24-88	2400	9.20	7.79

1MARCH 21400 SQ. MI. TVA & ANTECEDENT ON CHEROKEE WSHD

N.FK. HOLSTON R AT GATE CITY
DRAINAGE AREA = 672.00 SQUARE MILES

RAIN STATION	THIESSEN FACTOR	RECORDER	API		INITIAL USED		RI INITIAL USED		INITIAL USED	INITIAL USED
5	1.00	5	0.50	2.70	24TV	24TV	21TV	21TV		

AVERAGE SUBWATERSHED RAINFALL		SUBWATERSHED RUNOFF
FLOOD 1	4.19	2.49
FLOOD 2	8.10	6.69

UNIT GRAPH ORDINATES
DURATION - 6 HRS.
TIME INCR - 6 HRS.

	DATE	TIME	SUMMATION HOURLY RAIN	SUMMATION HOURLY RUNOFF	RUNOFF BLOCKED	DATE	TIME	SRO HYDROGRAPH	BASEFLOW	FLOOD HYDROGRAPH
0.	3-15-88	100	0.17	0.00	0.06072	3-15	1200	0.	1680.	1680.
1967.	3-15-88	200	0.17	0.00	0.10468	3-15	1800	119.	1680.	1799.
9510.	3-15-88	300	0.17	0.00	0.21462	3-15	2400	783.	1680.	2463.
9808.	3-15-88	400	0.17	0.00	0.43429	3-16	600	2013.	1680.	3693.
12265.	3-15-88	500	0.17	0.00	0.93572	3-16	1200	4667.	1680.	6347.
10528.	3-15-88	600	0.17	0.00	0.30000	3-16	1800	9999.	1680.	11679.
9535.	3-15-88	700	0.36	0.00	0.12858	3-16	2400	18062.	1680.	19742.
6305.	3-15-88	800	0.36	0.00	0.11310	3-17	600	21251.	1680.	22931.
3076.	3-15-88	900	0.36	0.00	0.10834	3-17	1200	23330.	1680.	25010.
2484.	3-15-88	1000	0.36	0.00	0.09167	3-17	1800	22048.	1680.	23728.
1892.	3-15-88	1100	0.36	0.00	0.00000	3-17	2400	19751.	1680.	21431.
1300.	3-15-88	1200	0.36	0.00	0.00000	3-18	600	15581.	1680.	17261.
1061.	3-15-88	1300	0.59	0.06	0.00000	3-18	1200	11100.	1680.	12780.
823.	3-15-88	1400	0.59	0.06	0.00000	3-18	1800	8663.	1680.	10343.
584.	3-15-88	1500	0.59	0.06	0.00000	3-18	2400	6536.	1680.	8216.
482.	3-15-88	1600	0.59	0.06	0.00000	3-19	600	4736.	1680.	6416.
380.	3-15-88	1700	0.59	0.06	0.00000	3-19	1200	3375.	1680.	5055.
278.	3-15-88	1800	0.59	0.06	0.00000	3-19	1800	2434.	1680.	4114.
0.	3-15-88	1900	0.88	0.17	0.00000	3-19	2400	1829.	1680.	3509.
	3-15-88	2000	0.88	0.17	0.00000	3-20	600	1391.	1680.	3071.
	3-15-88	2100	0.88	0.17	0.00000	3-20	1200	1023.	1680.	2703.
	3-15-88	2200	0.88	0.17	0.00000	3-20	1800	689.	1680.	2369.
	3-15-88	2300	0.88	0.17	0.00000	3-20	2400	325.	1680.	2005.
	3-15-88	2400	0.88	0.17	0.00000	3-21	600	184.	1680.	1864.
	3-16-88	100	1.36	0.38	0.00000	3-21	1200	117.	1680.	1797.
	3-16-88	200	1.36	0.38	0.00000	3-21	1800	65.	1680.	1745.
	3-16-88	300	1.36	0.38	0.05000	3-21	2400	25.	1680.	1705.
	3-16-88	400	1.36	0.38	0.19500	3-22	600	98.	1680.	1778.
	3-16-88	500	1.36	0.38	0.30501	3-22	1200	859.	1680.	2539.
	3-16-88	600	1.36	0.38	0.42143	3-22	1800	2945.	1680.	4625.
	3-16-88	700	2.05	0.81	0.81858	3-22	2400	6255.	1680.	7935.
	3-16-88	800	2.05	0.81	1.22000	3-23	600	11528.	1680.	13208.
	3-16-88	900	2.05	0.81	1.80000	3-23	1200	20589.	1680.	22269.

3-16-88	1000	2.05	0.81	0.78000	3-23	1800	33726.	1680.	35406.
3-16-88	1100	2.05	0.81	0.30001	3-23	2400	49386.	1680.	51066.
3-16-88	1200	2.05	0.81	0.30001	3-24	600	55909.	1680.	57589.
3-16-88	1300	3.29	1.75	0.30001	3-24	1200	57994.	1680.	59674.
3-16-88	1400	3.29	1.75	0.20001	3-24	1800	54185.	1680.	55865.
3-16-88	1500	3.29	1.75		3-24	2400	47384.	1680.	49064.
3-16-88	1600	3.29	1.75		3-25	600	37697.	1680.	39377.
3-16-88	1700	3.29	1.75		3-25	1200	27755.	1680.	29435.
3-16-88	1800	3.29	1.75		3-25	1800	21443.	1680.	23123.
3-16-88	1900	3.66	2.05		3-25	2400	16216.	1680.	17896.
3-16-88	2000	3.66	2.05		3-26	600	11732.	1680.	13412.
3-16-88	2100	3.66	2.05		3-26	1200	8276.	1680.	9956.
3-16-88	2200	3.66	2.05		3-26	1800	5979.	1680.	7659.
3-16-88	2300	3.66	2.05		3-26	2400	4482.	1680.	6162.
3-16-88	2400	3.66	2.05		3-27	600	3348.	1680.	5028.
3-17-88	100	3.82	2.18		3-27	1200	2400.	1680.	4080.
3-17-88	200	3.82	2.18		3-27	1800	1576.	1680.	3256.
3-17-88	300	3.82	2.18		3-27	2400	815.	1680.	2495.
3-17-88	400	3.82	2.18		3-28	600	459.	1680.	2139.
3-17-88	500	3.82	2.18		3-28	1200	294.	1680.	1974.
3-17-88	600	3.82	2.18		3-28	1800	159.	1680.	1839.
3-17-88	700	3.96	2.29		3-28	2400	56.	1680.	1736.
3-17-88	800	3.96	2.29		3-29	600	0.	1680.	1680.
3-17-88	900	3.96	2.29						
3-17-88	1000	3.96	2.29						
3-17-88	1100	3.96	2.29						
3-17-88	1200	3.96	2.29						
3-17-88	1300	4.08	2.40						
3-17-88	1400	4.08	2.40						
3-17-88	1500	4.08	2.40						
3-17-88	1600	4.08	2.40						
3-17-88	1700	4.08	2.40						
3-17-88	1800	4.08	2.40						
3-17-88	1900	4.19	2.49						
3-17-88	2000	4.19	2.49						
3-17-88	2100	4.19	2.49						
3-17-88	2200	4.19	2.49						
3-17-88	2300	4.19	2.49						
3-17-88	2400	4.19	2.49						
3-18-88	100	0.00	0.00						
3-18-88	200	0.00	0.00						
3-18-88	300	0.00	0.00						
3-18-88	400	0.00	0.00						
3-18-88	500	0.00	0.00						
3-18-88	600	0.00	0.00						
3-18-88	700	0.00	0.00						
3-18-88	800	0.00	0.00						
3-18-88	900	0.00	0.00						
3-18-88	1000	0.00	0.00						

3-18-88	1100	0.00	0.00
3-18-88	1200	0.00	0.00
3-18-88	1300	0.00	0.00
3-18-88	1400	0.00	0.00
3-18-88	1500	0.00	0.00
3-18-88	1600	0.00	0.00
3-18-88	1700	0.00	0.00
3-18-88	1800	0.00	0.00
3-18-88	1900	0.00	0.00
3-18-88	2000	0.00	0.00
3-18-88	2100	0.00	0.00
3-18-88	2200	0.00	0.00
3-18-88	2300	0.00	0.00
3-18-88	2400	0.00	0.00
3-19-88	100	0.00	0.00
3-19-88	200	0.00	0.00
3-19-88	300	0.00	0.00
3-19-88	400	0.00	0.00
3-19-88	500	0.00	0.00
3-19-88	600	0.00	0.00
3-19-88	700	0.00	0.00
3-19-88	800	0.00	0.00
3-19-88	900	0.00	0.00
3-19-88	1000	0.00	0.00
3-19-88	1100	0.00	0.00
3-19-88	1200	0.00	0.00
3-19-88	1300	0.00	0.00
3-19-88	1400	0.00	0.00
3-19-88	1500	0.00	0.00
3-19-88	1600	0.00	0.00
3-19-88	1700	0.00	0.00
3-19-88	1800	0.00	0.00
3-19-88	1900	0.00	0.00
3-19-88	2000	0.00	0.00
3-19-88	2100	0.00	0.00
3-19-88	2200	0.00	0.00
3-19-88	2300	0.00	0.00
3-19-88	2400	0.00	0.00
3-20-88	100	0.00	0.00
3-20-88	200	0.00	0.00
3-20-88	300	0.00	0.00
3-20-88	400	0.00	0.00
3-20-88	500	0.00	0.00
3-20-88	600	0.00	0.00
3-20-88	700	0.00	0.00
3-20-88	800	0.00	0.00
3-20-88	900	0.00	0.00
3-20-88	1000	0.00	0.00
3-20-88	1100	0.00	0.00

3-20-88	1200	0.00	0.00
3-20-88	1300	0.00	0.00
3-20-88	1400	0.00	0.00
3-20-88	1500	0.00	0.00
3-20-88	1600	0.00	0.00
3-20-88	1700	0.00	0.00
3-20-88	1800	0.00	0.00
3-20-88	1900	0.00	0.00
3-20-88	2000	0.00	0.00
3-20-88	2100	0.00	0.00
3-20-88	2200	0.00	0.00
3-20-88	2300	0.00	0.00
3-20-88	2400	0.00	0.00
3-21-88	100	0.00	0.00
3-21-88	200	0.00	0.00
3-21-88	300	0.00	0.00
3-21-88	400	0.00	0.00
3-21-88	500	0.00	0.00
3-21-88	600	0.00	0.00
3-21-88	700	0.00	0.00
3-21-88	800	0.00	0.00
3-21-88	900	0.00	0.00
3-21-88	1000	0.00	0.00
3-21-88	1100	0.00	0.00
3-21-88	1200	0.00	0.00
3-21-88	1300	0.00	0.00
3-21-88	1400	0.00	0.00
3-21-88	1500	0.00	0.00
3-21-88	1600	0.00	0.00
3-21-88	1700	0.00	0.00
3-21-88	1800	0.00	0.00
3-21-88	1900	0.00	0.00
3-21-88	2000	0.00	0.00
3-21-88	2100	0.00	0.00
3-21-88	2200	0.00	0.00
3-21-88	2300	0.00	0.00
3-21-88	2400	0.00	0.00
3-22-88	100	0.40	0.05
3-22-88	200	0.40	0.05
3-22-88	300	0.40	0.05
3-22-88	400	0.40	0.05
3-22-88	500	0.40	0.05
3-22-88	600	0.40	0.05
3-22-88	700	0.80	0.25
3-22-88	800	0.80	0.25
3-22-88	900	0.80	0.25
3-22-88	1000	0.80	0.25
3-22-88	1100	0.80	0.25
3-22-88	1200	0.80	0.25

3-22-88	1300	1.30	0.55
3-22-88	1400	1.30	0.55
3-22-88	1500	1.30	0.55
3-22-88	1600	1.30	0.55
3-22-88	1700	1.30	0.55
3-22-88	1800	1.30	0.55
3-22-88	1900	1.90	0.97
3-22-88	2000	1.90	0.97
3-22-88	2100	1.90	0.97
3-22-88	2200	1.90	0.97
3-22-88	2300	1.90	0.97
3-22-88	2400	1.90	0.97
3-23-88	100	2.90	1.79
3-23-88	200	2.90	1.79
3-23-88	300	2.90	1.79
3-23-88	400	2.90	1.79
3-23-88	500	2.90	1.79
3-23-88	600	2.90	1.79
3-23-88	700	4.30	3.01
3-23-88	800	4.30	3.01
3-23-88	900	4.30	3.01
3-23-88	1000	4.30	3.01
3-23-88	1100	4.30	3.01
3-23-88	1200	4.30	3.01
3-23-88	1300	6.20	4.81
3-23-88	1400	6.20	4.81
3-23-88	1500	6.20	4.81
3-23-88	1600	6.20	4.81
3-23-88	1700	6.20	4.81
3-23-88	1800	6.20	4.81
3-23-88	1900	7.00	5.59
3-23-88	2000	7.00	5.59
3-23-88	2100	7.00	5.59
3-23-88	2200	7.00	5.59
3-23-88	2300	7.00	5.59
3-23-88	2400	7.00	5.59
3-24-88	100	7.30	5.89
3-24-88	200	7.30	5.89
3-24-88	300	7.30	5.89
3-24-88	400	7.30	5.89
3-24-88	500	7.30	5.89
3-24-88	600	7.30	5.89
3-24-88	700	7.60	6.19
3-24-88	800	7.60	6.19
3-24-88	900	7.60	6.19
3-24-88	1000	7.60	6.19
3-24-88	1100	7.60	6.19
3-24-88	1200	7.60	6.19
3-24-88	1300	7.90	6.49

3-24-88	1400	7.90	6.49
3-24-88	1500	7.90	6.49
3-24-88	1600	7.90	6.49
3-24-88	1700	7.90	6.49
3-24-88	1800	7.90	6.49
3-24-88	1900	8.10	6.69
3-24-88	2000	8.10	6.69
3-24-88	2100	8.10	6.69
3-24-88	2200	8.10	6.69
3-24-88	2300	8.10	6.69
3-24-88	2400	8.10	6.69

1MARCH 21400 SQ. MI. TVA & ANTECEDENT ON CHEROKEE WSHD

HOLSTON RIVER AT SURGOINSVILLE
DRAINAGE AREA = 299.00 SQUARE MILES

RAIN STATION	THIESSEN FACTOR	RECORDER	API		INITIAL USED		RI INITIAL USED		INITIAL USED	INITIAL USED
6	1.00	6	0.50	2.70	24TV	24TV	21TV	21TV		

AVERAGE SUBWATERSHED RAINFALL		SUBWATERSHED RUNOFF
FLOOD 1	4.19	2.49
FLOOD 2	9.13	7.72

UNIT GRAPH ORDINATES
DURATION - 6 HRS.
TIME INCR - 2 HRS.

	DATE	TIME	SUMMATION HOURLY RAIN	SUMMATION HOURLY RUNOFF	RUNOFF BLOCKED	DATE	TIME	SRO HYDROGRAPH	BASEFLOW	FLOOD HYDROGRAPH
0.	3-15-88	100	0.17	0.00	0.06072	3-15	1200	0.	748.	748.
2200.	3-15-88	200	0.17	0.00	0.10468	3-15	1400	134.	748.	881.
4500.	3-15-88	300	0.17	0.00	0.21462	3-15	1600	273.	748.	1021.
7000.	3-15-88	400	0.17	0.00	0.43429	3-15	1800	425.	748.	1173.
8200.	3-15-88	500	0.17	0.00	0.93572	3-15	2000	728.	748.	1476.
9300.	3-15-88	600	0.17	0.00	0.30000	3-15	2200	1036.	748.	1783.
10300.	3-15-88	700	0.36	0.00	0.12858	3-15	2400	1358.	748.	2106.
8800.	3-15-88	800	0.36	0.00	0.11310	3-16	200	1865.	748.	2612.
6700.	3-15-88	900	0.36	0.00	0.10834	3-16	400	2346.	748.	3094.
5000.	3-15-88	1000	0.36	0.00	0.09167	3-16	600	2884.	748.	3632.
4600.	3-15-88	1100	0.36	0.00	0.00000	3-16	800	3916.	748.	4663.
4200.	3-15-88	1200	0.36	0.00	0.00000	3-16	1000	4907.	748.	5654.
3800.	3-15-88	1300	0.59	0.06	0.00000	3-16	1200	6005.	748.	6752.
3400.	3-15-88	1400	0.59	0.06	0.00000	3-16	1400	8196.	748.	8944.
2900.	3-15-88	1500	0.59	0.06	0.00000	3-16	1600	10303.	748.	11051.
2500.	3-15-88	1600	0.59	0.06	0.00000	3-16	1800	12646.	748.	13393.
2100.	3-15-88	1700	0.59	0.06	0.00000	3-16	2000	13625.	748.	14373.
1700.	3-15-88	1800	0.59	0.06	0.00000	3-16	2200	14270.	748.	15018.
1300.	3-15-88	1900	0.88	0.17	0.00000	3-16	2400	15066.	748.	15813.
1200.	3-15-88	2000	0.88	0.17	0.00000	3-17	200	13997.	748.	14745.
1100.	3-15-88	2100	0.88	0.17	0.00000	3-17	400	12329.	748.	13077.
1000.	3-15-88	2200	0.88	0.17	0.00000	3-17	600	11052.	748.	11800.
900.	3-15-88	2300	0.88	0.17	0.00000	3-17	800	10355.	748.	11103.
800.	3-15-88	2400	0.88	0.17	0.00000	3-17	1000	9433.	748.	10180.
700.	3-16-88	100	1.36	0.38	0.00000	3-17	1200	8684.	748.	9431.
600.	3-16-88	200	1.36	0.38	0.00000	3-17	1400	8159.	748.	8906.
500.	3-16-88	300	1.36	0.38	0.04167	3-17	1600	7463.	748.	8210.
400.	3-16-88	400	1.36	0.38	0.21389	3-17	1800	6922.	748.	7670.
300.	3-16-88	500	1.36	0.38	0.33195	3-17	2000	6457.	748.	7205.
200.	3-16-88	600	1.36	0.38	0.47679	3-17	2200	5892.	748.	6640.
100.	3-16-88	700	2.05	0.81	0.90239	3-17	2400	5411.	748.	6158.
100.	3-16-88	800	2.05	0.81	1.39334	3-18	200	4972.	748.	5720.
50.	3-16-88	900	2.05	0.81	2.36001	3-18	400	4444.	748.	5192.

0.	3-16-88	1000	2.05	0.81	0.81001	3-18	600	3963.	748.	4711.
	3-16-88	1100	2.05	0.81	0.34000	3-18	800	3497.	748.	4245.
	3-16-88	1200	2.05	0.81	0.31001	3-18	1000	2960.	748.	3707.
	3-16-88	1300	3.29	1.75	0.28000	3-18	1200	2470.	748.	3218.
	3-16-88	1400	3.29	1.75	0.26001	3-18	1400	2165.	748.	2913.
	3-16-88	1500	3.29	1.75		3-18	1600	1838.	748.	2586.
	3-16-88	1600	3.29	1.75		3-18	1800	1523.	748.	2270.
	3-16-88	1700	3.29	1.75		3-18	2000	1295.	748.	2042.
	3-16-88	1800	3.29	1.75		3-18	2200	1036.	748.	1784.
	3-16-88	1900	3.66	2.05		3-18	2400	787.	748.	1534.
	3-16-88	2000	3.66	2.05		3-19	200	685.	748.	1433.
	3-16-88	2100	3.66	2.05		3-19	400	537.	748.	1284.
	3-16-88	2200	3.66	2.05		3-19	600	388.	748.	1136.
	3-16-88	2300	3.66	2.05		3-19	800	344.	748.	1091.
	3-16-88	2400	3.66	2.05		3-19	1000	285.	748.	1032.
	3-17-88	100	3.82	2.18		3-19	1200	226.	748.	973.
	3-17-88	200	3.82	2.18		3-19	1400	194.	748.	942.
	3-17-88	300	3.82	2.18		3-19	1600	157.	748.	904.
	3-17-88	400	3.82	2.18		3-19	1800	119.	748.	866.
	3-17-88	500	3.82	2.18		3-19	2000	99.	748.	846.
	3-17-88	600	3.82	2.18		3-19	2200	73.	748.	821.
	3-17-88	700	3.96	2.29		3-19	2400	48.	748.	795.
	3-17-88	800	3.96	2.29		3-20	200	38.	748.	786.
	3-17-88	900	3.96	2.29		3-20	400	24.	748.	771.
	3-17-88	1000	3.96	2.29		3-20	600	9.	748.	757.
	3-17-88	1100	3.96	2.29		3-20	800	9.	748.	757.
	3-17-88	1200	3.96	2.29		3-20	1000	5.	748.	752.
	3-17-88	1300	4.08	2.40		3-20	1200	0.	748.	748.
	3-17-88	1400	4.08	2.40		3-20	1400	0.	748.	748.
	3-17-88	1500	4.08	2.40		3-20	1600	0.	748.	748.
	3-17-88	1600	4.08	2.40		3-20	1800	0.	748.	748.
	3-17-88	1700	4.08	2.40		3-20	2000	0.	748.	748.
	3-17-88	1800	4.08	2.40		3-20	2200	0.	748.	748.
	3-17-88	1900	4.19	2.49		3-20	2400	0.	748.	748.
	3-17-88	2000	4.19	2.49		3-21	200	0.	748.	748.
	3-17-88	2100	4.19	2.49		3-21	400	0.	748.	748.
	3-17-88	2200	4.19	2.49		3-21	600	0.	748.	748.
	3-17-88	2300	4.19	2.49		3-21	800	0.	748.	748.
	3-17-88	2400	4.19	2.49		3-21	1000	0.	748.	748.
	3-18-88	100	0.00	0.00		3-21	1200	0.	748.	748.
	3-18-88	200	0.00	0.00		3-21	1400	0.	748.	748.
	3-18-88	300	0.00	0.00		3-21	1600	0.	748.	748.
	3-18-88	400	0.00	0.00		3-21	1800	0.	748.	748.
	3-18-88	500	0.00	0.00		3-21	2000	0.	748.	748.
	3-18-88	600	0.00	0.00		3-21	2200	0.	748.	748.
	3-18-88	700	0.00	0.00		3-21	2400	0.	748.	748.
	3-18-88	800	0.00	0.00		3-22	200	92.	748.	839.
	3-18-88	900	0.00	0.00		3-22	400	188.	748.	935.
	3-18-88	1000	0.00	0.00		3-22	600	292.	748.	1039.

3-18-88	1100	0.00	0.00	3-22	800	812.	748.	1560.
3-18-88	1200	0.00	0.00	3-22	1000	1350.	748.	2098.
3-18-88	1300	0.00	0.00	3-22	1200	1926.	748.	2674.
3-18-88	1400	0.00	0.00	3-22	1400	2851.	748.	3598.
3-18-88	1500	0.00	0.00	3-22	1600	3762.	748.	4510.
3-18-88	1600	0.00	0.00	3-22	1800	4735.	748.	5483.
3-18-88	1700	0.00	0.00	3-22	2000	5845.	748.	6592.
3-18-88	1800	0.00	0.00	3-22	2200	6841.	748.	7588.
3-18-88	1900	0.00	0.00	3-22	2400	7984.	748.	8732.
3-18-88	2000	0.00	0.00	3-23	200	9942.	748.	10689.
3-18-88	2100	0.00	0.00	3-23	400	11738.	748.	12486.
3-18-88	2200	0.00	0.00	3-23	600	13804.	748.	14552.
3-18-88	2300	0.00	0.00	3-23	800	17002.	748.	17750.
3-18-88	2400	0.00	0.00	3-23	1000	19942.	748.	20690.
3-19-88	100	0.00	0.00	3-23	1200	23282.	748.	24030.
3-19-88	200	0.00	0.00	3-23	1400	28379.	748.	29127.
3-19-88	300	0.00	0.00	3-23	1600	32999.	748.	33746.
3-19-88	400	0.00	0.00	3-23	1800	38345.	748.	39092.
3-19-88	500	0.00	0.00	3-23	2000	40159.	748.	40906.
3-19-88	600	0.00	0.00	3-23	2200	40934.	748.	41682.
3-19-88	700	0.00	0.00	3-23	2400	42240.	748.	42988.
3-19-88	800	0.00	0.00	3-24	200	39253.	748.	40000.
3-19-88	900	0.00	0.00	3-24	400	34712.	748.	35459.
3-19-88	1000	0.00	0.00	3-24	600	31192.	748.	31939.
3-19-88	1100	0.00	0.00	3-24	800	29098.	748.	29846.
3-19-88	1200	0.00	0.00	3-24	1000	26376.	748.	27124.
3-19-88	1300	0.00	0.00	3-24	1200	24145.	748.	24893.
3-19-88	1400	0.00	0.00	3-24	1400	22606.	748.	23353.
3-19-88	1500	0.00	0.00	3-24	1600	20621.	748.	21368.
3-19-88	1600	0.00	0.00	3-24	1800	19033.	748.	19780.
3-19-88	1700	0.00	0.00	3-24	2000	17761.	748.	18509.
3-19-88	1800	0.00	0.00	3-24	2200	16210.	748.	16958.
3-19-88	1900	0.00	0.00	3-24	2400	14888.	748.	15636.
3-19-88	2000	0.00	0.00	3-25	200	13683.	748.	14430.
3-19-88	2100	0.00	0.00	3-25	400	12233.	748.	12980.
3-19-88	2200	0.00	0.00	3-25	600	10903.	748.	11651.
3-19-88	2300	0.00	0.00	3-25	800	9595.	748.	10342.
3-19-88	2400	0.00	0.00	3-25	1000	8075.	748.	8823.
3-20-88	100	0.00	0.00	3-25	1200	6691.	748.	7438.
3-20-88	200	0.00	0.00	3-25	1400	5860.	748.	6608.
3-20-88	300	0.00	0.00	3-25	1600	4957.	748.	5704.
3-20-88	400	0.00	0.00	3-25	1800	4081.	748.	4829.
3-20-88	500	0.00	0.00	3-25	2000	3483.	748.	4231.
3-20-88	600	0.00	0.00	3-25	2200	2790.	748.	3537.
3-20-88	700	0.00	0.00	3-25	2400	2122.	748.	2870.
3-20-88	800	0.00	0.00	3-26	200	1844.	748.	2592.
3-20-88	900	0.00	0.00	3-26	400	1448.	748.	2196.
3-20-88	1000	0.00	0.00	3-26	600	1052.	748.	1800.
3-20-88	1100	0.00	0.00	3-26	800	933.	748.	1681.

3-20-88	1200	0.00	0.00
3-20-88	1300	0.00	0.00
3-20-88	1400	0.00	0.00
3-20-88	1500	0.00	0.00
3-20-88	1600	0.00	0.00
3-20-88	1700	0.00	0.00
3-20-88	1800	0.00	0.00
3-20-88	1900	0.00	0.00
3-20-88	2000	0.00	0.00
3-20-88	2100	0.00	0.00
3-20-88	2200	0.00	0.00
3-20-88	2300	0.00	0.00
3-20-88	2400	0.00	0.00
3-21-88	100	0.00	0.00
3-21-88	200	0.00	0.00
3-21-88	300	0.00	0.00
3-21-88	400	0.00	0.00
3-21-88	500	0.00	0.00
3-21-88	600	0.00	0.00
3-21-88	700	0.00	0.00
3-21-88	800	0.00	0.00
3-21-88	900	0.00	0.00
3-21-88	1000	0.00	0.00
3-21-88	1100	0.00	0.00
3-21-88	1200	0.00	0.00
3-21-88	1300	0.00	0.00
3-21-88	1400	0.00	0.00
3-21-88	1500	0.00	0.00
3-21-88	1600	0.00	0.00
3-21-88	1700	0.00	0.00
3-21-88	1800	0.00	0.00
3-21-88	1900	0.00	0.00
3-21-88	2000	0.00	0.00
3-21-88	2100	0.00	0.00
3-21-88	2200	0.00	0.00
3-21-88	2300	0.00	0.00
3-21-88	2400	0.00	0.00
3-22-88	100	0.38	0.04
3-22-88	200	0.38	0.04
3-22-88	300	0.38	0.04
3-22-88	400	0.38	0.04
3-22-88	500	0.38	0.04
3-22-88	600	0.38	0.04
3-22-88	700	0.82	0.26
3-22-88	800	0.82	0.26
3-22-88	900	0.82	0.26
3-22-88	1000	0.82	0.26
3-22-88	1100	0.82	0.26
3-22-88	1200	0.82	0.26

3-26	1000	774.	748.	1521.
3-26	1200	614.	748.	1362.
3-26	1400	529.	748.	1277.
3-26	1600	427.	748.	1175.
3-26	1800	325.	748.	1073.
3-26	2000	271.	748.	1019.
3-26	2200	202.	748.	949.
3-26	2400	132.	748.	880.
3-27	200	106.	748.	854.
3-27	400	66.	748.	814.
3-27	600	26.	748.	774.
3-27	800	26.	748.	774.
3-27	1000	13.	748.	761.
3-27	1200	0.	748.	748.

3-22-88	1300	1.36	0.59
3-22-88	1400	1.36	0.59
3-22-88	1500	1.36	0.59
3-22-88	1600	1.36	0.59
3-22-88	1700	1.36	0.59
3-22-88	1800	1.36	0.59
3-22-88	1900	2.02	1.06
3-22-88	2000	2.02	1.06
3-22-88	2100	2.02	1.06
3-22-88	2200	2.02	1.06
3-22-88	2300	2.02	1.06
3-22-88	2400	2.02	1.06
3-23-88	100	3.10	1.97
3-23-88	200	3.10	1.97
3-23-88	300	3.10	1.97
3-23-88	400	3.10	1.97
3-23-88	500	3.10	1.97
3-23-88	600	3.10	1.97
3-23-88	700	4.68	3.36
3-23-88	800	4.68	3.36
3-23-88	900	4.68	3.36
3-23-88	1000	4.68	3.36
3-23-88	1100	4.68	3.36
3-23-88	1200	4.68	3.36
3-23-88	1300	7.13	5.72
3-23-88	1400	7.13	5.72
3-23-88	1500	7.13	5.72
3-23-88	1600	7.13	5.72
3-23-88	1700	7.13	5.72
3-23-88	1800	7.13	5.72
3-23-88	1900	7.94	6.53
3-23-88	2000	7.94	6.53
3-23-88	2100	7.94	6.53
3-23-88	2200	7.94	6.53
3-23-88	2300	7.94	6.53
3-23-88	2400	7.94	6.53
3-24-88	100	8.28	6.87
3-24-88	200	8.28	6.87
3-24-88	300	8.28	6.87
3-24-88	400	8.28	6.87
3-24-88	500	8.28	6.87
3-24-88	600	8.28	6.87
3-24-88	700	8.59	7.18
3-24-88	800	8.59	7.18
3-24-88	900	8.59	7.18
3-24-88	1000	8.59	7.18
3-24-88	1100	8.59	7.18
3-24-88	1200	8.59	7.18
3-24-88	1300	8.87	7.46

3-24-88	1400	8.87	7.46
3-24-88	1500	8.87	7.46
3-24-88	1600	8.87	7.46
3-24-88	1700	8.87	7.46
3-24-88	1800	8.87	7.46
3-24-88	1900	9.13	7.72
3-24-88	2000	9.13	7.72
3-24-88	2100	9.13	7.72
3-24-88	2200	9.13	7.72
3-24-88	2300	9.13	7.72
3-24-88	2400	9.13	7.72

1MARCH 21400 SQ. MI. TVA & ANTECEDENT ON CHEROKEE WSHD

CHEROKEE LOCAL
DRAINAGE AREA = 554.00 SQUARE MILES

RAIN STATION	THIESSEN FACTOR	RECORDER	API		INITIAL USED		RI INITIAL USED		INITIAL USED	INITIAL USED
7	1.00	7	0.50	2.70	24TV	24TV	21TV	21TV		

AVERAGE SUBWATERSHED RAINFALL		SUBWATERSHED RUNOFF
FLOOD 1	4.19	2.49
FLOOD 2	10.02	8.61

UNIT GRAPH ORDINATES
DURATION - 6 HRS.
TIME INCR - 6 HRS.

	DATE	TIME	SUMMATION HOURLY RAIN	SUMMATION HOURLY RUNOFF	RUNOFF BLOCKED	DATE	TIME	SRO HYDROGRAPH	BASEFLOW	FLOOD HYDROGRAPH
0.	3-15-88	100	0.17	0.00	0.06072	3-15	1200	0.	1385.	1385.
7425.	3-15-88	200	0.17	0.00	0.10468	3-15	1800	451.	1385.	1836.
18750.	3-15-88	300	0.17	0.00	0.21462	3-15	2400	1916.	1385.	3301.
11595.	3-15-88	400	0.17	0.00	0.43429	3-16	600	4260.	1385.	5645.
7100.	3-15-88	500	0.17	0.00	0.93572	3-16	1200	8894.	1385.	10279.
5100.	3-15-88	600	0.17	0.00	0.30000	3-16	1800	18632.	1385.	20017.
3800.	3-15-88	700	0.36	0.00	0.12858	3-16	2400	27096.	1385.	28481.
2700.	3-15-88	800	0.36	0.00	0.11310	3-17	600	22169.	1385.	23554.
1700.	3-15-88	900	0.36	0.00	0.10834	3-17	1200	16789.	1385.	18174.
1000.	3-15-88	1000	0.36	0.00	0.09167	3-17	1800	13787.	1385.	15172.
450.	3-15-88	1100	0.36	0.00	0.00000	3-17	2400	11691.	1385.	13076.
0.	3-15-88	1200	0.36	0.00	0.00000	3-18	600	9100.	1385.	10485.
	3-15-88	1300	0.59	0.06	0.00000	3-18	1200	5829.	1385.	7214.
	3-15-88	1400	0.59	0.06	0.00000	3-18	1800	3621.	1385.	5006.
	3-15-88	1500	0.59	0.06	0.00000	3-18	2400	2124.	1385.	3509.
	3-15-88	1600	0.59	0.06	0.00000	3-19	600	1097.	1385.	2482.
	3-15-88	1700	0.59	0.06	0.00000	3-19	1200	603.	1385.	1988.
	3-15-88	1800	0.59	0.06	0.00000	3-19	1800	315.	1385.	1700.
	3-15-88	1900	0.88	0.17	0.00000	3-19	2400	140.	1385.	1525.
	3-15-88	2000	0.88	0.17	0.00000	3-20	600	41.	1385.	1426.
	3-15-88	2100	0.88	0.17	0.00000	3-20	1200	0.	1385.	1385.
	3-15-88	2200	0.88	0.17	0.00000	3-20	1800	0.	1385.	1385.
	3-15-88	2300	0.88	0.17	0.00000	3-20	2400	0.	1385.	1385.
	3-15-88	2400	0.88	0.17	0.00000	3-21	600	0.	1385.	1385.
	3-16-88	100	1.36	0.38	0.00000	3-21	1200	0.	1385.	1385.
	3-16-88	200	1.36	0.38	0.00000	3-21	1800	0.	1385.	1385.
	3-16-88	300	1.36	0.38	0.05000	3-21	2400	0.	1385.	1385.
	3-16-88	400	1.36	0.38	0.23334	3-22	600	371.	1385.	1756.
	3-16-88	500	1.36	0.38	0.36667	3-22	1200	2670.	1385.	4055.
	3-16-88	600	1.36	0.38	0.50834	3-22	1800	7677.	1385.	9062.
	3-16-88	700	2.05	0.81	0.99167	3-22	2400	13710.	1385.	15095.
	3-16-88	800	2.05	0.81	1.51667	3-23	600	23058.	1385.	24443.
	3-16-88	900	2.05	0.81	2.76334	3-23	1200	39733.	1385.	41118.

3-16-88	1000	2.05	0.81	0.88001	3-23	1800	66955.	1385.	68340.
3-16-88	1100	2.05	0.81	0.37000	3-23	2400	87674.	1385.	89059.
3-16-88	1200	2.05	0.81	0.34001	3-24	600	70483.	1385.	71868.
3-16-88	1300	3.29	1.75	0.31001	3-24	1200	53041.	1385.	54426.
3-16-88	1400	3.29	1.75	0.28000	3-24	1800	43085.	1385.	44470.
3-16-88	1500	3.29	1.75		3-24	2400	35904.	1385.	37289.
3-16-88	1600	3.29	1.75		3-25	600	27749.	1385.	29134.
3-16-88	1700	3.29	1.75		3-25	1200	17624.	1385.	19009.
3-16-88	1800	3.29	1.75		3-25	1800	10802.	1385.	12187.
3-16-88	1900	3.66	2.05		3-25	2400	6277.	1385.	7662.
3-16-88	2000	3.66	2.05		3-26	600	3245.	1385.	4630.
3-16-88	2100	3.66	2.05		3-26	1200	1790.	1385.	3175.
3-16-88	2200	3.66	2.05		3-26	1800	939.	1385.	2324.
3-16-88	2300	3.66	2.05		3-26	2400	420.	1385.	1805.
3-16-88	2400	3.66	2.05		3-27	600	126.	1385.	1511.
3-17-88	100	3.82	2.18		3-27	1200	0.	1385.	1385.
3-17-88	200	3.82	2.18						
3-17-88	300	3.82	2.18						
3-17-88	400	3.82	2.18						
3-17-88	500	3.82	2.18						
3-17-88	600	3.82	2.18						
3-17-88	700	3.96	2.29						
3-17-88	800	3.96	2.29						
3-17-88	900	3.96	2.29						
3-17-88	1000	3.96	2.29						
3-17-88	1100	3.96	2.29						
3-17-88	1200	3.96	2.29						
3-17-88	1300	4.08	2.40						
3-17-88	1400	4.08	2.40						
3-17-88	1500	4.08	2.40						
3-17-88	1600	4.08	2.40						
3-17-88	1700	4.08	2.40						
3-17-88	1800	4.08	2.40						
3-17-88	1900	4.19	2.49						
3-17-88	2000	4.19	2.49						
3-17-88	2100	4.19	2.49						
3-17-88	2200	4.19	2.49						
3-17-88	2300	4.19	2.49						
3-17-88	2400	4.19	2.49						
3-18-88	100	0.00	0.00						
3-18-88	200	0.00	0.00						
3-18-88	300	0.00	0.00						
3-18-88	400	0.00	0.00						
3-18-88	500	0.00	0.00						
3-18-88	600	0.00	0.00						
3-18-88	700	0.00	0.00						
3-18-88	800	0.00	0.00						
3-18-88	900	0.00	0.00						
3-18-88	1000	0.00	0.00						

3-18-88	1100	0.00	0.00
3-18-88	1200	0.00	0.00
3-18-88	1300	0.00	0.00
3-18-88	1400	0.00	0.00
3-18-88	1500	0.00	0.00
3-18-88	1600	0.00	0.00
3-18-88	1700	0.00	0.00
3-18-88	1800	0.00	0.00
3-18-88	1900	0.00	0.00
3-18-88	2000	0.00	0.00
3-18-88	2100	0.00	0.00
3-18-88	2200	0.00	0.00
3-18-88	2300	0.00	0.00
3-18-88	2400	0.00	0.00
3-19-88	100	0.00	0.00
3-19-88	200	0.00	0.00
3-19-88	300	0.00	0.00
3-19-88	400	0.00	0.00
3-19-88	500	0.00	0.00
3-19-88	600	0.00	0.00
3-19-88	700	0.00	0.00
3-19-88	800	0.00	0.00
3-19-88	900	0.00	0.00
3-19-88	1000	0.00	0.00
3-19-88	1100	0.00	0.00
3-19-88	1200	0.00	0.00
3-19-88	1300	0.00	0.00
3-19-88	1400	0.00	0.00
3-19-88	1500	0.00	0.00
3-19-88	1600	0.00	0.00
3-19-88	1700	0.00	0.00
3-19-88	1800	0.00	0.00
3-19-88	1900	0.00	0.00
3-19-88	2000	0.00	0.00
3-19-88	2100	0.00	0.00
3-19-88	2200	0.00	0.00
3-19-88	2300	0.00	0.00
3-19-88	2400	0.00	0.00
3-20-88	100	0.00	0.00
3-20-88	200	0.00	0.00
3-20-88	300	0.00	0.00
3-20-88	400	0.00	0.00
3-20-88	500	0.00	0.00
3-20-88	600	0.00	0.00
3-20-88	700	0.00	0.00
3-20-88	800	0.00	0.00
3-20-88	900	0.00	0.00
3-20-88	1000	0.00	0.00
3-20-88	1100	0.00	0.00

3-20-88	1200	0.00	0.00
3-20-88	1300	0.00	0.00
3-20-88	1400	0.00	0.00
3-20-88	1500	0.00	0.00
3-20-88	1600	0.00	0.00
3-20-88	1700	0.00	0.00
3-20-88	1800	0.00	0.00
3-20-88	1900	0.00	0.00
3-20-88	2000	0.00	0.00
3-20-88	2100	0.00	0.00
3-20-88	2200	0.00	0.00
3-20-88	2300	0.00	0.00
3-20-88	2400	0.00	0.00
3-21-88	100	0.00	0.00
3-21-88	200	0.00	0.00
3-21-88	300	0.00	0.00
3-21-88	400	0.00	0.00
3-21-88	500	0.00	0.00
3-21-88	600	0.00	0.00
3-21-88	700	0.00	0.00
3-21-88	800	0.00	0.00
3-21-88	900	0.00	0.00
3-21-88	1000	0.00	0.00
3-21-88	1100	0.00	0.00
3-21-88	1200	0.00	0.00
3-21-88	1300	0.00	0.00
3-21-88	1400	0.00	0.00
3-21-88	1500	0.00	0.00
3-21-88	1600	0.00	0.00
3-21-88	1700	0.00	0.00
3-21-88	1800	0.00	0.00
3-21-88	1900	0.00	0.00
3-21-88	2000	0.00	0.00
3-21-88	2100	0.00	0.00
3-21-88	2200	0.00	0.00
3-21-88	2300	0.00	0.00
3-21-88	2400	0.00	0.00
3-22-88	100	0.40	0.05
3-22-88	200	0.40	0.05
3-22-88	300	0.40	0.05
3-22-88	400	0.40	0.05
3-22-88	500	0.40	0.05
3-22-88	600	0.40	0.05
3-22-88	700	0.87	0.28
3-22-88	800	0.87	0.28
3-22-88	900	0.87	0.28
3-22-88	1000	0.87	0.28
3-22-88	1100	0.87	0.28
3-22-88	1200	0.87	0.28

3-22-88	1300	1.45	0.65
3-22-88	1400	1.45	0.65
3-22-88	1500	1.45	0.65
3-22-88	1600	1.45	0.65
3-22-88	1700	1.45	0.65
3-22-88	1800	1.45	0.65
3-22-88	1900	2.14	1.16
3-22-88	2000	2.14	1.16
3-22-88	2100	2.14	1.16
3-22-88	2200	2.14	1.16
3-22-88	2300	2.14	1.16
3-22-88	2400	2.14	1.16
3-23-88	100	3.32	2.15
3-23-88	200	3.32	2.15
3-23-88	300	3.32	2.15
3-23-88	400	3.32	2.15
3-23-88	500	3.32	2.15
3-23-88	600	3.32	2.15
3-23-88	700	5.01	3.67
3-23-88	800	5.01	3.67
3-23-88	900	5.01	3.67
3-23-88	1000	5.01	3.67
3-23-88	1100	5.01	3.67
3-23-88	1200	5.01	3.67
3-23-88	1300	7.84	6.43
3-23-88	1400	7.84	6.43
3-23-88	1500	7.84	6.43
3-23-88	1600	7.84	6.43
3-23-88	1700	7.84	6.43
3-23-88	1800	7.84	6.43
3-23-88	1900	8.72	7.31
3-23-88	2000	8.72	7.31
3-23-88	2100	8.72	7.31
3-23-88	2200	8.72	7.31
3-23-88	2300	8.72	7.31
3-23-88	2400	8.72	7.31
3-24-88	100	9.09	7.68
3-24-88	200	9.09	7.68
3-24-88	300	9.09	7.68
3-24-88	400	9.09	7.68
3-24-88	500	9.09	7.68
3-24-88	600	9.09	7.68
3-24-88	700	9.43	8.02
3-24-88	800	9.43	8.02
3-24-88	900	9.43	8.02
3-24-88	1000	9.43	8.02
3-24-88	1100	9.43	8.02
3-24-88	1200	9.43	8.02
3-24-88	1300	9.74	8.33

3-24-88	1400	9.74	8.33
3-24-88	1500	9.74	8.33
3-24-88	1600	9.74	8.33
3-24-88	1700	9.74	8.33
3-24-88	1800	9.74	8.33
3-24-88	1900	10.02	8.61
3-24-88	2000	10.02	8.61
3-24-88	2100	10.02	8.61
3-24-88	2200	10.02	8.61
3-24-88	2300	10.02	8.61
3-24-88	2400	10.02	8.61

BASIN AVERAGE RAINFALL	RUNOFF
12.94	9.39

APPENDIX H – EXAMPLE FLDHYDRO FLOOD HYDROGRAPH OUTPUT FILE

The following is an example of the flood hydrograph output file produced by running FLDHYDRO with the input data given in the example presented in Appendix F. This is the file "Holston.hyd" entered in the dialog box described in Section 3.2. Data from this file is formatted to be used as input to other programs.

```
    56       6
  1770.    1770.    2681.    4069.    7217.   13142.   25932.   27633.   28847.   23779.
 19618.   16317.   12637.    9912.    7408.    5729.    4470.    3679.    3157.    2731.
  2402.    2141.    1959.    1879.    1830.    1799.    1779.    1770.    2520.    5295.
  9485.   15372.   26294.   41320.   62501.   66800.   64419.   54440.   44865.   36949.
 28344.   21497.   15406.   11307.    8332.    6379.    5066.    4037.    3231.    2636.
  2243.    2040.    1920.    1840.    1790.    1770.
    53       6
  1170.    1170.    1263.    1890.    3500.    6875.   15372.   20977.   16132.   10799.
  8560.    8129.    6583.    4341.    3188.    2649.    2299.    1926.    1623.    1404.
  1306.    1250.    1210.    1184.    1170.    1170.    1170.    1170.    1170.    2263.
  4977.    8723.   16122.   29515.   50193.   59197.   44132.   29041.   23312.   21516.
 16335.   10121.    6960.    5466.    4347.    3231.    2383.    1806.    1535.    1386.
  1275.    1202.    1170.
    54       6
  1672.    1672.    1893.    3141.    5623.   11116.   25818.   24285.   17601.   14923.
 13348.   12069.    8599.    6476.    5376.    4479.    3851.    3323.    2934.    2544.
  2096.    1923.    1831.    1761.    1709.    1672.    1672.    1672.    1673.    4266.
  7864.   13167.   27424.   48943.   82917.   73808.   54189.   45146.   39818.   35735.
 24699.   17658.   13989.   11052.    8890.    7055.    5653.    4311.    3012.    2489.
  2192.    1971.    1798.    1672.
    50       6
   158.     158.     312.     546.     951.    1787.    3611.    3208.    1967.    1567.
  1347.    1208.     879.     637.     506.     350.     257.     219.     196.     177.
   162.     158.     158.     158.     158.     158.     158.     158.     285.     755.
  1355.    1984.    3613.    6047.   10004.    8548.    5404.    4224.    3548.    3267.
  2299.    1526.    1127.     695.     447.     337.     272.     218.     173.     158.
    57       6
  1680.    1680.    1799.    2463.    3693.    6347.   11679.   19742.   22931.   25010.
 23728.   21431.   17261.   12780.   10343.    8216.    6416.    5055.    4114.    3509.
  3071.    2703.    2369.    2005.    1864.    1797.    1745.    1705.    1778.    2539.
  4625.    7935.   13208.   22269.   35406.   51066.   57589.   59674.   55865.   49064.
 39377.   29435.   23123.   17896.   13412.    9956.    7659.    6162.    5028.    4080.
  3256.    2495.    2139.    1974.    1839.    1736.    1680.
   148       2
   748.     748.     748.     748.     881.    1021.    1173.    1476.    1783.    2106.
  2612.    3094.    3632.    4663.    5654.    6752.    8944.   11051.   13393.   14373.
 15018.   15813.   14745.   13077.   11800.   11103.   10180.    9431.    8906.    8210.
  7670.    7205.    6640.    6158.    5720.    5192.    4711.    4245.    3707.    3218.
  2913.    2586.    2270.    2042.    1784.    1534.    1433.    1284.    1136.    1091.
  1032.     973.     942.     904.     866.     846.     821.     795.     786.     771.
   757.     757.     752.     748.     748.     748.     748.     748.     748.     748.
   748.     748.     748.     748.     748.     748.     748.     748.     748.     748.
   748.     748.     839.     935.    1039.    1560.    2098.    2674.    3598.    4510.
  5483.    6592.    7588.    8732.   10689.   12486.   14552.   17750.   20690.   24030.
 29127.   33746.   39092.   40906.   41682.   42988.   40000.   35459.   31939.   29846.
 27124.   24893.   23353.   21368.   19780.   18509.   16958.   15636.   14430.   12980.
 11651.   10342.    8823.    7438.    6608.    5704.    4829.    4231.    3537.    2870.
  2592.    2196.    1800.    1681.    1521.    1362.    1277.    1175.    1073.    1019.
   949.     880.     854.     814.     774.     774.     761.     748.
    50       6
  1385.    1385.    1836.    3301.    5645.   10279.   20017.   28481.   23554.   18174.
 15172.   13076.   10485.    7214.    5006.    3509.    2482.    1988.    1700.    1525.
  1426.    1385.    1385.    1385.    1385.    1385.    1385.    1385.    1756.    4055.
  9062.   15095.   24443.   41118.   68340.   89059.   71868.   54426.   44470.   37289.
 29134.   19009.   12187.    7662.    4630.    3175.    2324.    1805.    1511.    1385.
```

APPENDIX I – LISTING OF THE CHANROUT SOURCE CODE

```
C        ***********************************************************************
C        *
C        *        CHANROUT - QA REV1.0 - 11/04/2008
C        *
C        ***********************************************************************
C
C     THIS PROGRAM COMPUTES THE COEFFICIENTS OF AN ARMA (AUTOREGRESSIVE
C     MOVING AVERAGE) CHANNEL ROUTING MODEL OF WHICH THE MUSKINGUM
C     ROUTING EQUATION IS A SPECIAL CASE.  AN ARMA(P,Q) CHANNEL ROUTING
C     MODEL COMPUTES CURRENT OUTFLOW OUT OF A REACH AS A LINEAR
C     COMBINATION OF THE PREVIOUS P OUTFLOWS, PLUS THE PREVIOUS Q
C     INFLOWS AND CURRENT INFLOW INTO A REACH AS SHOWN BELOW.
C     (ARMA(1,1) IS EQUIVALENT TO THE MUSKINGUM ROUTING EQUATION.)
C
C          O(T) = A1*O(T-R) + A2*O(T-2*R) + ... + AP*O(T-P*R) +
C                 B0*I(T) + B1*I(T-R) + ... + BQ*I(T-Q*R)
C
C
C     THE COEFFICIENTS (A1,A2,...AP,B0,B1,...BQ) ARE OBTAINED BY
C     SOLVING THE FOLLOWING 2 EQUATIONS
C
C          A1 + A2 + ... + AP + B0 + B1 + ... + BQ = 1
C
C          DT*D*C = L + DT*Q      (LAGRANGIAN)
C
C     WHERE:
C
C         °¯O(T-R)    O(T-2*R) ... O(T-P*R)    I(T) I(T-R) ... I(T-Q*R) ¯°
C     D = ° O(T-R+1) O(T-2*R+1) . O(T-P*R+1) I(T+1) ...      I(T-Q*R+1) °
C         °   :          :        :     :        :    ...         :      °
C         ° O(M-R)    O(M-2*R) ... O(M-P*R)    I(M) I(M-R) ... I(M-Q*R)  °
C          ^                                                            ^
C
C                                          °¯A1¯°            °¯L¯°
C                 °¯O(T)   ¯°              ° A2 °            ° L °
C                 ° O(T+1) °               ° :  °            ° L °
C             Q = °  .     °          C = ° AP °        L = ° L °
C                 °  .     °              ° B0 °            °  . °
C                 °  .     °              ° B1 °            °  . °
C                 ° O(M)   °              ° :  °            °  . °
C                  ^      ^                ° BQ °            ° L °
C                                           ^  ^              ^ ^
C      AND:
C
C             DT ------- TRANSPOSE MATRIX OF D
C             L -------- LAGRANGIAN MULTIPLIER
C             R -------- ROUTING PERIOD DIVIDED BY FLOW INTERVAL
C             O(T-P*R) - FIRST OUTFLOW IF P &gt;= Q
C             I(T-Q*R) - ((P-Q)*R+1)TH INFLOW IF P &gt;= Q
C             I(T-Q*R) - FIRST INFLOW IF P &lt;= Q
C             O(T-P*R) - ((Q-P)*R+1)TH OUTFLOW IF P &lt;= Q
C             I(M) ----- LAST INFLOW
C
C
C     FOR THE MUSKINGUM ROUTING EQUATION TO BE PROPERLY APPLIED, THE
C     ROUTNG PERIOD MUST BE AT LEAST AS LONG AS THE APPROXIMATE TRAVEL
```

```
C     TIME THRU THE REACH.  ALSO, SUDDEN SURGES OR INCREASES IN INFLOWS
C     DO NOT ATTENUATE CORRECTLY DOWNSTREAM IF THE FLOW INTERVAL DOES
C     NOT EQUAL THE ROUTING PERIOD.  A HIGHER DEGREE ARMA CHANNEL
C     ROUTING MODEL (E.G., ARMA(3,2)) MAY ELIMINATE THESE "TIMING"
C     PROBLEMS, AS WELL AS BE MORE ACCURATE THAN THE SIMPLE MUSKINGUM
C     ROUTING EQUATION.
C
C
C
      INTEGER IBKPTS,OBKPTS,NFLOWS,DELTA,MXBPTS,NCOEFS,SHIFT,POINT
      REAL TIMINT,RP,CSUM,LSUM,LAMBDA
      REAL INFLO(300),OUTFLO(300),CMPFLO(300),DT(21,299),DTD(21,21)
      REAL COEFS(21,2),CCOEFS(21),LCOEFS(21)
      CHARACTER*80 TITLE
C
C
C     INPUT VARIABLES:
C
C          TITLE -- DESCRIPTION OF CHANNEL REACH
C          IBKPTS - NO. OF PREVIOUS INFLOWS (Q ABOVE) TO BE USED
C                   IN THE ARMA ROUTING MODEL. (MAX. IS 20-OBKPTS)
C          OBKPTS - NO. OF PREVIOUS OUTFLOWS (P ABOVE) TO BE USED
C                   IN THE ARMA ROUTING MODEL. (MAX. IS 20-IBKPTS)
C          NFLOWS - NO. OF INFLOWS/OUTFLOWS TO BE INPUT (M ABOVE) FOR
C                   COMPUTING THE COEFFICIENTS OF THE ARMA MODEL.
C                   (MAX. IS 200)
C          TIMINT - INFLOW/OUTFLOW TIME INTERVAL IN HOURS.
C          RP ----- ROUTING PERIOD IN HOURS.
C          INFLO -- INFLOWS INTO THE CHANNEL REACH.
C          OUTFLO - OUTFLOWS OUT OF THE CHANNEL REACH.
C
C
C     OUTPUT VARIABLES:
C
C          CCOEFS - COEFFICIENTS OF ARMA MODEL WITH OUTFLOW
C                   COEFFICIENTS FIRST (C VECTOR ABOVE).
C          CMPFLO - OUTFLOWS AS COMPUTED BY ARMA MODEL.
C
C
C     OTHER VARIABLES:
C
C          DELTA -- ROUTING PERIOD DIVIDED BY FLOW INTERVAL (R ABOVE)
C          MXBPTS - LARGER OF P &amp; Q
C          NCOEFS - TOTAL NO. OF COEFFICIENTS (P+Q+1)
C          SHIFT -- LARGER OF P*R &amp; Q*R
C          LAMBDA - LAGRANGIAN MULTIPLIER (L ABOVE)
C          DT ----- TRANSPOSE OF D MATRIX ABOVE
C          DTD ---- DT*D
C
C
      CHARACTER*80 INFILE,OUTFIL
      EQUIVALENCE (COEFS(1,1),CCOEFS),(COEFS(1,2),LCOEFS)
      DATA LCOEFS/21*1.0/
C
      WRITE (*,'('' Channel Routing Input File:  ''\)')
      READ (*,'(A)') INFILE
      WRITE (*,'('' List File (Type "PRN" for Printer):  ''\)')
      READ (*,'(A)') OUTFIL
      OPEN (5,FILE=INFILE)
      OPEN (6,FILE=OUTFIL)
```

```
C************* Change Revision Number Here *******************
      WRITE (6,1)
    1 FORMAT (" CHANROUT - QA REV1.0 - 11/04/2008"/)
C*************************************************************
C
C     INPUT REACH DESCRIPTION
C
      READ (5,100) TITLE
  100 FORMAT (A80)
      WRITE (6,120) TITLE
  120 FORMAT(1X,A80)
C
C     READ AND VALIDATE INPUT PARAMETERS
C
      READ (5,140) IBKPTS,OBKPTS,NFLOWS,TIMINT,RP
  140 FORMAT (3I8,2F8.0)
      WRITE (6,160) IBKPTS,OBKPTS,NFLOWS,TIMINT,RP
  160 FORMAT (1X,3I8,2F8.1)
      NCOEFS = IBKPTS + OBKPTS + 1
      DELTA = INT(RP/TIMINT)
      MXBPTS = MAX(IBKPTS,OBKPTS)
      SHIFT = MXBPTS * DELTA
      IF ( IBKPTS .LT. 1 .OR. OBKPTS .LT. 1 .OR. NCOEFS .GT. 21 )
     *   GO TO 910
      IF ( DELTA*TIMINT .NE. RP ) GO TO 920
      IF ( NFLOWS .LT. SHIFT ) GO TO 930
      IF ( NFLOWS .GT. 300 ) GO TO 940
C
C     READ IN INFLOWS & OUTFLOWS
C
      READ (5,180) (INFLO(I),I=1,NFLOWS)
  180 FORMAT (10F8.0)
      WRITE (6,200) (INFLO(I),I=1,NFLOWS)
  200 FORMAT (1X,10F8.0)
      READ (5,180) (OUTFLO(I),I=1,NFLOWS)
      WRITE (6,200) (OUTFLO(I),I=1,NFLOWS)
C
C     SET UP D TRANSPOSE MATRIX (DT)
C
      DO 300 I = 1,NFLOWS-SHIFT
         DO 220 J = 1,OBKPTS
            DT(J,I) = OUTFLO((MXBPTS-J)*DELTA+I)
  220    CONTINUE
         DO 240 J = OBKPTS+1,NCOEFS
            DT(J,I) = INFLO((OBKPTS+MXBPTS-J+1)*DELTA+I)
  240    CONTINUE
  300 CONTINUE
C
C     COMPUTE DT*D
C
      DO 350 I = 1,NCOEFS
      DO 350 J = 1,NCOEFS
         DTD(I,J) = 0.0
         DO 320 K = 1,NFLOWS-SHIFT
            DTD(I,J) = DTD(I,J) + DT(I,K) * DT(J,K)
  320    CONTINUE
  350 CONTINUE
C
C     COMPUTE DT*Q
C
```

```
      DO 400 I = 1,NCOEFS
         CCOEFS(I) = 0.0
         DO 380 K = 1,NFLOWS-SHIFT
            CCOEFS(I) = CCOEFS(I) + DT(I,K) * OUTFLO(K+SHIFT)
  380    CONTINUE
  400 CONTINUE
C
C     DETERMINE VECTORS LCOEFS &amp; CCOEFS SUCH THAT
C     C = LCOEFS*L + CCOEFS
C
      CALL XATEQ(21,DTD,COEFS,NCOEFS,2)
C
C     COMPUTE L (LAMBDA)
C
      CSUM = 0.0
      LSUM = 0.0
      DO 500 I = 1,NCOEFS
         CSUM = CSUM + CCOEFS(I)
         LSUM = LSUM + LCOEFS(I)
  500 CONTINUE
      IF ( LSUM .NE. 0.0 ) LAMBDA = ( 1.0 - CSUM ) / LSUM
C
C     COMPUTE COEFFICIENT MATRIX C (CCOEFS)
C
      DO 600 I = 1,NCOEFS
         CCOEFS(I) = CCOEFS(I) + LCOEFS(I) * LAMBDA
  600 CONTINUE
C
C     OUTPUT ROUTING EQUATION
C
      WRITE (6,700)
  700 FORMAT (//' ROUTING EQUATION'//5X,'O(T) ='/)
      DO 740 I = 1,OBKPTS
         POINT = INT(I*DELTA)
         WRITE (6,720) CCOEFS(I),POINT
  720    FORMAT (1X,F7.4,'*O(T-',I2,')'/8X,'+')
  740 CONTINUE
      WRITE (6,760) CCOEFS(OBKPTS+1)
  760 FORMAT (1X,F7.4,'*I(T)')
      DO 800 I = OBKPTS+2,NCOEFS
         POINT = INT((I-OBKPTS-1)*DELTA)
         WRITE (6,780) CCOEFS(I),POINT
  780    FORMAT (8X,'+'/1X,F7.4,'*I(T-',I2,')')
  800 CONTINUE
C
C     OUTPUT COMPARISON BETWEEN OBSERVED OUTFLOWS &amp; COMPUTED OUTFLOWS
C
      WRITE (6,820)
  820 FORMAT ('1',31X,'COMPUTED'/3X,'T',6X,'INFLOW',5X,'OUTFLOW',5X,
     *        'OUTFLOW'/)
      DO 900 I = 1,NFLOWS
         IF ( I .EQ. 1 ) THEN
            CMPFLO(I) = OUTFLO(I)
         ELSE
            CMPFLO(I) = CCOEFS(OBKPTS+1) * INFLO(I)
            DO 840 J = 1,OBKPTS
               IPTR = MAX(1,I-J*DELTA)
               CMPFLO(I) = CMPFLO(I) + CCOEFS(J) * CMPFLO(IPTR)
  840       CONTINUE
            DO 860 J = OBKPTS+2,NCOEFS
```

```
                IPTR = MAX(1,I-(J-OBKPTS-1)*DELTA)
                CMPFLO(I) = CMPFLO(I) + CCOEFS(J) * INFLO(IPTR)
  860       CONTINUE
          END IF
          WRITE (6,880) I,INFLO(I),OUTFLO(I),CMPFLO(I)
  880     FORMAT (1X,I3,5X,F7.0,5X,F7.0,5X,F7.0)
  900 CONTINUE
C
      GO TO 999
C
  910 CONTINUE
      WRITE (6,915) IBKPTS,OBKPTS
  915 FORMAT (' 1 - 10 BACK POINTS ALLOWED:  IBKPTS = ',I4,
     *        '; OBKPTS = ',I4)
      GO TO 990
C
  920 CONTINUE
      WRITE (6,925) RP,TIMINT
  925 FORMAT (' ROUTING PERIOD MUST BE A MULTIPLE OF TIME INCREMENT:'/
     *        6X,'RP = ',F4.1,'; TIMINT = ',F4.1)
      GO TO 990
C
  930 CONTINUE
      WRITE (6,935) SHIFT,NFLOWS
  935 FORMAT (' AT LEAST ',I3,' FLOWS MUST BE SPECIFIED FOR VIABLE ',
     *        'COMPUTATIONS:  NFLOWS = ',I4)
      GO TO 990
C
  940 CONTINUE
      WRITE (6,945) NFLOWS
  945 FORMAT (' MAX. NO. OF FLOWS IS 200:  NFLOWS = ',I4)
C
  990 CONTINUE
      STOP 4
C
  999 CONTINUE
      STOP
      END
      SUBROUTINE XATEQ(L,A,B,N,M)
C
C     ROUTINE SOLVES SYSTEM OF LINEAR EQUATIONS:
C
C           A*X = B
C
      DIMENSION A(L,1),B(L,1)
      IFLG=0
      I1=1
  100 XFACT=0.0
      DO 10 I=I1,N
      DO 10 J=1,N
      IF(A(I,J)-XFACT)10,10,1
    1 XFACT=A(I,J)
      IB=I
      JB=J
   10 CONTINUE
      IF(IFLG) 1701,1701,17
 1701 DO 11 J=1,N
      STOR=A(I1,J)
      A(I1,J)=A(IB,J)
      A(IB,J)=STOR
```

```
   11 CONTINUE
      IF(M) 201,201,200
  200 DO 12 J=1,M
      STOR=B(I1,J)
      B(I1,J)=B(IB,J)
      B(IB,J)=STOR
   12 CONTINUE
  201 I1=I1+1
      DO 16 I=I1,N
      XFACT=-(A(I,JB)/A(I1-1,JB))
      DO 14 J=1,N
      A(I,J)=A(I,J)+A(I1-1,J)*XFACT
   14 CONTINUE
      IF(M) 203,203,202
  202 DO 15 J=1,M
      B(I,J)=B(I,J)+B(I1-1,J)*XFACT
   15 CONTINUE
  203 A(I,JB)=0.0
   16 CONTINUE
      IF(I1-N)100,1700,1700
 1700 IFLG=1
      GO TO 100
   17 IF(M) 290,290,170
  170 N1=N
   23 DO 18 J=1,N
      IF(A(N1,J))19,18,19
   18 CONTINUE
   19 N2=N1-1
      DO 21 J1=1,M
      XFACT=B(N1,J1)/A(N1,J)
      B(N1,J1)=XFACT
      IF(N2) 21,21,210
  210 DO 20 I=1,N2
      B(I,J1)=B(I,J1)-XFACT*A(I,J)
   20 CONTINUE
   21 CONTINUE
      IF(N2  ) 25,25,220
  220 DO 22 I=1,N2
      A(I,J)=0.0
   22 CONTINUE
      N1=N1-1
      GO TO 23
   25 DO 29 I1=1,N
   28 DO 30 I=I1,N
      IF( ABS(A(I,I1))) 30,30,26
   30 CONTINUE
   26 DO 27 J=1,M
      STOR=B(I,J)
      B(I,J)=B(I1,J)
      B(I1,J)=STOR
   27 CONTINUE
      DO 300 J=1,N
      STOR=A(I,J)
      A(I,J)=A(I1,J)
      A(I1,J)=STOR
  300 CONTINUE
   29 CONTINUE
  290 RETURN
      END
```

APPENDIX J – EXAMPLE CHANROUT INPUT FILE

An example of a typical CHANROUT input data file is presented below. It is for the Yangtze River.

```
YANGTZE RIVER FLOOD OF 1974
       2       3      35      24      24
     179     182     257     365     387     357     305     284     353     391
     392     383     368     360     483     654     677     568     475     378
     296     239     232     331     452     495     429     363     353     382
     355     313     275     250     250
     179     180     181     237     327     363     354     318     302     351
     383     384     370     363     388     479     584     610     563     478
     389     315     260     245     303     395     438     412     386     361
     363     349     318     287     268
```

APPENDIX K – EXAMPLE CHANROUT OUTPUT FILE

The main output file (written out in Unit 6) produced by running CHANROUT for the example in Appendix J is listed below.

```
CHANROUT - QA REV1.0 - 11/04/2008

 YANGTZE RIVER FLOOD OF 1974
        2       3      35    24.0    24.0
     179.    182.    257.    365.    387.    357.    305.    284.    353.    391.
     392.    383.    368.    360.    483.    654.    677.    568.    475.    378.
     296.    239.    232.    331.    452.    495.    429.    363.    353.    382.
     355.    313.    275.    250.    250.
     179.    180.    181.    237.    327.    363.    354.    318.    302.    351.
     383.    384.    370.    363.    388.    479.    584.    610.    563.    478.
     389.    315.    260.    245.    303.    395.    438.    412.    386.    361.
     363.    349.    318.    287.    268.


 ROUTING EQUATION

     O(T) =

  0.9275*O(T- 1)
        +
 -0.2494*O(T- 2)
        +
  0.0217*O(T- 3)
        +
  0.1860*I(T)
        +
  0.3292*I(T- 1)
        +
 -0.2150*I(T- 2)
1                                  COMPUTED
   T       INFLOW      OUTFLOW      OUTFLOW

   1         179.        179.         179.
   2         182.        180.         180.
   3         257.        181.         195.
   4         365.        237.         253.
   5         387.        327.         327.
   6         357.        363.         360.
   7         305.        354.         349.
   8         284.        318.         317.
   9         353.        302.         309.
  10         391.        351.         343.
  11         392.        383.         373.
  12         383.        384.         384.
  13         368.        370.         381.
  14         360.        363.         371.
  15         483.        388.         387.
  16         654.        479.         478.
  17         677.        584.         592.
  18         568.        610.         626.
  19         475.        563.         573.
  20         378.        478.         493.
  21         296.        389.         405.
  22         239.        315.         326.
```

23	232.	260.	270.
24	331.	245.	265.
25	452.	303.	328.
26	495.	395.	414.
27	429.	438.	453.
28	363.	412.	427.
29	353.	386.	385.
30	382.	361.	369.
31	355.	363.	372.
32	313.	349.	354.
33	275.	318.	322.
34	250.	287.	288.
35	250.	268.	264.

APPENDIX L – LISTING OF THE TRBROUTE SOURCE CODE

```
C         ***********************************************************************
C         *
C         *        TRBROUTE - QA REV1.1 - 08/07/2009
C         *
C         ***********************************************************************
C
C      THE TRIBUTARY ROUTING PROGRAM PERFORMS THE CHANNEL AND
C      RESERVOIR ROUTINGS NECESSARY TO ROUTE FLOOD HYDROGRAPHS
C      THRU RESERVOIR NETWORKS, INCLUDING THE MAJOR TRIBUTARY
C      DAM SYSTEMS.  DISCHARGE RATING CURVES DEFINING THE IMPROVED
C      FIXED RULES OF THE MAJOR TRIBUTARY DAMS ARE HANDLED BY
C      THIS PROGRAM.  ARMA TYPE CHANNEL ROUTINGS ARE USED.
C
C
C
C      1987 REVISIONS:
C
C           1. INPUT HYDROGRAPHS CAN OPTIONALLY COME FROM ANOTHER
C              FILE GENERATED BY THE FLOOD HYDROLOGY PROGRAM.
C
C           2. INDIVIDUAL RESERVOIR RELEASES CAN OPTIONALLY BE
C              INPUT INSTEAD OF RATING CURVES
C
C
C      1988 REVISIONS:
C
C           1. IMPROVED FIXED RULE DISCHARGE RATING CURVES FOR THE
C              MAJOR TRIBUTARY DAMS ARE AUTOMATICALLY COMPUTED BY
C              THE PROGRAM.
C
C           2. STORAGE CURVES AND DAMS WITH FIXED DISCHARGE RATING
C              CURVES CAN BE STORED ON SEPARATE DISK FILES FOR
C              ACCESS BY THE PROGRAM.
C
C           3. THE PROGRAM CAN HANDLE MULTIPLE STORM SEQUENCES
C              (UP TO 3 STORMS) WITH MULTIPLE STARTING RESERVOIR
C              ELEVATIONS FOR APPLYING IMPROVED FIXED RULES, OR A
C              DIFFERENT DISCHARGE RATING CURVE FOR EACH STORM.
C
C           4. THE MOST DOWNSTREAM (I.E., FINAL) OUTPUT HYDROGRAPH
C              CAN BE STORED ON A DISK FILE FOR LATER PROCESSING
C              (OPTION).
C
C           5. SEASONAL GUIDES CAN NOW BE USED TO DETERMINE INITIAL
C              ELEVATIONS AS WELL AS DRAWDOWN (OPTION).
C
C           6. AN END-OF-ROUTING DATE AND TIME CAN BE SPECIFIED TO
C              DEFINE A ROUTING PERIOD BEYOND THE LENGTH OF THE
C              LONGEST INPUT HYDROGRAPH (OPTION). THE LAST ORDINATE
C              IS USED TO "FILL OUT" HYDROGRAPHS TO THE REQUIRED
C              LENGTH.
C
C           7. INPUT HYDROGRAPH INTERVALS AND CHANNEL ROUTING
C              PERIODS NO LONGER NEED TO BE INTEGER MULTIPLES OF
C              EACH OTHER.  LINEAR INTERPOLATION WILL BE USED TO
C              COMBINE HYDROGRAPHS.
```

```
C
C          8. INPUTTING THE RESERVOIR ROUTING PERIOD IS NOW
C             OPTIONAL.  IF NOT SPECIFIED, THE CURRENT HYDROGRAPH
C             INTERVAL IS USED.
C
C          9. IF FOR A MAJOR TRIBUTARY DAM, THE EMPTYING RATE IS
C             GREATER THAN THE MOST RECENT RELEASE BEFORE THE
C             EMPTYING RATE IS TO GO INTO EFFECT, THAT "MOST
C             RECENT RELEASE" BECOMES THE EMPTYING RATE.
C
C         10. IF FOR A MAJOR TRIBUTARY DAM, THE HEADWATER CRESTS
C             ABOVE TOP-OF-GATES, THEN DISCHARGE WILL FOLLOW THE
C             RATING CURVE UNTIL TOP-OF-GATES IS REACHED, AT
C             WHICH TIME THE TOP-OF-GATES ELEVATION WILL BE HELD
C             UNTIL DISCHARGE RECEDES TO THE EMPTYING RATE.
C
C         11. IF FOR A MAJOR TRIBUTARY DAM, MAXIMUM INFLOW
C             OCCURS BEFORE THE NORMAL UPPER LIMIT ELEVATION IS
C             REACHED, AND HOLDING DISCHARGE UNTIL HEADWATER
C             CRESTS BRINGS THE HEADWATER TO TOP-OF-GATES, THEN
C             DISCHARGES WILL FOLLOW RATING CURVE WHEN NORMAL
C             UPPER LIMIT ELEVATION IS REACHED.
C
C         12. FOR A MAJOR TRIBUTARY DAM WITH A MULTIPLE STORM
C             SEQUENCE, THE DISCHARGE USED AT THE END OF THE
C             FIRST (SECOND) STORM WILL BE USED AS THE INITIAL
C             DISCHARGE (UNTIL THE RATING CURVE IS "REACHED")
C             AT THE BEGINNING OF THE SECOND (THIRD) STORM.
C
C         13. CHANNEL ROUTING ALLOWS MULTIPLE BACKPOINTS VIA AN
C             ARMA(P,Q) MODEL WHERE P IS THE NUMBER OF OUTFLOW
C             BACKPOINTS AND Q IS THE NUMBER OF INFLOW BACKPOINTS
C             (ARMA(1,1) IS THE MUSKINGUM ROUTING MODEL).
C
C
C     2009 REVISIONS:
C
C          1. THE PROGRAM CAN HANDLE UP TO 9 STORMS.
C
C
      COMMON /TABLES/ DMO(12),MODAYS(12)
      INTEGER DMO,MODAYS
C
      COMMON /PARMS/ NSTRMS,NIC,IC(100),HI(25),NORD(25),RP(10),
     *               RATCOD(9,10),INDIVQ(10),SEASON(10),HYDIN,HYDOUT
      INTEGER NSTRMS,NIC,IC,NORD,RATCOD
      REAL HI,RP
      LOGICAL INDIVQ,SEASON,HYDIN,HYDOUT
C
      COMMON /TIMES/ SDATES(9),EDATE,STIMES(9),ETIME,NUMHRS(9),TOTHRS
      INTEGER SDATES,EDATE
      INTEGER STIMES,ETIME
      REAL NUMHRS,TOTHRS
C
      COMMON /NAMES/ ANAMES(25)
      CHARACTER*80 ANAMES
C
      COMMON /RATING/ ELEV(50,10),STO(50,10),QRAT(50,9,10),FEL(10),
     *                FOUT(10),QEMPTY(10),NUL(10),TOG(10)
      REAL ELEV,STO,QRAT,FEL,FOUT,QEMPTY,NUL,TOG
```

```
C
      COMMON /DISCH/ DSCHRG(800,10),NDSCHR(10),DSCHTM(10)
      REAL DSCHRG,DSCHTM
      INTEGER NDSCHR
C
      COMMON /RESRVR/ RSVRNM(10),RRPTR,NPTS(10),EL(800),OUT(800)
      CHARACTER RSVRNM*16
      INTEGER RRPTR,NPTS
      REAL EL,OUT
C
      COMMON /CHANEL/ IBKPTS(30),OBKPTS(30),CRP(30),C(21,30)
      INTEGER IBKPTS,OBKPTS
      REAL CRP,C
C
      COMMON /HYDRGR/ CHANNL,WRKHI,WKNORD,HYDWRK(800),DSCWRK(800),UPDSCH
      REAL WRKHI,HYDWRK,DSCWRK
      INTEGER CHANNL
      INTEGER WKNORD
      LOGICAL UPDSCH
C
      CHARACTER*240 INFILE,OUTFIL,IHGFIL,OHGFIL
         COMMON /FILES/INFILE,OUTFIL,IHGFIL,OHGFIL
C
      INTEGER INHYD,OUTHYD,ENDATE,CODES(6),NPRINS,NSCRC,NRR,NTH
      INTEGER RATCRV,STOCOD,SGUIDE,SVNPTS,STMPTR,NUMPTS
      REAL SVELEV(50),QELEV(50),SHOURS(9),EHOURS
      LOGICAL ENDPER,USRRAT,USRSTO,DSKRAT
      CHARACTER TITLE*80
      CHARACTER*240 TBLFIL
       INTEGER*2 ARGONE,LTH,LENGTH
      INTEGER NDAYS
C
      EQUIVALENCE (CODES(1),NTH),(CODES(2),NRR),(CODES(3),NSCRC),
     *            (CODES(6),NPRINS)
C
      DATA CODES/6*0/
C
       ARGONE = 1
      CALL GETARG (ARGONE, TBLFIL, LTH)
C
C     OPEN ALL LOOKUP TABLES
C
       IF ( LTH .LT. 0 ) THEN
         WRITE (TBLFIL(1:240),'("STORAGES")')
       ELSE
         WRITE (TBLFIL(LTH+1:240),'("\STORAGES")')
       END IF
      OPEN(UNIT=8,FILE=TBLFIL,STATUS='OLD')

       IF ( LTH .LT. 0 ) THEN
         WRITE (TBLFIL(1:240),'("QRATINGS")')
       ELSE
         WRITE (TBLFIL(LTH+1:240),'("\QRATINGS")')
       END IF
      OPEN(UNIT=9,FILE=TBLFIL,STATUS='OLD')

       IF ( LTH .LT. 0 ) THEN
         WRITE (TBLFIL(1:240),'("IMPRULES")')
       ELSE
         WRITE (TBLFIL(LTH+1:240),'("\IMPRULES")')
```

```
      END IF
      OPEN(UNIT=10,FILE=TBLFIL,STATUS='OLD')

      IF ( LTH .LT. 0 ) THEN
        WRITE (TBLFIL(1:240),'("SGUIDES")')
      ELSE
        WRITE (TBLFIL(LTH+1:240),'("\SGUIDES")')
      END IF
      OPEN(UNIT=11,FILE=TBLFIL,STATUS='OLD')

      IF ( NARGS() .LE. 2 ) THEN
            CALL DoDialog( )
      ELSE
            ARGONE = 2
            CALL GETARG(ARGONE,INFILE,LENGTH)
      END IF
      OPEN (5,FILE=INFILE)
C
C     READ IN OUTPUT LISTING TITLE
C
      READ (5,10) TITLE
   10 FORMAT (A80)
C
C     READ IN NO. OF STORMS (NSTRMS), INPUT HYDROGRAPH FLAG (INHYD),
C     OUTPUT HYDROGRAPH FLAG (OUTHYD), AND ENDING DATE FLAG (ENDATE)
C
      READ (5,30) NSTRMS,INHYD,OUTHYD,ENDATE
   30 FORMAT (20I4)
      HYDIN = INHYD .NE. 0
C**** CHANNL = OUTHYD
      HYDOUT = OUTHYD .NE. 0
      ENDPER = ENDATE .NE. 0
C
      IF ( HYDIN ) THEN
          IF ( NARGS() .GT. 2 ) THEN
            WRITE (*,'('' Hydrograph(s) Input File:  ''\)')
            READ (*,'(A)') IHGFIL
          END IF
         OPEN (2,FILE=IHGFIL,STATUS='OLD')
      END IF
C
      IF ( HYDOUT ) THEN
          IF ( NARGS() .GT. 2 ) THEN
            WRITE (*,'('' Hydrograph(s) Output File:  ''\)')
            READ (*,'(A)') OHGFIL
          END IF
         OPEN (3,FILE=OHGFIL)
      END IF
C
      IF ( NARGS() .GT. 2 ) THEN
            WRITE (*,'('' List File (Type "PRN" for Printer):  ''\)')
            READ (*,'(A)') OUTFIL
      END IF
      OPEN (6,FILE=OUTFIL)
C************* Change Revision Number Here *******************
      WRITE (6,1)
    1 FORMAT (" TRBROUTE - QA REV1.1 - 08/07/2009"/)
C*************************************************************
C
      WRITE (6,20) TITLE
```

```
   20 FORMAT ('1',A80//)
      WRITE (6,40) NSTRMS,INHYD,OUTHYD,ENDATE
   40 FORMAT (1X,20I4)
C
      IF ( NSTRMS .LT. 1 .OR. NSTRMS .GT. 9 ) GO TO 910
C
C
C     READ IN STARTING DATE(S) AND TIME(S) OF EACH STORM,
C     PLUS OPTIONAL ENDING DATE
C
      IF ( ENDPER ) THEN
         READ (5,50) (SDATES(I),I=1,NSTRMS),EDATE
   50    FORMAT (10I8)
         WRITE (6,52) (SDATES(I),I=1,NSTRMS),EDATE
         READ (5,50) (STIMES(I),I=1,NSTRMS),ETIME
         WRITE (6,54) (STIMES(I),I=1,NSTRMS),ETIME
   52    FORMAT (1X,10I8.6)
   54    FORMAT (1X,10I8.4)
   60    FORMAT (1X,10I8)
      ELSE
         READ (5,50) (SDATES(I),I=1,NSTRMS)
         WRITE (6,52) (SDATES(I),I=1,NSTRMS)
         READ (5,50) (STIMES(I),I=1,NSTRMS)
         WRITE (6,54) (STIMES(I),I=1,NSTRMS)
      END IF
      IF ( MOD(SDATES(1),4) .EQ. 0 ) DMO(2) = 229
C
C     READ IN INSTRUCTIONS CODES
C
      READ (5,30) NIC,(IC(I),I=1,NIC)
      WRITE (6,40) NIC,(IC(I),I=1,NIC)
      DO 70 I = 1,NIC
         IF ( IC(I) .LT. 1 .OR. IC(I) .GT. 6 ) GO TO 920
         CODES(IC(I)) = CODES(IC(I)) + 1
   70 CONTINUE
C
C     READ IN DESCRIPTION OF EACH ROUTING OUTPUT
C
      READ (5,10) (ANAMES(I),I=1,NPRINS)
      WRITE (6,80) (ANAMES(I),I=1,NPRINS)
   80 FORMAT (1X,A80)
C
C     IF REQUIRED, READ IN CHANNEL ROUTING PARAMETERS AND COEFFICIENTS
C
      IF ( NSCRC .GT. 0 ) THEN
         DO 110 I = 1,NSCRC
            READ (5,82) IBKPTS(I),OBKPTS(I),CRP(I)
   82       FORMAT (2I8,F8.0)
            WRITE (6,84) IBKPTS(I),OBKPTS(I),CRP(I)
   84       FORMAT (1X,2I8,F8.0)
            READ (5,90) (C(J,I),J=1,IBKPTS(I)+OBKPTS(I)+1)
   90       FORMAT (10F8.0)
            WRITE (6,100) (C(J,I),J=1,IBKPTS(I)+OBKPTS(I)+1)
  100       FORMAT (1X,10F8.2)
  110    CONTINUE
      END IF
C
C     FOR EACH RESERVOIR ...
C
      IF ( NRR .GT. 0 ) THEN
```

```
      DO 210 RRPTR = 1,NRR
C
C        READ IN RESERVOIR NAME
C
         READ (5,120) RSVRNM(RRPTR)
  120    FORMAT (A16)
         WRITE (6,130) RSVRNM(RRPTR)
  130    FORMAT (1X,A16)
C
C        READ IN RESERVOIR PARAMETERS
C
         READ (5,140) RATCRV,STOCOD,SGUIDE,FEL(RRPTR),FOUT(RRPTR),
     *                RP(RRPTR),DSCHTM(RRPTR),NDSCHR(RRPTR),SVNPTS
  140    FORMAT (3I8,4F8.0,2I8)
         WRITE (6,150) RATCRV,STOCOD,SGUIDE,FEL(RRPTR),FOUT(RRPTR),
     *                 RP(RRPTR),DSCHTM(RRPTR),NDSCHR(RRPTR),SVNPTS
  150    FORMAT (1X,3I8,F8.2,F8.0,2F8.1,2I8)
         SEASON(RRPTR) = SGUIDE .NE. 0
         USRSTO = STOCOD .EQ. 0
C
C        IF RATING CURVE(S) TO BE USED, READ IN RATING CURVE CODE(S)
C
         USRRAT = .FALSE.
         DSKRAT = .FALSE.
         IF ( RATCRV .GT. 0 ) THEN
            READ (5,50) (RATCOD(I,RRPTR),I=1,NSTRMS)
            WRITE (6,60) (RATCOD(I,RRPTR),I=1,NSTRMS)
            DO 160 I = 1,NSTRMS
               IF ( RATCOD(I,RRPTR) .EQ. 0 ) USRRAT = .TRUE.
               IF ( RATCOD(I,RRPTR) .EQ. 1 ) DSKRAT = .TRUE.
  160       CONTINUE
C
C        ELSE, READ IN INDIVIDUAL AVERAGE DISCHARGES OVER EACH
C        "DISCHARGE PERIOD" (DSCHTM).  FIRST DISCHARGE CORRESPONDS
C        TO DISCHARGE PRECEDING FIRST RESERVOIR ROUTING PERIOD.
C
         ELSE
            INDIVQ(RRPTR) = .TRUE.
            READ (5,90) (DSCHRG(I,RRPTR),I=1,NDSCHR(RRPTR))
            WRITE (6,170) (DSCHRG(I,RRPTR),I=1,NDSCHR(RRPTR))
  170       FORMAT (1X,10F8.0)
         END IF
C
C        IF USER DEFINED STORAGE AND/OR RATING CURVE READ IN
C        ELEVATIONS IN FEET ABOVE MSL
C
         IF ( USRSTO .OR. USRRAT ) THEN
            READ (5,90) (SVELEV(I),I=1,SVNPTS)
            WRITE (6,180) (SVELEV(I),I=1,SVNPTS)
  180       FORMAT (1X,10F8.1)
         END IF
C
C        IF USER DEFINED STORAGE CURVE, READ IN STORAGES IN DSF
C
         IF ( USRSTO ) THEN
            DO 190 I = 1,SVNPTS
               ELEV(I,RRPTR) = SVELEV(I)
  190       CONTINUE
            READ (5,90) (STO(I,RRPTR),I=1,SVNPTS)
            WRITE (6,170) (STO(I,RRPTR),I=1,SVNPTS)
```

```
               NPTS(RRPTR) = SVNPTS
C
C           ELSE, READ IN STORAGE CURVE FROM STORAGE CURVE DISK FILE
C           AND MERGE TABULATED ELEVATIONS
C
            ELSE
               CALL GETSTO(RSVRNM(RRPTR),STO(1,RRPTR),NPTS(RRPTR),
     *                     ELEV(1,RRPTR))
               IF ( USRRAT ) CALL SRTMRG(SVELEV,SVNPTS,ELEV(1,RRPTR),
     *                                   NPTS(RRPTR),QRAT(1,1,RRPTR),
     *                                   STO(1,RRPTR))
            END IF
C
C           IF SPECIFIED, MERGE TABULATED ELEVATIONS FROM DISK FILE
C
            IF ( DSKRAT ) THEN
               CALL GETRAT(RSVRNM(RRPTR),QRAT(1,1,RRPTR),NUMPTS,QELEV)
               CALL SRTMRG(QELEV,NUMPTS,ELEV(1,RRPTR),NPTS(RRPTR),
     *                     QRAT(1,1,RRPTR),STO(1,RRPTR))
                  END IF
C
C           IF RATING CURVES TO BE USED, FOR EACH STORM ...
C
            IF ( RATCRV .GT. 0 ) THEN
               DO 200 STMPTR = 1,NSTRMS
C
C                 IF USER DEFINED RATING CURVE, READ IN DISCHS. IN CFS
C
                  IF ( RATCOD(STMPTR,RRPTR) .EQ. 0 ) THEN
                     READ (5,90) (QRAT(I,STMPTR,RRPTR),I=1,SVNPTS)
                     WRITE (6,170) (QRAT(I,STMPTR,RRPTR),I=1,SVNPTS)
                     IF ( DSKRAT .OR. .NOT. USRSTO )
     *                  CALL SRTMRG(SVELEV,SVNPTS,ELEV(1,RRPTR),
     *                              NPTS(RRPTR),QRAT(1,STMPTR,RRPTR),
     *                              STO(1,RRPTR))
C
C                 OR IF RATING CURVE ON DISK, READ IN FROM RATING CURVE
C                 DISK FILE
C
                  ELSE IF ( RATCOD(STMPTR,RRPTR) .EQ. 1 ) THEN
                     CALL GETRAT(RSVRNM(RRPTR),QRAT(1,STMPTR,RRPTR),
     *                           NUMPTS,QELEV)
                     CALL SRTMRG(QELEV,NUMPTS,ELEV(1,RRPTR),NPTS(RRPTR),
     *                           QRAT(1,STMPTR,RRPTR),STO(1,RRPTR))
C
                  ELSE IF ( RATCOD(STMPTR,RRPTR) .NE. 2 ) THEN
C
                     GO TO 930
C
                  END IF
  200          CONTINUE
            END IF
  210    CONTINUE
      END IF
C
      IF ( .NOT. HYDIN ) THEN
C
C     IF HYDROGRAPHS IN INPUT DATA SET, READ IN HYDROGRAPH INTERVAL
C     FOR EACH HYDROGRAPH
C
```

```
         READ (5,90) (HI(I),I=1,NTH)
         WRITE (6,180) (HI(I),I=1,NTH)
C
C     IF HYDROGRAPHS IN INPUT DATA SET, READ IN NO. OF ORDINATES FOR
C     EACH HYDROGRAPH
C
         READ (5,50) (NORD(I),I=1,NTH)
         WRITE (6,60) (NORD(I),I=1,NTH)
C
C     ELSE, READ IN HYDROGRAPH INTERVAL AND NO. OF ORDINATES FROM
C     INPUT HYDROGRAPH DISK FILE
C
      ELSE
         BCKSPC = 0
         DO I = 1,NTH
            READ (2,250) NORD(I),HI(I)
  250       FORMAT (I9,F9.0)
            READ (2,290) (OUT(J),J=1,NORD(I))
  290       FORMAT (8F9.0)
            BCKSPC = BCKSPC + ( NORD(I) + 7 ) / 8 + 1
         END DO
         DO I = 1,BCKSPC
            BACKSPACE (2)
         END DO
      END IF
C
C     COMPUTE NO. OF HOURS OF EACH STORM PERIOD
C
      IF ( NSTRMS+ENDATE .GT. 1 )
     *   SHOURS(1) = NDAYS(SDATES(1),IDUM,IDUM,IDUM) * 24. +
     *               STIMES(1) / 100 + MOD(STIMES(1),100) / 60.
      IF ( NSTRMS .GT. 1 ) THEN
         DO 300 I = 2,NSTRMS
            SHOURS(I) = NDAYS(SDATES(I),IDUM,IDUM,IDUM) * 24. +
     *                  STIMES(I) / 100 + MOD(STIMES(I),100) / 60.
            NUMHRS(I-1) = SHOURS(I) - SHOURS(I-1)
  300    CONTINUE
      END IF
C
C     COMPUTE TOTAL ROUTING PERIOD AS ...
C
      IF ( ENDPER ) THEN
C
C        EXTENDING TO ENDING DATE, OR ...
C
         EHOURS = NDAYS(EDATE,IDUM,IDUM,IDUM) * 24. +
     *            ETIME / 100 + MOD(ETIME,100) / 60.
         NUMHRS(NSTRMS) = EHOURS - SHOURS(NSTRMS)
         TOTHRS = EHOURS - SHOURS(1)
      ELSE
C
C        LENGTH OF LONGEST HYDROGRAPH
C
         TOTHRS = 0
         DO 350 I = 1,NTH
            IF ( HI(I)*(NORD(I)-1) .GT. TOTHRS )
     *         TOTHRS = HI(I) * ( NORD(I) - 1 )
  350    CONTINUE
         IF ( NSTRMS .GT. 1 ) THEN
            NUMHRS(NSTRMS) = TOTHRS - ( SHOURS(NSTRMS) - SHOURS(1) )
```

```
         ELSE
            NUMHRS(NSTRMS) = TOTHRS
         END IF
      END IF
C
C     ROUTE THE HYDROGRAPHS
C
      CALL ROUTE
C
      STOP
C
  910 CONTINUE
      WRITE (6,915) NSTRMS
  915 FORMAT (//1X,I3,' IS INVALID AS NUMBER OF STORMS; MAXIMUM IS 9')
      GO TO 999
C
  920 CONTINUE
      WRITE (6,925) IC(I)
  925 FORMAT (//1X,I3,' IS AN INVALID INSTRUCTION CODE;',
     *                ' RANGE IS 1 TO 6')
      GO TO 999
C
  930 CONTINUE
      WRITE (6,935) RATCOD
  935 FORMAT (//1X,I3,' IS AN INVALID CODE FOR RATING CURVES;',
     *                ' RANGE IS 0 TO 2')
C
  999 CONTINUE
      STOP 4
      END
      BLOCK DATA
C
      COMMON /TABLES/ DMO(12),MODAYS(12)
      INTEGER DMO,MODAYS
C
      COMMON /PARMS/ NSTRMS,NIC,IC(100),HI(25),NORD(25),RP(10),
     *               RATCOD(9,10),INDIVQ(10),SEASON(10),HYDIN,HYDOUT
      INTEGER NSTRMS,NIC,IC,NORD,RATCOD
      REAL HI,RP
      LOGICAL INDIVQ,SEASON,HYDIN,HYDOUT
C
      COMMON /TIMES/ SDATES(9),EDATE,STIMES(9),ETIME,NUMHRS(9),TOTHRS
      INTEGER SDATES,EDATE
      INTEGER STIMES,ETIME
      REAL NUMHRS,TOTHRS
C
      COMMON /NAMES/ ANAMES(25)
      CHARACTER*80 ANAMES
C
      COMMON /RATING/ ELEV(50,10),STO(50,10),QRAT(50,9,10),FEL(10),
     *                FOUT(10),QEMPTY(10),NUL(10),TOG(10)
      REAL ELEV,STO,QRAT,FEL,FOUT,QEMPTY,NUL,TOG
C
      COMMON /DISCH/ DSCHRG(800,10),NDSCHR(10),DSCHTM(10)
      REAL DSCHRG,DSCHTM
      INTEGER NDSCHR
C
      COMMON /RESRVR/ RSVRNM(10),RRPTR,NPTS(10),EL(800),OUT(800)
      CHARACTER RSVRNM*16
      INTEGER RRPTR,NPTS
```

```
      REAL EL,OUT
C
      COMMON /CHANEL/ IBKPTS(30),OBKPTS(30),CRP(30),C(21,30)
      INTEGER IBKPTS,OBKPTS
      REAL CRP,C
C
      COMMON /HYDRGR/ CHANNL,WRKHI,WKNORD,HYDWRK(800),DSCWRK(800),UPDSCH
      REAL WRKHI,HYDWRK,DSCWRK
      INTEGER CHANNL
      INTEGER WKNORD
      LOGICAL UPDSCH
C
      DATA INDIVQ/10*.FALSE./,HYDWRK/800*0.0/,DSCWRK/800*0.0/
      DATA DMO/131,228,331,430,531,630,731,831,930,1031,1130,1231/
      DATA MODAYS/31,28,31,30,31,30,31,31,30,31,30,31/
C
      END
      SUBROUTINE ROUTE
C
C     ROUTINE TO ROUTE HYDROGRAPHS
C
      COMMON /PARMS/ NSTRMS,NIC,IC(100),HI(25),NORD(25),RP(10),
     *               RATCOD(9,10),INDIVQ(10),SEASON(10),HYDIN,HYDOUT
      INTEGER NSTRMS,NIC,IC,NORD,RATCOD
      REAL HI,RP
      LOGICAL INDIVQ,SEASON,HYDIN,HYDOUT
C
      COMMON /TIMES/ SDATES(9),EDATE,STIMES(9),ETIME,NUMHRS(9),TOTHRS
      INTEGER SDATES,EDATE
      INTEGER STIMES,ETIME
      REAL NUMHRS,TOTHRS
C
      COMMON /RESRVR/ RSVRNM(10),RRPTR,NPTS(10),EL(800),OUT(800)
      CHARACTER RSVRNM*16
      INTEGER RRPTR,NPTS
      REAL EL,OUT
C
      COMMON /CHANEL/ IBKPTS(30),OBKPTS(30),CRP(30),C(21,30)
      INTEGER IBKPTS,OBKPTS
      REAL CRP,C
C
      COMMON /HYDRGR/ CHANNL,WRKHI,WKNORD,HYDWRK(800),DSCWRK(800),UPDSCH
      REAL WRKHI,HYDWRK,DSCWRK
      INTEGER CHANNL
      INTEGER WKNORD
      LOGICAL UPDSCH
C
      INTEGER CODPTR,CODE,HYDPTR,NUMORD,TNORD,OWKNRD,DELTA,CRPTR
      INTEGER INTRVL,BCKPTR,STKPTR,STNORD(3),PRTPTR
      REAL Q(800),OUTDSC(800),HYDSTO(800,3),DSCSTO(800,3),STOHI(3)
      REAL GCDHI
      LOGICAL DSCHUP(3)
      REAL GCD
C
      DATA HYDPTR,CRPTR,STKPTR/3*0/
C
      NORDS(X) = INT((TOTHRS-.001)/X) + 2
C
      RRPTR = 0
      WRKHI = HI(1)
```

```
      WKNORD = NORDS(WRKHI)
      UPDSCH = .FALSE.
C
C     DETERMINE NEXT INSTRUCTION CODE TO BE FOLLOWED
C
      DO 800 CODPTR = 1,NIC
         CODE = IC(CODPTR)
C
C        FOR CODE = 1, ADD NEXT HYDROGRAPH TO WORKING HYDROGRAPH
C
         IF ( CODE .EQ. 1 ) THEN
            HYDPTR = HYDPTR + 1
C
C           READ IN NEXT HYDROGRAPH
C
            IF ( HYDIN ) THEN
               READ (2,1005) NUMORD
 1005          FORMAT (I9,F9.0)
               READ (2,1010) (Q(I),I=1,NUMORD)
 1010          FORMAT (8F9.0)
            ELSE
                  NUMORD = NORD(HYDPTR)
               READ (5,10) (Q(I),I=1,NUMORD)
   10          FORMAT (10F8.0)
               WRITE (6,20) (Q(I),I=1,NUMORD)
   20          FORMAT (1H1,10X,'INFLOW HYDROGRAPH'//50(1X,10F8.0/))
            END IF
C
C           EXTEND NEXT HYDROGRAPH TO TOTAL LENGTH OF ROUTING BY
C           FILLING END OF HYDROGRAPH WITH LAST FLOW
C
            TNORD = NORDS(HI(HYDPTR))
            DO 30 I = NUMORD+1,TNORD
               Q(I) = Q(NUMORD)
   30       CONTINUE
            NUMORD = TNORD
C
C           IF NOT EQUAL, CHANGE HYDROGRAPH INTERVAL OF NEXT HYDROGRAPH
C           AND/OR WORKING HYDROGRAPH TO BE EQUAL (USING GREATEST
C           COMMON DIVISOR AS NEW INTERVAL)
C
            IF ( HI(HYDPTR) .NE. WRKHI ) THEN
               GCDHI = GCD(HI(HYDPTR),WRKHI)
               IF ( HI(HYDPTR) .NE. GCDHI )
     *            CALL CHGHI(Q,HI(HYDPTR),GCDHI,NUMORD,.FALSE.)
               IF ( WRKHI .NE. GCDHI ) THEN
                  CALL CHGHI(HYDWRK,WRKHI,GCDHI,WKNORD,.FALSE.)
                  IF ( UPDSCH )
     *               CALL CHGHI(DSCWRK,WRKHI,GCDHI,WKNORD,.TRUE.)
                  WRKHI = GCDHI
                  WKNORD = NORDS(GCDHI)
               END IF
            END IF
C
C           ADD NEXT HYDROGRAPH TO WORKING HYDROGRAPH
C
            DO 40 I = 1,WKNORD
               HYDWRK(I) = HYDWRK(I) + Q(I)
   40       CONTINUE
C
```

```
C        FOR CODE = 2, RESERVOIR ROUTE WORKING HYDROGRAPH, WITH OUTFLOW
C        HYDROGRAPH BECOMING NEW WORKING HYDROGRAPH
C
         ELSE IF ( CODE .EQ. 2 ) THEN
            RRPTR = RRPTR + 1
C
C           IF USER SUPPLIED RESERVOIR PERIOD IS DIFFERENT FROM
C           HYDROGRAPH INTERVAL OF WORKING HYDROGRAPH ...
C
            IF ( RP(RRPTR) .GT. 0.0 .AND. RP(RRPTR) .NE. WRKHI ) THEN
               GCDHI = GCD(RP(RRPTR),WRKHI)
C
C              IF NECESSARY, CHANGE HYDROGRAPH INTERVAL TO BE COMMON
C              DIVISOR OF THE RESERVOIR ROUTING PERIOD
C
               IF ( WRKHI .NE. GCDHI ) THEN
                  CALL CHGHI(HYDWRK,WRKHI,GCDHI,WKNORD,.FALSE.)
                  IF ( UPDSCH )
     *               CALL CHGHI(DSCWRK,WRKHI,GCDHI,WKNORD,.TRUE.)
                  WRKHI = GCDHI
                  WKNORD = NORDS(GCDHI)
               END IF
C
C              NEXT, IF THE HYDROGRAPH INTERVAL IS NOT EQUAL TO THE
C              RESERVOIR ROUTING PERIOD, CHANGE THE HYDROGRAPH INTERVAL
C              TO BE EQUAL TO THE ROUTING PERIOD
C
               IF ( WRKHI .NE. RP(RRPTR) ) THEN
                  DELTA = RP(RRPTR) / WRKHI
                  WRKHI = RP(RRPTR)
                  OWKNRD = WKNORD
                  WKNORD = NORDS(RP(RRPTR))
                  DO 44 I = 2,WKNORD-1
                     HYDWRK(I) = HYDWRK(DELTA*(I-1)+1)
                     DSCWRK(I) = DSCWRK(DELTA*(I-1)+1)
                     DO 42 J = 1,DELTA-1
                        DSCWRK(I) = DSCWRK(I) + DSCWRK(DELTA*(I-1)+1-J)
   42                CONTINUE
                     DSCWRK(I) = DSCWRK(I)/DELTA
   44             CONTINUE
                  HYDWRK(WKNORD) = HYDWRK(OWKNRD)
                  DSCWRK(WKNORD) = DSCWRK(OWKNRD)
                  DO 46 I = DELTA*(WKNORD-2)+2,OWKNRD-1
                     DSCWRK(WKNORD) = DSCWRK(WKNORD) + DSCWRK(I)
   46             CONTINUE
                  DSCWRK(WKNORD) = DSCWRK(WKNORD) /
     *                           ( OWKNRD - DELTA * ( WKNORD - 2 ) - 1 )
                  DO 48 I = WKNORD+1,OWKNRD
                     HYDWRK(I) = 0.0
                     DSCWRK(I) = 0.0
   48             CONTINUE
               END IF
            END IF
C
C           RESERVOIR ROUTE WORKING HYDROGRAPH
C
            CALL RROUTE
C
            IF ( IC(CODPTR+1) .NE. 6 ) THEN
C
```

```
C              IF USER SUPPLIED INDIVIDUAL DISCHARGES, STORE AVERAGE
C              DISCHARGES OVER RESERVOIR ROUTING PERIOD IN ARRAY DSCWRK
C
               IF ( UPDSCH ) THEN
                  DO 50 I = 1,WKNORD
                     DSCWRK(I) = OUT(I)
                     HYDWRK(I) = 0.0
   50             CONTINUE
C
C              ELSE, STORE INSTANTANEOUS DISCHARGES AT END OF RESERVOIR
C              PERIOD IN ARRAY HYDWRK
C
               ELSE
                  DO 60 I = 1,WKNORD
                     HYDWRK(I) = OUT(I)
                     DSCWRK(I) = 0.0
   60             CONTINUE
               END IF
            END IF
C
C        FOR CODE = 3, CHANNEL ROUTE WORKING HYDROGRAPH, AND USE OUTFLOW
C        HYDROGRAPH AS WORKING HYDROGRAPH
C
         ELSE IF ( CODE .EQ. 3 ) THEN
            CRPTR = CRPTR + 1
            GCDHI = GCD(CRP(CRPTR),WRKHI)
C
C           IF NECESSARY, CHANGE HYDROGRAPH INTERVAL TO BE A COMMON
C           DIVISOR OF THE CHANNEL ROUTING PERIOD
C
            IF ( GCDHI .NE. WRKHI ) THEN
               CALL CHGHI(HYDWRK,WRKHI,GCDHI,WKNORD,.FALSE.)
               IF ( UPDSCH )
     *            CALL CHGHI(DSCWRK,WRKHI,GCDHI,WKNORD,.TRUE.)
               WRKHI = GCDHI
               WKNORD = NORDS(GCDHI)
            END IF
C
C           CHANNEL ROUTE USING ARMA ROUTING MODEL.  FOR EARLY POINTS
C           ASSUME CONSTANT INFLOW THRU FIRST INFLOW.
C
            INTRVL = CRP(CRPTR) / WRKHI
            OUT(1) = HYDWRK(1)
            OUTDSC(1) = DSCWRK(1)
            DO 80 I = 2,WKNORD
               OUT(I) = C(1,CRPTR) * HYDWRK(I)
               OUTDSC(I) = C(1,CRPTR) * DSCWRK(I)
               BCKPTR = MAX(I-INTRVL,1)
               DO 70 J = 2,IBKPTS(CRPTR)+1
                  OUT(I) = OUT(I) + C(J,CRPTR) * HYDWRK(BCKPTR)
                  OUTDSC(I) = OUTDSC(I) + C(J,CRPTR) * DSCWRK(BCKPTR)
                  BCKPTR = MAX(BCKPTR-INTRVL,1)
   70          CONTINUE
               BCKPTR = MAX(I-INTRVL,1)
               DO 75 J = IBKPTS(CRPTR)+2,IBKPTS(CRPTR)+OBKPTS(CRPTR)+1
                  OUT(I) = OUT(I) + C(J,CRPTR) * OUT(BCKPTR)
                  OUTDSC(I) = OUTDSC(I) + C(J,CRPTR) * OUTDSC(BCKPTR)
                  BCKPTR = MAX(BCKPTR-INTRVL,1)
   75          CONTINUE
   80       CONTINUE
```

```
            DO 90 I = 1,WKNORD
               HYDWRK(I) = OUT(I)
               DSCWRK(I) = OUTDSC(I)
   90       CONTINUE
C
C        FOR CODE = 4, STORE WORKING HYDROGRAPH ON A "STACK".
C        INITIALIZE WORKING HYDROGRAPH TO ZEROES
C
         ELSE IF ( CODE .EQ. 4 ) THEN
            STKPTR = STKPTR + 1
            DO 100 I = 1,WKNORD
               HYDSTO(I,STKPTR) = HYDWRK(I)
               DSCSTO(I,STKPTR) = DSCWRK(I)
               HYDWRK(I) = 0.0
               DSCWRK(I) = 0.0
  100       CONTINUE
            STOHI(STKPTR) = WRKHI
            STNORD(STKPTR) = WKNORD
            DSCHUP(STKPTR) = UPDSCH
            WRKHI = HI(HYDPTR+1)
            WKNORD = NORDS(WRKHI)
            UPDSCH = .FALSE.
C
C        FOR CODE = 5, "POP" HYDROGRAPH FROM "STACK" AND ADD TO WORKING
C        HYDROGRAPH
C
         ELSE IF ( CODE .EQ. 5 ) THEN
C
C           IF NOT EQUAL, CHANGE HYDROGRAPH INTERVAL OF "POPPED"
C           HYDROGRAPH AND/OR WORKING HYDROGRAPH TO BE EQUAL (USING
C           GREATEST COMMON DIVISOR AS NEW INTERVAL)
C
            IF ( STOHI(STKPTR) .NE. WRKHI ) THEN
               GCDHI = GCD(STOHI(STKPTR),WRKHI)
               IF ( STOHI(STKPTR) .NE. GCDHI ) THEN
                  CALL CHGHI(HYDSTO(1,STKPTR),STOHI(STKPTR),GCDHI,
     *                     STNORD(STKPTR),.FALSE.)
                  IF ( DSCHUP(STKPTR) )
     *               CALL CHGHI(DSCSTO(1,STKPTR),STOHI(STKPTR),GCDHI,
     *                          STNORD(STKPTR),.TRUE.)
               END IF
               IF ( WRKHI .NE. GCDHI ) THEN
                  CALL CHGHI(HYDWRK,WRKHI,GCDHI,WKNORD,.FALSE.)
                  IF ( UPDSCH )
     *               CALL CHGHI(DSCWRK,WRKHI,GCDHI,WKNORD,.TRUE.)
                  WRKHI = GCDHI
                  WKNORD = NORDS(GCDHI)
               END IF
            END IF
C
C           ADD "POPPED" HYDROGRAPH TO WORKING HYDROGRAPH
C
            DO 110 I = 1,WKNORD
               HYDWRK(I) = HYDWRK(I) + HYDSTO(I,STKPTR)
  110       CONTINUE
            IF ( DSCHUP(STKPTR) ) THEN
               DO 120 I = 1,WKNORD
                  DSCWRK(I) = DSCWRK(I) + DSCSTO(I,STKPTR)
  120          CONTINUE
            END IF
```

```
            UPDSCH = UPDSCH .OR. DSCHUP(STKPTR)
            STKPTR = STKPTR - 1
C
C        FOR CODE = 6, PRINT OUT CURRENT HYDROGRAPH OR RESERVOIR ROUTING
C
         ELSE IF ( CODE .EQ. 6 ) THEN
            PRTPTR = PRTPTR + 1
            CALL WRITE(IC(CODPTR-1),PRTPTR)
            IF ( IC(CODPTR-1) .EQ. 2 ) THEN
               IF ( UPDSCH ) THEN
                  DO 130 I = 1,WKNORD
                     DSCWRK(I) = OUT(I)
                     HYDWRK(I) = 0.0
  130             CONTINUE
               ELSE
                  DO 140 I = 1,WKNORD
                     HYDWRK(I) = OUT(I)
                     DSCWRK(I) = 0.0
  140             CONTINUE
               END IF
            END IF
         END IF
  800 CONTINUE
C
C     IF REQUESTED, OUTPUT FINAL HYDROGRAPH TO DISK FILE
C
C     IF ( CHANNL .GT. 0 ) THEN
C        WRITE(3,820) CHANNL
C 820    FORMAT(I3)
C        WRITE(3,840) (HYDWRK(I),I=1,WKNORD)
C 840    FORMAT(8F9.0)
C     END IF
      IF ( HYDOUT ) THEN
         WRITE (3,1105) WKNORD,WRKHI
 1105     FORMAT(9X,I9,F9.0)
         WRITE (3,1010) (HYDWRK(I),I=1,WKNORD)
c1010     FORMAT(8F9.0)
      END IF
      RETURN
      END
      SUBROUTINE RROUTE
C
C     ROUTINE TO PERFORM RESERVOIR ROUTING
C
      COMMON /PARMS/ NSTRMS,NIC,IC(100),HI(25),NORD(25),RP(10),
     *               RATCOD(9,10),INDIVQ(10),SEASON(10),HYDIN,HYDOUT
      INTEGER NSTRMS,NIC,IC,NORD,RATCOD
      REAL HI,RP
      LOGICAL INDIVQ,SEASON,HYDIN,HYDOUT
C
      COMMON /TIMES/ SDATES(9),EDATE,STIMES(9),ETIME,NUMHRS(9),TOTHRS
      INTEGER SDATES,EDATE
      INTEGER STIMES,ETIME
      REAL NUMHRS,TOTHRS
C
      COMMON /RATING/ ELEV(50,10),STO(50,10),QRAT(50,9,10),FEL(10),
     *                FOUT(10),QEMPTY(10),NUL(10),TOG(10)
      REAL ELEV,STO,QRAT,FEL,FOUT,QEMPTY,NUL,TOG
C
      COMMON /DISCH/ DSCHRG(800,10),NDSCHR(10),DSCHTM(10)
```

```
      REAL DSCHRG,DSCHTM
      INTEGER NDSCHR
C
      COMMON /RESRVR/ RSVRNM(10),RRPTR,NPTS(10),EL(800),OUT(800)
      CHARACTER RSVRNM*16
      INTEGER RRPTR,NPTS
      REAL EL,OUT
C
      COMMON /HYDRGR/ CHANNL,WRKHI,WKNORD,HYDWRK(800),DSCWRK(800),UPDSCH
      REAL WRKHI,HYDWRK,DSCWRK
      INTEGER CHANNL
      INTEGER WKNORD
      LOGICAL UPDSCH
C
      REAL KS(800),OS(800),OKS(50),SVELEV(50),TELEV(50),INFHRS,DSCHRS
      REAL INC,WT,QUINMX,ELHOLD,KSHOLD,EMPRAT,KSTO,ELGUID,TOPZON,INITQ
      INTEGER SVNPTS,NUMPTS,PTR,SAVPTR,DSCPTR,STMPTR,NULPTR,START,END
      LOGICAL SAVFLG
C
      TOTINF(I) = HYDWRK(I) + DSCWRK(I)
      GETOS(I) = HYDWRK(I) + HYDWRK(I-1) + 2. * DSCWRK(I) - OUT(I-1) +
     *           KS(I-1)
      GETOUT(I,J) = ( QRAT(J,STMPTR,RRPTR) - QRAT(J-1,STMPTR,RRPTR) ) *
     *              ( OS(I) - OKS(J-1) ) / ( OKS(J) - OKS(J-1) ) +
     *              QRAT(J-1,STMPTR,RRPTR)
      GETEL1(I,J) = ( ELEV(J,RRPTR) - ELEV(J-1,RRPTR) ) *
     *              ( OS(I) - OKS(J-1) ) / ( OKS(J) - OKS(J-1) ) +
     *              ELEV(J-1,RRPTR)
      GETEL2(S,J) = ( ELEV(J,RRPTR) - ELEV(J-1,RRPTR) ) * ( S -
     *              STO(J-1,RRPTR) ) / ( STO(J,RRPTR) - STO(J-1,RRPTR) )
     *              + ELEV(J-1,RRPTR)
      GETKS(I,J) = 48. / WRKHI * ( ( ( STO(J,RRPTR) - STO(J-1,RRPTR) ) *
     *             ( EL(I) - ELEV(J-1,RRPTR) ) / (ELEV(J,RRPTR) -
     *             ELEV(J-1,RRPTR) ) ) + STO(J-1,RRPTR) )
C
C     COMPUTE KS CORRESPONDING TO INITIAL HW ELEVATION
C
      NUMPTS = NPTS(RRPTR)
      IF ( SEASON(RRPTR) .OR. FEL(RRPTR) .LE. 0.0 )
     1   CALL FRSTEL(RSVRNM(RRPTR),SDATES(1),STIMES(1),ELGUID,TOPZON)
      IF ( FEL(RRPTR) .LE. 0.0 ) THEN
         EL(1) = ELGUID
      ELSE
         EL(1) = FEL(RRPTR)
      END IF
      DO 20 I = 2,NUMPTS
         PTR = I
         IF ( EL(1) .LE. ELEV(I,RRPTR) ) GO TO 30
   20 CONTINUE
   30 CONTINUE
      KS(1) = GETKS(1,PTR)
      SAVPTR = PTR
C
C
C     IF RESERVOIR RELEASES ARE SPECIFIED INDIVIDUALLY ...
C
      IF ( INDIVQ(RRPTR) ) THEN
C
         OUT(1) = DSCHRG(1,RRPTR)
         KS(1) = KS(1) * WRKHI / 48.
```

```
         INFHRS = 0.0
         DSCHRS = 0.0
         INC = GCD(WRKHI,DSCHTM(RRPTR))
         WT = INC / WRKHI
C
C        FOR EACH RESERVOIR ROUTING PERIOD ...
C
         DO 80 I = 2,WKNORD
            INFHRS = INFHRS + WRKHI
            OUT(I) = 0.0
C
C           COMPUTE AVERAGE DISCHARGE, ...
C
   40       CONTINUE
            IF ( DSCHRS+INC .LE. INFHRS ) THEN
               DSCHRS = DSCHRS + INC
               DSCPTR = MIN(INT((DSCHRS-.001)/DSCHTM(RRPTR))+2,
     *                      NDSCHR(RRPTR))
               OUT(I) = OUT(I) + WT * DSCHRG(DSCPTR,RRPTR)
            GO TO 40
            END IF
C
C           AND END OF ROUTING PERIOD HW ELEVATION
C
            KS(I) = ( WRKHI / 48. ) * ( HYDWRK(I) + HYDWRK(I-1) +
     *              2. * ( DSCWRK(I) - OUT(I) ) ) + KS(I-1)
            DO 60 J = 2,NUMPTS
               PTR = J
               IF ( KS(I) .LE. STO(J,RRPTR) ) GO TO 70
   60       CONTINUE
   70       CONTINUE
            EL(I) = GETEL2(KS(I),PTR)
   80    CONTINUE
         UPDSCH = .TRUE.
C
C     ELSE, RESERVOIR RELEASES ARE COMPUTED FROM RATING CURVE(S)
C
      ELSE
C
         SAVFLG = ( NSTRMS .GT. 1 .AND.
     *            RATCOD(1,RRPTR) - RATCOD(2,RRPTR) .EQ. 2 ) .OR.
     *            ( NSTRMS .GT. 2 .AND.
     *            RATCOD(2,RRPTR) - RATCOD(3,RRPTR) .EQ. 2 ) .OR.
     *            ( NSTRMS .GT. 3 .AND.
     *            RATCOD(3,RRPTR) - RATCOD(4,RRPTR) .EQ. 2 ) .OR.
     *            ( NSTRMS .GT. 4 .AND.
     *            RATCOD(4,RRPTR) - RATCOD(5,RRPTR) .EQ. 2 ) .OR.
     *            ( NSTRMS .GT. 5 .AND.
     *            RATCOD(5,RRPTR) - RATCOD(6,RRPTR) .EQ. 2 ) .OR.
     *            ( NSTRMS .GT. 6 .AND.
     *            RATCOD(6,RRPTR) - RATCOD(7,RRPTR) .EQ. 2 ) .OR.
     *            ( NSTRMS .GT. 7 .AND.
     *            RATCOD(7,RRPTR) - RATCOD(8,RRPTR) .EQ. 2 ) .OR.
     *            ( NSTRMS .GT. 8 .AND.
     *            RATCOD(8,RRPTR) - RATCOD(9,RRPTR) .EQ. 2 )
         IF ( SAVFLG ) THEN
            DO 100 I = 1,NUMPTS
               SVELEV(I) = ELEV(I,RRPTR)
  100       CONTINUE
            SVNPTS = NUMPTS
```

```
         END IF
         OUT(1) = TOTINF(1)
         END = 1
C
C        FOR EACH STORM PERIOD ...
C
         DO 900 STMPTR = 1,NSTRMS
C
C           COMPUTE STARTING AND ENDING HYDROGRAPH ORDINATES
C
            START = END
            END = START + INT((NUMHRS(STMPTR)-.001)/WRKHI) + 1
            IF ( SEASON(RRPTR) .AND. EL(START) .LT. ELGUID )
     *         OUT(START) = 0.
C
C           IF NEXT RATING CURVE IS AN IMPROVED FIXED RULE
C           USE FINAL ELEVATION AT END OF CURRENT STORM TO
C           COMPUTE RATING CURVE FOR NEXT STORM
C
            IF ( RATCOD(STMPTR,RRPTR) .EQ. 2 ) THEN
               INITQ = OUT(START)
               IF ( STMPTR .EQ. 1 ) INITQ = FOUT(RRPTR)
               CALL GETIFR(RSVRNM(RRPTR),EL(START),INITQ,NUMPTS,
     *                     TELEV,QRAT(1,STMPTR,RRPTR),NUL(RRPTR),
     *                     TOG(RRPTR),QEMPTY(RRPTR))
               CALL SRTMRG(TELEV,NUMPTS,ELEV(1,RRPTR),NPTS(RRPTR),
     *                     QRAT(1,STMPTR,RRPTR),STO(1,RRPTR))
               NUMPTS = NPTS(RRPTR)
            ELSE IF ( SAVFLG .AND. STMPTR .GT. 1 ) THEN
               CALL SRTMRG(SVELEV,SVNPTS,ELEV(1,RRPTR),NPTS(RRPTR),
     *                     QRAT(1,STMPTR,RRPTR),STO(1,RRPTR))
            END IF
C
C           OUTPUT DISCHARGE AND STORAGE CURVES
C
            CALL OUTRAT(RSVRNM(RRPTR),STMPTR,ELEV(1,RRPTR),
     *                  QRAT(1,STMPTR,RRPTR),STO(1,RRPTR),NUMPTS)
            IF ( RATCOD(STMPTR,RRPTR) .EQ. 2 )
     *         WRITE (6,160) EL(START),NUL(RRPTR)
  160        FORMAT (//' INITIAL ELEVATION = ',F8.2/
     *                 ' NORMAL UPPER LIMIT ELEVATION = ',F8.2)
C
C           COMPUTE O + KS FOR EACH ELEVATION ON RATING CURVE
C
            DO 180 I = 1,NUMPTS
               OKS(I) = QRAT(I,STMPTR,RRPTR) + STO(I,RRPTR) * 48. /
     *                  WRKHI
  180       CONTINUE
C
C           IF IMPROVED FIXED RULE, FIND MAXIMUM INFLOW FOR LATER USE
C
            IF ( RATCOD(STMPTR,RRPTR) .EQ. 2 ) THEN
               QUINMX = TOTINF(START)
               DO 200 I = START+1,END
                  IF ( TOTINF(I) .GT. QUINMX ) QUINMX = TOTINF(I)
  200          CONTINUE
            END IF
C
C           FOLLOW "NORMAL" RATING CURVE UNTIL END OF STORM PERIOD,
C           OR IMPROVED FIXED RULE CURVE UNTIL MAX. INFLOW IS REACHED
```

```
C
            DO 280 I = START+1,END
               IF ( SEASON(RRPTR) ) CALL UPDATE(WRKHI,ELGUID,TOPZON)
               OS(I) = GETOS(I)
               DO 220 J = 2,NUMPTS
                  PTR = J
                  IF ( OS(I) .LE. OKS(J) ) GO TO 230
  220          CONTINUE
  230          CONTINUE
               EL(I) = GETEL1(I,PTR)
C
C              IF COMPUTED ELEVATION IS LOWER THAN SEASONAL GUIDE,
C              SET ELEVATION TO SEASONAL GUIDE OR DISCHARGE TO ZERO
C
               IF ( SEASON(RRPTR) .AND. EL(I) .LT. ELGUID .AND.
     *              RATCOD(STMPTR,RRPTR) .NE. 2 ) THEN
                  EL(I) = ELGUID
                  DO 240 J = 2,NUMPTS
                     PTR = J
                     IF ( EL(I) .LT. ELEV(J,RRPTR) ) GO TO 250
  240             CONTINUE
  250             CONTINUE
                  KS(I) = GETKS(I,PTR)
                  OUT(I) = MAX(GETOS(I)-KS(I),0.)
                  IF ( EL(I) .EQ. EL(I-1) ) OUT(I) = TOTINF(I)
                  IF ( KS(I) .GT. GETOS(I) ) THEN
                     KS(I) = GETOS(I)
                     KSTO = KS(I) * WRKHI / 48.
                     DO 260 J = 2,NUMPTS
                        PTR = J
                        IF ( KSTO .LE. STO(J,RRPTR) ) GO TO 270
  260                CONTINUE
  270                CONTINUE
                     EL(I) = GETEL2(KSTO,PTR)
                  END IF
C
C              IF COMPUTED ELEVATION IS LOWER THAN INITIAL
C              ELEVATION, SET ELEVATION TO INITIAL ELEVATION
C              AND OUTFLOW = INFLOW
C
               ELSE IF ( EL(I) .LT. EL(1) .AND. ( .NOT. SEASON(RRPTR)
     *                   .OR. RATCOD(STMPTR,RRPTR) .EQ. 2 ) ) THEN
                  EL(I) = EL(1)
                  OUT(I) = TOTINF(I)
                  KS(I) = KS(1)
               ELSE
                  OUT(I) = GETOUT(I,PTR)
                  KS(I) = OS(I) - OUT(I)
                  IF ( EL(I) .EQ. EL(I-1) ) OUT(I) = TOTINF(I)
               END IF
               IF ( TOTINF(I) .GE. QUINMX .AND.
     *              RATCOD(STMPTR,RRPTR) .EQ. 2 ) GO TO 300
  280       CONTINUE
            GO TO 800
C
C           REMAINDER OF ROUTINE DEALS WITH IMPROVED FIXED RULE OPER.
C
  300       CONTINUE
            START = I + 1
  320       CONTINUE
```

```
C
C           MAXIMUM INFLOW HAS BEEN REACHED
C
            IF ( EL(I) .GE. NUL(RRPTR) ) THEN
C
C              THE ELEVATION IS GREATER THAN OR EQUAL TO THE NORMAL
C              UPPER LIMIT ELEVATION.  FOLLOW "NORMAL" PROCEDURE
C              UNTIL HEADWATER CRESTS
C
               DO 360 I = START,END
                  IF ( SEASON(RRPTR) ) CALL UPDATE(WRKHI,ELGUID,TOPZON)
                  OS(I) = GETOS(I)
                  DO 340 J = 2,NUMPTS
                     PTR = J
                     IF ( OS(I) .LE. OKS(J) ) GO TO 350
  340             CONTINUE
  350             CONTINUE
                  OUT(I) = GETOUT(I,PTR)
                  KS(I) = OS(I) - OUT(I)
                  EL(I) = GETEL1(I,PTR)
                  IF ( EL(I) .LT. EL(I-1) ) GO TO 460
                  IF ( EL(I) .EQ. EL(I-1) ) OUT(I) = TOTINF(I)
  360          CONTINUE
C
            ELSE
C
C              ELEVATION IS LESS THAN THE NORMAL UPPER LIMIT ELEVATION.
C              HOLD DISCHARGE UNTIL HEADWATER CRESTS OR TOP OF GATES IS
C              REACHED
C
               NULPTR = 9999
               DO 440 I = START,END
                  IF ( SEASON(RRPTR) ) CALL UPDATE(WRKHI,ELGUID,TOPZON)
                  OS(I) = GETOS(I)
                  OUT(I) = OUT(I-1)
                  KS(I) = OS(I) - OUT(I)
                  KSTO = KS(I) * WRKHI / 48.
                  DO 380 J = 2,NUMPTS
                     PTR = J
                     IF ( KSTO .LE. STO(J,RRPTR) ) GO TO 390
  380             CONTINUE
  390             CONTINUE
                  EL(I) = GETEL2(KSTO,PTR)
                  IF ( EL(I) .LT. EL(I-1) ) GO TO 540
                  IF ( EL(I) .GT. NUL(RRPTR) ) NULPTR = MIN(NULPTR,I)
                  IF ( EL(I) .GT. TOG(RRPTR) ) THEN
C
C                    DISCHARGE CANNOT BE HELD BEYOND TOP OF GATES;
C                    BACK UP TO NORMAL UPPER LIMIT ELEVATION AND
C                    FOLLOW NORMAL PROCEDURE
C
                     IF ( SEASON(RRPTR) )
     1                  CALL UPDATE((NULPTR-I)*WRKHI,ELGUID,TOPZON)
                     DO 400 J = 2,NUMPTS
                        PTR = J
                        IF ( OS(NULPTR) .LE. OKS(J) ) GO TO 410
  400                CONTINUE
  410                CONTINUE
                     EL(NULPTR) = GETEL1(NULPTR,PTR)
                     OUT(NULPTR) = GETOUT(NULPTR,PTR)
```

```
                    KS(NULPTR) = OS(NULPTR) - OUT(NULPTR)
                    IF ( EL(NULPTR) .LT. NUL(RRPTR) ) THEN
                       EL(NULPTR) = NUL(RRPTR)
                       DO 420 J = 2,NUMPTS
                          PTR = J
                         IF ( EL(NULPTR) .LT. ELEV(J,RRPTR) ) GO TO 430
  420                  CONTINUE
  430                  CONTINUE
                       KS(NULPTR) = GETKS(NULPTR,PTR)
                       OUT(NULPTR) = OS(NULPTR) - KS(NULPTR)
                    END IF
                    START = NULPTR + 1
                    GO TO 320
                 END IF
  440         CONTINUE
           END IF
           GO TO 800
C
C          HEADWATER CREST HAS BEEN REACHED.  IF ELEVATION IS ABOVE
C          TOP OF GATES, FOLLOW NORMAL PROCEDURE UNTIL ELEVATION
C          RECEDES TO TOP OF GATES
C
  460      CONTINUE
           IF ( EL(I) .GT. TOG(RRPTR) ) THEN
              START = I + 1
              DO 520 I = START,END
                 IF ( SEASON(RRPTR) ) CALL UPDATE(WRKHI,ELGUID,TOPZON)
                 OS(I) = GETOS(I)
                 DO 480 J = 2,NUMPTS
                    PTR = J
                    IF ( OS(I) .LE. OKS(J) ) GO TO 490
  480            CONTINUE
  490            CONTINUE
                 OUT(I) = MAX(GETOUT(I,PTR),QEMPTY(RRPTR))
                 KS(I) = OS(I) - OUT(I)
                 EL(I) = GETEL1(I,PTR)
                 IF ( EL(I) .LT. TOG(RRPTR) ) THEN
                    EL(I) = TOG(RRPTR)
                    DO 500 J = 2,NUMPTS
                       PTR = J
                       IF ( EL(I) .LT. ELEV(J,RRPTR) ) GO TO 510
  500               CONTINUE
  510               CONTINUE
                    KS(I) = GETKS(I,PTR)
                    OUT(I) = TOTINF(I)
                 END IF
                 IF ( EL(I) .EQ. TOG(RRPTR) ) GO TO 560
  520         CONTINUE
              GO TO 800
           END IF
C
C          HEADWATER CREST HAS BEEN REACHED,
C
  540      CONTINUE
           I = I - 1
           IF ( SEASON(RRPTR) ) CALL UPDATE(-WRKHI,ELGUID,TOPZON)
              GO TO 570
C
C          OR HEADWATER HAS RECEDED TO TOP OF GATES
C
```

```
  560       CONTINUE
               IF ( OUT(I) .LT. QEMPTY(RRPTR) ) I = I - 1
  570       CONTINUE
C
C           HOLD THIS ELEVATION UNTIL DISCHARGE RECEDES TO EMPTYING
C           RATE (QEMPTY)
C
            ELHOLD = EL(I)
            KSHOLD = KS(I)
            START = I + 1
            DO 580 I = START,END
               IF ( SEASON(RRPTR) ) CALL UPDATE(WRKHI,ELGUID,TOPZON)
               OS(I) = GETOS(I)
               EL(I) = ELHOLD
               KS(I) = KSHOLD
               OUT(I) = OS(I) - KS(I)
               IF ( EL(I) .EQ. EL(I-1) ) OUT(I) = TOTINF(I)
               IF ( OUT(I) .LT. QEMPTY(RRPTR) ) GO TO 600
  580       CONTINUE
            GO TO 800
C
C           EMPTYING RATE HAS BEEN REACHED.  HOLD AT EMPTYING RATE
C           OR HEADWATER CREST DISCHARGE, WHICHEVER IS LESS, UNTIL
C           ELEVATION FALLS BELOW SEASONAL GUIDE, REGULATING ZONE
C           OR INITIAL ELEVATION, WHICHEVER IS APPLICABLE
C
  600       CONTINUE
               IF ( EL(I) .LT. TOG(RRPTR) ) THEN
               EMPRAT = MIN(QEMPTY(RRPTR),OUT(I-1))
            ELSE
               EMPRAT = QEMPTY(RRPTR)
               END IF
            START = I
            IF ( SEASON(RRPTR) ) THEN
               CALL UPDATE(-WRKHI,ELGUID,TOPZON)
            ELSE
               TOPZON = EL(1)
               ELGUID = EL(1)
            END IF
            DO 660 I = START,END
               IF ( SEASON(RRPTR) ) CALL UPDATE(WRKHI,ELGUID,TOPZON)
               OS(I) = GETOS(I)
  620          CONTINUE
               OUT(I) = EMPRAT
               KS(I) = OS(I) - OUT(I)
               KSTO = KS(I) * WRKHI / 48.
               DO 640 J = 2,NUMPTS
                  PTR = J
                  IF ( KSTO .LE. STO(J,RRPTR) ) GO TO 650
  640          CONTINUE
  650          CONTINUE
               EL(I) = GETEL2(KSTO,J)
               IF ( EL(I) .LT. TOPZON .AND. FOUT(RRPTR) .LT. EMPRAT )
     *         THEN
                  EMPRAT = FOUT(RRPTR)
                  GO TO 620
               ELSE IF ( EL(I) .LT. TOPZON ) THEN
                  GO TO 680
               END IF
  660       CONTINUE
```

```
            GO TO 800
C
C           INITIAL ELEVATION OR SEASONAL GUIDE HAS BEEN REACHED.
C           HOLD UNTIL END OF STORM.
C
  680       CONTINUE
            START = I
            IF ( SEASON(RRPTR) ) CALL UPDATE(-WRKHI,ELGUID,TOPZON)
            DO 760 I = START,END
               IF ( SEASON(RRPTR) ) THEN
                   CALL UPDATE(WRKHI,ELGUID,TOPZON)
                  OS(I) = GETOS(I)
                  EL(I) = ELGUID
                  DO 700 J = 2,NUMPTS
                     PTR = J
                     IF ( EL(I) .LT. ELEV(J,RRPTR) ) GO TO 710
  700             CONTINUE
  710             CONTINUE
                  KS(I) = GETKS(I,PTR)
                  OUT(I) = MAX(GETOS(I)-KS(I),0.)
                  IF ( EL(I) .EQ. EL(I-1) ) OUT(I) = TOTINF(I)
                  IF ( KS(I) .GT. GETOS(I) ) THEN
                     KS(I) = GETOS(I)
                     KSTO = KS(I) * WRKHI / 48.
                     DO 720 J = 2,NUMPTS
                        PTR = J
                        IF ( KSTO .LE. STO(J,RRPTR) ) GO TO 730
  720                CONTINUE
  730                CONTINUE
                     EL(I) = GETEL2(KSTO,PTR)
                  END IF
                  IF ( OUT(I) .GT. FOUT(RRPTR) ) THEN
                     OUT(I) = FOUT(RRPTR)
                     KS(I) = OS(I) - OUT(I)
                     KSTO = KS(I) * WRKHI / 48.
                     DO 740 J = 2,NUMPTS
                        PTR = J
                        IF ( KSTO .LE. STO(J,RRPTR) ) GO TO 750
  740                CONTINUE
  750                CONTINUE
                     EL(I) = GETEL2(KSTO,PTR)
                  END IF
               ELSE
                  EL(I) = EL(1)
                  OUT(I) = TOTINF(I)
                  KS(I) = KS(1)
               END IF
  760       CONTINUE
C
  800       CONTINUE
  900    CONTINUE
      END IF
      UPDSCH = .FALSE.
      RETURN
      END
      SUBROUTINE WRITE(PREVCD,PTR)
      INTEGER PREVCD,PTR
C
C     ROUTINE TO OUTPUT HYDROGRAPH ROUTING
C
```

```
      COMMON /TABLES/ DMO(12),MODAYS(12)
      INTEGER DMO,MODAYS
C
      COMMON /TIMES/ SDATES(9),EDATE,STIMES(9),ETIME,NUMHRS(9),TOTHRS
      INTEGER SDATES,EDATE
      INTEGER STIMES,ETIME
      REAL NUMHRS,TOTHRS
C
      COMMON /NAMES/ ANAMES(25)
      CHARACTER*80 ANAMES
C
      COMMON /RESRVR/ RSVRNM(10),RRPTR,NPTS(10),EL(800),OUT(800)
      CHARACTER RSVRNM*16
      INTEGER RRPTR,NPTS
      REAL EL,OUT
C
      COMMON /HYDRGR/ CHANNL,WRKHI,WKNORD,HYDWRK(800),DSCWRK(800),UPDSCH
      REAL WRKHI,HYDWRK,DSCWRK
      INTEGER CHANNL
      INTEGER WKNORD
      LOGICAL UPDSCH
C
      REAL CHI,MMHI,MM,WOUT
      INTEGER HHHI,NFPD,MONTH,HH,DATE,HYDPTR,DAY,START,END
C
      TOTINF(I) = HYDWRK(I) + DSCWRK(I)
C
C     OUTPUT ROUTING TITLE AND HEADINGS
C
      WRITE (6,50) ANAMES(PTR)
   50 FORMAT (1H1,A80//)
      IF ( PREVCD .EQ. 2 ) THEN
         IF ( UPDSCH ) WRITE (6,100)
  100       FORMAT (T20,'AVE.',T29,'AVE.')
         WRITE (6,150)
  150    FORMAT (T3,'DATE',T10,'TIME',T19,'INFLOW',T28,'OUTFLOW',T39,
     *           'ELEVATION'/)
      ELSE
         WRITE (6,200)
  200    FORMAT (T3,'DATE',T10,'TIME',T19,'INFLOW'/)
      END IF
C
C     INITIALIZE VARIABLES FOR COMPUTING CURRENT DATE AND TIME
C
      CHI = 100. * WRKHI
      HHHI = INT(WRKHI)
      MMHI = 60. * ( WRKHI - INT(WRKHI) )
      NFPD = 24 / WRKHI
      MONTH = SDATES(1) / 10000
      HH = STIMES(1) / 100
      MM = MOD(STIMES(1),100)
      DATE = SDATES(1) / 100
      HYDPTR = 1
C
C     FOR EACH DAY ...
C
      DO 800 NFLOWS = INT((2400-STIMES(1))/CHI)+1,WKNORD+NFPD-1,NFPD
C
C        COMPUTE AND OUTPUT FIRST FLOW OF DAY
C
```

```
         DAY = DATE - MONTH * 100
         IF ( PREVCD .EQ. 2 ) THEN
            IF ( UPDSCH ) THEN
               IF ( HYDPTR .EQ. 1 ) THEN
                  WOUT = TOTINF(HYDPTR)
               ELSE
                  WOUT = ( HYDWRK(HYDPTR) + HYDWRK(HYDPTR-1) ) / 2. +
     *                 DSCWRK(HYDPTR)
               END IF
            ELSE
               WOUT = HYDWRK(HYDPTR)
            END IF
            WRITE (6,300) MONTH,DAY,HH,NINT(MM),WOUT,OUT(HYDPTR),
     *                    EL(HYDPTR)
  300       FORMAT (I3,I3,I5.2,I2.2,F11.0,F10.0,F12.2)
         ELSE
            WRITE (6,350) MONTH,DAY,HH,NINT(MM),TOTINF(HYDPTR)
  350       FORMAT (I3,I3,I5.2,I2.2,F11.0)
         END IF
C
C        FOR EACH REMAINING TIME PERIOD DURING DAY ...
C
         START = HYDPTR + 1
         END = MIN(NFLOWS,WKNORD)
         DO 500 HYDPTR = START,END
C
C           UPDATE TIME
C
            MM = MM + MMHI
            IF ( MM .GE. 59.5 ) THEN
               MM = MM - 60.
               HH = HH + 1
            END IF
            HH = HH + HHHI
C
C           AND OUTPUT TIME ALONG WITH COMPUTED FLOW
C
            IF ( PREVCD .EQ. 2 ) THEN
               IF ( UPDSCH ) THEN
                  WOUT = ( HYDWRK(HYDPTR) + HYDWRK(HYDPTR-1) ) / 2. +
     *                 DSCWRK(HYDPTR)
               ELSE
                  WOUT = HYDWRK(HYDPTR)
               END IF
               WRITE (6,400) HH,NINT(MM),WOUT,OUT(HYDPTR),EL(HYDPTR)
  400          FORMAT (I11.2,I2.2,F11.0,F10.0,F12.2)
            ELSE
               WRITE (6,450) HH,NINT(MM),TOTINF(HYDPTR)
  450          FORMAT (I11.2,I2.2,F11.0)
            END IF
  500    CONTINUE
C
C        CHECK FOR END OF MONTH
C
         IF ( DATE .GE. DMO(MONTH) ) THEN
            MONTH = MOD(MONTH,12) + 1
            DATE = MONTH * 100 + 1
         ELSE
            DATE = DATE + 1
         END IF
```

```
         MM = MM + MMHI
         IF ( MM .GE. 59.5 ) THEN
            MM = MM - 60.
            HH = HH + 1
         END IF
         HH = HH + HHHI - 24
         HYDPTR = END + 1
  800 CONTINUE
      RETURN
      END
      SUBROUTINE OUTRAT(RSVRNM,STMPTR,ELEV,QRAT,STO,NUMPTS)
      CHARACTER*16 RSVRNM
      INTEGER STMPTR,NUMPTS
      REAL ELEV(50),QRAT(50),STO(50)
C
C     ROUTINE TO OUTPUT RATING CURVE FOR CURRENT STORM AND RESERVOIR
C
      WRITE (6,50) RSVRNM,STMPTR
   50 FORMAT ('1',14X,A16/13X,'DISCHARGE & STORAGE'/13X,'CURVES FOR ',
     *        'STORM ',I1//T5,'ELEVATION',T19,'DISCHARGE',T33,
     *        'STORAGE'/)
      WRITE (6,100) (ELEV(I),QRAT(I),STO(I),I=1,NUMPTS)
  100 FORMAT (T6,F6.1,T20,F7.0,T32,F8.0)
      RETURN
      END
      SUBROUTINE GETSTO(RSVRNM,STO,NUMPTS,ELEV)
      CHARACTER RSVRNM*16
      REAL STO(50),ELEV(50)
      INTEGER NUMPTS
C
C     ROUTINE TO SEARCH STORAGE CURVE FILE FOR STORAGE CURVE
C     USING RESERVOIR NAME
C
      CHARACTER NAME*16
C
      REWIND 8
C
   50 CONTINUE
         READ (8,100,END=910) NAME,NUMPTS
  100    FORMAT (A16/I4)
         READ (8,150,END=910) (ELEV(I),I=1,NUMPTS)
         READ (8,150,END=910) (STO(I),I=1,NUMPTS)
  150    FORMAT (10F8.0)
      IF ( NAME .NE. RSVRNM ) GO TO 50
C
      GO TO 999
C
  910 CONTINUE
      IF ( NAME .NE. RSVRNM ) WRITE (6,915) RSVRNM
  915 FORMAT (//' RESERVOIR NAME ',A16,
     *          ' NOT FOUND IN STORAGE CURVES FILE'//)
C
  999 CONTINUE
      RETURN
      END
      SUBROUTINE GETRAT(RSVRNM,QRAT,NUMPTS,ELEV)
      CHARACTER RSVRNM*16
      REAL QRAT(50),ELEV(50)
      INTEGER NUMPTS
C
```

```
C     ROUTINE TO SEARCH RATING CURVE FILE FOR RATING CURVE
C     USING RESERVOIR NAME
C
      CHARACTER NAME*16
C
      REWIND 9
C
   50 CONTINUE
         READ (9,100,END=910) NAME,NUMPTS
  100    FORMAT (A16/I4)
         READ (9,150,END=910) (ELEV(I),I=1,NUMPTS)
         READ (9,150,END=910) (QRAT(I),I=1,NUMPTS)
  150    FORMAT (10F8.0)
      IF ( NAME .NE. RSVRNM ) GO TO 50
C
      GO TO 999
C
  910 CONTINUE
      IF ( NAME .NE. RSVRNM ) WRITE (6,915) RSVRNM
  915 FORMAT (//' RESERVOIR NAME ',A16,
     *          ' NOT FOUND IN DISCHARGE CURVES FILE'//)
C
  999 CONTINUE
      RETURN
      END
      SUBROUTINE GETIFR(RSVRNM,FEL,FOUT,NUMPTS,ELEV,QRAT,NUL,TOG,QEMPTY)
      CHARACTER RSVRNM*16
      REAL FEL,FOUT,ELEV(50),QRAT(50),NUL,TOG,QEMPTY
      INTEGER NUMPTS
C
C     ROUTINE TO COMPUTE IMPROVED FIXED RULES RATING CURVE
C
      REAL EL(50),NULEL(50),NULQ(50),TOGQ(50),ZERFLO,QNUL,QTOG,WT,SLOPE
      INTEGER NPTS1,NPTS2
      LOGICAL FOUND
      CHARACTER NAME*16,SKIP(70)
C
      REWIND 10
C
C     USE RESERVOIR NAME TO FIND RESERVOIR
C
   50 CONTINUE
         READ (10,100,END=910) NAME,NPTS1,NPTS2,ZERFLO,TOG,QEMPTY
  100    FORMAT (A16/2I8,3F8.0)
         IF ( RSVRNM .NE. NAME ) THEN
            NCARDS = NPTS1 + ( ( NPTS2 + 9 ) / 10 ) * 2
            READ (10,150) (SKIP(I),I=1,NCARDS)
  150       FORMAT (A1)
         GO TO 50
         END IF
C
C     SEARCH FOR "INTERPOLATING" ELEVATIONS
C
      FOUND = .FALSE.
      READ (10,200) EL(1),NULEL(1),NULQ(1),TOGQ(1)
      DO 300 I = 2,NPTS1
         READ (10,200) EL(I),NULEL(I),NULQ(I),TOGQ(I)
  200    FORMAT (10F8.0)
         IF ( .NOT. FOUND ) THEN
C
```

```
C           WHEN ELEVATIONS ARE FOUND, COMPUTE NORMAL UPPER LIMIT
C           ELEVATION (NUL) AND DISCHARGE (QNUL), AND TOP OF GATES
C           DISCHARGE (QTOG) ASSOCIATED WITH INITIAL ELEVATION (FEL)
C
            IF ( FEL .LE. EL(I) ) THEN
               WT = ( FEL - EL(I-1) ) / ( EL(I) - EL(I-1) )
               NUL = ( NULEL(I) - NULEL(I-1) ) * WT + NULEL(I-1)
               QNUL = ( NULQ(I) - NULQ(I-1) ) * WT + NULQ(I-1)
               QTOG = ( TOGQ(I) - TOGQ(I-1) ) * WT + TOGQ(I-1)
               FOUND = .TRUE.
            END IF
         END IF
  300 CONTINUE
C
C     DETERMINE POINTS ON RATING CURVE
C
      ELEV(1) = FEL
      IF ( FEL .GE. ZERFLO ) THEN
         QRAT(1) = FOUT
         SLOPE = ( NUL - FEL ) / QNUL
         ELEV(2) = SLOPE * FOUT + FEL
         QRAT(2) = FOUT
      ELSE
         QRAT(1) = 0.0
         ELEV(2) = ZERFLO
         QRAT(2) = 0.0
      END IF
      ELEV(3) = NUL
      QRAT(3) = QNUL
      ELEV(4) = TOG
      QRAT(4) = QTOG
C
C     INCLUDING UNCONTROLLED PORTION OF RATING CURVE
C
      NUMPTS = NPTS2 + 4
      READ (10,200) (ELEV(I),I=5,NUMPTS)
      READ (10,200) (QRAT(I),I=5,NUMPTS)
      GO TO 999
C
  910 CONTINUE
      WRITE (6,915) RSVRNM
  915 FORMAT (//' RESERVOIR NAME ',A16,' NOT FOUND IN IMPROVED FIXED',
     *          ' RULES FILE'//)
C
  999 CONTINUE
      RETURN
      END
      SUBROUTINE SRTMRG(FROMX,FNUM,TOX,TNUM,FROMY,TOY)
      REAL FROMX(50),TOX(50),FROMY(50),TOY(50)
      INTEGER FNUM,TNUM
C
C     THIS ROUTING PERFORMS A SORT/MERGE.  INPUT ARE 2 ORDERED PAIRS:
C     (FROMX,FROMY) & (TOX,TOY), WHERE FROMX & TOX ARE SORTED ARRAYS
C     OF "X-ORDINATES", EACH WITH AN ASSOCIATED ARRAY OF "Y-ORDINATES",
C     FROMY & TOY, RESPECTIVELY.  OUTPUT IS 1 ORDERED TRIPLE
C     (TOX,TOY,FROMY), WHERE ALL UNIQUE X-ORDINATES FROM FROMX ARE
C     ADDED TO TOX, ALONG WITH ANY INTERPOLATED VALUES NECESSARY TO
C     FILL IN ARRAYS TOY & FROMY.
C
      INTEGER FPTRS(50),TPTRS(50),FPTR,TPTR,TOTNUM,FIDX,TIDX,IDXH
```

```
      REAL LINTRP
C
      FPTR = 1
      TPTR = 1
      TOTNUM = 0
C
C     FIRST, SET UP POINTERS TO FIND UNIQUE X-ORDINATES IN FROMX
C
   50 CONTINUE
         TOTNUM = TOTNUM + 1
         IF ( FROMX(FPTR) .LT. TOX(TPTR) ) THEN
            FPTRS(FPTR) = TOTNUM
            FPTR = FPTR + 1
         ELSE IF ( FROMX(FPTR) .GT. TOX(TPTR) ) THEN
            TPTRS(TPTR) = TOTNUM
            TPTR = TPTR + 1
         ELSE
            FPTRS(FPTR) = TOTNUM
            TPTRS(TPTR) = TOTNUM
            FPTR = FPTR + 1
            TPTR = TPTR + 1
         END IF
      IF ( FPTR .LE. FNUM .AND. TPTR .LE. TNUM ) GO TO 50
C
      IF ( TPTR .LE. TNUM ) THEN
         DO 100 I = TPTR,TNUM
            TOTNUM = TOTNUM + 1
            TPTRS(I) = TOTNUM
  100    CONTINUE
      ELSE
         DO 150 I = FPTR,FNUM
            TOTNUM = TOTNUM + 1
            FPTRS(I) = TOTNUM
  150    CONTINUE
      END IF
C
C     THEN USE POINTERS TO MERGE INTO TOX
C
      FPTR = FNUM
      TPTR = TNUM
  200 CONTINUE
         FIDX = FPTRS(FPTR)
         TIDX = TPTRS(TPTR)
         IF ( FIDX .LT. TIDX ) THEN
            TOX(TIDX) = TOX(TPTR)
            TOY(TIDX) = TOY(TPTR)
            IDXH = MIN(FPTR+1,FNUM)
            FROMY(TIDX) = LINTRP(FROMY(IDXH),FROMY(IDXH-1),
     *                           FROMX(IDXH),FROMX(IDXH-1),TOX(TIDX))
            TPTR = TPTR - 1
         ELSE IF ( FIDX .GT. TIDX ) THEN
            IDXH = MIN(TPTR+1,TNUM)
            TOY(FIDX) = LINTRP(TOY(IDXH),TOY(IDXH-1),TOX(IDXH),
     *                         TOX(IDXH-1),FROMX(FPTR))
            TOX(FIDX) = FROMX(FPTR)
            FROMY(FIDX) = FROMY(FPTR)
            FPTR = FPTR - 1
         ELSE
            TOX(TIDX) = TOX(TPTR)
            TOY(TIDX) = TOY(TPTR)
```

```
            FROMY(FIDX) = FROMY(FPTR)
            TPTR = TPTR - 1
            FPTR = FPTR - 1
         END IF
      IF ( TPTR*FPTR .GT. 0 ) GO TO 200
C
      IF ( TPTR .GT. 0 ) THEN
         DO 300 TIDX = TPTR,1,-1
            FROMY(TIDX) = LINTRP(FROMY(TIDX+2),FROMY(TIDX+1),FROMX(2),
     *                           FROMX(1),TOX(TIDX))
  300    CONTINUE
      ELSE
         DO 350 FIDX = FPTR,1,-1
            TOX(FIDX) = FROMX(FIDX)
            TOY(FIDX) = LINTRP(TOY(FIDX+2),TOY(FIDX+1),TOX(FIDX+2),
     *                         TOX(FIDX+1),TOX(FIDX))
  350    CONTINUE
      END IF
      TNUM = TOTNUM
      RETURN
      END
      SUBROUTINE FRSTEL(RSVRNM,DATE,TIME,GUIDE,TOPZON)
      CHARACTER*16 RSVRNM
      INTEGER DATE,TIME
      REAL GUIDE,TOPZON
C
      COMMON /GUIDES/GNMPTS,GPTR,SPTR,DAYS,GDAYS,HOUR,GELEVS,ZELEVS,
     *               GSLOPE,ZSLOPE
      INTEGER GNMPTS,GPTR,SPTR,DAYS,GDAYS(20),HOUR
      REAL GELEVS(20),ZELEVS(20),GSLOPE(20),ZSLOPE(20)
C
      CHARACTER*16 NAME
      INTEGER ZPTR,OLDPTR,YEAR,ZYEAR,ZDATE
      INTEGER GDATES(20),ZDAYS,HIDAYS,LODAYS,SDAYS
      INTEGER NDAYS
      DATA ZDATE/316/
C
      REWIND 11
C
   50 CONTINUE
         READ (11,100,END=910) NAME,GNMPTS,ZELEVS(1)
  100    FORMAT (A16/I8,F8.0)
         READ (11,150,END=910) (GDATES(I),I=1,GNMPTS)
  150    FORMAT (10I8)
         READ (11,200,END=910) (GELEVS(I),I=1,GNMPTS)
  200    FORMAT (10F8.0)
      IF ( NAME .NE. RSVRNM ) GO TO 50
C
      ZPTR = 0
      DAYS = NDAYS(DATE,YEAR,IDUM,IDUM)
      GDATES(GNMPTS+1) = 9999
C
C     IF REGULATING ZONE, ADD "INTERSECT" DATE (ZDATE) AND ELEV.
C     GELEVS(ZPTR), AND COMPUTE TOP OF REGULATING ZONE SLOPE (ZSLOPE(1))
C
      IF ( ZELEVS(1) .GT. 0.0 ) THEN
         DO 300 I = 2,GNMPTS+1
            IF ( GDATES(I) .GE. ZDATE ) GO TO 350
  300    CONTINUE
  350    CONTINUE
```

```
C
         ZPTR = I
         ZYEAR = YEAR
         IF ( GDATES(I) .NE. ZDATE ) THEN
            GNMPTS = GNMPTS + 1
            DO 400 I = GNMPTS+1,ZPTR+1,-1
               GDATES(I) = GDATES(I-1)
               GELEVS(I) = GELEVS(I-1)
  400       CONTINUE
            GDATES(ZPTR) = ZDATE
            IF ( GDATES(ZPTR+1) .LT. DATE/100 ) ZYEAR = ZYEAR + 1
            HIDAYS = NDAYS(GDATES(ZPTR+1)*100+ZYEAR,IDUM,IDUM,IDUM)
            LODAYS = NDAYS(GDATES(ZPTR-1)*100+ZYEAR,IDUM,IDUM,IDUM)
            ZDAYS = NDAYS(GDATES(ZPTR)*100+ZYEAR,IDUM,IDUM,IDUM)
            GELEVS(ZPTR) = GELEVS(ZPTR-1) + ( ZDAYS - LODAYS ) *
     1                     ( GELEVS(ZPTR+1) - GELEVS(ZPTR-1) ) /
     2                     ( HIDAYS - LODAYS )
         ELSE
            IF ( GDATES(ZPTR) .LT. DATE/100 ) ZYEAR = ZYEAR + 1
            ZDAYS = NDAYS(GDATES(ZPTR)*100+ZYEAR,IDUM,IDUM,IDUM)
         END IF
         ZSLOPE(1) = ( GELEVS(ZPTR) - ZELEVS(1) ) / ( 24. * ( ZDAYS -
     1                 NDAYS(GDATES(1)*100+ZYEAR,IDUM,IDUM,IDUM) ) )
      END IF
C
C     COMPUTE SLOPES OF SEASONAL GUIDE ELEVATIONS
C
      DO 500 I = 1,GNMPTS+1
         IF ( GDATES(I) .GT. DATE/100 ) GO TO 550
  500 CONTINUE
  550 CONTINUE
C
      GPTR = I - 1
      SPTR = GPTR
      GDAYS(GPTR) = NDAYS(GDATES(GPTR)*100+YEAR,IDUM,IDUM,IDUM)
      SDAYS = GDAYS(GPTR)
      DO 600 I = 1,GNMPTS
         OLDPTR = GPTR
         GPTR = MOD(GPTR,GNMPTS) + 1
         IF ( GPTR .EQ. 1 ) YEAR = YEAR + 1
         GDAYS(GPTR) = NDAYS(GDATES(GPTR)*100+YEAR,IDUM,IDUM,IDUM)
         GSLOPE(OLDPTR) = ( GELEVS(GPTR) - GELEVS(OLDPTR) ) / ( 24. *
     1                ( GDAYS(GPTR) - GDAYS(OLDPTR) ) )
         IF ( GPTR .LE. ZPTR .AND. GPTR .GT. 1 ) THEN
            ZELEVS(GPTR) = ZELEVS(1) + ZSLOPE(1) * 24. *
     1                     ( GDAYS(GPTR) - GDAYS(1) )
            ZSLOPE(OLDPTR) = ZSLOPE(1)
         ELSE IF ( GPTR .GT. ZPTR ) THEN
            ZELEVS(GPTR) = GELEVS(GPTR)
            ZSLOPE(OLDPTR) = GSLOPE(OLDPTR)
         ELSE
            ZSLOPE(OLDPTR) = GSLOPE(OLDPTR)
         END IF
  600  CONTINUE
      IF ( ZPTR .GT. 0 ) ZELEVS(ZPTR) = GELEVS(ZPTR)
C
C     COMPUTE SEASONAL GUIDE AND TOP OF REG. ZONE ELEVATIONS
C
      GUIDE = GELEVS(GPTR) + ( DAYS - SDAYS ) * 24. * GSLOPE(GPTR)
      TOPZON = ZELEVS(GPTR) + ( DAYS - SDAYS ) * 24. * ZSLOPE(GPTR)
```

```
      HOUR = TIME / 100. + MOD(TIME,100) / 60.
      GUIDE = GUIDE + HOUR * GSLOPE(GPTR)
      TOPZON = TOPZON + HOUR * ZSLOPE(GPTR)
      GO TO 999
C
  910 CONTINUE
      IF ( NAME .NE. RSVRNM ) WRITE (6,915) RSVRNM
  915 FORMAT (//' RESERVOIR NAME ',A16,
     *          ' NOT FOUND IN SEASONAL GUIDES FILE'//)
C
  999 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE UPDATE(DELTAT,GUIDE,TOPZON)
      REAL DELTAT,GUIDE,TOPZON
C
      COMMON /GUIDES/GNMPTS,GPTR,SPTR,DAYS,GDAYS,HOUR,GELEVS,ZELEVS,
     *               GSLOPE,ZSLOPE
      INTEGER GNMPTS,GPTR,SPTR,DAYS,GDAYS(20),HOUR
      REAL GELEVS(20),ZELEVS(20),GSLOPE(20),ZSLOPE(20)
C
      INTEGER NXTPTR
      REAL CHANGE
C
C     ENTRY UPDATE(DELTAT,GUIDE,TOPZON)
C
C     ENTRY TO UPDATE ELEVATIONS
C
      CHANGE = DELTAT
C
  800 CONTINUE
      IF ( HOUR+CHANGE .GT. 24. ) THEN
         CHANGE = CHANGE + HOUR - 24.
         DAYS = DAYS + 1
         GUIDE = GUIDE + ( 24. - HOUR ) * GSLOPE(GPTR)
         TOPZON = TOPZON + ( 24. - HOUR ) * ZSLOPE(GPTR)
         HOUR = 0.
         NXTPTR = MOD(GPTR,GNMPTS) + 1
         IF ( DAYS .GE. GDAYS(NXTPTR) ) THEN
            GPTR = NXTPTR
            GUIDE = GELEVS(NXTPTR)
            TOPZON = ZELEVS(NXTPTR)
         END IF
         GO TO 800
      ELSE IF ( HOUR+CHANGE .LT. 0. ) THEN
         CHANGE = CHANGE + HOUR
         DAYS = DAYS - 1
         GUIDE = GUIDE - HOUR * GSLOPE(GPTR)
         TOPZON = TOPZON - HOUR * ZSLOPE(GPTR)
         HOUR = 24.
         NXTPTR = MOD(GPTR+GNMPTS-2,GNMPTS) + 1
         IF ( DAYS .LE. GDAYS(GPTR) .AND. GPTR .NE. SPTR ) GPTR = NXTPTR
         GO TO 800
      ELSE
         HOUR = HOUR + CHANGE
         GUIDE = GUIDE + CHANGE * GSLOPE(GPTR)
         TOPZON = TOPZON + CHANGE * ZSLOPE(GPTR)
      END IF
```

```
      RETURN
      END
      REAL FUNCTION GCD(NUM1,NUM2)
      REAL NUM1,NUM2
C
C     FUNCTION RETURNS THE LARGEST REAL NUMBER THAT DIVIDES BOTH
C     NUM1 & NUM2
C
      I = 0
  100 CONTINUE
         I = I + 1
         GCD = NUM1 / I
         MULT = NINT(NUM2/GCD)
         IF ( ABS(MULT*GCD-NUM2) .LT. 1.E-4 ) GO TO 900
      GO TO 100
  900 CONTINUE
      IF ( MULT .EQ. 1 ) GCD = NUM2
      RETURN
      END
      INTEGER FUNCTION NDAYS(DATE,YEAR,MONTH,DAY)
      INTEGER DATE,YEAR,MONTH,DAY
C
C     FUNCTION RETURNS NUMBER OF DAYS BETWEEN "TURN OF CENTURY" AND
C     DATE (MMDDYY) ALONG WITH YEAR (YY), MONTH (MM), AND DAY (DD).
C
      COMMON /TABLES/ DMO(12),MODAYS(12)
      INTEGER DMO,MODAYS
C
      INTEGER YR,MO,DY
C
      YR = MOD(DATE,100)
      MO = DATE / 10000
      DY = DATE / 100 - MO * 100
      NDAYS = DY
      IF ( MO .GT. 1 ) THEN
         DO 100 I = 1,MO-1
            NDAYS = NDAYS + MODAYS(I)
  100    CONTINUE
      END IF
      NDAYS = NDAYS + YR * 365 + YR / 4
      IF ( MOD(YR,4) .EQ. 0 .AND. MO .LE. 2 ) NDAYS = NDAYS - 1
      YEAR = YR
      MONTH = MO
      DAY = DY
      RETURN
      END
      REAL FUNCTION LINTRP(Y1,Y2,X1,X2,X)
C
C        STANDARD LINEAR INTERPOLATING FUNCTION
C
      IF (X1.EQ.X2) THEN
         LINTRP=Y1
      ELSE
         LINTRP=Y1+(X-X1)*(Y2-Y1)/(X2-X1)
      ENDIF
      RETURN
      END
      SUBROUTINE CHGHI(FLOWS,OLDHI,NEWHI,NUMORD,AVE)
      REAL FLOWS(800),OLDHI,NEWHI
      INTEGER NUMORD
```

```
      LOGICAL AVE
C
C     THIS ROUTINE CHANGES THE HYDROGRAPH ORDINATE INTERVAL FROM
C     OLDHI TO NEWHI.  OLDHI IS AN INTEGER MULTIPLE OF NEWHI.  IF
C     AVE = .TRUE., ORDINATES REPRESENT AVERAGE VALUES OVER INTERVAL.
C
      INTEGER INC,NUM,PTR
      REAL DELTA
C
      INC = NINT(OLDHI/NEWHI)
      NUM = INC * ( NUMORD - 1 ) + 1
      PTR = NUM
      DELTA = 0.0
      DO 200 I = NUMORD,2,-1
         IF ( .NOT. AVE ) DELTA = ( FLOWS(I) - FLOWS(I-1) ) / INC
         FLOWS(PTR) = FLOWS(I)
         DO 100 J = 1,INC-1
            PTR = PTR - 1
            FLOWS(PTR) = FLOWS(PTR+1) - DELTA
  100    CONTINUE
         PTR = PTR - 1
  200 CONTINUE
      RETURN
      END

      SUBROUTINE DoDialog()
      USE DIALOGM
      IMPLICIT NONE
      INCLUDE 'TRBROUTE.fd'

      CHARACTER*240 INFILE,OUTFIL,IHGFIL,OHGFIL
        COMMON /FILES/INFILE,OUTFIL,IHGFIL,OHGFIL
C
      INTEGER retint
      LOGICAL retlog, enable
      TYPE (dialog) dlg
      character*240 dirname
      integer istat
       EXTERNAL UpdateFiles, UpdateButton
       INTEGER GETCWD
!      Initialize
       INFILE = "*.dat"
       OUTFIL = "*.out"
       IHGFIL = "*.hyd"
       OHGFIL = "*.rte"
       IF ( .not. DlgInit( IDD_TRBROUTE, dlg ) ) THEN
             WRITE (*,*) "Error: dialog not found"
       ELSE
!      variable dirname must be long enough to hold entire string
             enable = .false.
             retlog = DlgSet( dlg, IDOK, .false., dlg_enable )
             retlog = DlgSet( dlg, IDC_BUTTON_PWD, enable, dlg_enable )
             retlog = DlgSet( dlg, IDC_BUTTON_OUT, enable, dlg_enable )
             retlog = DlgSet( dlg, IDC_BUTTON_HYD, enable, dlg_enable )
             retlog = DlgSet( dlg, IDC_BUTTON_RTE, enable, dlg_enable )
             ISTAT = GETCWD (dirname)
             IF (ISTAT == 0)
     1       retlog = DlgSet( dlg, IDC_TRBROUTE_PWD, dirname )
             retlog = DlgSet( dlg, IDC_TRBROUTE_DAT, INFILE, 1 )
             retlog = DlgSet( dlg, IDC_TRBROUTE_OUT, OUTFIL, 1 )
```

```
            retlog = DlgSet( dlg, IDC_TRBROUTE_HYD, IHGFIL, 1 )
            retlog = DlgSet( dlg, IDC_TRBROUTE_RTE, OHGFIL, 1 )
            retlog = DlgSetSub( dlg, IDC_TRBROUTE_DAT, UpdateButton,
     1                                  dlg_selchange )
            retlog = DlgSetSub( dlg, IDC_TRBROUTE_DAT, UpdateButton,
     1                                  dlg_update )
            call UpdateButton( dlg, IDC_TRBROUTE_DAT, dlg_update )
            retlog = DlgSetSub( dlg, IDC_BUTTON_DAT, UpdateFiles )
            retlog = DlgSetSub( dlg, IDC_BUTTON_OUT, UpdateFiles )
            retlog = DlgSetSub( dlg, IDC_BUTTON_HYD, UpdateFiles )
            retlog = DlgSetSub( dlg, IDC_BUTTON_RTE, UpdateFiles )
            call UpdateFiles( dlg, IDC_BUTTON_PWD, dlg_clicked )
            call UpdateFiles( dlg, IDC_BUTTON_DAT, dlg_clicked )
            call UpdateFiles( dlg, IDC_BUTTON_OUT, dlg_clicked )
            call UpdateFiles( dlg, IDC_BUTTON_HYD, dlg_clicked )
            call UpdateFiles( dlg, IDC_BUTTON_RTE, dlg_clicked )
!           Activate the dialog.
            retint = DlgModal( dlg )
            IF ( retint .eq. IDOK ) THEN
                  retlog = DlgGet( dlg, IDC_STATIC_DAT, INFILE )
                  retlog = DlgGet( dlg, IDC_STATIC_OUT, OUTFIL )
                  retlog = DlgGet( dlg, IDC_STATIC_HYD, IHGFIL )
                  retlog = DlgGet( dlg, IDC_STATIC_RTE, OHGFIL )
            ELSE
                  STOP
            END IF
!           Release dialog resources.
            CALL DlgUninit( dlg )
      END IF
      END SUBROUTINE DoDialog

      SUBROUTINE UpdateFiles( dlg, control_name, callbacktype )
      USE DIALOGM
      IMPLICIT NONE
      INCLUDE 'TRBROUTE.fd'
      TYPE (dialog) dlg
      INTEGER control_name
      INTEGER callbacktype
      INTEGER local_callbacktype, numcalls
      character*240 dirname
      LOGICAL retlog
       LOGICAL input,output
       LOGICAL UpdateDir
       DATA numcalls/0/
       DATA input/.false./,output/.true./
      numcalls = numcalls + 1
       local_callbacktype = callbacktype
       IF ( numcalls .gt. 5 ) THEN
          retlog = DlgSet( dlg, IDC_STATIC_MSG, "Status Message" )
          IF ( UpdateDir( dlg, IDC_TRBROUTE_PWD, dirname )   ) THEN
             IF ( control_name .eq. IDC_BUTTON_PWD ) THEN
               CALL UpdateDat( dlg, IDC_TRBROUTE_DAT, IDC_STATIC_DAT,
     1                         IDC_BUTTON_DAT, dirname, input )
               CALL UpdateDat( dlg, IDC_TRBROUTE_OUT, IDC_STATIC_OUT,
     1                         IDC_BUTTON_DAT, dirname, output )
               CALL UpdateDat( dlg, IDC_TRBROUTE_HYD, IDC_STATIC_HYD,
     1                         IDC_BUTTON_DAT, dirname, input )
               CALL UpdateDat( dlg, IDC_TRBROUTE_RTE, IDC_STATIC_RTE,
     1                         IDC_BUTTON_DAT, dirname, output )
             ELSE
```

```
            SELECT CASE ( control_name )
              CASE ( IDC_BUTTON_DAT )
                 CALL UpdateDat( dlg, IDC_TRBROUTE_DAT,
1                                IDC_STATIC_DAT, IDC_BUTTON_DAT,
2                                dirname, input )
              CASE ( IDC_BUTTON_OUT )
                 CALL UpdateDat( dlg, IDC_TRBROUTE_OUT,
1                                IDC_STATIC_OUT, IDC_BUTTON_OUT,
2                                dirname, output )
              CASE ( IDC_BUTTON_HYD )
                 CALL UpdateDat( dlg, IDC_TRBROUTE_HYD,
1                                IDC_STATIC_HYD, IDC_BUTTON_HYD,
2                                dirname, input )
              CASE ( IDC_BUTTON_RTE )
                 CALL UpdateDat( dlg, IDC_TRBROUTE_RTE,
1                                IDC_STATIC_RTE, IDC_BUTTON_RTE,
2                                dirname, output )
            END SELECT
         END IF
      END IF
   END IF
   RETURN
   END SUBROUTINE UpdateFiles

   SUBROUTINE UpdateButton( dlg, control_name, callbacktype )
   USE DIALOGM
   IMPLICIT NONE
   INCLUDE 'TRBROUTE.fd'
   TYPE (dialog) dlg
   INTEGER control_name
   INTEGER callbacktype
   INTEGER local_callbacktype, button_control
   LOGICAL retlog
   character*240 filename,blank
    character*11 button_title
    INTEGER SCAN
    CHARACTER star
    DATA star/"*"/,blank/" "/
    local_callbacktype = callbacktype
   retlog = DlgGet( dlg, control_name, filename, 1 )
   IF ( SCAN(filename,star) .ne. 0 .or. filename .eq. blank ) THEN
      button_title = "Update List"
    ELSE
      button_title = "Select File"
    END IF
    SELECT CASE ( control_name )
      CASE ( IDC_TRBROUTE_DAT )
         button_control = IDC_BUTTON_DAT
      CASE ( IDC_TRBROUTE_OUT )
         button_control = IDC_BUTTON_OUT
      CASE ( IDC_TRBROUTE_HYD )
         button_control = IDC_BUTTON_HYD
      CASE ( IDC_TRBROUTE_RTE )
         button_control = IDC_BUTTON_RTE
   END SELECT
   retlog = DlgSet( dlg, button_control, button_title, dlg_title )
   RETURN
    END SUBROUTINE UpdateButton

   LOGICAL FUNCTION UpdateDir( dlg, control_name, curname )
```

```
      USE DIALOGM
      USE MSFLIB
      IMPLICIT NONE
      TYPE (dialog) dlg
      INTEGER control_name
      CHARACTER*240 curname
       INTEGER istat
      CHARACTER*240 dirname
      LOGICAL retlog
       INTEGER GETCWD
       INTEGER CHDIR
      retlog = DlgGet( dlg, control_name, dirname )
      IF ( CHDIR(dirname) .eq. 0 ) THEN
         UpdateDir = .TRUE.
          curname = dirname
      ELSE
         UpdateDir = .FALSE.
         ISTAT = GETCWD (curname)
          UpdateDir = dirname .eq. curname
         IF (ISTAT == 0 .and. .not. UpdateDir )
     1      retlog = DlgSet( dlg, control_name, curname )
       END IF
      RETURN
      END FUNCTION UpdateDir

      SUBROUTINE UpdateDat( dlg, control_name, static_file,
       1                      button_control, dirname, ofile )
      USE DIALOGM
      USE MSFLIB
      IMPLICIT NONE
      INCLUDE 'TRBROUTE.fd'
      TYPE (dialog) dlg
      INTEGER control_name, static_file, button_control
      CHARACTER*240 dirname

      CHARACTER*240 INFILE,OUTFIL,IHGFIL,OHGFIL
         COMMON /FILES/INFILE,OUTFIL,IHGFIL,OHGFIL
       LOGICAL ofile
      INTEGER index,numfiles
      CHARACTER*240 datname,blank,required,stardot,na
       CHARACTER*11 update,select
      CHARACTER*240 datlist(100)
       CHARACTER*4 xtension
      CHARACTER*80 CARD
      INTEGER NSTRMS,INHYD,OUTHYD,ENDATE
      LOGICAL retlog
       LOGICAL input,output,enable,disable
      INTEGER  handle, length
      TYPE  (FILE$INFO)  info
       DATA blank/" "/,stardot/"*.*"/,required/"Required"/,na/"NA"/
       DATA update/"Update List"/,select/"Select File"/
       DATA input/.false./,output/.true./,enable/.true./,disable/.false./

      retlog = DlgGet( dlg, control_name, datname )
       IF ( datname .eq. blank ) datname = stardot
      handle = FILE$FIRST
       numfiles = 1
      DO WHILE (.TRUE.)
         length = GETFILEINFOQQ(datname, info, handle)
         IF ((handle .EQ. FILE$LAST) .OR.
```

```
     1        (handle .EQ. FILE$ERROR)) THEN
            IF ( numfiles .gt. 1 ) THEN
                 numfiles = numfiles - 1
            ELSE
                IF ( ofile ) THEN
                   OPEN (6,FILE=datname,ERR=100,STATUS='NEW')
                   CLOSE(6,STATUS='DELETE')
                   numfiles = 1
                   datlist(1) = datname
                   GO TO 200
100                CONTINUE
                   retlog = DlgSet( dlg, IDC_STATIC_MSG,
     1                              "Invalid filename" )
                  datlist(1) = stardot
                   retlog = DlgSet( dlg, button_control, update,
     1                               dlg_title )
200               CONTINUE
               ELSE
                   retlog = DlgSet( dlg, IDC_STATIC_MSG,
     1                               "File does not exist" )
                  datlist(1) = stardot
                   retlog = DlgSet( dlg, button_control, update,
     1                               dlg_title )
               END IF
            END IF
            EXIT
         ELSE
            IF ( info.permit .eq. 32 ) THEN
               datlist(numfiles) = info.name
               numfiles = min(numfiles + 1, 100)
            END IF
         END IF
      END DO
      IF ( datlist(1) .ne. stardot )
      1   retlog = DlgSet( dlg, button_control, select, dlg_title )
      retlog = DlgSet( dlg, control_name, numfiles )
      DO index = 1,numfiles
        retlog = DlgSet( dlg, control_name, datlist(index), index )
      END DO
      IF ( numfiles .eq. 1 .and. datlist(1) .ne. stardot ) THEN
         datname = TRIM(dirname)//"\"//datlist(1)
         IF ( control_name .eq. IDC_TRBROUTE_DAT ) THEN
            OPEN (5,FILE=datname,ERR=900)
            READ(5,250) CARD
250         FORMAT(A)
            READ (5,300) NSTRMS,INHYD,OUTHYD,ENDATE
300         FORMAT(4I4)
            CLOSE(5)

            CALL SETFIL( dlg, IDC_STATIC_DAT, datname, input, Blank  )

            retlog = DlgSet( dlg, IDC_BUTTON_OUT, enable, dlg_enable )
            xtension = OUTFIL(2:5)
            CALL SETFIL( dlg, IDC_STATIC_OUT, required, output,
     1                   xtension )

            IF ( INHYD .NE. 0 ) THEN
               retlog = DlgSet( dlg, IDC_BUTTON_HYD, enable, dlg_enable)
               xtension = IHGFIL(2:5)
               CALL SETFIL( dlg, IDC_STATIC_HYD, required, input,
```

```
     1                      xtension )
          ELSE
             retlog = DlgSet( dlg, IDC_BUTTON_HYD, disable, dlg_enable)
             CALL SETFIL( dlg, IDC_STATIC_HYD, na, input, Blank )
          END IF

          IF ( OUTHYD .NE. 0 ) THEN
             retlog = DlgSet( dlg, IDC_BUTTON_RTE, enable, dlg_enable)
             xtension = OHGFIL(2:5)
             CALL SETFIL( dlg, IDC_STATIC_RTE, required, output,
     1                      xtension )
          ELSE
             retlog = DlgSet( dlg, IDC_BUTTON_RTE, disable, dlg_enable)
             CALL SETFIL( dlg, IDC_STATIC_RTE, na, output, Blank )
          END IF
       ELSE
          CALL SETFIL( dlg, static_file, datname, ofile, Blank )
       END IF
     END IF
     RETURN
900  CONTINUE
     retlog = DlgSet( dlg, IDC_STATIC_MSG,
     1                "Error in Input File; not updated" )

     END SUBROUTINE UpdateDat

     SUBROUTINE SETFIL( dlg, static_file, datname, Output, xtension )
     USE DIALOGM
     USE MSFLIB
     IMPLICIT NONE
     INCLUDE 'TRBROUTE.fd'
     TYPE (dialog) dlg
     INTEGER static_file
     CHARACTER*240 datname
     LOGICAL Output
     CHARACTER*4 xtension
     CHARACTER*240 oldname,newname,required,na,qmark
     INTEGER numreq,oldnum
     LOGICAL retlog
     INTEGER  handle, length, i
     CHARACTER dot
     LOGICAL back, enable, disable
     TYPE  (FILE$INFO)  info
     INTEGER SCAN,LEN
     DATA numreq/2/,dot/'.'/
     DATA back/.true./,enable/.true./,disable/.false./
     DATA required/'Required'/,na/'NA'/,qmark/'?'/

     newname = datname
     retlog = DlgGet( dlg, static_file, oldname )
     IF ( newname .eq. required ) THEN
        IF ( oldname .eq. na .or.
     1        oldname .eq. qmark .or. oldname .eq. required ) THEN
           retlog = DlgGet( dlg, IDC_STATIC_DAT, newname, dlg_title )
          i = SCAN(newname, dot, back) - 1
           if ( i .lt. 1 ) i = LEN(TRIM(newname))
           newname = newname(1:i)//xtension
          handle = FILE$FIRST
          length = GETFILEINFOQQ(newname, info, handle)
          IF ( handle .EQ. FILE$LAST ) THEN
```

```
                IF ( output ) THEN
                   OPEN (6,FILE=datname,ERR=100,STATUS='NEW')
                   CLOSE(6,STATUS='DELETE')
                   GO TO 200
100               CONTINUE
                   newname = required
200               CONTINUE
               ELSE
                   newname = required
                END IF
            END IF
        ELSE
            newname = oldname
        END IF
      END IF
      retlog = DlgSet( dlg, static_file, newname )
      oldnum = numreq
      IF ( oldname .eq. required ) numreq = numreq - 1
      IF ( newname .eq. required ) numreq = numreq + 1
     IF ( oldnum .eq. 0 .and. numreq .gt. 0 )
      1   retlog = DlgSet( dlg, IDOK, disable, dlg_enable )
     IF ( oldnum .gt. 0 .and. numreq .eq. 0 )
      1   retlog = DlgSet( dlg, IDOK, enable, dlg_enable )
      RETURN
      END SUBROUTINE SETFIL
```

APPENDIX M – EXAMPLE TRBROUTE INPUT FILE

The following example illustrates the structure of a TRBROUTE input data file read from Unit 5. The data are for the Holston basin. This is the file "Holston.dat" entered in the dialog box described in Section5.2.3.

```
MARCH 21400 SQ.MI. TVA & ANTECEDENT, CHEROKEE INFLOWS
   2   1   1   0
  031588  032288
    0600    0600
  24   1   2   6   4   1   2   6   5   3   1   2   6   1   2   6   4   1   5   3
   1   3   1   2   6
SOUTH HOLSTON RESERVOIR
WATAUGA RESERVOIR
BOONE RESERVOIR
FT PAT RESERVOIR
CHEROKEE RESERVOIR
       1       1       6
       0       1       0
       1       1      12
       0       1       0
       1       1       4
       0       1       0
SOUTH HOLSTON
       1       1       1  1713.0    3000       0       0       0       0
       1       1
WATAUGA
       1       1       0  1945.0    3000       0       0       0       0
       1       1
BOONE
       1       1       0  1368.5   17500       0       0       0       0
       1       1
FORT PAT HENRY
       1       1       0  1261.0     158       0       0       0       0
       1       1
CHEROKEE
       1       1       1  1042.5       0       0       0       0       0
       2       2
```

APPENDIX N –TRBROUTE INPUT FILES DEVELOPED BY TVA

TRBROUTE uses four files developed by TVA. These four files are named STORAGES, QRATINGS, IMPRULES, SGUIDES and they contain reservoir storage data, rating curves, and operation rules and seasonal elevation guidelines. The names of these files are "hardwired" in TRBROUTE. These files must be in the folder chosen in the dialog window as the current directory (see Section 5.2.3). An example of the contents of these files is presented below.

STORAGES File:

```
APALACHIA
  12
    1270    1272    1274    1276    1278    1280    1282    1284    1286    1288
    1290    1292
   23750   24780   25840   26920   28020   29140   30280   31440   32620   33840
   35090   36380
BEAR
  19
     570.    580.    590.    600.    602.    604.    606.    608.    610.    612.
     614.    616.    618.    619.    620.    622.    624.    626.    628.
    1060.   3720.   8220.  15430.  17270.  19250.  21360.  23590.  25940.  28410.
   31020.  33750.  36610.  38090.  39600.  42770.  45970.  49350.  52860.
BLUE RIDGE
  31
    1600    1605    1610    1615    1620    1625    1630    1635    1640    1645
    1650    1655    1660    1665    1670    1675    1680    1682    1684    1686
    1688    1690    1692    1694    1696    1698    1700    1705    1710    1715
    1720
    9480   11610   14020   16640   19510   22670   26120   29880   34030   38620
   43560   48780   54350   60370   66850   73800   81170   84230   87350   90540
   93780   97090  100460  103890  107400  111000  114700  124380  134610  145270
  156290
BOONE
  29
    1346.   1348.   1350.   1352.   1354.   1356.   1358.   1360.   1362.   1364.
    1366.   1368.   1370.   1372.   1374.   1376.   1378.   1380.   1382.   1384.
    1385.   1386.   1388.   1390.   1392.   1396.   1400.   1405.   1408.
   37040.  39150.  41330.  43600.  45950.  48400.  50950.  53620.  56400.  59300.
   62320.  65350.  68700.  72050.  75530.  79150.  82920.  86880.  91010.  95320.
   97530.  99770. 104340. 109030. 113830. 123680. 133840. 146820. 154700.
CEDAR
  16
     578.    580.    582.    584.    586.    588.    590.    592.    594.    596.
     598.    599.   599.5   600.5   601.5   602.5   603.5
   35580.  39360.  43400.  47700.  52340.  57200.  62250.  67490.  72920.  78510.
   84260.  87200.  88680.  91670.  94700.  97770. 100880.
CHATUGE
  29
    1890    1892    1894    1896    1898    1900    1902    1904    1906    1908
    1910    1912    1914    1916    1918    1920    1922    1924    1926    1928
    1930    1932    1934    1936    1938    1940    1942    1944    1946
   34690   37420   40300   43350   46570   49960   53530   57290   61240   65400
   69780   74370   79210   84310   89680   95340  101300  107600  114240  121250
  128640  136380  144410  152710  161250  170000  178950  188100  197450
CHEROKEE
  38
```

```
    1020    1022    1024    1026    1028    1030    1032    1034    1036    1038
    1040    1042    1044    1046    1048    1050    1052    1054    1056    1058
    1060    1062    1064    1066    1068    1070    1072    1074    1075    1076
    1078    1080    1082    1084    1086    1088    1090    1092
  198130  210690  223820  237540  251860  266790  282330  298510  315320  332780
  350890  369670  389120  409230  430010  451070  473560  496340  519790  543910
  568690  594150  620290  647130  674680  702950  731970  761740  776910  792290
  823870  857000  892160  929870  970630 1014860 1062940 1115200
CHILHOWEE
   5
     870     872     874     876     877
   21400   23090   24830   26630   27580
DOUGLAS
  23
     940     945     950     955     960     965     970     975     980     985
     990     995    1000    1002    1004    1006    1008    1010    1012    1014
    1016    1018    1020
  105870  132360  163350  198500  237960  281840  329720  381210  436600  496360
  561130  631250  705800  736580  768070  801660  838970  880530  925780  974110
 1024920 1077720 1132150
FONTANA
  34
    1620    1625    1630    1635    1640    1645    1650    1655    1660    1662
    1664    1666    1668    1670    1672    1674    1676    1678    1680    1682
    1684    1686    1688    1690    1695    1700    1705    1710    1715    1720
    1725    1730    1735    1737
  355940  371400  387360  403870  420970  438710  457070  476040  495590  503570
  511650  519810  528080  536440  544910  553470  562140  570910  579780  588770
  597870  607080  616410  625860  650050  675070  700940  727500  754680  782960
  812910  844970  879540  894170
FONTANA FAILURE
  34
    1620    1625    1630    1635    1640    1645    1650    1655    1660    1662
    1664    1666    1668    1670    1672    1674    1676    1678    1680    1682
    1684    1686    1688    1690    1695    1700    1705    1710    1715    1720
    1725    1730    1735    1737
  355940  371400  387360  403870  420970  438710  457070  476040  495590  503570
  511650  519810  528080  536440  544910  553470  562140  570910  579780  588770
  597870  607080  616410  625860  650050  675070  700940  727500  754680  782960
  812910  844970  879540  894170
FONTANA W/O SPILLWAY
  34
    1620    1625    1630    1635    1640    1645    1650    1655    1660    1662
    1664    1666    1668    1670    1672    1674    1676    1678    1680    1682
    1684    1686    1688    1690    1695    1700    1705    1710    1715    1720
    1725    1730    1735    1737
  355940  371400  387360  403870  420970  438710  457070  476040  495590  503570
  511650  519810  528080  536440  544910  553470  562140  570910  579780  588770
  597870  607080  616410  625860  650050  675070  700940  727500  754680  782960
  812910  844970  879540  894170
FORT PAT HENRY
  19
   1252.   1253.   1254.   1255.   1256.   1257.   1258.   1259.   1260.   1261.
   1262.   1263.   1264.   1266.   1270.   1275.   1280.   1285.   1290.
   9120.   9480.   9860.  10250.  10640.  11040.  11440.  11850.  12270.  12690.
  13120.  13560.  14010.  14920.  16890.  19710.  23000.  27000.  32500.
GREAT FALLS
  18
   791.2     795     800     802     803     805     808     810     814     820
     824     828     830     835     840     845     850     855
```

```
   13740   16440   20470   22180   23070   25000   28400   30900   36600   46700
   54700   63700   68700   82300   98100  116100  136600  159800
HIWASSEE
  27
    1430    1435    1440    1445    1450    1455    1460    1465    1470    1475
    1480    1485    1490    1495    1500    1505    1510    1515    1520    1525
  1526.5    1530    1535    1540    1543    1545    1550
   46330   50200   54450   59270   64530   70110   76130   82620   89740   97780
  106380  115140  124530  134960  146210  158210  170910  183910  198130  214290
  218810  230540  248050  266820  278800  287100  308900
LITTLE BEAR
  15
    618.    620.    622.    624.    626.    628.    630.    632.    634.    636.
    638.    640.    641.    642.    643.
  16700.  18090.  19570.  21110.  22740.  24460.  26270.  28190.  30230.  32410.
  34730.  37210.  38510.  39850.  41230.
MELTON HILL
  26
     750     752     754     756     758     760     762     764     766     768
     770     772     774     776     778     780     782     784     786     788
     790     792     794     796     798     800
    3230    3990    4820    5740    6770    7920    9140   10430   11850   13460
   15330   17430   19730   22250   25020   28080   31380   34940   38790   42950
   47440   52300   57620   63520   69790   76130
NANTAHALA
  12
    2840    2845    2850    2855    2860    2865    2870    2875    2880    2885
    2890    2893
   35590   38460   41490   44590   47740   50990   54350   57860   61510   65290
   69170   71530
NORMANDY
  14
     840     845     850     855     860     865     870     875     880     885
     890     895     900     905
   14170   18330   23090   28410   34280   40690   47690   55310   63570   73000
   83400   94500  106100  117970
NORRIS
  34
     970     975     980     985     990     995    1000    1002    1004    1006
    1008    1010    1012    1014    1016    1018    1020    1022    1024    1026
    1028    1030    1032    1034    1036    1038    1040    1042    1044    1046
    1048    1050    1055    1060
  397780  442850  491560  544050  600450  660900  725490  752500  780220  808640
  837780  867660  898290  929670  961840  994760 1028490 1063010 1098330 1134420
 1171320 1208970 1247420 1286610 1326600 1367660 1410130 1454290 1500040 1547200
 1595600 1645070 1772410 1903440
NORRIS RRR
  34
     970     975     980     985     990     995    1000    1002    1004    1006
    1008    1010    1012    1014    1016    1018    1020    1022    1024    1026
    1028    1030    1032    1034    1036    1038    1040    1042    1044    1046
    1048    1050    1055    1060
  397780  442850  491560  544050  600450  660900  725490  752500  780220  808640
  837780  867660  898290  929670  961840  994760 1028490 1063010 1098330 1134420
 1171320 1208970 1247420 1286610 1326600 1367660 1410130 1454290 1500040 1547200
 1595600 1645070 1772410 1903440
NOTTELY
  21
    1710    1715    1720    1725    1730    1735    1740    1745    1750    1755
    1760    1765    1770    1775    1780    1785    1790    1795    1800    1805
```

```
    1807
   13510   15950   18700   21750   25110   28820   32920   37450   42450   47980
   54150   61080   68920   77790   87870   99470  111880  124980  138890  153820
  160130
OCOEE NO. 1
  13
     814     816     818     820     822     824     826     828     830     832
     834     836     837
   28250   29570   30960   32420   33980   35650   37430   39300   41240   43240
   45270   47320   48350
OCOEE NO. 3
   8
    1420    1426    1430    1432    1434    1436    1438    1440
     550     800    1260    1540    1890    2340    2900    3560
SANTEETLAH
  10
    1790    1795    1800    1805    1810    1812    1814    1816    1817    1818
   46180   51360   56920   62830   69170   71850   74590   77390   78800   80220
SOUTH HOLSTON
  35
   1665.   1670.   1675.   1680.   1685.   1690.   1695.   1700.   1705.   1710.
   1715.   1720.   1722.   1724.   1726.   1728.   1730.   1732.   1734.   1736.
   1738.   1740.   1742.   1743.   1744.   1746.   1748.   1750.   1752.   1754.
   1756.   1758.   1760.   1765.   1770.
 141020. 152270. 164180. 176740. 189900. 203640. 217920. 232770. 248200. 264270.
 281010. 298350. 305640. 312940. 320360. 327900. 335560. 343350. 351290. 359410.
 367210. 376330. 385200. 389740. 394360. 403810. 413510. 423440. 433580. 443890.
 454410. 465170. 476200. 505140. 536350.
THORPE
  12
    3050    3055    3060    3065    3070    3075    3080    3085    3090    3095
    3100    3105
    8070    9910   12000   14330   16840   19450   22230   25270   28540   31980
   35540   39170
TIMS FORD
  15
     880     882     884     886     888     890     892     893     893     894
     895     895     896     897     898
  226870  236490  246420  256660  267200  278040  287180  294870  294870  300660
  306530  306530  312520  318600  324680
UPPER BEAR
  16
    795.    797.    799.    800.    802.    804.    806.    808.    810.    812.
    813.    814.    815.    816.    817.    818.
  12560.  14190.  15950.  16920.  19000.  21270.  23650.  26110.  28630.  31250.
  32610.  34000.  35430.  36910.  38430.  40000.
WATAUGA
  45
   1900.   1905.   1910.   1915.   1920.   1925.   1930.   1935.   1940.   1942.
   1944.   1946.   1948.   1950.   1952.   1954.   1956.   1958.   1960.   1962.
   1964.   1966.   1968.   1970.   1972.   1974.   1975.   1976.   1978.   1980.
   1982.   1984.   1986.   1988.   1990.   1992.   1994.   1996.   1998.   2000.
   2002.   2004.   2006.   2008.   2010.
 130070. 140600. 151750. 163370. 175450. 188030. 201160. 214820. 228890. 234590.
 240350. 246180. 252100. 258130. 264270. 270530. 276890. 283350. 289890. 296510.
 303200. 309960. 316780. 323670. 330630. 337710. 341320. 344970. 352420. 359970.
 367580. 375220. 382890. 390580. 398290. 406020. 413840. 421830. 430060. 438620.
 447570. 456990. 466920. 477440. 488600.
```

SGUIDES File:

```
APALACHIA
       2      0.
    0101    0701
   1280.   1280.
BOONE
       3      0.
    0101    0501    1016
   1358.   1385.   1385.
CHATUGE
       6   1915.
    0101    0126    0316    0401    0501    1116
   1912.   1912.   1916.   1920.   1928.   1928.
CHEROKEE
       7   1035.
    0101    0204    0316    0401    0501    1116    1207
   1030.   1030.   1042.   1052.   1073.   1073.   1060.
CHILHOWEE
       2      0.
    0101    0701
    874.    874.
DOUGLAS
       7    945.
    0101    0117    0316    0401    0501    1108    1204
    940.    940.    958.    970.   1000.   1000.    980.
FONTANA
       6   1640.
    0101    0114    0316    0401    0501    1025
   1620.   1620.   1620.   1620.   1620.   1620.
FONTANA FAILURE
       6   1640.
    0101    0114    0316    0401    0501    1025
   1620.   1620.   1620.   1620.   1620.   1620.
FORT PAT HENRY
       2      0.
    0101    0701
   1263.   1263.
HIWASSEE
       6   1475.
    0101    0128    0316    0401    0501    1024
   1465.   1465.   1482.   1490.  1524.5  1524.5
MELTON HILL
       2      0.
    0101    0701
    795.    795.
NORRIS
       6    995.
    0101    0125    0316    0401    0501    1016
    985.    985.   1000.   1007.   1020.   1020.
NORRIS RRR
       6    995.
    0101    0125    0316    0401    0501    1016
    985.    985.   1000.   1007.   1020.   1020.
NOTTELY
       7   1752.
    0101    0113    0316    0401    0501    1119    1218
   1745.   1745.   1755.   1763.   1779.   1779.   1760.
```

```
OCOEE NO. 1
       2      0.
    0101    0701
    838.    838.
SOUTH HOLSTON
       4      0.
    0101    0316    0416    1111
    1702    1713    1729    1729
WATAUGA
       4   1945.
    0101    0126    0416    1204
   1940.   1940.   1959.   1959.
```

QRATINGS File:

```
APALACHIA
  20
    1270    1271    1272    1273    1274    1275    1276    1277    1278    1279
    1280    1281    1282    1284    1286    1288    1289    1289    1290    1292
   52920   59700   66790   74210   81940   89990   98400  107100  116100  125500
  135100  145200  155000  175100  197400  221500  237100  187500  199400  228200
BLUE RIDGE
  20
    1600    1688    1688    1690    1692    1694    1696    1698    1699    1700
    1702    1704    1706    1708    1710    1712    1714    1716    1718    1720
    2000    2000   28310   35480   43280   51690   60710   70330   75360   75510
   80390   84980   89350   95110  102300  110200  118800  128000  137600  147600
BOONE
  17
   1346.  1363.5   1380.   1385.   1385.   1386.   1388.   1390.   1392. 1394.42
   1396.   1398.   1400.   1402.   1405.   1407.   1408.
  12000.  12000.  30000.  30000. 145300. 152200. 165000. 172700. 179100. 191200.
 201300. 216300. 233600. 254700. 291500. 319800. 334800.
CHATUGE
  26
    1890    1923    1924    1925    1926    1927    1928    1929    1930    1931
    1932    1933    1934    1935 1935.01    1936    1937    1938    1939    1940
    1941    1942    1943    1944    1945    1946
    1400    1400    2400    4230    6680    9670   13120   15600   19860   24510
   29480   34780   40450   46520   37360   40240   42980   46690   51210   56230
   61270   67040   72710   79080   85280   92170
CHILHOWEE
   5
     870     873     874     875     877
  150000  171000  179000  186600  201000
FONTANA FAILURE
  16
    1650    1695    1696    1698    1700    1702    1704    1706    1708    1710
    1715    1720    1725    1730    1735    1740
       0       0    6000   32400   70100  116500  170000  230000  296000  367000
  565000  790000 1039000 1309000 1600000 1909000
FORT PAT HENRY
  19
   1252.   1253.   1254.   1255.   1256.   1257.   1258.   1259.   1260.   1261.
   1262.   1263.   1264.   1266.   1270. 1272.42   1275.   1280.   1290.
  75000.  80000.  86000.  92000.  97000. 104000. 109300. 116000. 121700. 130000.
 134700. 141500. 148400. 165000. 177700. 189900. 204900. 242700. 358200.
GREAT FALLS
  18
   791.2     795     800     802     803     805     808     810     814     820
     824     828     830     835     840     845     850     855
       0   11300   41300   57100   65700   84400  115500  139000  159000  204000
  234000  274000  301000  375000  460000  554000  658000  767000
MELTON HILL
  26
     750     752     754     756     758     760     762     764     766     768
     770     772     774     776     778     780     782     784     786     788
     790     792     794     796     798     800
       0       0       0    1000    3000    6000    8000   12000   16000   20000
   25000   30000   36000   42000   48000   55000   63000   71000   78000   88040
   96210  104700  113200  122000  131000  140000
NANTAHALA
```

```
  15
    2840    2845    2850    2855    2860    2865    2870    2875    2880    2885
    2890    2890  2891.5  2891.5    2893
     640     640     640     640     640     640     640     640     640     640
     640   22000   24800   33000   36100
NOTTELY
  15
    1710    1775    1780    1783    1785    1787    1789 1789.01    1791    1796
    1798    1800    1802    1804    1807
    1500    1500   11600   24500   35000   46900   60000   46400   56000   70400
   78800   89100  100900  113900  134000
OCOEE NO. 1
  10
     814     825  827.11  829.11  831.11  832.83  833.11     837     840  843.11
    2250    2500    3600    5090    7040   11170   28400   52000   81600  125500
OCOEE NO. 3
   8
    1420    1426    1430    1432    1434    1436    1438    1440
   17360   42280   63630   75670   83550  102410  117110  139400
SOUTH HOLSTON
  15
   1665.   1732.   1732.   1742.   1743.   1744.   1746.   1748.   1750.   1752.
   1754.   1756.   1758.   1760.   1765.
   3000.   3000.  10000.  10000.  11140.  12560.  22500.  36600.  55700.  77800.
 101100. 127600. 142400. 156900. 196400.
THORPE
  19
    3050    3055    3060    3065    3070    3075    3080    3085    3090    3095
    3095    3100    3102    3102    3103    3103    3104    3104    3105
      50      50      50      50      50      50      50      50      50      50
    2280    5540    7030   16000   17900   28300   31800   45600   49500
TIMS FORD
  15
     880     882     884     886     888     890     892     893     893     894
     895     895     896     897     898
    4500    4500    4500    4500    4500    4500    4500    4500   15000   15000
   15000  109600  114000  118700  123200
WATAUGA
  23
   1890.   1962.   1962.   1975.   1975.   1976.   1978.   1980.   1982.   1984.
   1986.   1988.   1990.   1992.   1994.   1996.   1998.   2000.   2002.   2004.
   2006.   2008.   2010.
   3000.   3000.   8000.   8000.   9640.  11700.  16200.  23500.  33300.  44800.
  57300.  70400.  80800.  81500.  82200.  82900.  83660.  84300.  84930.  85675.
  86300.  86950.  87700.
```

IMPRULES File:

```
CHEROKEE
      11       11     1042     1075    20000
    1020   1053.6    15000    15000
    1030   1058.7    22500    23000
    1040   1065.4    36000    45000
    1045   1067.7    42000    75000
    1050   1070.0    48000   138000
    1055   1071.6    56000   183000
    1060   1073.1    63000   203000
    1065   1073.8    71500   215000
    1070   1074.5    80000   220000
    1073   1075.0    90000   280000
    1075   1075.0   100000   281700
    1075     1076     1078   1080.5     1082     1085     1087     1089     1090     1092
    1095
  281700   295100   322500   358600   360680   392570   418720   446700   476815   595415
  857635
DOUGLAS
      11       10      958     1002    25000
     940    990.0    72000   192000
     950    991.0    75000   218000
     955    992.0    78000   233000
     960    992.8    82000   249000
     965    994.0    87000   270000
     970    995.3    92000   290000
     975    996.6   100000   310000
     980    997.6   108000   320000
     990    999.4   125000   330000
    1000   1001.3   150000   332000
    1002   1002.0   160000   335000
    1002     1004     1006     1008     1010     1012     1014     1016     1018     1020
  335600   369000   400000   426000   443000   469000   497000   529000   564000   598000
FONTANA
      13        9     1644     1710    15000
    1620   1678.5    29000    41000
    1630   1681.0    30000    45000
    1635   1683.0    32000    59000
    1640   1685.0    34000    73000
    1645   1687.0    36000    88000
    1650   1689.0    38000   104000
    1655   1691.5    40000   120000
    1660   1693.2    42000   138000
    1670   1698.5    48500   142000
    1680   1702.5    57500   142000
    1690   1706.0    68500   142000
    1700   1709.0    82000   142000
    1710   1710.0   100000   142000
    1710     1715     1720     1723     1727     1730     1732     1735     1737
  142580   161790   196890   222460   260070   326500   382920   485675   555000
FONTANA W/O SPILLWAY
      13        9     1644     1710    15000
    1620   1678.5    29000    41000
    1630   1681.0    30000    45000
    1635   1683.0    32000    59000
    1640   1685.0    34000    73000
    1645   1687.0    36000    88000
    1650   1689.0    38000   104000
```

```
     1655  1691.5   40000  120000
     1660  1693.2   42000  138000
     1670  1698.5   49000  142000
     1680  1702.5   57500  142000
     1690  1706.0   68500  142000
     1700  1709.0   82000  142000
     1710  1710.0  100000  142000
     1710    1715    1720    1723    1727    1730    1732    1735    1737
   142580  161790  189890  208290  234070  290100  339020  429675  499605
HIWASSEE
       13       8    1472  1526.5   10000
     1460  1501.5   13500   13500
     1470  1502.8   16000   16000
     1475  1504.8   18000   22000
     1480  1507.4   20000   31000
     1485  1509.8   22500   43500
     1490  1513.0   26000   59000
     1495  1516.5   31000   76000
     1500  1520.0   35500   94000
     1505  1522.6   41000  116000
     1510  1524.5   46000  116000
     1515  1525.6   52500  116000
     1520  1526.5   59000  116000
   1524.5  1526.5   59000  116000
   1526.5    1530    1532    1535  1537.5    1540    1545    1550
   116000  135000  150100  174400  183900  208200  288800  395300
NORRIS
        9       4     990    1044   20000
      970  1016.5    5000   12000
      980  1021.0   13000   21000
      990  1024.0   21000   32000
     1000  1028.0   36000   58000
     1010  1031.0   56000   98000
     1020  1032.8   85000  134000
     1024  1033.0   93000  145000
     1033  1033.0   93000  170000
     1044  1044.0  170000  170000
     1044    1048    1050    1056
   170000  205000  226200  290400
NORRIS RRR
        9       4     990    1047   20000
      970  1016.5    5000    5000
      980  1021.0   13000   13000
      990  1024.0   21000   21000
     1000  1028.0   36000   36000
     1010  1031.0   56000   56000
     1020  1032.8   85000   85000
     1024  1033.3   93000   93000
   1033.3  1033.3   93000   93000
     1047  1047.0  196000  196000
     1047    1048    1050    1056
   196000  205000  225000  291000
```

APPENDIX O –EXAMPLE TRBROUTE MAIN OUTPUT FILE

The main output file (written out in Unit 6) produced by running TRBROUTE with the input files presented in Appendicies M and H is listed below. This is the file "Holston.prn" entered in the dialog box described in Section 5.2.3.

```
TRBROUTE - QA REV1.0 - 11/07/2008

1MARCH 21400 SQ.MI. TVA & ANTECEDENT, CHEROKEE INFLOWS


    2   1   1   0
   031588  032288
     0600    0600
   24   1   2   6   4   1   2   6   5   3   1   2   6   1   2   6   4   1   5   3
    1   3   1   2   6
 SOUTH HOLSTON RESERVOIR
 WATAUGA RESERVOIR
 BOONE RESERVOIR
 FT PAT RESERVOIR
 CHEROKEE RESERVOIR
        1       1      6.
     0.00    1.00    0.00
        1       1     12.
     0.00    1.00    0.00
        1       1      4.
     0.00    1.00    0.00
 SOUTH HOLSTON
        1       1       1 1713.00   3000.     0.0     0.0       0       0
        1       1
 WATAUGA
        1       1       0 1945.00   3000.     0.0     0.0       0       0
        1       1
 BOONE
        1       1       0 1368.50  17500.     0.0     0.0       0       0
        1       1
 FORT PAT HENRY
        1       1       0 1261.00    158.     0.0     0.0       0       0
        1       1
 CHEROKEE
        1       1       1 1042.50      0.     0.0     0.0       0       0
        2       2
1              SOUTH HOLSTON
             DISCHARGE & STORAGE
             CURVES FOR STORM 1

    ELEVATION     DISCHARGE     STORAGE

     1665.0          3000.      141020.
     1670.0          3000.      152270.
     1675.0          3000.      164180.
     1680.0          3000.      176740.
     1685.0          3000.      189900.
     1690.0          3000.      203640.
     1695.0          3000.      217920.
     1700.0          3000.      232770.
     1705.0          3000.      248200.
     1710.0          3000.      264270.
     1715.0          3000.      281010.
```

1720.0	3000.	298350.
1722.0	3000.	305640.
1724.0	3000.	312940.
1726.0	3000.	320360.
1728.0	3000.	327900.
1730.0	3000.	335560.
1732.0	3000.	343350.
1732.0	10000.	343350.
1734.0	10000.	351290.
1736.0	10000.	359410.
1738.0	10000.	367210.
1740.0	10000.	376330.
1742.0	10000.	385200.
1743.0	11140.	389740.
1744.0	12560.	394360.
1746.0	22500.	403810.
1748.0	36600.	413510.
1750.0	55700.	423440.
1752.0	77800.	433580.
1754.0	101100.	443890.
1756.0	127600.	454410.
1758.0	142400.	465170.
1760.0	156900.	476200.
1765.0	196400.	505140.
1770.0	235900.	536350.

1 SOUTH HOLSTON
DISCHARGE & STORAGE
CURVES FOR STORM 2

ELEVATION	DISCHARGE	STORAGE
1665.0	3000.	141020.
1670.0	3000.	152270.
1675.0	3000.	164180.
1680.0	3000.	176740.
1685.0	3000.	189900.
1690.0	3000.	203640.
1695.0	3000.	217920.
1700.0	3000.	232770.
1705.0	3000.	248200.
1710.0	3000.	264270.
1715.0	3000.	281010.
1720.0	3000.	298350.
1722.0	3000.	305640.
1724.0	3000.	312940.
1726.0	3000.	320360.
1728.0	3000.	327900.
1730.0	3000.	335560.
1732.0	3000.	343350.
1732.0	10000.	343350.
1734.0	10000.	351290.
1736.0	10000.	359410.
1738.0	10000.	367210.
1740.0	10000.	376330.
1742.0	10000.	385200.
1743.0	11140.	389740.
1744.0	12560.	394360.
1746.0	22500.	403810.
1748.0	36600.	413510.
1750.0	55700.	423440.

```
     1752.0          77800.       433580.
     1754.0         101100.       443890.
     1756.0         127600.       454410.
     1758.0         142400.       465170.
     1760.0         156900.       476200.
     1765.0         196400.       505140.
     1770.0         235900.       536350.
1SOUTH HOLSTON RESERVOIR
```

DATE	TIME	INFLOW	OUTFLOW	ELEVATION
3 15	0600	1770.	1770.	1713.00
	1200	1770.	3000.	1712.95
	1800	2681.	1205.	1712.96
	2400	4069.	3000.	1713.06
3 16	0600	7217.	3000.	1713.26
	1200	13142.	3000.	1713.79
	1800	25932.	3000.	1715.03
	2400	27633.	3000.	1716.74
3 17	0600	28847.	3000.	1718.56
	1200	23779.	3000.	1720.23
	1800	19618.	3000.	1721.51
	2400	16317.	3000.	1722.54
3 18	0600	12637.	3000.	1723.32
	1200	9912.	3000.	1723.89
	1800	7408.	3000.	1724.27
	2400	5729.	3000.	1724.51
3 19	0600	4470.	3000.	1724.65
	1200	3679.	3000.	1724.73
	1800	3157.	3000.	1724.76
	2400	2731.	3000.	1724.75
3 20	0600	2402.	3000.	1724.72
	1200	2141.	3000.	1724.67
	1800	1959.	3000.	1724.61
	2400	1879.	3000.	1724.54
3 21	0600	1830.	3000.	1724.46
	1200	1799.	3000.	1724.38
	1800	1779.	3000.	1724.30
	2400	1770.	3000.	1724.22
3 22	0600	2520.	3000.	1724.16
	1200	5295.	3000.	1724.22
	1800	9485.	3000.	1724.51
	2400	15372.	3000.	1725.15
3 23	0600	26294.	3000.	1726.35
	1200	41320.	3000.	1728.38
	1800	62501.	3000.	1731.55
	2400	66800.	10000.	1735.19
3 24	0600	64419.	10000.	1738.62
	1200	54440.	10000.	1741.37
	1800	44865.	11857.	1743.50
	2400	36949.	17103.	1744.91
3 25	0600	28344.	20715.	1745.64
	1200	21497.	21693.	1745.84
	1800	15406.	20939.	1745.69
	2400	11307.	19177.	1745.33
3 26	0600	8332.	17002.	1744.89
	1200	6379.	14760.	1744.44
	1800	5066.	12660.	1744.02
	2400	4037.	11992.	1743.60

```
  3 27   0600      3231.    11373.     1743.16
         1200      2636.    10818.     1742.72
         1800      2243.    10308.     1742.27
         2400      2040.    10000.     1741.83
  3 28   0600      1920.    10000.     1741.37
         1200      1840.    10000.     1740.92
         1800      1790.    10000.     1740.45
         2400      1770.    10000.     1739.99
  3 29   0600      1770.    10000.     1739.54
1              WATAUGA
             DISCHARGE & STORAGE
             CURVES FOR STORM 1

    ELEVATION     DISCHARGE     STORAGE

     1890.0          3000.      109010.
     1900.0          3000.      130070.
     1905.0          3000.      140600.
     1910.0          3000.      151750.
     1915.0          3000.      163370.
     1920.0          3000.      175450.
     1925.0          3000.      188030.
     1930.0          3000.      201160.
     1935.0          3000.      214820.
     1940.0          3000.      228890.
     1942.0          3000.      234590.
     1944.0          3000.      240350.
     1946.0          3000.      246180.
     1948.0          3000.      252100.
     1950.0          3000.      258130.
     1952.0          3000.      264270.
     1954.0          3000.      270530.
     1956.0          3000.      276890.
     1958.0          3000.      283350.
     1960.0          3000.      289890.
     1962.0          3000.      296510.
     1962.0          8000.      296510.
     1964.0          8000.      303200.
     1966.0          8000.      309960.
     1968.0          8000.      316780.
     1970.0          8000.      323670.
     1972.0          8000.      330630.
     1974.0          8000.      337710.
     1975.0          8000.      341320.
     1975.0          9640.      341320.
     1976.0         11700.      344970.
     1978.0         16200.      352420.
     1980.0         23500.      359970.
     1982.0         33300.      367580.
     1984.0         44800.      375220.
     1986.0         57300.      382890.
     1988.0         70400.      390580.
     1990.0         80800.      398290.
     1992.0         81500.      406020.
     1994.0         82200.      413840.
     1996.0         82900.      421830.
     1998.0         83660.      430060.
     2000.0         84300.      438620.
     2002.0         84930.      447570.
     2004.0         85675.      456990.
```

```
     2006.0         86300.      466920.
     2008.0         86950.      477440.
     2010.0         87700.      488600.
1              WATAUGA
             DISCHARGE & STORAGE
             CURVES FOR STORM 2

    ELEVATION     DISCHARGE     STORAGE

     1890.0          3000.      109010.
     1900.0          3000.      130070.
     1905.0          3000.      140600.
     1910.0          3000.      151750.
     1915.0          3000.      163370.
     1920.0          3000.      175450.
     1925.0          3000.      188030.
     1930.0          3000.      201160.
     1935.0          3000.      214820.
     1940.0          3000.      228890.
     1942.0          3000.      234590.
     1944.0          3000.      240350.
     1946.0          3000.      246180.
     1948.0          3000.      252100.
     1950.0          3000.      258130.
     1952.0          3000.      264270.
     1954.0          3000.      270530.
     1956.0          3000.      276890.
     1958.0          3000.      283350.
     1960.0          3000.      289890.
     1962.0          3000.      296510.
     1962.0          8000.      296510.
     1964.0          8000.      303200.
     1966.0          8000.      309960.
     1968.0          8000.      316780.
     1970.0          8000.      323670.
     1972.0          8000.      330630.
     1974.0          8000.      337710.
     1975.0          8000.      341320.
     1975.0          9640.      341320.
     1976.0         11700.      344970.
     1978.0         16200.      352420.
     1980.0         23500.      359970.
     1982.0         33300.      367580.
     1984.0         44800.      375220.
     1986.0         57300.      382890.
     1988.0         70400.      390580.
     1990.0         80800.      398290.
     1992.0         81500.      406020.
     1994.0         82200.      413840.
     1996.0         82900.      421830.
     1998.0         83660.      430060.
     2000.0         84300.      438620.
     2002.0         84930.      447570.
     2004.0         85675.      456990.
     2006.0         86300.      466920.
     2008.0         86950.      477440.
     2010.0         87700.      488600.
1WATAUGA RESERVOIR
```

DATE	TIME	INFLOW	OUTFLOW	ELEVATION
3 15	0600	1170.	1170.	1945.00
	1200	1170.	1170.	1945.00
	1800	1263.	1263.	1945.00
	2400	1890.	1890.	1945.00
3 16	0600	3500.	3000.	1945.02
	1200	6875.	3000.	1945.21
	1800	15372.	3000.	1945.91
	2400	20977.	3000.	1947.19
3 17	0600	16132.	3000.	1948.49
	1200	10799.	3000.	1949.36
	1800	8560.	3000.	1949.92
	2400	8129.	3000.	1950.35
3 18	0600	6583.	3000.	1950.71
	1200	4341.	3000.	1950.91
	1800	3188.	3000.	1950.97
	2400	2649.	3000.	1950.96
3 19	0600	2299.	3000.	1950.92
	1200	1926.	3000.	1950.85
	1800	1623.	3000.	1950.75
	2400	1404.	3000.	1950.63
3 20	0600	1306.	3000.	1950.49
	1200	1250.	3000.	1950.35
	1800	1210.	3000.	1950.21
	2400	1184.	3000.	1950.06
3 21	0600	1170.	3000.	1949.91
	1200	1170.	3000.	1949.76
	1800	1170.	3000.	1949.61
	2400	1170.	3000.	1949.46
3 22	0600	1170.	3000.	1949.30
	1200	2263.	3000.	1949.20
	1800	4977.	3000.	1949.25
	2400	8723.	3000.	1949.57
3 23	0600	16122.	3000.	1950.34
	1200	29515.	3000.	1951.96
	1800	50193.	3000.	1954.89
	2400	59197.	3000.	1958.90
3 24	0600	44132.	8000.	1962.39
	1200	29041.	8000.	1964.52
	1800	23312.	8000.	1965.87
	2400	21516.	8000.	1966.92
3 25	0600	16335.	8000.	1967.73
	1200	10121.	8000.	1968.11
	1800	6960.	8000.	1968.15
	2400	5466.	8000.	1968.02
3 26	0600	4347.	8000.	1967.79
	1200	3231.	8000.	1967.48
	1800	2383.	8000.	1967.10
	2400	1806.	8000.	1966.67
3 27	0600	1535.	8000.	1966.20
	1200	1386.	8000.	1965.72
	1800	1275.	8000.	1965.23
	2400	1202.	8000.	1964.73
3 28	0600	1170.	8000.	1964.22
	1200	1170.	8000.	1963.72
	1800	1170.	8000.	1963.21
	2400	1170.	8000.	1962.70
3 29	0600	1170.	8000.	1962.19

1 BOONE

DISCHARGE & STORAGE
CURVES FOR STORM 1

ELEVATION	DISCHARGE	STORAGE
1346.0	12000.	37040.
1348.0	12000.	39150.
1350.0	12000.	41330.
1352.0	12000.	43600.
1354.0	12000.	45950.
1356.0	12000.	48400.
1358.0	12000.	50950.
1360.0	12000.	53620.
1362.0	12000.	56400.
1363.5	12000.	58575.
1364.0	12545.	59300.
1366.0	14727.	62320.
1368.0	16909.	65350.
1370.0	19091.	68700.
1372.0	21273.	72050.
1374.0	23455.	75530.
1376.0	25636.	79150.
1378.0	27818.	82920.
1380.0	30000.	86880.
1382.0	30000.	91010.
1384.0	30000.	95320.
1385.0	30000.	97530.
1385.0	145300.	97530.
1386.0	152200.	99770.
1388.0	165000.	104340.
1390.0	172700.	109030.
1392.0	179100.	113830.
1394.4	191200.	119789.
1396.0	201300.	123680.
1398.0	216300.	128760.
1400.0	233600.	133840.
1402.0	254700.	139032.
1405.0	291500.	146820.
1407.0	319800.	152073.
1408.0	334800.	154700.

1 BOONE
DISCHARGE & STORAGE
CURVES FOR STORM 2

ELEVATION	DISCHARGE	STORAGE
1346.0	12000.	37040.
1348.0	12000.	39150.
1350.0	12000.	41330.
1352.0	12000.	43600.
1354.0	12000.	45950.
1356.0	12000.	48400.
1358.0	12000.	50950.
1360.0	12000.	53620.
1362.0	12000.	56400.
1363.5	12000.	58575.
1364.0	12545.	59300.
1366.0	14727.	62320.
1368.0	16909.	65350.
1370.0	19091.	68700.

```
     1372.0          21273.        72050.
     1374.0          23455.        75530.
     1376.0          25636.        79150.
     1378.0          27818.        82920.
     1380.0          30000.        86880.
     1382.0          30000.        91010.
     1384.0          30000.        95320.
     1385.0          30000.        97530.
     1385.0         145300.        97530.
     1386.0         152200.        99770.
     1388.0         165000.       104340.
     1390.0         172700.       109030.
     1392.0         179100.       113830.
     1394.4         191200.       119789.
     1396.0         201300.       123680.
     1398.0         216300.       128760.
     1400.0         233600.       133840.
     1402.0         254700.       139032.
     1405.0         291500.       146820.
     1407.0         319800.       152073.
     1408.0         334800.       154700.
1BOONE RESERVOIR

  DATE   TIME     INFLOW   OUTFLOW    ELEVATION

  3 15   0600      4612.     4612.     1368.50
         1200      4612.     4612.     1368.50
         1800      6063.     6063.     1368.50
         2400      5609.     5609.     1368.50
  3 16   0600     10513.    10513.     1368.50
         1200     17116.    17116.     1368.50
         1800     31818.    18536.     1369.49
         2400     30285.    20420.     1371.22
  3 17   0600     23601.    21398.     1372.11
         1200     20923.    21523.     1372.23
         1800     19348.    21322.     1372.04
         2400     18069.    20930.     1371.69
  3 18   0600     14599.    20238.     1371.05
         1200     12476.    19229.     1370.13
         1800     11376.    18130.     1369.12
         2400     10479.    10479.     1368.50
  3 19   0600      9851.     9851.     1368.50
         1200      9323.     9323.     1368.50
         1800      8934.     8934.     1368.50
         2400      8544.     8544.     1368.50
  3 20   0600      8096.     8096.     1368.50
         1200      7923.     7923.     1368.50
         1800      7831.     7831.     1368.50
         2400      7761.     7761.     1368.50
  3 21   0600      7709.     7709.     1368.50
         1200      7672.     7672.     1368.50
         1800      7672.     7672.     1368.50
         2400      7672.     7672.     1368.50
  3 22   0600      7673.     7673.     1368.50
         1200     10266.    10266.     1368.50
         1800     13864.    13864.     1368.50
         2400     19167.    17583.     1368.62
  3 23   0600     33424.    18895.     1369.82
         1200     54943.    22653.     1373.27
```

```
          1800     88917.    29367.     1379.42
          2400     79808.    44972.     1385.00
   3 24   0600     67189.    67189.     1385.00
          1200     63146.    63146.     1385.00
          1800     57818.    57818.     1385.00
          2400     55592.    55592.     1385.00
   3 25   0600     49802.    49802.     1385.00
          1200     46373.    46373.     1385.00
          1800     43682.    43682.     1385.00
          2400     39991.    39991.     1385.00
   3 26   0600     36067.    36067.     1385.00
          1200     32057.    32057.     1385.00
          1800     28413.    30000.     1384.91
          2400     24971.    30000.     1384.54
   3 27   0600     23004.    30000.     1383.85
          1200     21862.    30000.     1382.97
          1800     21010.    30000.     1381.98
          2400     20279.    30000.     1380.85
   3 28   0600     19798.    29618.     1379.65
          1200     19672.    28345.     1378.48
          1800     19672.    27199.     1377.43
          2400     19672.    26184.     1376.50
   3 29   0600     19672.    25292.     1375.68
1              FORT PAT HENRY
             DISCHARGE & STORAGE
             CURVES FOR STORM 1

    ELEVATION     DISCHARGE     STORAGE

     1252.0         75000.        9120.
     1253.0         80000.        9480.
     1254.0         86000.        9860.
     1255.0         92000.       10250.
     1256.0         97000.       10640.
     1257.0        104000.       11040.
     1258.0        109300.       11440.
     1259.0        116000.       11850.
     1260.0        121700.       12270.
     1261.0        130000.       12690.
     1262.0        134700.       13120.
     1263.0        141500.       13560.
     1264.0        148400.       14010.
     1266.0        165000.       14920.
     1270.0        177700.       16890.
     1272.4        189900.       18255.
     1275.0        204900.       19710.
     1280.0        242700.       23000.
     1285.0        300450.       27000.
     1290.0        358200.       32500.
1              FORT PAT HENRY
             DISCHARGE & STORAGE
             CURVES FOR STORM 2

    ELEVATION     DISCHARGE     STORAGE

     1252.0         75000.        9120.
     1253.0         80000.        9480.
     1254.0         86000.        9860.
     1255.0         92000.       10250.
     1256.0         97000.       10640.
```

1257.0	104000.	11040.
1258.0	109300.	11440.
1259.0	116000.	11850.
1260.0	121700.	12270.
1261.0	130000.	12690.
1262.0	134700.	13120.
1263.0	141500.	13560.
1264.0	148400.	14010.
1266.0	165000.	14920.
1270.0	177700.	16890.
1272.4	189900.	18255.
1275.0	204900.	19710.
1280.0	242700.	23000.
1285.0	300450.	27000.
1290.0	358200.	32500.

1FT PAT RESERVOIR

DATE	TIME	INFLOW	OUTFLOW	ELEVATION
3 15	0600	4770.	4770.	1261.00
	1200	4770.	4770.	1261.00
	1800	6375.	6375.	1261.00
	2400	6155.	6155.	1261.00
3 16	0600	11464.	11464.	1261.00
	1200	18903.	18903.	1261.00
	1800	22147.	22147.	1261.00
	2400	23628.	23628.	1261.00
3 17	0600	23365.	23365.	1261.00
	1200	23090.	23090.	1261.00
	1800	22669.	22669.	1261.00
	2400	22138.	22138.	1261.00
3 18	0600	21117.	21117.	1261.00
	1200	19866.	19866.	1261.00
	1800	18636.	18636.	1261.00
	2400	10829.	10829.	1261.00
3 19	0600	10108.	10108.	1261.00
	1200	9542.	9542.	1261.00
	1800	9130.	9130.	1261.00
	2400	8721.	8721.	1261.00
3 20	0600	8258.	8258.	1261.00
	1200	8081.	8081.	1261.00
	1800	7989.	7989.	1261.00
	2400	7919.	7919.	1261.00
3 21	0600	7867.	7867.	1261.00
	1200	7830.	7830.	1261.00
	1800	7830.	7830.	1261.00
	2400	7830.	7830.	1261.00
3 22	0600	7958.	7958.	1261.00
	1200	11021.	11021.	1261.00
	1800	15219.	15219.	1261.00
	2400	19567.	19567.	1261.00
3 23	0600	22508.	22508.	1261.00
	1200	28700.	28700.	1261.00
	1800	39371.	39371.	1261.00
	2400	53520.	53520.	1261.00
3 24	0600	72593.	72593.	1261.00
	1200	67370.	67370.	1261.00
	1800	61366.	61366.	1261.00
	2400	58859.	58859.	1261.00

```
  3 25   0600     52101.    52101.     1261.00
         1200     47899.    47899.     1261.00
         1800     44809.    44809.     1261.00
         2400     40686.    40686.     1261.00
  3 26   0600     36514.    36514.     1261.00
         1200     32394.    32394.     1261.00
         1800     30272.    30272.     1261.00
         2400     30218.    30218.     1261.00
  3 27   0600     30173.    30173.     1261.00
         1200     30158.    30158.     1261.00
         1800     30158.    30158.     1261.00
         2400     30158.    30158.     1261.00
  3 28   0600     29776.    29776.     1261.00
         1200     28503.    28503.     1261.00
         1800     27357.    27357.     1261.00
         2400     26342.    26342.     1261.00
  3 29   0600     25450.    25450.     1261.00
1              CHEROKEE
             DISCHARGE & STORAGE
             CURVES FOR STORM 1

    ELEVATION     DISCHARGE     STORAGE

     1020.0            0.      198130.
     1022.0            0.      210690.
     1024.0            0.      223820.
     1026.0            0.      237540.
     1028.0            0.      251860.
     1030.0            0.      266790.
     1032.0            0.      282330.
     1034.0            0.      298510.
     1036.0            0.      315320.
     1038.0            0.      332780.
     1040.0            0.      350890.
     1042.0            0.      369670.
     1042.5            0.      374532.
     1042.5            0.      374532.
     1044.0         2432.      389120.
     1046.0         5676.      409230.
     1048.0         8919.      430010.
     1050.0        12162.      451070.
     1052.0        15405.      473560.
     1054.0        18649.      496340.
     1056.0        21892.      519790.
     1058.0        25135.      543910.
     1060.0        28378.      568690.
     1062.0        31622.      594150.
     1064.0        34865.      620290.
     1066.0        38108.      647130.
     1066.6        39000.      654707.
     1068.0        42603.      674680.
     1070.0        47574.      702950.
     1072.0        52544.      731970.
     1074.0        57515.      761740.
     1075.0        60000.      776910.
     1075.0       281700.      776910.
     1076.0       295100.      792290.
     1078.0       322500.      823870.
     1080.0       351380.      857000.
     1080.5       358600.      865790.
```

1082.0	360680.	892160.
1084.0	381940.	929870.
1085.0	392570.	950250.
1086.0	405645.	970630.
1087.0	418720.	992745.
1088.0	432710.	1014860.
1089.0	446700.	1038900.
1090.0	476815.	1062940.
1092.0	595415.	1115200.
1095.0	857635.	1193590.

INITIAL ELEVATION = 1042.50
NORMAL UPPER LIMIT ELEVATION = 1066.55
1 CHEROKEE
DISCHARGE & STORAGE
CURVES FOR STORM 2

ELEVATION	DISCHARGE	STORAGE
1020.0	11209.	198130.
1022.0	11209.	210690.
1024.0	11209.	223820.
1026.0	11209.	237540.
1028.0	11209.	251860.
1030.0	11209.	266790.
1032.0	11209.	282330.
1034.0	11209.	298510.
1036.0	11209.	315320.
1038.0	11209.	332780.
1040.0	11209.	350890.
1042.0	11209.	369670.
1042.5	11209.	374532.
1042.5	11209.	374532.
1044.0	11209.	389120.
1046.0	11209.	409230.
1048.0	11209.	430010.
1050.0	11209.	451070.
1052.0	11209.	473560.
1054.0	11209.	496340.
1056.0	11209.	519790.
1057.0	11209.	531915.
1058.0	11209.	543910.
1059.9	11209.	567474.
1060.0	11589.	568690.
1062.0	19329.	594150.
1064.0	27068.	620290.
1066.0	34808.	647130.
1066.6	36937.	654707.
1068.0	42548.	674680.
1070.0	50288.	702950.
1072.0	58028.	731970.
1072.2	58808.	734970.
1074.0	143776.	761740.
1075.0	191021.	776910.
1075.0	281700.	776910.
1076.0	295100.	792290.
1078.0	322500.	823870.
1080.0	351380.	857000.
1080.5	358600.	865790.

1082.0	360680.	892160.
1084.0	381940.	929870.
1085.0	392570.	950250.
1086.0	405645.	970630.
1087.0	418720.	992745.
1088.0	432710.	1014860.
1089.0	446700.	1038900.
1090.0	476815.	1062940.
1092.0	595415.	1115200.
1095.0	857635.	1193590.

INITIAL ELEVATION = 1057.01
NORMAL UPPER LIMIT ELEVATION = 1072.20
1CHEROKEE RESERVOIR

DATE	TIME	INFLOW	OUTFLOW	ELEVATION
3 15	0600	8583.	8583.	1042.50
	0800	8583.	59.	1042.54
	1000	8583.	177.	1042.61
	1200	8583.	293.	1042.68
	1400	8733.	408.	1042.75
	1600	8884.	524.	1042.82
	1800	9167.	642.	1042.90
	2000	9795.	764.	1042.97
	2200	10436.	893.	1043.05
	2400	11227.	1030.	1043.14
3 16	0200	12315.	1178.	1043.23
	0400	13420.	1339.	1043.33
	0600	15282.	1519.	1043.44
	0800	17883.	1727.	1043.56
	1000	20540.	1968.	1043.71
	1200	23264.	2243.	1043.88
	1400	27649.	2559.	1044.08
	1600	32141.	2924.	1044.30
	1800	39759.	3365.	1044.58
	2000	46867.	3898.	1044.90
	2200	54210.	4521.	1045.29
	2400	61375.	5232.	1045.73
3 17	0200	63742.	5987.	1046.19
	0400	66259.	6750.	1046.66
	0600	66408.	7520.	1047.14
	0800	65805.	8277.	1047.60
	1000	65593.	9017.	1048.06
	1200	66284.	9743.	1048.51
	1400	67542.	10472.	1048.96
	1600	68974.	11209.	1049.41
	1800	68423.	11209.	1049.87
	2000	68004.	11209.	1050.30
	2200	67741.	11209.	1050.72
	2400	67178.	11209.	1051.13
3 18	0200	66351.	11209.	1051.55
	0400	65607.	11209.	1051.95
	0600	63738.	11209.	1052.34
	0800	61551.	11209.	1052.72
	1000	59412.	11209.	1053.08
	1200	56913.	11209.	1053.42
	1400	54697.	11209.	1053.75

	1600	52529.	11209.	1054.06
	1800	49758.	11209.	1054.34
	2000	47201.	11209.	1054.61
	2200	44656.	11209.	1054.85
	2400	42018.	11209.	1055.08
3 19	0200	39507.	11209.	1055.29
	0400	37005.	11209.	1055.49
	0600	35339.	11209.	1055.66
	0800	33802.	11209.	1055.83
	1000	32267.	11209.	1055.98
	1200	28746.	11209.	1056.12
	1400	25280.	11209.	1056.23
	1600	21814.	11209.	1056.31
	1800	20847.	11209.	1056.38
	2000	19910.	11209.	1056.45
	2200	18973.	11209.	1056.50
	2400	18253.	11209.	1056.55
3 20	0200	17552.	11209.	1056.60
	0400	16851.	11209.	1056.64
	0600	16358.	11209.	1056.68
	0800	15878.	11209.	1056.71
	1000	15400.	11209.	1056.74
	1200	15048.	11209.	1056.77
	1400	14705.	11209.	1056.80
	1600	14363.	11209.	1056.82
	1800	14063.	11209.	1056.84
	2000	13762.	11209.	1056.86
	2200	13462.	11209.	1056.88
	2400	13280.	11209.	1056.89
3 21	0200	13099.	11209.	1056.90
	0400	12917.	11209.	1056.92
	0600	12775.	11209.	1056.93
	0800	12633.	11209.	1056.94
	1000	12491.	11209.	1056.95
	1200	12346.	11209.	1056.96
	1400	12202.	11209.	1056.96
	1600	12057.	11209.	1056.97
	1800	11993.	11209.	1056.97
	2000	11928.	11209.	1056.98
	2200	11864.	11209.	1056.98
	2400	11829.	11209.	1056.99
3 22	0200	11918.	11209.	1056.99
	0400	12007.	11209.	1057.00
	0600	12205.	11209.	1057.01
	0800	13050.	11209.	1057.02
	1000	13903.	11209.	1057.03
	1200	15177.	11209.	1057.05
	1400	17370.	11209.	1057.09
	1600	19602.	11209.	1057.14
	1800	22262.	11209.	1057.21
	2000	25252.	11209.	1057.29
	2200	28303.	11209.	1057.40
	2400	32698.	11209.	1057.53
3 23	0200	38084.	11209.	1057.70
	0400	43619.	11209.	1057.91
	0600	50787.	11209.	1058.15
	0800	60237.	11209.	1058.45
	1000	69956.	11209.	1058.81
	1200	81265.	11209.	1059.24
	1400	95832.	11209.	1059.76

	1600	110798.	13011.	1060.37
	1800	127707.	15669.	1061.05
	2000	141971.	18650.	1061.82
	2200	156961.	21856.	1062.65
	2400	170766.	25317.	1063.55
3 24	0200	170896.	28817.	1064.45
	0400	171556.	32199.	1065.33
	0600	170773.	35481.	1066.17
	0800	168354.	38584.	1066.98
	1000	166956.	41571.	1067.75
	1200	168985.	44447.	1068.49
	1400	172881.	47300.	1069.23
	1600	177267.	50182.	1069.97
	1800	180941.	53019.	1070.71
	2000	185094.	55876.	1071.44
	2200	189645.	58748.	1072.19
	2400	184934.	88188.	1072.82
3 25	0200	179619.	110168.	1073.29
	0400	174532.	125798.	1073.62
	0600	167337.	136342.	1073.84
	0800	159241.	142637.	1073.98
	1000	151266.	145554.	1074.04
	1200	143479.	145972.	1074.05
	1400	136584.	136584.	1074.05
	1600	129822.	129822.	1074.05
	1800	121236.	121236.	1074.05
	2000	113342.	113342.	1074.05
	2200	105477.	105477.	1074.05
	2400	98656.	98656.	1074.05
3 26	0200	92237.	92237.	1074.05
	0400	85845.	85845.	1074.05
	0600	81422.	81422.	1074.05
	0800	77407.	77407.	1074.05
	1000	73392.	73392.	1074.05
	1200	69671.	69671.	1074.05
	1400	66111.	66111.	1074.05
	1600	62552.	62552.	1074.05
	1800	59298.	59298.	1074.05
	2000	56137.	56137.	1074.05
	2200	52977.	52977.	1074.05
	2400	50225.	50225.	1074.05
3 27	0200	47532.	47532.	1074.05
	0400	44839.	44839.	1074.05
	0600	43242.	43242.	1074.05
	0800	41687.	41687.	1074.05
	1000	40132.	40132.	1074.05
	1200	39573.	39573.	1074.05
	1400	39043.	39043.	1074.05
	1600	38513.	38513.	1074.05
	1800	38120.	38120.	1074.05
	2000	37727.	37727.	1074.05
	2200	37334.	37334.	1074.05
	2400	37013.	37013.	1074.05
3 28	0200	36692.	36692.	1074.05
	0400	36371.	36371.	1074.05
	0600	36096.	36096.	1074.05
	0800	35822.	35822.	1074.05
	1000	35547.	35547.	1074.05
	1200	35293.	35293.	1074.05
	1400	35040.	35040.	1074.05

```
        1600     34786.    34786.     1074.05
        1800     34540.    34540.     1074.05
        2000     34294.    34294.     1074.05
        2200     34048.    34048.     1074.05
        2400     33569.    33569.     1074.05
 3 29   0200     33089.    33089.     1074.05
        0400     32610.    32610.     1074.05
        0600     32183.    32183.     1074.05
```

APPENDIX P –EXAMPLE TRBROUTE FLOW OUTPUT FILE

The following is an example of the flow output file produced by running TRBROUTE with the input files presented in Appendicies M and H. This is the file "Holston.rte" entered in the dialog box described in Section 5.2.3.

```
             169       2.
   8583.      59.     177.     293.     408.     524.     642.     764.
    893.    1030.    1178.    1339.    1519.    1727.    1968.    2243.
   2559.    2924.    3365.    3898.    4521.    5232.    5987.    6750.
   7520.    8277.    9017.    9743.   10472.   11209.   11209.   11209.
  11209.   11209.   11209.   11209.   11209.   11209.   11209.   11209.
  11209.   11209.   11209.   11209.   11209.   11209.   11209.   11209.
  11209.   11209.   11209.   11209.   11209.   11209.   11209.   11209.
  11209.   11209.   11209.   11209.   11209.   11209.   11209.   11209.
  11209.   11209.   11209.   11209.   11209.   11209.   11209.   11209.
  11209.   11209.   11209.   11209.   11209.   11209.   11209.   11209.
  11209.   11209.   11209.   11209.   11209.   11209.   11209.   11209.
  11209.   11209.   11209.   11209.   11209.   11209.   11209.   11209.
  11209.   11209.   11209.   11209.   11209.   13011.   15669.   18650.
  21856.   25317.   28817.   32199.   35481.   38584.   41571.   44447.
  47300.   50182.   53019.   55876.   58748.   88188.  110168.  125798.
 136342.  142637.  145554.  145972.  136584.  129822.  121236.  113342.
 105477.   98656.   92237.   85845.   81422.   77407.   73392.   69671.
  66111.   62552.   59298.   56137.   52977.   50225.   47532.   44839.
  43242.   41687.   40132.   39573.   39043.   38513.   38120.   37727.
  37334.   37013.   36692.   36371.   36096.   35822.   35547.   35293.
  35040.   34786.   34540.   34294.   34048.   33569.   33089.   32610.
  32183.
```