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

ASSOCIATED ATTACHMENTS/ENCLOSURES:

Attachment 02.04.03-8AJ: Fort Loudon-Telico Dam Local Watershed (Subbasins 8, 16, 17, 18, and 24) Unit Hydrograph Validation

(83 Pages including Cover Sheet)

# NPG CALCULATION COVERSHEET/CCRIS UPDATE



| REV 0 EDMS/RIMS NO. | EDMS TYPE: | EDMS ACCESSION NO (N/A for REV. 0) |
|---|---|---|
| L58090511001 | calculations(nuclear) | L58 091230 045 |

Calc Title: Fort Loudoun-Tellico Dam Local Watershed (Subbasins 8, 16, 17, 18, and 24) Unit Hydrograph Validation

| CALC ID | TYPE | ORG | PLANT | BRANCH | NUMBER | CUR REV | NEW REV | REVISION APPLICABILITY |
|---|---|---|---|---|---|---|---|---|
| CURRENT | CN | NUC | GEN | CEB | CDQ000020080069 | 1 | 2 | Entire calc ☒ Selected pages ☐ |
| NEW | | | | | | | | |

| ACTION | NEW ☐ REVISION ☒ | DELETE ☐ RENAME ☐ | SUPERSEDE ☐ DUPLICATE ☐ | CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required) | No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required) |
|---|---|---|---|---|---|

| UNITS | SYSTEMS | UNIDS |
|---|---|---|
| N/A | N/A | N/A |

| DCN,EDC,N/A | APPLICABLE DESIGN DOCUMENT(S) | CLASSIFICATION |
|---|---|---|
| See ** Below | N/A | "E" |

| QUALITY RELATED? | SAFETY RELATED? (If yes, QR = yes) | UNVERIFIED ASSUMPTION | SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS? | DESIGN OUTPUT ATTACHMENT? | SAR/TS and/or ISFSI SAR/CoC AFFECTED |
|---|---|---|---|---|---|
| Yes ☒ No ☐ | Yes ☒ No ☐ | Yes ☐ No ☒ | Yes ☐ No ☒ | Yes ☐ No ☒ | Yes ☐ No ☒ |

| PREPARER ID | PREPARER PHONE NO | PREPARING ORG (BRANCH) | VERIFICATION METHOD | NEW METHOD OF ANALYSIS |
|---|---|---|---|---|
| HSSawyer | 615-252-4362 | CEB | Design Review | ☐ Yes ☒ No |

| PREPARER SIGNATURE | DATE | CHECKER SIGNATURE | DATE |
|---|---|---|---|
| Heather Smith Sawyer | 12/17/09 | Bill Hamilton | 12/17/09 |

| VERIFIER SIGNATURE | DATE | APPROVAL SIGNATURE | DATE |
|---|---|---|---|
| Bill Hamilton | 12/17/09 | K. R. Srates | 12/23/09 |

STATEMENT OF PROBLEM/ABSTRACT

Validate the existing unit hydrographs for the subbasins of the Fort Loudoun-Tellico Watershed (Subbasins 8, 16, 17, 18, and 24) using the 1973 and 2003 floods of record.

**EDCN- 22404A (SQN), EDCN- 54018A (WBN), EDCN-Later (BFN)

*This calculation contains electronic attachments and must be stored in EDMS as an Adobe .pdf file to maintain the ability to retrieve the electronic attachments.*

MICROFICHE/EFICHE Yes ☐ No ☒ FICHE NUMBER(S)

☐ LOAD INTO EDMS AND DESTROY
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS: LP4D-C
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

## NPG CALCULATION COVERSHEET/CCRIS UPDATE



| REV 0 EDMS/RIMS NO. | EDMS TYPE: | EDMS ACCESSION NO (N/A for REV. 0) |
|---|---|---|
| L58 090511 001 | calculations(nuclear) | N/A |

Calc Title: Calculation of Initial Flood Flows from the Fort Loudoun-Tellico Watershed (Subbasins 8, 16, 17, 18, and 24) for Use in the SOCH Model Calibration and Unit Hydrograph Validation

| CALC ID | TYPE | ORG | PLANT | BRANCH | NUMBER | CUR REV | NEW REV | REVISION APPLICABILITY |
|---|---|---|---|---|---|---|---|---|
| CURRENT | CN | NUC | | | | | | Entire calc ☐ Selected pages ☐ |
| NEW | CN | NUC | GEN | CEB | CDQ000020080069 | N/A | 0 | |

| ACTION | | | | |
|---|---|---|---|---|
| ACTION | NEW ☒ REVISION ☐ | DELETE ☐ RENAME ☐ | SUPERSEDE ☐ DUPLICATE ☐ | CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required) | No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required) |

| UNITS | SYSTEMS | UNIDS |
|---|---|---|
| N/A | N/A | N/A |

| DCN,EDC,N/A | APPLICABLE DESIGN DOCUMENT(S) | CLASSIFICATION |
|---|---|---|
| N/A | N/A | "E" |

| QUALITY RELATED? | SAFETY RELATED? (If yes, QR = yes) | UNVERIFIED ASSUMPTION | SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS? | DESIGN OUTPUT ATTACHMENT? | SAR/TS and/or ISFSI SAR/CoC AFFECTED |
|---|---|---|---|---|---|
| Yes ☒ No ☐ | Yes ☒ No ☐ | Yes ☐ No ☒ | Yes ☐ No ☒ | Yes ☐ No ☒ | Yes ☐ No ☒ |

| PREPARER ID | PREPARER PHONE NO | PREPARING ORG (BRANCH) | VERIFICATION METHOD | NEW METHOD OF ANALYSIS |
|---|---|---|---|---|
| MCCARNEY | (415) 768-3588 | Bechtel (CEB) | Design Review | ☐ Yes ☒ No |

| PREPARER SIGNATURE | DATE | CHECKER SIGNATURE | DATE |
|---|---|---|---|
| Matthew C. Carney [signature] | 4/23/09 | Nicholas D. Martin [signature] | 4/23/2009 |

| VERIFIER SIGNATURE | DATE | APPROVAL SIGNATURE | DATE |
|---|---|---|---|
| Robert E. Swain [signature] | 4/23/2009 | [signature] K.R. Spates | 4/27/09 |

STATEMENT OF PROBLEM/ABSTRACT


Prepare initial flood flow hydrographs for the Fort Loudoun-Tellico Watershed (Subbasins 8, 16, 17, 18, and 24) for two floods that occurred in March 1973 and May 2003 to be used in the SOCH model calibration and unit hydrograph validation.


*This calculation contains electronic attachments and must be stored in EDMS as an Adobe .pdf file to maintain the ability to retrieve the electronic attachments.*

MICROFICHE/EFICHE Yes ☐ No ☒ FICHE NUMBER(S)

☐ LOAD INTO EDMS AND DESTROY
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS: LP4D-C
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

# NPG CALCULATION COVERSHEET/CCRIS UPDATE



| REV 0 EDMS/RIMS NO. | EDMS TYPE: | EDMS ACCESSION NO (N/A for REV. 0) |
|---|---|---|
| L58090511001 | calculations(nuclear) | L58 090722 001 |

Calc Title: Fort Loudoun-Tellico Dam Local Watershed (Subbasins 8, 16, 17, 18, and 24) Unit Hydrograph Validation

| CALC ID | TYPE | ORG | PLANT | BRANCH | NUMBER | CUR REV | NEW REV | REVISION APPLICABILITY |
|---|---|---|---|---|---|---|---|---|
| CURRENT | CN | NUC | GEN | CEB | CDQ000020080069 | 0 | 1 | Entire calc ☒<br>Selected pages ☐ |
| NEW | CN | NUC | | | | | | |

| ACTION | NEW ☐<br>REVISION ☒ | DELETE ☐<br>RENAME ☒ | SUPERSEDE ☐<br>DUPLICATE ☐ | CCRIS UPDATE ONLY ☐<br>(Verifier Approval Signatures Not Required) | No CCRIS Changes ☐<br>(For calc revision, CCRIS been reviewed and no CCRIS changes required) |
|---|---|---|---|---|---|

| UNITS | SYSTEMS | UNIDS |
|---|---|---|
| N/A | N/A | N/A |

| DCN,EDC,N/A | APPLICABLE DESIGN DOCUMENT(S) | CLASSIFICATION |
|---|---|---|
| See ** Below | N/A | "E" |

| QUALITY RELATED? | SAFETY RELATED? (If yes, QR = yes) | UNVERIFIED ASSUMPTION | SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS? | DESIGN OUTPUT ATTACHMENT? | SAR/TS and/or ISFSI SAR/CoC AFFECTED |
|---|---|---|---|---|---|
| Yes ☒ No ☐ | Yes ☒ No ☐ | Yes ☒ No ☐ | Yes ☐ No ☒ | Yes ☐ No ☒ | Yes ☐ No ☒ |

| PREPARER ID | PREPARER PHONE NO | PREPARING ORG (BRANCH) | VERIFICATION METHOD | NEW METHOD OF ANALYSIS |
|---|---|---|---|---|
| AWard | 615-252-4329 | BWSC (CEB) | Design Review | ☐ Yes ☒ No |

| PREPARER SIGNATURE | DATE | CHECKER SIGNATURE | DATE |
|---|---|---|---|
| Adrian Ward (signed) Adrian Ward | 7/21/09 | (signed) Bill Hamilton | 7/21/09 |
| **VERIFIER SIGNATURE** | **DATE** | **APPROVAL SIGNATURE** | **DATE** |
| (signed) Bill Hamilton | 7/21/09 | cpc for PDm 7/22/09<br>PBSelman for K.R. Spates<br>P.B. Selman | 7/22/09 |

STATEMENT OF PROBLEM/ABSTRACT

Validate the existing unit hydrographs for the subbasins of the Fort Loudoun-Tellico Watershed (Subbasins 8, 16, 17, 18, and 24) using the 1973 and 2003 floods of record.

**EDCN- 22404 (SQN), EDCN- 54018 (WBN), EDCN-Later (BFN)

***This calculation contains electronic attachments and must be stored in EDMS as an Adobe .pdf file to maintain the ability to retrieve the electronic attachments.***

MICROFICHE/EFICHE Yes ☐ No ☒ FICHE NUMBER(S)

☐ LOAD INTO EDMS AND DESTROY
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS: LP4D-C
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

# NPG CALCULATION COVERSHEET/CCRIS UPDATE



| CALC ID | TYPE | ORG | PLANT | BRANCH | NUMBER | REV |
|---|---|---|---|---|---|---|
| | CN | NUC | GEN | CEB | CDQ000020080069 | 2 |

**ALTERNATE CALCULATION IDENTIFICATION**

| BLDG | ROOM | ELEV | COORD/AZIM | FIRM | Print Report Yes ☐ |
|---|---|---|---|---|---|
| | | | | BWSC | |

CATEGORIES NA

## KEY NOUNS (A-add, D-delete)

| ACTION (A/D) | KEY NOUN | A/D | KEY NOUN |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

## CROSS-REFERENCES (A-add, C-change, D-delete)

| ACTION (A/C/D) | XREF CODE | XREF TYPE | XREF PLANT | XREF BRANCH | XREF NUMBER | XREF REV |
|---|---|---|---|---|---|---|
| A | P | CO | GEN | CEB | FLDHYDRO Version 1.0 | |
| A | P | CO | GEN | CEB | UNITGRPH Version 1.0 | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

CCRIS ONLY UPDATES:
Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

| PREPARER SIGNATURE | DATE | CHECKER SIGNATURE | DATE |
|---|---|---|---|
| PREPARER PHONE NO. | EDMS ACCESSION NO. | | |

| NPG CALCULATION RECORD OF REVISION | |
|---|---|
| CALCULATION IDENTIFIER | CDQ000020080069 |
| Title | Fort Loudoun-Tellico Dam Local Watershed (Subbasins 8, 16, 17, 18, and 24) Unit Hydrograph Validation, Revision 2 |
| Revision No. | DESCRIPTION OF REVISION |
| 0 | Initial issue 60 pages |
| 1 | This calculation was revised to validate unit hydrographs for Subbasins 8, 16, 17, 18, and 24 of the Fort Loudoun-Tellico Dam Local Watershed using the 1973 and 2003 floods of record. As a result of this revision, the calculation title has been changed to reflect final validation of the local unit hydrographs. Significant changes to text are marked with a right-hand margin revision bar.<br><br>Changes and Additions:<br>Content on pages 1 – 11, 13-15 Revision 0 (R0) was modified as indicated on pages 1 – 11, 13-16 of Revision 1 (R1) with pages 1a and 10a added.<br><br>Content on pages 19-20, 52-56, 58, 59 R0 was modified as indicated on pages 20-21, 54-58, 60-61 of R1.<br><br>New pages 62-74 were added.<br>Attachment 1-1 was revised<br><br>Added new electronic Attachments 4-1, 4-2 and 4-3<br><br>Total hardcopy pages R1: 76 |
| 2 | This calculation was revised to address the following:<br><br>• PER 203951-The verification of the original calculation was completed by personnel who had not completed the required NEDP-7 Job Performance Record (JPR). A verification JPR is now in place for all personnel engaged in verification tasks. Checking included only changes made in this revision as the checking of the calculation was not impacted by PER 203951. The verification is inclusive of work completed prior to this revision.<br><br>• PER 203872- replace NEDP-2 forms on Pages 1 through 7 & 10 with the forms from the NEDP-2 Revision in effect at the time of calculations issuance.<br><br>• PER 175596- was initiated to address inflow data errors discovered in Attachment 1-1. The errors apparently occurred as inflow data for the local hydrographs were transferred (via copy/paste) into an Excel spreadsheet in order to combine them with baseflow and runoff from the actual water surface. The dates (and times) that a particular flow occurs in the direct runoff hydrographs are shifted. These errors have been corrected in the spreadsheet for use in Revision 1 of this calculation. Cells in the Attachment 1-1 spreadsheet showing the corrected data have been highlighted in yellow. |

| NPG CALCULATION RECORD OF REVISION | |
|---|---|
| CALCULATION IDENTIFIER | CDQ000020080069 |
| Title | Fort Loudoun-Tellico Dam Local Watershed (Subbasins 8, 16, 17, 18, and 24) Unit Hydrograph Validation, Revision 2 |
| Revision No. | DESCRIPTION OF REVISION |
| 2 | Significant changes in Revision 2 are noted with a right margin revision bar. Administrative changes and typos are excluded.<br><br>Content was modified on pages 1-7, 12-14, 20-22, 28-29 & 62-70 R1 as shown on pages 1-7, 12-15, 20-22, 28-29 & 62-70 R2.<br>Pages Added: 1b, 4a, 10b, 20a, 22a<br><br>Total pages of calculation hard copy for Revision 2= 82 |
| | |
| | |

**NPG CALCULATION TABLE OF CONTENTS**

| Calculation Identifier: CDQ000020080069 | Revision: 2 | |
|---|---|---|

TABLE OF CONTENTS

| SECTION | TITLE | PAGE |
|---|---|---|

## NPG CALCULATION TABLE OF CONTENTS

| Calculation Identifier: CDQ000020080069 | Revision: 2 | |
|---|---|---|

TABLE OF CONTENTS



Note: N/A indicates electronically attached file(s).

| NPG CALCULATION TABLE OF CONTENTS | | |
|---|---|---|
| Calculation Identifier: CDQ000020080069 | Revision: 2 | |

TABLE OF CONTENTS (Continued)

SECTION TITLE PAGE

**List of Tables:**

**NPG CALCULATION TABLE OF CONTENTS**

| Calculation Identifier: CDQ000020080069 | Revision: 2 | |
|---|---|---|

TABLE OF CONTENTS (Continued)

| SECTION | TITLE | PAGE |
|---|---|---|

**List of Figures:**

| NPG COMPUTER INPUT FILE STORAGE INFORMATION SHEET | | | |
|---|---|---|---|
| Document CDQ000020080069 | Rev. 2 | Plant: GEN | |
| Subject: Fort Loudoun-Tellico Dam Local Watershed (Subbasins 8, 16, 17, 18, and 24) Unit Hydrograph Validation | | | |

☐ Electronic storage of the input files for this calculation is not required. Comments:

☒ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

See listing of electronically attached files on the following two pages.

☐ Microfiche/eFiche

| ELECTRONIC FILE ATTACHMENTS | | | |
|---|---|---|---|
| Document CDQ000020080069 | Rev. 1 | Plant: GEN | |

Subject: Fort Loudoun-Tellico Dam Local Watershed (Subbasins 8, 16, 17, 18, and 24) Unit Hydrograph Validation

The files listed below, which contain both input and output data, are electronically attached to the parent Adobe .pdf calculation file. All files are therefore stored in an unalterable medium and are retrievable through the EDMS number for this calculation. Click on the "Attachments" Tab within Adobe to view the attachment listing, to access and view the files as needed.

| Electronic Attachment | Name of File or Folder | File Location |
|---|---|---|
| **Supporting Spreadsheets and Data** | | |
| Attachment 1-1 | Att 1-1_Fort Loudoun-Tellico (8, 16, 17, 18, & 24) hydrographs.xls | Attached to PDF |
| Attachment 1-2 | Att 1-2_Cherokee_rev0 (daily).xls (TVA database file) | Attached to PDF |
| Attachment 1-3 | Att 1-3_Douglas_rev0 (daily).xls (TVA database file) | Attached to PDF |
| Attachment 1-4 | Att 1-4_Little Tennessee River below Chilhowee Dam.txt | Attached to PDF |
| Attachment 1-5 | Att 1-5_Chilhowee.xls | |
| Attachment 1-6 | Att 1-6_FortLoudoun_rev0 (daily).xls (TVA database file) | Attached to PDF |
| Attachment 1-7 | Att 1-7_Tellico_rev0 (daily).xls (TVA database file) | Attached to PDF |
| Attachment 1-8 | Att 1-8_03470000 Little Pigeon River at Sevierville_daily.txt | Attached to PDF |
| Attachment 1-9 | Att 1-9_03495500 Holston River near Knoxville.txt | Attached to PDF |
| Attachment 1-10 | Att 1-10_03470500 French Broad River near Knoxville.txt | Attached to PDF |
| Attachment 1-11 | Att 1-11_03498500 Little River near Maryville.txt | Attached to PDF |
| Attachment 1-12 | Att 1-12_03498850 Little River near Alcoa.txt | Attached to PDF |
| Attachment 1-13 | Att 1-13_LittlePigeonAtSevierville_rev0.xls | Attached to PDF |
| Attachment 1-14 | Att 1-14_Gridded rainfall for May 2003 storm.xls | Attached to PDF |
| Attachment 1-15 | Att 1-15_Water budgets for Fort Loudoun-Tellico basins.xls | Attached to PDF |
| Attachment 1-16 | Att 1-16_Reservoir elevation-area data.xls | Attached to PDF |
| **UNITGRPH Files** | | |
| Attachment 2-1 | Att 2-1_Basins7_8_Composite.dat | Attached to PDF |
| Attachment 2-2 | Att 2-2_Basins7_8_Composite.prn | Attached to PDF |
| Attachment 2-3 | Att 2-3_Basin16_Composite.dat | Attached to PDF |
| Attachment 2-4 | Att 2-4_Basin16_Composite.prn | Attached to PDF |
| Attachment 2-5 | Att 2-5_Basin17_Composite.dat | Attached to PDF |
| Attachment 2-6 | Att 2-6_Basin17_Composite.prn | Attached to PDF |
| Attachment 2-7 | Att 2-7_Basin18_Composite.dat | Attached to PDF |
| Attachment 2-8 | Att 2-8_Basin18_Composite.prn | Attached to PDF |
| Attachment 2-9 | Att 2-9_LittleTennesseeR_Composite.dat | Attached to PDF |
| Attachment 2-10 | Att 2-10_LittleTennesseeR_Composite.prn | Attached to PDF |

| ELECTRONIC FILE ATTACHMENTS | | | |
|---|---|---|---|
| Document CDQ000020080069 | Rev. 1 | Plant: GEN | |

Subject: Fort Loudoun-Tellico Dam Local Watershed (Subbasins 8, 16, 17, 18, and 24) Unit Hydrograph Validation

The files listed below, which contain both input and output data, are electronically attached to the parent Adobe .pdf calculation file. All files are therefore stored in an unalterable medium and are retrievable through the EDMS number for this calculation. Click on the "Attachments" Tab within Adobe to view the attachment listing, to access and view the files as needed.

| Electronic Attachment | Name of File or Folder | File Location |
|---|---|---|
| | **FLDHYDRO Files** | |
| Attachment 3-1 | Att 3-1_Basin8_March1973.dat | Attached to PDF |
| Attachment 3-2 | Att 3-2_Basin8_March1973.out | Attached to PDF |
| Attachment 3-3 | Att 3-3_Basin16_March1973.dat | Attached to PDF |
| Attachment 3-4 | Att 3-4_Basin16_March1973.out | Attached to PDF |
| Attachment 3-5 | Att 3-5_Basin17_March1973.dat | Attached to PDF |
| Attachment 3-6 | Att 3-6_Basin17_March1973.out | Attached to PDF |
| Attachment 3-7 | Att 3-7_Basin18_March1973_1.dat | Attached to PDF |
| Attachment 3-8 | Att 3-8_Basin18_March1973_1.out | Attached to PDF |
| Attachment 3-9 | Att 3-9_FortLoudounReservoir_March1973_1.dat | Attached to PDF |
| Attachment 3-10 | Att 3-10_FortLoudounReservoir_March1973_1.out | Attached to PDF |
| Attachment 3-11 | Att 3-11_Basin18_March1973_2.dat | Attached to PDF |
| Attachment 3-12 | Att 3-12_Basin18_March1973_2.out | Attached to PDF |
| Attachment 3-13 | Att 3-13_FortLoudounReservoir_March1973_2.dat | Attached to PDF |
| Attachment 3-14 | Att 3-14_FortLoudounReservoir_March1973_2.out | Attached to PDF |
| Attachment 3-15 | Att 3-15_Basin24_March1973.dat | Attached to PDF |
| Attachment 3-16 | Att 3-16_Basin24_March1973.out | Attached to PDF |
| Attachment 3-17 | Att 3-17_Basin17_May2003.dat | Attached to PDF |
| Attachment 3-18 | Att 3-18_Basin17_May2003.out | Attached to PDF |
| Attachment 3-19 | Att 3-19_FortLoudounTellico_May2003_1.dat | Attached to PDF |
| Attachment 3-20 | Att 3-20_FortLoudounTellico_May2003_1.out | Attached to PDF |
| Attachment 3-21 | Att 3-21_FortLoudounTellico_May2003_2.dat | Attached to PDF |
| Attachment 3-22 | Att 3-22_FortLoudounTellico_May2003_2.out | Attached to PDF |
| Attachment 4-1: | Attachment_4-1_Observed vs SOCH Mar 1973 Hydrographs.xls | Attached to PDF |
| Attachment 4-2: | Attachment_4-2_Observed vs SOCH May 2003 Hydrographs.xls | Attached to PDF |
| Attachment 4-3: | Attachment_4-3_Validated_6HR_UH.xls | Attached to PDF |
| | | |

**NPG CALCULATION VERIFICATION FORM**

| | | |
|---|---|---|
| Calculation Identifier CDQ000020080069 | | Revision 2 |
| Method of verification used:<br>1. Design Review ☒<br>2. Alternate Calculation ☐<br>3. Qualification Test ☐ | Verifier Bill Hamilton (signature: Bill Hamilton) | Date 12/17/09 |

Comments:

This calculation entitled, Fort Loudoun-Tellico Dam Local Watershed (Subbasins 8, 16, 17, 18, and 24) Unit Hydrograph Validation was verified by independent design review. The process involved a critical review of the calculation to ensure that it is correct and complete, uses appropriate methodologies, and achieves its intended purpose. The inputs were reviewed and determined to be appropriate inputs for this calculation. The results of the calculation were reviewed and were found to be reasonable and consistent with the inputs provided. Backup files and documents were consulted as necessary to verify data and analysis details found in the calculation.

Detailed comments and editorial suggestions for the changes made in this revision were transmitted to the author and reviewer by email along with a marked up copy of the calculation.

(Note: The design verification of this calculation revision is for the total calculation, not just the changes made in the revision. This complete re-verification is performed to disposition PER 203951 as described in the Calculation Revision Log on Page 3).

**NPG CALCULATION VERIFICATION FORM**

Calculation Identifier CDQ000020080069 Revision 0

| Method of verification used: | | |
|---|---|---|
| 1. Design Review | ☒ | |
| 2. Alternate Calculation | ☐ | Verifier Bob Swain Date 4/23/2009 |
| 3. Qualification Test | ☐ | |

Comments:

The calculation entitled, "Calculation of Initial Flood Flows from the Fort Loudoun-Tellico Watershed (Subbasins 8, 16, 17, 18, and 24) for Use in the SOCH Model Calibration and Unit Hydrograph Validation" was verified by an independent design review. The process involved a critical review of the calculation to ensure that it is correct and complete, uses appropriate methodologies, and achieves its intended purpose. Backup files and documents were consulted as necessary to verify data and analysis details found in the calculation. Detailed comments and editorial suggestions were transmitted to the author and reviewer by email along with a marked up copy of the calculation.

Several issues were discussed and resolved during the verification process. Almost all of the editorial suggestions were adopted in the final document. The following discussion briefly describes the most important issues and the resolution process.

1. The discussion of the creation of the Subbasin 8 unit was shortened and summarized in Section 6.2.1. The Subbasin 8 unit hydrograph was developed by subtracting the Subbasin 7 unit hydrograph from the combined unit hydrograph for Subbasins 7 and 8. The floods used to develop each individual unit hydrograph are mentioned in the report.

2. The Subbasin 24 unit hydrograph "prior to Tellico Reservoir" was used to simulate the 1973 flood, which occurred before Tellico Dam was built, and the Subbasin 24 unit hydrograph "after Tellico Reservoir" was used to simulate the 2003 flood. The unit hydrograph "after Tellico Reservoir" will be used in the TVA Nuclear site probable maximum flood study. The unit hydrograph "prior to Tellico Reservoir" is no longer applicable with the construction of the reservoir.

3. More discussion was added about the derivation of baseflow. The analysis for Subbasin 16 was changed to use linear interpolation between the starting and ending flood discharges.

4. The surface area-elevation relationships for the reservoirs were checked to determine if appropriate surface area values were used to determine additional reservoir runoff. Because additional reservoir runoff is based on reservoir surface areas determined from GIS and a topographic survey, the check was made to insure that the reservoir surface areas correspond to the time of the floods.

The calculation presents the development of initial simulated flows from Subbasins 8, 16, 17, 18, and 24 for floods that occurred in March 1973 and May 2003. The initial simulated flows are for use in the calibration of the SOCH model and to validate the unit hydrographs for Subbasins 8, 16, 17, 18, and 24.

## NPG CALCULATION VERIFICATION FORM

Calculation Identifier CDQ000020080069 Revision 1

| Method of verification used: | | |
|---|---|---|
| 1. Design Review | ☒ | Verifier Bill Hamilton Date 7/16/09 |
| 2. Alternate Calculation | ☐ | |
| 3. Qualification Test | ☐ | |

Comments:

The calculation entitled, "Fort Loudoun-Tellico Local Watershed (Subbasins 8, 16, 17, 18, and 24) Unit Hydrograph Validation " was verified by an independent design review. The process involved a critical review of the calculation to ensure that it is correct and complete, uses appropriate methodologies, and achieves its intended purpose. Backup files and documents were consulted as necessary to verify data and analysis details found in the calculation. Detailed comments and editorial suggestions were transmitted to the author and reviewer by email along with a marked up copy of the calculation.

The calculation presents the development of initial simulated flows from Subbasins 8, 16, 17, 18, and 24 for floods that occurred in March 1973 and May 2003. The initial simulated flows are for use in the calibration of the SOCH model and to validate the unit hydrographs for Subbasins 8, 16, 17, 18, and 24. The comparison between the observed and simulated flows and water surface elevations at several locations supports the conclusion that the unit hydrographs developed for Subbasins 8, 16, 17, 18, and 24 have been indirectly validated against floods that occurred in March 1973 and May 2003.

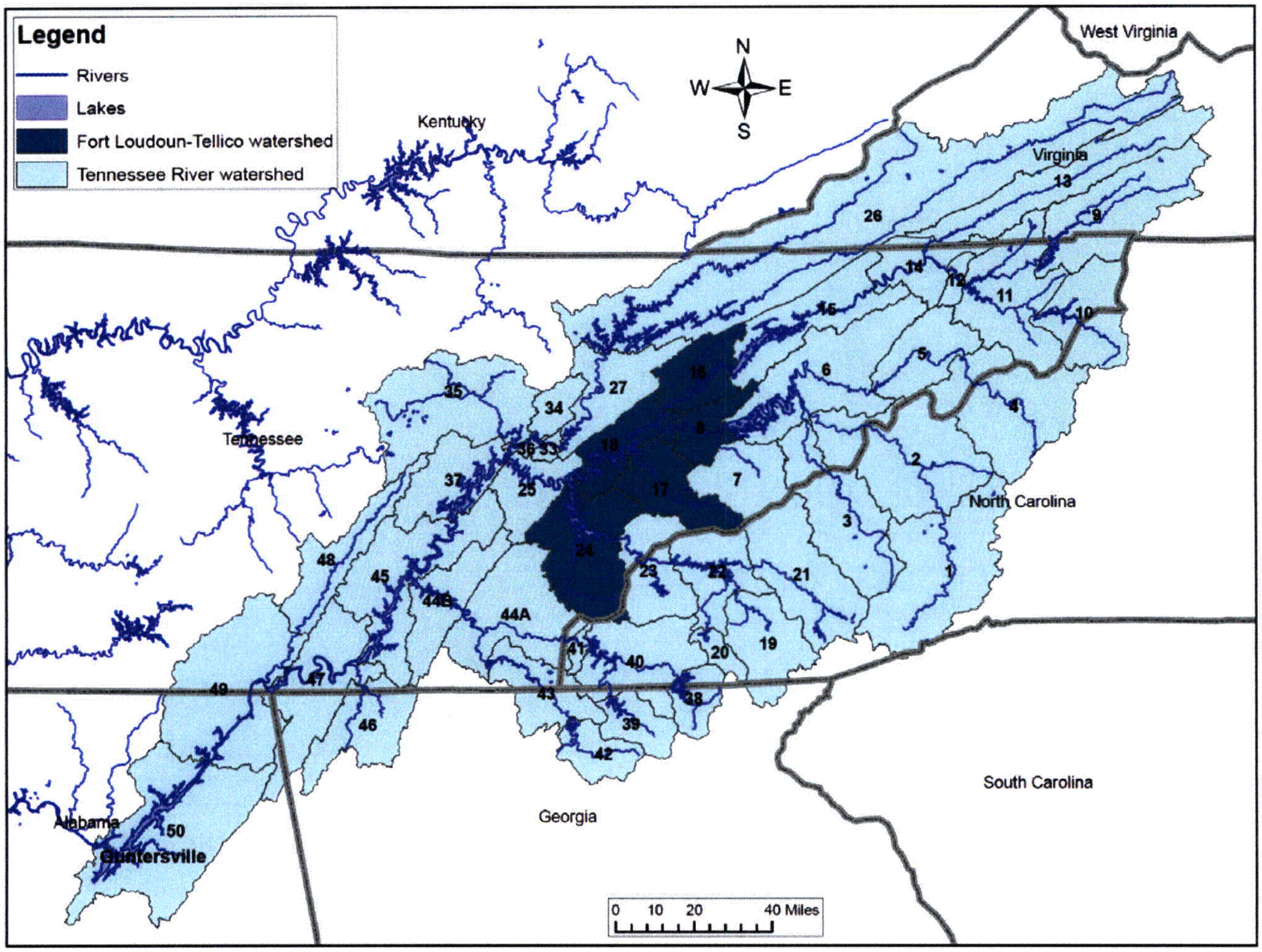
# 1 Purpose

The TVA's Water Management Group has adapted computer codes and data sets developed from flood studies carried out over the past 40 years to develop a dynamic hydrologic model (Reference 1) of the Tennessee River upstream of the Guntersville Dam for use in the Probable Maximum Flood (PMF) and dam break analysis for the Sequoyah, Watts Bar, and planned Bellefonte Nuclear Plant sites (Note that this calculation will also be used in similar future PMF and dam break analyses for the Browns Ferry Nuclear Plant).

Inputs to the dynamic model include hydrographs for 47 subbasins developed from design rainfall inputs convoluted with unit hydrographs (UH) developed specifically for each subbasin. These unit hydrographs were developed by the TVA in previous studies, mostly in the 1970s and early 1980s, using observed rainfall and streamflow and reservoir headwater and discharge data, and are validated by checking their performance in reproducing recent floods.

As part of the dynamic hydrologic model of the Tennessee River system, the subbasin hydrographs are used as inputs to the Simulated Open Channel Hydraulic (SOCH) model. The SOCH model is used to determine elevation and discharge hydrographs. This calculation presents the development of initial simulated flows from the Fort Loudoun-Tellico Watershed (Subbasins 8, 16, 17, 18, and 24) as well as the unit hydrograph validation for floods that occurred in March 1973 and May 2003. The March 1973 and May 2003 floods were selected by the TVA to be analyzed using the SOCH model. The simulated flows will be used in the calibration of the SOCH model and to validate the TVA unit hydrographs for these subbasins (References 2 to 7). Subbasins 8, 16, 17, 18, and 24 are located in the Tennessee River Basin as shown in Figure 1.

**Figure 1: Location Map of the Fort Loudoun-Tellico Watershed (Subbasins 8, 16, 17, 18, and 24).**




# 2 References


1. Tennessee Valley Authority, Bellefonte Nuclear Plant - White Paper, Hydrologic Analysis, Revision 1, July 25, 2008, (EDMS No. L58 081219 800). FOR INFORMATION ONLY

2. Tennessee Valley Authority, response to Bechtel Request for Information (RFI) 25447-000-GRI-GEX-00052, No. 24, Little Tennessee River Local, Chilhowee Dam to Tellico Dam, Rev. 0, (EDMS No. L58 081119 800).

3. Tennessee Valley Authority, File Book Reference for Unit Area 8, French Broad Local (EDMS No. L58 081223 807).

4. Tennessee Valley Authority, File Book Reference for Unit Area 16, Holston River Local, Cherokee Dam to Knoxville Gage (EDMS No. L58 081223 815).

5. Tennessee Valley Authority, File Book Reference for Unit Area 17, Little River (EDMS No. L58 081223 816).

6. Tennessee Valley Authority, File Book Reference for Unit Area 18, Fort Loudoun Local (EDMS No. L58 081223 817).

7. Tennessee Valley Authority, File Book Reference for Unit Area 24, Little Tennessee River Local, Chilhowee to Tellico Dam (EDMS No. L58 081223 820).

8. Viessman, W., J.W. Knapp, G.L. Lewis, and T.E. Harbaugh, *Introduction to Hydrology, Second Edition,* Harper & Row, Publishers, 1977.

9. Chow, V.T., D.R. Maidment, and L.W. Mays, *Applied Hydrology*, McGraw-Hill Book Company, 1988.

10. Tennessee Valley Authority, *UNITGRPH-FLDHYDRO-TRBROUTE-CHANROUT User's Manual*, Version 1.0, March 2009 (EDMS No. L58 090325 001).

11. Tennessee Valley Authority, Rainfall data for the March 1973 storm – Loudoun-Tellico subbasins, Response to Bechtel Request for Information RFI 25447-000-GRI-GEX-00037, Rev. 0, 10/31/2008. (EDMS No. L58 081030 005).

12. Tennessee Valley Authority, Unit Area 7, Little Pigeon River at Sevierville, File Book Reference. (EDMS No. L58 081223 806)

13. Tennessee Valley Authority, Data request for developing inflows to the SOCH model for the 1973 flood, for stage-storage tables, and for all reservoir and stream flow data for years 1997 to 2007, Response to Bechtel Request for Information RFI 25447-000-GRI-GEX-00053, Rev. 0, 11/12/2008. (EDMS No. L58 081126 800)

14. U.S. Geological Survey (USGS), National Water Information System (NWIS), online at: http://waterdata.usgs.gov/nwis, accessed 01/06/2009.

15. Tennessee Valley Authority, Calculation No. CDQ000020080055, Processing and Validation of National Weather Service's NEXRAD Stage III Hourly Precipitation Data for Hydrologic and Hydraulic Analysis of Watersheds, Revision 3

16. U.S. Geological Survey, *Water Resources Data – Tennessee – Water Year 2003*, by D.F. Flohr, J.W. Garrett, J.T. Hamilton, and T.D. Phillips, Water-Data Report TN-03-01, Nashville, TN, 2004.

17: Weaver, J.D. and Gamble, C.R., *Flood Frequency of Streams in Rural Basins of Tennessee*, U.S. Geological Survey Water-Resources Investigations Report 92-4165, 1993.

18. Linsley, R.K., Kohler, M.A., and J.L.H.Paulhus, *Hydrology for Engineers*, McGraw-Hill Book Company, 1982.

19. Tennessee Valley Authority, *TVA Water Control Projects and Other Major Hydro Developments in the Tennessee and Cumberland Valleys*, Technical Monograph No. 55, Volume 1, Knoxville, TN, March 1980.

20. Kohler, M.A., and R.K. Linsley, Predicting the Runoff from Storm Rainfall, *Research Paper No. 34*, U.S. Department of Commerce, September 1951. (EDMS No. L58 080910 001)

21. Tennessee Valley Authority, Calculation CDQ00020080036, SOCH Model Calibration, Ft. Loudoun-Tellico, Rev 0 (not approved).

22. American Nuclear Society, American National Standard for Determining Design Basis Flooding at Power Reactor Sites, ANSI/ANS-2.8-1992, 1992.

23. US Nuclear Regulatory Commission, Standard Review Plan 2.4.3, Probably Maximum Flood (PMF) on Streams and Rivers, NUREG-0800, Revision 4, March 2007.

24. Problem Evaluation Report (PER) 175596, Inflow Data Error found in Calculation CDQ000020080069 Rev 0, July 2009.

# 3 Assumptions

## *3.1 General Assumptions*

None.

### *3.2 Unverified Assumptions*

None

# 4 Background

### *4.1 Unit Hydrograph Theory*

The unit hydrograph is used to predict the runoff response at the outlet of a watershed, or subbasin, to the input of one inch of excess rainfall applied over a given duration of time. Runoff from other depths of excess rainfall can be obtained by scaling (References 8 and 9).

The unit hydrograph is used to obtain the direct runoff hydrograph resulting from a series of excess rainfall inputs of any depth using the process of "convolution." The discrete convolution equation, states that the direct runoff, $Q$, is obtained by summing the products of the excess rainfall depths (direct runoff depths), $P$, and the unit hydrograph ordinates, $U$ (References 8 and 9). The reverse process, called deconvolution, is used to derive the ordinates of the unit hydrograph by reconstituting floods from rainfall and streamflow data. The unit hydrograph is derived from the unit duration of uniform excess rainfall applied evenly across the watershed.

Unit hydrograph theory is applicable under the following conditions (Reference 9):

1. Excess rainfall has a constant intensity within the effective duration.
2. Excess rainfall is uniformly distributed over the entire subbasin.
3. The duration of direct runoff resulting from a unit of excess rainfall is constant.
4. The ordinates of the unit hydrograph are directly proportional to the total amount of direct runoff (linear response).
5. The surface runoff hydrograph reflects all the unique physical characteristics and runoff processes in the drainage basin in a given "epoch."

# 5 Methodology

Direct runoff originating within several subbasins of the Tennessee Valley basin which empty directly into the Tennessee River cannot be accurately calculated because the observed flood hydrograph at the subbasin outlet is not available. For these subbasins, the TVA will employ SOCH model results to validate the unit hydrographs. The SOCH model requires estimated flood hydrographs for these subbasins as inputs during the model calibration process.

Input flood hydrographs for individual subbasins requiring SOCH model validation are estimated by using a water budget to calculate total flow volume during a flood. The water budget area is chosen so that the observed flood hydrograph at the outlet of the water budget area can be reliably estimated. Total inflow to the water budget area is then partitioned among the component subbasins to obtain input flood hydrographs for individual subbasins using the methods described below and in Section 7.3.

The methodology used for unit hydrograph validation follows that described in ANSI/ANS-2.8-1992 (Reference 22). This document is included as a reference in the NRC's Standard Review Plan 2.4.3, Probable Maximum Flood on Streams and Rivers (Reference 23). ANSI/ANS-2.8-1992 states that "deterministic simulation models including unit hydrographs should be verified or calibrated by comparing results of the simulation with the highest two or more floods for which suitable precipitation data are available."

In general, the methodology used for this calculation includes the following steps:

1. Delineate the area for water budgeting. Perform water budget calculations for the March 1973 and May 2003 floods to estimate the volume of each flood that originates within this area.
2. Separate baseflow from the total local flow to obtain the direct runoff for the budget area.
3. Obtain observed rainfall data for the March 1973 and May 2003 floods and calculate the basin-average rainfall for each subbasin within the water budget area and also for the reservoir areas.
4. Convert the observed rainfall series to excess rainfall series using the TVA's API-RI method as implemented in FLDHYDRO (Reference 10). The observed direct runoff volumes are used by FLDHYDRO to ensure that the calculated excess rainfall volumes agree with the observed. FLDHYDRO allocates excess rainfall among the subbasins according to their calculated API values.
5. If there is a reservoir within the water budget area, compute the additional direct runoff generated by rainfall on the surface of the reservoir. All rain falling on the reservoir surface becomes runoff. Therefore, additional direct runoff is equal to the observed rainfall (Step 3) less the direct runoff calculated in Step 4. Check that the volume of direct runoff from Step 2 equals the sum of the direct runoff from Steps 4 and 5. If necessary, adjust the CHKVOL value in FLDHYDRO and redo Steps 4 and 5.
6. Convolute the TVA unit hydrograph and the excess rainfall series to generate the initial simulated local direct runoff hydrograph for each subbasin.
7. Compare the SOCH model simulated and the observed discharge and stage hydrographs for appropriate stations along the Tennessee River to indirectly validate the performance of the TVA unit hydrographs in simulating local runoff along the study reach of the Tennessee River.

# 6 Design Input Data

The input data necessary for developing initial SOCH inflow hydrographs for the Fort Loudoun-Tellico watershed are summarized below.

- Subbasin drainage areas
- Surface areas of Fort Loudoun and Tellico Reservoirs
- Unit hydrograph ordinates and durations
- Daily flows observed at gages on the Little Pigeon River at Sevierville, the Holston River near Knoxville, the French Broad River near Knoxville, and at three locations within Subbasin 17 on the Little River.
- Observed daily discharges at Cherokee, Douglas, and Chilhowee Dams
- Observed daily storage and discharges at Fort Loudoun and Tellico Dams
- Observed rainfall data associated with the March 1973 and May 2003 floods

Each of these inputs is described in more detail in the following sub-sections.

## *6.1 Subbasin Locations and Areas*

A hydrologic map of the Fort Loudoun-Tellico watershed is shown in Figure 2. A schematic diagram of the river and reservoir system contained in the watershed is shown in Figure 3.

Tellico Dam, which is shown in Figure 3, was not completed until 1979 and did not impound any water during the March 1973 flood. Therefore, Tellico Dam affects only the May 2003 flood analysis.

**Figure 2: Hydrologic Map of the Fort Loudoun-Tellico Watershed (Subbasins 8, 16, 17, 18, and 24).**

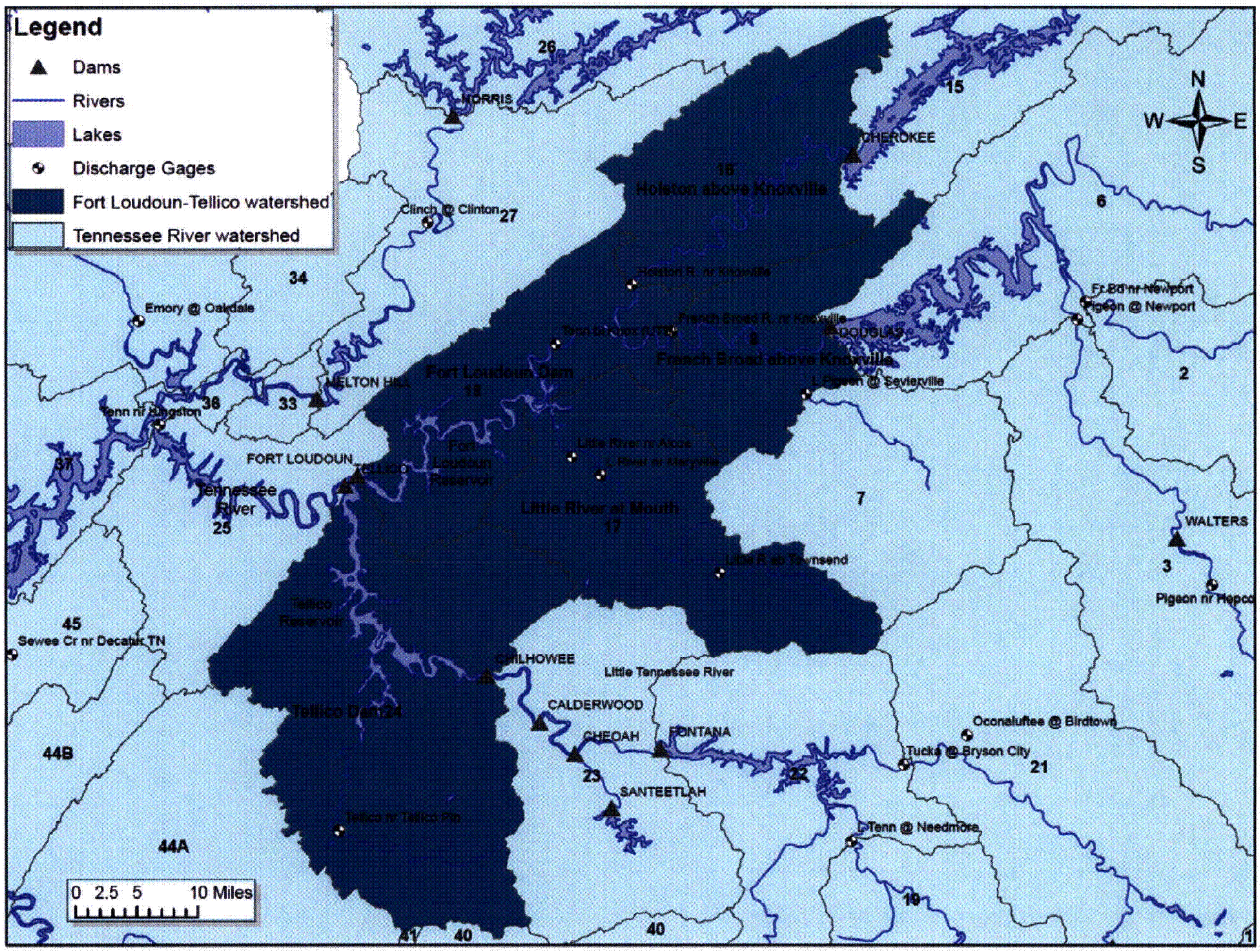
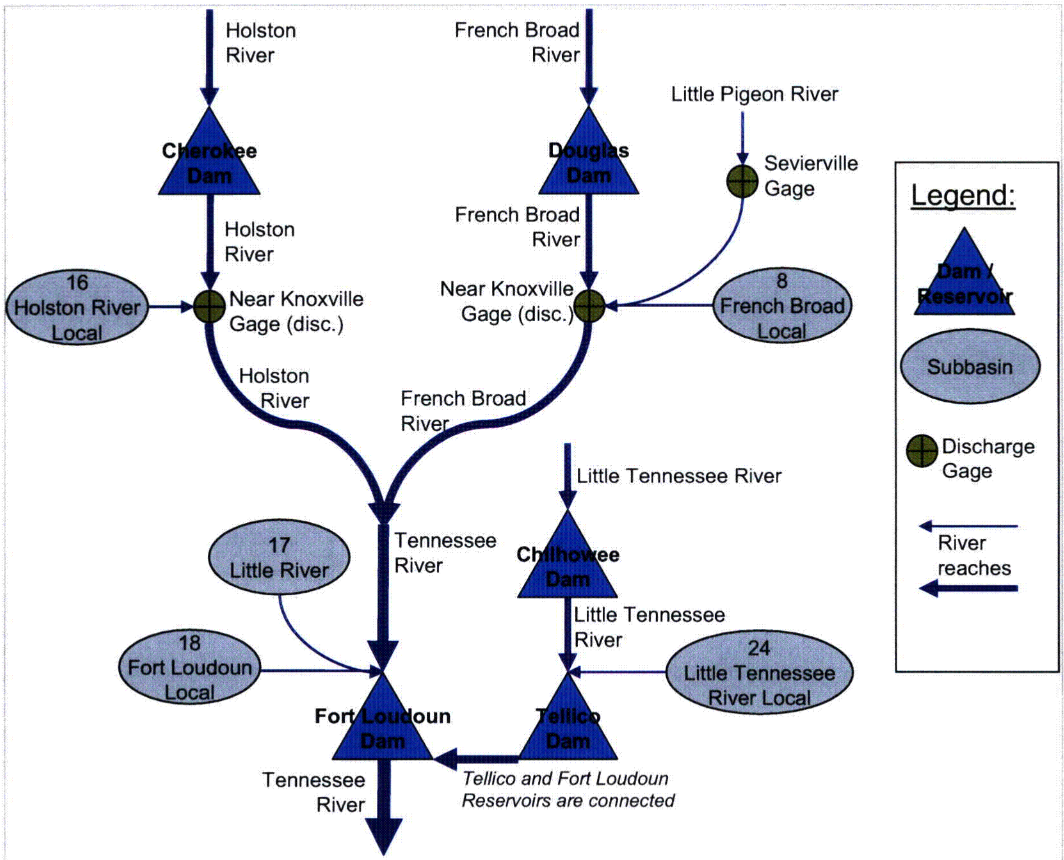


**Figure 3: Schematic of the Fort Loudoun-Tellico Watershed (Subbasins 8, 16, 17, 18, and 24).**




The flows of the French Broad, Holston, Tennessee, and Little Tennessee Rivers in Subbasins 8, 16, 18, and 24 are affected by multiple upstream dams. The drainage areas of these subbasins are shown in Table 1 (References 2 to 7), along with nominal reservoir surface areas (Reference 11).

**Table 1: Subbasin Drainage Areas and Reservoir Areas.**

| Sub-basin number | Subbasin Name | Original TVA Area (mi$^2$) | GIS Area (mi$^2$) | Difference (%) | Reservoir Area (mi$^2$) |
|---|---|---|---|---|---|
| 8 | French Broad Local | 207 | 206.5 | -0.26% | --- |
| 16 | Holston River Local, Cherokee Dam to Knoxville Gage | 289[1] | 289.6 | 0.21% | --- |
| 17 | Little River | 379 | 378.6 | -0.09% | --- |
| 18 | Fort Loudoun Local | 323 | 323.4 | 0.11% | 23.49 |
| 24 | Little Tennessee River Local, Chilhowee to Tellico Dam | 650 | 650.2 | 0.02% | 24.50 |
| Sum | Fort Loudoun-Tellico | 1,848 | 1,848.2 | 0.01% | 47.99 |

[1] Reference 4 indicates that of the total subbasin drainage area of 319 square miles, 30 square miles are non-contributing.

Table 1 shows that the GIS calculated areas agree closely with the TVA's original estimates. In this calculation, the GIS drainage areas were used.

## *6.2 Unit Hydrograph Ordinates*

**The unit hydrographs for Subbasins 8, 16, 17, 18, and 24 are plotted in Figure 4 to**

Figure 8. The time base and ordinates for the unit hydrographs are provided in Table 2 to Table 6, along with volume checks demonstrating that the total volumes of runoff are equivalent to one inch of excess rainfall over subbasins. The unit hydrograph discharges are specified in units of cubic feet per second (cfs). The unit hydrographs for these subbasins are also provided on the "UHs" worksheet in Attachment 1-1.

### 6.2.1 Subbasin 8 – French Broad Local

The six-hour unit hydrograph for Subbasin 8 was developed in 1977 by the TVA (Reference 3) based on the following two existing unit hydrographs:

(1) A six-hour unit hydrograph for the combined area of Subbasins 7 and 8, which corresponds to the French Broad River from Douglas Dam to Knoxville (558.6 $mi^2$), and

(2) A six-hour unit hydrograph for Subbasin 7, the Little Pigeon River at Sevierville (352.1 $mi^2$).

The Subbasin 8 unit hydrograph was obtained by subtracting the Subbasin 7 UH from the combined Subbasins 7 and 8 UH.

The unit hydrograph for Subbasin 7, the Little Pigeon River at Sevierville, was developed by the TVA in 1957 from the following historical floods (Reference 12):

- July 26, 1943
- May 13, 1945
- March 9, 1946
- April 9, 1946
- April 16, 1946

A four-hour unit hydrograph was obtained from the runoff hydrograph for each flood using the process of deconvolution, and a composite four-hour unit hydrograph was developed from the runoff hydrographs. The computation of the six-hour UH for Subbasin 7 from the four-hour UH has not been found. Application of the S-graph method (Reference 9) to the four-hour UH yielded a six-hour UH that is very similar, but not identical, to the six-hour UH for Subbasin 7 that was used by the TVA to obtain the UH for Subbasin 8.

The combined Subbasins 7 and 8 UH was developed by the TVA in 1977 from the following historical floods, using the UNITGRPH program (References 3 and 10):

- February 3, 1956
- April 16, 1956
- April 8, 1957
- March 12, 1963

The Subbasin 7 UH was subtracted from the combined Subbasins 7 and 8 UH to obtain the initial six-hour Subbasin 8 UH, which was smoothed to obtain the discharge ordinates shown in Figure 4 and Table 2. The unit hydrograph for Subbasin 8 was subsequently modified during SOCH model calibration to be applied as a distributed local unit hydrograph as opposed to the point local unit hydrograph presented in Figure 4 and Table 2. To be applied as a distributed local inflow, the peak of the unit hydrograph needed to be higher and sooner than the peak of the original point local unit hydrograph. Detailed methodology for this modification can be found in Appendix B of Reference 21. The distributed local unit hydrograph to be used in SOCH modeling is shown in Figure 4a and Table 2a.

**Figure 4: Six-Hour Unit Hydrograph for Subbasin 8, French Broad Local.**

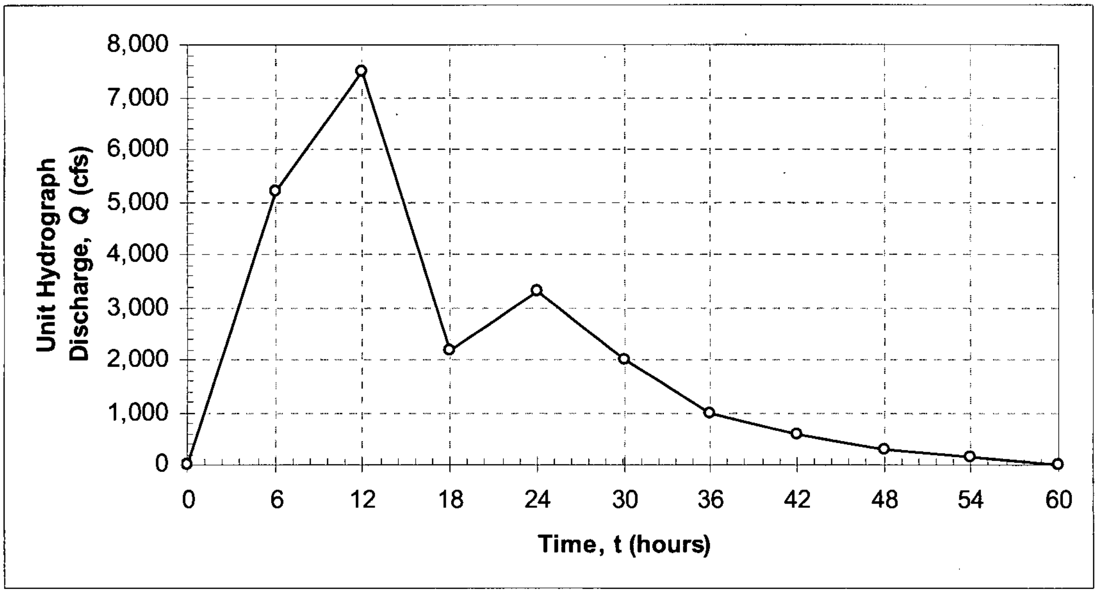



**Table 2: Six-Hour Unit Hydrograph for Subbasin 8, French Broad Local.**

| Ordinate no. | *t*, hours | *Q*, cfs |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 6 | 5,200 |
| 3 | 12 | 7,500 |
| 4 | 18 | 2,200 |
| 5 | 24 | 3,300 |
| 6 | 30 | 2,000 |
| 7 | 36 | 1,000 |
| 8 | 42 | 600 |
| 9 | 48 | 300 |
| 10 | 54 | 150 |
| 11 | 60 | 0 |
| Volume, acre-feet (1) | | 11,033 |
| Drainage Area (sq. miles) | | 206.5 |
| Runoff depth, inches (2) | | 1.0018 |

**Figure 4a: Six-hour Distributed Unit Hydrograph for Subbasin 8, French Broad Local**

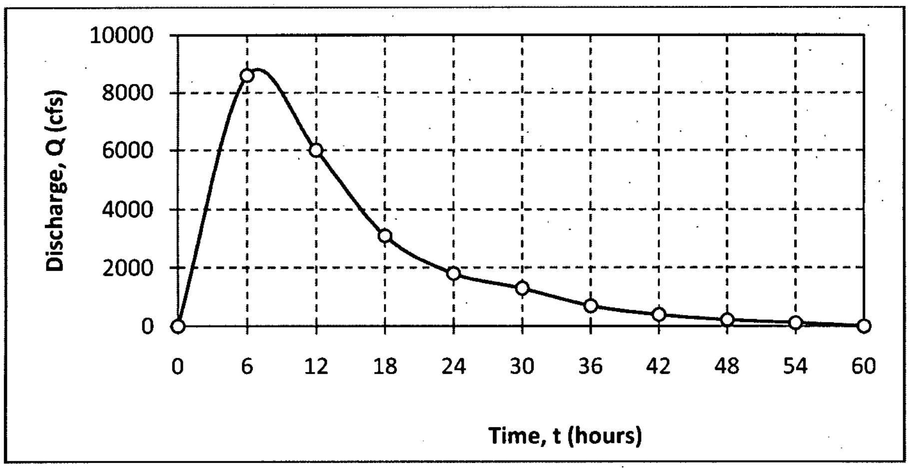



**Table 2a: Six-hour Distributed Unit Hydrograph for Subbasin 8, French Broad Local**

| Ordinate No. | t, hours | Q (cfs) |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 6 | 8,600 |
| 3 | 12 | 6,000 |
| 4 | 18 | 3,100 |
| 5 | 24 | 1,800 |
| 6 | 30 | 1,300 |
| 7 | 36 | 700 |
| 8 | 42 | 400 |
| 9 | 48 | 220 |
| 10 | 54 | 120 |
| 11 | 60 | 0 |
| Volume, ac-ft (1) | | 11027 |
| Drainage Area, sq miles | | 206.5 |
| Runoff Depth, inches (2) | | 1.0013 |

**Notes:**

1) $$Volume = \sum_{i=1}^{no.ordinates} Q_i \tfrac{ft^3}{\sec} \times 3600 \tfrac{\sec}{hr} \times \Delta t(hours) \times \frac{1acft}{43560 ft^3}$$

2) $$Depth = \frac{Volume.acft}{Area.mi^2} \frac{mi^2}{640.acre} \frac{12.inch}{ft}$$

### 6.2.2 Subbasin 16 – Holston River Local, Cherokee Dam to Knoxville Gage

The Subbasin 16 unit hydrograph was developed in 1977 by the TVA (Reference 4) based on historical floods that occurred in March 1963 and March 1973, using the UNITGRPH program (Reference 10). Single unit hydrographs were computed for each of these floods and a composite unit hydrograph was developed using both floods. Separately, a four-flood composite was also developed using these two floods, as well as floods that occurred in February 1956 and February 1961. The TVA determined that the four-flood composite UH was inadequate. The two-flood composite unit hydrograph based on the March 1963 and March 1973 floods was adopted (Reference 4). The TVA smoothed the six-hour unit hydrograph from UNITGRPH and interpolated to obtain the tri-hourly discharge ordinates shown in Figure 5 and Table 3. The unit hydrograph for subbasin 16 was subsequently modified during SOCH model calibration to be applied as a distributed local unit hydrograph as opposed to the point local unit hydrograph presented in Figure 5 and Table 3. To be applied as a distributed local inflow, the peak of the unit hydrograph needed to be higher and sooner than the peak of the original point local unit hydrograph. Detailed methodology for this modification can be found in Appendix B of Reference 21. The distributed local unit hydrograph to be used in SOCH modeling is shown in Figure 5a and Table 3a.

**Figure 5: Six-Hour Unit Hydrograph for Subbasin 16, Holston River Local, Cherokee Dam to Knoxville Gage.**

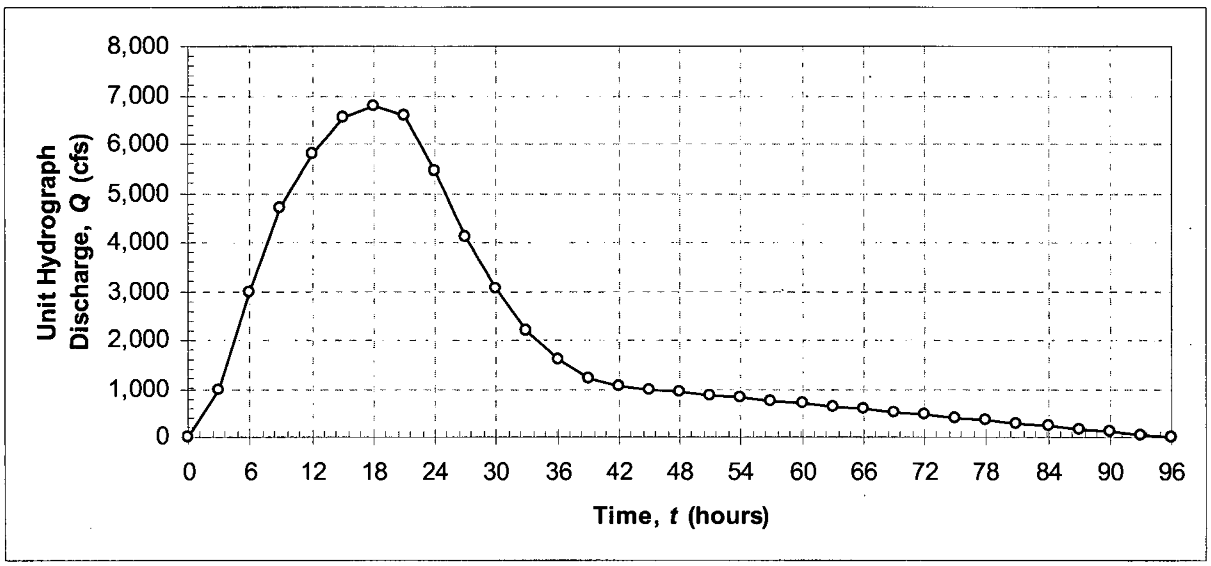


**Table 3: Six-Hour Unit Hydrograph for Subbasin 16, Holston River Local, Cherokee Dam to Knoxville Gage.**

| Ordinate no. | *t, hours* | *Q, cfs* |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 3 | 1000 |
| 3 | 6 | 3000 |
| 4 | 9 | 4700 |
| 5 | 12 | 5800 |
| 6 | 15 | 6550 |
| 7 | 18 | 6800 |
| 8 | 21 | 6600 |
| 9 | 24 | 5450 |
| 10 | 27 | 4100 |
| 11 | 30 | 3050 |
| 12 | 33 | 2200 |
| 13 | 36 | 1625 |
| 14 | 39 | 1225 |
| 15 | 42 | 1050 |
| 16 | 45 | 990 |
| 17 | 48 | 950 |
| 18 | 51 | 870 |

| Ordinate no. | *t, hours* | *Q, cfs* |
|---|---|---|
| 19 | 54 | 820 |
| 20 | 57 | 750 |
| 21 | 60 | 720 |
| 22 | 63 | 630 |
| 23 | 66 | 600 |
| 24 | 69 | 500 |
| 25 | 72 | 470 |
| 26 | 75 | 380 |
| 27 | 78 | 350 |
| 28 | 81 | 260 |
| 29 | 84 | 220 |
| 30 | 87 | 140 |
| 31 | 90 | 100 |
| 32 | 93 | 40 |
| 33 | 96 | 0 |
| Volume, acre-feet (1) | | 15,357 |
| Drainage Area (sq. miles) | | 289.6 |
| Runoff depth, inches (2) | | 0.9943 |

See notes 1 and 2 at the bottom of Table 2.

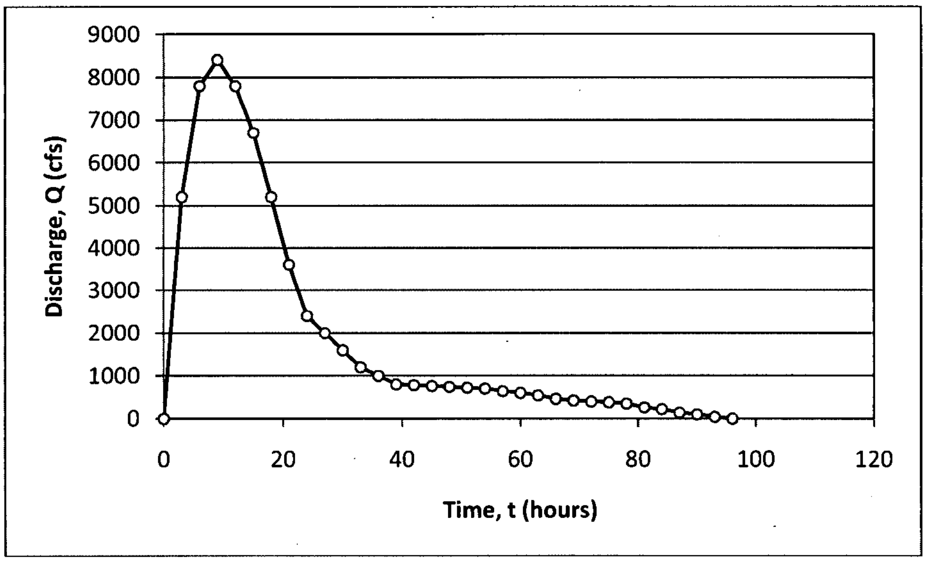



**Figure 5a: Six-hour Distributed Unit Hydrograph for Subbasin 16, Holston River Local**

**Table 3a: Six-hour Distributed Unit Hydrograph for Subbasin 16, Holston River Local**

| Ordinate No. | t, hours | Q, cfs |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 3 | 5,200 |
| 3 | 6 | 7,800 |
| 4 | 9 | 8,400 |
| 5 | 12 | 7,800 |
| 6 | 15 | 6,700 |
| 7 | 18 | 5,200 |
| 8 | 21 | 3,600 |
| 9 | 24 | 2,400 |
| 10 | 27 | 2,000 |
| 11 | 30 | 1,600 |
| 12 | 33 | 1,200 |
| 13 | 36 | 1,000 |
| 14 | 39 | 800 |
| 15 | 42 | 780 |
| 16 | 45 | 760 |
| 17 | 48 | 740 |
| 18 | 51 | 720 |

| Ordinate No. | t, hours | Q, cfs |
|---|---|---|
| 19 | 54 | 700 |
| 20 | 57 | 640 |
| 21 | 60 | 600 |
| 22 | 63 | 540 |
| 23 | 66 | 460 |
| 24 | 69 | 420 |
| 25 | 72 | 400 |
| 26 | 75 | 380 |
| 27 | 78 | 350 |
| 28 | 81 | 260 |
| 29 | 84 | 220 |
| 30 | 87 | 140 |
| 31 | 90 | 100 |
| 32 | 93 | 40 |
| 33 | 96 | 0 |
| Volume, ac-ft (1) | | 15360 |
| Drainage Area, sq miles | | 289.6 |
| Runoff Depth, inches (2) | | .9945 |

### 6.2.3 Subbasin 17 – Little River

The Subbasin 17 unit hydrograph was developed in 1977 by the TVA (Reference 5) as a two-flood composite from historical floods that occurred in March 1963 and March 1973, using the UNITGRPH program. The flood hydrographs for the local area used in the unit hydrograph development were determined using the SOCH model. The TVA smoothed the four-hour unit hydrograph from UNITGRPH and interpolated to obtain the bi-hourly discharge ordinates shown in Figure 6 and Table 4, which are used in this calculation.

**Figure 6: Four-Hour Unit Hydrograph for Subbasin 17, Little River.**

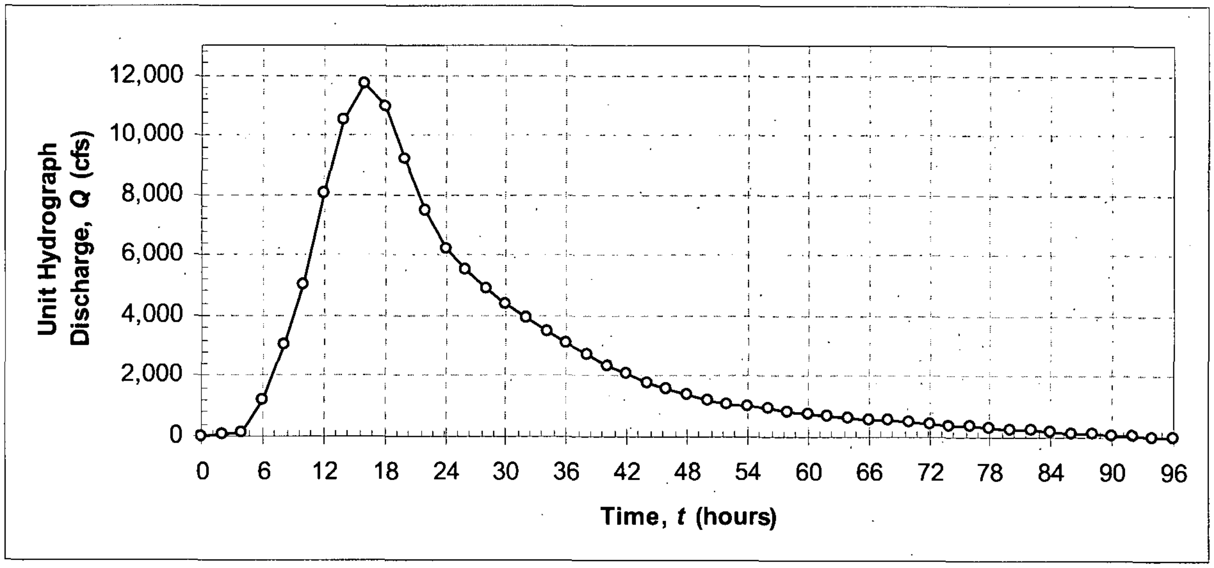



**Table 4: Four-Hour Unit Hydrograph for Subbasin 17, Little River.**

| Ordinate no. | t, hours | Q, cfs |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 2 | 50 |
| 3 | 4 | 102 |
| 4 | 6 | 1200 |
| 5 | 8 | 3021 |
| 6 | 10 | 5000 |
| 7 | 12 | 8025 |
| 8 | 14 | 10500 |
| 9 | 16 | 11726 |
| 10 | 18 | 11000 |
| 11 | 20 | 9213 |
| 12 | 22 | 7500 |
| 13 | 24 | 6245 |
| 14 | 26 | 5500 |
| 15 | 28 | 4876 |
| 16 | 30 | 4350 |
| 17 | 32 | 3950 |
| 18 | 34 | 3500 |
| 19 | 36 | 3100 |
| 20 | 38 | 2700 |
| 21 | 40 | 2350 |
| 22 | 42 | 2100 |
| 23 | 44 | 1800 |
| 24 | 46 | 1600 |
| 25 | 48 | 1400 |
| 26 | 50 | 1225 |

| Ordinate no. | t, hours | Q, cfs |
|---|---|---|
| 27 | 52 | 1100 |
| 28 | 54 | 1000 |
| 29 | 56 | 950 |
| 30 | 58 | 850 |
| 31 | 60 | 775 |
| 32 | 62 | 700 |
| 33 | 64 | 650 |
| 34 | 66 | 600 |
| 35 | 68 | 550 |
| 36 | 70 | 500 |
| 37 | 72 | 450 |
| 38 | 74 | 400 |
| 39 | 76 | 350 |
| 40 | 78 | 300 |
| 41 | 80 | 250 |
| 42 | 82 | 225 |
| 43 | 84 | 200 |
| 44 | 86 | 150 |
| 45 | 88 | 100 |
| 46 | 90 | 75 |
| 47 | 92 | 50 |
| 48 | 94 | 25 |
| 49 | 96 | 0 |
| Volume, acre-feet (1) | | 20,212 |
| Drainage Area (sq. miles) | | 378.6 |
| Runoff depth, inches (2) | | 1.0010 |

See notes 1 and 2 at the bottom of Table 2.

### 6.2.4 Subbasin 18 – Fort Loudoun Local

The Subbasin 18 unit hydrograph was developed in 1977 by the TVA (Reference 6) as a two-flood composite from historical floods that occurred in March 1963 and March 1973. The flood hydrographs for the local area used in the unit hydrograph development were determined using the SOCH model. Single unit hydrographs were computed for each of the two floods, and a composite unit hydrograph was developed from both floods, using the UNITGRPH program. The composite unit hydrograph reproduced both floods well (Reference 6). The TVA smoothed the six-hour unit hydrograph from UNITGRPH and interpolated to obtain the tri-hourly discharge ordinates shown in Figure 7 and Table 5, which are used in this calculation.

**Figure 7: Six-Hour Unit Hydrograph for Subbasin 18, Fort Loudoun Local.**

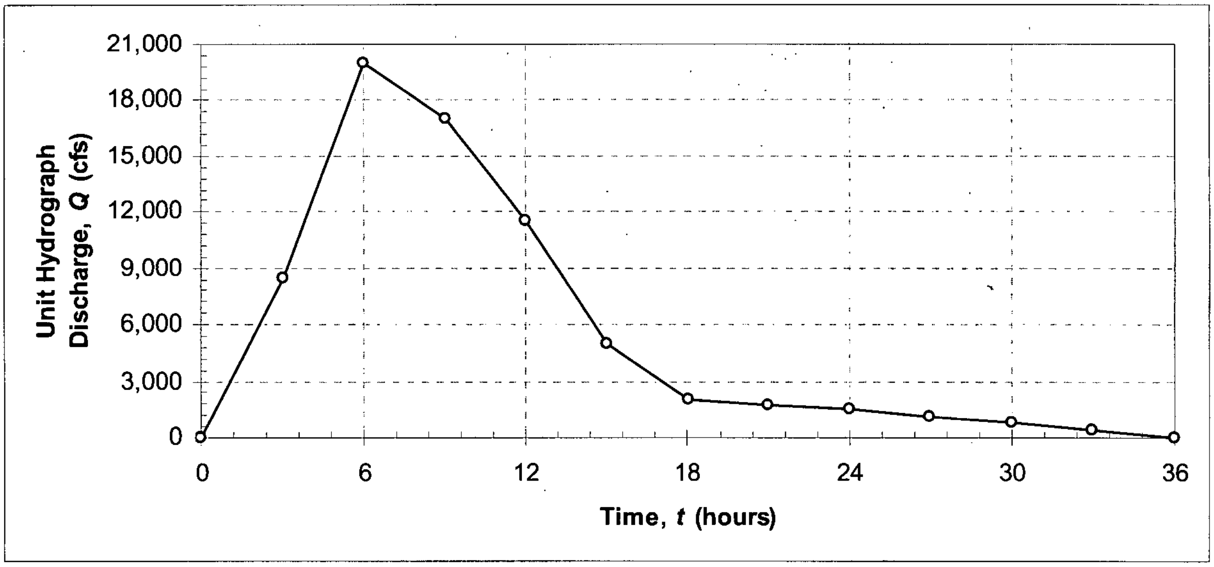


**Table 5: Six-Hour Unit Hydrograph for Subbasin 18, Fort Loudoun Local.**

| Ordinate no. | *t*, hours | *Q*, cfs |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 3 | 8500 |
| 3 | 6 | 20000 |
| 4 | 9 | 17000 |
| 5 | 12 | 11500 |
| 6 | 15 | 5000 |
| 7 | 18 | 2000 |
| 8 | 21 | 1700 |
| 9 | 24 | 1487 |
| 10 | 27 | 1100 |
| 11 | 30 | 861 |
| 12 | 33 | 400 |
| 13 | 36 | 0 |
| Volume, acre-feet (1) | | 17,243 |
| Drainage Area (sq. miles) | | 323.4 |
| Runoff depth, inches (2) | | 0.9997 |

See notes 1 and 2 at the bottom of Table 2.

### 6.2.5 Subbasin 24 – Little Tennessee River Local, Chilhowee to Tellico Dam

Two unit hydrographs are considered for Subbasin 24: One for the March 1973 flood, prior to the existence of Tellico Reservoir, and the other for the May 2003 flood, with Tellico Reservoir in place. The development of these unit hydrographs is discussed in the following subsections, and the unit hydrographs are shown below in Figure 8 and Table 6. The post-Tellico unit hydrograph for this subbasin is applicable only to the May 2003 flood; therefore this calculation provides only one initial flood inflow hydrograph that may be used to validate the Subbasin 24 unit hydrograph.

#### 6.2.5.1 Unit Hydrograph for Subbasin 24 Prior to Tellico Reservoir

The unit hydrograph for Subbasin 24 prior to the completion of Tellico Dam and Reservoir was developed in 1977 by the TVA using information from another unit hydrograph that had been developed earlier for the 872 square mile Little Tennessee River watershed from Fontana Dam to the stream flow gage at McGhee, located at River Mile 19.2 (Reference 7). The drainage area between Chilhowee Dam and the McGhee gage is 466 square miles (Reference 7). Therefore, approximately 72 percent of Subbasin 24 (i.e., 466/650) is contained within this 872 square mile watershed. The TVA calculated the Subbasin 24 unit hydrograph ordinates as follows:

- The peak discharge for Subbasin 24 ($Q_{peak}$) was obtained by multiplying by the ratio of the square roots of the drainage area, i.e., $Q_{peak} = 17{,}000 cfs \cong \frac{\sqrt{650}}{\sqrt{872}} \times 19{,}750 cfs$.
- The remaining Subbasin 24 unit hydrograph ordinates were obtained by multiplying by the ratios of the drainage areas (i.e., 650/872) and then smoothed to obtain one inch of volume over the subbasin.

The six-hour unit hydrograph for the Little Tennessee River from Fontana Dam to the McGhee gage was developed by the TVA in 1965 as a composite from floods that occurred in April 1964, February 1957, and January 1947, using the UNITGRPH program. The UNITGRPH program inputs for this composite were obtained from Reference 7 and rerun using the revised 2008 version of the UNITGRPH program to regenerate the existing TVA unit hydrograph. Attachments 2-9 and 2-10 provide the input and output files for this regeneration. The TVA's original unit hydrograph for Subbasin 24, shown in Figure 8 and Table 6, is used in this calculation to simulate the March 1973 flood.

6.2.5.2 <u>Unit Hydrograph for Subbasin 24 with Tellico Reservoir</u>

The original TVA unit hydrograph for Subbasin 24 was developed before completion of Tellico Dam and Reservoir in 1979. To address the effects of the reservoir on the unit hydrograph, the TVA developed a revised unit hydrograph for Subbasin 24 that reflects the presence of Tellico Reservoir (Reference 2).

The new, revised post-reservoir unit hydrograph was developed by adjusting the existing, pre-reservoir unit hydrograph as follows:

- Peak discharge timing was advanced by six-hours
- Peak discharge magnitude was increased by approximately 35% to 22,600 cfs
- The base time of the unit hydrograph was reduced by 39%, from 72 hours to 52 hours, which was rounded to 54-hours, the nearest six-hour time increment.

These adjustments were developed by the TVA based on other subbasin unit hydrographs that were affected by the construction of reservoirs (Reference 2). The revised, post-reservoir unit hydrograph for Subbasin 24, shown in

Figure 8 and Table 6, is used to simulate the May 2003 flood.

**Figure 8: Six-Hour Unit Hydrograph for Subbasin 24, Little Tennessee River Local, Chilhowee to Tellico Dam.**

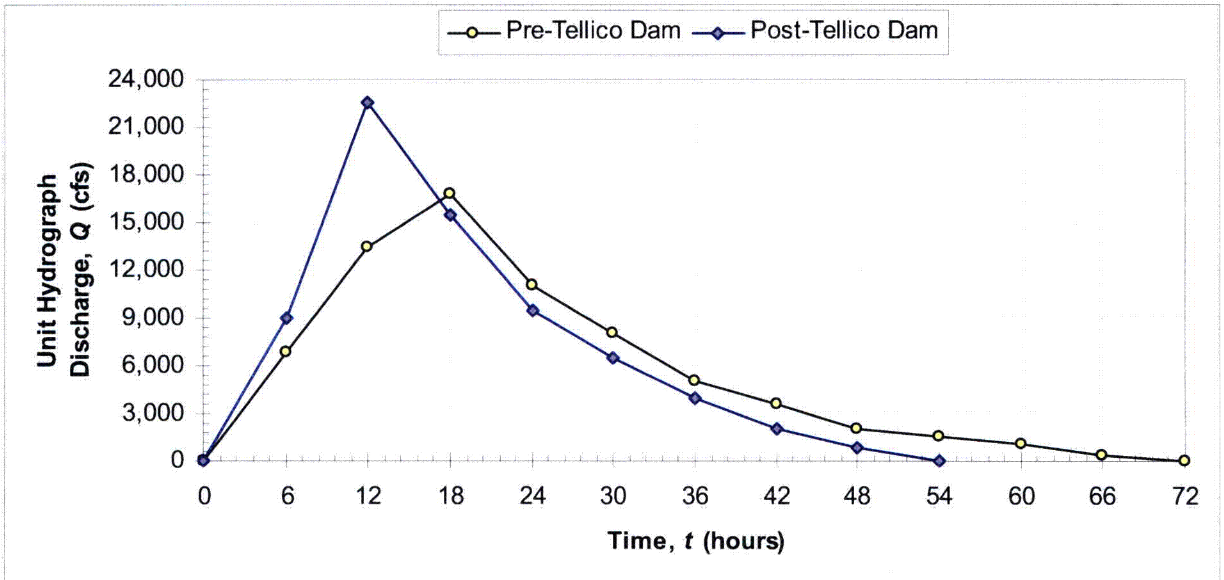



**Table 6: Six-Hour Unit Hydrograph for Subbasin 24, Little Tennessee River Local, Chilhowee to Tellico Dam.**

| Ordinate no. | *t*, hours | Pre-Tellico Dam *Q*, cfs | Post-Tellico Dam *Q*, cfs |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 2 | 6 | 6900 | 9000 |
| 3 | 12 | 13400 | 22600 |
| 4 | 18 | 16750 | 15500 |
| 5 | 24 | 11000 | 9500 |
| 6 | 30 | 8000 | 6500 |
| 7 | 36 | 5100 | 4000 |
| 8 | 42 | 3600 | 2000 |
| 9 | 48 | 2100 | 900 |
| 10 | 54 | 1550 | 0 |
| 11 | 60 | 1100 | |
| 12 | 66 | 400 | |
| 13 | 72 | 0 | |
| Volume, acre-feet (1) | | 34,661 | 34,711 |
| Drainage Area (sq. miles) | | 650.2 | 650.2 |
| Runoff depth, inches (2) | | 0.9995 | 1.0010 |

See notes 1 and 2 at the bottom of Table 2.

### 6.2.6 UNITGRPH Regeneration

The TVA's UNITGRPH program was used in the development of the unit hydrographs for Subbasins 8, 16, 17, 18, and 24 (Reference 10). This program was revised to correct a code error in 2008. Therefore, to regenerate these unit hydrographs, the original program inputs were obtained and rerun using the revised 2008 version of UNITGRPH. In these regeneration runs, the original TVA drainage areas shown in Table 1 were used[2]. The UNITGRPH regeneration runs are summarized in

**Table 7**, which lists the sources of original UNITGRPH program inputs and also lists the attached UNITGRPH regeneration input and output files. These runs successfully reproduced the unit hydrographs that had been computed using the original UNITGRPH program.

**Table 7: Summary of UNITGRPH Runs Performed to Regenerate Existing TVA Unit Hydrographs.**

| Sub-basin number | Subbasin Name | Source(s) of UNITGRPH Inputs | UNITGRPH Input & Output File Attachments |
|---|---|---|---|
| 8 | French Broad Local | Reference 3 | 2-1 & 2-2 |
| 16 | Holston River Local, Cherokee Dam to Knoxville Gage | Reference 4 | 2-3 & 2-4 |
| 17 | Little River | Reference 5 | 2-5 & 2-6 |
| 18 | Fort Loudoun Local | Reference 6 | 2-7 & 2-8 |
| 24 | Little Tennessee River Local, Chilhowee to Tellico Dam | Reference 7 | 2-9 & 2-10 |

The UNITGRPH computed unit hydrographs were manually smoothed by the TVA (References 3 to 7). The smoothed unit hydrographs, which are presented above in Figure 4 to Figure 8 and in Table 2 to Table 6, were used in this calculation to simulate the floods of March 1973 and May 2003.

### 6.2.7 SOCH Model Input

The following unit hydrographs are to be used as input to SOCH:

- Subbasin 8, French Broad Local: Distributed six-hour unit hydrograph found in table 2a.
- Subbasin 16, Holston River Local: Distributed six-hour unit hydrograph found in table 3a.
- Subbasin 17, Little River: Four-hour unit hydrograph found in table 4.
- Subbasin 18, Fort Loudoun Local: Six-hour unit hydrograph found in table 5.
- Subbasin 24, Little Tennessee River Local: Six-hour unit hydrograph found in table 6.

---

[2] Exception: The UNITGRPH regeneration for Subbasin 24 was performed using the TVA's original 872 square mile area for the Little Tennessee River watershed between Fontana Dam and the McGhee stream flow gage (Section 6.2.5.1). This unit hydrograph was used by the TVA in the development of the pre-reservoir unit hydrograph for Subbasin 24 (Reference 7).

### *6.3 Observed Discharge and Storage*

The observed daily outflows from Cherokee and Douglas Dams were obtained from the TVA databases (Attachments 1-2 and 1-3; Reference 13). Daily outflows from Chilhowee Dam were obtained from the U.S. Geological Survey (USGS) gage 03518300 Little Tennessee River below Chilhowee Dam (Attachment 1-4; Reference 14) for the March 1973 flood, and from the TVA's hourly reservoir database for the May 2003 flood (Attachment 1-5; Reference 14). The observed daily storage and discharge records at Fort Loudoun and Tellico Dams were obtained from the TVA databases (Attachments 1-6 and 1-7; Reference 13).

The daily stream flow records for the Little Pigeon River at Sevierville, the Holston River near Knoxville, the French Broad River near Knoxville, the Little River near Maryville, and the Little River near Alcoa were obtained from the USGS (Attachments 1-8 to 1-12; Reference 14). For the May 2003 flood, the flows of the Little Pigeon River were obtained from the TVA bihourly flows database (Attachment 1-13; Reference 14).

These observed flows were used in the water budget analysis, which is presented in Section 7.3.

### *6.4 Observed Rainfall*

Two sources of observed rainfall data were used in this calculation: TVA rain gage data with Thiessen weights were used to simulate the March 1973 flood, and gridded precipitation data from the U.S. National Weather Service (NWS) were used to simulate the May 2003 flood. The TVA rainfall data are presented in Reference 11. The NWS gridded precipitation data are discussed in this section.

Radar-based, geospatially referenced precipitation data is extremely useful for hydrologic analysis because of its comprehensive spatial and temporal detail. Gridded daily precipitation data are available

Radar-based, geospatially referenced precipitation data is extremely useful for hydrologic analysis because of its comprehensive spatial and temporal detail. Gridded daily precipitation data are available at http://water.weather.gov/ from 2005 to present. Hourly precipitation data are not generally available without special arrangements with the National Weather Service (NWS).

NWS NEXRAD Stage III hourly precipitation data were obtained from the Lower Mississippi River Forecast Center (LMRFC) from January 1997 to April 2008. A Microsoft.Net utility was developed to generate radar-based Mean Areal Precipitation (MAPX) time series for each of the subbasins (Reference 15). The utility reads the raw hourly precipitation depth data for each 4-km square grid cell, performs necessary coordinate system and projection calculations, and then calculates the average precipitation depth within each subbasin, grouping output into a matrix of MAPX elements arrayed by subbasin and time (Greenwich Mean Time, GMT). Each column of this matrix is equivalent to an annual hyetograph for each subbasin in the TVA model. The results are stored in an Excel spreadsheet for each year of record. Reference 15 describes the methodology used to process the precipitation data and includes resulting subbasin-averaged hourly values for the January 1997 to April 2008 period of record. The precipitation data needed to simulate the May 2003 flood were obtained from this database.

# 7 Computations and Analyses

## 7.1 Floods for Unit Hydrograph Validation

As mentioned above, the TVA selected the March 1973 and May 2003 floods as being the largest to occur in the Tennessee River upstream of Guntersville Dam in recent decades. In the Fort Loudoun-Tellico watershed, the storms generating these floods spanned the following times:

- March 15, 1973, 06:00 hrs to March 17, 1973, 07:00 hrs, the "March 1973" storm
- May 5, 2003, 03:00 hrs to May 7, 2003, 17:00 hrs, the "May 2003" storm

## 7.2 Observed Rainfall

Observed rainfall for the March 1973 and May 2003 storms were obtained from References 11 and 15. The hourly precipitation series developed from NWS gridded data for the May 2003 storm is provided in Attachment 1-14, along with adjustments for Central time and unit conversion. The March 1973 rainfall data are shown in the "1973 Rainfall" and "1973 Reservoir" worksheets in Attachment 1-1.

## 7.3 Water Budget Analyses

Daily water budget analyses were performed to determine the daily runoff in Subbasins 8, 16, 18, and 24 for the March 1973 and May 2003 floods; Subbasin 17 was analyzed using a different approach, as discussed in Section 7.3.2. Baseflows were subtracted from the flows to obtain direct runoff hydrographs for these floods. Finally, reservoir runoff series were also developed to account for the additional runoff from Fort Loudoun and Tellico Reservoirs due to rain falling on their reservoirs' water surfaces. These operations are discussed in the following subsections; the water budget computations are included in Attachment 1-15.

### 7.3.1 Flood Volumes

The water budget analysis consists of solving the mass balance for a particular water budget area (e.g., one or more subbasins), which can be stated as (Reference 9):

$$L = O + \frac{\Delta S}{\Delta t} - I, \quad (1)$$

where $L$ is the local flow originating in the water budget area, $O$ is the outflow from the area, and $I$ is the inflow from upstream subbasins, all averaged over the time interval $\Delta t$, which in the case of this calculation is one day. $\Delta S/\Delta t$ is the change in reservoir storage over $\Delta t$.

This daily water budget method occasionally results in computed local flows that are negative. These negative values may occur because the daily water budget calculations do not take into account routing times, channel storage, bank storage, or possible inaccuracies in the storage and discharge measurements, any of which may result in errors (positive or negative) in the computed daily local flows. It is assumed that any errors are unbiased and, over the long term, self-canceling. Correcting only the negative errors, by setting them to zero, but not the positives, would bias the mean upwards and result in overestimated flow volumes. Therefore, since the local flows are used to estimate flood flow volumes, any computed negative values are not set to zero in this calculation.

The resulting daily water budgets for the March 1973 and May 2003 floods are presented in the following subsections. The water budget analyses are also included in Attachment 1-15.

#### 7.3.1.1 Subbasin 8, March 1973 Flood

The daily local flow from Subbasin 8 for the March 1973 flood was determined by the water budget method using observed inflows and outflows at subbasin boundaries. Because this subbasin does not include a reservoir, the local flow was computed as the outflow minus the sum of the inflows. The water budget analysis and resulting daily local flows are shown in Table 8.

**Table 8: Daily Water Budget for the March 1973 Flood in Subbasin 8, French Broad Local.**

| Date | French Broad River at Douglas Dam *I* cfs | Little Pigeon River at Sevierville *I* cfs | French Broad River near Knoxville *O* cfs | Local Flow *L* cfs |
|---|---|---|---|---|
| 13-Mar-1973 | 5,866 | 544 | 6,090 | -320 |
| 14-Mar-1973 | 6,099 | 466 | 7,020 | 455 |
| 15-Mar-1973 | 6,343 | 960 | 8,160 | 857 |
| 16-Mar-1973 | 4,858 | 24,300 | 34,600 | 5,442 |
| 17-Mar-1973 | 3,157 | 15,100 | 33,000 | 14,743 |
| 18-Mar-1973 | 9,514 | 3,610 | 10,500 | -2,624 |
| 19-Mar-1973 | 17,804 | 2,020 | 20,100 | 276 |
| 20-Mar-1973 | 17,876 | 1,570 | 19,700 | 254 |

7.3.1.2 Subbasin 16, March 1973 Flood

The daily local flow from Subbasin 16 for the March 1973 flood was determined by the water budget method using observed inflows and outflows at subbasin boundaries in a similar manner to Subbasin 8. The water budget analysis and resulting daily local flows are shown in Table 9.

**Table 9: Daily Water Budget for the March 1973 Flood in Subbasin 16, Holston River Local, Cherokee Dam to Knoxville Gage.**

| Date | Holston River at Cherokee Dam *I* cfs | Holston River near Knoxville *O* cfs | Local Flow *L* cfs |
|---|---|---|---|
| 14-Mar-1973 | 0 | 580 | 580 |
| 15-Mar-1973 | 0 | 2,000 | 2,000 |
| 16-Mar-1973 | 0 | 15,800 | 15,800 |
| 17-Mar-1973 | 0 | 12,500 | 12,500 |
| 18-Mar-1973 | 0 | 3,980 | 3,980 |
| 19-Mar-1973 | 4,328 | 4,600 | 272 |
| 20-Mar-1973 | 3,484 | 5,360 | 1,876 |

7.3.1.3 Subbasin 18, March 1973 Flood

The daily local flow from Subbasin 18 for the March 1973 flood was determined by the water budget method using observed inflows and outflows at subbasin boundaries and the daily storage in Fort Loudoun Reservoir. The water budget analysis and resulting daily local flows are shown in Table 10.

**Table 10: Daily Water Budget for the March 1973 Flood in Subbasin 18, Fort Loudoun Local.**

| | | | | Fort Loudoun Dam | | | |
|---|---|---|---|---|---|---|---|
| Date | Holston River near Knoxville<br>*I*<br>cfs | French Broad R. near Knoxville<br>*I*<br>Cfs | Little River at Mouth<br>*I*<br>cfs | End-of-day Storage<br>*S*<br>1,000 dsf[3] | Change in Storage<br>*ΔS*<br>cfs | Discharge<br>*O*<br>cfs | Local Flow<br>*L*<br>cfs |
| 3/14/1973 | 580 | 7,020 | 698 | 146.28 | -1.48 | 10,400 | 622 |
| 3/15/1973 | 2,000 | 8,160 | 1,217 | 152.37 | 6.09 | 10,900 | 5,613 |
| 3/16/1973 | 15,800 | 34,600 | 21,710 | 191.01 | 38.64 | 50,300 | 16,830 |
| 3/17/1973 | 12,500 | 33,000 | 15,990 | 184.95 | -6.06 | 75,300 | 7,750 |
| 3/18/1973 | 3,980 | 10,500 | 4,212 | 174.02 | -10.93 | 32,500 | 2,878 |
| 3/19/1973 | 4,600 | 20,100 | 2,418 | 172.17 | -1.85 | 31,200 | 2,232 |
| 3/20/1973 | 5,360 | 19,700 | 1,950 | 170.45 | -1.72 | 31,400 | 2,670 |
| 3/21/1973 | 4,780 | 20,400 | 2,600 | 165.30 | -5.15 | 35,800 | 2,870 |

7.3.1.4 Subbasin 24, March 1973 Flood

The daily local flow from Subbasin 24 for the March 1973 flood was determined by the water budget method using observed inflows and outflows at subbasin boundaries. At the time of this flood, Tellico Dam construction had begun, but the reservoir was not yet completed. The flows of the Little Tennessee River were diverted past the construction site and discharged into Watts Bar Reservoir. These discharges are reported as Tellico Dam outflows in the TVA's daily reservoir database (Reference 13). Therefore, the local flow for this subbasin was computed as the outflow minus the inflow from Chilhowee Dam. The water budget and resulting daily local flows are shown in Table 11.

**Table 11: Daily Water Budget for the March 1973 Flood in Subbasin 24, Little Tennessee River Local, Chilhowee to Tellico Dam.**

| Date | Little Tennessee River below Chilhowee Dam<br>*I*<br>cfs | Tellico Dam outflow<br>*O*<br>cfs | Local Flow<br>*L*<br>cfs |
|---|---|---|---|
| 3/14/1973 | 5,010 | 6,199 | 1,189 |
| 3/15/1973 | 4,490 | 8,964 | 4,474 |
| 3/16/1973 | 21,600 | 57,783 | 36,183 |
| 3/17/1973 | 13,600 | 33,254 | 19,654 |
| 3/18/1973 | 6,200 | 11,294 | 5,094 |
| 3/19/1973 | 7,390 | 10,510 | 3,120 |
| 3/20/1973 | 7,850 | 10,665 | 2,815 |
| 3/21/1973 | 11,400 | 15,562 | 4,162 |

[3] A dsf is defined as the volume of water resulting from a flow of 1 cfs for one day (86,400 seconds). This is equal to 86,400 cubic feet of water, or about 1.9835 acre-feet.

7.3.1.5 Subbasins 8, 16, 18, and 24, May 2003 Flood

The daily local flow from Subbasins 8, 16, 18, and 24 for the May 2003 flood was determined by the water budget method using observed inflows and outflows at water budget area boundaries and the daily storage in Fort Loudoun and Tellico Reservoirs. Because the streamflow gages on the Holston and French Broad Rivers near Knoxville were no longer in operation during the May 2003 flood, it was necessary to include Subbasins 8 and 16 in the water budget area for Fort Loudoun Reservoir. Also, because Tellico Reservoir is connected to Fort Loudoun Reservoir with a canal, it is necessary to also include Subbasin 24 in this water budget area. Therefore, the inflows to the water budget area consist of the discharges from Cherokee, Douglas, and Chilhowee Dams and the discharges of the Little Pigeon River at Sevierville and of the Little River at the Mouth. Outflows from the water budget area are the discharges from Fort Loudoun and Tellico Dams. The water budget analysis and resulting daily local flows are shown in Table 12.

**Table 12: Daily Water Budget for the May 2003 Flood in Subbasins 8, 16, 18, and 24.**

| Date | Cherokee Dam outflow *I*, cfs | Douglas Dam outflow *I*, cfs | Little Pigeon River at Sevierville *I*, cfs | Little River at Mouth *I*, cfs | Chilhowee Dam outflow *I*, cfs | Fort Loudoun Dam storage *S*, dsf[4] | Tellico Dam storage *S*, dsf | Fort Loudoun & Tellico combined change in storage *ΔS*, dsf | Fort Loudoun Dam outflow *O*, cfs | Tellico Dam outflow *O*, cfs | Local Flow *L*, cfs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/2/2003 | 349 | 5,542 | 488 | 499 | 2,035 | 182,114 | 198,102 | | 13,687 | 0 | |
| 5/3/2003 | 353 | 1,488 | 480 | 526 | 1,341 | 179,447 | 196,455 | 2.67 | 12,157 | 0 | 3,655 |
| 5/4/2003 | 346 | 1,487 | 396 | 452 | 1,277 | 177,948 | 194,113 | -4.31 | 9,735 | 0 | 1,936 |
| 5/5/2003 | 3,535 | 7,477 | 1,796 | 829 | 4,079 | 183,798 | 201,573 | -3.84 | 14,175 | 0 | 9,769 |
| 5/6/2003 | 2,193 | 652 | 22,767 | 11,520 | 25,305 | 205,787 | 221,457 | 13.31 | 59,296 | 19,265 | 57,997 |
| 5/7/2003 | 378 | 16,304 | 10,372 | 11,640 | 23,001 | 204,342 | 220,935 | 41.87 | 59,991 | 39,030 | 35,359 |
| 5/8/2003 | 348 | 26,703 | 4,993 | 5,304 | 30,725 | 202,894 | 219,032 | -1.97 | 62,736 | 19,177 | 10,488 |
| 5/9/2003 | 3,247 | 31,128 | 2,676 | 2,760 | 25,256 | 195,037 | 209,950 | -3.35 | 66,578 | 19,005 | 3,577 |
| 5/10/2003 | 357 | 31,103 | 1,885 | 1,776 | 14,785 | 189,819 | 204,922 | -16.94 | 60,084 | 8,584 | 8,516 |
| 5/11/2003 | 352 | 31,074 | 1,670 | 1,500 | 12,966 | 189,308 | 204,361 | -10.25 | 54,668 | 0 | 6,034 |
| 5/12/2003 | 6,874 | 31,259 | 1,308 | 1,248 | 12,795 | 184,184 | 199,203 | -1.07 | 60,655 | 0 | -3,112 |
| 5/13/2003 | 6,593 | 26,566 | 1,043 | 1,042 | 13,292 | 180,014 | 195,438 | -10.28 | 60,933 | 0 | 4,463 |
| 5/14/2003 | 6,896 | 21,315 | 893 | 926 | 11,392 | 178,444 | 192,713 | -7.94 | 48,215 | 0 | 2,498 |
| 5/15/2003 | 6,299 | 21,527 | 932 | 871 | 8,316 | 177,629 | 192,325 | -4.30 | 44,659 | 0 | 5,511 |

[4] A dsf is defined as the volume of water resulting from a flow of 1 cfs for one day (86,400 seconds). This is equal to 86,400 cubic feet of water, or about 1.9835 acre-feet.

### 7.3.2 Estimated "Observed" Discharges of Subbasin 17

7.3.2.1 Methodology

Streamflow gages have recorded the observed flows of the Little River at locations within Subbasin 17, but not at the basin outlet. Table 13 lists three gages for which observed discharge data are available for one or both of the March 1973 and May 2003 floods; the locations of these gages are shown in Figure 2.

**Table 13: Streamflow Gages in Subbasin 17 Containing Data for the March 1973 and/or May 2003 Floods.**

| Station ID | Station Name | Period of Record | Drainage Area (sq. miles) |
|---|---|---|---|
| 03497300 | Little River above Townsend | 1963-2008 | 106 |
| 03498500 | Little River near Maryville | 1951-present | 269 |
| 03498850 | Little River near Alcoa | 1986-present | 300 |
| | | Subbasin 17 – Little River at Mouth | 378.6 |

Observed streamflow at the basin outlet location is needed for comparison with that estimated with the unit hydrograph for Subbasin 17. Discharge at the subbasin outlet was estimated using a method for calculating peak discharges for 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals at ungaged sites in rural Tennessee (Reference 17). The Little River gages above Townsend and near Maryville were among those used in developing the methods provided by this reference.

Reference 17 provides a methodology for estimating peak discharges of various recurrence intervals at an ungaged site from a relatively near gage site (on the same stream) when the ungaged site drainage area is within 50 percent of the drainage area of the gaged site. This methodology includes a means to estimate the discharge magnitude, transferred downstream to the ungaged site, from the known discharge at the gaged site as shown in Equation (2):

$$Q_w^{'} = \left( \frac{A_u}{A_g} \right)^b Q_w \quad (2)$$

where $Q'_w$ is the discharge for the ungaged site; $A_u$ is the watershed area of the ungaged site; $A_g$ is the watershed area of the gaged site; $b$ is the regression coefficient; and, $Q_w$ is the discharge for the gaged site. In Reference 17, the $Q'_w$ value for the selected recurrence interval is then further adjusted based on the regression analysis underlying the method.

For this calculation, the gage measurements need to be transferred downstream to the subbasin outlet, for which $A_u$ is 378.6 sq. miles. A scaling factor was used to estimate discharges at the Subbasin 17 outlet from measured discharge values at the upstream gages. The selected scaling factor comes from the area ratio raised to the regression coefficient, as shown in Equation (2). Table 14 provides the calculated scaling factor for each recurrence interval and for each gage. When the calculated scaling factors are rounded to two significant digits, scaling factors of 1.3 and 1.2 are obtained for the Little

River gages near Maryville and near Alcoa. This method was not applied to the gage above Townsend because the differences in drainage areas exceed the 50 percent criterion for this method.

**Table 14: Computation of Scaling Factors for the Little River Gages Using Equation (2).**

| Little River Gage | | near Maryville | near Alcoa |
|---|---|---|---|
| Drainage Area (sq. miles) | | 269 | 300 |
| Area Ratio ($A_u/A_g$) | | 1.408 | 1.262 |
| Recurrence Interval (years) | Regression Coefficient *b* | Scaling Factor $(A_u/A_g)^b$ | |
| 2 | 0.753 | 1.294 | 1.192 |
| 5 | 0.736 | 1.286 | 1.187 |
| 10 | 0.727 | 1.282 | 1.184 |
| 25 | 0.717 | 1.278 | 1.182 |
| 50 | 0.711 | 1.275 | 1.180 |
| 100 | 0.703 | 1.272 | 1.178 |
| 500 | 0.694 | 1.268 | 1.175 |
| Rounded to 2 significant figures | | **1.3** | **1.2** |

To estimate Little River discharge at the subbasin outlet, the measured discharge values at the gages near Maryville and near Alcoa were multiplied by the scaling factors of 1.3 and 1.2, respectively. These adjustments simply increase discharge by weighted ratios of the watershed area of the ungaged outlet to the watershed areas of the gage locations. This method does not account for possible changes in channel storage from the additional reach of the Little River or changes in unit hydrograph timing and shape as a result of the increased drainage area.

### 7.3.2.2 March 1973 Flood Flows in Subbasin 17

Using this method, the daily flows of the Little River at the Mouth were estimated for the March 1973 flood; the results are shown in Table 15. The gage near Maryville was used because the gage near Alcoa did not exist at the time of this flood.

**Table 15: Estimated Daily Flows of the Little River at Mouth for the March 1973 Flood.**

| Date | Little River near Maryville cfs | Scaling Factor | Little River at Mouth cfs |
|---|---|---|---|
| 14-Mar-1973 | 537 | 1.3 | 698 |
| 15-Mar-1973 | 936 | 1.3 | 1,217 |
| 16-Mar-1973 | 16,700 | 1.3 | 21,710 |
| 17-Mar-1973 | 12,300 | 1.3 | 15,990 |
| 18-Mar-1973 | 3,240 | 1.3 | 4,212 |
| 19-Mar-1973 | 1,860 | 1.3 | 2,418 |
| 20-Mar-1973 | 1,500 | 1.3 | 1,950 |

7.3.2.3 May 2003 Flood Flows in Subbasin 17

The gage flows available for the May 2003 flood are shown in Table 16.

**Table 16: Daily Flows of the Little River for the May 2003 Flood.**

| Date | Above Townsend cfs | Near Maryville cfs | Near Alcoa cfs |
|---|---|---|---|
| 5/4/2003 | 188 | 324 | 377 |
| 5/5/2003 | 342 | 691 | 691 |
| 5/6/2003 | 6,920 | *19,000* | *9,600* |
| 5/7/2003 | 3,190 | *12,000* | *9,700* |
| 5/8/2003 | 1,670 | 4,050 | 4,420 |
| 5/9/2003 | 996 | 2,190 | 2,300 |
| 5/10/2003 | 711 | 1,420 | 1,480 |
| 5/11/2003 | 638 | 1,190 | 1,250 |
| 5/12/2003 | 495 | 929 | 1,040 |
| 5/13/2003 | 416 | 787 | 868 |
| 5/14/2003 | 365 | 705 | 772 |

*Italicized discharges are estimated values (Reference 16).*

It may be seen from Table 16 that the flows on May 6-7 are estimated for the gages near Maryville and Alcoa, and that the estimated flows at these gages are very different. The observed flow volumes for May 5 to 11, 2003, the period during which most of the flow occurred, are summarized in Table 17.

**Table 17: Observed Little River Discharge Volumes and Runoff Depths for May 5-11, 2003.**

| | Total / Cumulative Values | | | Incremental Values | | |
|---|---|---|---|---|---|---|
| Little River Gage | Drainage Area (sq. mi.) | Discharge (ac-ft) | Total Runoff Depth (inches) | Drainage Area (sq. mi.) | Discharge (ac-ft) | Total Runoff Depth (inches) |
| Above Townsend | 106 | 28,695 | 5.076 | 106 | 28,695 | 5.076 |
| Near Maryville | 269 | 80,412 | 5.605 | 163* | 51,717 | 5.949 |
| Near Alcoa | 300 | 58,395 | 3.650 | 194* | 29,700 | 2.871 |

* Drainage area downstream of the gage above Townsend.

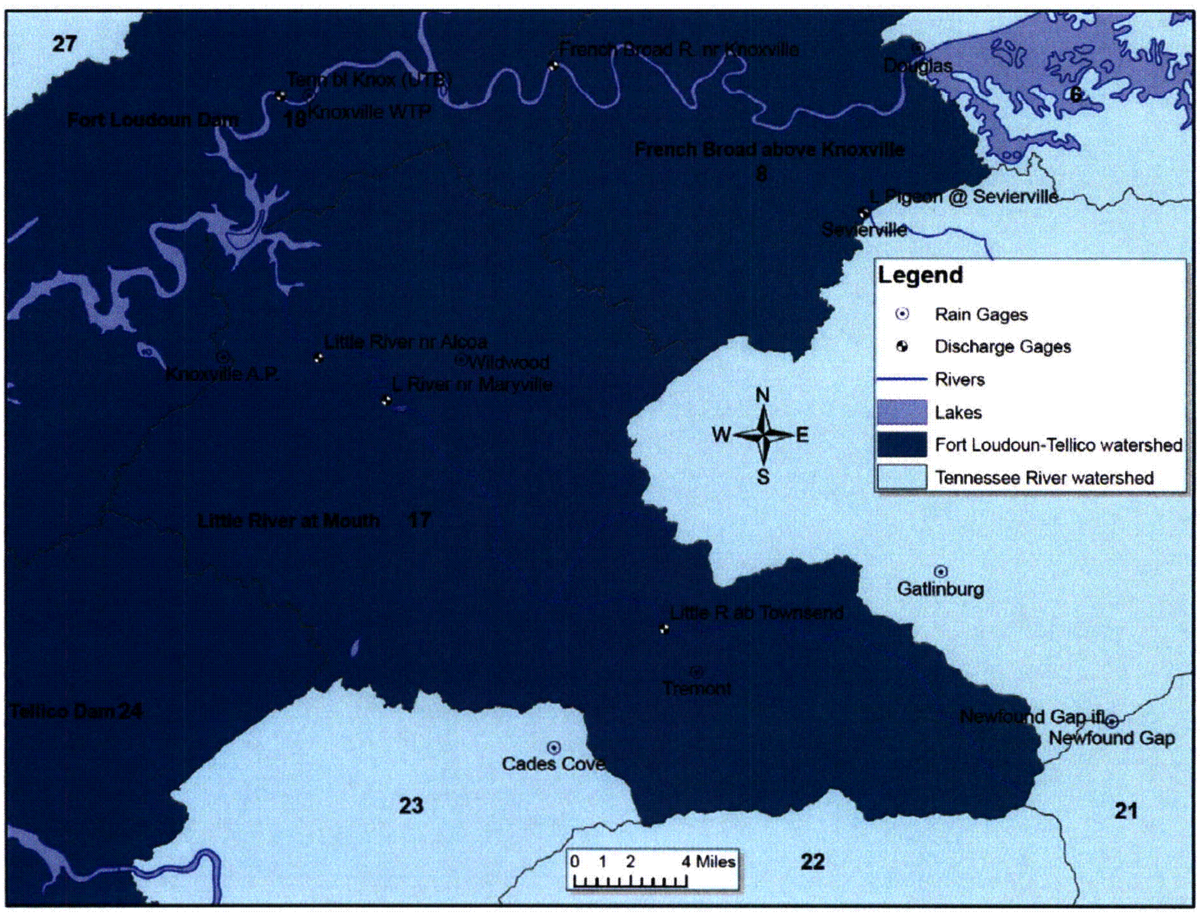
Table 17 shows that the observed incremental runoff depths for the drainage areas between the gage near Townsend and the gages near Maryville and Alcoa are very different (5.949 versus 2.871 inches), even though these areas are similar and largely overlapping.

The rainfall data for the storm causing the May 2003 flood in Subbasin 17 was examined to see if it might help in deciding how the disparate streamflow records for this flood should be used. The NWS gridded rainfall for May 5 to 11, 2003 totals 6.60 inches in Subbasin 17. The depths recorded in the TVA's six-hour rainfall database at rain gages in or near Subbasin 17 are shown in Table 18; the locations of these rain gages are shown in Figure 9. The Thiessen-weighted average storm depth for May 5 to 11 is 6.07 inches.

**Table 18: Rainfall Depths at TVA Rain Gages for May 5-11, 2003.**

| TVA Station ID | Station Name | Theissen weight | Rainfall (inches) |
|---|---|---|---|
| 0177 | Cades Cove | 13.6% | 6.84 |
| 0207 | Knoxville WTP | 2.8% | 4.61 |
| 0209 | Gatlinburg | 6.2% | 6.81 |
| 0409 | Knoxville A.P. | 19.0% | 5.74 |
| 0642 | Sevierville | 0.0% | 4.89 |
| 0715 | Tremont | 21.8% | 6.50 |
| 0716 | Wildwood | 32.4% | 5.34 |
| 0819 | Newfound Gap | 0.6% | 8.06 |
| 1543 | Newfound Gap iflows | 3.6% | 8.49 |
| Subbasin 17, Little River at Mouth | | 100.0% | 6.07 |

**Figure 9: Locations of TVA Rain Gages in and around Subbasin 17, Little River at Mouth.**



According to Figure 9, the rain gages in or nearest to the lower portion of the Little River basin, downstream of the near Townsend gage, include Wildwood, Knoxville A.P., Knoxville WTP, and to a lesser degree Cades Cove. The average depth recorded at the first three of these gages is 5.23 inches. On the basis of this observed rainfall depth, which is smaller than the 5.949 inch runoff depth mentioned above for the gage near Maryville, it seems likely that the Maryville gage overestimates the runoff for the May 2003 flood. Conversely, the 2.871 inches of runoff mentioned above for the gage near Alcoa may possibly underestimate the flood, given the observed rainfall data. Therefore, given that there is uncertainty in the accuracy of both gage records, the discharge of the Little River for the May 2003 flood was estimated by averaging the two gage records.

Using the scaling factors of 1.3 and 1.2 that were developed for the gages near Maryville and Alcoa (respectively), the daily flows of the Little River at Mouth were estimated for the May 2003 flood, the results of which are shown in Table 19.

**Table 19: Estimated Daily Flows of the Little River at Mouth for the May 2003 Flood.**

| Date | Little River near Maryville cfs | Scaling Factor for Maryville | Little River Near Alcoa cfs | Scaling Factor for Alcoa | Little River at Mouth cfs |
|---|---|---|---|---|---|
| 5/5/2003 | 691 | 1.3 | 691 | 1.2 | 864 |
| 5/6/2003 | 19,000 | 1.3 | 9,600 | 1.2 | 18,110 |
| 5/7/2003 | 12,000 | 1.3 | 9,700 | 1.2 | 13,620 |
| 5/8/2003 | 4,050 | 1.3 | 4,420 | 1.2 | 5,285 |
| 5/9/2003 | 2,190 | 1.3 | 2,300 | 1.2 | 2,804 |
| 5/10/2003 | 1,420 | 1.3 | 1,480 | 1.2 | 1,811 |
| 5/11/2003 | 691 | 1.3 | 1,250 | 1.2 | 864 |

### 7.3.3 Baseflows

Baseflows were subtracted from the local flows to obtain direct runoff hydrographs for the March 1973 and May 2003 floods. For this calculation, the inclined straight line method is employed, with the base line drawn from the starting point of runoff to a point on the receding limb of the hydrograph where base flow resumes (Reference 9).

In general, the starting and ending baseflows for each flood were estimated from the calculated local flows preceding and following the flood. Baseflows for days between the beginning and end of each flood were generally estimated by linear interpolation. Direct runoff was estimated by subtracting the baseflows from the calculated local flows, subject to the constraint that it may not be negative.

The duration, $N$ in days, of direct flood runoff following peak discharge in each subbasin was preliminarily estimated using Linsley et al.'s (Reference 18) expression: $N = A^{0.2}$, where $A$ is the subbasin drainage area in square miles. The resulting durations were adjusted as needed based on the daily hydrographs. The baseflow separation analyses and resulting daily local direct runoff values are shown in the following subsections.

7.3.3.1 Subbasin 8, March 1973 Flood

The baseflow separation analysis for the March 1973 flood in Subbasin 8 is shown in Table 20. The computed local flows for the days leading into this flood are highly variable, with five negative values in the preceding nine days; the sample standard deviation for these nine days is more than four times larger than the mean. The computed computed local flows on March 13 and 14 were -320 cfs and 455 cfs, respectively, as shown in Table 20. Therefore, given the extreme noisiness of the data and the negative flow immediately preceding it, the 455 cfs discharge on March 14 is not considered to be a good estimate of the baseflow at the start of the flood, and it is also not considered to be direct runoff because the storm does not begin until March 15. Therefore, the starting baseflow of 125 cfs from Reference 11, which lies between the average for the preceding two days (68 cfs) and the average for the preceding nine days (285 cfs) was adopted for March 15. Based on the estimated duration of direct runoff given by Linsley et al.'s criterion (Reference 18), the ending baseflow was set equal to the computed local flow on March 20th. Baseflows for days between the start and end were estimated by linear interpolation.

**Table 20: Baseflow Separation for the March 1973 Flood in Subbasin 8, French Broad Local.**

| Date | Local Flow *L* cfs | Baseflow cfs | Local Direct Runoff cfs |
|---|---|---|---|
| 3/13/1973 | -320 | --- | 0 |
| 3/14/1973 | 455 | --- | 0 |
| 3/15/1973 | 857 | 125 | 732 |
| 3/16/1973 | 5,442 | 151 | 5,291 |
| 3/17/1973 | 14,743 | 177 | 14,566 |
| 3/18/1973 | -2,624 | 202 | -2,826 |
| 3/19/1973 | 276 | 228 | 48 |
| 3/20/1973 | 254 | 254 | 0 |
| | | Volume, ac-ft | 35,328 |
| | | Depth, inches | **3.208** |

7.3.3.2 Subbasin 16, March 1973 Flood

The baseflow separation analysis for the March 1973 flood in Subbasin 16 is shown in Table 21. The starting baseflow was set equal to the computed local flow of 580 cfs on March 14; this value is close to the average local flows for the preceding 7 and 10 day periods (582 and 584 cfs, respectively). Based on a visual inspection of the daily hydrograph, and taking into consideration the duration of direct runoff estimated by Linsley et al.'s criterion (Reference 18), the ending baseflow was set equal to the computed local flow on March 19. Baseflows for days between the start and end were estimated by linear interpolation.

**Table 21: Baseflow Separation for the March 1973 Flood in Subbasin 16, Holston River Local, Cherokee Dam to Knoxville Gage.**

| Date | Local Flow *L* cfs | Baseflow cfs | Local Direct Runoff cfs |
|---|---|---|---|
| 3/14/1973 | 580 | 580 | 0 |
| 3/15/1973 | 2,000 | 518 | 1,482 |
| 3/16/1973 | 15,800 | 457 | 15,343 |
| 3/17/1973 | 12,500 | 395 | 12,105 |
| 3/18/1973 | 3,980 | 334 | 3,646 |
| 3/19/1973 | 272 | 272 | 0 |
| | | Volume, ac-ft | 64,614 |
| | | Depth, inches | **4.183** |

7.3.3.3 <u>Subbasin 17, March 1973 Flood</u>

The baseflow separation analysis for the March 1973 flood in Subbasin 17 is shown in Table 22. The starting baseflow was set equal to the computed local flow of 698 cfs on March 14; this value is close to the average local flows for the preceding 7 and 10 day periods (685 and 720 cfs, respectively). Based on the estimated duration of direct runoff given by Linsley et al.'s criterion (Reference 18), the ending baseflow was set equal to the computed local flow on March 20. Baseflows for days between the start and end were estimated by linear interpolation.

**Table 22: Baseflow Separation for the March 1973 Flood in Subbasin 17, Little River at Mouth.**

| Date | Local Flow *L* cfs | Baseflow cfs | Local Direct Runoff cfs |
|---|---|---|---|
| 3/14/1973 | 698 | 698 | 0 |
| 3/15/1973 | 1,217 | 907 | 310 |
| 3/16/1973 | 21,710 | 1,115 | 20,595 |
| 3/17/1973 | 15,990 | 1,324 | 14,666 |
| 3/18/1973 | 4,212 | 1,533 | 2,679 |
| 3/19/1973 | 2,418 | 1,741 | 677 |
| 3/20/1973 | 1,950 | 1,950 | 0 |
| | | Volume, ac-ft | 77,210 |
| | | Depth, inches | **3.823** |

7.3.3.4 <u>Subbasin 18, March 1973 Flood</u>

The baseflow separation analysis for the March 1973 flood in Subbasin 18 is shown in Table 23. The starting baseflow was set equal to the computed local flow of 622 cfs on March 14th, which is close to the average discharge for the days preceding the flood. Based on the estimated duration of direct runoff given by Linsley et al.'s criterion (Reference 18), the ending baseflow was set equal to the computed local flow on March 20. Baseflows in between the starting and ending values were estimated by linear interpolation, subject to the constraint that they may not exceed the local flows.

**Table 23: Baseflow Separation for the March 1973 Flood in Subbasin 18, Fort Loudoun Local.**

| Date | Local Flow *L* cfs | Baseflow cfs | Local Direct Runoff cfs |
|---|---|---|---|
| 3/14/1973 | 622 | 622 | 0 |
| 3/15/1973 | 5,613 | 963 | 4,650 |
| 3/16/1973 | 16,830 | 1,305 | 15,525 |
| 3/17/1973 | 7,750 | 1,646 | 6,104 |
| 3/18/1973 | 2,878 | 1,987 | 891 |
| 3/19/1973 | 2,232 | 2,232 | 0 |
| 3/20/1973 | 2,670 | 2,670 | 0 |
| | | Volume, ac-ft | 53,891 |
| | | Depth, inches | **3.125** |

7.3.3.5 Subbasin 24, March 1973 Flood

The baseflow separation analysis for the March 1973 flood in Subbasin 24 is shown in Table 24. The starting baseflow was estimated by considering the local flows in the days before the flood: The averages for the preceding 3, 7, and 14 days were 1,589 cfs, 1659 cfs, and 1,459 cfs, respectively. From these three estimates, and considering the variability in the daily values, 1,600 cfs was determined to be a reasonable estimate of the starting baseflow for March 15. Based on a visual inspection of the daily hydrograph, and taking into consideration the duration of direct runoff estimated by Linsley et al.'s criterion (Reference 18), the ending baseflow was set equal to the calculated local flow on March 20$^{th}$. Baseflows in between the starting and ending values were estimated by linear interpolation.

**Table 24: Baseflow Separation for the March 1973 Flood in Subbasin 24, Little Tennessee River Local, Chilhowee to Tellico Dam.**

| Date | Local Flow *L* cfs | Baseflow cfs | Local Direct Runoff cfs |
|---|---|---|---|
| 3/14/1973 | 1,189 | 1,189 | 0 |
| 3/15/1973 | 4,474 | 1,600 | 2,874 |
| 3/16/1973 | 36,183 | 1,843 | 34,340 |
| 3/17/1973 | 19,654 | 2,086 | 17,568 |
| 3/18/1973 | 5,094 | 2,329 | 2,765 |
| 3/19/1973 | 3,120 | 2,572 | 548 |
| 3/20/1973 | 2,815 | 2,815 | 0 |
| | | Volume, ac-ft | 115,230 |
| | | Depth, inches | **3.323** |

7.3.3.6 Subbasin 17, May 2003 Flood

For the May 2003 flood in Subbasin 17, the initial baseflow was estimated by considering that the discharge for May 2, 3, and 4 averaged 475 cfs and was relatively consistent. Based on the duration of direct runoff estimated by Linsley et al.'s criterion (Reference 18), the ending baseflow was set equal to the computed local flow on May 10$^{th}$. Baseflows in between the starting and ending values were estimated by linear interpolation. The baseflow separation analysis and results are shown in Table 25.

**Table 25: Baseflow Separation for the May 2003 Flood in Subbasin 17, Little River at Mouth.**

| Date | Local Flow *L* cfs | Baseflow cfs | Local Direct Runoff cfs |
|---|---|---|---|
| 5/4/2003 | 437 | 437 | 0 |
| 5/5/2003 | 864 | 475 | 389 |
| 5/6/2003 | 18,110 | 742 | 17,368 |
| 5/7/2003 | 13,620 | 1,010 | 12,610 |
| 5/8/2003 | 5,285 | 1,277 | 4,008 |
| 5/9/2003 | 2,804 | 1,544 | 1,260 |
| 5/10/2003 | 1,811 | 1,811 | 0 |
| | | Volume, ac-ft | 70,679 |
| | | Depth, inches | 3.500 |

7.3.3.7 Subbasins 8, 16, 18, and 24, May 2003 Flood

The baseflow separation analysis for the May 2003 flood in Subbasins 8, 16, 18, and 24 is shown in Table 26. The beginning baseflow was estimated as equal to the calculated local flow of 1,952 cfs on

May 4th, the day preceding the start of the flood. This value lies between the local flow averages flows for the 7 and 10 day periods preceding the flow (1,802 cfs and 2,366 cfs, respectively). Based on a visual inspection of the daily hydrograph, and taking into consideration the duration of direct runoff estimated by Linsley et al.'s criterion (Reference 18), the ending baseflow was set equal to the calculated local flow of 4,472 cfs on May 13th.

**Table 26: Baseflow Separation for the May 2003 Flood in Subbasins 8, 16, 18, and 24.**

| Date | Local Flow *L* cfs | Baseflow cfs | Local Direct Runoff cfs |
|---|---|---|---|
| 5/4/2003 | 1,952 | 1,952 | 0 |
| 5/5/2003 | 9,734 | 2,232 | 7,503 |
| 5/6/2003 | 51,407 | 2,512 | 48,895 |
| 5/7/2003 | 33,379 | 2,792 | 30,587 |
| 5/8/2003 | 10,508 | 3,072 | 7,436 |
| 5/9/2003 | 3,534 | 3,352 | 182 |
| 5/10/2003 | 8,481 | 3,632 | 4,849 |
| 5/11/2003 | 6,010 | 3,912 | 2,098 |
| 5/12/2003 | -3,092 | 4,192 | 0 |
| 5/13/2003 | 4,472 | 4,472 | 0 |
| | | Volume, ac-ft | 201,423 |
| | | Depth, inches | 2.570 |

The direct runoff depths shown in the bottom rows of Table 20 to Table 26 were calculated using the subbasin drainage areas from Table 1. The local direct runoff depths represent the subbasin-wide average excess rainfall depths, $P_{eff}$, that resulted from the March 1973 and May 2003 storms. The baseflow separation calculations are shown in Attachment 1-15. The baseflows for all subbasins and both floods are shown on the "Baseflows" tab in this attachment. Due to the uncertain nature of the daily baseflow estimates, no attempt was made to disaggregate them into sub-daily values.

### 7.3.4 Additional Reservoir Runoff

The calculated water budgets for the March 1973 and May 2003 floods provide total volumes of direct runoff originating from the water budget areas considered. Because the water budgets were calculated using a mass balance approach that considers all inflows, outflows, and changes in storage, they implicitly include direct runoff from rain falling on the Fort Loudoun and Tellico Reservoir water surfaces. The reservoir runoff would result in nearly instant responses at the basin outlets, due to the absence of overland flow or stream channel travel time and would be equal to the rain falling on the reservoir. The reservoir runoff volume considered in the unit hydrograph convolution is the excess rainfall determined for the total basin. Therefore, the remaining rainfall on the reservoir, over and above that computed in the unit hydrograph convolution, must be considered. This "additional" reservoir runoff was computed separately for the March 1973 and May 2003 floods.

The depths of additional reservoir runoff, $P_{RRO}$, considered in this computation are equal to the differences between the rainfall depths on the reservoirs and the basin-wide excess rainfall depths, shown in Table 20 to Table 26. For the March 1973 storm, the rainfall depth on Fort Loudoun Reservoir was obtained from Reference 11. For the May 2003 storm, the rainfall depths on Fort Loudoun and Tellico Reservoirs were obtained from the NWS gridded precipitation data. The volumes of additional reservoir runoff are equal to the products of $P_{RRO}$ and the surface areas of reservoirs shown in Table 1.

The Fort Loudoun Reservoir surface areas during these floods were estimated using daily stage data from Attachment 1-6 and the area-elevation table (Reference 19). The average areas estimated for March 15-17, 1973 and May 5-8, 2003 are 22.03 $mi^2$ and 24.19 $mi^2$, respectively. Considering the closeness of the 23.49 $mi^2$ area shown in Table 1 to these two estimates, it is reasonable to use this area to determine the additional reservoir runoff. The area-elevation table for Tellico Reservoir is not available. However, using the daily stage-storage data in Attachment 1-7, the surface area during the May 2003 flood was estimated to be approximately 25.9 $mi^2$, within 6% of the area of 24.5 $mi^2$ shown in Table 1. Therefore, Table 1 provides reasonable values for the areas used in determining the additional reservoir runoff volumes. The elevation-area comparisons are included in Attachment 1-16.

The additional reservoir runoff volume calculations are shown in Section 7.4.1 and in Attachment 1-15. The resulting hourly reservoir runoff series are shown in the "2003 Reservoir" and "1973 Reservoir" worksheets in Attachment 1-1.

## *7.4 Excess Rainfall Hyetographs*

The excess rainfall hyetograph is the input to the basin model that is converted into direct runoff at the basin outlet via convolution with the unit hydrograph. This is developed from the observed rainfall hyetograph by the application of a loss rate function which accounts for the hydrologic abstractions of evaporation and transpiration, interception, depression storage, and infiltration (Reference 8). Excess rainfall is also known as "runoff" or "effective rainfall;" all three terms refer to the same quantity.

The TVA uses the FLDHYDRO computer program (Reference 10) to estimate excess precipitation from a given rain storm for use with the UH for runoff prediction. Reference 10 provides detailed information concerning the operation of the FLDHYDRO program. The TVA created this program to implement the Antecedent Precipitation Index (API)/Runoff Index (RI) methodology developed by the United States Weather Bureau (USWB) and described in References 18 and 20. In this method, antecedent precipitation data are used to define the basin state at the beginning of the storm through the API. Seasonal, empirical relationships (the RI component) are employed to account for expected seasonal variation in runoff resulting from observed seasonal variations in evapotranspiration.

### 7.4.1 FLDHYDRO Operation

The excess rainfall hyetographs for the Fort Loudoun-Tellico subbasins were computed for the March 1973 and May 2003 storms using the FLDHYDRO program and the available rainfall data. Several steps were performed to determine the depths of additional reservoir runoff, $P_{RRO}$, and to adjust the excess rainfall depths to account for the inclusion of $P_{RRO}$ in the water balance. These additional steps affect only Subbasin 18 for the March 1973 flood and only Subbasins 8, 16, 18, and 24 for the May 2003 flood because these are the only water budgets that include reservoirs (Sections 7.3.1.3 and 7.3.1.5). These steps are described below and the corresponding results are shown in Table 27.

1. The excess rainfall depths, $P_{eff}$, were obtained from Table 23 and Table 26. These are 3.125 inches for the March 1973 storm in Subbasin 18 and 2.570 inches for the May 2003 storm in Subbasins 8, 16, 18, and 24.
2. The $P_{eff}$ values were input as CHKVOL values to FLDHYDRO, which was run for each storm (March 1973 and May 2003) to obtain preliminary excess rainfall predictions. The resulting predicted area weighted average excess rainfall depths for these storms are 3.14 and 2.55 inches for the March 1973 and May 2003 storms, respectively. The FLDHYDRO input and output files for these preliminary runs are included as Attachments 3-7 to 3-10 and 3-19 to 3-20.
3. The additional reservoir runoff, $P_{RRO}$, was estimated for each flood as the difference between the rainfall on the reservoirs (shown in Table 27) and the predicted excess rainfall depths. For March 1973, this yields $P_{RRO} = 6.68 - 3.15 = 3.53$ inches; for May 2003, $P_{RRO}$ is 2.87 inches for Fort Loudoun Reservoir and is 3.72 inches for Tellico Reservoir. The italicized depths of *0.256* inches for March 1973 and *0.115* inches for May 2003 shown on the Step 3 row are equal to the additional reservoir runoff volumes divided by the water budget areas (323.4 mi$^2$ for 1973 and 1,469.6 mi$^2$ for 2003).
4. The italicized $P_{RRO}$ values, which are distributed across the water budget areas, were subtracted from the water budget depths (Step 1) to obtain adjusted CHKVOL values of 2.868 and 2.455 inches for the March 1973 and May 2003 storms, respectively.
5. The FLDHYDRO program was re-run for all subbasins and, in the case of the March 1973 flood, for Fort Loudoun Reservoir, using the adjusted CHKVOL values from Step 4. The revised FLDHYDRO results and $P_{RRO}$ values were area-weighted across the water budget area and compared with the initial water budget values from Steps 1 to 3. The FLDHYDRO input and output files for these runs are included as Attachments 3-11 to 3-14 and 3-21 to 3-22.

**Table 27: Steps Used to Determine CHKVOL Values and Additional Reservoir Runoff Depths.**

| | Storm / Flood | March 1973 | | May 2003 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Step | Subbasin | 18 | Fort Loudoun Reservoir | 8 | 16 | 18 | 24 | Water Budget Area | Fort Loudoun Reservoir | Tellico Reservoir |
| | Area, mi$^2$ | 323.4 | 23.5 | 206.5 | 289.6 | 323.4 | 650.2 | 1,469.6 | 23.5 | 24.5 |
| | Rainfall, in. | 6.81 | 6.68 | 3.94 | 2.65 | 5.33 | 7.84 | 5.72 | 5.33 | 7.84 |
| 1 | CHKVOL from water budget, in. | 3.125 | 3.125 | | | | | 2.570 | | |
| 2 | Initial FLDHYDRO runoff, in. | 3.14 | 3.15 | 1.28 | 0.91 | 2.46 | 3.72 | 2.55 | 2.46 | 3.72 |
| 3 | *$P_{RRO}$, or additional reservoir runoff, in.* | *0.256* | 3.53 | | | | | *0.115* | 2.87 | 4.12 |
| 4 | Adjusted CHKVOL, in. | 2.868 | 2.868 | | | | | 2.455 | | |
| 5 | Revised FLDHYDRO runoff, in. | 2.88 | 2.89 | 1.21 | 0.83 | 2.34 | 3.54 | 2.41 | 2.34 | 3.54 |

Following the above analysis, the additional reservoir runoff series were computed. For the March 1973 storm, the additional reservoir runoff was computed using FLDHYDRO with an input CHKVOL value of 2.868 inches (from Step 4). For the May 2003 storm, the additional runoff series for Fort Loudoun and Tellico Reservoirs were obtained from the Step 5 FLDHYDRO rainfall and excess rainfall results for Subbasins 18 and 24, respectively. The methods used for the two floods were not the same because reservoir-specific rainfall data is available for the March 1973 storm, but not for the May 2003 storm. In both cases, the hourly reservoir runoff was set equal to the hourly difference between the rainfall and the excess rainfall. The FLDHYDRO input and output files for the final March 1973 additional reservoir runoff computation are included as Attachments 3-13 and 3-14.

### 7.4.2 FLDHYDRO Results

Figure 10 to Figure 17 provide plots of the FLDHYDRO results for the March 1973 and May 2003 storms in Subbasins 8, 16, 17, 18, and 24. The sum of the hourly losses and hourly runoff values shown in these figures (i.e. the total column height for each hour in the figures) is equal to the hourly rainfall depths that were input to FLDHYDRO. It may be seen from these figures that the percentage of rainfall that becomes runoff tends to increase over the course of each storm. The FLDHYDRO results are also shown on the"1973 Rainfall" and "2003 Rainfall" tabs in Attachment 1-1. The FLDHYDRO input and output files are included as Attachments 3-1 to 3-22.

**Figure 10: FLDHYDRO Calculated Hourly Rainfall Losses and Runoff for the March 1973 Storm in Subbasin 8.**

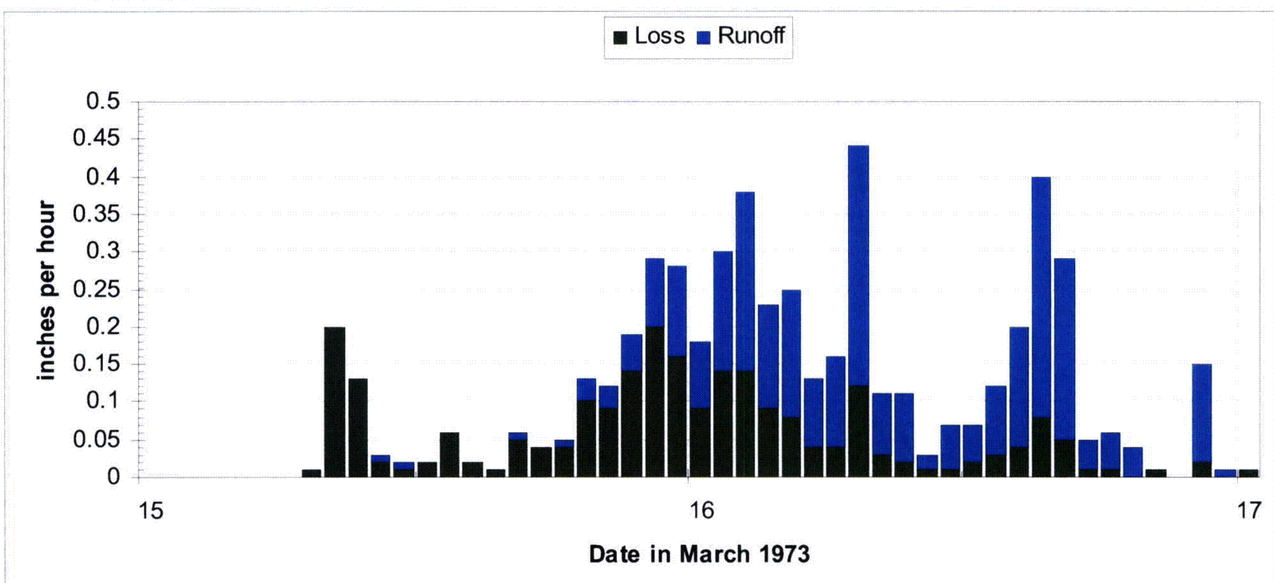


**Figure 11: FLDHYDRO Calculated Hourly Rainfall Losses and Runoff for the March 1973 Storm in Subbasin 16.**

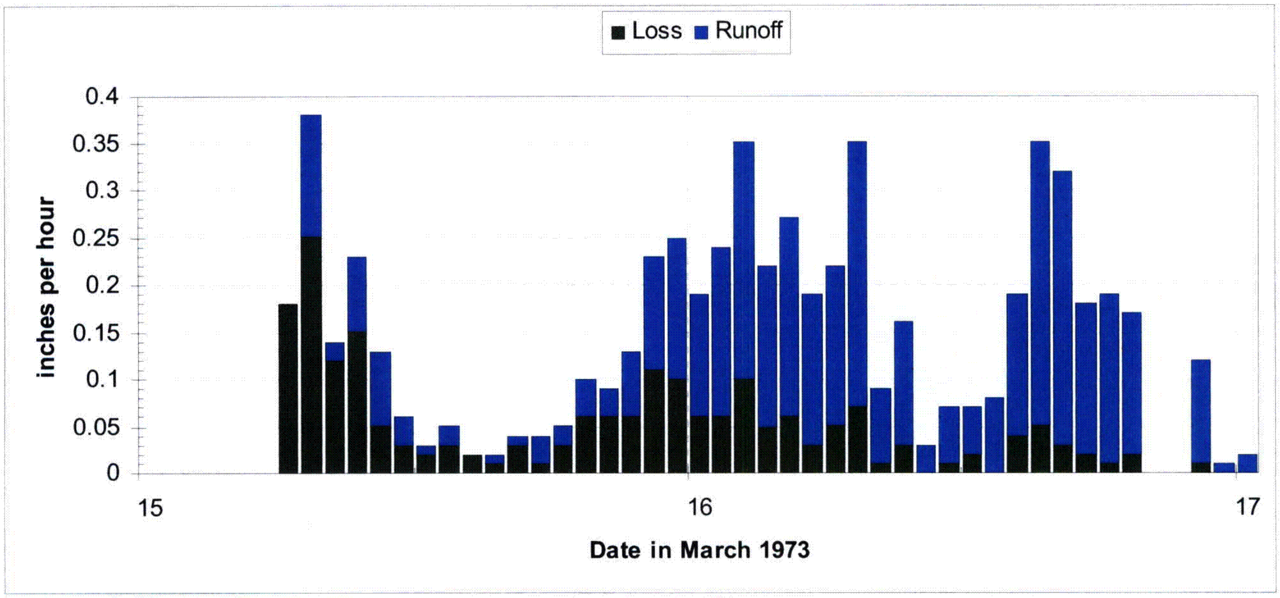



**Figure 12: FLDHYDRO Calculated Hourly Rainfall Losses and Runoff for the March 1973 Storm in Subbasin 17.**

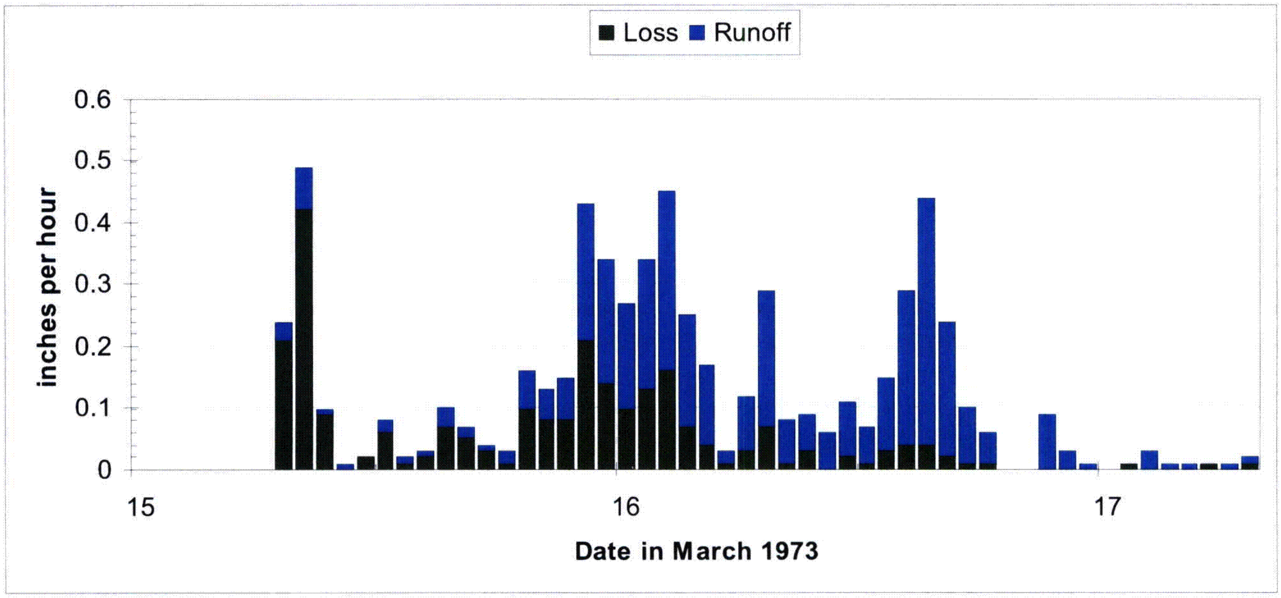


**Figure 13: FLDHYDRO Calculated Hourly Rainfall Losses and Runoff for the March 1973 Storm in Subbasin 18.**

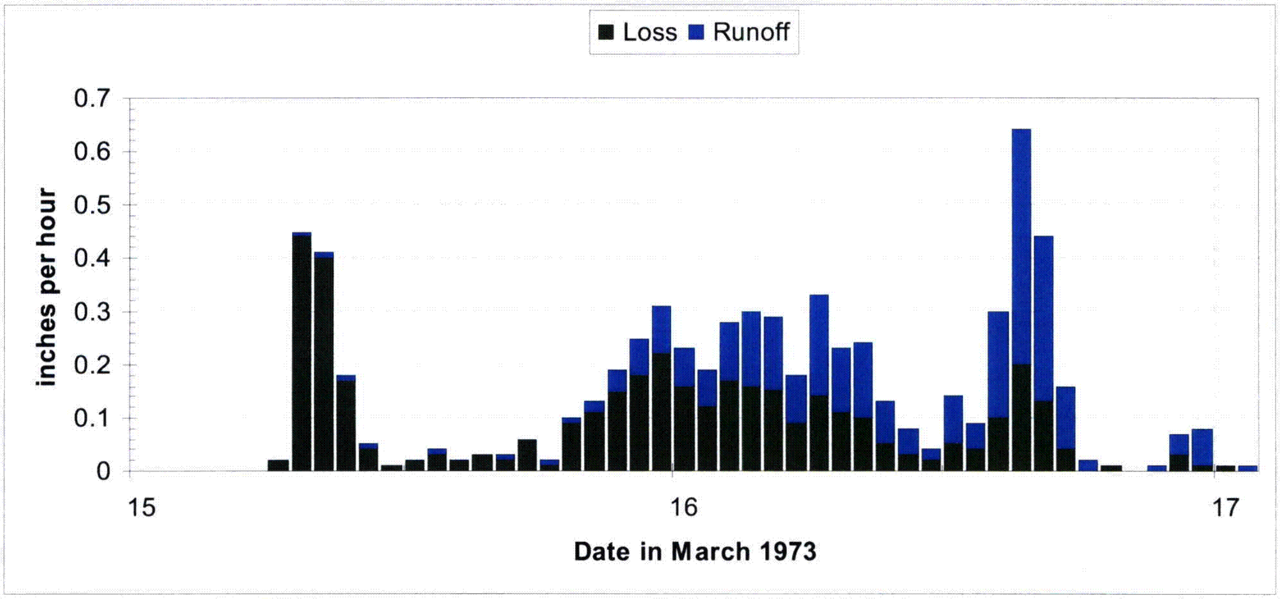



**Figure 14: FLDHYDRO Calculated Hourly Rainfall Losses and Runoff for the March 1973 Storm in Subbasin 24.**

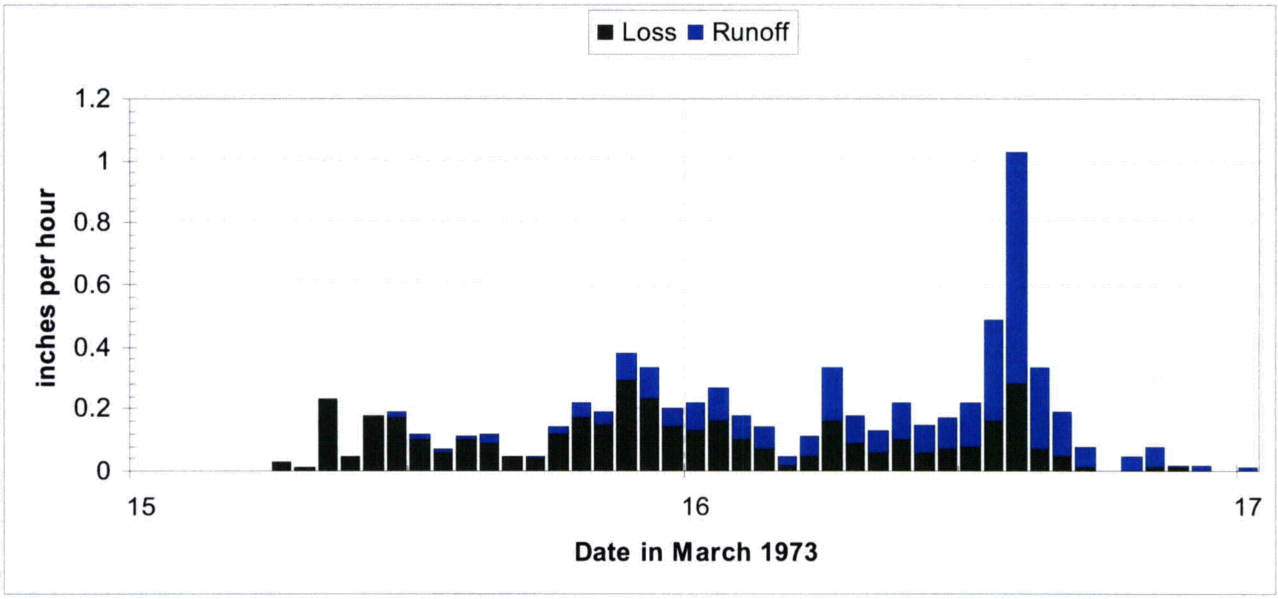


**Figure 15: FLDHYDRO Calculated Hourly Rainfall Losses and Runoff for the May 2003 Storm in Subbasin 8.**

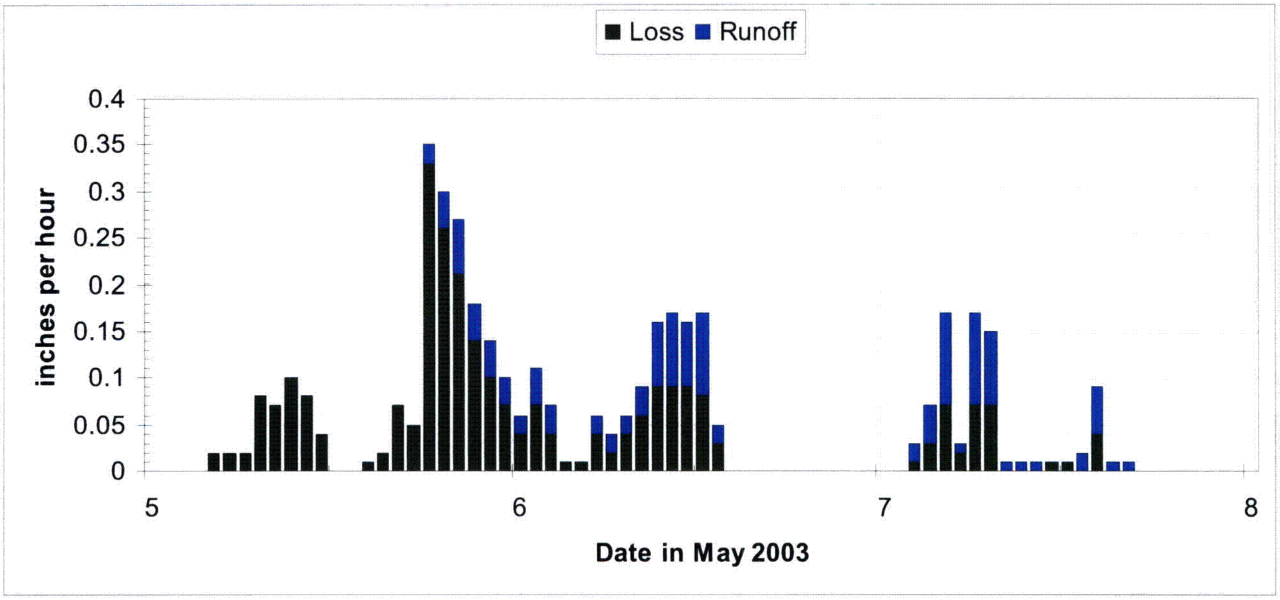



**Figure 16: FLDHYDRO Calculated Hourly Rainfall Losses and Runoff for the May 2003 Storm in Subbasin 16.**

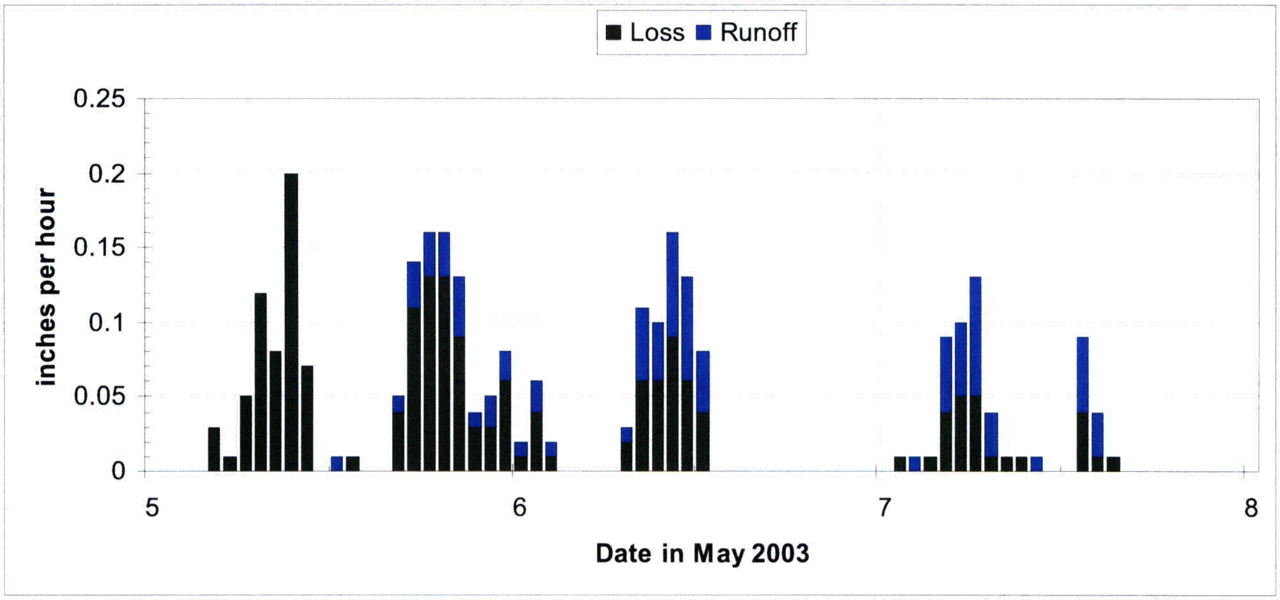


**Figure 17: FLDHYDRO Calculated Hourly Rainfall Losses and Runoff for the May 2003 Storm in Subbasin 17.**

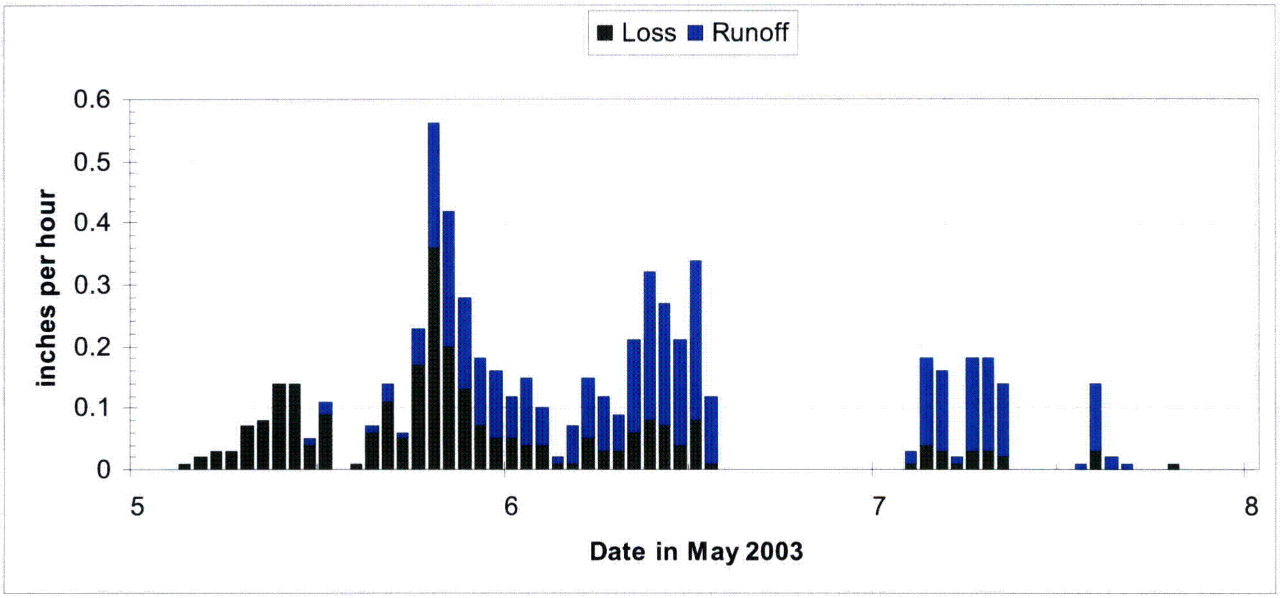



**Figure 18: FLDHYDRO Calculated Hourly Rainfall Losses and Runoff for the May 2003 Storm in Subbasin 18.**

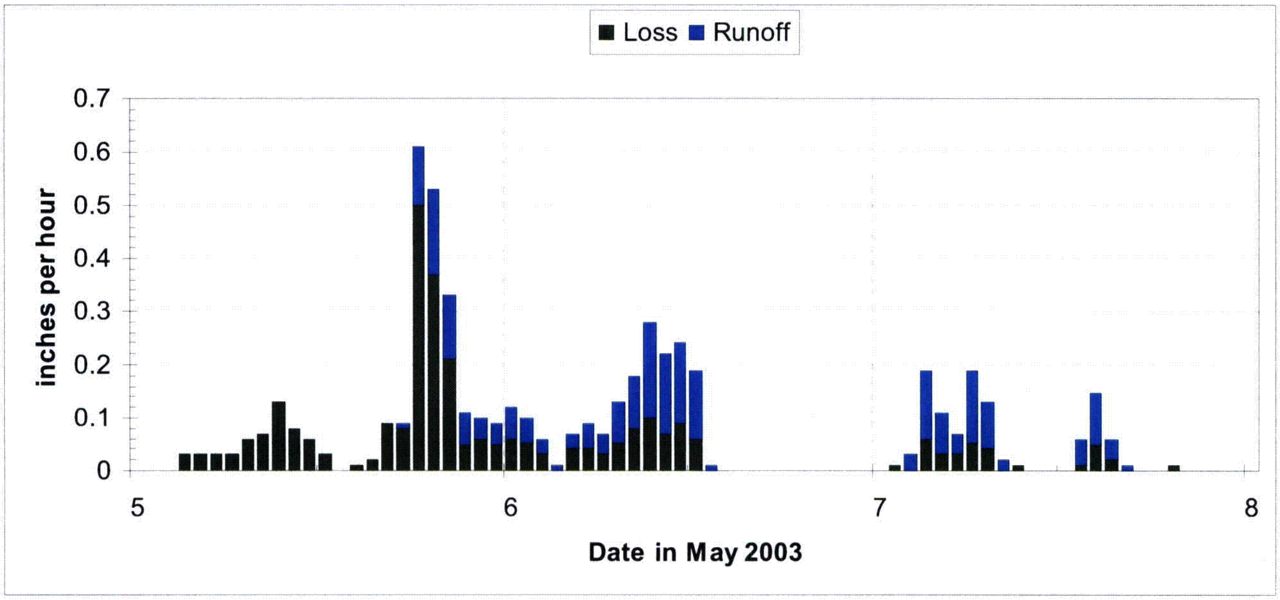
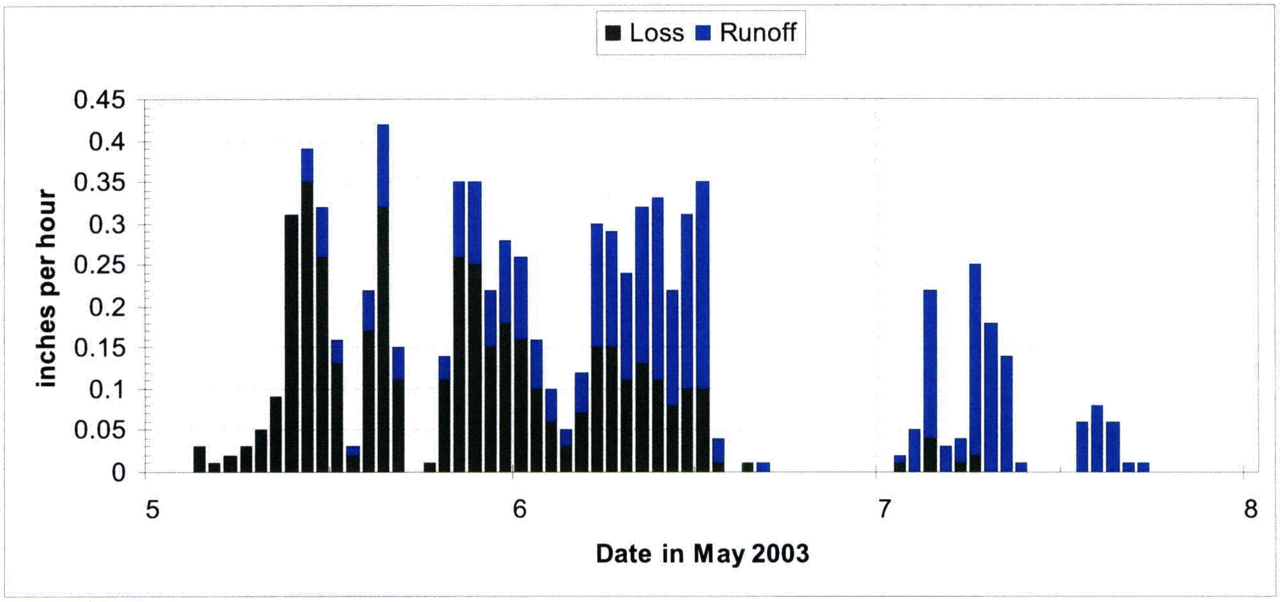


**Figure 19: FLDHYDRO Calculated Hourly Rainfall Losses and Runoff for the May 2003 Storm in Subbasin 24.**




The hourly excess rainfall series shown in Figure 10 to Figure 19 were aggregated to the effective durations of the unit hydrographs for use in the unit hydrograph convolutions. Therefore, excess rainfall for Subbasin 17 was aggregated to four-hour values, and excess rainfall series for the other subbasins were aggregated to six-hour values.

### *7.5 Direct Runoff and Baseflow Hydrographs*

The unit hydrographs for Subbasins 8, 16, 17, 18, and 24 were convoluted with the excess rainfall series to simulate the direct runoff hydrographs for the March 1973 and May 2003 floods. The resulting initial direct runoff hydrographs, and the baseflows from Section 7.3.3, are plotted in Figure 20 to Figure 29.

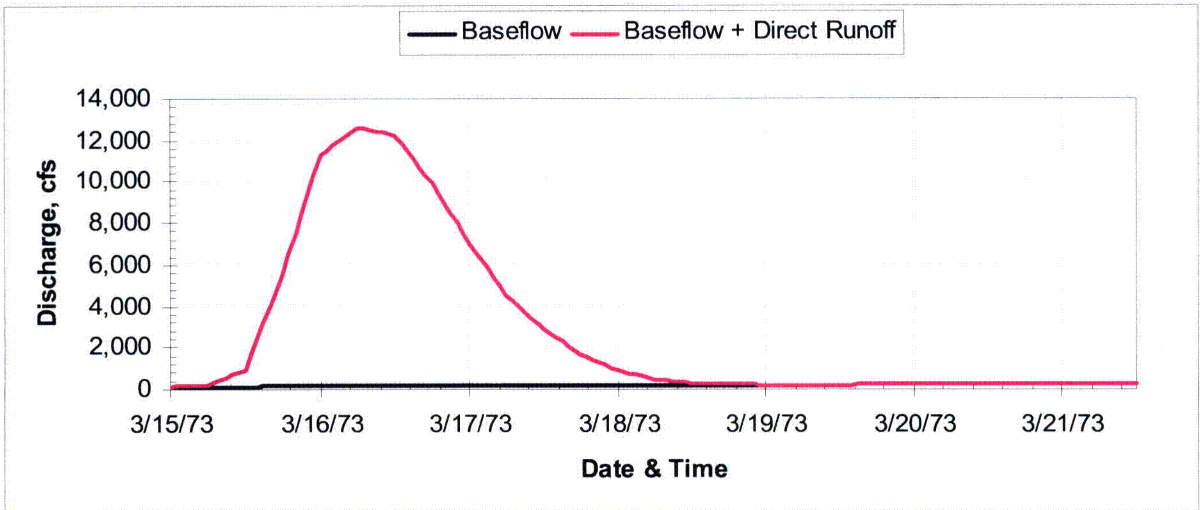



**Figure 20: Direct Runoff and Baseflow Hydrographs from Subbasin 8, French Broad Local, for the March 1973 Flood.**

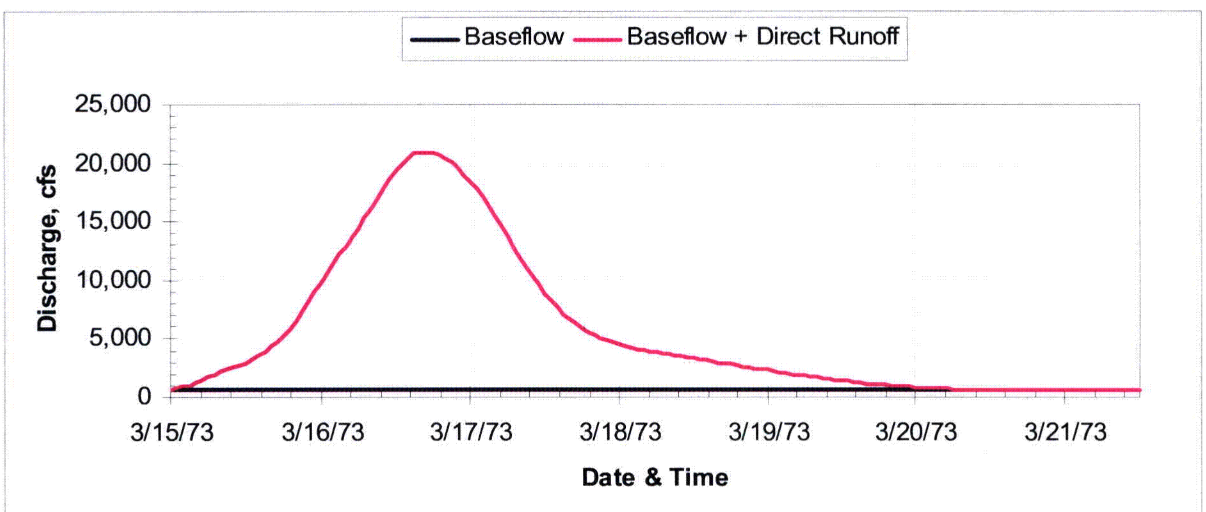



**Figure 21: Direct Runoff and Baseflow Hydrographs from Subbasin 16, Holston River Local, Cherokee Dam to Knoxville Gage, for the March 1973 Flood.**

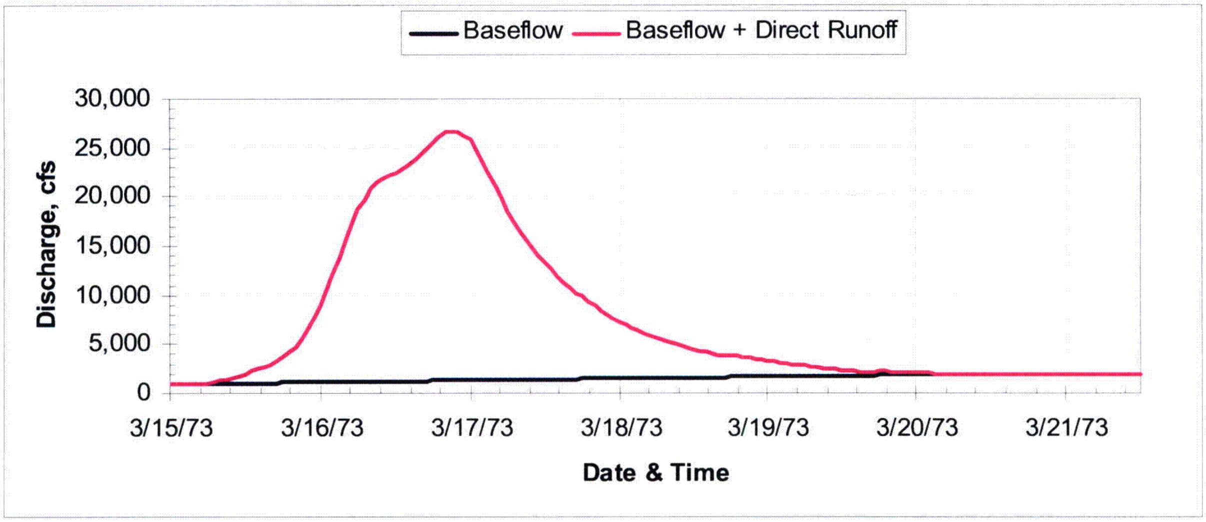



**Figure 22: Direct Runoff and Baseflow Hydrographs from Subbasin 17, Little River at Mouth, for the March 1973 Flood.**

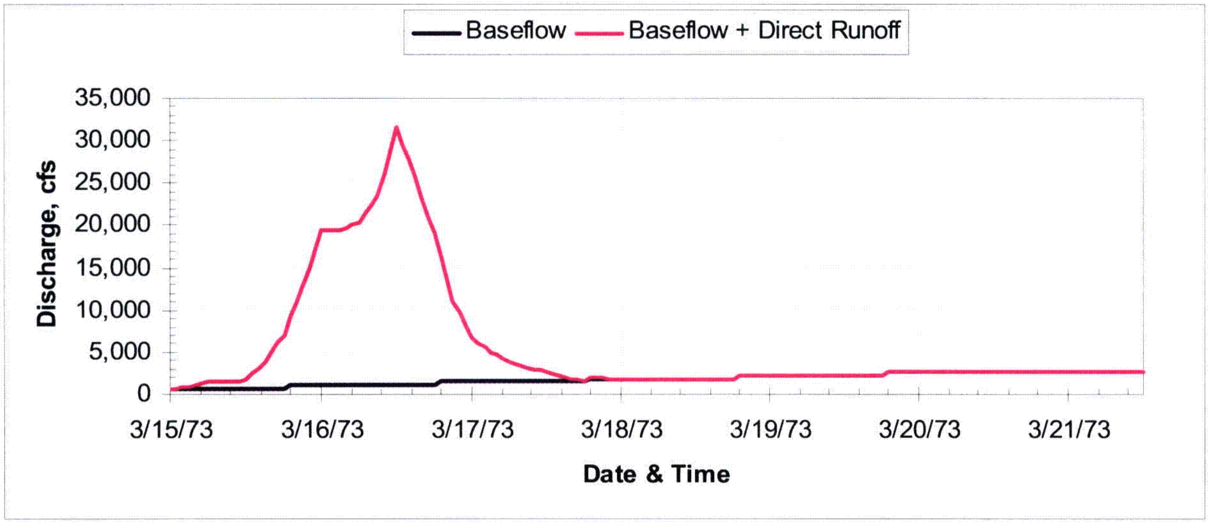



**Figure 23: Direct Runoff and Baseflow Hydrographs from Subbasin 18, Fort Loudoun Local, for the March 1973 Flood.**

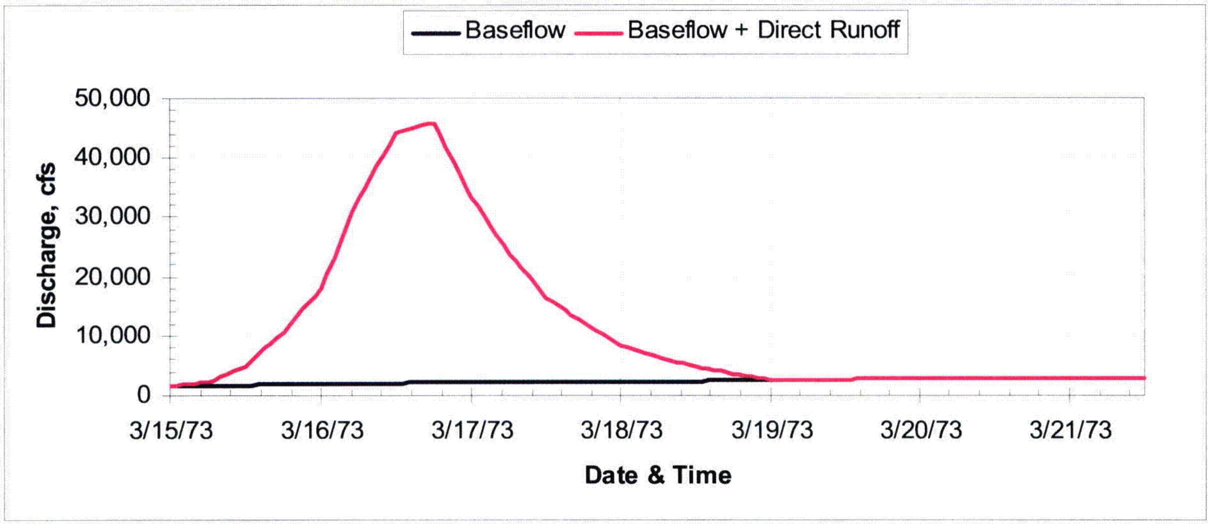



**Figure 24: Direct Runoff and Baseflow Hydrographs from Subbasin 24, Little Tennessee River Local, Chilhowee to Tellico Dam, for the March 1973 Flood.**

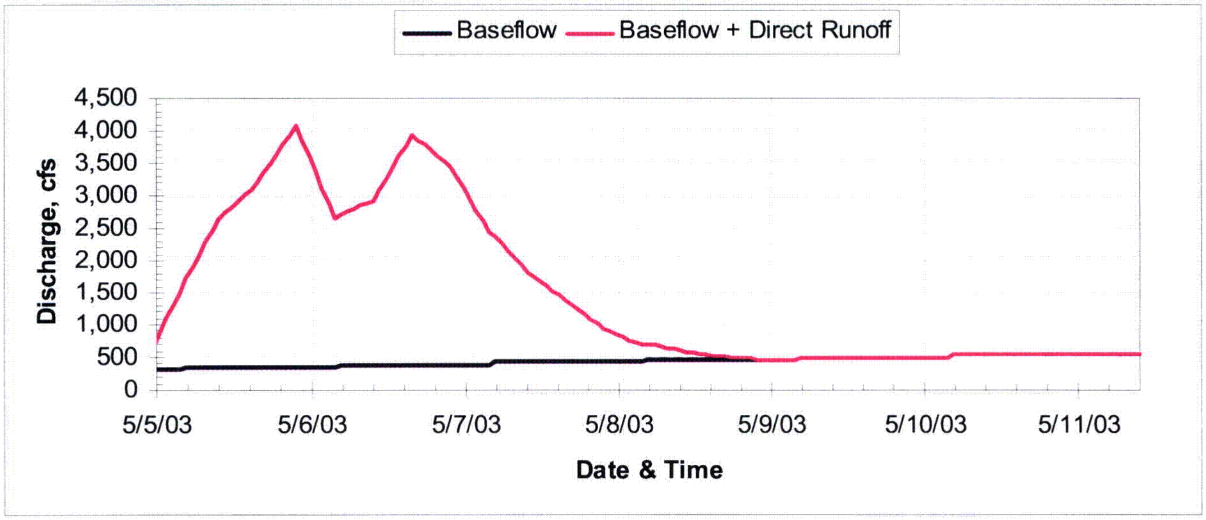



**Figure 25: Direct Runoff and Baseflow Hydrographs from Subbasin 8, French Broad Local, for the May 2003 Flood.**

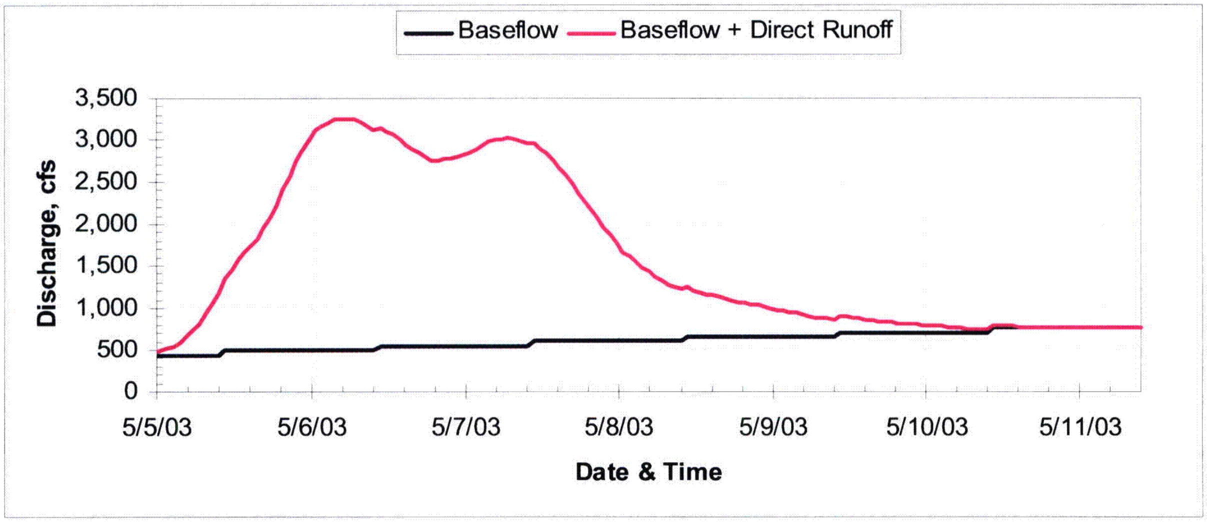



**Figure 26: Direct Runoff and Baseflow Hydrographs from Subbasin 16, Holston River Local, Cherokee Dam to Knoxville Gage, for the May 2003 Flood.**

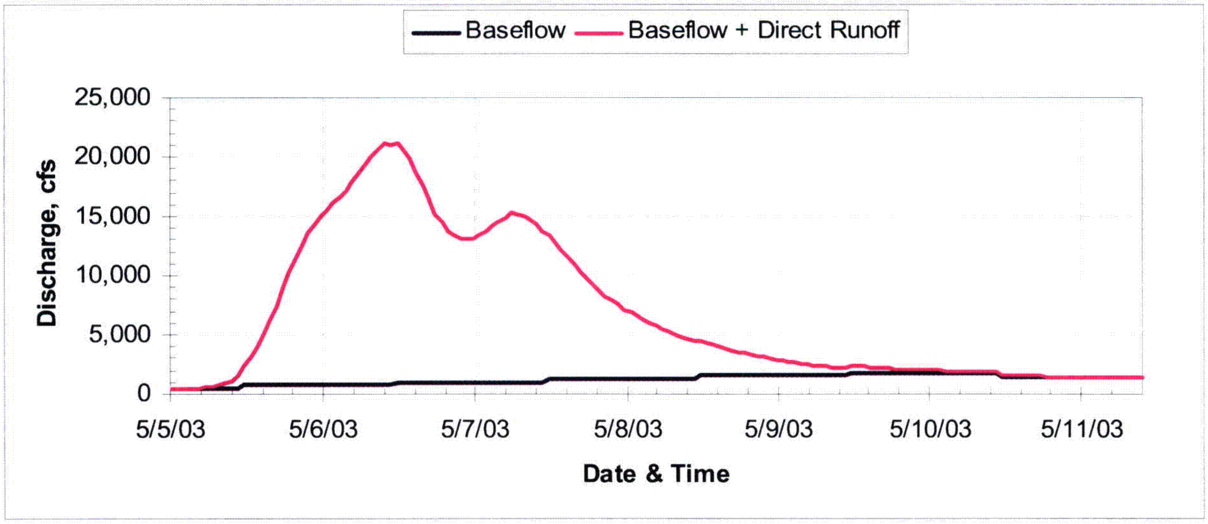



**Figure 27: Direct Runoff and Baseflow Hydrographs from Subbasin 17, Little River at Mouth, for the May 2003 Flood.**

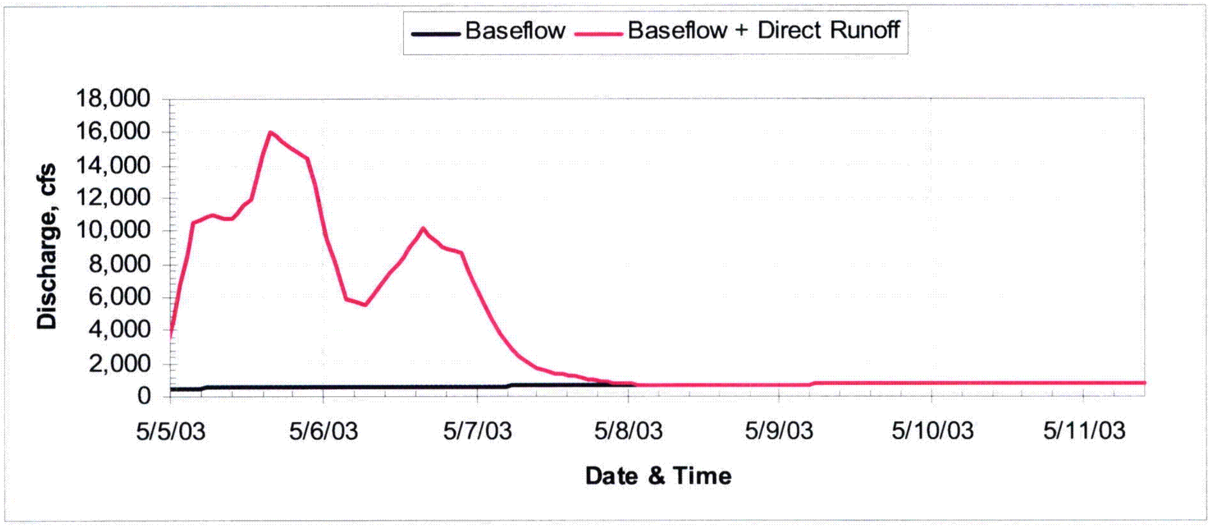



**Figure 28: Direct Runoff and Baseflow Hydrographs from Subbasin 18, Fort Loudoun Local, for the May 2003 Flood.**

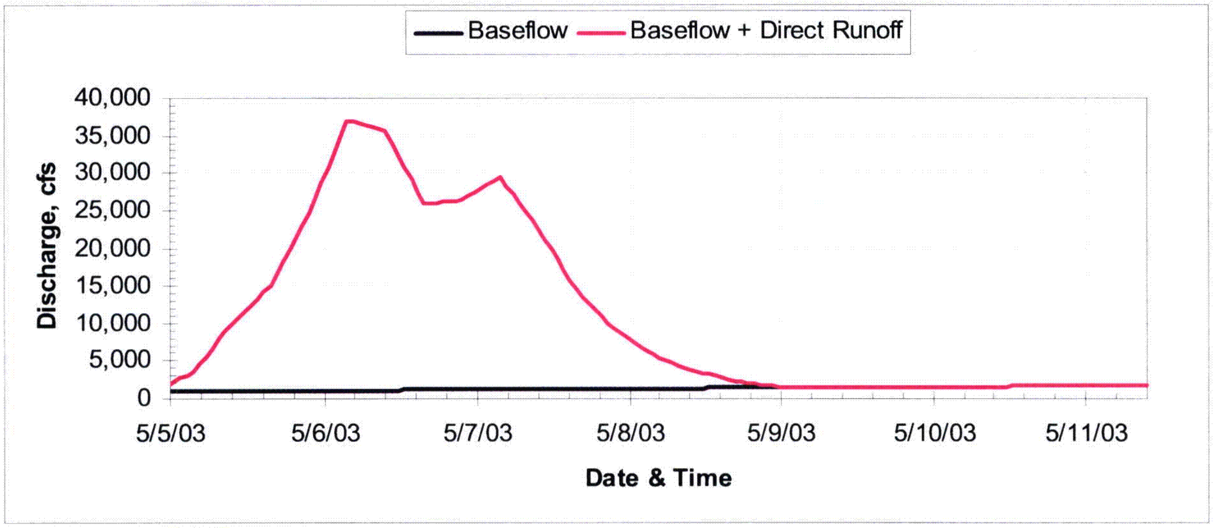



**Figure 29: Direct Runoff and Baseflow Hydrographs from Subbasin 24, Little Tennessee River Local, Chilhowee to Tellico Dam, for the May 2003 Flood.**

The unit hydrograph convolutions were performed in an Excel spreadsheet; calculations and resulting hydrographs are in the "1973 Convolutions" and "2003 Convolutions" tabs in Attachment 1-1.

### *7.6 Additional Reservoir Runoff Hydrographs*

The computed additional runoff hydrographs from Fort Loudoun and Tellico Reservoirs are shown in Figure 30 to Figure 32. These hourly additional reservoir runoff series were determined using the methods described in Section 7.3.4 and at the end of Section 7.4.1.

**Figure 30: Additional Fort Loudoun Reservoir Runoff from the March 1973 Flood.**

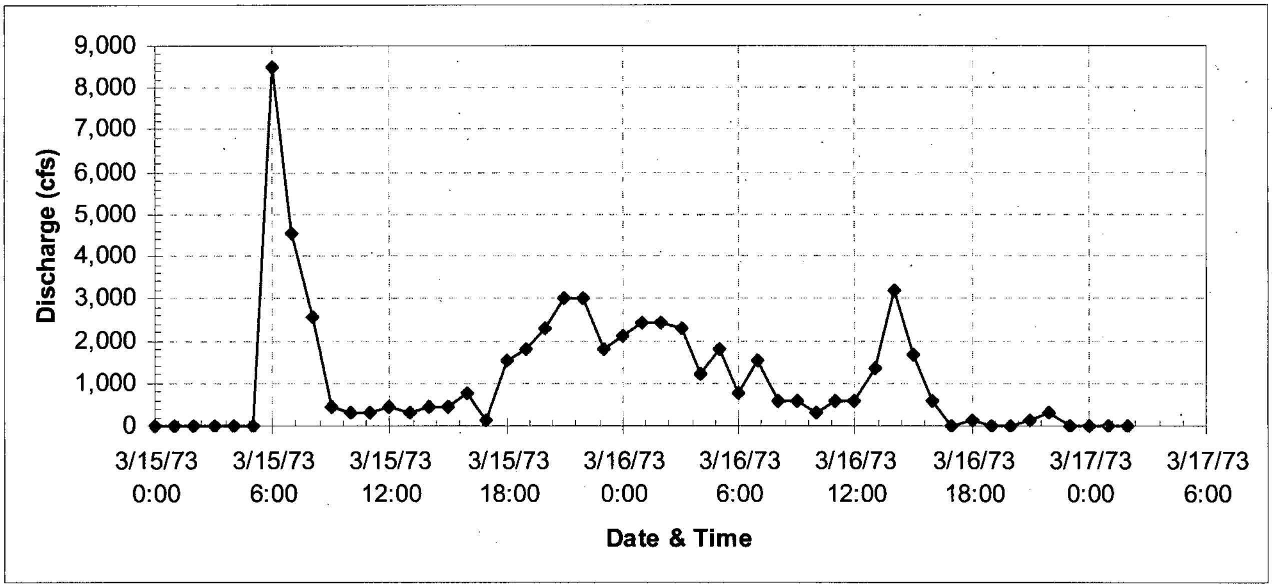



**Figure 31: Additional Fort Loudoun Reservoir Runoff from the May 2003 Flood.**

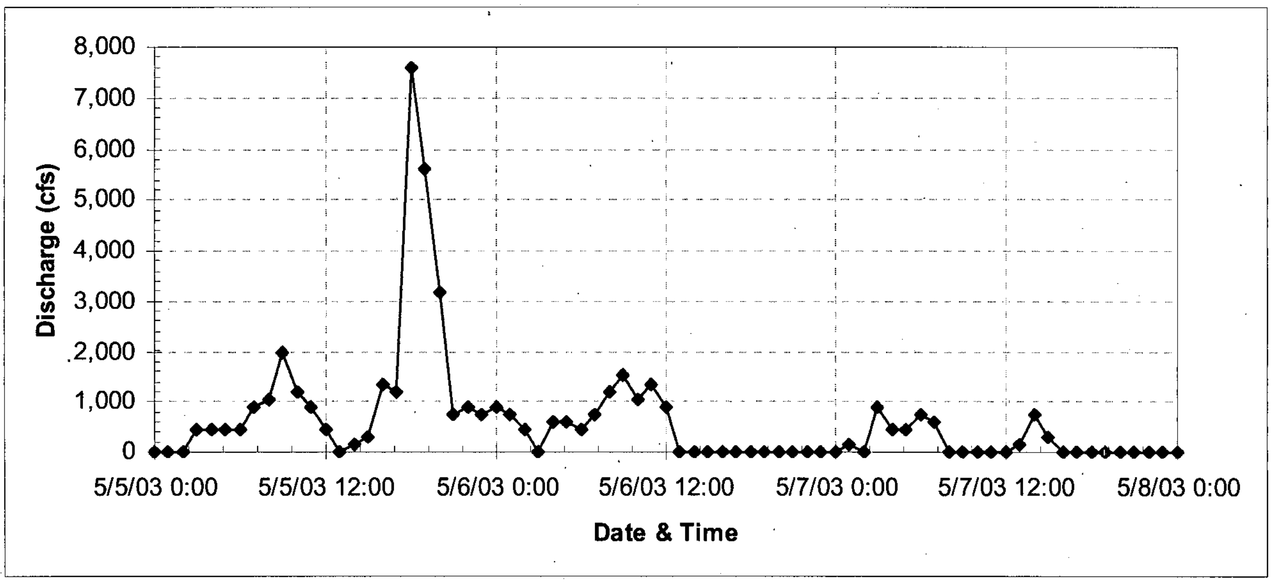
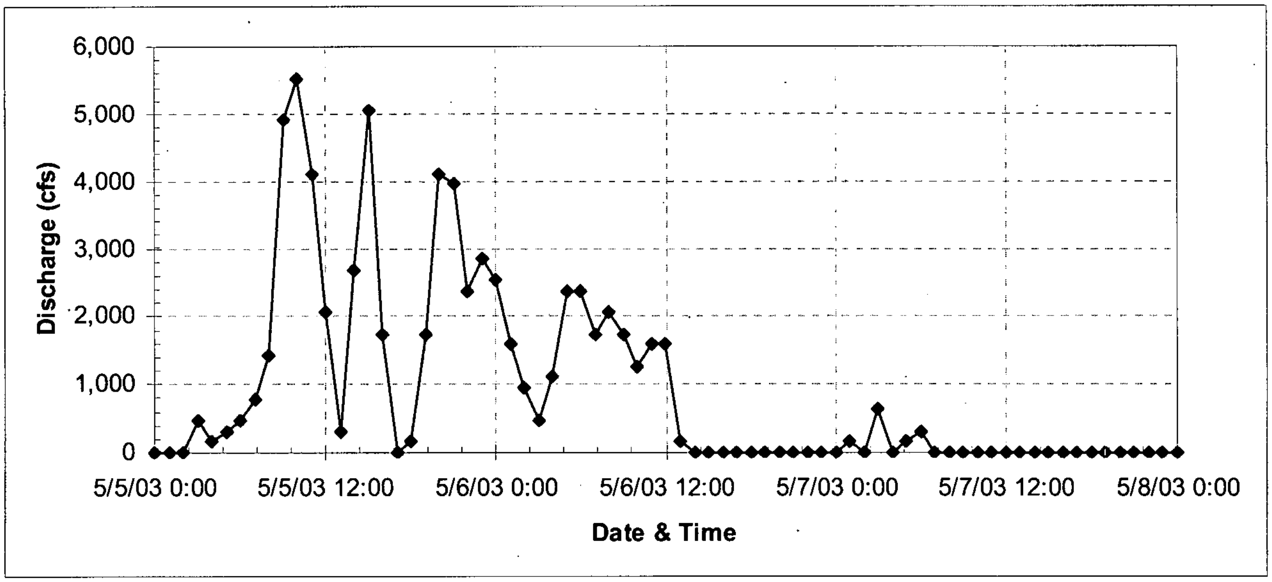


**Figure 32: Additional Tellico Reservoir Runoff from the May 2003 Flood.**




The hourly additional reservoir runoff calculations are presented in the "1973 Reservoir" and "2003 Reservoirs" worksheets in Attachment 1-1.

## 7.7 SOCH Model Input

Four time series were provided for use in the SOCH models for the March 1973 and the May 2003 validation runs. These inputs are as follows:

- Total direct runoff for Subbasin 8,
- Total direct runoff for Subbasin 16,
- Total direct runoff for Subbasin 17,
- Total direct runoff for Subbasin 18,
- Total direct runoff for Subbasin 24,
- Losses and runoff for Subbasin 8,
- Losses and runoff for Subbasin 16,
- Losses and runoff for Subbasin 17,
- Losses and runoff for Subbasin 18,
- Losses and runoff for Subbasin 24,

The time series were developed in spreadsheets in Attachment 1-1. Plots of the component time series are provided as Figures 20 through 29 in Section 7.5.

### *7.8 SOCH Model Output and Unit Hydrograph Validation*

The component time series presented in Section 7.5 of this calculation were used as inputs to a SOCH model of the Fort Loudoun-Tellico Dam Local Watershed.

For the March 1973 event, simulated and observed water surface elevations were compared at six gage locations: TRM 645.1 & 651.40; FBRM 7.4 & 32.3; HRM 52.3 & 5.5. For the May 2003 event, simulated and observed water surface elevations were compared at five gage locations: TRM 645.1; FBRM 32.3; HRM 52.3; LTRM 33.6 & 0.3. Simulated and observed discharges were compared at TRM 602.3 for both historic events.

As described in Reference 21, the local inflows to Fort Loudoun- Tellico Dam Local Watershed from Subbasins 8, 16, 17, 18, and 24 were combined with the observed data for the March 1973 and May 2003 events to reproduce the observed elevations at gage locations along the reservoir for the historic floods. These comparisons are shown in Figures 33 through 41. As a result, the unit hydrographs developed for basins 8, 16, 17, 18, and 24 were validated and deemed adequate for use in developing flood inflows for other events, including PMF. Data and simulation results for the aforementioned figures are provided in Attachments 4-1 and 4-2.

# 8 Conclusions

Unit hydrographs for Subbasins 8, 16, 17, 18, and 24 for the simulation of local inflow to the Tennessee River between in the Fort Loudoun - Tellico Dam Local Watershed were developed by TVA previously. The unit hydrographs for Subbasins 8 and 16 were modified as described in Reference 21. In compliance with NRC requirements, the unit hydrographs were indirectly validated in this calculation for two events: the floods of March 1973 and May 2003.

### *8.1 Unit Hydrograph Validation*

The modified unit hydrographs for Subbasins 8 and 16 and the original unit hydrographs for Subbasins 17, 18, and 24 were indirectly validated for the March 1973 and May 2003 floods in this calculation and are provided in Tables 28-32 (Attachment 4-3). Since the stage and discharge hydrographs simulated in the SOCH model runs utilizing local inputs developed with the unit hydrographs adequately predict observed data, it is concluded that the modified unit hydrographs for Subbasins 8 and 16 and the original unit hydrographs adequately describe the response of the local catchment areas between the reservoirs and are valid for use in hydrologic studies to determine PMF. The computed evaluation at HRM 5.5 (shown in Figure 35) reproduces the peak and timing of the observed elevation at HRM 5.5; however the elevations differ for the rising and falling limbs of the hydrographs. A potential cause for this difference may be related to gaging information and will be discussed in Reference 21. Also refer to Reference 21 for the proper application of the modified unit hydrograph versus the original unit hydrograph in modeling design storms.

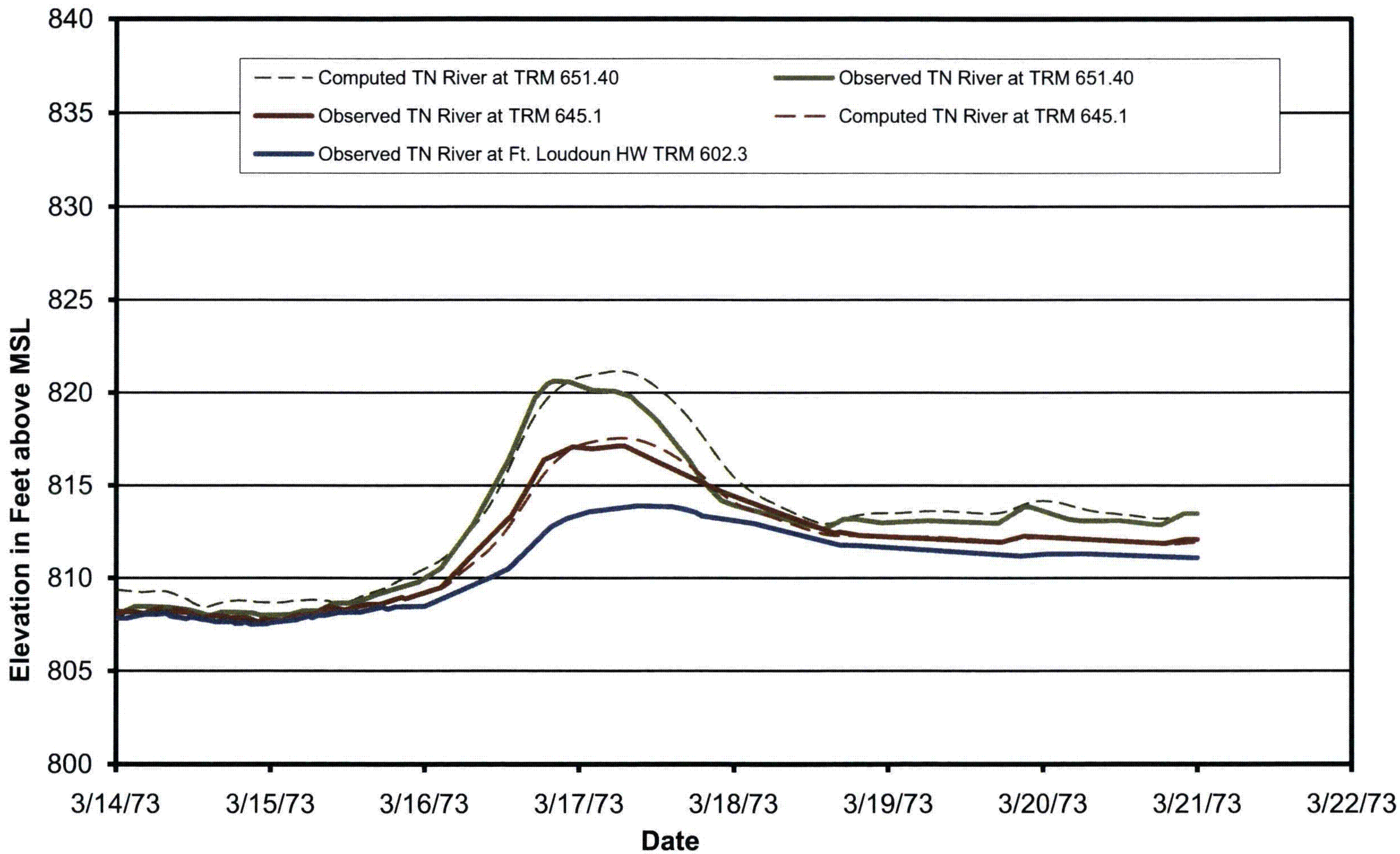



**Figure 33: Observed and Simulated Stage Hydrographs for the Fort Loudoun-Tellico Watershed, March 1973**

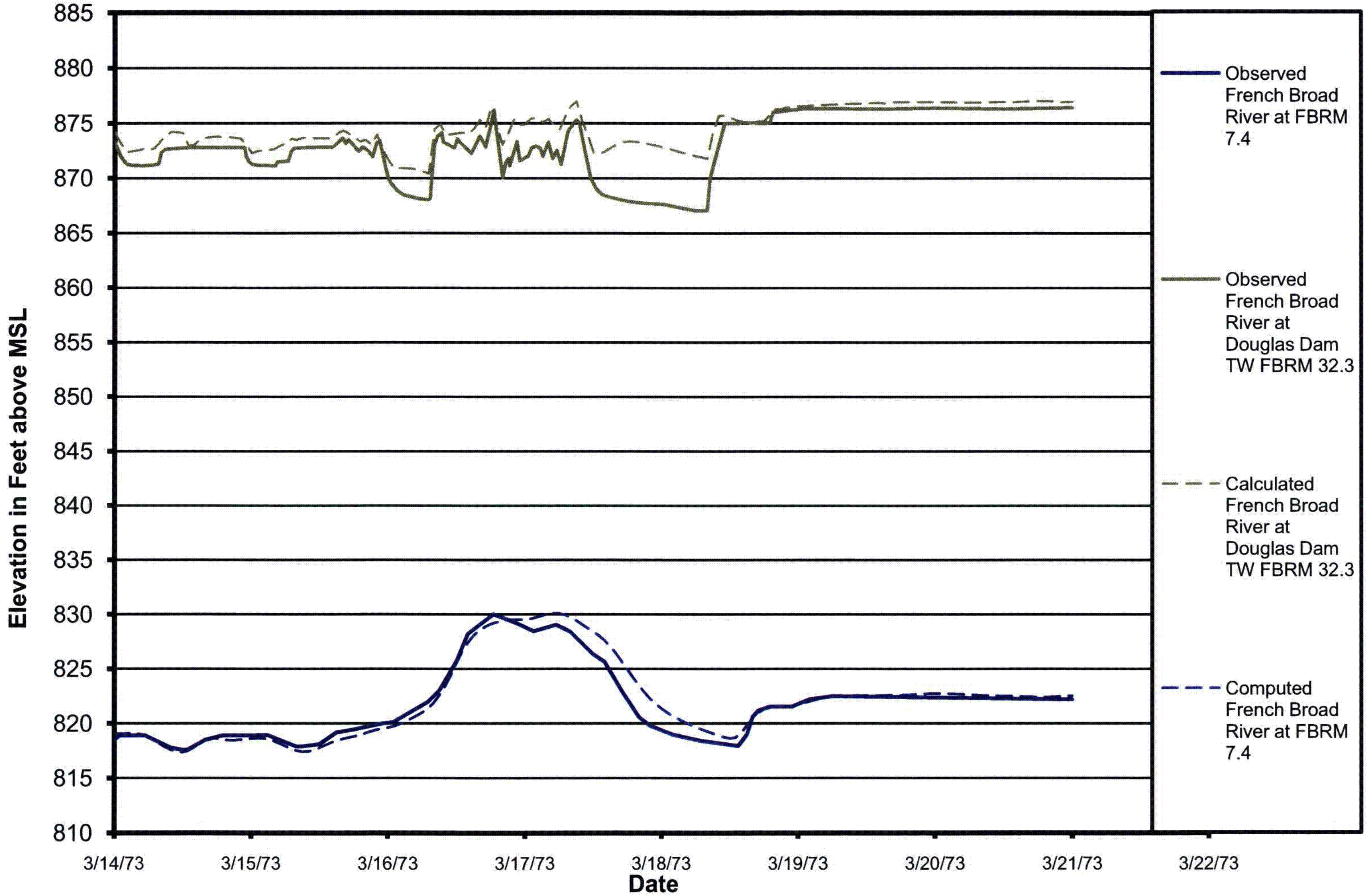



**Figure 34: Observed and Simulated Stage Hydrographs for the Fort Loudoun-Tellico Watershed, March 1973**

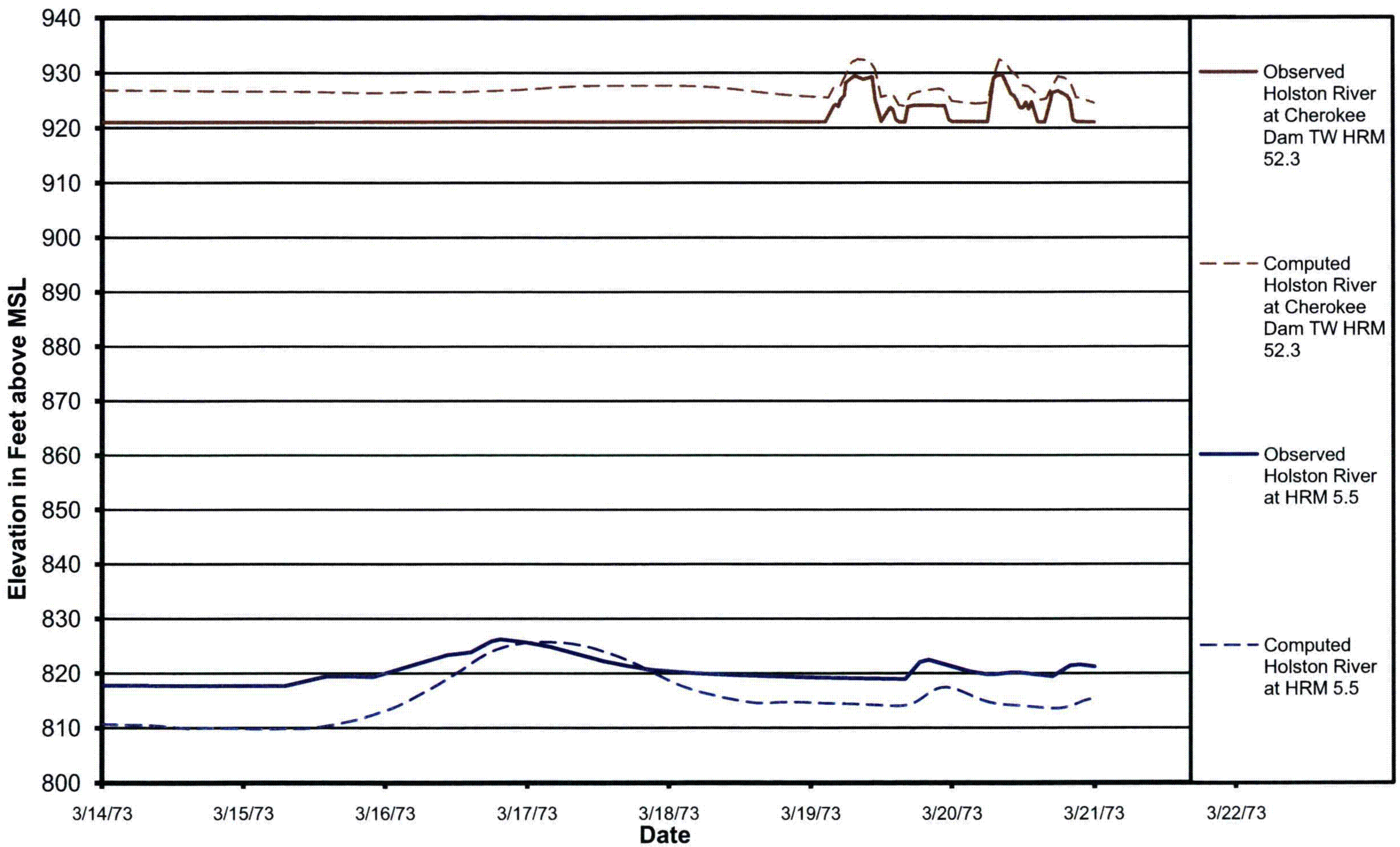



**Figure 35: Observed and Simulated Stage Hydrographs for the Fort Loudoun-Tellico Watershed, March 1973**

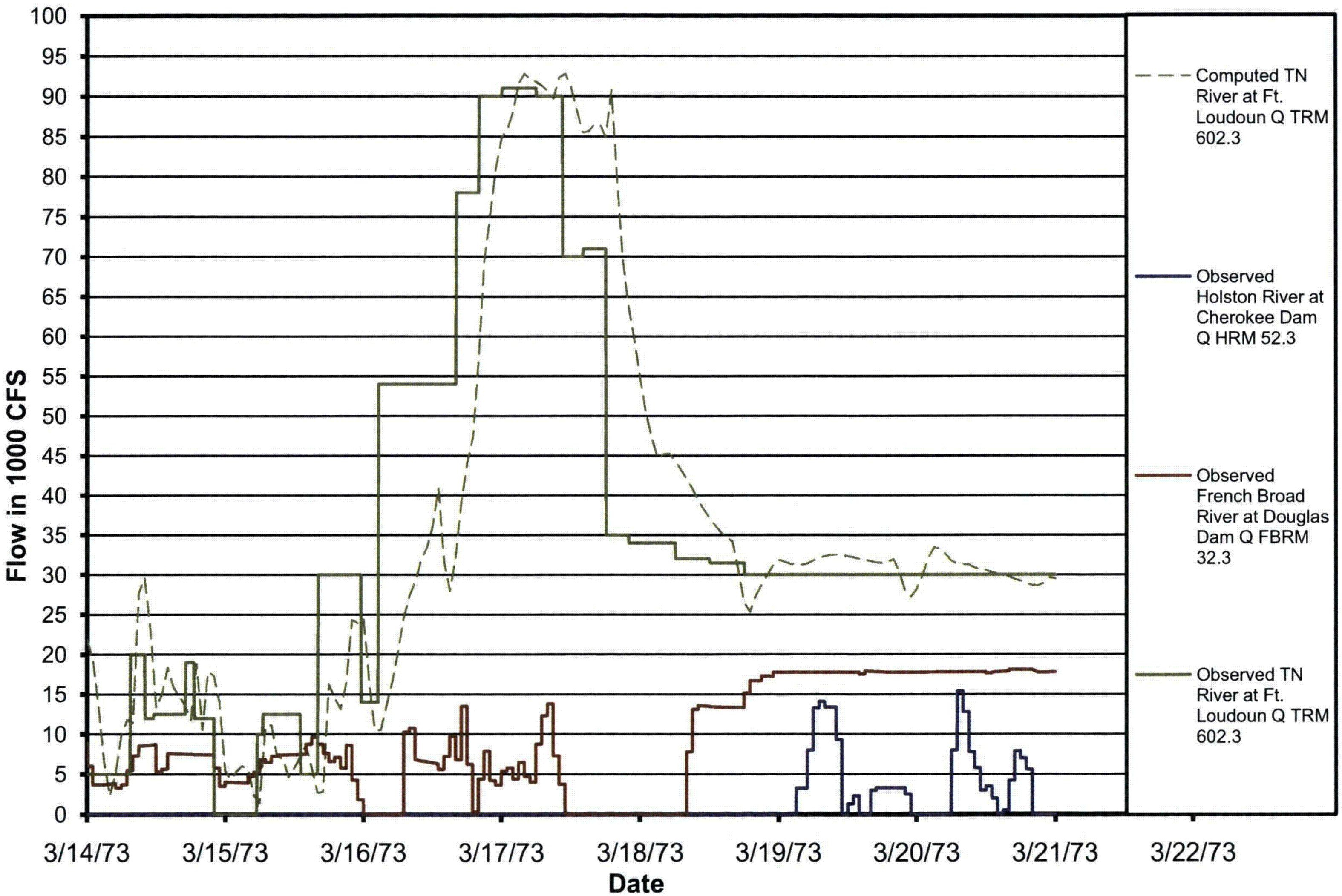



**Figure 36: Observed and Simulated Discharge Hydrographs for the Fort Loudoun-Tellico Watershed, March 1973**

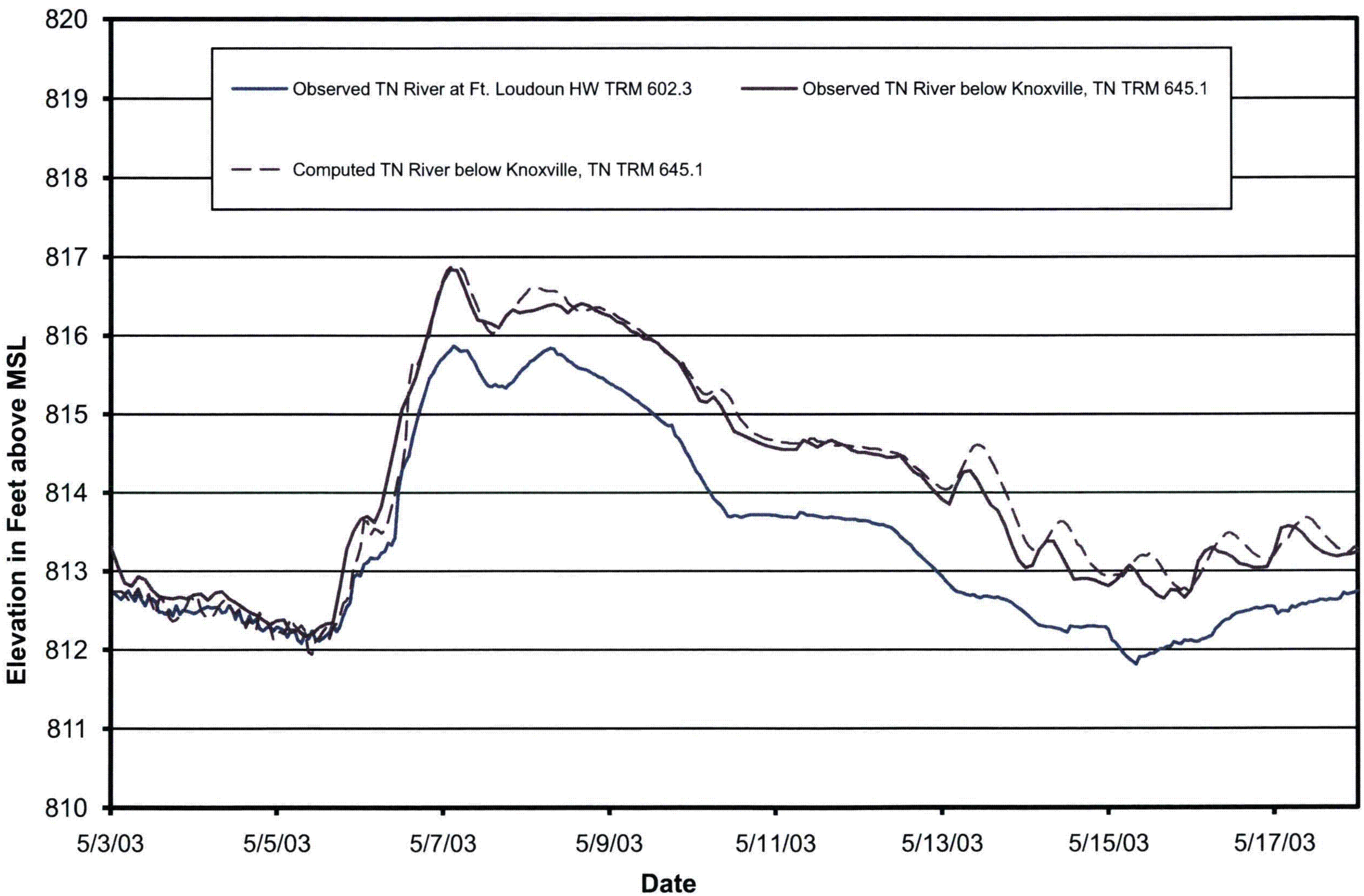



**Figure 37: Observed and Simulated Stage Hydrographs for the Fort Loudoun-Tellico Watershed, May 2003**

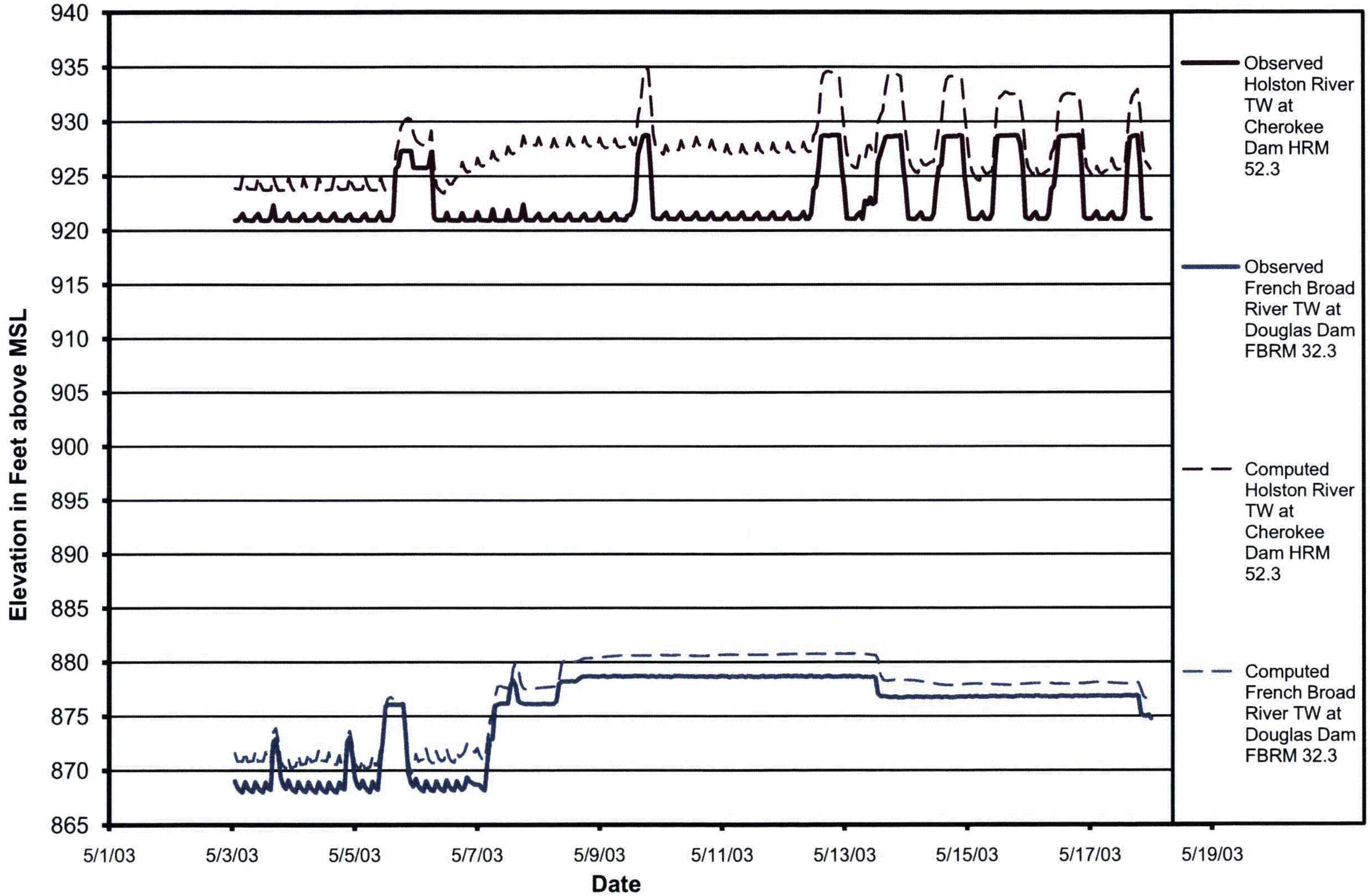



Figure 38: Observed and Simulated Stage Hydrographs for the Fort Loudoun-Tellico Watershed, May 2003

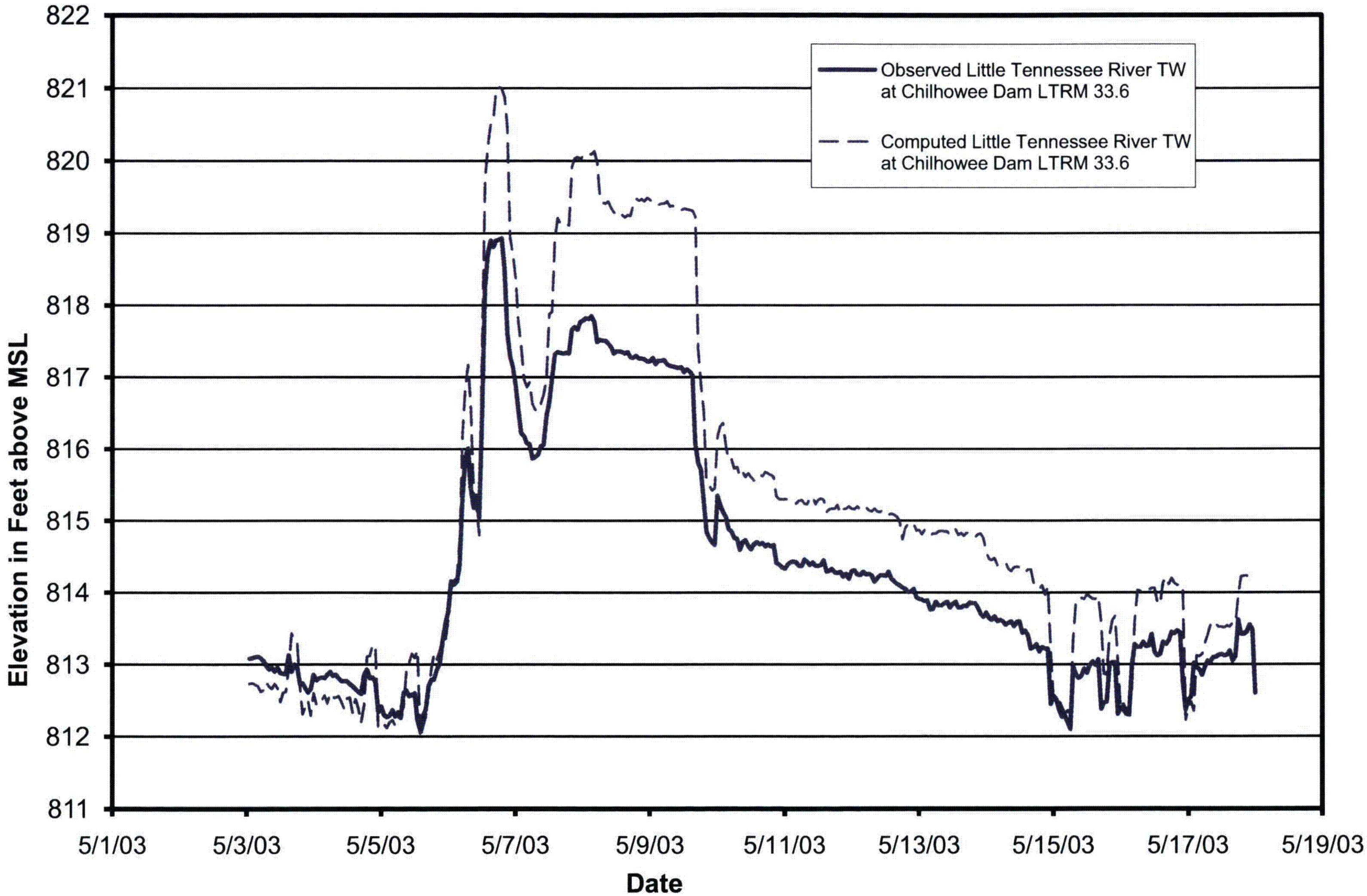



**Figure 39: Observed and Simulated Stage Hydrographs for the Fort Loudoun-Tellico Watershed, May 2003**

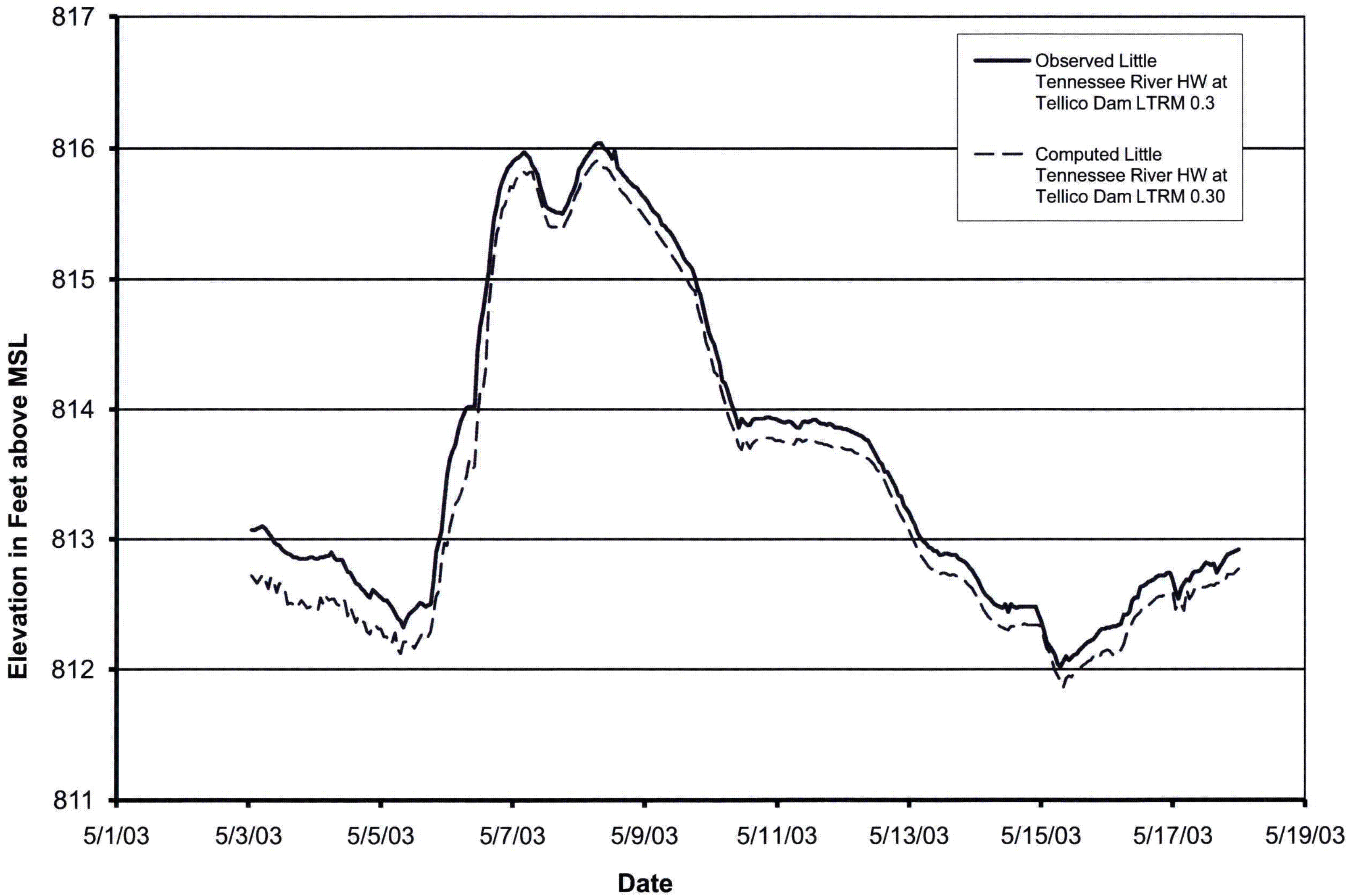



**Figure 40: Observed and Simulated Stage Hydrographs for the Fort Loudoun-Tellico Watershed, May 2003**

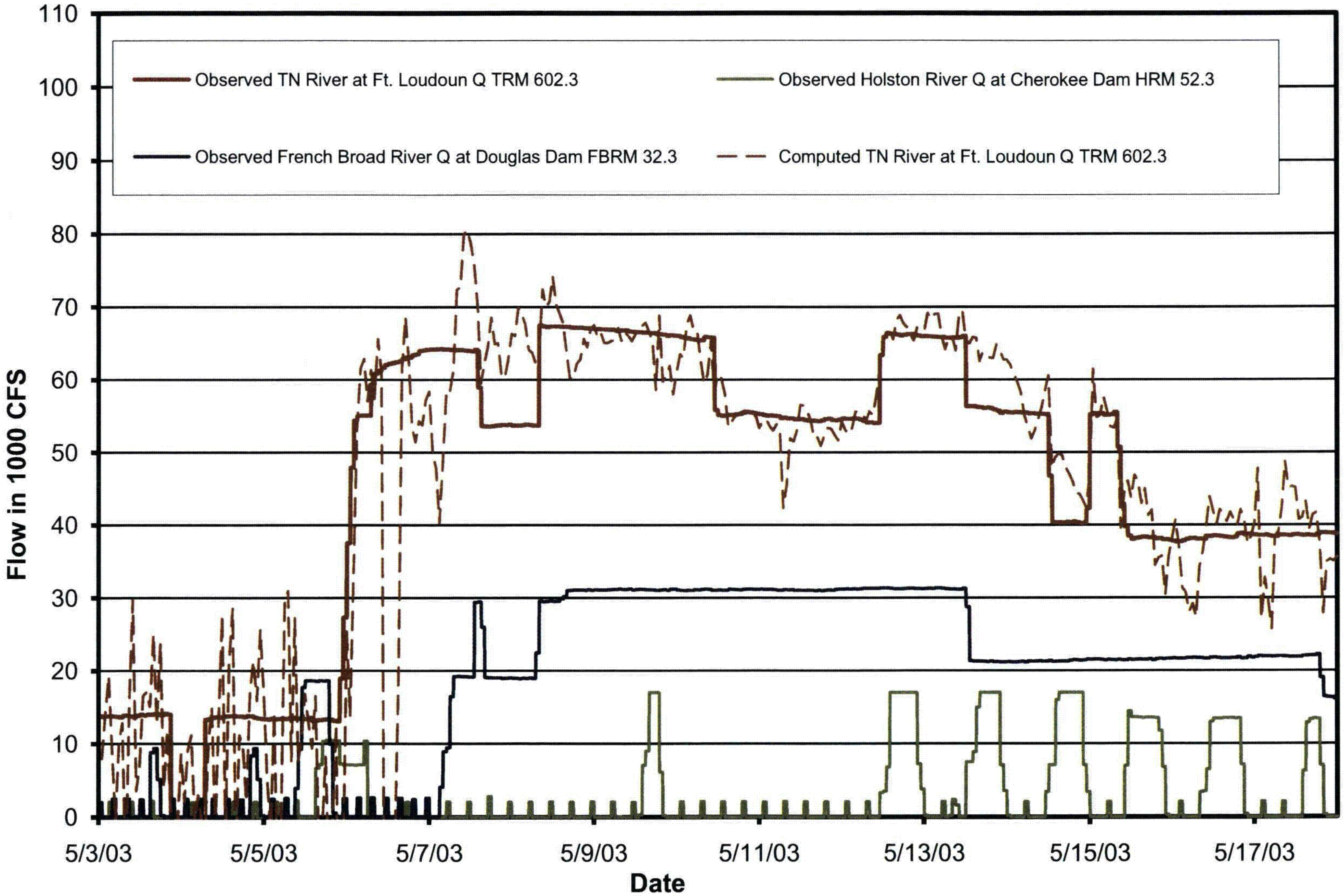



**Figure 41: Observed and Simulated Discharge Hydrographs for the Fort Loudoun-Tellico Watershed, May 2003**

**Table 28: Validated Six-hour Unit Hydrograph for Subbasin 8, French Broad Local.**

| Ordinate No. | t, hours | Q (cfs) |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 6 | 8,600 |
| 3 | 12 | 6,000 |
| 4 | 18 | 3,100 |
| 5 | 24 | 1,800 |
| 6 | 30 | 1,300 |
| 7 | 36 | 700 |
| 8 | 42 | 400 |
| 9 | 48 | 220 |
| 10 | 54 | 120 |
| 11 | 60 | 0 |

**Table 29: Validated Six-hour Unit Hydrograph for Subbasin 16, Holston River Local, Cherokee Dam to Knoxville Gage**

| Ordinate No. | t, hours | Q, cfs |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 3 | 5,200 |
| 3 | 6 | 7,800 |
| 4 | 9 | 8,400 |
| 5 | 12 | 7,800 |
| 6 | 15 | 6,700 |
| 7 | 18 | 5,200 |
| 8 | 21 | 3,600 |
| 9 | 24 | 2,400 |
| 10 | 27 | 2,000 |
| 11 | 30 | 1,600 |
| 12 | 33 | 1,200 |
| 13 | 36 | 1,000 |
| 14 | 39 | 800 |
| 15 | 42 | 780 |
| 16 | 45 | 760 |
| 17 | 48 | 740 |
| 18 | 51 | 720 |
| 19 | 54 | 700 |
| 20 | 57 | 640 |
| 21 | 60 | 600 |
| 22 | 63 | 540 |
| 23 | 66 | 460 |
| 24 | 69 | 420 |
| 25 | 72 | 400 |
| 26 | 75 | 380 |
| 27 | 78 | 350 |
| 28 | 81 | 260 |
| 29 | 84 | 220 |
| 30 | 87 | 140 |
| 31 | 90 | 100 |
| 32 | 93 | 40 |
| 33 | 96 | 0 |

**Table 30: Validated Four-hour Unit Hydrograph for Subbasin 17, Little River.**

| Ordinate No. | *t*, hours | *Q*, cfs |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 2 | 50 |
| 3 | 4 | 102 |
| 4 | 6 | 1200 |
| 5 | 8 | 3021 |
| 6 | 10 | 5000 |
| 7 | 12 | 8025 |
| 8 | 14 | 10500 |
| 9 | 16 | 11726 |
| 10 | 18 | 11000 |
| 11 | 20 | 9213 |
| 12 | 22 | 7500 |
| 13 | 24 | 6245 |
| 14 | 26 | 5500 |
| 15 | 28 | 4876 |
| 16 | 30 | 4350 |
| 17 | 32 | 3950 |
| 18 | 34 | 3500 |
| 19 | 36 | 3100 |
| 20 | 38 | 2700 |
| 21 | 40 | 2350 |
| 22 | 42 | 2100 |
| 23 | 44 | 1800 |
| 24 | 46 | 1600 |

| Ordinate No. | *t*, hours | *Q*, cfs |
|---|---|---|
| 25 | 48 | 1400 |
| 26 | 50 | 1225 |
| 27 | 52 | 1100 |
| 28 | 54 | 1000 |
| 29 | 56 | 950 |
| 30 | 58 | 850 |
| 31 | 60 | 775 |
| 32 | 62 | 700 |
| 33 | 64 | 650 |
| 234 | 66 | 600 |
| 35 | 68 | 550 |
| 36 | 70 | 500 |
| 37 | 72 | 450 |
| 38 | 74 | 400 |
| 39 | 76 | 350 |
| 40 | 78 | 300 |
| 41 | 80 | 250 |
| 42 | 82 | 225 |
| 43 | 84 | 200 |
| 44 | 86 | 150 |
| 45 | 88 | 100 |
| 46 | 90 | 75 |
| 47 | 92 | 50 |
| 48 | 94 | 25 |
| 49 | 96 | 0 |

**Table 31: Validated Six-hour Unit Hydrograph for Subbasin 18, Fort Loudoun Local.**

| Ordinate No. | *t*, hours | *Q*, cfs |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 3 | 8500 |
| 3 | 6 | 20000 |
| 4 | 9 | 17000 |
| 5 | 12 | 11500 |
| 6 | 15 | 5000 |
| 7 | 18 | 2000 |
| 8 | 21 | 1700 |
| 9 | 24 | 1487 |
| 10 | 27 | 1100 |
| 11 | 30 | 861 |
| 12 | 33 | 400 |
| 13 | 36 | 0 |

**Table 32: Validated Six-hour Unit Hydrograph for Subbasin 24, Little Tennessee River Local, Chilhowee to Tellico Dam.**

| Ordinate no. | *t*, hours | Post-Tellico Dam *Q*, cfs |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 6 | 9,000 |
| 3 | 12 | 22,600 |
| 4 | 18 | 15,500 |
| 5 | 24 | 9,500 |
| 6 | 30 | 6,500 |
| 7 | 36 | 4,000 |
| 8 | 42 | 2,000 |
| 9 | 48 | 900 |
| 10 | 54 | 0 |