PMBeICOL PEmails

From: Spink, Thomas E [tespink@tva.gov]
Sent: Thursday, August 27, 2009 10:13 AM
To: Sebrosky, Joseph
Subject: Hydrology Calc Submittal Test
Attachments: Calc CDQ000020080049_Rev0_1973 Flood Data Verification_060509.pdf

Joe,

Please find attached a hydrology calculation PDF file to use as a test for acceptance as an electronic submittal. I will follow this test with a second test due to differences in the cover signature page quality. Please let me know if this file can be successfully processed.

Thank you

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Hearing Identifier: Bellefonte_COL_Public_EX
Email Number: 1649

Mail Envelope Properties (B648F67990B15146B8646584D20B8DD10AC5DA4B)

Subject: Hydrology Calc Submittal Test
Sent Date: 8/27/2009 10:13:10 AM
Received Date: 8/27/2009 10:14:41 AM
From: Spink, Thomas E

Created By: tespink@tva.gov

Recipients:
"Sebrosky, Joseph" <Joseph.Sebrosky@nrc.gov>
Tracking Status: None

Post Office: TVACOCXVS2.main.tva.gov

Files	**Size**	**Date & Time**
MESSAGE	493	8/27/2009 10:14:41 AM
Calc CDQ000020080049_Rev0_1973 Flood Data Verification_060509.pdf	3656422	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
0 L58 090612 001	calculations(nuclear)	

Calc Title: 1973 Flood Data Verification Package

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	CDQ000020080049	N/A	0	

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 EDCNs 22404 (SQN), 54018 (WBN), Later BFN | APPLICABLE DESIGN DOCUMENT(S) N/A | CLASSIFICATION 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
snhenry	632-6315	CEB	See Page 5	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Stuart N. Henry DAVID B HUNT	27 May 2009 27MAY09	- Excluding App. A Eric EDDS	27 May 2009
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
BENJAMIN C. WEMES MICHAEL T. STANLEY	27 May 2009 27MAY09	6/8/09 K.R. Spates	6-9-09

STATEMENT OF PROBLEM/ABSTRACT

6/5/09

Review and qualify rainfall and related input data to the FLDHYDRO subroutine from March 1973 storm. This calculation assembles and documents historical data related to the March 1973 storm rainfall used as inputs into the FLDHYDRO code used to compute basin average hourly rainfall for the March 1973 storm.

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	CDQ000020080049	0

ALTERNATE CALCULATION IDENTIFICATION

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

CATEGORIES

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN
A	PMF		
A	Rain		
A	Flood		
A	River		

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	S	CN	GEN	CEB	CDQ000020080036 - SOCH Calibration Ft. Loudon Reservoir	0
A	S	CN	GEN	CEB	CDQ000020080037 - SOCH Calibration Watts Bar Reservoir	0
A	S	CN	GEN	CEB	CDQ000020080038 - SOCH Calibration Melton Hill Reservoir	0
A	S	CN	GEN	CEB	CDQ000020080039 - SOCH Calibration Chickamauga Reservoir	0
A	S	CN	GEN	CEB	CDQ000020080040 - SOCH Calibration Nickajack Reservoir	0
A	S	CN	GEN	CEB	CDQ000020080041 - SOCH Calibration Guntersville Reservoir	0
A	P	CN	GEN	CEB	CDQ000020080057 - Sub-Basin (48) Sequatchie at Whitwell UH Validation	0
A	P	CN	GEN	CEB	CDQ000020080058 - Sub-Basin (46) South Chickamauga Near Chattanooga UH Validation	0
A	P	CN	GEN	CEB	CDQ000020080059 - Sub-Basin (49-50) Guntersville Local UH Validation	0
A	P	CN	GEN	CEB	CDQ000020080060 - Sub-Basin (47A) Nickajack Local and (47B) North Chickamauga Creek UH Validation	0
A	P	CN	GEN	CEB	CDQ000020080062 - Sub-Basin (7,17) Little Pigeon/Little River UH Validation	0
A	P	CN	GEN	CEB	CDQ000020080064 - Sub-Basin (44A, 44B, 45) Chickamauga Local UH Validation	0
A	P	CN	GEN	CEB	CDQ000020080065 - Sub-Basin (25, 33, 34,37) Watts Bar Basins UH Validation	0
A	P	CN	GEN	CEB	CDQ000020080068 - Sub-Basin (27) Melton Hill Local UH Validation	0
A	P	CN	GEN	CEB	CDQ000020080069 - Sub-Basin (8, 16-18, 24) Ft. Loudon-Tellico UH Validation	0

NPG CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER CDQ000020080049

Title 1973 Flood Data Verification Package

Revision No.	DESCRIPTION OF REVISION
0	Initial Issue (23 PAGES)

NPG COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document	1973 Flood Data Verification Package	Rev. 0	Plant: GEN	

Subject:
The purpose of this calc is to verify the 1973 Flood Data for input into the SOCH model.

☐ 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.)

The files listed below 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.

Attachments:

A	Appendix_A_Thiessen Polygon and Area Measurement Software Check.pdf
1	Attachment_01_FLDHYDRO_Input_Files_with_Overlays.pdf
2	Attachment _02_Guntersville_Thiessens_6_GIE_322_E_200803_R2_D_05112009_Rev2pjn.pdf
3	Attachment_03_Summary_Thiessens_ESRI_vs_Geopak.pdf
4	Attachment_04_USWB Rainfall Map.pdf
5	Attachment_05_Rainfall Data Hourly Summation & Daily Adjustments.xls
6	Attachment_06_Calculated_vs_Corrected_Thiessens.pdf
7	Attachment_07_Feb_1973_Precipitation_Data.pdf
8	Attachment_08_March_1973_Precipitation_Data.pdf
9	Attachment_09_FLDHYDRO Input 12May09.pdf
10	Attachment_10_Twts_1973GagingStations_gdb_05112009_Rev4pjn.pdf

☐ Microfiche/eFiche

NPG CALCULATION VERIFICATION FORM

Calculation Identifier CDQ000020080049 Revision 0

Method of verification used:

1. Design Review ☒
2. Alternate Calculation ☒
3. Qualification Test ☐

5-13-09

Verifier Date

Benjamin C. Nemec

Comments:

This calculation was verified by an independent design review and utilized alternate calculations or methods to verify the adequacy of non-QA software programs. 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 needed to verify data and analysis details found in this calculation.

The calculations performed by non-QA software were con firmed for acceptability by alternate computational methods (i.e., computer software or alternate hand methods) as required by NEDP-2, Section 9.0.P. The alternate computational methods are described in Appendix A and in Sections 4.4, 4.5, 7.3 and 7.4.

NPG CALCULATION TABLE OF CONTENTS

Calculation Identifier: 1973 Flood Data Verification Package	Revision:	0

TABLE OF CONTENTS

1. Purpose

Data from historical storms in the Tennessee River and its tributaries above the existing Bellefonte Nuclear Plant (BLN) site are required in the development and calibration of the runoff and stream course models used to determine the design basis flood levels for the TVA Nuclear Plant sites. One of the tasks involves the calibration of the Tennessee Valley Authority (TVA) Simulated Open Channel Hydraulic (SOCH) model, which performs transient flow routing calculations to determine elevation and discharge at selected locations. The data from the historical storms is used in the FLDHYDRO code (Reference 2.2) to compute discharges for those areas draining directly into the modeled reservoirs, which are inputs to the SOCH model.

The purpose of this calculation is to document the March 1973 rainfall input used to develop flood inflow inputs to the SOCH model to support the BLN Combined Operating License Application (COLA) and the design basis Probable Maximum Flood (PMF) analysis for the TVA operating nuclear plants. The March 1973 rainfall includes the recorded hourly and daily rainfall amounts from March 15-March 17, 1973, for the sub-basins encompassing the Guntersville, Nickajack, Fort Loudon, Chickamauga, Watts Bar, and Melton Hill Reservoirs. This calculation also documents the data for the rainfall gage location, the 30-day antecedent rainfall, the watershed basin and reservoir areas, the Thiessen weights and the Antecedent Precipitation Index (API) region code used in the flood rainfall determination.

History

TVA developed the method of analysis, procedures and computer programs needed to determine the design basis flood levels for nuclear plant sites in the 1970s. At that time there were no standard computer programs (codes) available that would handle unsteady flow and dam failure analysis. As a result of this early work and method development, TVA developed a runoff and stream course modeling process for the TVA reservoir system that provided the basis for currently licensed plants (Sequoyah Nuclear Plant, Watts Bar Nuclear Plant and Browns Ferry Nuclear Plant). The BLN Unit 1 and Unit 2 Final Safety Analysis Report (FSAR) and the BLN Unit 3 and Unit 4 COLA were also based on this process.

2. References

2.1 Hydrology for Engineers, Third Edition, R.K. Linsley, Jr., M.A. Kohler, J.L.H. Paulus, McGraw-Hill Book Company, Inc., 1982, ISBN 0-07-037956-4, section 3-11, pg. 71-72.

2.2 UNITGRPH, FLDHYDRO,TRBROUTE, CHANROUT Users Manual (EDMS No. #L58 090325 001)

2.3 CDQ000020080057, "Sub basin (48) Sequatchie at Whitwell Unit Hydrograph Validation", Rev0 (EDMS #L58 081125 800)

2.4 CDQ000020080058, "Sub basin (46) South Chickamauga Near Chattanooga Unit Hydrograph Validation", Rev0 (EDMS #L58 081105 002)

2.5 CDQ000020080059, "Sub basin (49-50) Guntersville Local Unit Hydrograph Validation", Rev0 (EDMS # L58 090603 002)

2.6 CDQ000020080060, "Sub basin (47A) Nickajack Local and (47B) North Chickamauga Creek Unit Hydrograph Validation", Rev0 (EDMS #L58 090424 005)

2.7 CDQ000020080062, "Sub basin (7, 17) Little Pigeon/Little River Unit Hydrograph Validation", Rev0 (EDMS #L58 090227 001)

2.8 CDQ000020080064, "Sub basin (44A, 44B, 45) Chickamauga Local Unit Hydrograph Validation", Rev0 (EDMS #L58 090224 004)

2.9 CDQ000020080065, "Sub basin (25, 33, 34, 37) Watts Bar Basins Unit Hydrograph Validation", Rev0 (EDMS #L58 090511 002)

2.10 CDQ000020080068, "Sub basin (27) Melton Hill Local Unit Hydrograph Validation", Rev0 (EDMS #L58 090511 003)

2.11 CDQ000020080069, "Sub basin (8, 16-18, 24) Ft. Loudon-Tellico Unit Hydrograph Validation", Rev0 (EDMS #L58 090511 001)

2.12 Not Used

2.13 Thiessen Weights Above Guntersville Dam for 1973 Event with Precipitation Areas, TVA map #6 Guntersville_Thiessens_6_GIE_322_E_200803_R2_D_05112009_Rev2pjn.pdf (Attachment 2) provided by RFI BE2112300B008 rev3 (EDMS #L58 090512 800)

2.14 "Rainfall Station Descriptions for the Tennessee Valley Watershed Above Guntersville Reservoir for use in the BLN COLA SOCH Model" (EDMS #L58 090212 800)

2.15 TVA Water Control Projects and Other Major Hydro Developments in the Tennessee and Cumberland Valleys (also known as 'the Blue Book'), Technical Monograph No. 55, Volumes One and Two, Tennessee Valley Authority, Tellico information dated April 1999, all others dated January 1978.

2.16 "Rainfall Recorder Hourly Precipitation Data for March of 1973 for use in the BLN COLA SOCH Model" (EDMS #L58 090306 801)

2.17 TVA prepared FLDHYDRO input data files (Attachment 9), and a pdf of historical USWB Rainfall Relations map (Attachment 4) provided by RFI BE21142230B006 rev 1 (EDMS #L58 090512 801)

2.18 U.S. Geologic Survey Quadrangle maps, stored in the TVA Enterprise GIS Data Repository; Data Type: SDE Raster, Server: tvagisp; User: ras_viewer; Instance: rasp; Database: ; Raster: DRGDBA.DRG_24K.

3. Assumptions

3.1 General Assumptions

3.1.1 **Assumption**: The gage rainfall and location data used in this calculation is adequate for use in the design basis PMF analysis.
Technical Justification: The rainfall and other input data were not obtained via a 10 CFR 50 Appendix B program; however it represents the best and most complete data set available. Based on the Acceptance Criteria Section of NUREG 0800 Standard Review Plan (SRP) 2.4.1 this data is not expected to meet the requirements of an Appendix B program, excerpt follows:

"*Data collected, maintained, and distributed by Federal and State agencies, such as USGS, NOAA, NRCS, USACE, and various State water resources departments, are adequate for safety evaluation of the plant.*"

TVA is the Federal agency that owns and operates the reservoir system in the watersheds of concern. TVA and National Weather Service were responsible for operating the majority of the gages in the Tennessee Valley at the time of the 1973 flood.

The historical data from TVA records used to calibrate the models to the 1973 historical flood of record has been reviewed for adequacy by the steps addressed in the Methodology sections 4.1-4.5.

3.1.2 **Assumption:** Hourly rainfall data used from transcribed pages, provided by TVA (Reference 2.16), is adequate for use in the design basis PMF analysis.
Technical Justification: Original gage charts and/or forms used to record the hourly data were not located.Since the rainfall recorder system was operated by TVA, the hourly recorder data transcribed by TVA was considered to be accurate if it summed to within ±0.05 inches of the total daily rainfall published in the February 1973 and March 1973 Precipitation in the Tennessee River Basin Reports compiled by the TVA Hydraulic Data Branch (Attachments 7 and 8). The Methodology is documented in Section 4.2

3.1.3 **Assumption:** Rainfall station location latitude and longitude determined by scaling from the reference index map in the February 1973 and March 1973 Precipitation in the Tennessee River Basin Reports (Attachments 7 and 8) are adequate for use in the design basis PMF analysis.
Technical Justification: TVA "Description of Rainfall Station" forms were not available for stations C19 (Double Springs ES) and 426A (Lenoir City). Plotted locations for station C19 and 426A were checked for adequacy against the historical maps included in Attachments 7 and 8 to confirm the acceptability of the scaling.

3.1.4 **Assumption:** Rainfall Station locations determined from the gage station location log books, "Description of Rainfall Station" forms, provided by TVA, (applicable pages found in Reference 2.14) are acceptable for use in the design basis PMF analysis.
Technical Justification: TVA "Description of Rainfall Station" forms were not available for station 157 (Roddy R ES) and 711 (Oak Ridge ES). Station locations were checked for adequacy against the historical maps included in February 1973 and March 1973 Precipitation in the Tennessee River Basin Reports (Attachments 7 and 8).

3.1.5 **Assumption:** Rainfall station location latitude and longitude determined based on UT Knoxville Geology building location is acceptable for use in the design basis PMF analysis.
Technical Justification: TVA "Description of Rainfall Station" form was not available for station 651 (U of TN Geology Z ES). Station location was checked for adequacy against the known building location which has not changed since prior to 1973.

3.1.6 **Assumption:** Watershed basin and reservoir areas and Thiessen weights determined using ESRI Arcmap 9.2 GIS mapping software are acceptable for use in the design basis PMF analysis.
Technical Justification: The ESRI Arcmap 9.2 GIS mapping software was used to calculate watershed basin and reservoir areas and Thiessen weights. This non-QA software is used widely in the industry for GIS mapping and is considered the best currently available method for performing these calculations. The areas obtained by the software were verified against published values and alternate calculation methods (see Appendix A), and show an acceptable level of agreement as described in Sections 4.3 and 4.4.

Based on age, the published values were determined by graphical hand methods (planimeter, graph paper, etc.) and the Arcmap results are considered to be of equivalent accuracy.

3.2 Unverified Assumptions

None.

4. Methodology

4.1 Gage Selection and Location Review - Figure 1

Existing published data and TVA files were reviewed to determine rainfall gages that were in service at the time of the March 1973 storm event and in or near the boundaries of the watersheds of interest. Files were reviewed to find records of gage locations and recorded rainfall amounts. The following steps were taken to independently document this data prior to inclusion in this calculation.

- The data in Reference 2.14 was collected from information retrieved from TVA files.
- Dates were checked to ensure the gage was in place during the period of the 1973 event.
- Locations for gages in place during the period of the 1973 event were taken from the station description sheet in the file and were assumed correct if within ±200' of the plotted map location (Attachment 2) when compared to USGS quadrangle maps (Reference 2.18).

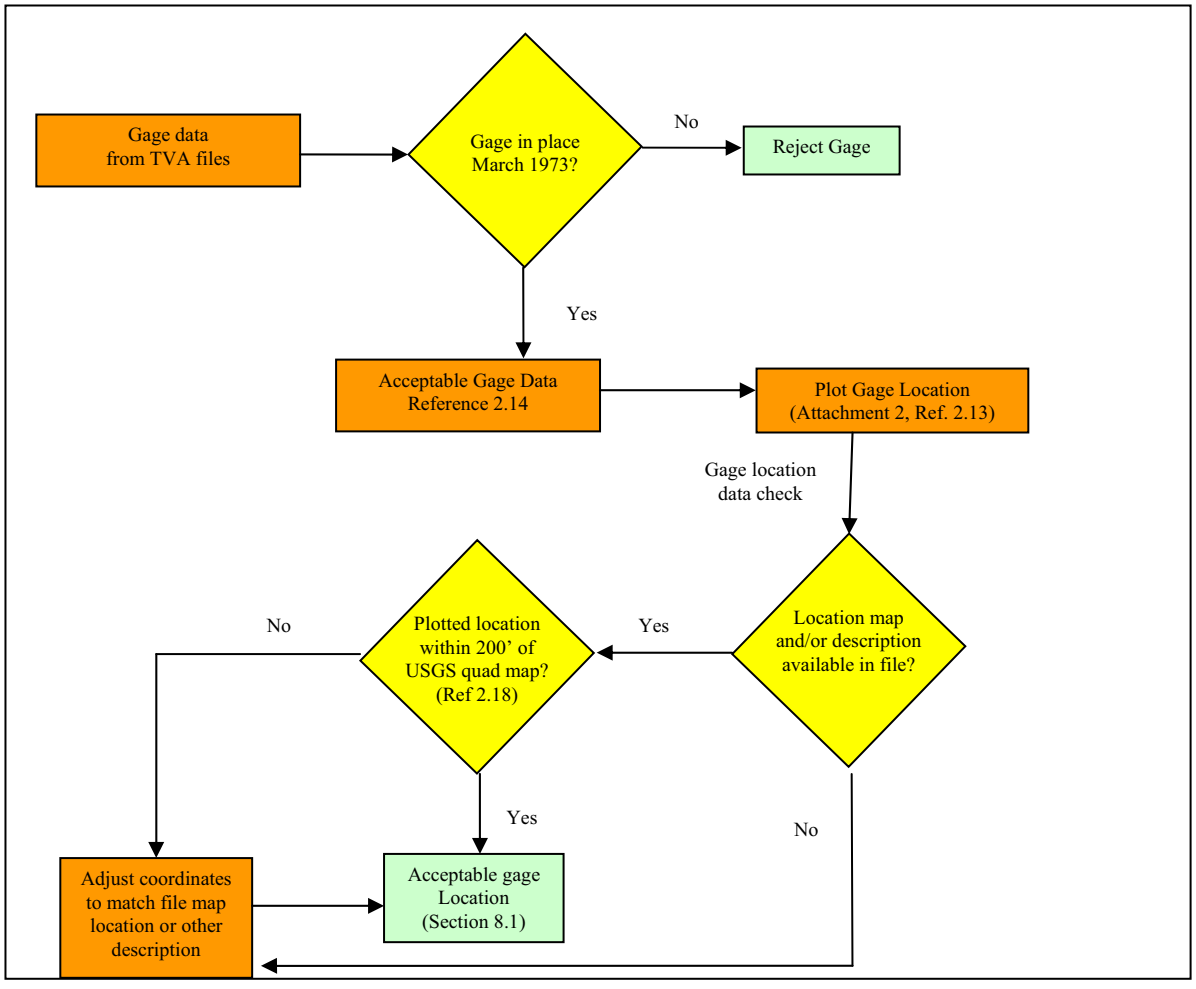

Figure 1 - Process Used for Gage Selection and Location Review

4.2 Rainfall Data Validation - Figure 2

Original gage charts and/or forms used to record the hourly data were not located. Hourly rainfall data was used from transcribed pages and original BLN FSAR studies (Reference 2.16) and was input into the FLDHYDRO input file format (Attachment 9). This hourly data was then input into a Microsoft Excel spreadsheet (Attachment 5), summed, and checked against published daily rainfall data (Attachment 8).

The daily rainfall values were taken from the published daily rainfall data (Attachment 8). Some of the gages were read at times of day different than the standard morning reading time or had rainfall from a previous period included. These stations required adjustment to be used in the FLDHYDRO program. The rainfall from daily stations was time redistributed based on a nearby recording gage. Recording gages were chosen based on nearness to the adjusted gage and rainfall amount; i.e. the nearest gage with the closest total rainfall amount was used for the adjustment.

Re-distribution was performed on stations requiring adjustment as follows:

$$\frac{Sta.A_{total}}{Sta.B_{total}} \times \text{Sta.B Incremental Rainfall} = \text{Sta.A Adjusted Incremental Rainfal}$$

Where Station A is the station requiring adjustment and Station B is the nearby recording gage. These adjustments were calculated and then checked against the FLDHYDRO input files (Attachment 5). See Section 7.2 for a table of stations requiring adjustment and the stations used to make the adjustments.

The 30-day antecedent rainfall used in the FLDHYDRO input files were also checked against the published daily rainfall data (Attachments 7 & 8).

Note: Recorders are designated in data files using an ‘R’ after the number. Where recorders would have a 5 digit name (e.g. 403AR), alphabetic station designation (i.e. ‘A’) is dropped due to code limits of 4 characters (e.g. 403A is a recorder but shows up in data as 403R).

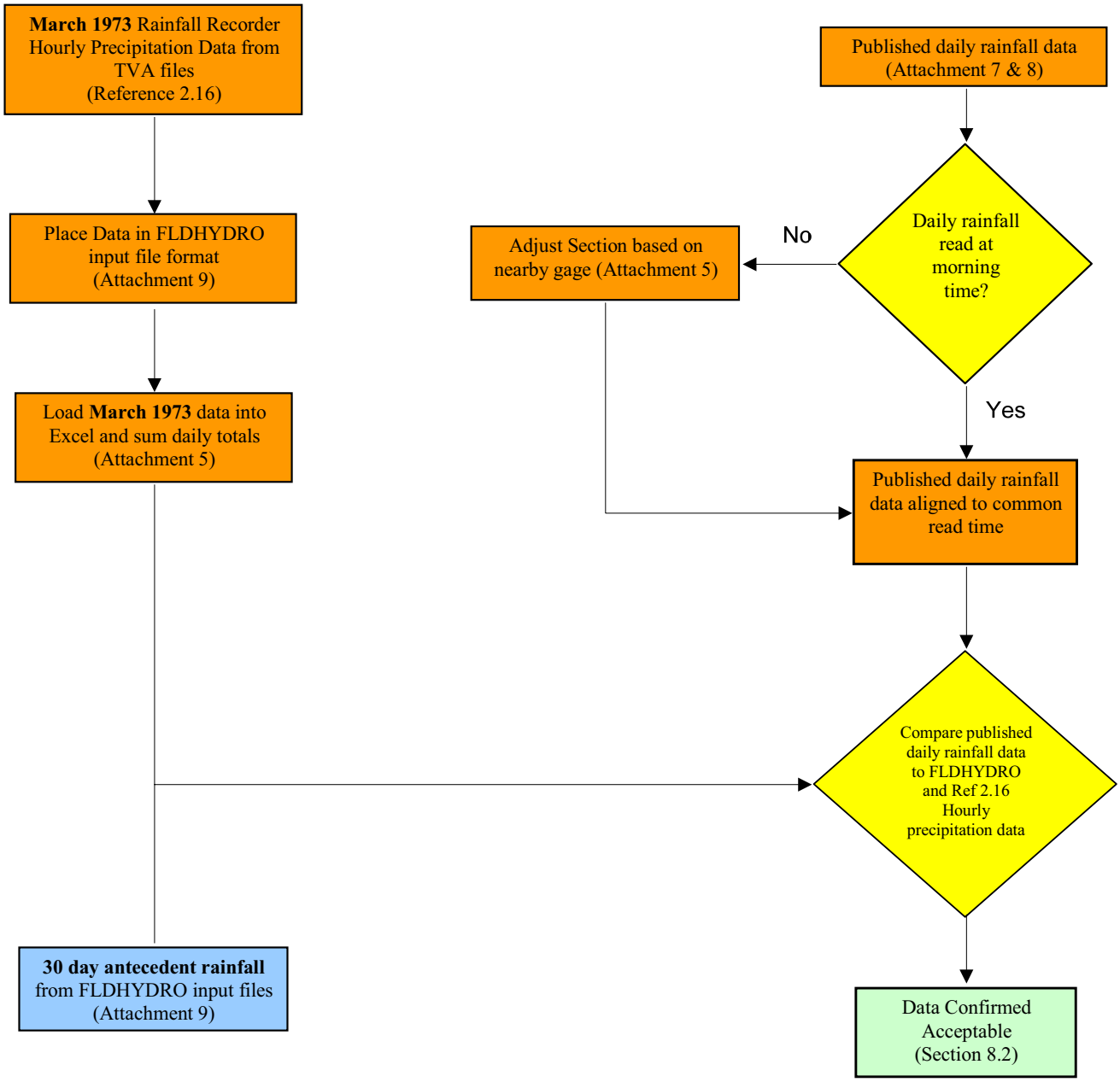

Figure 2: Process Flow Chart for Rainfall Data Validation

4.3 Watershed Basin and Reservoir Area Review - Figure 3

USGS quadrangle maps (References 2.18) were geo-referenced and digitized. Watershed basin and reservoir areas were calculated using ESRI Arcmap 9.2 GIS mapping software as a planimeter. Since ESRI Arcmap 9.2 GIS mapping software is non-QA software, values were checked by alternate calculation presented in Appendix A.

To confirm the watershed basin area calculations, the areas were checked against those used in the FLDYDRO input files (Reference 2.17) and those used in the unit hydrograph calculations (References 2.3- 2.11). A comparison table is located in Section 7.3.

The calculated reservoir areas were compared against the reservoir areas published in Reference 2.15. A comparison table of the calculated reservoir areas and the published reservoir areas is given in Section 7.3.

The watershed basin and reservoir areas calculated are provided in two tables on the Thiessen weight map (Attachment 2).

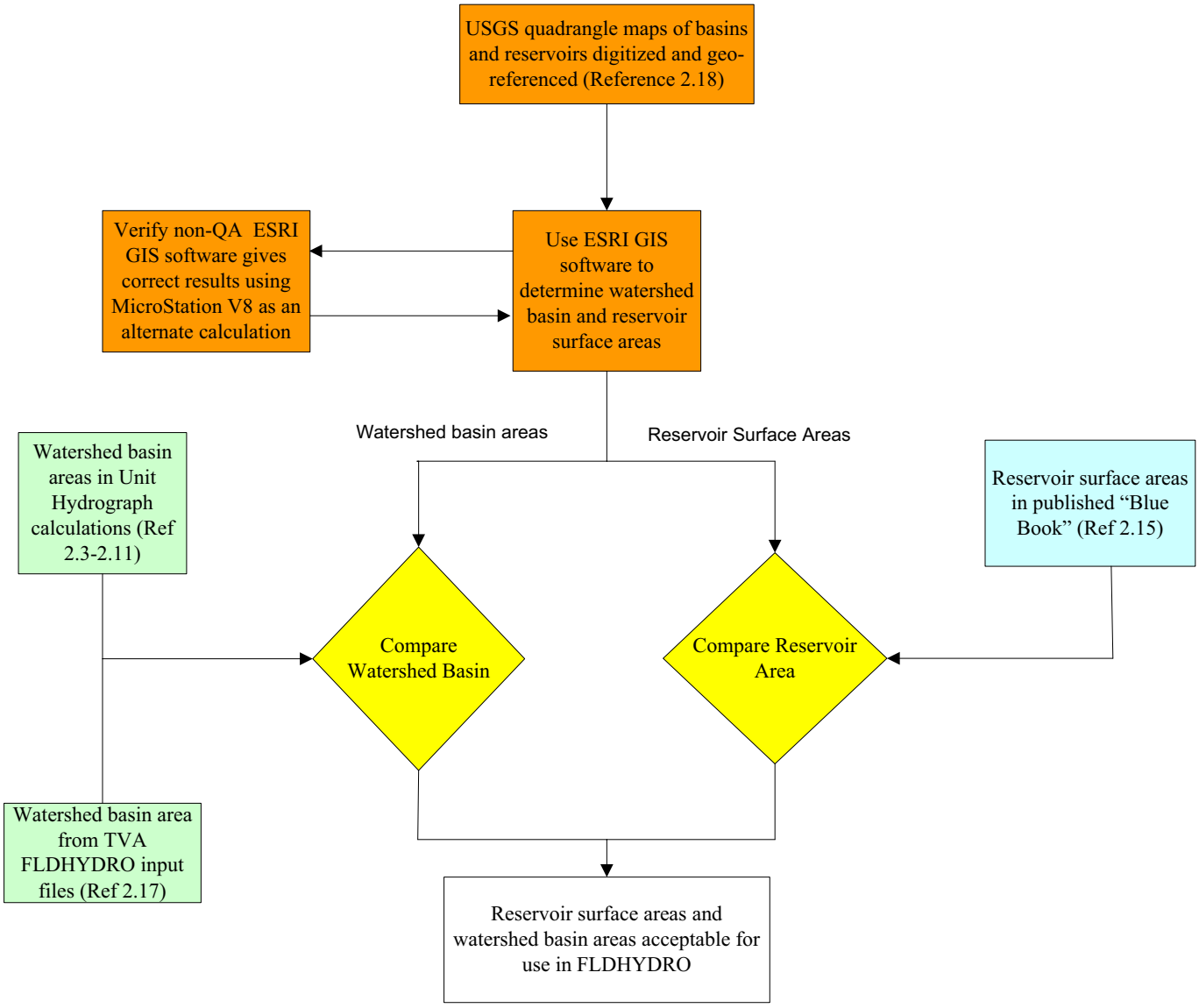

Figure 3: Process Flow Chart for Watershed Basin and Reservoir Area Calculation

4.4 Thiessen Weight Review - Figure 4

The Thiessen method is a common method for calculating weighting factors used to determine the gage influence on a watershed and distribute rainfall across the watershed area based on a non-uniform distribution of recording gages (Ref. 2.1). Watershed areas in Reference 2.3 through Reference 2.11 calculations were determined using GIS software and are shown on Attachment 2, Reference 2.13. Coordinate data in Reference 2.14 was used for the rainfall gage locations shown on the map (Attachment 2, Reference 2.13) and Thiessen weight calculation was performed using the Thiessen polygon tool included in the ESRI Arcmap 9.2 GIS mapping software. The resulting weights were rounded to three (3) significant digits and resulting weights were modified to ensure that they totaled 1.000 within each watershed (Attachment 6). Since ESRI Arcmap 9.2 GIS mapping software is non-QA, the software results are checked by alternate methods and documented in Appendix A.

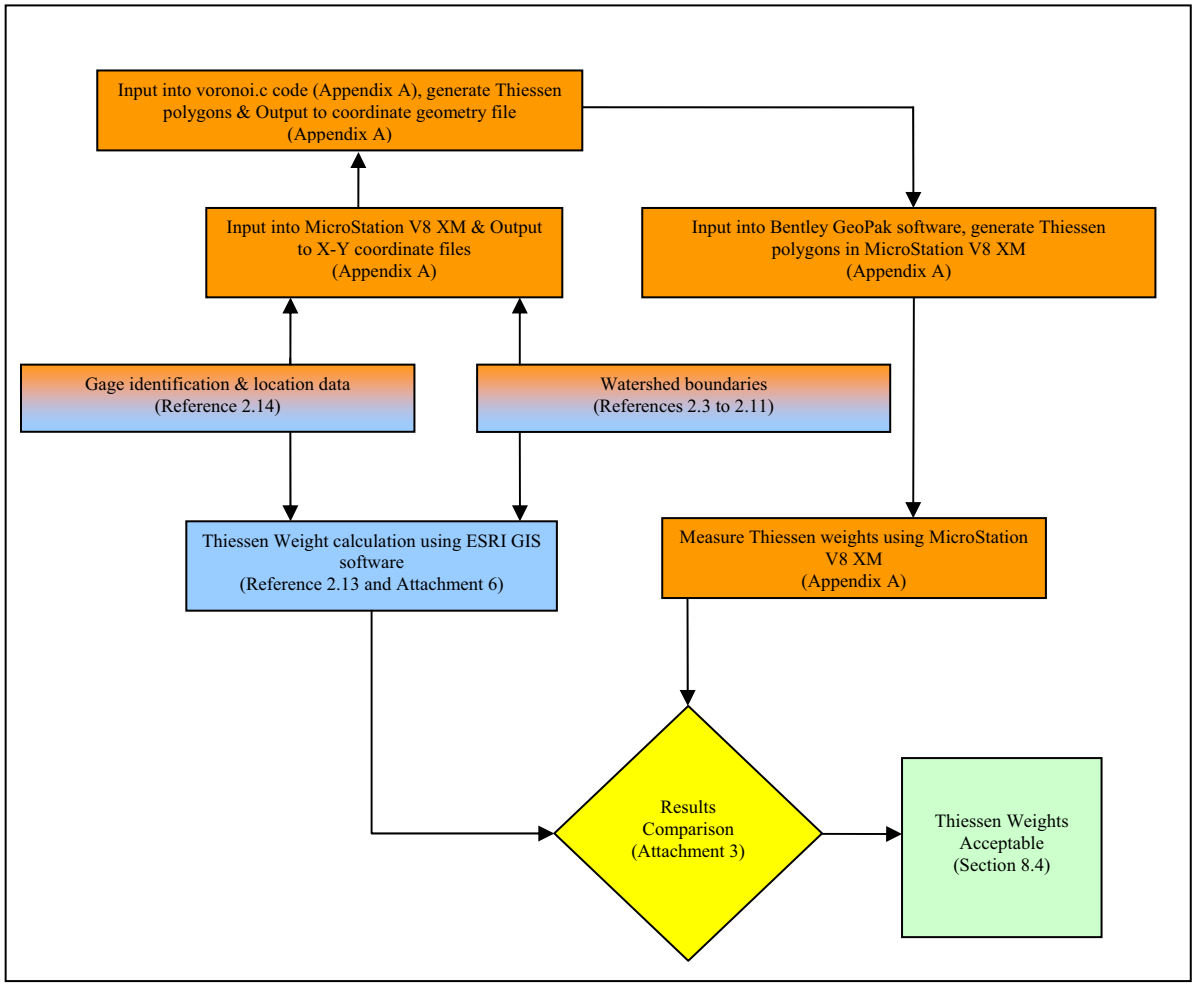

Figure 4: Process Flow Chart for Thiessen Weight Verification

4.5 API Region for Gages Review - Figure 5

The Tennessee Valley is broken into 6 API (Antecedent Precipitation Index) regions based on their rainfall-runoff relationships. The regions were determined by the USWB (U.S. Weather Bureau) in the 1950s, and are shown on the USWB API Region map (Attachment 4). This map is a historical document which has been digitized and geo-referenced using the ESRI GIS Software. The gages used during the 1973 flood were plotted on this same map (Attachment 2), based on their location listed in Reference 2.14. The API Regions SE, E, NE, N, W, and S correspond with a number 1-6 in the FLDHYDRO code. The API region codes used in the FLDHYDRO Input files were checked against the Thiessen weight map (Attachment 2) to verify the API region for each gage used.

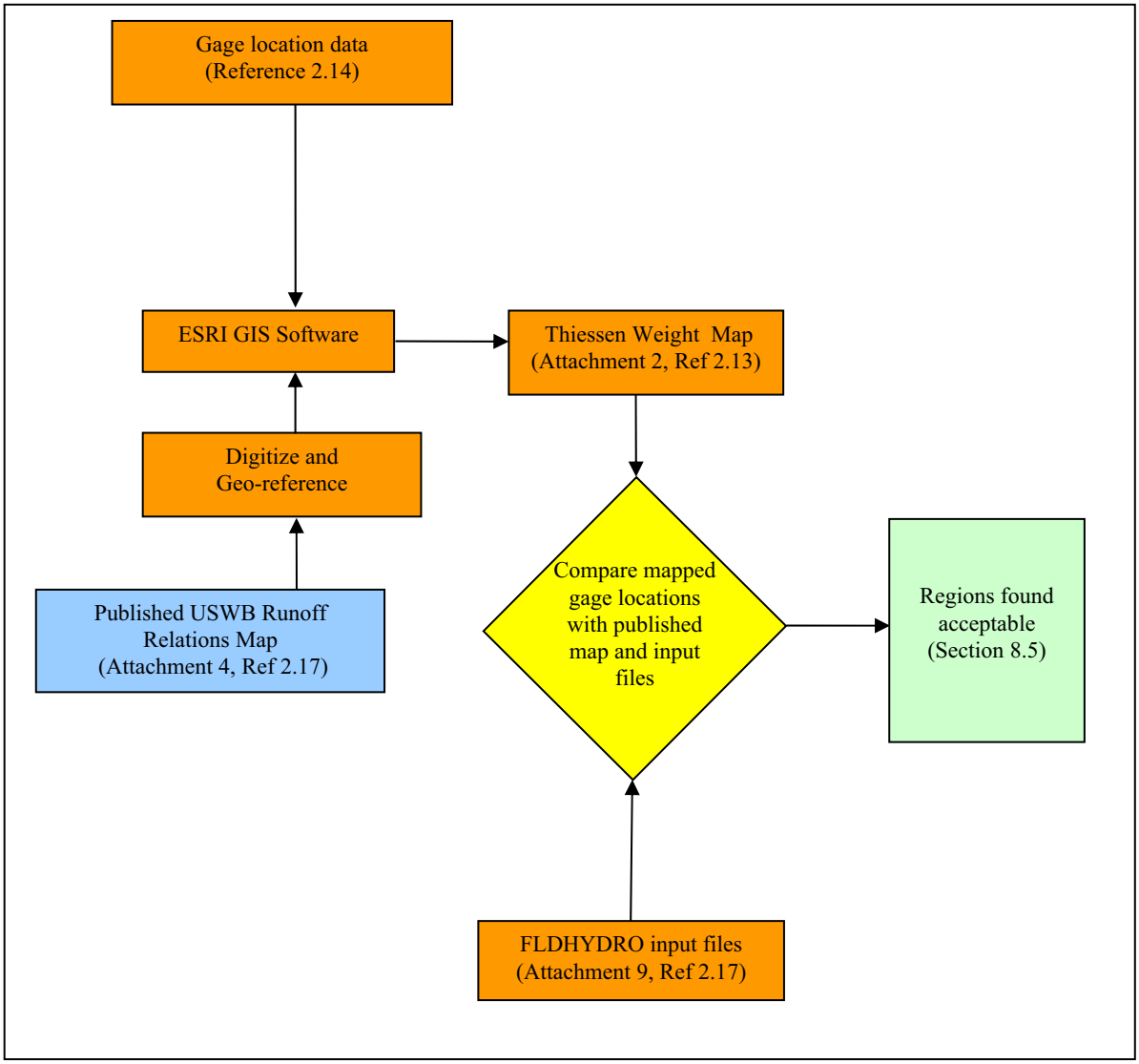

Figure 5: Process Flow Chart for API Region for Gages Verification

5. Design Input

Historical data included in appendices, attachments and references.

Sect	Input Parameter	Source
4.1 & 4.2	Gage hourly rainfall data from TVA files	Reference 2.16
4.1, 4.4,& 4.5	Gage location, installation date and removal date	Reference 2.14
4.1 & 4.3	USGS quadrangle mapping data	Reference 2.18
4.3, 4.4 & 4.5	Thiessen Weight map	Reference 2.13
4.5	Historical USWB Runoff Relations map	Reference 2.17
4.3, 4.4	Watershed basin areas	References 2.3 - 2.11
4.3	'Blue Book' reservoir surface area	Reference 2.15
4.2 & 4.5	FLDHYDRO input files	Reference 2.17

6. Special Requirements/Limiting Conditions

N/A

7. Calculations

7.1 Gage Selection and Location Review

Confirmed gage locations were input into ESRI Arcmap 9.2 GIS mapping software based on latitude and longitude listed in the file documentation (Reference 2.14). The gages used during the 1973 flood, and used in the FLDHYDRO subroutine, are shown on the Thiessen Weight Map (Attachment 2). The gage locations were determined to be acceptable if the plotted station description location plot was within +/- 200 feet of the plotted location on the USGS quadrangle map location.

7.2 Rainfall Data Review

The published rainfall data include stations that required adjustment because the gaged rainfall was read daily at significantly different times than the standard morning reading time or had rainfall from previous period included. The rainfall from daily stations was time redistributed based on a nearby gage. Gages were chosen based on nearness to the adjusted gage and rainfall amount; i.e. the nearest gage with the closest total rainfall amount was used for the adjustment. Re-distribution performed on stations requiring adjustment as follows:

$$\frac{Sta.A_{total}}{Sta.B_{total}} \times \text{Sta.B Incremental Rainfall} = \text{Sta.A Adjusted Incremental Rainfall}$$

The following table lists the stations requiring adjustment, the reason for adjustment and the station used for adjustment.

Table 7.2

Station	Reason for Adjustment	Adjusted by Station:
72	Not a recorder, read in evening	482A
83	Not a recorder, read in evening	387
430	Rainfall on 16th included in 17th reading	90
472	Not a recorder, read in evening	438
524	Not a recorder, read in evening	763
579	Not a recorder, read in evening	212
642A	Not a recorder, read in evening	642
651	Not a recorder, read near noon	207A
751	Not a recorder, read in evening	747
768	Not a recorder, read in evening	747
783	Not a recorder, read near noon	171
795	Not a recorder, read near noon	479B
429A	Not a recorder, read in evening	429

Attachment 5, an Excel spreadsheet, contains an 'Adjustments' tab. The daily rainfall totals for all of the above stations are listed and the adjustment calculations have been made in the spreadsheet.

The hourly rainfall data was summed and checked against the published daily values. The spreadsheets used to sum hourly values are also included in Attachment 5.

An example calculation for verification of rainfall data is provided below.

EXAMPLE CALCULATION TO VERIFY FLDHYDRO HOURLY RAINFALL DATA:
FLDHYDRO data is located in Attachments 1 & 9. Attachment 1 contains pdfs of the data files with overlays to aid in reader's use and Attachment 9 contains the electronic versions of the *.dat files.
The following steps were taken to verify hourly rainfall data.

- Go to Attachment 1, first section, Chickamauga Local, on the created overlay.
- Go to the first section, containing the hourly rainfall for the Recording Gages, and find corresponding area on FLDHYDRO input data sheet (behind overlay). See excerpt next page.

CHICKAMAUGA LOCAL - BASIN AVERAGE HOURLY RAIN - MARCH 1973 FLOOD
0 1 0 1 3 16 3 7- **Input Parameters**
488R747R157R-**Recording Gage Number**
031573 031573 031573- **Start date of 1973 Flood (mm/dd/yr)**
6 6 6 - **Start time of Recording (Military)**
42 41 50 - **Hours of Recorder Rainfall**

.001	.001	.37	.01	.09	0	.08	.05	.23	.12
.06	.09	.08	.40	.47	.40	.17	.20	.24	.40
.24	.09	0	.07	1.17	.20	.06	.10	.11	.28
.26	.70	.62	.09	0	.01	.01	.02	0	0
0	.01								
1.02	0	.10	0	0	.10	.01	0	.04	.06
.01	.08	.20	.25	.35	.50	.20	.22	.28	.15
.30	.02	.43	.75	.10	.06	.06	.03	.10	.02
.15	.80	.30	.27	0	0	0	.03	.01	.03
.01									
.85	.36	.01	.02	0	0	.01	0	0	.10
0	0	.25	.20	.25	.40	.30	.20	.20	.30
.25	.13	.42	.50	.10	.15	.02	.03	.05	.05
.30	.40	.30	.19	0	0	.01	.01	.02	0
0	.02	0	0	0	0	0	0	0	.05

- Start with Recorder 488R. Go to Attachment 8, March 1973 Precipitation Data to find published recorded daily rainfall values. Look at map on page 15 to find recorder 488R to determine which table the precipitation data is in. 488R is located right below Chattanooga, so it is located in Table 1. (To ease this process, Attachment 1 lists what table the daily values can be found in for all recorders)
- In Table 1, locate 488R CHATTANOOGA AIRPORT R XX ES. The footnotes at the end of the table state that R= Recording Gage, XX = precipitation value observed at or near midnight, and ES= data recorded in Eastern Standard Time. Go across to the 15th-17th and locate the daily totals for those days: 15th-2.82, 16th-4.68, 17th-*T. *T = only a trace amount recorded.
- Go back up to the FLDHYDRO data sheets to sum up the hourly data and check versus the published daily totals. (Attachment 5 is a spreadsheet created to simplify the summing of hourly data.)

The start time of the recording is 6 am on March 15th, 1973, data gathered at midnight EST = 11pm CST. (Note: To enhance program stability, 0.001 was entered as a data point instead of the recorded 0 value).

.001**6am** .001 **7am** .37 **8am** .01 **9am** .09 **10am** 0 **11am** .08 **noon** .05 **1pm** .23 **2pm** .12**3pm**
.06 4pm .09 **5pm** .08 **6pm** .40 **7pm** .47 **8pm** .40 **9pm** .17
10pm .20**11pm, sum=2.82 (15th)**

.24 **12am** .40 **1am**
.24 .09 0 .07 1.17 .20 .06 .10 .11 .28
.26 **noon** .70 .62 .09 0 .01 .01 .02 0 0
0 .01 **11pm, sum = 4.68 (16th)**

Hourly sums equal published daily values. No hourly data for 17th; 'trace' in published data, OK

- Next, look at recorder 747R: Attachment 8, Table 1 BOGGE CROSSROADS R ES. March 15th-1.02, March 16th-4.21, March 17th-1.81. 24-hour precipitation data taken at or around 8am, here, Eastern Standard Time.

(Attachment 5 spreadsheet sums the daily totals.) The start time of the recording is 6 am on March 15th, 1973, data gathered at 8 am EST = 7am CST

1.02 **6am** 0 **7am, March 15th, sum=1.02**
.10 **8am** 0 **9am** 0 .10 .01 0
.04 .06
.01 .08 .20 .25 .35 .50 .20 .22
.28 .15
.30 .02 .43 .75 .10 .06 **7am, March 16th, sum= 4.21**
.06 .03
.10 .02
.15 .80 .30 .27 0 0 0 .03
.01 .03
.01 **end of storm, March 17th sum=1.81**

Hourly sums equal published daily values. OK

7.3 Watershed Basin and Reservoir Area Review

Watershed basin and reservoir areas were calculated using ESRI Arcmap 9.2 GIS mapping software as a planimeter to measure surfaces in geo-referenced USGS quadrangle maps. Watershed basin and reservoir areas were confirmed using alternate methods presented in Appendix A. FLDHYDRO uses these watershed basins and reservoir areas as input into the program to calculate storm runoff. See summary table below with a comparison of areas obtained by ESRI Arcmap 9.2 GIS and Microstation, and those used in FLDHYDRO.

Table 7.3.1

	ESRI Arcmap 9.2 GIS (Sq. Miles)	Microstation (See Appendix A) (Sq Miles)	FLDHYDRO Input Files (Sq Miles)
Chickamuaga Local	792.1	792.1	792.1
Chickamauga Reservoir	55.44	52.5	55.44
Clinch River Local Above Mile 16	37.2	37.2	37.2
Clinch River Mouth to Mile 16	29.3	29.3	29.3
Fort Loudoun Local	323.4	323.3	323.4
Fort Loudoun Reservoir	23.49	21.96	23.49
French Broad River Local	206.47	206.4	206.47
Guntersville North Local	1044.1	1044.2	1027.1*
Guntersville Reservoir	103.04	101.88	103.04
Guntersville South Local	1154.9	1155.5	1068.9*
Hiwassee River Local Mouth	396	396	396
Holston River Local	319.6	319.6	289.6**
Little River at the Mouth	378.6	378.6	378.6
Little Tennessee River Local	650.2	650.1	650.2
Melton Hill Local	431.9	431.8	431.9
Melton Hill Reservoir	8.74	8.10	8.74
Nickajack Local	545.71	546.2	545.71
Nickajack Reservoir	16.31	15.99	16.31
North Chickamauga Creek	98.3	98.3	98.3
Poplar Creek at Mouth	135.2	135.2	135.2
Tellico Reservoir	24.5	23.1	24.5
Watts Bar Local Above Clinch River	295.3	295.3	295.3
Watts Bar Local Below Clinch River	408.38	408.3	408.38
Watts Bar Reservoir	59.47	57.6	59.47

*Note: Area used is from Unit Hydrograph Calculation (see Ref 2.5). Reservoir Area has been subtracted from GIS based total basin area to produce "dry land" area.
**Note: Total Basin Area is 319.6 square miles. 30 square miles are non- contributing and not included in the unit hydrograph calculation or FLDHYDRO input.

The alternate calculation presented in Appendix A confirms the calculation method. Alternate calculations performed in Appendix A compared to the GIS reservoir areas vary from -1% to -8% with an average of -3.51%. Differences are attributed to the simplifications necessary to allow calculation by the MicroStation software used in the alternate method. These simplifications are outlined in Appendix A.

Digitized reservoir areas are compared against the published data in the following table.

Table 7.3.2

	Published (Ref. 2.15)			GIS			
Reservoir	Area (in acres)	Area (in sq mi)	Max. Pool Elevation	Area (in acres)	Area (in sq mi)	Max. Pool Elev.(USGS)	Difference in Area
Guntersville	67,900	106.1	595	65,938.9	103.0	595	-2.89%
Nickajack	10,370	16.2	634	10,440.1	16.3	634	0.68%
Chickamauga	35,400	55.3	682.5	35,478.5	55.4	683	0.22%
Watts Bar	39,000	60.9	741	38,062.5	59.5	741	-2.40%
Melton Hill	5,690	8.9	795	5,596.2	8.7	795	-1.65%
Fort Loudon	14,600	22.8	813	15,034.1	23.5	813	2.97%
Tellico	16,500	25.8	813	15,682.2	24.5	813	-4.96%
Total	189,460	296.0	-	186,232	291.0	Average	-1.70%

Note that the maximum pool elevations listed under the GIS heading were taken from USGS quadrangle map information.

The Arcmap software calculated reservoir areas differed from published values by -4.96% to +2.97% with an average of 1.7% and were considered to be within the necessary level of accuracy for this calculation. This comparison was considered adequate to confirm that the digitized areas were equivalent to the published values. Based on age, the published values were most likely determined by graphical hand methods (planimeter, graph paper, etc.) and the Arcmap results are considered to be of equivalent accuracy. Reservoir areas calculated by the GIS software were used instead of the published values to be consistent with the watershed areas calculated in References 2.3-2.11.

7.4 Thiessen Weight Review

The Thiessen weight calculation was performed using the Thiessen polygon tool included in the ESRI Arcmap 9.2 GIS mapping software. The resulting weights were rounded to three (3) significant digits and modified to ensure that they totaled 1.000 within each watershed (Attachment 6).

See Attachment 3, 'Summary_Thiessens_ESRI_vs_Geopak.pdf' for a spreadsheet comparing Thiessen weights produced with ESRI Arcmap 9.2 GIS mapping software versus Bentley Microstation V8 XM Geopak software.

7.5 API Region for Gages Review

The historic API area map (Attachment 4) was scanned, digitized, and geo-referenced using the ESRI Arcmap 9.2 GIS mapping software. Attachment 2, the Thiessen Weight Map, shows the designated API regions from the historical map with different colors. The API areas in the FLDHYDRO input files correspond to a numerical designation as follows:

Table 7.5

API Area	Number
SE	1
E	2
NE	3
N	4
W	5
S	6

EXAMPLE CALCULATION TO VERIFY FLDHYDRO API REGION CODES:

FLDHYDRO data is located in Attachments 1 & 9. Attachment 1 contains pdfs of the data files with overlays to aid in reader's use and Attachment 9 contains the electronic versions of the *.dat files.

- Go to Attachment 1, first section, Chickamauga Local, on the created overlay.
- Go to second sheet, line '1 Row of API data' and find corresponding area on FLDHYDRO input data sheet (behind overlay) See excerpt below.
- The first row is the API Region: 1=SE, 2=E, 3=NE, 4=N, 5=W, 6=S
- The first column is All Recording and Non-Recording Gages used in basin.
- Go to Attachment 2 and locate first recorder, 488R. 488R is in the darker green region which equals S, Region 6. (Reference 2.14 contains tables with each recorder's latitude and longitude to make locating stations easier.)
- Continue for all the recorders to verify the remaining region codes.

```
CHICKAMAUGA LOCAL - MARCH 1973 RAINFALL
6   6   4   4   4   4   4   6   6   6   4   4   6   6   4   6
```

488R	6	S
747R	6	S
157R	4	N
768	4	N
92	4	N
420	4	N
393	4	N
685	6	S
90	6	S
93	6	S
389	4	N
421	4	N
427	6	S
430	6	S
751	4	N
838	6	S

Figure 7.5 Data taken from Attachment 1: FLDHYDRO input data file

8. Results/Conclusions

The following items in Sections 8.1-8.5 are data inputs required for the FLDHYDRO program. The rainfall data for the gages used during the 1973 flood is combined with the watershed basin areas, Thiessen weights and API region codes to produce the FLDHYDRO input files (*.dat files, Attachment 9). These sets of data are inputs to the FLDHYDRO subroutine used to calculate local inflow inputs to SOCH for model calibration.

8.1 Gage Selection and Location

Reference 2.14 contains the rainfall station descriptions and locations for the gages used during the March 1973 storm event. Pages 3 and 4 of Reference 2.14 contain tables listing each gage station used, and its corresponding station name and latitude and longitude location. The rainfall station descriptions were checked to verify that the gage was in place during the March 1973 storm event and that the locations in the file were within ±200' of the plotted map location when compared to USGS quadrangle maps (Reference 2.18). After performing these checks,

the gage selection and location used for determining the 1973 storm rainfall data are confirmed as acceptable for use in the design basis PMF analysis.

8.2 Rainfall Data

Rainfall gage data used in FLDHYDRO input files (Attachment 9) matched the published daily values, (Attachments 7&8) within .05 inch. Attachment 5, an Excel spreadsheet, was used to simplify daily rainfall calculation from the hourly values contained in Reference 2.16 and Attachment 9. The comparison of these documents confirms the acceptability for the 1973 storm rainfall data to be used in the design basis PMF analysis.

8.3 Watershed Basin and Reservoir Area

The comparison of the watershed basin and reservoir areas calculated by the GIS software with the published values and the alternate methods in Appendix A confirms the acceptability of their use in the design basis PMF analysis.

8.4 Thiessen Weight

This calculation compared the Thiessen weights calculated with the ESRI GIS software and those generated using Bentley Geopak software in MicroStation V8 XM. The comparison of the Thiessen weights generated from both applications confirms the acceptability of their use in the design basis PMF analysis.

8.5 API Region for Gages

This calculation compares the mapped gage locations (Attachment 2) to API region areas used in the FLDHYDRO input files (Attachment 9) and the published USWB Runoff Relations map (Attachment 4). The comparison of these three documents confirms the acceptability of the API region-gage association for use in the design basis PMF analysis.