~~Proprietary Information Withhold from Public Disclosure~~
~~Under 10 CFR 2.390~~
This letter is decontrolled when separated from Enclosure 2

Tennessee Valley Authority, 1101 Market Street, Chattanooga, Tennessee 37402

CNL-20-032

May 14, 2020

10 CFR 50.90

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Sequoyah Nuclear Plant, Units 1 and 2
Renewed Facility License Nos. DPR-77 and DPR-79
NRC Docket Nos. 50-327 and 50-328

Subject: **Application to Revise Sequoyah Nuclear Plant Units 1 and 2 Updated Final Safety Analysis Report Regarding Changes to Hydrologic Analysis - Response to Request for Additional Information (TS-19-02) (EPID L-2020-LLA-0004)**

References:

1. TVA Letter to NRC, CNL-19-066, "Application to Revise Sequoyah Nuclear Plant Units 1 and 2 Updated Final Safety Analysis Report Regarding Changes to Hydrologic Analysis (TS-19-02)," dated January 14, 2020 (ML20016A396 and ML20016A397)

2. TVA Letter to NRC, CNL-20-026, "Supplement to Application to Revise Sequoyah Nuclear Plant Units 1 and 2 Updated Final Safety Analysis Report Regarding Changes to Hydrologic Analysis, (TS-19-02) (EPID L-2020-LLA-0004)," dated February 18, 2020 (ML20049H184)

3. NRC Electronic Mail to TVA, "Sequoyah Nuclear Plant, Request for Additional Information Regarding the Hydrologic Analysis LAR (EPID L-2020-LLA-0004)," dated April 14, 2020 (ML20106F104)

In Reference 1, Tennessee Valley Authority (TVA) submitted a request for an amendment to Renewed Facility Operating License Nos. DPR-77 and DPR-79 for Sequoyah Nuclear Plant (SQN) Units 1 and 2, respectively. This license amendment request (LAR) revises the SQN Units 1 and 2, Updated Final Safety Analysis Report (UFSAR) to reflect the results from the new hydrologic analysis. TVA determined that the proposed changes to the SQN UFSAR require prior Nuclear Regulatory Commission (NRC) approval.

~~Proprietary Information Withhold from Public Disclosure~~
~~Under 10 CFR 2.390~~
This letter is decontrolled when separated from Enclosure 2

In Reference 2, TVA provided a response to a request for information to support the NRC acceptance review of the LAR. In Reference 3, the NRC provided a request for additional information (RAI). Enclosure 1 to this letter provides the response to the RAI. In support of this RAI response, Enclosure 2 to this letter contains portions of the Barge Design Solutions (Barge) Software Dedication Report, and Enclosure 3 contains portions of TVA calculation CDQ0000002016000044, "Gridded Probable Maximum Precipitation (PMP) Development." For Enclosures 2 and 3, executable files and some supplemental files have been removed to support transmittal, but can be made available if needed for NRC review.

Enclosure 2, in its entirety, contains information that Barge considers to be proprietary pursuant to Title 10 of the *Code of Federal Regulations (*10 CFR) 2.390, "Public inspections, exemptions, requests for withholding," paragraph (a)(4). Enclosure 4 provides the Barge affidavit supporting this proprietary withholding request. The affidavit sets forth the basis on which the information may be withheld from public disclosure by the NRC and addresses with specificity the considerations listed in paragraph (b)(4) of 10 CFR 2.390. Accordingly, TVA requests that the information which is proprietary to Barge be withheld from public disclosure in accordance with 10 CFR 2.390.

This letter does not change the no significant hazard considerations nor the environmental considerations contained in Reference 1. Additionally, in accordance with 10 CFR 50.91(b)(1), TVA is sending a copy of this letter and the enclosure to the Tennessee Department of Environment and Conservation.

Please address any questions regarding this request to Kimberly D. Hulvey, Senior Manager, Fleet Licensing, at 423-751-3275. There are no new regulatory commitments contained in this submittal.

I declare under penalty of perjury that the foregoing is true and correct. Executed on this 14th day of May 2020.

Respectfully,

James Barstow
Vice President, Nuclear Regulatory Affairs & Support Services

Enclosures:

1. Response to NRC IQVB Request for Additional Information
2. Barge Software Dedication Report (Proprietary)
3. Gridded PMP Development Calculation (Calculation CDQ0000002016000044)
4. Barge Affidavit

cc: See Page 3

NRC Introduction

In a letter dated January 14, 2020 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML20016A396), as supplemented by a letter dated February 18, 2020 (ADAMS Accession No. ML20049H184), Tennessee Valley Authority (TVA) submitted a license amendment request (LAR) for Sequoyah Nuclear Plant related to a new hydrologic analysis. The NRC staff has reviewed the information in the submittals and has determined that additional information is needed in order for the NRC staff to complete its review.

RAI-IQVB-1

Title 10 of the Code of Federal Regulations (10 CFR) 50.34(b)(6)(ii) requires information to be provided regarding the managerial and administrative controls to be used to assure safe operation, including a discussion of how applicable requirements within Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," are satisfied. In the February 18, 2020, Supplement TVA stated, in part, "The dedication of the [Probable Maximum Precipitation (PMP)] Evaluation Tool was performed under the Barge Design Solutions (Barge) Nuclear Quality Assurance (QA) program...The Barge QA program has been audited and accepted by TVA and is on the TVA Acceptable Supplier List (ASL)...While the ArcGIS and [Quantum GIS (QGIS)] evaluation tools were not dedicated, the calculations performed using these tools were checked by either hand calculations or using alternative software in accordance with Barge procedures for design calculations and computer program applications, under the Barge QA program, which complies with NQA-1 Part II Subpart 2.7 Paragraph 202 and is consistent with similar TVA process control procedures under the TVA QA Program. The ArcGIS software functions that are outside of the functions included in the PMP Evaluation Tool [Software Dedication Report (SDR)], as noted above, were checked using QGIS as the alternate software in accordance with NQA-1 Part II Subpart 2.7 Paragraph 202 under the Barge QA Program."

In accordance with NQA-1-2008 and the 2009 Addenda, Part II, Subpart 2.7, Paragraph 202, "The appropriate software engineering elements, described in para. 202 of this Subpart, shall define the control points and associated reviews. Reviews of software shall ensure compliance with the approved software design requirements...When review alone is not adequate to determine if requirements are met, alternate calculations shall be used, or tests shall be developed and integrated into the appropriate activities of the software development cycle."

The NRC staff reviewed the supplemental information provided by TVA and finds that the following additional information is needed to determine whether the procurement and use of the ArcGIS and QGIS evaluation tools are appropriately controlled under TVA's QA program in accordance with the requirements of Appendix B to 10 CFR Part 50. Specifically, the NRC staff requests TVA to provide the following:

a) *Information to clarify how hand calculations are used to verify the outputs of any of the tools used, including the PMP Evaluation Tool, ArcGIS and QGIS.*

b) *For cases where the output of one software tool (e.g., QGIS) is used to verify the output of another software tool (ArcGIS), information to demonstrate that these tools are sufficiently diverse (e.g., use of different software developers, different calculation methods, different software algorithms, different programming languages used to develop the tools) such that the potential for these tools to produce the same erroneous outputs are significantly reduced.*

c) *Information supporting the dedication of the PMP Evaluation Tool performed by Barge Design Solutions, including the dedication plan, the critical characteristics of the tool, the acceptance methods used, and documents (e.g., PMP Evaluation Tool SDR) demonstrating that commercial grade dedication was implemented adequately.*

TVA Response to NRC RAI Quality Assurance Vendor Inspection Branch (IQVB)-1 Part a:

In Reference 1, TVA provided general information in regard to the methodologies used to perform alternate calculations. This general information stated that hand calculations could be used as an alternate calculation. However, in the development of the basin average PMP depths, hand calculations were not used to check the results of the PMP Evaluation tool or the ArcGIS and the QGIS tools outside of the PMP Evaluation Tool. Calculations made within ArcGIS outside of the PMP Evaluation Tool were checked via alternate methodologies within QGIS by comparison of the average basin rainfall depth determined by the two different GIS methodologies as described in the gridded PMP development calculation (Enclosure 3). The Microsoft Excel workbook and those portions of the Python scripting outside the PMP Evaluation tool were checked and design verified under the Barge QA program. Detailed descriptions of the Microsoft Excel workbook and Python scripting are provided in Appendix A of Enclosure 3.

The PMP Evaluation Tool has been dedicated utilizing the Barge Nuclear QA program through rigorous testing and research for features of the software by completion of a series of test cases. These results along with the limitation of the PMP Evaluation Tool software are documented in the SDR (Enclosure 2). Therefore, Barge concluded the PMP Evaluation Tool software is dedicated and may be used as pre-verified software.

Figure 1 shows the key elements in the development of the gridded PMP and to note the verification method for each element.

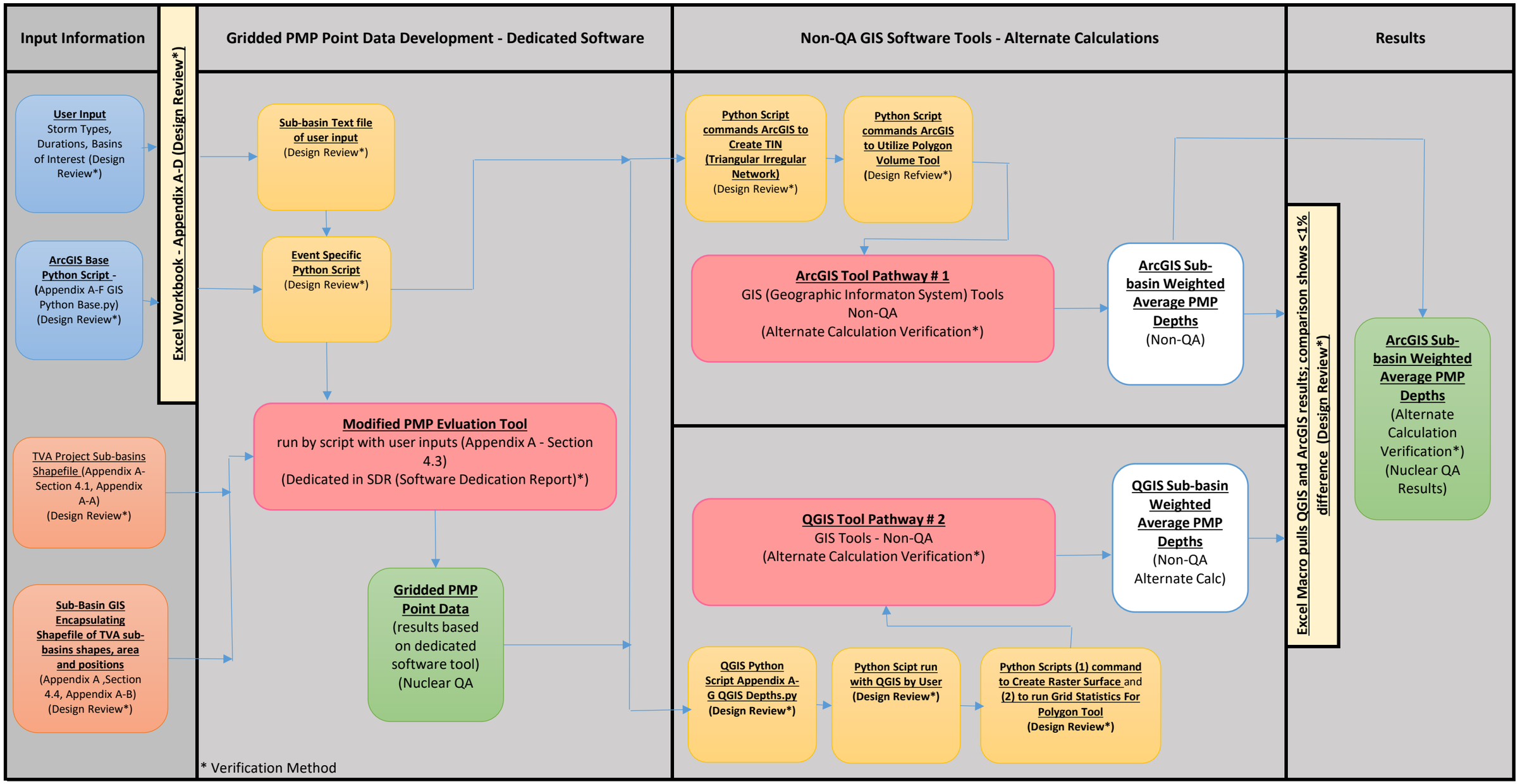
Input Information
Excel Workbook - Appendix A-D (Design Review*)
Gridded PMP Point Data Development - Dedicated Software
Non-QA GIS Software Tools - Alternate Calculations
Results
User Input
Storm Types, Durations, Basins of Interest (Design Review*)
ArcGIS Base Python Script - (Appendix A-F GIS Python Base.py) (Design Review*)
TVA Project Sub-basins Shapefile (Appendix A-Section 4.1, Appendix A-A) (Design Review*)
Sub-Basin GIS Encapsulating Shapefile of TVA sub-basins shapes, area and positions (Appendix A ,Section 4.4, Appendix A-B) (Design Review*)
Sub-basin Text file of user input (Design Review*)
Event Specific Python Script (Design Review*)
Modified PMP Evluation Tool
run by script with user inputs (Appendix A - Section 4.3)
(Dedicated in SDR (Software Dedication Report)*)
Gridded PMP Point Data
(results based on dedicated software tool)
(Nuclear QA
Python Script commands ArcGIS to Create TIN (Triangular Irregular Network)
(Design Review*)
Python Script commands ArcGIS to Utilize Polygon Volume Tool
(Design Refview*)
ArcGIS Tool Pathway # 1
GIS (Geographic Informaton System) Tools
Non-QA
(Alternate Calculation Verification*)
ArcGIS Sub-basin Weighted Average PMP Depths
(Non-QA)
QGIS Tool Pathway # 2
GIS Tools - Non-QA
(Alternate Calculation Verification*)
QGIS Sub-basin Weighted Average PMP Depths
(Non-QA Alternate Calc)
QGIS Python Script Appendix A-G QGIS Depths.py
(Design Review*)
Python Scipt run with QGIS by User
(Design Review*)
Python Scripts (1) command to Create Raster Surface and (2) to run Grid Statistics For Polygon Tool
(Design Review*)
Excel Macro pulls QGIS and ArcGIS results; comparison shows <1% difference (Design Review*)
ArcGIS Sub-basin Weighted Average PMP Depths
(Alternate Calculation Verification*)
(Nuclear QA Results)
* Verification Method

Figure No. 1

TVA Response to NRC RAI IQVB-1 Part b:

The dedicated PMP Evaluation tool generated gridded precipitation shapefile data. The gridded precipitation shapefile was used to generate sub-basin average PMP depths for use in the subsequent hydrologic analysis. Sub-basin average PMP depths computed in ArcGIS were verified using independently developed QGIS software as an alternate calculation method.

ArcGIS, an industry standard software package for large scale geospatial analysis, was developed by Environmental Systems Research Institute (ESRI). ESRI does not provide access or distribute the source code to the public or other developers without proper licensing. Alternatively, QGIS is an independently developed software that utilizes contributions from multiple sources including non-governmental organizations and academic research. QGIS is also widely used in the industry and academia for large scale geospatial analysis.

The sub-basin average rainfall depths used for the PMP analysis were computed using two different calculation methods applied within the ArcGIS and QGIS software packages. In ESRIs ArcGIS, the gridded shapefile data was utilized to create a Triangular Irregular Network (TIN) surface. The resulting TIN surface was processed using a polygon volume tool to compute sub-basin average PMP depths. The QGIS alternate methodology utilized the nearest neighbor geoprocessing tool to generate a raster surface. A grid statistics tool within QGIS was utilized to compute the sub-basin average PMP depths. The nearest neighbor and grid statistics geoprocessing tools within QGIS were originally part of the SAGA GIS software which was developed by the Department of Physical Geography at the University of Göttingen, Germany.

Because ArcGIS and QGIS tools utilize different software developers, different calculation methods, and different software algorithms, the potential for the tools to produce the same erroneous outputs are significantly reduced. These tools are sufficiently diverse such that comparison of the outputs provides an alternate calculation for verifying the computer program results for each application as required by Barge QA program procedures.

TVA Response to NRC RAI IQVB-1 Part c:

The PMP Evaluation Tool has been dedicated utilizing the Barge Nuclear QA program through testing and research for features of the software by completion of a series of test cases. The PMP Evaluation Tool SDR (Enclosure 2) details the Dedication Plan (Attachment 4 to Enclosure 2), critical characteristics of the tool (Section 4 to Enclosure 2), and acceptance methods used (Attachment 4 to Enclosure 2). The PMP Evaluation Tool SDR demonstrates the software dedication was implemented adequately under the Barge Design Solutions QA Program.

RAI-IQVB-2

10 CFR Part 21 defines the term "dedication," in part as, "an acceptance process undertaken to provide reasonable assurance that a commercial grade item to be used as a basic component will perform its intended safety and, in this respect deemed equivalent to an item designed and manufactured under a 10 CFR Part 50, Appendix B quality assurance program. In all cases, the dedication process must be conducted in

accordance with applicable provisions of 10 CFR Part 50, Appendix B." Criterion III, "Design Control" of Appendix B to 10 CFR Part 50, requires, in part, that "Measures shall also be established for the selection and review for suitability of application of materials, parts, equipment, and processes that are essential to the safety-related functions of the structures, systems and components... Design changes, including field changes, shall be subject to design control measures commensurate with those applied to the original design and be approved by the organization that performed the original design unless the applicant designates another responsible organization." In Attachment A to LAR to Enclosure 5, TVA stated in part, that "The [Probable Maximum Precipitation (PMP) Evaluation] Tool was used, as provided, as part of commercial grade dedication, with the following minor modifications." This attachment identified four modifications made to PMP Evaluation Tool and the rationale for making these modifications.

The NRC staff evaluated the information presented by TVA regarding these modifications to the previous dedicated PMP Evaluation Tool and finds that additional information is needed to support the staff's safety evaluation. Specifically, the NRC staff requests that TVA provide information to demonstrate that the minor modifications made to the PMP Evaluation Tool do not invalidate the results of the dedication of this tool and that these modifications were conducted under TVA's quality assurance program, as required by Criterion III of Appendix B to 10 CFR Part 50.

TVA Response to RAI 2:

In Attachment A to Enclosure 5 of Reference 2, TVA stated in part,

> "The [Probable Maximum Precipitation (PMP) Evaluation] tool was used, as provided, as part of the software dedication, with the following minor modifications."

TVA clarifies the sentence structure as follows:

> "The [Probable Maximum Precipitation (PMP) Evaluation] tool was used, as provided, ~~as part of the software dedication,~~ with the following minor modifications **as part of the software dedication.**"

The minor modifications to the PMP Evaluation Tool discussed in Attachment A to Enclosure 5 of Reference 2 are addressed in Enclosure 2 under the Barge QA program as required by Criterion III of Appendix B to 10 CFR Part 50. Therefore, the minor modifications made to the PMP Evaluation Tool do not invalidate the results of the dedication of this tool and that these modifications were conducted under TVA's QA program, as required by Criterion III of Appendix B to 10 CFR Part 50.

References:

1. TVA Letter to NRC, CNL-20-026, "Supplement to Application to Revise Sequoyah Nuclear Plant Units 1 and 2 Updated Final Safety Analysis Report Regarding Changes to Hydrologic Analysis, (TS-19-02) (EPID L-2020-LLA-0004)," dated February 18, 2020 (ML20049H184)
2. TVA Letter to NRC, CNL-19-066, "Application to Revise Sequoyah Nuclear Plant Units 1 and 2 Updated Final Safety Analysis Report Regarding Changes to Hydrologic Analysis (TS-19-02)," dated January 14, 2020 (ML20016A396 and ML20016A397)

~~**Proprietary Information - Withhold Under 10 CFR § 2.390**~~

Enclosure 2

Barge Software Dedication Report (Proprietary)
(Executable files removed)

Enclosure 3

Gridded PMP Development Calculation
(Executable Files Removed)

QA Record

TVA NUCLEAR CALCULATION COVERSHEET / CTS UPDATE

REV 0 EDMS/RIMS NO.	CTS TYPE:	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV 0)
B41180918001	Calculation	CALCULATIONS (NUCLEAR)	N/A

Calc Title: Gridded Probable Maximum Precipitation Development

	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV
CALC ID	NUC	GEN	CEB	CDQ0000002016000044	N/A	000

CTS UPDATE ONLY ☐
(Verifier and Approval Signatures Not Required)

NO CTS CHANGES ☐
(For calc revision, CTS has been reviewed and no CTS changes required)

UNIT (check one)	SYSTEMS	UNIDS
0 ☒, 1 ☐, 2 ☐, 3 ☐	000	N/A

ECP, 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 ☐

CALCULATION NUMBER REQUESTOR	PREPARING DISCIPLINE	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
Name: Stuart Henry Phone: 865-637-2810	CEB	Design Review	☑ Yes ☐ No

PREPARER (PRINT NAME AND SIGN)	DATE	CHECKER (PRINT NAME AND SIGN)	DATE
Stuart N. Henry	8/17/18	Eric King	8/17/18
VERIFIER (PRINT NAME AND SIGN)	DATE	APPROVAL (PRINT NAME AND SIGN)	DATE
Andrew Murr	8/17/18	B. Simril	9/14/18

STATEMENT OF PROBLEM/ABSTRACT

This calculation prepares inputs for the flood hazard reevaluation models using the gridded Probable Maximum Precipitation (PMP) Analysis. Outputs consist of sub-basin PMP values for use in subsequent calculations.

This calculation will support development of calculations to support License Amendment Requests for revision of the Watts Bar and Sequoyah Nuclear Plant design basis river flooding analysis and will support a revision to the Browns Ferry Nuclear Plant Flood Hazard Re-evaluation river flooding analysis if it is controlling at Browns Ferry. This calculation will support a re-evaluation of flood mechanism parameters to demonstrate the flood mechanism is bounded as documented in the Focused Evaluation for SQN, WBN, and BFN.

NOTE: Utilization of the contents of this calculation for the Browns Ferry Design Basis requires NRC approval via a License Amendment Request (LAR).

** SQN - DCN 23628
WBN - DCN 66358

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

NPG CALCULATION COVERSHEET / CTS UPDATE

CALC ID	ORG	PLANT	BRANCH	NUMBER	REV
	NUC	GEN	CEB	CDQ0000002016000044	000

BUILDING	ROOM	ELEVATION	COORD/AZIM	FIRM
NA	NA	NA	NA	Barge

CATEGORIES

KEYWORDS (A-add, D-delete)

ACTION (A/D)	KEYWORD	A/D	KEYWORD
	HYDROLOGY		
	INFLOWS		
	RAINFALL		

CROSS-REFERENCES (A-add, D-delete)

ACTION (A/D)	XREF CODE	XREF PLANT	XREF TYPE	XREF NUMBER	XREF REV
A	S	WBN	DCN	66358	
A	S	SQN	DCN	23628	
A	P	GEN	Calculation	CDQ0000002016000041	001
A	P	GEN	Calculation	CDQ0000002016000045	000
A	P	GEN	Calculation	CDQ000020080056	1
A	P	GEN	Calculation	CDQ000020080057	2
A	P	GEN	Calculation	CDQ000020080058	2
A	P	GEN	Calculation	CDQ000020080059	2
A	P	GEN	Calculation	CDQ000020080060	3
A	P	GEN	Calculation	CDQ000020080061	2
A	P	GEN	Calculation	CDQ000020080062	2
A	P	GEN	Calculation	CDQ000020080063	2
A	P	GEN	Calculation	CDQ000020080064	3
A	P	GEN	Calculation	CDQ000020080065	2
A	P	GEN	Calculation	CDQ000020080066	2
A	P	GEN	Calculation	CDQ000020080067	2
A	P	GEN	Calculation	CDQ000020080068	2
A	P	GEN	Calculation	CDQ000020080069	2
A	P	GEN	Calculation	CDQ000020080070	2
A	P	GEN	Calculation	CDQ000020080071	2
A	P	GEN	Calculation	CDQ000020080072	2

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

PREPARER (PRINT NAME AND SIGN)	DATE	CHECKER (PRINT NAME AND SIGN)	DATE
PREPARER PHONE NO.	EDMS ACCESSION NO.		

NPG CALCULATION COVERSHEET / CTS UPDATE

CALC ID	ORG	PLANT	BRANCH	NUMBER	REV
	NUC	GEN	CEB	CDQ0000002016000044	000

BUILDING	ROOM	ELEVATION	COORD/AZIM	FIRM
NA	NA	NA	NA	Barge

CATEGORIES

KEYWORDS (A-add, D-delete)

ACTION (A/D)	KEYWORD	A/D	KEYWORD

CROSS-REFERENCES (A-add, D-delete)

ACTION (A/D)	XREF CODE	XREF PLANT	XREF TYPE	XREF NUMBER	XREF REV
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A	P	GEN	Calculation	CDQ000020080091	2
A	P	GEN	Calculation	RSOO1HROGCDX00032620100001	0
A	P	GEN	Calculation	CDQ0000002014000015	0
A	S	GEN	Calculation	CDQ0000002017000054	000
A	S	GEN	Calculation	CDQ0000002017000055	000
A	S	GEN	Calculation	CDQ0000002017000056	000
A	S	GEN	Calculation	CDQ0000002017000057	000
A	S	GEN	Calculation	CDQ0000002017000058	000
A	S	GEN	Calculation	CDQ0000002017000059	000
A	S	GEN	Calculation	CDQ0000002017000060	000
A	S	GEN	Calculation	CDQ0000002017000061	000
A	S	GEN	Calculation	CDQ0000002017000062	000
A	S	GEN	Calculation	CDQ0000002017000063	000
A	S	GEN	Calculation	CDQ0000002017000064	000
A	S	GEN	Calculation	CDQ0000002017000065	000
A	S	GEN	Calculation	CDQ0000002017000067	000
A	S	GEN	Calculation	CDQ0000002017000068	000
A	S	GEN	Calculation	CDQ0000002017000069	000
A	S	GEN	Calculation	CDQ0000002017000070	000

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

PREPARER (PRINT NAME AND SIGN)	DATE	CHECKER (PRINT NAME AND SIGN)	DATE
PREPARER PHONE NO.	EDMS ACCESSION NO.		

NPG CALCULATION COVERSHEET / CTS UPDATE

CALC ID	ORG	PLANT	BRANCH	NUMBER	REV
	NUC	GEN	CEB	CDQ0000002016000044	000

BUILDING	ROOM	ELEVATION	COORD/AZIM	FIRM
NA	NA	NA	NA	Barge

CATEGORIES

KEYWORDS (A-add, D-delete)

ACTION (A/D)	KEYWORD	A/D	KEYWORD

CROSS-REFERENCES (A-add, D-delete)

ACTION (A/D)	XREF CODE	XREF PLANT	XREF TYPE	XREF NUMBER	XREF REV
A	S	GEN	Calculation	CDQ0000002017000071	000
A	S	GEN	Calculation	CDQ0000002017000072	000
A	S	GEN	Calculation	CDQ0000002017000073	000
A	S	GEN	Calculation	CDQ0000002017000074	000
A	S	GEN	Calculation	CDQ0000002017000075	000
A	S	GEN	Calculation	CDQ0000002017000076	000
A	S	GEN	Calculation	CDQ0000002017000077	000
A	S	GEN	Calculation	CDQ0000002017000078	000
A	S	GEN	Calculation	CDQ0000002017000080	000

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

PREPARER (PRINT NAME AND SIGN)	DATE	CHECKER (PRINT NAME AND SIGN)	DATE
PREPARER PHONE NO.	EDMS ACCESSION NO.		

TVA NUCLEAR CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER CDQ0000002016000044

Title Gridded Probable Maximum Precipitation Development

Revision No.	DESCRIPTION OF REVISION
000	Initial Issue: 29 Pages UFSAR for WBN and UFSAR for SQN have been reviewed and are affected by this calculation. A License Amendment Request is required. The UFSAR/TSs/ISFSI documents are not affected for BFN since the calculation is beyond design basis for BFN. Tech Specs for WBN and SQN have been reviewed and determined not to be affected by this revision of the calculation. ISFSI CFSARs and CoCs for WBN and SQN were reviewed and determined not to be affected by this calculation. The 10 CFR 72.212 Evaluation Reports for WBN and SQN are affected by this calculation. Review was performed by H.L. Smith Sawyer with knowledge of the analysis inputs and methodologies which are described in each UFSAR. This review does not represent a 50.59 or 72.48 review in accordance with NPG-SPP-09.4 and NPG-SPP-09.9, as applicable. This calculation will support development of calculations to support a License Amendment Request for revision of the WBN and SQN design basis river flooding analysis and will support a re-evaluation of flood mechanism parameters to demonstrate the flood mechanism is bounded as documented in the Focused Evaluation for SQN, WBN, and BFN. NOTE: Utilization of the contents of this calculation for the Browns Ferry Design Basis requires prior NRC approval via a License Amendment Request (LAR). Barge software controls for QA software applications meet the intent of NPG-SPP-12.7

TVA NUCLEAR CALCULATION TABLE OF CONTENTS

Calculation Identifier: CDQ0000002016000044	Revision:	000

TABLE OF CONTENTS

TVA NUCLEAR CALCULATION VERIFICATION FORM

Calculation Identifier CDQ0000002016000044 Revision 000

Method of verification used:

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

Verifier Andrew Murr Date 8/17/18

Comments:

This calculation, entitled Gridded Probable Maximum Precipitation Development, 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.

This calculation has been approved for release by authorized personnel. The approver ensures that the calculation has been developed, reviewed, and verified by trained and qualified project personnel.

TVA NUCLEAR COMPUTER INPUT FILE STORAGE INFORMATION SHEET

Document CDQ0000002016000044	Rev. 000	Plant: GEN	

Subject: Gridded Probable Maximum Precipitation Development

☐ 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.)

These files are electronically attached to the parent ADOBE.pdf calculation file or stored in Filekeeper. All files are therefore stored in an unalterable medium and are retrievable through the EDMS number for this calculation or from Filekeeper.

Electronically attached files are listed in the CDQ0000002016000044 **_Electronic_File_Attachments.pdf**.

☐ Microfiche/eFiche

COMPUTER PROGRAM APPLICATION

Program Name: Note 3 **Microsoft Excel**	**Program Version:** 2016

Description of Program:
Microsoft Excel is a spreadsheet application that features calculating, graphing, and macro programming. Excel organizes, analyzes, and formats data.

Description of the supporting application or function of the Computer Program to the Calculation:
Microsoft Excel was used as a calculator with graphing functions employed for visual review.

COMPUTER PROGRAM APPLICATION QUESTIONS	EVALUATION RESULTS
1. Is the Computer Program and version in the Software Library with an acceptable status of "Active" for use for the final design? Note 2 • If "No," STOP and consult the Project Manager or list computer program as an unverified assumption.	☐**Yes** ☐**No**
2. Is the Computer Program and version in the Software Library the same as used in the calculation? Note 1	☒**Yes** ☐**No**
3. Is the Computer Program a preverified program? Note 1 • If "No," discuss below in Comments or additional clarification. ☒ Verified for each application. ☐ Verified by alternate calculation. • If "Yes," list the Software Dedication Report (SDR) number below. SDR with Revision:_____ Is the scope of this calculation within the capabilities and limitations of the SDR? Note 1 ☐**Yes** ☐**No**	☐**Yes** ☒**No**
4. Are the computer program inputs listed or identified in the calculation? Note 1	☒**Yes** ☐**No**
5. Are the computer program outputs listed or identified in the calculation? Note 1	☒**Yes** ☐**No**
6. Are there any outstanding computer program errors that could affect the results? • If "Yes," is the issue listed as an unverified assumption or otherwise identified? Note 1 ☐**Yes** ☐**No**	☐**Yes** ☒**No**
7. Was the analysis performed on a computer designated to run the Computer Program? Note 1	☒**Yes** ☐**No**

List the verification method used (See QA-CP-06, Computer Program Applications) for the computer program where results are verified for each application or by alternate calculation:

Hand calculation

Comments or additional clarification (a No response to questions 2–5 or 7, or a Yes to question 6 requires an explanation):

Verified by hand calculation for each application

Note:
1. A No response to questions 2–5 or 7, or a Yes to question 6 indicates the calculation is incomplete or requires an explanation in the comments block for special circumstances.
2. Consult the Software Library for a listing of Barge approved Computer Programs or software and associated user manuals.
3. Utilize a separate page for each Computer Program used in the calculation.

COMPUTER PROGRAM APPLICATION

Program Name: Note 3 **ArcGIS**	**Program Version:** 10.2.2

Description of Program:
ArcGIS is geographic information system (GIS) software. A GIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows users to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts.

Description of the supporting application or function of the Computer Program to the Calculation:
Software was used to develop average sub-basin rainfall depths from the gridded Probable Maximum Precipitation (PMP) depths as provided by References 2.3 and 2.23.

COMPUTER PROGRAM APPLICATION QUESTIONS	EVALUATION RESULTS
1. Is the Computer Program and version in the Software Library with an acceptable status of "Active" for use for the final design? Note 2 • If "No," STOP and consult the Project Manager or list computer program as an unverified assumption.	☒**Yes** ☐**No**
2. Is the Computer Program and version in the Software Library the same as used in the calculation? Note 1	☒**Yes** ☐**No**
3. Is the Computer Program a preverified program? Note 1 • If "No," discuss below in Comments or additional clarification. ☐ Verified for each application. ☒ Verified by alternate calculation. • If "Yes," list the Software Dedication Report (SDR) number below. SDR with Revision:_____ Is the scope of this calculation within the capabilities and limitations of the SDR? Note 1 ☐**Yes** ☐**No**	☐**Yes** ☒**No**
4. Are the computer program inputs listed or identified in the calculation? Note 1	☒**Yes** ☐**No**
5. Are the computer program outputs listed or identified in the calculation? Note 1	☒**Yes** ☐**No**
6. Are there any outstanding computer program errors that could affect the results? • If "Yes," is the issue listed as an unverified assumption or otherwise identified? Note 1 ☐**Yes** ☐**No**	☐**Yes** ☒**No**
7. Was the analysis performed on a computer designated to run the Computer Program? Note 1	☒**Yes** ☐**No**

List the verification method used (See QA-CP-06, Computer Program Applications) for the computer program where results are verified for each application or by alternate calculation:
Alternate analyses using comparable software were performed using the same input data. Comparison of the output from both primary and alternate implementations is included in Appendix A.

Comments or additional clarification (a No response to questions 2–5 or 7, or a Yes to question 6 requires an explanation):

ArcGIS operation verified using QGIS.

Note:
1. A No response to questions 2–5 or 7, or a Yes to question 6 indicates the calculation is incomplete or requires an explanation in the comments block for special circumstances.
2. Consult the Software Library for a listing of Barge approved Computer Programs or software and associated user manuals.
3. Utilize a separate page for each Computer Program used in the calculation.

COMPUTER PROGRAM APPLICATION

Program Name: Note 3 **Quantum GIS (QGIS)**	**Program Version:** 2.8.2

Description of Program:
QGIS is a geographic information system (GIS) software package that integrates spatial data capture, management, analysis and display.

Description of the supporting application or function of the Computer Program to the Calculation:
QGIS software was used to validate ArcGIS software operation in development of average sub-basin rainfall depths from the gridded Probable Maximum Precipitation (PMP) depths as provided by References 2.3 and 2.23.

COMPUTER PROGRAM APPLICATION QUESTIONS	EVALUATION RESULTS
1. Is the Computer Program and version in the Software Library with an acceptable status of "Active" for use for the final design? Note 2 • If "No," STOP and consult the Project Manager or list computer program as an unverified assumption.	☒**Yes** ☐**No**
2. Is the Computer Program and version in the Software Library the same as used in the calculation? Note 1	☒**Yes** ☐**No**
3. Is the Computer Program a preverified program? Note 1 • If "No," discuss below in Comments or additional clarification. ☐ Verified for each application. ☒ Verified by alternate calculation. • If "Yes," list the Software Dedication Report (SDR) number below. SDR with Revision:_____ Is the scope of this calculation within the capabilities and limitations of the SDR? Note 1 ☐**Yes** ☐**No**	☐**Yes** ☒**No**
4. Are the computer program inputs listed or identified in the calculation? Note 1	☒**Yes** ☐**No**
5. Are the computer program outputs listed or identified in the calculation? Note 1	☒**Yes** ☐**No**
6. Are there any outstanding computer program errors that could affect the results? • If "Yes," is the issue listed as an unverified assumption or otherwise identified? Note 1 ☐**Yes** ☐**No**	☐**Yes** ☒**No**
7. Was the analysis performed on a computer designated to run the Computer Program? Note 1	☒**Yes** ☐**No**

List the verification method used (See QA-CP-06, Computer Program Applications) for the computer program where results are verified for each application or by alternate calculation:

Comparable proven computer software application.

Comments or additional clarification (a No response to questions 2–5 or 7, or a Yes to question 6 requires an explanation):

QGIS was used to verify ArcGIS operation.

Note:
1. A No response to questions 2–5 or 7, or a Yes to question 6 indicates the calculation is incomplete or requires an explanation in the comments block for special circumstances.
2. Consult the Software Library for a listing of Barge approved Computer Programs or software and associated user manuals.
3. Utilize a separate page for each Computer Program used in the calculation.

COMPUTER PROGRAM APPLICATION

Program Name: Note 3 **PMP Evaluation Tool**	**Program Version:** 1.01

Description of Program:
The PMP Evaluation Tool was developed in Reference 2.3 as an ArcGIS add-in.

Description of the supporting application or function of the Computer Program to the Calculation:
The PMP Evaluation Tool queries a database and provides Probable Maximum Precipitation (PMP) depths for the specified storm duration and type.

COMPUTER PROGRAM APPLICATION QUESTIONS	EVALUATION RESULTS
1. Is the Computer Program and version in the Software Library with an acceptable status of "Active" for use for the final design? Note 2 • If "No," STOP and consult the Project Manager or list computer program as an unverified assumption.	☒**Yes** ☐**No**
2. Is the Computer Program and version in the Software Library the same as used in the calculation? Note 1	☒**Yes** ☐**No**
3. Is the Computer Program a preverified program? Note 1 • If "No," discuss below in Comments or additional clarification. ☐ Verified for each application. ☐ Verified by alternate calculation. • If "Yes," list the Software Dedication Report (SDR) number below. SDR with Revision: SDR-16-01 Revision 001 Is the scope of this calculation within the capabilities and limitations of the SDR? Note 1 ☒**Yes** ☐**No**	☒**Yes** ☐**No**
4. Are the computer program inputs listed or identified in the calculation? Note 1	☒**Yes** ☐**No**
5. Are the computer program outputs listed or identified in the calculation? Note 1	☒**Yes** ☐**No**
6. Are there any outstanding computer program errors that could affect the results? • If "Yes," is the issue listed as an unverified assumption or otherwise identified? Note 1 ☐**Yes** ☐**No**	☐**Yes** ☒**No**
7. Was the analysis performed on a computer designated to run the Computer Program? Note 1	☒**Yes** ☐**No**

List the verification method used (See QA-CP-06, Computer Program Applications) for the computer program where results are verified for each application or by alternate calculation:

SDR-16-01, Revision 001

Comments or additional clarification (a No response to questions 2–5 or 7, or a Yes to question 6 requires an explanation):

Note:
1. A No response to questions 2–5 or 7, or a Yes to question 6 indicates the calculation is incomplete or requires an explanation in the comments block for special circumstances.
2. Consult the Software Library for a listing of Barge approved Computer Programs or software and associated user manuals.
3. Utilize a separate page for each Computer Program used in the calculation.

1.0 Purpose

The purpose of this calculation is to determine the Probable Maximum Precipitation (PMP) values for all candidate storms based on Reference 2.3, review the resulting PMP depth – duration relationship and recommend the appropriate PMP event duration. The results will be used as input to subsequent surface runoff hydrograph development calculations.

2.0 References

2.1 Schwarz, Francis K., *Probable Maximum and TVA Precipitation over the Tennessee River Basin above Chattanooga*, Hydrometeorological Report No. 41, Hydrometeorological Section, Office of Hydrology, U.S. Weather Bureau, U.S. Department of Commerce, Washington, D.C., dated June 1965. Web. 28 Mar 2013. Copy included as Supplement 1.

2.2 Zurndorfer, E. A., F.K. Schwarz, E.M. Hansen, D.D. Fenn and J.F. Miller, *Probable Maximum and TVA Precipitation Estimates with Areal Distribution for Tennessee River Drainages Less Than 3,000 Mi^2 in Area*, Hydrometeorological Report No. 56, Hydrometeorological Section, Office of Hydrology, National Weather Service, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, dated October 1986. Web. 1 Apr 2010. Copy included as Supplement 2.

2.3 Tennessee Valley Authority, Calculation CDQ0000002016000041, TVA Overall Basin Probable Maximum Precipitation and Local Intense Precipitation Analysis, Revision 001.

2.4 Tennessee Valley Authority, Calculation CDQ000020080056, Sub Basin (1-6) Douglas Dam Watershed Unit Hydrograph Validation, Revision 1.

2.5 Tennessee Valley Authority, Calculation CDQ000020080057, Sub Basin 48 (Sequatchie River) Unit Hydrograph Validation, Revision 2.

2.6 Tennessee Valley Authority, Calculation CDQ000020080058, Sub Basin 46 (South Chickamauga Creek) Unit Hydrograph Validation, Revision 2.

2.7 Tennessee Valley Authority, Calculation CDQ000020080059, Sub Basin (49-50) Guntersville Local Unit Hydrograph Validation, Revision 2.

2.8 Tennessee Valley Authority, Calculation CDQ000020080060, Nickajack Dam Local Watershed (Subbasins 47A and 47B) Unit Hydrograph Validation, Revision 4.

2.9 Tennessee Valley Authority, Calculation CDQ000020080061, Subbasins 38 (Chatuge Dam), 39 (Nottely Dam), 40 (Hiwassee Dam), 41 (Apalachia Dam), and 43 (Ocoee No. 1 Dam) Unit Hydrograph Validations, Revision 2.

2.10 Tennessee Valley Authority, Calculation CDQ000020080062, Unit Hydrograph Validation for Subbasin 7 (Little Pigeon River at Sevierville), Revision 2.

2.11 Tennessee Valley Authority, Calculation CDQ000020080063, Holston River Watershed above Cherokee Dam (Subbasins 9 through 15) Unit Hydrograph Validation, Revision 2.

2.12 Tennessee Valley Authority, Calculation CDQ000020080064, Chickamauga Dam Local (Subbasins 44B & 45) Unit Hydrograph Validation, Revision 3.

2.13 Tennessee Valley Authority, Calculation CDQ000020080065, Watts Bar Dam Local Watershed (Subbasins 25, 33, 34, 36 and 37) Unit Hydrograph Validation, Revision 2.

2.14 Tennessee Valley Authority, Calculation CDQ000020080066, Subbasin 26 (Norris Dam) Unit Hydrograph Validation, Revision 2.

2.15 Tennessee Valley Authority, Calculation CDQ000020080067, Subbasin 35 (Emory River at Mouth) Unit Hydrograph Validation, Revision 2.

2.16 Tennessee Valley Authority, Calculation CDQ000020080068, Melton Hill Local (Subbasin 27) Unit Hydrograph Validation, Revision 2.

2.17 Tennessee Valley Authority, Calculation CDQ000020080069, Ft. Loudoun-Tellico Dam Local Watershed (Subbasins 8, 16, 17, 18, and 24) Unit Hydrograph Validation, Revision 2.

2.18 Tennessee Valley Authority, Calculation CDQ000020080070, Little Tennessee River Watershed above Chilhowee Dam (Subbasins 19 through 23) Unit Hydrograph Validation, Revision 2.

2.19 Tennessee Valley Authority, Calculation CDQ000020080071, Unit Hydrograph Validation for Subbasin 44A, the Lower Hiwassee River from Charleston (River Mile 18.9) to Apalachia and Ocoee No. 1 Dams, Revision 2.

2.20 Tennessee Valley Authority, Calculation CDQ000020080072, Wheeler Dam Watershed (Subbasins 51, 52, 54, 55, 56, 58, 63, 64 and 65) Unit Hydrograph Validation, Revision 2.

2.21 Tennessee Valley Authority, Calculation CDQ000020080073, Wheeler Dam Watershed (Subbasins 53, 57, 59, 60, 61 and 62) Unit Hydrograph Validation, Revision 1.

2.22 Tennessee Valley Authority, Calculation CDQ000020080091, Subbasin 42 (Blue Ridge Dam) Unit Hydrograph Validation, Revision 2.

2.23 BWSC Software Dedication Report (SDR) No. 16-01, “PMP Evaluation Tool Package”, July 2018, Revision 1, EDMS# W50 180807 001.

2.24 Tennessee Valley Authority, Calculation CDQ0000002016000045, Weekly API Determination, Revision 000.

2.25 Tennessee Valley Authority, Calculation RSOO1HROGCDX00032620100001, “Ocoee No. 1 Project Specific PMF Hydrologic Analysis”, Revision 0.

2.26 Tennessee Valley Authority, Calculation CDQ0000002014000015, “Inflows”, Revision 0.

2.27 Tennessee Valley Authority, ”Areal Application of PMP Event Data for the Tennessee River Model above Wheeler Dam”, April 12, 2017, EDMS # B41 170420 001.

3.0 Assumptions – None

4.0 Design Input Data

Sec.	Input Parameter	Source	Location	Value/Description
4.1	Sub-basin GIS Shapefile	Reference 2.24	Original - Reference 2.24 Data as used - Appendix A	Sub-basin shapes, positions and areas
4.2	Reservoir GIS Shapefile	Reference 2.26	Original - Reference 2.26 Data as used - Appendix A	Reservoir shapes, positions and areas
4.3	Critical Storm Data	Reference 2.3	Original - Reference 2.3 Data as used - Appendix A	Storm type, duration and date of occurrence
4.4	PMP Evaluation Tool	References 2.3 and 2.23	Original - References 2.3 and 2.23 As used - Appendix A	ArcGIS Tool for gridded PMP depths

5.0 Special Requirements / Limiting Conditions – None

6.0 Computations and Analysis

6.1 Microsoft Excel 2016 software was used as a calculator for this calculation.

6.2 Previous PMP development for Tennessee Valley sub-basins was based on information published by the National Weather Service specifically for the Tennessee Valley watershed (References 2.1 and 2.2). Since the data and analysis methods used for both of these publications were over 30-years old, an updated study of the PMP specifically for the Tennessee Valley using all data available to date was commissioned (Reference 2.3). This analysis produced an ArcGIS software tool to generate gridded PMP depths for a range of storm types and durations. The tool generated gridded PMP depth data that was then processed to produce weighted average PMP depths over the Tennessee Valley Authority project sub-basins. A detailed description of this process is presented in Appendix A. An additional check of the ArcGIS software function using comparable software (QGIS) was also performed in Appendix A.

6.3 Storm types included in the PMP data were based on information provided in Reference 2.3. General and Tropical event type data were calculated for all events. As specified in Reference 2.3, the local type event is only applicable to total watershed areas of "…approximately 500 square miles." Since no variance is specified, local event type data for total watershed areas up to 500 square miles were reviewed. The Local event type was analyzed by determining the gridded point depth-duration data for all points within the TVA watershed for a 500 square mile event. The Local event type rainfall depths for the upper limit of 500 square-miles provides a bounding condition that can be used to evaluate the possibility of the local storm types controlling at projects across the TVA watershed.

Review of Reference 2.3 indicates that the depth-area-duration data developed represent rainfall volume bounding conditions but do not identify all possible PMP event orientations that could occur. This means that a smaller (i.e. heavier rainfall) PMP event could be embedded inside a larger area event as long as the larger event PMP volume is not exceeded. As a result, it would be possible to have a smaller embedded PMP event that would challenge an upstream project while the overall PMP event would not.

Therefore, rainfall data sets developed in this calculation are based on analysis of watersheds above and between modeled TVA projects. In order to adequately track the resulting large number of data sets, Project IDs were assigned to identify the event limits and are shown in Table 6.3.

Table 6.3

Project	Project ID		Project	Project ID
Norris	NO		Watts Bar	WB
Melton Hill	MH		Chatuge	CT
South Holston	SH		Nottely	NT
Watauga	WT		Hiwassee	HI
Boone	BO		Apalachia	AP
Ft. Patrick Henry	FP		Blue Ridge	BR
Cherokee	CR		Ocoee #1	O1
Douglas	DG		Chickamauga	CH
Ft. Loudoun	FL		Nickajack	NJ
Fontana	FN		Guntersville	GU
Tellico	TE		Tims Ford	TF
Ft. Loudoun-Tellico	FT		Wheeler	WE

6.4 Project PMP events anticipated to be required for subsequent PMF determinations and those recommended in Reference 2.27 based on total project drainage area were reviewed, judged appropriate for use and are shown in Tables 6.4a, 6.4b, 6.4c and 6.4d. Smaller project PMP events were included to allow evaluation of project overtopping and failure potential. Event rainfalls were calculated both to provide PMP depths over an entire project watershed as well as PMP depths concentrated over postulated critical watersheds between projects to allow evaluation of project overtopping potential and flood storage effects. The PMP events developed and the naming convention used are presented Tables 6.4a, 6.4b, 6.4c and 6.4d. PMP data were produced and a storm database file for each of the Local, Tropical and General storm types were developed for use in subsequent calculations. A generalized overview of the PMP depth data generation process is provided in Attachment 1 with further descriptions detailed in Appendix A.

Table 6.4a

PMP Event Area	Designation	Basins in PMP Area	Total Area (sq.mi.)
Apalachia to Chatuge-Nottely	AP_CTNT	40-41	614.9
Above Apalachia	AP	38-41	1,018.3
Apalachia to Hiwassee	AP_HI	41	49.8
Above Boone and Douglas	BODG	1-6, 9-11	6,382.4
Above Boone	BO	9-11	1,839.2
Above Boone-Douglas-Fontana	BODGFN	1-6, 9-11, 19-22	7,953.3
Boone to South Holston-Watauga	BO_SHWT	11	667.7
Above Blue Ridge	BR	42	231.6
Chickamauga-Tellico to Norris-Fort Loudoun-Fontana	CHTE_NOFLFN	23-25, 27, 33-43, 44A, 44B, 45	6,748.3
Chickamauga-Tellico to Norris-Fort Loudoun	CHTE_NOFL	19-25, 27, 33-43, 44A, 44B,45	8,319.1
Chickamauga-Tellico to Watts Bar-Fontana	CHTE_WBFN	23, 24, 38-43, 44A, 44B, 45	4,542.1
Chickamauga and Tellico to Watts Bar	CHTE_WB	19-24, 38-43, 44A, 44B, 45	6,113.0
Above Chickamauga	CH	1-45	20,780.8
Chickamauga to Norris-Cherokee-Douglas-Chatuge-Nottely-Blue Ridge	CH_NOCRDGCTNTBR	7-8, 16-25, 27, 33-37, 40, 41, 43, 44A, 44B, 45	9,264.3
Chickamauga to Norris-Cherokee-Douglas-Fontana-Chatuge-Nottely-Blue Ridge	CH_NOCRDGFNCTNTBR	7-8, 16-18, 23-25, 27, 33-37, 40, 41, 43, 44A, 44B, 45	7,693.4
Chickamauga to Norris-Cherokee-Douglas-Fontana-Hiwassee-Blue Ridge	CH_NOCRDGFNHIBR	7-8, 16-18, 23-25, 27, 33-37, 41, 43, 44A, 44B, 45	7,128.3
Chickamauga to Norris-Cherokee-Douglas-Fontana	CH_NOCRDGFN	7-8, 16-18, 23-25, 27, 33-43, 44A, 44B, 45	8,328.4
Chickamauga to Norris-Cherokee-Douglas-Hiwassee-Blue Ridge	CH_NOCRDGHIBR	7-8, 16-25, 27, 33-37, 41, 43, 44A, 44B, 45	8,699.2
Chickamauga to Norris-Cherokee-Douglas	CH_NOCRDG	7-8, 16-25, 27, 33-43, 44A, 44B, 45	9,899.3
Chickamauga to Norris-Fort Loudoun-Chatuge-Nottely-Blue Ridge	CH_NOFLCTNTBR	19-25, 27, 33-37, 40, 41, 43, 44A, 44B, 45	7,684.2
Chickamauga to Norris-Fort Loudoun-Hiwassee-Blue Ridge	CH_NOFLHIBR	19-25, 27, 33-37, 41, 43, 44A, 44B, 45	7,119.1
Chickamauga to Norris-Fort Loudoun-Tellico-Chatuge-Nottely-Blue Ridge	CH_NOFTCTNTBR	25, 27, 33-37, 40, 41, 43, 44A, 44B, 45	5,058.4
Chickamauga to Norris-Fort Loudoun-Tellico-Hiwassee-Blue Ridge	CH_NOFTHIBR	25, 27, 33-37, 41, 43, 44A, 44B, 45	4,493.3
Chickamauga to Norris-Fort Loudoun-Tellico	CH_NOFT	25, 27, 33-43, 44A, 44B, 45	5,693.4
Chickamauga to Watts Bar-Chatuge-Nottely-Blue Ridge	CH_WBCTNTBR	40, 41, 43, 44A, 44B, 45	2,852.3
Chickamauga to Watts Bar-Hiwassee-Blue Ridge	CH_WBHIBR	41, 43, 44A, 44B, 45	2,287.2
Chickamauga to Watts Bar	CH_WB	38-43, 44A, 44B, 45	3,487.3
Cherokee to Boone and Above Douglas-Fontana-Chatuge-Nottely-Blue Ridge	CRDGFNCTNTBR_BO	1-6, 12-15, 19-22, 38, 39, 42	8,335.4
Above Cherokee-Douglas-Fontana-Chatuge-Nottely-Blue Ridge	CRDGFNCTNTBR	1-6, 9-15, 19-22, 38, 39, 42	10,174.6
Cherokee to South Holston-Watauga and Above Douglas-Fontana-Chatuge-Nottely-Blue Ridge	CRDGFNCTNTBR_SHWT	1-6, 11-15, 19-22, 38, 39, 42	9,003.1

Table 6.4b

PMP Event Area	Designation	Basins in PMP Area	Total Area (sq.mi.)
Cherokee to Boone and Above Douglas-Fontana-Hiwassee-Blue Ridge	CRDGFNHIBR_BO	1-6, 12-15, 19-22, 38-40, 42	8,900.5
Above Blue Ridge-Hiwassee-Fontana-Douglas-Cherokee	CRDGFNHIBR	38-40, 42, 19-22, 1-6, 9-15	10,739.7
Cherokee to South Holston-Watauga and Above Douglas-Fontana-Hiwassee-Blue Ridge	CRDGFNHIBR_SHWT	1-6, 11-15, 19-22, 38-40, 42	9,568.2
Above Cherokee - Douglas - Fontana	CRDGFN	1-6, 9-15, 19-22	9,539.6
Cherokee to Boone and Above Douglas-Tellico-Chatuge-Nottely-Blue Ridge	CRDGTECTNTBR_BO	1-6, 12-15, 19-24, 38, 39, 42	9,390.3
Above Cherokee-Douglas-Tellico-Chatuge-Nottely-Blue Ridge	CRDGTECTNTBR	1-6, 9-15, 19-24, 38, 39, 42	11,229.5
Cherokee to South Holston-Watauga and Above Douglas-Tellico-Chatuge-Nottely-Blue Ridge	CRDGTECTNTBR_SHWT	1-6, 11-15, 19-24, 38, 39, 42	10,058.0
Cherokee to Boone and Above Douglas-Tellico-Hiwassee-Blue Ridge	CRDGTEHIBR_BO	1-6, 12-15, 19-24, 38-40, 42	9,955.4
Above Cherokee-Douglas-Tellico-Hiwassee-Blue Ridge	CRDGTEHIBR	1-6, 9-15, 19-24, 38-40, 42	11,794.5
Cherokee to South Holston-Watauga and Above Douglas-Tellico-Hiwassee-Blue Ridge	CRDGTEHIBR_SHWT	1-6, 11-15, 19-24, 38-40, 42	10,623.0
Cherokee to Boone and Above Douglas-Tellico	CRDGTE_BO	1-6, 12-15, 19-24	8,755.3
Above Cherokee-Douglas-Tellico	CRDGTE	1-6, 9-15, 19-24	10,594.5
Cherokee to South Holston-Watauga and Above Douglas-Tellico	CRDGTE_SHWT	1-6, 11-15, 19-24	9,423.0
Cherokee to Boone and Above Douglas	CRDG_BO	1-6, 12, 13, 14&15	6,129.5
Above Cherokee-Douglas	CRDG	1-6, 9-15	7,968.7
Cherokee to South Holston-Watauga and Above Douglas	CRDG_SHWT	1-6, 11-13, 14&15	6,797.2
Cherokee to Boone	CR_BO	12, 13, 14&15	1,586.3
Cherokee to Ft. Patrick Henry	CR_FP	13, 14&15	1,523.5
Above Cherokee	CR	9-15	3,425.5
Cherokee to South Holston-Watauga	CR_SHWT	11-13, 14&15	2,254.0
Above Chatuge-Nottely	CTNT	38-39	403.4
Above Chatuge	CT	38	189.1
Above Douglas-Fontana-Chatuge-Nottely-Blue Ridge	DGFNCTNTBR	1-6, 19-22, 38, 39, 42	6,749.1
Above Blue Ridge-Hiwassee-Fontana-Douglas	DGFNHIBR	1-6, 19-22, 38-40, 42	7,314.2
Above Douglas - Fontana	DGFN	1-6, 19-22	6,114.1
Above Douglas-Tellico-Chatuge-Nottely-Blue Ridge	DGTECTNTBR	1-6, 19-24, 38, 39, 42	7,804.0
Above Douglas-Tellico-Hiwassee-Blue Ridge	DGTEHIBR	1-6, 19-24, 38-40, 42	8,369.1
Above Douglas-Tellico	DGTE	1-6, 19-24	7,169.0
Above Douglas	DG	1-6	4,543.3
Fort Loudoun-Fontana to Cherokee	FLFN_CR	1-8, 16-22	7,694.3
Fort Loudoun to Boone	FL_BO	1-8, 12-18	7,709.7
Ft. Loudoun to Cherokee-Douglas	FL_CRDG	7-8, 16-18	1,580.1
Fort Loudoun to Cherokee	FL_CR	1-8, 16-18	6,123.4
Above Ft. Loudoun	FL	1-18	9,548.9
Fort Loudoun to South Holston-Watauga	FL_SHWT	1-8, 11-18	8,377.4
Above Blue Ridge-Hiwassee-Fontana	FNHIBR	38-40, 42, 19-22	2,770.9

Table 6.4c

PMP Event Area	Designation	Basins in PMP Area	Total Area (sq.mi.)
Above Fontana	FN	19-22	1,570.9
Ft. Patrick Henry to Boone	FP_BO	12	62.8
Above Ft. Patrick Henry	FP	9-12	1,901.9
Ft. Patrick Henry to South Holston-Watauga	FP_SHWT	11-12	730.4
Fort Loudoun-Tellico-Chatuge-Nottely-Blue Ridge to Boone	FTCTNTBR_BO	1-8, 12-24, 38, 39, 42	10,970.4
Fort Loudoun-Tellico-Chatuge-Nottely-Blue Ridge	FTCTNTBR	1-24, 38, 39, 42	12,809.6
Fort Loudoun-Tellico-Chatuge-Nottely-Blue Ridge to South-Holston-Watauga	FTCTNTBR_SHWT	1-8, 11-24, 38, 39, 42	11,638.1
Fort Loudoun-Tellico-Hiwassee-Blue Ridge to Boone-Fontana	FTHIBR_BOFN	1-8, 12-18, 23, 24, 38-40, 42	9,964.6
Fort Loudoun-Tellico-Hiwassee-Blue Ridge to Boone	FTHIBR_BO	1-8, 12-24, 38-40, 42	11,535.5
Fort Loudoun-Tellico-Hiwassee-Blue Ridge to Cherokee-Douglas-Fontana	FTHIBR_CRDGFN	7, 8, 16-18, 23-24, 38-39, 40, 42	3,835.1
Fort Loudoun-Tellico-Hiwassee-Blue Ridge to Cherokee-Douglas	FTHIBR_CRDG	7, 8, 16-24, 38, 39, 40, 42	5,405.9
Above Fort Loudoun-Tellico-Hiwassee-Blue Ridge	FTHIBR	1-24, 38-40, 42	13,374.7
Fort-Loudoun-Tellico-Hiwassee-Blue Ridge to South Holston-Watauga-Fontana	FTHIBR_SHWTFN	1-8, 11-18, 23, 24, 38-40, 42	10,632.3
Fort-Loudoun-Tellico-Hiwassee-Blue Ridge to South Holston-Watauga	FTHIBR_SHWT	1-8, 11-24, 38-40, 42	12,203.2
Ft. Loudoun-Tellico to Boone-Fontana	FT_BOFN	1-8, 12-18, 23, 24	8,764.5
Ft. Loudoun-Tellico to Boone	FT_BO	1-8, 12-24	10,335.4
Ft. Loudoun-Tellico to Cherokee-Douglas-Fontana	FT_CRDGFN	7-8, 16-18, 23-24	2,635.0
Ft. Loudoun-Tellico to Cherokee-Douglas	FT_CRDG	7-8, 16-24	4,205.9
Fort Loudoun-Tellico to Cherokee-Fontana	FT_CRFN	1-8, 16-18, 23-24	7,178.3
Fort Loudoun-Tellico to Cherokee	FT_CR	1-8, 16-24	8,749.1
Ft. Loudoun-Tellico to Fontana	FT_FN	1-18, 23, 24	10,603.7
Above Ft. Loudoun - Tellico	FT	1-24	12,174.6
Fort Loudoun-Tellico to South Holston-Watauga-Fontana	FT_SHWTFN	1-8, 11-18, 23, 24	9,432.2
Fort Loudoun-Tellico to South Holston-Watauga	FT_SHWT	1-8, 11-24	11,003.1
Guntersville to Chickamauga	GU_CH	46, 47A, 47B, 48-50	3,671.3
Above Guntersville	GU	1-50	24,452.1
Guntersville to Blue Ridge-Hiwassee-Fontana-Douglas-Cherokee-Norris	GU_NOCRDGFNHIBR	7-8, 16-18, 23-25, 27, 33-37, 41, 43, 44A, 44B, 45, 46, 47A, 47B, 48-50	10,799.6
Guntersville to Watts Bar-Hiwassee-Blue Ridge	GU_WBHIBR	41, 43, 44A, 44B, 45, 46, 47A, 47B, 48-50	5,958.5
Above Blue Ridge - Hiwassee	HIBR	38-40, 42	1,200.1
Hiwassee to Chatuge-Nottely	HI_CTNT	40	565.1
Above Hiwassee	HI	38-40	968.4
Above Melton Hill	MH	26-27	3,344.7
Melton Hill to Norris	MH_NO	27	431.9
Above Nickajack	NJ	1-47B	21,852.9
Nickajack to Blue Ridge-Hiwassee-Fontana-Douglas-Cherokee-Norris	NJ_NOCRDGFNHIBR	7-8, 16-18, 23-25, 27, 33-37, 41, 43, 44A, 44B, 45, 46, 47A, 47B	8,200.4
Above Blue Ridge-Hiwassee-Fontana-Douglas-Cherokee-Norris	NOCRDGFNHIBR	38-40, 42, 19-22, 1-6, 9-15, 26	13,652.5
Above Norris-Cherokee-Douglas-Fontana	NOCRDGFN	1-6, 9-15, 19-22, 26	12,452.4

Table 6.4d

PMP Event Area	Designation	Basins in PMP Area	Total Area (sq.mi.)
Above Norris - Cherokee-Douglas	NOCRDG	1-6, 9-15, 26	10,881.5
Above Norris - Cherokee	NOCR	9-15, 26	6,338.3
Above Norris	NO	26	2,912.8
Above Nottely	NT	39	214.3
Ocoee #1 to Blue Ridge	O1_BR	43	362.6
Above Ocoee #1	O1	42-43	594.3
Above South Holston-Watauga-Douglas	SHWTDG	1-6, 9, 10	5,714.8
Above South Holston-Watauga-Douglas-Fontana	SHWTDGFN	1-6, 9, 10, 19-22	7,285.6
Above South Holston-Watauga	SHWT	9-10	1,171.5
Above South Holston	SH	9	703.3
Tellico-Hiwassee-Blue Ridge to Fontana	TEHIBR_FN	23, 24, 38, 39, 40, 42	2,254.9
Tellico-Hiwassee-Blue Ridge	TEHIBR	19-24, 38, 39, 40, 42	3,825.8
Tellico to Fontana	TE_FN	23-24	1,054.9
Above Tellico	TE	19-24	2,625.8
Above Tims Ford	TF	59	533.3
Above Watts Bar-Chatuge-Nottely-Blue Ridge	WBCTNTBR	1-38, 39, 42	17,928.5
Above Watts Bar-Hiwassee-Blue Ridge	WBHIBR	1-40, 42	18,493.6
Watts Bar-Hiwassee-Blue Ridge to Norris-Cherokee-Douglas-Fontana	WBHIBR_NOCRDGFN	7,8,16-18, 23-25, 27, 33-40, 42	6,041.2
Watts Bar-Hiwassee-Blue Ridge to Norris-Cherokee-Douglas	WBHIBR_NOCRDG	7, 8, 16-25, 27, 33-40, 42	7,612.1
Watts Bar to Fort Loudoun	WB_FL	19-27, 33-37	7,744.7
Watts Bar to Fort Loudoun-Tellico	WB_FT	25-27, 33-37	5,118.9
Above Watts Bar	WB	1-37	17,293.5
Watts Bar to Norris-Cherokee-Douglas-Fontana	WB_NOCRDGFN	7-8, 16-18, 23-25, 27, 33-37	4,841.1
Watts Bar to Norris-Cherokee-Douglas	WB_NOCRDG	7-8, 16-25, 27, 33-37	6,412.0
Watts Bar to Norris-Cherokee	WB_NOCR	1-8, 16-25, 27, 33-37	10,955.3
Watts Bar to Norris-Fort Loudoun	WB_NOFL	19-25, 27, 33-37	4,831.9
Watts Bar to Norris-Fort Loudoun-Tellico	WB_NOFT	25, 27, 33-37	2,206.1
Watts Bar to Norris	WB_NO	1-25, 27-37	14,380.7
Wheeler to Chickamauga	WE_CH	46, 47A, 47B, 48-65	8,812.0
Above Wheeler	WE	1-65	29,592.8
Wheeler to Norris-Cherokee-Douglas-Fontana	WE_NOCRDGFN	7-8, 16-18, 23-25, 27, 33-43, 44A, 44B, 45, 46, 47A, 47B, 48-65	17,140.4
Wheeler to Guntersville	WE_TFGU	51-58, 60-65	4,607.4
Wheeler to Tims Ford-Blue Ridge-Hiwassee-Fontana-Douglas-Cherokee-Norris	WE_TFNOCRDGFNHIBR	7-8, 16-18, 23-25, 27, 33-37, 41, 43, 44A, 44B, 45, 46, 47A, 47B, 48-50, 51-58, 60-65	15,407.0
Wheeler to Watts Bar-Hiwassee-Blue Ridge	WE_WBHIBR	41, 43, 44A, 44B, 45, 46, 47A, 47B, 48-65	11,099.2
Above Watauga-Douglas	WTDG	1-6, 10	5,011.5
Above Watauga	WT	10	468.2

6.5 Simplification of the Rain-On-Reservoir (ROR) inflow component by utilization of the sub-basin area-weighted PMP depths for the ROR component as compared to each sub-basin and affiliated reservoir(s) having unique PMP depth-duration data was reviewed. The surface area of reservoirs within the Tennessee Valley watershed above Wheeler Dam is minimal with respect to the total watershed area. Consequently, small changes in the ROR inflow component will have minor impacts on the total inflow volume within each sub-basin. The typical location of reservoirs within the more sheltered, lower lying areas of a watershed combined with orographic effects generally leads to reduced PMP rainfall depths over the reservoir in comparison to the remaining watershed.

Comparison of the two methodologies is described in Section 6.6 of Appendix A. Analysis, included as Appendix B, calculated differences in PMP depth between the simplified approach and the reservoir area specific PMP for all three storm types applied to the watersheds above Watts Bar, Chickamauga and Wheeler. Analysis results are summarized below in Table 6.5 with negative values indicating that the simplified approach produces a higher (i.e. more conservative) PMP depth. All differences between the two ROR development methodologies were less than one-hundredth of an inch of PMP volume for the total watersheds reviewed. The analysis shows negligible differences in watershed applied PMP volume between the calculation of ROR using sub-basin averaged rainfall versus using unique GIS reservoir area rainfall. Therefore, it is appropriate for subsequent calculations to utilize the simplified approach and apply sub-basin average PMP depths during development of the ROR inflow component.

Table 6.5

Difference in Total Watershed Average PMP Depth Using Unique GIS Calculated ROR and Basin Area Averages (Inches)				
Total Watershed	Square-Miles	24hr Local	120hr General	120hr Tropical
Above WBH	17,293.53	-0.007	0.003	0.000
Above CMH	20,780.79	-0.009	-0.001	-0.007
Above WEH	29,592.76	-0.007	-0.007	0.000

7.0 Summary of Results

7.1 A database of PMP event depths as described in Section 6.4 was developed for each of the three storm types: General, Local and Tropical. Due to the large data set, the results contained in the database are adopted by reference.

7.2 The following Tables 7.2a, 7.2b, 7.2c, 7.2d, 7.2e, 7.2f and 7.2g show the cumulative PMP Event watershed average rainfall depths for the general and tropical type events at the specified durations as developed in Appendix A.

Table 7.2a

PMP Event Area	Storm Type	Designation	Duration (in hours) 1	6	12	18	24	48	72	96	120
Apalachia to Chatuge-Nottely	General	g_AP_CTNT	3.60	13.75	17.84	18.90	19.26	23.17	23.51	23.51	23.51
	Tropical	t_AP_CTNT	3.86	11.32	13.99	17.22	21.12	25.68	29.20	29.78	29.87
Above Apalachia	General	g_AP	2.96	11.73	16.40	17.34	17.65	22.05	22.30	22.30	22.30
	Tropical	t_AP	3.16	9.37	12.66	15.51	17.63	23.57	26.89	27.38	27.60
Apalachia to Hiwassee	General	g_AP_HI	5.17	18.07	21.37	22.01	24.00	27.40	27.99	27.99	27.99
	Tropical	t_AP_HI	4.75	13.63	16.21	20.23	24.37	29.23	33.92	35.07	35.11
Above Boone and Douglas	General	g_BODG	1.34	4.67	8.39	9.50	10.28	14.40	15.08	15.16	15.16
	Tropical	t_BODG	1.18	5.38	7.83	9.20	9.80	12.09	13.64	13.90	14.13
Above Boone-Douglas-Fontana	General	g_BODGFN	1.30	4.60	8.52	9.68	10.36	14.88	15.47	15.53	15.53
	Tropical	t_BODGFN	1.15	5.33	7.87	9.35	9.92	12.43	14.27	14.61	15.08
Above Boone	General	g_BO	1.82	6.47	9.52	11.21	11.92	15.00	15.50	15.76	15.76
	Tropical	t_BO	1.49	5.88	8.19	9.71	10.35	12.77	14.00	14.29	14.58
Boone to South Holston-Watauga	General	g_BO_SHWT	2.53	7.20	9.48	11.69	12.80	15.25	15.64	15.77	15.78
	Tropical	t_BO_SHWT	1.39	5.56	7.69	9.01	9.90	11.48	12.36	12.53	12.53
Above Blue Ridge	General	g_BR	4.70	16.85	20.84	21.66	22.04	25.36	26.25	26.25	26.25
	Tropical	t_BR	4.64	13.74	16.49	20.50	25.14	29.39	33.28	34.06	34.36
Chickamauga-Tellico to Norris-Fort Loudoun-Fontana	General	g_CHTE_NOFLFN	1.73	5.38	9.79	10.99	11.95	16.15	16.50	16.57	16.57
	Tropical	t_CHTE_NOFLFN	1.35	6.35	9.27	10.89	11.47	13.49	15.90	16.31	16.76
Chickamauga-Tellico to Norris-Fort Loudoun	General	g_CHTE_NOFL	1.59	5.05	9.51	10.74	11.66	16.14	16.48	16.55	16.55
	Tropical	t_CHTE_NOFL	1.28	6.04	8.96	10.66	11.20	13.31	15.85	16.43	17.32
Chickamauga-Tellico to Watts Bar-Fontana	General	g_CHTE_WBFN	1.92	6.57	11.25	12.46	13.33	17.71	18.07	18.13	18.13
	Tropical	t_CHTE_WBFN	1.59	6.93	9.92	11.61	12.41	15.69	18.20	18.57	18.86
Chickamauga and Tellico to Watts Bar	General	g_CHTE_WB	1.76	6.05	10.90	12.20	13.04	17.77	18.10	18.15	18.15
	Tropical	t_CHTE_WB	1.46	6.59	9.57	11.29	12.13	15.42	18.11	18.54	18.91
Above Chickamauga	General	g_CH	0.79	3.02	5.57	6.68	8.01	11.51	12.06	12.24	12.42
	Tropical	t_CH	0.79	3.68	6.21	7.83	8.35	9.21	10.05	10.95	11.39
Chickamauga to Norris-Cherokee-Douglas-Chatuge-Nottely-Blue Ridge	General	g_CH_NOCRDGCTNTBR	1.50	4.59	8.84	10.03	11.01	15.30	15.71	15.80	15.81
	Tropical	t_CH_NOCRDGCTNTBR	1.20	5.75	8.61	10.32	10.73	12.46	14.53	15.10	16.01
Chickamauga to Norris-Cherokee-Douglas-Fontana-Chatuge-Nottely-Blue Ridge	General	g_CH_NOCRDGFNCTNTBR	1.64	4.91	9.11	10.27	11.29	15.29	15.72	15.81	15.81
	Tropical	t_CH_NOCRDGFNCTNTBR	1.26	6.04	8.91	10.53	10.99	12.43	14.45	14.86	15.41
Chickamauga to Norris-Cherokee-Douglas-Fontana-Hiwassee-Blue Ridge	General	g_CH_NOCRDGFNHIBR	1.69	5.00	9.18	10.32	11.35	15.24	15.68	15.78	15.78
	Tropical	t_CH_NOCRDGFNHIBR	1.29	6.13	8.99	10.58	11.06	12.43	14.38	14.73	15.15
Chickamauga to Norris-Cherokee-Douglas-Fontana	General	g_CH_NOCRDGFN	1.58	4.77	8.98	10.15	11.15	15.25	15.67	15.77	15.77
	Tropical	t_CH_NOCRDGFN	1.23	5.93	8.79	10.45	10.87	12.38	14.43	14.89	15.60
Chickamauga to Norris-Cherokee-Douglas-Hiwassee-Blue Ridge	General	g_CH_NOCRDGHIBR	1.56	4.73	8.98	10.16	11.16	15.37	15.78	15.88	15.88
	Tropical	t_CH_NOCRDGHIBR	1.22	5.86	8.72	10.39	10.85	12.53	14.63	15.14	15.90
Chickamauga to Norris-Cherokee-Douglas	General	g_CH_NOCRDG	1.44	4.41	8.64	9.84	10.79	15.18	15.58	15.67	15.69
	Tropical	t_CH_NOCRDG	1.16	5.63	8.48	10.22	10.57	12.33	14.35	15.00	16.06
Chickamauga to Norris-Fort Loudoun-Chatuge-Nottely-Blue Ridge	General	g_CH_NOFLCTNTBR	1.65	5.22	9.70	10.93	11.87	16.27	16.61	16.68	16.68
	Tropical	t_CH_NOFLCTNTBR	1.32	6.17	9.09	10.77	11.36	13.50	16.05	16.57	17.28
Chickamauga to Norris-Fort Loudoun-Hiwassee-Blue Ridge	General	g_CH_NOFLHIBR	1.71	5.36	9.83	11.05	12.01	16.32	16.67	16.74	16.74
	Tropical	t_CH_NOFLHIBR	1.35	6.27	9.19	10.85	11.49	13.65	16.16	16.62	17.18

Table 7.2b

			Duration (in hours)								
PMP Event Area	Storm Type	Designation	1	6	12	18	24	48	72	96	120
Chickamauga to Norris-Fort Loudoun-Tellico-Chatuge-Nottely-Blue Ridge	General	g_CH_NOFTCTNTBR	1.90	5.80	10.25	11.43	12.36	16.43	16.73	16.78	16.78
	Tropical	t_CH_NOFTCTNTBR	1.44	6.71	9.67	11.21	11.86	13.99	16.39	16.70	16.83
Chickamauga to Norris-Fort Loudoun-Tellico-Hiwassee-Blue Ridge	General	g_CH_NOFTHIBR	1.99	6.06	10.35	11.46	12.33	16.26	16.56	16.63	16.63
	Tropical	t_CH_NOFTHIBR	1.49	6.83	9.78	11.33	11.93	14.04	16.35	16.61	16.82
Chickamauga to Norris-Fort Loudoun-Tellico	General	g_CH_NOFT	1.83	5.70	10.19	11.39	12.33	16.50	16.80	16.85	16.85
	Tropical	t_CH_NOFT	1.42	6.60	9.55	11.14	11.79	14.00	16.47	16.83	17.09
Chickamauga to Watts Bar-Chatuge-Nottely-Blue Ridge	General	g_CH_WBCTNTBR	2.24	7.85	12.23	13.28	14.07	18.22	18.49	18.56	18.56
	Tropical	t_CH_WBCTNTBR	1.98	7.50	10.53	12.37	13.15	17.05	19.72	19.99	20.66
Chickamauga to Watts Bar-Hiwassee-Blue Ridge	General	g_CH_WBHIBR	2.33	7.99	12.13	13.09	13.84	17.76	18.02	18.12	18.12
	Tropical	t_CH_WBHIBR	2.05	7.53	10.55	12.33	12.98	16.82	19.40	19.58	20.38
Chickamauga to Watts Bar	General	g_CH_WB	2.13	7.50	12.07	13.20	14.00	18.33	18.60	18.66	18.66
	Tropical	t_CH_WB	1.84	7.34	10.37	12.20	13.04	16.91	19.59	19.95	20.48
Cherokee to Boone and Above Douglas-Fontana-Chatuge-Nottely-Blue Ridge	General	g_CRDGFNCTNTBR_BO	1.30	4.49	8.40	9.54	10.26	14.84	15.52	15.60	15.60
	Tropical	t_CRDGFNCTNTBR_BO	1.13	5.26	7.79	9.28	9.81	12.18	13.88	14.22	14.76
Above Cherokee-Douglas-Fontana-Chatuge-Nottely-Blue Ridge	General	g_CRDGFNCTNTBR	1.12	3.84	7.42	8.51	9.19	13.75	14.44	14.53	14.53
	Tropical	t_CRDGFNCTNTBR	0.99	4.78	7.22	8.72	9.05	10.93	12.48	12.88	13.54
Cherokee to South Holston-Watauga and Above Douglas-Fontana-Chatuge-Nottely-	General	g_CRDGFNCTNTBR_SHWT	1.22	4.19	7.93	9.05	9.78	14.33	15.04	15.12	15.12
	Tropical	t_CRDGFNCTNTBR_SHWT	1.06	5.03	7.50	8.97	9.42	11.55	13.16	13.51	14.10
Cherokee to Boone and Above Douglas-Fontana-Hiwassee-Blue Ridge	General	g_CRDGFNHIBR_BO	1.27	4.39	8.33	9.47	10.16	14.84	15.49	15.57	15.57
	Tropical	t_CRDGFNHIBR_BO	1.11	5.21	7.77	9.29	9.76	12.11	13.87	14.27	14.93
Above Blue Ridge-Hiwassee-Fontana-Douglas-Cherokee	General	g_CRDGFNHIBR	1.11	3.85	7.44	8.53	9.23	13.81	14.48	14.57	14.57
	Tropical	t_CRDGFNHIBR	0.99	4.76	7.24	8.75	9.08	10.99	12.59	13.05	13.75
Cherokee to South Holston-Watauga and Above Douglas-Fontana-Hiwassee-Blue	General	g_CRDGFNHIBR_SHWT	1.19	4.10	7.86	8.99	9.67	14.33	15.00	15.09	15.09
	Tropical	t_CRDGFNHIBR_SHWT	1.04	4.98	7.48	8.99	9.38	11.49	13.16	13.57	14.28
Above Cherokee - Douglas - Fontana	General	g_CRDGFN	1.15	3.91	7.47	8.55	9.27	13.73	14.46	14.56	14.56
	Tropical	t_CRDGFN	1.01	4.82	7.24	8.69	9.06	10.96	12.45	12.79	13.35
Cherokee to Boone and Above Douglas-Tellico-Chatuge-Nottely-Blue Ridge	General	g_CRDGTECTNTBR_BO	1.23	4.22	8.09	9.22	9.91	14.55	15.23	15.31	15.31
	Tropical	t_CRDGTECTNTBR_BO	1.08	5.12	7.68	9.21	9.62	11.80	13.49	13.90	14.59
Above Cherokee-Douglas-Tellico-Chatuge-Nottely-Blue Ridge	General	g_CRDGTECTNTBR	1.09	3.79	7.32	8.40	9.15	13.64	14.33	14.43	14.43
	Tropical	t_CRDGTECTNTBR	0.98	4.71	7.18	8.70	9.04	10.85	12.40	12.86	13.52
Cherokee to South Holston-Watauga and Above Douglas-Tellico-Chatuge-Nottely-	General	g_CRDGTECTNTBR_SHWT	1.16	3.95	7.66	8.77	9.46	14.08	14.77	14.86	14.86
	Tropical	t_CRDGTECTNTBR_SHWT	1.02	4.90	7.40	8.93	9.26	11.23	12.83	13.25	13.98
Cherokee to Boone and Above Douglas-Tellico-Hiwassee-Blue Ridge	General	g_CRDGTEHIBR_BO	1.20	4.11	7.99	9.12	9.77	14.52	15.16	15.24	15.24
	Tropical	t_CRDGTEHIBR_BO	1.05	5.06	7.63	9.20	9.56	11.69	13.43	13.90	14.72
Above Cherokee-Douglas-Tellico-Hiwassee-Blue Ridge	General	g_CRDGTEHIBR	1.08	3.80	7.32	8.41	9.16	13.68	14.35	14.44	14.44
	Tropical	t_CRDGTEHIBR	0.97	4.68	7.18	8.72	9.06	10.88	12.47	12.99	13.69
Cherokee to South Holston-Watauga and Above Douglas-Tellico-Hiwassee-Blue Ridge	General	g_CRDGTEHIBR_SHWT	1.14	3.96	7.66	8.78	9.48	14.13	14.80	14.88	14.88
	Tropical	t_CRDGTEHIBR_SHWT	1.01	4.88	7.40	8.95	9.29	11.27	12.92	13.40	14.16
Cherokee to Boone and Above Douglas-Tellico	General	g_CRDGTE_BO	1.28	4.34	8.20	9.32	10.06	14.59	15.30	15.39	15.39
	Tropical	t_CRDGTE_BO	1.10	5.19	7.72	9.21	9.69	11.90	13.53	13.88	14.44

Table 7.2c

			Duration (in hours)								
PMP Event Area	Storm Type	Designation	1	6	12	18	24	48	72	96	120
Above Cherokee-Douglas-Tellico	General	g_CRDGTE	1.11	3.79	7.32	8.40	9.13	13.59	14.32	14.42	14.42
	Tropical	t_CRDGTE	0.98	4.74	7.19	8.68	9.01	10.81	12.30	12.71	13.33
Cherokee to South Holston-Watauga and Above Douglas-Tellico	General	g_CRDGTE_SHWT	1.20	4.06	7.75	8.85	9.59	14.10	14.84	14.93	14.93
	Tropical	t_CRDGTE_SHWT	1.04	4.96	7.43	8.92	9.31	11.31	12.85	13.21	13.81
Cherokee to Boone and Above Douglas	General	g_CRDG_BO	1.37	4.60	8.25	9.33	10.18	14.23	15.10	15.20	15.20
	Tropical	t_CRDG_BO	1.16	5.31	7.72	9.06	9.64	11.65	12.92	13.13	13.31
Above Cherokee-Douglas	General	g_CRDG	1.21	4.02	7.40	8.45	9.27	13.35	14.20	14.31	14.31
	Tropical	t_CRDG	1.04	4.88	7.21	8.55	8.97	10.68	11.88	12.10	12.38
Cherokee to South Holston-Watauga and Above Douglas	General	g_CRDG_SHWT	1.30	4.33	7.80	8.89	9.74	13.78	14.67	14.77	14.77
	Tropical	t_CRDG_SHWT	1.10	5.08	7.43	8.75	9.25	11.09	12.29	12.49	12.69
Cherokee to Boone	General	g_CR_BO	1.93	5.78	8.30	10.64	11.62	14.23	15.05	15.50	15.52
	Tropical	t_CR_BO	1.27	5.20	7.31	8.57	8.93	9.07	9.07	9.07	9.07
Cherokee to Ft. Patrick Henry	General	g_CR_FP	1.96	5.87	8.40	10.70	11.71	14.30	15.11	15.53	15.57
	Tropical	t_CR_FP	1.29	5.26	7.39	8.67	9.03	9.17	9.17	9.17	9.17
Above Cherokee	General	g_CR	1.52	4.99	7.87	9.39	10.26	13.58	14.49	14.80	14.80
	Tropical	t_CR	1.20	5.15	7.28	8.53	9.03	10.25	10.90	11.03	11.17
Cherokee to South Holston-Watauga	General	g_CR_SHWT	1.69	5.19	7.76	9.90	10.71	13.52	14.35	14.88	14.88
	Tropical	t_CR_SHWT	1.19	5.00	6.99	8.18	8.57	9.11	9.33	9.39	9.45
Above Chatuge-Nottely	General	g_CTNT	3.74	13.93	17.71	18.44	18.80	22.23	22.48	22.48	22.48
	Tropical	t_CTNT	4.04	11.79	14.40	17.67	21.81	25.97	29.33	29.51	29.73
Above Chatuge	General	g_CT	4.83	17.13	21.03	21.87	23.18	26.61	27.71	27.71	27.71
	Tropical	t_CT	4.98	14.83	17.76	22.13	27.11	30.97	35.14	35.83	36.12
Above Douglas-Fontana-Chatuge-Nottely-Blue Ridge	General	g_DGFNCTNTBR	1.48	5.34	9.73	10.94	11.65	16.32	16.82	16.86	16.86
	Tropical	t_DGFNCTNTBR	1.31	5.88	8.58	10.16	10.93	14.12	16.26	16.62	16.99
Above Blue Ridge-Hiwassee-Fontana-Douglas	General	g_DGFNHIBR	1.44	5.23	9.63	10.85	11.52	16.30	16.77	16.81	16.81
	Tropical	t_DGFNHIBR	1.28	5.82	8.54	10.13	10.85	13.99	16.17	16.56	17.06
Above Douglas - Fontana	General	g_DGFN	1.52	5.46	9.83	11.03	11.79	16.34	16.87	16.92	16.92
	Tropical	t_DGFN	1.34	5.94	8.62	10.20	11.02	14.23	16.32	16.66	16.95
Above Douglas-Tellico-Chatuge-Nottely-Blue Ridge	General	g_DGTECTNTBR	1.41	5.02	9.32	10.52	11.19	15.92	16.43	16.48	16.48
	Tropical	t_DGTECTNTBR	1.24	5.71	8.41	10.00	10.64	13.53	15.61	16.00	16.57
Above Douglas-Tellico-Hiwassee-Blue Ridge	General	g_DGTEHIBR	1.37	4.89	9.20	10.41	11.03	15.87	16.35	16.40	16.40
	Tropical	t_DGTEHIBR	1.22	5.64	8.36	9.96	10.54	13.38	15.49	15.93	16.63
Above Douglas-Tellico	General	g_DGTE	1.45	5.15	9.46	10.65	11.37	15.98	16.53	16.58	16.58
	Tropical	t_DGTE	1.27	5.78	8.47	10.04	10.74	13.69	15.73	16.08	16.51
Above Douglas	General	g_DG	1.57	5.66	9.69	10.83	11.64	15.71	16.32	16.41	16.41
	Tropical	t_DG	1.39	6.01	8.59	10.11	10.89	13.80	15.55	15.86	16.11
Fort Loudoun-Fontana to Cherokee	General	g_FLFN_CR	1.42	4.88	9.05	10.22	10.94	15.44	15.98	16.05	16.05
	Tropical	t_FLFN_CR	1.22	5.64	8.31	9.86	10.47	13.01	14.75	15.07	15.49
Fort Loudoun to Boone	General	g_FL_BO	1.32	4.27	7.88	8.94	9.79	13.85	14.66	14.77	14.77
	Tropical	t_FL_BO	1.10	5.18	7.63	9.03	9.48	11.16	12.26	12.44	12.68

Table 7.2d

			Duration (in hours)								
PMP Event Area	Storm Type	Designation	1	6	12	18	24	48	72	96	120
Ft. Loudoun to Cherokee-Douglas	General	g_FL_CRDG	2.36	8.41	12.20	13.11	13.78	17.29	17.73	17.96	17.96
	Tropical	t_FL_CRDG	1.78	7.30	10.31	12.18	12.87	14.34	14.97	15.14	15.23
Fort Loudoun to Cherokee	General	g_FL_CR	1.49	5.02	9.03	10.14	10.94	15.05	15.68	15.76	15.76
	Tropical	t_FL_CR	1.26	5.76	8.37	9.82	10.45	12.70	14.13	14.36	14.56
Above Ft. Loudoun	General	g_FL	1.15	3.68	7.04	8.06	8.89	12.98	13.79	13.91	13.91
	Tropical	t_FL	0.98	4.73	7.10	8.52	8.82	10.24	11.31	11.51	11.86
Fort Loudoun to South Holston-Watauga	General	g_FL_SHWT	1.25	4.01	7.47	8.52	9.39	13.43	14.27	14.38	14.38
	Tropical	t_FL_SHWT	1.04	4.96	7.35	8.75	9.13	10.67	11.72	11.90	12.18
Above Blue Ridge-Hiwassee-Fontana	General	g_FNHIBR	2.30	9.33	14.48	15.72	16.61	21.52	21.83	21.83	21.83
	Tropical	t_FNHIBR	2.36	8.16	11.30	13.83	15.40	21.10	24.19	24.71	25.46
Above Fontana	General	g_FN	2.77	11.23	16.28	17.39	18.05	22.84	23.13	23.13	23.13
	Tropical	t_FN	2.86	9.24	12.67	15.73	17.80	23.95	27.37	27.87	28.51
Ft. Patrick Henry to Boone	General	g_FP_BO	4.05	8.06	9.97	13.59	16.07	18.18	18.51	18.83	18.86
	Tropical	t_FP_BO	1.48	5.95	8.19	9.01	9.02	9.10	9.10	9.10	9.10
Above Ft. Patrick Henry	General	g_FP	1.79	6.34	9.37	11.11	11.83	14.91	15.43	15.71	15.71
	Tropical	t_FP	1.47	5.80	8.08	9.57	10.19	12.50	13.69	13.97	14.27
Ft. Patrick Henry to South Holston-Watauga	General	g_FP_SHWT	2.47	7.01	9.30	11.64	12.75	15.23	15.66	15.80	15.80
	Tropical	t_FP_SHWT	1.35	5.41	7.52	8.82	9.58	11.08	11.87	12.02	12.02
Fort Loudoun-Tellico-Chatuge-Nottely-Blue Ridge to Boone	General	g_FTCTNTBR_BO	1.17	3.93	7.63	8.73	9.51	13.99	14.66	14.76	14.76
	Tropical	t_FTCTNTBR_BO	1.02	4.91	7.47	9.04	9.38	11.22	12.70	13.14	13.79
Fort Loudoun-Tellico-Chatuge-Nottely-Blue Ridge	General	g_FTCTNTBR	1.05	3.66	7.02	8.08	8.96	13.24	13.93	14.05	14.05
	Tropical	t_FTCTNTBR	0.94	4.55	7.04	8.58	8.93	10.52	11.90	12.39	12.95
Fort Loudoun-Tellico-Chatuge-Nottely-Blue Ridge to South-Holston-Watauga	General	g_FTCTNTBR_SHWT	1.12	3.80	7.34	8.43	9.26	13.64	14.34	14.45	14.45
	Tropical	t_FTCTNTBR_SHWT	0.98	4.74	7.26	8.81	9.14	10.86	12.28	12.72	13.33
Fort Loudoun-Tellico-Hiwassee-Blue Ridge to Boone-Fontana	General	g_FTHIBR_BOFN	1.20	3.90	7.58	8.66	9.43	13.81	14.53	14.63	14.64
	Tropical	t_FTHIBR_BOFN	1.02	4.98	7.50	9.04	9.34	11.03	12.36	12.70	13.30
Fort Loudoun-Tellico-Hiwassee-Blue Ridge to Boone	General	g_FTHIBR_BO	1.15	3.93	7.62	8.72	9.51	14.02	14.67	14.77	14.77
	Tropical	t_FTHIBR_BO	1.01	4.87	7.45	9.04	9.38	11.24	12.77	13.26	13.95
Fort Loudoun-Tellico-Hiwassee-Blue Ridge to Cherokee-Douglas-Fontana	General	g_FTHIBR_CRDGFN	1.98	7.09	11.62	12.76	13.57	17.88	18.35	18.47	18.47
	Tropical	t_FTHIBR_CRDGFN	1.71	7.01	9.94	11.74	12.64	15.72	17.40	17.72	18.03
Fort Loudoun-Tellico-Hiwassee-Blue Ridge to Cherokee-Douglas	General	g_FTHIBR_CRDG	1.79	6.29	11.19	12.49	13.33	18.03	18.48	18.53	18.53
	Tropical	t_FTHIBR_CRDG	1.50	6.64	9.59	11.32	12.28	15.74	17.85	18.19	18.44
Above Fort Loudoun-Tellico-Hiwassee-Blue Ridge	General	g_FTHIBR	1.03	3.65	7.00	8.07	8.95	13.26	13.93	14.04	14.05
	Tropical	t_FTHIBR	0.94	4.51	7.02	8.58	8.93	10.53	11.95	12.49	13.09
Fort-Loudoun-Tellico-Hiwassee-Blue Ridge to South Holston-Watauga-Fontana	General	g_FTHIBR_SHWTFN	1.14	3.77	7.29	8.35	9.17	13.47	14.21	14.32	14.32
	Tropical	t_FTHIBR_SHWTFN	0.99	4.80	7.28	8.80	9.09	10.67	11.94	12.30	12.85
Fort-Loudoun-Tellico-Hiwassee-Blue Ridge to South Holston-Watauga	General	g_FTHIBR_SHWT	1.10	3.80	7.33	8.42	9.26	13.67	14.35	14.45	14.45
	Tropical	t_FTHIBR_SHWT	0.97	4.71	7.24	8.81	9.15	10.88	12.34	12.85	13.49
Ft. Loudoun-Tellico to Boone-Fontana	General	g_FT_BOFN	1.27	4.08	7.71	8.76	9.61	13.75	14.55	14.66	14.66
	Tropical	t_FT_BOFN	1.06	5.08	7.56	9.02	9.40	11.05	12.22	12.44	12.81

Table 7.2e

PMP Event Area	Storm Type	Designation	Duration (in hours)								
			1	6	12	18	24	48	72	96	120
Ft. Loudoun-Tellico to Boone	General	g_FT_BO	1.19	3.93	7.65	8.74	9.51	13.96	14.67	14.77	14.77
	Tropical	t_FT_BO	1.02	4.95	7.49	9.04	9.37	11.19	12.62	12.99	13.59
Ft. Loudoun-Tellico to Cherokee-Douglas-Fontana	General	g_FT_CRDGFN	2.14	7.59	11.70	12.69	13.47	17.38	17.85	18.10	18.10
	Tropical	t_FT_CRDGFN	1.79	7.18	10.06	11.89	12.71	14.97	16.11	16.36	16.64
Ft. Loudoun-Tellico to Cherokee-Douglas	General	g_FT_CRDG	1.96	6.98	11.71	12.92	13.75	18.23	18.70	18.80	18.80
	Tropical	t_FT_CRDG	1.67	6.94	9.87	11.77	12.81	16.17	18.07	18.40	18.69
Fort Loudoun-Tellico to Cherokee-Fontana	General	g_FT_CRFN	1.43	4.80	8.81	9.93	10.71	14.92	15.54	15.63	15.63
	Tropical	t_FT_CRFN	1.21	5.65	8.28	9.77	10.32	12.49	13.96	14.21	14.49
Fort Loudoun-Tellico to Cherokee	General	g_FT_CR	1.34	4.58	8.69	9.85	10.54	15.11	15.66	15.74	15.74
	Tropical	t_FT_CR	1.16	5.47	8.15	9.73	10.22	12.56	14.29	14.65	15.22
Ft. Loudoun-Tellico to Fontana	General	g_FT_FN	1.11	3.60	6.95	7.97	8.82	12.93	13.73	13.85	13.85
	Tropical	t_FT_FN	0.96	4.66	7.06	8.54	8.81	10.21	11.33	11.60	12.01
Above Ft. Loudoun - Tellico	General	g_FT	1.07	3.66	7.05	8.10	8.96	13.22	13.94	14.06	14.06
	Tropical	t_FT	0.95	4.59	7.06	8.59	8.92	10.50	11.83	12.26	12.79
Fort Loudoun-Tellico to South Holston-Watauga-Fontana	General	g_FT_SHWTFN	1.20	3.83	7.30	8.35	9.20	13.34	14.15	14.27	14.27
	Tropical	t_FT_SHWTFN	1.01	4.87	7.29	8.75	9.06	10.57	11.68	11.92	12.30
Fort Loudoun-Tellico to South Holston-Watauga	General	g_FT_SHWT	1.14	3.80	7.35	8.43	9.26	13.61	14.34	14.45	14.45
	Tropical	t_FT_SHWT	0.99	4.78	7.27	8.80	9.13	10.83	12.19	12.58	13.14
Guntersville to Chickamauga	General	g_GU_CH	2.37	7.52	12.22	13.40	14.20	18.68	18.95	18.95	18.95
	Tropical	t_GU_CH	1.72	7.45	10.57	12.28	12.92	15.82	18.65	18.83	19.33
Above Guntersville	General	g_GU	0.79	2.92	5.43	6.64	8.04	11.34	11.83	11.98	12.42
	Tropical	t_GU	0.76	3.62	6.12	7.73	8.26	9.05	9.71	10.67	11.20
Guntersville to Blue Ridge-Hiwassee-Fontana-Douglas-Cherokee-Norris	General	g_GU_NOCRDGFNHIBR	1.50	4.17	8.17	9.32	10.68	14.51	14.88	14.97	15.03
	Tropical	t_GU_NOCRDGFNHIBR	1.12	5.52	8.38	10.14	10.43	11.33	13.19	13.93	14.98
Guntersville to Watts Bar-Hiwassee-Blue Ridge	General	g_GU_WBHIBR	1.97	5.81	10.43	11.67	12.64	16.96	17.21	17.24	17.24
	Tropical	t_GU_WBHIBR	1.41	6.70	9.73	11.33	11.89	13.57	16.40	16.82	17.15
Above Blue Ridge - Hiwassee	General	g_HIBR	2.89	11.53	16.30	17.29	17.71	22.22	22.48	22.48	22.48
	Tropical	t_HIBR	3.09	9.25	12.50	15.33	17.36	23.37	26.66	27.14	27.48
Hiwassee to Chatuge-Nottely	General	g_HI_CTNT	3.69	14.03	18.04	19.13	19.48	23.34	23.69	23.69	23.69
	Tropical	t_HI_CTNT	3.97	11.64	14.27	17.53	21.65	26.03	29.62	30.20	30.30
Above Hiwassee	General	g_HI	3.02	11.92	16.53	17.48	17.78	22.14	22.40	22.40	22.40
	Tropical	t_HI	3.23	9.55	12.81	15.71	17.98	23.82	27.16	27.65	27.85
Above Melton Hill	General	g_MH	1.97	6.17	9.86	10.79	11.47	15.04	15.48	15.63	15.63
	Tropical	t_MH	1.47	6.39	9.05	10.53	11.06	11.64	11.91	11.92	11.98
Melton Hill to Norris	General	g_MH_NO	3.51	12.23	15.56	16.30	16.85	19.70	19.97	20.00	20.01
	Tropical	t_MH_NO	2.70	9.65	12.55	14.93	15.66	17.21	18.39	18.49	18.61
Above Nickajack	General	g_NJ	0.80	2.99	5.53	6.67	8.02	11.46	11.99	12.16	12.42
	Tropical	t_NJ	0.78	3.66	6.19	7.81	8.33	9.17	9.95	10.88	11.35

Table 7.2f

			Duration (in hours)								
PMP Event Area	Storm Type	Designation	1	6	12	18	24	48	72	96	120
Nickajack to Blue Ridge-Hiwassee-Fontana-Douglas-Cherokee-Norris	General	g_NJ_NOCRDGFNHIBR	1.64	4.72	8.86	10.01	11.13	15.01	15.43	15.53	15.53
	Tropical	t_NJ_NOCRDGFNHIBR	1.23	5.95	8.82	10.46	10.86	11.95	14.05	14.50	15.15
Above Blue Ridge-Hiwassee-Fontana-Douglas-Cherokee-Norris	General	g_NOCRDGFNHIBR	1.02	3.52	6.73	7.76	8.71	12.82	13.46	13.58	13.58
	Tropical	t_NOCRDGFNHIBR	0.91	4.38	6.84	8.37	8.72	10.13	11.36	11.85	12.37
Above Norris-Cherokee-Douglas-Fontana	General	g_NOCRDGFN	1.06	3.51	6.75	7.77	8.69	12.74	13.43	13.55	13.55
	Tropical	t_NOCRDGFN	0.92	4.45	6.87	8.36	8.69	10.06	11.19	11.56	12.02
Above Norris - Cherokee-Douglas	General	g_NOCRDG	1.10	3.43	6.62	7.60	8.52	12.41	13.17	13.29	13.29
	Tropical	t_NOCRDG	0.92	4.51	6.85	8.29	8.55	9.71	10.59	10.81	11.14
Above Norris - Cherokee	General	g_NOCR	1.39	4.13	7.38	8.41	9.29	12.93	13.82	13.94	13.94
	Tropical	t_NOCR	1.07	5.04	7.34	8.58	9.01	9.79	10.21	10.28	10.34
Above Norris	General	g_NO	1.98	6.32	9.87	10.78	11.46	14.88	15.34	15.52	15.52
	Tropical	t_NO	1.49	6.36	8.96	10.45	10.97	11.42	11.59	11.59	11.64
Above Nottely	General	g_NT	3.87	13.78	17.00	17.67	18.02	20.71	21.55	21.55	21.55
	Tropical	t_NT	3.77	11.22	14.01	16.71	20.48	24.45	27.63	28.42	28.66
Ocoee #1 to Blue Ridge	General	g_O1_BR	3.75	13.79	17.43	18.14	18.44	21.72	21.96	22.02	22.02
	Tropical	t_O1_BR	3.85	11.20	13.74	16.75	20.41	24.74	27.79	28.05	28.30
Above Ocoee #1	General	g_O1	3.52	13.37	17.28	18.32	18.66	22.41	22.74	22.74	22.74
	Tropical	t_O1	3.67	10.77	13.56	16.28	19.84	24.60	27.91	28.48	28.55
Above South Holston-Watauga-Douglas	General	g_SHWTDG	1.42	5.00	8.93	10.03	10.81	14.94	15.58	15.65	15.65
	Tropical	t_SHWTDG	1.25	5.65	8.17	9.59	10.27	12.83	14.50	14.77	14.99
Above South Holston-Watauga-Douglas-Fontana	General	g_SHWTDGFN	1.38	4.93	9.06	10.22	10.91	15.46	16.01	16.06	16.06
	Tropical	t_SHWTDGFN	1.23	5.59	8.20	9.72	10.39	13.19	15.15	15.49	15.90
Above South Holston-Watauga	General	g_SHWT	2.19	7.95	11.19	12.58	13.20	16.34	16.75	16.87	16.91
	Tropical	t_SHWT	1.81	6.71	9.38	11.24	12.16	15.37	17.01	17.29	17.40
Above South Holston	General	g_SH	2.47	7.53	9.93	11.63	12.69	15.15	15.55	15.76	15.80
	Tropical	t_SH	1.53	6.13	8.54	10.00	10.89	12.55	13.43	13.60	13.60
Tellico-Hiwassee-Blue Ridge to Fontana	General	g_TEHIBR_FN	2.28	9.06	13.73	14.83	15.70	20.12	20.51	20.62	20.62
	Tropical	t_TEHIBR_FN	2.33	8.02	11.05	13.29	14.56	19.27	21.78	22.22	22.89
Tellico-Hiwassee-Blue Ridge	General	g_TEHIBR	2.06	7.96	13.05	14.33	15.20	20.06	20.43	20.48	20.48
	Tropical	t_TEHIBR	1.93	7.41	10.45	12.63	13.92	18.77	21.51	21.98	22.47
Tellico to Fontana	General	g_TE_FN	2.74	10.40	14.56	15.50	16.17	19.95	20.43	20.51	20.51
	Tropical	t_TE_FN	2.52	8.44	11.62	14.06	15.49	19.54	21.76	22.09	22.24
Above Tellico	General	g_TE	2.28	9.04	13.93	15.10	15.98	20.63	21.03	21.12	21.12
	Tropical	t_TE	2.26	8.01	11.10	13.55	15.01	19.98	22.68	23.13	23.82
Above Tims Ford	General	g_TF	3.44	12.67	16.20	17.18	17.50	20.90	21.22	21.35	21.35
	Tropical	t_TF	3.36	9.86	12.74	14.86	16.58	21.07	24.57	24.83	25.14
Above Watts Bar-Chatuge-Nottely-Blue Ridge	General	g_WBCTNTBR	0.85	3.17	5.94	6.96	8.23	11.87	12.48	12.64	12.72
	Tropical	t_WBCTNTBR	0.83	3.92	6.43	8.02	8.47	9.45	10.42	11.11	11.54
Above Watts Bar-Hiwassee-Blue Ridge	General	g_WBHIBR	0.83	3.16	5.88	6.92	8.20	11.86	12.45	12.61	12.69
	Tropical	t_WBHIBR	0.82	3.86	6.39	7.99	8.45	9.44	10.42	11.16	11.60

Table 7.2g

PMP Event Area	Storm Type	Designation	Duration (in hours)								
			1	6	12	18	24	48	72	96	120
Watts Bar-Hiwassee-Blue Ridge to Norris-Cherokee-Douglas-Fontana	General	g_WBHIBR_NOCRDGFN	1.75	5.54	9.97	11.15	12.07	16.24	16.69	16.76	16.76
	Tropical	t_WBHIBR_NOCRDGFN	1.38	6.40	9.29	10.87	11.52	13.64	15.46	15.75	15.98
Watts Bar-Hiwassee-Blue Ridge to Norris-Cherokee-Douglas	General	g_WBHIBR_NOCRDG	1.62	5.26	9.76	10.99	11.87	16.35	16.76	16.83	16.83
	Tropical	t_WBHIBR_NOCRDG	1.32	6.13	9.02	10.68	11.31	13.67	15.78	16.19	16.76
Watts Bar to Fort Loudoun	General	g_WB_FL	1.59	4.84	8.99	10.13	11.06	15.16	15.60	15.67	15.67
	Tropical	t_WB_FL	1.24	5.83	8.59	10.18	10.72	12.36	13.96	14.28	14.72
Watts Bar to Fort Loudoun-Tellico	General	g_WB_FT	1.78	5.13	9.08	10.13	10.94	14.63	15.09	15.16	15.16
	Tropical	t_WB_FT	1.31	6.15	8.87	10.26	10.81	11.69	12.67	12.78	12.82
Above Watts Bar	General	g_WB	0.88	3.19	6.00	7.00	8.27	11.89	12.52	12.68	12.75
	Tropical	t_WB	0.84	3.98	6.48	8.05	8.48	9.47	10.42	11.06	11.48
Watts Bar to Norris-Cherokee-Douglas-Fontana	General	g_WB_NOCRDGFN	1.86	5.75	10.04	11.17	12.06	15.99	16.47	16.56	16.56
	Tropical	t_WB_NOCRDGFN	1.43	6.57	9.45	10.96	11.63	13.41	14.95	15.16	15.28
Watts Bar to Norris-Cherokee-Douglas	General	g_WB_NOCRDG	1.74	5.55	10.04	11.25	12.17	16.46	16.90	16.97	16.97
	Tropical	t_WB_NOCRDG	1.38	6.34	9.22	10.86	11.58	13.90	15.87	16.19	16.49
Watts Bar to Norris-Cherokee	General	g_WB_NOCR	1.25	4.05	7.90	9.02	9.90	14.22	14.73	14.81	14.84
	Tropical	t_WB_NOCR	1.06	5.15	7.83	9.47	9.82	11.55	13.22	13.75	14.50
Watts Bar to Norris-Fort Loudoun	General	g_WB_NOFL	1.92	6.36	11.10	12.35	13.25	17.66	18.05	18.10	18.10
	Tropical	t_WB_NOFL	1.55	6.81	9.78	11.53	12.45	15.56	17.94	18.27	18.47
Watts Bar to Norris-Fort Loudoun-Tellico	General	g_WB_NOFT	2.38	7.66	11.59	12.50	13.21	16.93	17.22	17.36	17.36
	Tropical	t_WB_NOFT	1.96	7.44	10.41	12.17	12.75	15.57	17.54	17.57	18.25
Watts Bar to Norris	General	g_WB_NO	1.01	3.49	6.66	7.68	8.78	12.74	13.40	13.53	13.58
	Tropical	t_WB_NO	0.91	4.39	6.91	8.47	8.84	10.12	11.38	11.98	12.53
Wheeler to Chickamauga	General	g_WE_CH	1.85	5.09	9.70	10.99	12.23	16.63	16.82	16.82	16.83
	Tropical	t_WE_CH	1.27	6.19	9.23	11.00	11.36	11.98	15.05	15.80	16.92
Above Wheeler	General	g_WE	0.78	2.76	5.18	6.56	7.99	11.04	11.47	11.59	12.38
	Tropical	t_WE	0.73	3.51	5.94	7.51	8.05	8.80	9.26	10.12	10.77
Wheeler to Norris-Cherokee-Douglas-Fontana	General	g_WE_NOCRDGFN	1.09	3.74	7.09	8.20	9.97	13.71	13.96	14.04	14.53
	Tropical	t_WE_NOCRDGFN	0.98	4.63	7.52	9.35	9.84	10.62	11.65	13.16	13.96
Wheeler to Guntersville	General	g_WE_TFGU	2.26	6.96	11.98	13.28	14.09	18.90	19.18	19.18	19.18
	Tropical	t_WE_TFGU	1.57	7.23	10.36	11.99	12.63	14.93	17.81	18.09	18.28
Wheeler to Tims Ford-Blue Ridge-Hiwassee-Fontana-Douglas-Cherokee-Norris	General	g_WE_TFNOCRDGFNHIBR	1.22	3.87	7.41	8.53	10.25	13.96	14.24	14.32	14.66
	Tropical	t_WE_TFNOCRDGFNHIBR	1.02	4.89	7.78	9.59	10.03	10.75	11.99	13.30	14.18
Wheeler to Watts Bar-Hiwassee-Blue Ridge	General	g_WE_WBHIBR	1.61	4.45	8.70	9.93	11.39	15.50	15.70	15.74	15.78
	Tropical	t_WE_WBHIBR	1.15	5.69	8.66	10.48	10.79	11.51	13.83	14.84	16.20
Above Watauga-Douglas	General	g_WTDG	1.51	5.38	9.50	10.64	11.44	15.60	16.20	16.26	16.26
	Tropical	t_WTDG	1.33	5.92	8.51	9.98	10.75	13.64	15.46	15.76	15.98
Above Watauga	General	g_WT	3.26	12.26	15.59	16.43	16.84	19.89	20.25	20.25	20.25
	Tropical	t_WT	3.03	10.00	12.94	15.76	19.58	23.20	26.32	26.72	26.85

7.3 The following Table 7.3 shows the PMP event watershed average rainfall depths for the Local type event for watersheds up to 500-sq.-mi. and durations to 24 hours.

Table 7.3

PMP Event Area	Area (sq.mi.)	Designation	Duration (in hours) 1	2	3	4	5	6	12	24
Above Watauga	468.2	l_WT	4.91	9.83	12.82	15.18	15.38	15.65	17.18	17.55
Above Chatuge	189.1	l_CT	7.33	14.65	19.13	22.73	23.05	23.52	25.90	26.33
Above Nottely	214.3	l_NT	7.04	14.06	18.37	21.82	22.13	22.55	24.83	25.29
Above Blue Ridge	231.6	l_BR	7.09	14.17	18.51	21.97	22.29	22.68	24.99	25.46
Ocoee #1 to Blue Ridge	362.6	l_O1_BR	6.21	12.41	16.20	19.20	19.48	19.81	21.78	22.21
Melton Hill to Norris	431.9	l_MH_NO	4.81	9.62	12.54	14.85	15.06	15.34	16.82	17.17
Ft. Patrick Henry to Boone	62.8	l_FP_BO	5.39	8.87	11.59	13.78	13.94	14.29	15.97	16.10
Above Chatuge-Nottely	403.4	l_CTNT	6.31	12.62	16.46	19.49	19.77	20.16	22.09	22.53
Apalachia to Hiwassee	49.8	l_AP_HI	7.53	14.97	19.55	23.25	23.52	24.11	27.01	27.29

8.0 Conclusions

8.1 Tennessee Valley sub-basin average PMP depths were calculated and results were placed in a database format for each of three storm types analyzed: General, Tropical, and Local. These data are adopted by reference for use in the parent calculation and subsequent calculations.

ELECTRONIC FILE ATTACHMENTS

Document: CDQ0000002016000044	Rev. 000	Plant: GEN	
Subject: Gridded Probable Maximum Precipitation Development			
The files listed below, which contain both input and output data, are stored in TVA FILEKEEPER.			

		Attachment Name
Attached to Parent Calculation		
	Supplement 1	Supplement 1 - HMR41.pdf
	Supplement 2	Supplement 2 - HMR56.pdf
Contained in CDQ0000002016000044 Files.zip (FILEKEEPER # KDQ0000002018000009)		
	Parent Calculation	
	Native Files	
	Calculation Form	NEDP-2 R19 FORMS.docx
	Calculation Form	NEDP-2-2 thru 2-6.docx
	Calculation Body	QA-DE-01-F01-F07 Calculation Forms.docx
	Tables for worksheet calculation & appendices	Rainfall_Tables.xlsx.txt
	Electronic File Table	CDQ0000002016000044_Electronic_File_Attachments.docx
	Electronic File Table PDF	CDQ0000002016000044_Electronic_File_Attachments.pdf
	Appendix A -Daily Rainfall Data Extraction.pdf	
		Appendix A -Daily Rainfall Data Extraction.docx
		Appendix_A-A_Subbasins_Reservoirs.zip.txt
		Appendix_A-B_FULLBASINSHAPEFORTOOL.zip.txt
		Appendix_A-C_QGIS_ArcGIS_Automation_Instructions.pdf
		Appendix_A-D_Base_Macro_File_AWA_Tool_Automation.xlsm.txt
		Appendix_A-E_LinebyLine_Automation_Descriptions.xlsx.txt
		Appendix_A-F_GIS_Python_Base.py
		Appendix_A-G_QGIS_Depths.py
		Appendix_A-H_Raster_PMP_Subbasin_Coverage.xlsx.txt
		Appendix_A-I_Alternate_Depth_Area_Check.xlsm.txt
		Appendix_A-J_ GISOutputs.xlsx.txt
		Appendix_A-K_Reservoir_Depths.xlsx.txt
	Appendix B	Appendix_B_Reservoir_Analysis.xlsx.txt
	Attachment 1	Attachment_1_PMP_Depth_Generation.pdf

1.0 Purpose

The purpose of this appendix is to document the processing of gridded PMP depth data produced from the ArcGIS software tool (Reference 2.23) to provide weighted average PMP depths over the Tennessee Valley Authority project sub-basins. Because the computation of project sub-basin average PMP depths from the PMP evaluation tool output performed in ArcGIS did not utilize NQA dedicated software, the determination was also performed with an alternate method that utilized Quantum GIS (QGIS). The primary objective is to verify weighted average PMP depths and distributions for project sub-basins for each PMP event in ArcGIS by comparison with values computed utilizing QGIS.

2.0 References

The references in Section 2.0 of the parent calculation are applicable to this Appendix.

3.0 Assumptions

The assumptions in Section 3.0 of the parent calculation are applicable to this Appendix.

4.0 Design Input Data

Sec.	Input Parameter	Source	Location	Value/Description
4.1	Sub-basin GIS Shapefile	Appendix A-A of Reference 2.24	Appendix A-A	Sub-basin shapes, areas and positions
4.2	Reservoir GIS Shapefile	Appendix A-2 of Reference 2.26	Appendix A-A	Reservoir shapes, areas and positions
4.3	ArcGIS PMP Evaluation Tool	Reference 2.23	Reference 2.23	ArcGIS Tool for gridded PMP depths
4.4	SDR PMP Evaluation Tool TVA Project Sub-basins Encapsulating Shapefile	Reference 2.23	Appendix A-B	Shape to encapsulate TVA Project Sub-basins

5.0 Special Requirements/Limiting Conditions - None

6.0 Computations and Analysis

6.1 Microsoft Excel 2016 software was used as a calculator for this appendix. Data were input and calculations performed using built-in Excel functions.

6.2 Base GIS sub-basin and encapsulating shapefiles required for GIS processing are included as Appendix A-A and A-B, respectively. The base GIS sub-basin shapefile defining the TVA project sub-basin areas is appropriate for use in determination of sub-basin average PMP depths. Confirmation of the GIS sub-basin shapes is provided by the comparison presented in Appendix A-I and below in Table 6.2 that shows negligible differences between the computed areas and those defined by the references denoted below in Table 6.2. Detailed GIS methodology is described in Sections 6.3.2 and 6.4.2.

Table 6.2

Sub-basin #	Sub-basin Lable	ArcGIS Area (sq.mi.)[1]	Source	Source Area (sq.mi.)[2]	Δ	Δ (sq.mi.)
01	French Broad River at Asheville	944.42	Ref. 2.4, Table 1	944.4	0.00%	0.02
02	French Broad River, Newport to Asheville	913.08	Ref. 2.4, Table 1	913.1	0.00%	-0.02
03	Pigeon River at Newport	667.14	Ref. 2.4, Table 1	667.1	0.01%	0.04
04	Nolichucky River at Embreeville	804.85	Ref. 2.4, Table 1	804.8	0.01%	0.05
05	Nolichucky local, Embreeville to Nolichucky Dam	378.71	Ref. 2.4, Table 1	378.7	0.00%	0.01
06	Douglas Dam local	835.04	Ref. 2.4, Table 1	835	0.01%	0.04
07	Little Pigeon River at Sevierville	352.06	Ref. 2.10, Sec. 6.1	352.1	-0.01%	-0.04
08	French Broad River local	206.47	Ref. 2.17, Table 1	206.5	-0.01%	-0.03
09	South Holston Dam	703.25	Ref. 2.11, Sec. 6.1	703.2	0.01%	0.05
10	Watauga Dam	468.25	Ref. 2.11, Sec. 6.1	468.2	0.01%	0.05
11	Boone local	667.67	Ref. 2.11, Sec. 6.1	667.7	0.00%	-0.03
12	Fort Patrick Henry	62.77	Ref. 2.11, Sec. 6.1	62.8	-0.05%	-0.03
13	North Fork Holston River near Gate City	668.89	Ref. 2.11, Sec. 6.1	668.9	0.00%	-0.01
14-15	Total Cherokee	854.63	Ref. 2.11, Sec. 6.1	854.6	0.00%	0.03
16	Holston River local, Cherokee Dam to Knoxville gage[3]	319.60	Ref. 2.17, Table 1	319.6	0.00%	0.00
17	Little River at mouth	378.65	Ref. 2.17, Table 1	378.6	0.01%	0.05
18	Fort Loudoun local	323.36	Ref. 2.17, Table 1	323.4	-0.01%	-0.04
19	Little Tennessee River at Needmore	436.50	Ref. 2.18, Table 1	436.5	0.00%	0.00
20	Nantahala	90.88	Ref. 2.18, Table 1	90.9	-0.03%	-0.02
21	Tuckasegee River at Bryson City	653.77	Ref. 2.18, Table 1	653.8	-0.01%	-0.03
22	Fontana local	389.75	Ref. 2.18, Table 1	389.8	-0.01%	-0.05
23	Little Tennessee River local, Fontana Dam to Chilhowee Dam	404.70	Ref. 2.18, Table 1	404.7	0.00%	0.00
24	Little Tennessee River local, Chilhowee Dam to Tellico Dam	650.16	Ref. 2.17, Table 1	650.2	-0.01%	-0.04
25	Watts Bar local above Clinch River	295.28	Ref. 2.13, Table 1	295.3	-0.01%	-0.02
26	Clinch River at Norris Dam	2912.79	Ref. 2.14, Sec. 6.1	2912.8	0.00%	-0.01
27	Melton Hill local	431.87	Ref. 2.16, Sec. 6.1	431.9	-0.01%	-0.03
33	Clinch River local above mile 16	37.24	Ref. 2.13, Table 1	37.2	0.10%	0.04
34	Poplar Creek at mouth	135.23	Ref. 2.13, Table 1	135.2	0.02%	0.03
35	Emory River at mouth	868.79	Ref. 2.15, Sec. 6.1	868.8	0.00%	-0.01
36	Clinch River local, mouth to mile 16	29.34	Ref. 2.13, Table 1	29.3	0.12%	0.04
37	Watts Bar local below Clinch River	408.38	Ref. 2.13, Table 1	408.4	0.00%	-0.02
38	Chatuge Dam	189.08	Ref. 2.9, Table 1	189.1	-0.01%	-0.02
39	Nottely Dam	214.30	Ref. 2.9, Table 1	214.3	0.00%	0.00

Table 6.2

Sub-basin #	Sub-basin Lable	ArcGIS Area (sq.mi.)[1]	Source	Source Area (sq.mi.)[2]	Δ	Δ (sq.mi.)
40	Hiwassee River local below Chatuge and Nottely	565.07	Ref. 2.9, Table 1	565.1	-0.01%	-0.03
41	Apalachia local	49.82	Ref. 2.9, Table 1	49.8	0.05%	0.02
42	Blue Ridge Dam	231.62	Ref. 2.22, Sec. 6.1	231.6	0.01%	0.02
43	Ocoee No. 1 local, Ocoee No. 1 to Blue Ridge Dam	362.64	Ref. 2.9, Table 1	362.6	0.01%	0.04
44A	Hiwassee River local, Charleston gage at mile 18.9 to Apalachia and Ocoee No. 1 Dams	686.61	Ref. 2.19, Sec. 6.1	686.6	0.00%	0.01
44B	Hiwassee River local, mouth to Charleston gage at mile 18.9	396.03	Ref. 2.12, Table 1	396	0.01%	0.03
45	Chickamauga local	792.10	Ref. 2.12, Table 1	792.1	0.00%	0.00
46	South Chickamauga Creek near Chattanooga	428.09	Ref. 2.6, Sec. 7.1	428.1	0.00%	-0.01
47A	Nickajack local below North Chickamauga Creek @ gage	545.71	Ref. 2.8, Table 1	545.7	0.00%	0.01
47B	North Chickamauga Creek @ gage	98.30	Ref. 2.8, Table 1	98.3	0.00%	0.00
48	Sequatchie River at Whitwell[4]	400.02	Ref. 2.5, Sec. 6.1	400	0.00%	0.02
49	Guntersville North local	1025.94	Ref. 2.7, Table 1	1027.1	-0.11%	-1.16
50	Guntersville South local	1069.10	Ref. 2.7, Table 1	1068.9	0.02%	0.20
	Guntersville Reservoir	104.11	Ref. 2.7, Table 1	103	1.07%	1.11
51	Paint Rock Creek near Woodville	321.02	Ref. 2.20, Table 1	321.07	-0.02%	-0.05
52	Paint Rock Local	138.07	Ref. 2.20, Table 1	138.09	-0.02%	-0.02
53	Flint River near Chase	343.04	Ref. 2.21, Table 1	343.1	-0.02%	-0.06
54	Flint River Local	224.87	Ref. 2.20, Table 1	224.85	0.01%	0.02
55	Cotaco Creek at Florette	136.21	Ref. 2.20, Table 1	136.21	0.00%	0.00
56	Cotaco Creek Local	101.05	Ref. 2.20, Table 1	101.05	0.00%	0.00
57	Limestone Creek near Athens	121.31	Ref. 2.21, Table 1	121.3	0.01%	0.01
58	Limestone Creek Local	157.42	Ref. 2.20, Table 1	157.42	0.00%	0.00
59	Tims Ford Dam	533.31	Ref. 2.21, Table 1	533.2	0.02%	0.11
60	Elk River Local, Tims Ford to Fayetteville	293.36	Ref. 2.21, Table 1	293.4	-0.01%	-0.04
61	Elk River Local, Fayetteville to Prospect	490.20	Ref. 2.21, Table 1	490.2	0.00%	0.00
62	Richland Creek at Mouth	487.97	Ref. 2.21, Table 1	488	-0.01%	-0.03
63	Sugar Creek at Mouth	176.95	Ref. 2.20, Table 1	176.95	0.00%	0.00
64	Elk River Local, Mile 16.5 to Prospect Gage	145.12	Ref. 2.20, Table 1	145.12	0.00%	0.00
65	Wheeler Local	1381.05	Ref. 2.20, Table 1	1379.95	0.08%	1.10
	Wheeler Reservoir	89.74	Ref. 2.20, Table 1	90.9	-1.27%	-1.16
	Totals	29592.76		29592.61	0.00%	0.145

NOTES:

1 ArcGIS results shown to two decimal places. Actual results to nine decimal places and left unrounded for all

2 Source results shown to accuracy reported in written reference.

3 Area includes 30-sq.-mi. of karst considered non-contribution for surface runoff.

4 Area includes 18-sq.-mi. of karst considered non-contribution for surface runoff.

6.3 The AWA PMP tool computes point depth-duration values for defined grid points spaced at 90 arc-second (0.025 decimal degree) intervals across the Tennessee Valley watershed above Kentucky Dam as well as the Great Falls project basin. The PMP point values are determined for General, Tropical and Local type events over the TVA project sub-basins for durations specified by the user from a list. A number of automation routines were developed that utilize both the Visual Basic for Applications (VBA) and Python programming language to run the PMP evaluation tool and perform subsequent ArcGIS processing to produce weighted average PMP depths over project sub-basins throughout the Tennessee Valley. The weighted average PMP depths computed within ArcGIS were compared to values calculated in QGIS to ensure that the ArcGIS software platform was operating correctly and with the required degree of precision. A template Microsoft Excel workbook was developed to execute the PMP evaluation tool, write a project PMP specific Python script for ArcGIS processing, execution of Python script and retrieval/storage of ArcGIS computed weighted average depths. A separate Python script was developed to allow GIS processing of the gridded precipitation data within the QGIS software environment. A flow chart of the ArcGIS automation and general user directions describing the required directory structure, naming conventions and inputs for the automations are described in Appendix A-C. The ArcGIS spatial analyses performed and descriptions of each automation routine are provided below.

6.3.1 The template Excel file (Appendix A-D) is required to be named according to the event designation for each PMP event detailed in Tables 6.4a and 6.4b of the parent calculation. The development of the project PMP specific Python script requires an input text file to identify the sub-basins within each PMP event area as noted in Tables 6.4a, 6.4b, 6.4c and 6.4d of the parent calculation. Once the workbook has been copied to the working directory of the user's choice and renamed according to the PMP event designator, the sub-basins within the PMP event area of interest can be input by the user under the column header "Primary Sub-basins" in column B of the "Inputs" tab of the Excel workbook. Following insertion of each sub-basin within the PMP area, a VBA macro linked to the button labeled "Create Python Input File" can be executed. A text file is created that identifies the number and IDs of the sub-basins within the project PMP area. A line-by-line description of the Excel macro to produce the Python input file can be seen in Appendix A-E.

6.3.2 Additional input in the form of a base Python script is required before the PMP event specific Python script can be developed via an Excel VBA macro. The base Python script includes all the necessary functionality for execution of the AWA tool and ArcGIS spatial processing of rainfall data but requires modifications dependent on the specific PMP event and user options. The base ArcGIS Python script is included as Appendix A-F. A line-by-line description of the base Python script is included in Appendix A-E and a summary of GIS processing steps are detailed below.

6.3.2.1 The sub-basins within the PMP area are read from the input text file and extracted from the base sub-basins shapefile (Reference/Section 4.2) to produce an event specific shapefile with only those sub-basins of interest. The resulting shapefile follows the naming convention "XXX_Final.shp" with the XXX corresponding to the PMP event designator.

6.3.2.2 The event specific shapefile produced in Section 6.3.2.1 is dissolved into one shape and the PMP event area in square-miles is calculated. The resulting dissolved shapefile follows the naming convention "XXX_Dissolved.shp" with the XXX corresponding to the PMP event designator. The computed area in square-miles is entered into the PMP evaluation tool interface to define the PMP area utilized during DAD table lookups. The remaining storm type and duration selections are entered based on user responses during creation of event specific PMP Python script as detailed below in Section 6.3.3.

6.3.2.3 The resulting gridded point PMP data from the PMP evaluation tool for the TVA watershed above Kentucky Dam are trimmed to within 15,000 feet of the shapefile created as described in Section 6.3.2.1 to reduce subsequent spatial processing time but still provide adequate point coverage for TIN creation. The resulting trimmed point data shapefile follows the naming convention "XXX_X_Points_Final.shp" where XXX corresponds to the PMP event designator and X is either G, T or L corresponding to the General, Tropical and Local storm types, respectively.

6.3.2.4 The trimmed gridded point PMP data was then utilized to create an individual Triangular Irregular Network (TIN) for each duration and storm type utilizing the depth as the height field from the gridded point data for the TIN. The resulting TINs are then processed with the ArcGIS "polygon volume" tool to compute a total volume above each sub-basin. Individual sub-basin average rainfall depths are computed by dividing the volume of precipitation over each sub-basin by the sub-basin square footage to return average depth in inches.

6.3.3 The Microsoft Excel macro linked to the button labeled "Create Temporary Python Script" is executed to modify the base Python script, Appendix A-F, detailed in Appendix A-E and Section 6.3.2. The base Python script is modified based on user responses and logic as detailed in the flow diagram presented below in Figure 6.3 to provide the desired functionality. The temporary scenario script created for the Watts Bar to Norris, Cherokee and Douglas Dams(WB_NOCRDG) storm event required manual modification to account for rounding errors when defining the AWA Tool output geodatabase. Line 139 of the resulting temporary simulation specific script was modified to add a value of 1 to provide the correct AWA tool output geodatabase name. No modifications for remaining storm events were required.

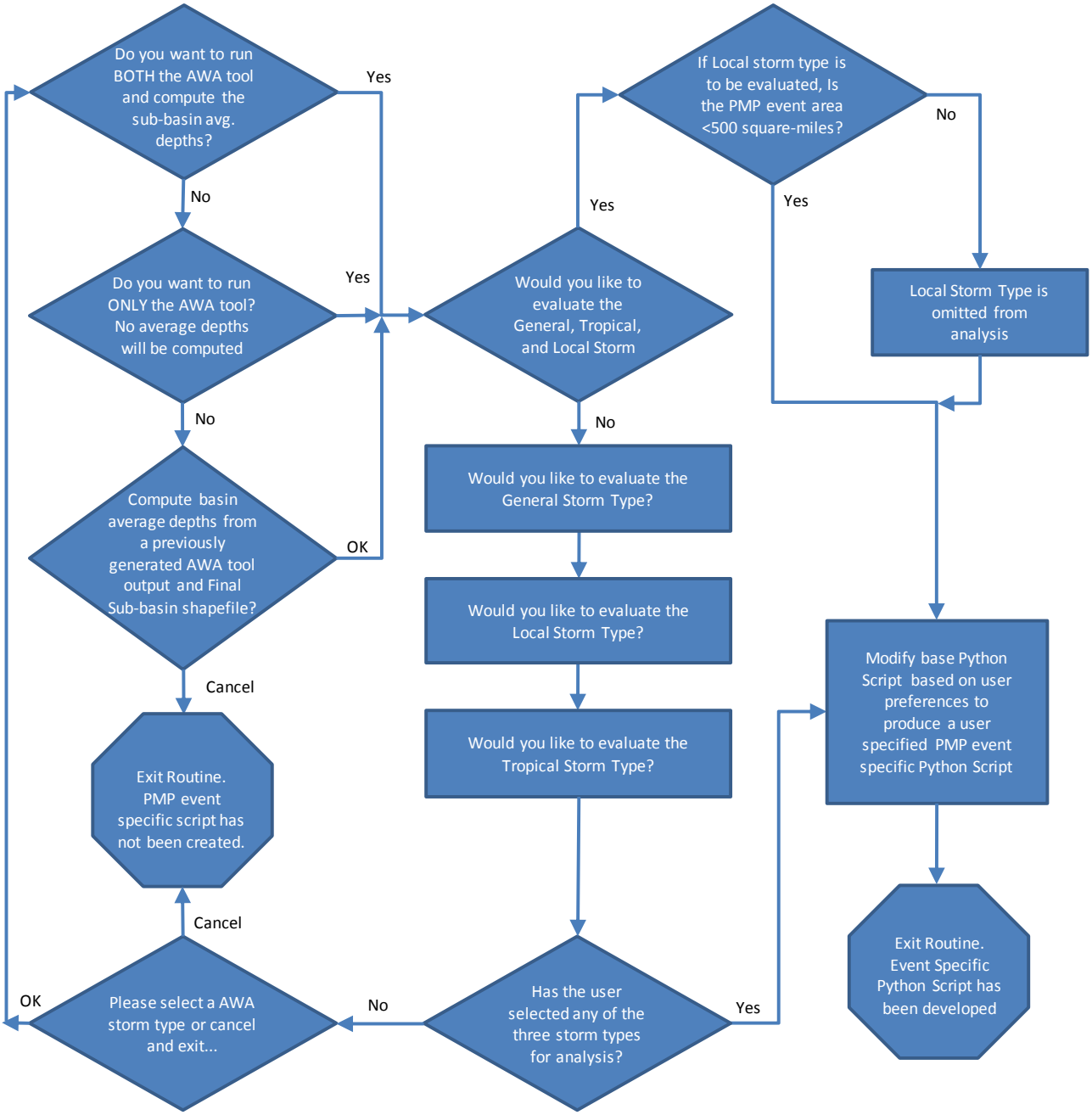


Figure 6.3 PMP Event Specific Python Script Generation Flow Diagram

6.3.4 The Microsoft Excel macro named "Run_AWA_Tool" and linked to the button labeled "Execute Script" is run to open an instance of a Python shell window to allow execution of the previously developed PMP event specific Python script. A line-by-line description of the Excel macro to execute the python script is contained in Appendix A-E.

6.3.5 Execution of the Excel macros and Python script described in Sections 6.3.1 through 6.3.4 produces a final ArcGIS polygon shapefile with an attribute table containing the computed weighted average depth for each sub-basin within the PMP event area. The Excel macro named "AverageDepth" and linked to the button labeled "Get AWA Rainfall Depths from GIS Files" opens the .dbf file associated with the final ArcGIS shapefile and extracts the computed sub-basin average depths. The sub-basin average depths for each storm type and duration are stored in a newly created Excel file with the name XXX_GIS_Output.xlsx where XXX is the PMP designator. Additionally, a PMP summary table is prepared in which computed watershed average depths are reported for each duration and storm type. The sub-basin and total PMP event watershed average depths are stored in the "Basin GIS Output" and "PMP Summary" tabs of the Excel file, respectively. A line-by-line description of the Excel macro is contained in Appendix A-E. An additional sub-routine was prepared to format a standard table for reporting the total PMP event watershed average depths. This sub-routine solely performs administrative formatting tasks consequently a line-by-line description has not been included.

6.4 The ArcGIS spatial analysis and computations were checked with alternate software as they did not utilize NQA dedicated software. Confirmation of the ArcGIS analysis and computations following execution of the PMP evaluation tool was provided by direct comparison of computed sub-basin average depths for each storm type and duration for all PMP events with values developed in an alternate methodology that utilized QGIS. A python script was developed to provide sub-basin average PMP depths resulting from the PMP evaluation tool gridded depth data output and is included as Appendix A-G. A line-by-line description of the Python script is included in Appendix A-E and a summary of processing steps are detailed below.

6.4.1 The QGIS Python script requires a number of inputs from the user to include the base sub-basins shapefile (Appendix A-A), the Local, General and Tropical gridded point output file from the PMP evaluation tool and the processing directory of user choice. The user also is given the option to select by checkmark whether to evaluate each of the three storm types.

6.4.2 Following entry of required inputs, the script then creates a raster file with the value of each cell equating to the PMP depth for a given storm type and duration at a given location. The raster of PMP depths across the Tennessee Valley is created to provide a pixel size equivalent to the 90 arc-second spacing of the PMP evaluation tool. The final algorithm utilized to compute the spatial statistics of the PMP depth-data determines an average value of raster cells with their centroid in each sub-basin. The coarse spacing of the raster cell centroids and the irregular sub-basin shapes produce instances in which the raster centroids are outside of the basin yet still account for some of the coverage over the sub-basin. Increased spatial coverage and accuracy of spatial statistics is provided by resampling to a finer resolution by use of a bilinear interpolation yielding final raster datasets with cell sizes reduced by an order of magnitude. The final algorithm to compute the sub-basin average PMP event depths creates a sub-basin shapefile for each storm type and duration with the final sub-basin average weighted PMP event depths within the attribute table. The final sub-basin average weighted PMP event depths for each duration can then be extracted for comparison to the depth-duration data computed in ArcGIS.

6.5 The PMP evaluation Tool produces a point grid of PMP depth-duration data that is utilized to create TINs and raster surfaces for determination of weighted average sub-basin depths within ArcGIS and QGIS, respectively. Analysis of available depth-duration data points showed multiple sub-basin boundary locations without data points outside of the sub-basin boundary. The lack of data points outside of the sub-basin boundary leads to incomplete coverage and/or incorrect interpolations of resulting TIN and raster files used in the PMP sub-basin average depth computations. Sub-basins in the TVA watershed above Wheeler Dam without sufficient depth-duration coverage are shown below in Table 6.5.1. The total area without coverage is less than two-hundredths of a square-mile; therefore, the small portions of the watershed without coverage have a minor impact on the final computed sub-basin average depths. The analysis of raster coverage for the TVA sub-basins above Wheeler Dam, including GIS processing steps, is included as Appendix A-H.

Table 6.5.1 TVA Watershed Above Wheeler Raster Coverage

Sub-Basin ID	Sub-basin Area (Square Miles)	Area Without Raster Coverage (Square Miles)	Percentage Without Raster Coverage
1 to 12	7003.72	0.0000	0.00000%
13	668.89	0.0113	0.00169%
14 to 49	15606.24	0.0000	0.00000%
50[A]	1173.20	0.0039	0.00033%
51 to 65[B]	5140.70	0.0000	0.00000%
Total	29592.76	0.0152	0.00005%

[A] Guntersville Reservoir Area Included
[B] Wheeler Reservoir Area Included

The full data set output from the PMP evaluation tool was utilized to create the raster surfaces within QGIS, but due to processing time the ArcGIS process selects only those output data points within 15,000 feet of the sub-basins of interest to be utilized during TIN creation. The loss of potential triangulation points and the inherent TIN creation process leads to larger sub-basin areas without sufficient PMP depth data coverage. Although the TIN and volume analyses performed in ArcGIS have reduced coverage it is minimal and has an insignificant impact on the final computed sub-basin average depths. This assertion is further substantiated by equivalent results between the two software platforms and methodologies as shown below in Table 6.5.2 with maximum absolute percent differences of less than one percent. The alternate QGIS check confirms accurate ArcGIS operation in addition to the confirmation of appropriate methodologies by computing sub-basin average depths with the use of raster files and spatial grid statistics as compared to the use of TIN files and volume analyses as performed in ArcGIS. The full analysis of PMP event depth-duration data between the software platforms is included as Appendix A-I. Review of computed PMP depths across the ArcGIS and QGIS platforms identified a project PMP depth above Chatuge as an outlier. Analysis indicated areas around the sub-basin boundary with zero depth as the PMP points from the AWA tool did not provide adequate coverage during TIN creation for the single sub-basin. PMP depths utilized for Chatuge are based on the QGIS analysis to eliminate results without the complete PMP coverage.

An additional analysis was performed to evaluate the upper limit of the Local storm type by manual implementation of the ArcGIS processing steps detailed in Sections 6.3. The PMP evaluation tool was run such that the PMP event area utilized during DAD table lookups coincided with the 500 square-mile limit of the Local Storm type (Reference 2.23). Following the ArcGIS processing the PMP evaluation tool results were checked with the alternate QGIS software/methodology as described in Section 6.4. Analysis of the Local Storm type at the upper limit of 500 square-miles between the software platforms has been included within Appendix A-I and is presented below in Table 6.5.2.

Table 6.5.2 Differences between QGIS and ArcGIS computed Sub-basin Average Depths for All Durations and Storm Types

PMP Event Designator	Max Δ (inches)	Average Δ (inches)	Max %Δ	Average %Δ
AP	0.02	0.00	0.08%	-0.01%
AP_CTNT	0.01	0.00	0.03%	0.01%
AP_HI	0.01	0.01	0.03%	0.03%
BO	0.01	0.00	0.05%	0.00%
BO_SHWT	0.01	0.00	0.06%	0.02%
BODG	0.02	0.00	0.12%	-0.01%
BODGFN	0.02	0.00	0.08%	0.00%
BR	0.06	-0.03	0.17%	-0.15%
CH	0.03	0.00	0.32%	-0.01%
CH_NOCRDG	0.05	0.00	0.45%	-0.01%
CH_NOCRDGCTNTBR	0.05	0.00	0.44%	0.00%
CH_NOCRDGFN	0.05	0.00	0.43%	-0.01%
CH_NOCRDGFNCTNTBR	0.05	0.00	0.42%	0.00%
CH_NOCRDGFNHIBR	0.05	0.00	0.42%	0.00%
CH_NOCRDGHIBR	0.05	0.00	0.43%	0.00%
CH_NOFLCTNTBR	0.05	0.00	0.42%	0.00%
CH_NOFLHIBR	0.05	0.00	0.42%	0.00%
CH_NOFT	0.05	0.00	0.40%	-0.01%
CH_NOFTCTNTBR	0.04	0.00	0.40%	0.00%
CH_NOFTHIBR	0.05	0.00	0.43%	0.00%
CH_WB	0.04	0.00	0.17%	-0.01%
CH_WBCTNTBR	0.01	0.00	0.03%	0.01%
CH_WBHIBR	0.01	0.00	0.03%	0.01%
CHTE_NOFL	0.05	0.00	0.43%	-0.01%
CHTE_NOFLFN	0.05	0.00	0.41%	-0.01%
CHTE_WB	0.04	0.00	0.17%	-0.01%
CHTE_WBFN	0.04	0.00	0.17%	-0.01%
CR	0.02	0.00	0.22%	-0.03%
CR_BO	0.02	-0.01	0.22%	-0.07%
CR_FP	0.02	-0.01	0.22%	-0.10%
CR_SHWT	0.02	0.00	0.22%	-0.05%
CRDG	0.02	0.00	0.22%	-0.02%
CRDG_BO	0.02	0.00	0.22%	-0.03%
CRDG_SHWT	0.02	0.00	0.22%	-0.02%
CRDGFN	0.02	0.00	0.22%	-0.01%
CRDGFNCTNTBR	0.04	0.00	0.22%	-0.02%
CRDGFNCTNTBR_BO	0.04	0.00	0.22%	-0.02%
CRDGFNCTNTBR_SHWT	0.04	0.00	0.22%	-0.02%
CRDGFNHIBR	0.03	0.00	0.22%	-0.02%
CRDGFNHIBR_BO	0.04	0.00	0.22%	-0.02%
CRDGFNHIBR_SHWT	0.04	0.00	0.22%	-0.02%
CRDGTE	0.02	0.00	0.22%	-0.01%
CRDGTE_BO	0.02	0.00	0.22%	-0.01%
CRDGTE_SHWT	0.02	0.00	0.22%	-0.01%
CRDGTECTNTBR	0.03	0.00	0.22%	-0.01%
CRDGTECTNTBR_BO	0.04	0.00	0.22%	-0.02%
CRDGTECTNTBR_SHWT	0.04	0.00	0.22%	-0.01%
CRDGTEHIBR	0.03	0.00	0.22%	-0.01%
CRDGTEHIBR_BO	0.04	0.00	0.22%	-0.02%
CRDGTEHIBR_SHWT	0.03	0.00	0.22%	-0.01%
CT	0.25	-0.13	0.74%	-0.58%
CTNT	0.02	-0.01	0.08%	-0.03%
DG	0.02	0.00	0.12%	-0.01%
DGFN	0.02	0.00	0.10%	0.00%
DGFNCTNTBR	0.04	0.00	0.17%	-0.01%
DGFNHIBR	0.04	0.00	0.17%	-0.01%
DGTE	0.02	0.00	0.09%	0.01%
DGTECTNTBR	0.04	0.00	0.17%	-0.01%
DGTEHIBR	0.04	0.00	0.17%	-0.01%
FL	0.02	0.00	0.22%	-0.02%
FL_BO	0.02	0.00	0.22%	-0.02%
FL_CR	0.02	0.00	0.12%	-0.01%
FL_CRDG	0.01	0.00	0.03%	-0.01%
FL_SHWT	0.02	0.00	0.22%	-0.02%
FLFN_CR	0.02	0.00	0.09%	0.00%
FN	0.02	0.00	0.06%	0.00%
FNHIBR	0.04	0.00	0.17%	-0.02%
FP	0.01	0.00	0.05%	0.00%
FP_BO	0.00	0.00	0.02%	-0.01%
FP_SHWT	0.01	0.00	0.06%	0.01%
FT	0.02	0.00	0.22%	-0.01%
FT_BO	0.02	0.00	0.22%	-0.01%
FT_BOFN	0.02	0.00	0.22%	-0.02%
FT_CR	0.02	0.00	0.08%	0.00%
FT_CRDG	0.02	0.00	0.06%	0.00%
FT_CRDGFN	0.01	0.00	0.04%	0.00%
FT_CRFN	0.02	0.00	0.12%	-0.01%
FT_FN	0.02	0.00	0.22%	-0.01%
FT_SHWT	0.02	0.00	0.22%	-0.01%
FT_SHWTFN	0.02	0.00	0.22%	-0.01%
FTCTNTBR	0.03	0.00	0.22%	-0.01%
FTCTNTBR_BO	0.03	0.00	0.22%	-0.01%
FTCTNTBR_SHWT	0.03	0.00	0.22%	-0.01%
FTHIBR	0.03	0.00	0.22%	-0.01%
FTHIBR_BO	0.03	0.00	0.22%	-0.01%
FTHIBR_BOFN	0.04	0.00	0.22%	-0.02%
FTHIBR_CRDG	0.04	0.00	0.17%	-0.01%
FTHIBR_CRDGFN	0.04	0.00	0.17%	-0.02%
FTHIBR_SHWT	0.03	0.00	0.22%	-0.01%
FTHIBR_SHWTFN	0.03	0.00	0.22%	-0.01%
GU	0.03	0.00	0.30%	-0.01%
GU_CH	0.01	0.00	0.05%	-0.01%
GU_NOCRDGFNHIBR	0.05	0.00	0.44%	0.00%
GU_WBHIBR	0.01	0.00	0.04%	0.00%
HI	0.02	0.00	0.08%	-0.02%
HI_CTNT	0.00	0.00	0.00%	0.00%
HIBR	0.05	-0.01	0.17%	-0.04%
MH	0.01	0.00	0.05%	0.01%
MH_NO	0.01	0.00	0.05%	-0.01%
NJ	0.03	0.00	0.32%	-0.01%
NJ_NOCRDGFNHIBR	0.05	0.00	0.43%	0.00%
NO	0.01	0.00	0.05%	0.03%
NOCR	0.02	0.00	0.22%	-0.02%
NOCRDG	0.02	0.00	0.22%	-0.02%
NOCRDGFN	0.02	0.00	0.22%	-0.01%
NOCRDGFNHIBR	0.03	0.00	0.22%	-0.01%
NT	0.02	-0.01	0.08%	-0.07%
O1	0.05	-0.01	0.17%	-0.07%
O1_BR	0.01	0.00	0.03%	0.02%
SH	0.01	0.00	0.04%	-0.03%
SHWT	0.01	0.00	0.04%	-0.01%
SHWTDG	0.02	0.00	0.12%	-0.01%
SHWTDGFN	0.02	0.00	0.09%	0.00%
TE	0.02	0.00	0.06%	0.00%
TE_FN	0.01	0.00	0.04%	0.01%
TEHIBR	0.04	0.00	0.17%	-0.02%
TEHIBR_FN	0.04	0.00	0.17%	-0.03%
TF	0.00	0.00	0.00%	0.00%
WB	0.03	0.00	0.36%	0.00%
WB_FL	0.05	0.00	0.42%	0.00%
WB_FT	0.04	0.00	0.40%	0.00%
WB_NO	0.04	0.00	0.40%	-0.01%
WB_NOCR	0.04	0.00	0.44%	0.00%
WB_NOCRDG	0.05	0.00	0.41%	0.00%
WB_NOCRDGFN	0.05	0.00	0.41%	0.00%
WB_NOFL	0.05	0.00	0.41%	0.00%
WB_NOFT	0.07	0.00	0.58%	-0.01%
WBCTNTBR	0.03	0.00	0.36%	-0.01%
WBHIBR	0.03	0.00	0.35%	-0.01%
WBHIBR_NOCRDG	0.05	0.00	0.42%	-0.01%
WBHIBR_NOCRDGFN	0.05	0.00	0.41%	-0.01%
WE	0.02	0.00	0.26%	0.00%
WE_CH	0.01	0.00	0.05%	0.00%
WE_NOCRDGFN	0.03	0.00	0.37%	0.00%
WE_TFGU	0.01	0.00	0.04%	0.00%
WE_TFNOCRDGFNHIBR	0.04	0.00	0.39%	0.00%
WE_WBHIBR	0.01	0.00	0.04%	0.00%
WT	0.04	-0.02	0.16%	-0.15%
WTDG	0.03	0.00	0.16%	-0.03%
500Local	0.03	0.00	0.20%	0.00%
Max	0.25	0.13	0.74%	0.58%
Average	0.03	0.00	0.21%	-0.02%

6.6 Area-weighted average PMP rainfall depth-duration data were computed for the reservoirs noted below in Table 6.6.1 for the 500 square-mile limit Local event in addition to the Tropical and General type PMP events above Wheeler Dam for analysis within the parent calculation. The shapefile for Watts Bar reservoir was subdivided based on sub-basin boundaries to provide the portion of Watts Bar reservoir within each sub-basin. Reservoir GIS shapefiles from Appendix A-2 of Reference 2.26 were input into ArcGIS and the TINs developed for the General, Tropical and Local event types (Section 6.3.2.4 and 6.5) were then utilized to compute the reservoir average PMP depth by use of the ArcGIS "polygon volume" tool. Computed PMP depth data for the 500 square-mile limit Local event, Tropical event above Wheeler and the General event above Wheeler computed for each reservoir and duration are included on the "Reservoir Depths" and "Watts Bar By Basin Depths" tabs of the Microsoft Excel document included as Appendix A-K.

The ArcGIS spatial analysis and computations were checked with alternate software as they did not utilize NQA dedicated software. Confirmation of the ArcGIS analysis was provided by direct comparison of computed reservoir average depths for each storm type and duration with values developed in an alternate methodology that utilized QGIS. The python script described in section 6.4 was employed to provide the average rainfall over each reservoir for the 500 square-mile limit Local event, Tropical event above Wheeler and the General event above Wheeler. Analysis of results between the software platforms showed a maximum absolute percent differences of less than one-quarter of a percent between the two software platforms and methodologies, as shown in the "QGIS Check" tab of Appendix A-K.

Table 6.6.1 – Reservoirs and Associated Sub-basins

Reservoir	Located Within Basin ID	Square-Miles	Reservoir	Located Within Basin ID	Square-Miles
South Holston	9	11.97	Ocoee #1	43	3.27
Fort Patrick Henry	12	1.31	Chickamauga	45	55.40
Boone	11	6.85	Chatuge	38	11.12
Watauga	10	9.93	Hiwassee	40	9.48
Norris	26	52.06	Blue Ridge	42	5.18
Cherokee	14&15	43.32	Nottely	39	6.52
Douglas	6	47.32	Nickajack	47A	16.30
Melton Hill	27	8.74	Ocoee #3	43	0.93
Fort Loudoun	18	23.66	Ocoee #2	43	0.25
Tellico	24	24.49	Watts Bar (25)	25	12.01
Fontana	22	15.82	Watts Bar (33)	33	0.75
Tims Ford	59	22.01	Watts Bar (36)	36	6.14
Apalachia	41	1.72	Watts Bar (37)	37	40.57

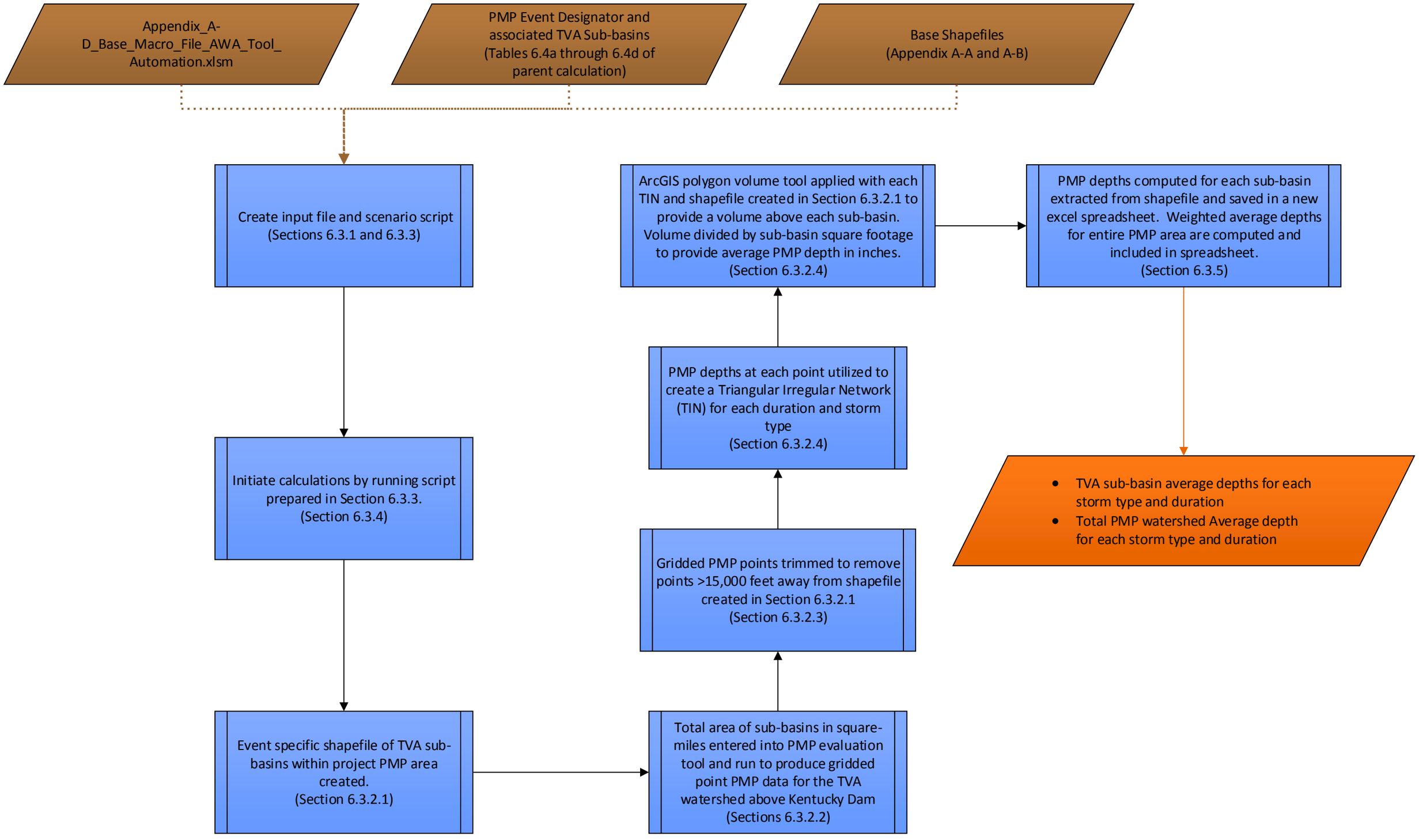
7.0 Summary of Results

The PMP event depths computed by ArcGIS for each of the PMP Evaluation tool outputs on the Tennessee River above Wheeler Dam have been checked by parallel computation on the Quantum GIS platform. Total PMP event rainfall depths for the Tennessee River sub-basins above Wheeler Dam differed by less than one percent for the 1, 2, 3, 4, 5, 6, 12, 18, 24, 48, 72, 96 and 120 hour durations within the PMP event and storm types analyzed. The sub-basin weighted average depths computed for each PMP event are suitable for use in the parent and subsequent calculations. PMP event depth-duration data for the General, Local and Tropical storm types are included as Appendix A-J.

8.0 Conclusions

Computations performed in ArcGIS have been checked by Quantum GIS and any differences are within the precision required. Calculations performed in the development of final PMP sub-basin average depths and their distribution within the Tennessee River sub-basins are suitable for use in subsequent calculations and the parent calculation.

Attachment 1 - PMP Depth Generation Process



Enclosure 4

Barge Affidavit

AFFIDAVIT

STATE OF TENNESSEE)

)ss.

COUNTY OF DAVIDSON)

1. My name is Carrie Stokes. I am Senior Vice President, for Barge Design Solutions, Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by Barge Design Solutions, Inc. to determine whether certain Barge Design Solutions, Inc. information is a trade secret, proprietary, and commercially sensitive. I am familiar with the policies established by Barge Design Solutions, Inc. to ensure the proper application of these criteria.

3. I am familiar with the Barge Design Solutions, Inc. information contained in the report:

> "Software Dedication Report, PMP Evaluation Tool Package, SDR 16-01" dated August 2018 and referred to herein as "Dedication Report." Information regarding the dedication methodology and test problem suite has been classified by Barge Design Solutions, Inc. as proprietary and a trade secret in accordance with the policies established by Barge Design Solutions, Inc. for the control and protection of proprietary information in furtherance of the business of Barge Design Solutions, Inc..

4. This Dedication Report contains trade secrets and information of a proprietary nature of the type customarily held in confidence by Barge Design Solutions, Inc. and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Dedication Report as commercially sensitive, trade secrets, proprietary, and confidential.

5. This Dedication Report has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made

in accordance with 10 CFR 2.390. The information for which withholding from disclosure is requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information."

6. The following criteria are customarily applied by Barge Design Solutions, Inc. to determine whether information should be classified as proprietary:

(a) The information reveals details of Barge Design Solutions, Inc.'s research and development processes or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for Barge Design Solutions, Inc. in product optimization or marketability.

(e) The information is vital to a competitive advantage held by Barge Design Solutions, Inc., would be helpful to competitors, and would likely cause substantial harm to the competitive position of Barge Design Solutions, Inc.

The information in the Dedication Report is considered proprietary for the reasons set forth in paragraphs 6(a) - 6(e) above.

7. In accordance with Barge Design Solutions, Inc.'s policies governing the protection and control of information, trade secrets and confidential or proprietary information contained in this Dedication Report have been made available, on a limited basis, to others outside Barge Design Solutions, Inc. only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. Barge Design Solutions, Inc. policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

FURTHER AFFIANT SAYETH NOT.

SUBSCRIBED before me this 4th day of May, 2020

Notary Public

My Commission Expires:

3-17-2021

JENNIFER A. BARNES
STATE OF TENNESSEE NOTARY PUBLIC
WILSON COUNTY