ASSOCIATED ATTACHMENTS/ENCLOSURES:

Attachment 02.04.03-09C: CDQ000020080033, Rev. 0, SOCH Geometry Calculation - Wheeler

(403 Pages including Cover Sheet)

NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
L58 091023 003	calculations(nuclear)	N/A

Calc Title: SOCH Geometry Verification for Wheeler Reservoir

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	GEN					Entire calc ☐ Selected pages ☐
NEW	CN	NUC	GEN	CEB	CDQ000020080033	N/A	0	

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

UNITS	SYSTEMS	UNIDS
N/A	N/A	N/A

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

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

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
Eric King	(423) 756-3025	CEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Eric E. King, PE [signature]	10/21/09	Lance A. Wagner, PE [signature]	10/21/09
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE** P.B. Selman	**DATE**
Lance A. Wagner, PE [signature]	10/21/09	PBS 10/23/09 PB Selman for KR Gates	10/23/09

STATEMENT OF PROBLEM/ABSTRACT

TVA utilizes the computer program SOCH (Simulated Open Channel Hydraulics) for calculation of flood flows through Wheeler Reservoir. SOCH requires input of data describing the hydraulic characteristics of the reservoir channel that is derived from reservoir cross-section data and the reservoir storage information as obtained from topographic mapping.

Verification of the geometric data and input parameters required for the SOCH model of Wheeler Reservoir is presented in this calculation.

* EDCN 22404A(SQN), EDCN54018A(WBN), LATER (BFN)

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

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

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

NPG CALCULATION COVERSHEET/CCRIS UPDATE

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	GEN	CEB	CDQ000020080033	0

ALTERNATE CALCULATION IDENTIFICATION

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

CATEGORIES NA

KEY NOUNS (A-add, D-delete)

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

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

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	S	CN	GEN	CEB	CDQ000020080042	0
A	S	CN	GEN	CEB	CDQ000020080054	0
A	P	EN	WBN	CEB	54018	
A	P	EN	SQN	CEB	22404	

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

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE

PREPARER PHONE NO.	EDMS ACCESSION NO.

NPG CALCULATION RECORD OF REVISION		
CALCULATION IDENTIFIER: CDQ000020080033		
Title: SOCH Geometry Verification for Wheeler Reservoir		
Revision No.	DESCRIPTION OF REVISION	Date
0	Original Issue. 50 pages.	

NPG CALCULATION TABLE OF CONTENTS

Calculation Identifier: CDQ000020080033	Revision: 0	

TABLE OF CONTENTS

NPG CALCULATION TABLE OF CONTENTS		
Calculation Identifier: CDQ000020080033	Revision: 0	

List of Tables:

List of Figures:

List of Appendices: (All appendices are electronically attached to this calculation)

NPG CALCULATION TABLE OF CONTENTS

Calculation Identifier: CDQ000020080033	Revision: 0	

List of Attachments:

List of Acronyms:

BLN	Bellefonte Nuclear Plant
CONVEY	A computer program that TVA uses to calculate the conveyance of the channel cross-section
DEM	Digital Elevation Model
DLG	Digital Line Graphs
DRG	Digital Raster Graphic
ESRI	Environmental Systems Research Institute
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center, River Analysis System (U. S. Army Corps of Engineers computer program)
NAIP	National Agriculture Imagery Program
NAVD 88	North American Vertical Datum of 1988 (Survey datum for NED data)
NED	National Elevation Dataset
NGS	National Geodetic Survey
NGVD 29	National Geodetic Vertical Datum of 1929 (Survey datum for TVA elevation data)
NHD	National Hydrography Dataset
NRC	Nuclear Regulatory Commission
PER	Problem Evaluation Report
PMF	Probable Maximum Flood
RFI	Request for Information
ROB	Right Overbank
SOCH	Simulated Open Channel Hydraulics (TVA computer program for routing of floods on the Tennessee River)
TIN	Triangulated Irregular Network
TRM	Tennessee River Mile (Mileage along the Tennessee River)
TVA	Tennessee Valley Authority
USGS	United States Geological Survey
USACE	U.S. Army Corps of Engineers
VERTCON	A computer program used by the NGS to calculate differences in elevation between NGVD 29 and NAVD 88
WWIDTH	A computer program that TVA uses to calculate the weighted width parameter to characterize the storage characteristics of Wheeler Reservoir

NPG CALCULATION TABLE OF CONTENTS		
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List of Variables:

Note: The U. S. Standard System of Units (lb, ft, sec) was used in this calculation for all computations performed by TVA and all checking done by BWSC. All units in this calculation are therefore quoted in the U.S. Standard System.

A	cross-sectional area in ft^2
A_1	cross-sectional area in ft^2
A_2	cross-sectional area in ft^2
A_t	total cross-sectional area in ft^2
B_1	top width in feet
B_2	top width in feet
B_w	weighted width in feet
C	conveyance
n	Manning's "n", (not dimensionless, but the numerical value in SI and U. S. Standard units is identical)
R	hydraulic radius in ft
WP_t	total wetted perimeter in feet for cross-section with area A_t

NPG CALCULATION VERIFICATION FORM

Calculation Identifier: CDQ000020080033	Revision: 0

Method of verification used:	
1. Design Review ☒	
2. Alternate Calculation ☒	Verifier: Lance A. Wagner [signature] Date 10/21/09
3. Qualification Test ☐	

Comments:

Design Review verification method was used in this calculation with the exception of specific areas where an alternate method was used to confirm the acceptability of a non-quality assured software package, per the requirements of NEDP-2. The following parts of the calculation required an alternate calculation to confirm the acceptability:

- Surface area calculations
- Cross-section profiles

NPG COMPUTER INPUT FILE STORAGE INFORMATION SHEET

Document CDQ000020080033	Rev. 0	Plant: GEN	
Subject: SOCH Geometry Verification for Wheeler Reservoir			

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

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

See listing of electronically attached Input & Output files on the following pages.

Other electronic files in FILEKEEPER:

Original Input Data CDQ000020080033_INPUT.ZIP (FILEKEEPER No. 312879)

☐ Microfiche/eFiche

ELECTRONIC FILE ATTACHMENTS			
Document: CDQ000020080033	Rev. 0	Plant: Gen	
Subject: SOCH Geometry Verification for Wheeler Reservoir			
The files listed below, which contain both input and output data, are electronically attached to the parent Adobe .pdf calculation file. All files are therefore stored in an unalterable medium and are retrievable through the EDMS number for this calculation. Click on the "Attachments" Tab within Adobe to view the attachment listing, to access and view the files as needed.			

Electronic Input Attachments

Electronic Attachment 1-1 – Scans of Paper USGS 1:24K Quad Maps	
Att_01-01_Wheeler_Cross_Section_Location_Maps_rev0.pdf	
Electronic Attachment 1-2 – Scans of Paper TVA Historical Silt Range Plots	
Att_01-02_Wheeler_Reservoir_Silt_Survey_Range_Plots_rev0.pdf	
Electronic Attachment 1-3 – Original HEC-RAS files for Wheeler Reservoir	
Att_01-03_Original HEC-RAS_Files_from_1992_FEMA_Flood_Study.pdf	

Electronic Output Attachments

Electronic Attachment B-1 – Initial SOCH Geometry File	
Wheeler20090929.geo	
Electronic Attachment B-2 – Initial HEC-RAS Geometry File	
Wheeler20090928.g01	
Electronic Attachment B-3 – Master Excel Geometry File	
Wheeler_Master.xls	
Electronic Attachment D-1 – USACE TINs	
Att_D-01_USACE_TINs_rev0.pdf	
Electronic Attachment F-1 – Section Locations GIS Database	
Att_F-01_Wheeler_Section_Locations_gdb_eek_rev0.pdf	See attached README.TXT
Electronic Attachment I-1 – Storage Surface Areas GIS Database	
Att_I-01_Wheeler_Surface_Areas_gdb_eek_rev0.pdf	See attached README.TXT
Electronic Attachment I-2 – Storage Elevation-Area Table	
Att_I-02_Wheeler_Surface_Areas_rev0.xls	

1 Purpose

The Tennessee Valley Authority (TVA) developed the methods of analysis, procedures and computer programs in the 1960's and 1970's that were needed to determine the design basis flood levels for nuclear plant sites (Ref. 2.5) located in the Tennessee River Basin. These methods will be used in the analyses necessary for determining the design basis flood level at TVA's Nuclear Operating Plants and the Bellefonte Nuclear Plant (BLN) site which is located on the northwest bank of Guntersville Reservoir at Tennessee River Mile (TRM) 391.5.

The principal component of the suite of computer programs used to route floods through Wheeler Reservoir is the SOCH (Simulated Open Channel Hydraulics) (Ref. 2.9) computer model of the Tennessee River Basin. SOCH requires input of data describing the geometric characteristics of each reservoir to be modeled on the Tennessee River. These data are derived from reservoir cross-sections and from reservoir topography that establishes the volume of the reservoir as a function of water-surface elevation in the reservoir (the storage-elevation curve).

The primary purpose of this calculation is to verify the geometric data used to obtain the geometric input for the SOCH model of Wheeler Reservoir from Wheeler Dam (Tennessee River Mile 274.90) to Guntersville Dam (Tennessee River Mile 349.00) and to verify the input parameters to SOCH derived from the geometric data. The two principal objectives of this verification process are therefore:

1. Verify that the cross-section and topographic data used to develop the geometric parameters for the SOCH model of Wheeler Reservoir are confirmed, verifiable and satisfactory for use in the SOCH model.
2. Verify that the geometric parameters derived from the cross-section and topographic data are correct and satisfactory for use in the SOCH model of Wheeler Reservoir.

A secondary purpose of this calculation is to support the development of HEC-RAS input files for the possible future development of HEC-RAS models, using the confirmed geometry and initial Manning's numbers.

The specific tasks necessary to verify and validate the geometric data include:

- Verify and validate the physical surveys.
- Confirm that the data therefrom are correctly transcribed into the corresponding computer files.
- Review, confirm and describe the adjustments made to the physical survey data to account for the effective flow area for each of the 37 individual cross-sections in Wheeler Reservoir.
- Confirm that the data for the adjusted cross-sections are correctly transcribed into the corresponding spreadsheets and files.
- Independently check the surface area of the reservoir between successive cross-sections as a function of water-surface elevation.

- Use the verified water-surface elevation-area table as input to the verified WWIDTH software program to calculate off-channel storage properties for inclusion in the initial SOCH model geometry input files.
- Use the verified cross-section geometry and roughness values as input to the verified CONVEY code to calculate cross-section geometric parameters for inclusion in the initial SOCH model geometry input files.
- Confirm that the WWIDTH and CONVEY output is correctly transcribed into the initial SOCH model geometry input files.

For the purpose of this calculation, the acceptance criteria for the results to be deemed as satisfactory are:

- The physical survey data are traceable to the original source work, or, if the original source work is not available, that the physical survey data are fully documented and corroborated by later surveys, comparison with verified contour maps, or can be reconstructed using modern GIS mapping techniques.
- The original data are accurately transcribed into the spreadsheets and files.
- Any adjustments made to the physical survey data are reasonable and are fully explained and documented.
- The adjusted data are accurately transcribed into the spreadsheets and files.
- Computations to produce the geometric input parameters from the geometric data are correct.

The approach and methodology for the performance of each of these tasks is fully detailed and explained in the subsequent sections of this calculation.

2 References

Note: All relevant pages from the references cited in this calculation that are not readily available are contained in Attachment 1 and 2 to expedite checking and review.

2.1 Chow, V., T. (1959) "Open Channel Hydraulics", McGraw-Hill, New York [Attachment 2-1].

2.2 TVA (1951) "Surveying, Mapping and Related Engineering", Technical Report No. 23, U. S. Government Printing Office [Attachment 2-2].

2.3 TVA (1980) "TVA Water Control Projects", Technical Monograph No. 55, March, 1980 [Attachment 2-3].

2.4 TVA (2008a) "Bellefonte Nuclear Plant, White Paper, Hydrologic Analysis", Revision 1, July 25, 2008 (EDMS L58 081219 800).

2.5 U.S. Nuclear Regulatory Commission (NRC) (1977) "Design Basis Floods for Nuclear Power Plants," Regulatory Guide 1.59, Revision 2.

2.6 U.S. Army Corps of Engineers (2003) "HEC-RAS, Hydrologic River System, Users Manual", Version 3.1.1, Hydrologic Engineering Center.

2.7 TVA "Conveyance (CONVEY) and Weighted Width (WWIDTH) [2009], Users Manual", Version 1.0, Tennessee Valley Authority River Systems Operations (EDMS L58 090213 001).

2.8 TVA, Weighted Width (WWIDTH) and Conveyance (CONVEY) Software Verification and Validation Report (SVVR), Version 1.0 (2009), (EDMS L58 090210 005).

2.9 TVA, "Simulated Open Channel Hydraulics (SOCH) 2009, Users Manual", Version 1.0, Tennessee Valley Authority River Systems Operations (EDMS L58 090528 002).

2.10 Copies of USGS topographic maps with cross-section orientations (1966 to 1982), RFI BE21211080B033 (EDMS L58 090619801) [Attachment 1-1].

2.11 Copies of TVA Silt Range Plots (Dec. 1938), RFI BE21211080B033 (EDMS L58 090619801) [Attachment 1-2].

2.12 Original Wheeler HEC-RAS Files (1992), RFI BE21211080B033 (EDMS L58 090619801) [Attachment 1-3].

2.13 Preliminary Wheeler 1.5M CFS Water Surface Profile (2009), RFI BE21211080B033 (EDMS L58 090619801) [Attachment 2-4].

2.14 NAIP aerial photos, accessed via the USGS ArcIMS GIS Data Server (July 2009), http://ims.cr.usgs.gov.

2.15 Digital Elevation Model (DEM) 10m data, USGS, downloaded from http://data.geocomm.com/ (May 2009) RFI BE21211080B033 (EDMS L58 090619801) [FILEKEEPER No. 312879].

2.16 National Elevation Dataset (NED) 1/3 arc-second data, USGS, downloaded from the National Map Seamless Data Server (May 2009), http://seamless.usgs.gov [FILEKEEPER No. 312879].

2.17 Digital Line Graph (DLG) data, USGS, downloaded from http://edc2.usgs.gov/geodata/ (May 2009), [FILEKEEPER No. 312879].

2.18 National Hydrography Dataset (NHD) data, USGS, downloaded from http://nhd.usgs.gov/data.html (June 2009) [FILEKEEPER No. 312879].

2.19 Digital Raster Graphics (DRG) data, USGS and TVA, accessed via the USGS ArcIMS GIS Data Server (May 2009 – July 2009), http://ims.cr.usgs.gov.

2.20 U.S. Army Corps of Engineers Hydrographic Survey point data (2006), RFI BE21211080B033 (EDMS L58 090619801) [FILEKEEPER No. 312879].

2.21 Technical Memo, USACE Hydrographic Survey Date and Coordinate System Documentation, June 23, 2009 [Attachment 2-5].

2.22 U.S. Army Corps of Engineers (2002) "Engineering and Design – Hydrographic Surveying", EM 1110-2-1003.

2.23 Height Conversion Methodology, National Geodetic Survey, May 12, 1999 [Attachment 2-6].

3 Assumptions

3.1 General Assumptions

1. Elevation data provided in references 2.3, 2.11, 2.12, and 2.13 are referenced to NGVD 29.

   Technical Justification: Vertical datum for TVA projects is recorded in NGVD 29, as documented in Ref. 2.2. Since the reference documents noted above were prepared and developed for and in conjunction with TVA projects, it is reasonable to conclude that the reference data collection was conducted per the guidelines of Ref 2.2. Therefore, the vertical datum for the information provided in the above references is NGVD 29.

2. The TVA Silt Range surveys conducted between 1936 and 1961 were conducted in accordance with industry standards.

   Technical Justification: Description of the horizontal and vertical control and monumenting of the TVA Silt Ranges are documented in TVA (1951) Ref. 2.2.

3. The U. S. Army Corps of Engineers Hydrographic Survey has been conducted in accordance with industry standards for bathymetric surveys.

   Technical Justification: The USACE Hydrographic Survey was conducted for the purpose of updating the navigation charts for the Tennessee River. The U.S. Army Corps of Engineers is responsible for the operation and maintenance of the Nation's waterway system to insure efficient and safe passage of commercial and recreational vessels. Survey methodology employed by the USACE is described in Ref. 2.22 and can be considered to have been applied in accordance with industry standards.

3.2 Unverified Assumptions

None.

4 Design Input and Methodology

4.1 Wheeler Reservoir

Wheeler Reservoir extends from Wheeler Dam at Tennessee River Mile (TRM) 274.90 upstream to Guntersville Dam at TRM 349.00 and is located primarily in Lauderdale, Lawrence, Limestone, Morgan, Madison, and Marshall Counties, Alabama (Ref. 2.10). Wheeler Reservoir includes the Elk River from its mouth near TRM 277 to Tim's Ford Dam. The spillway crest elevation for Wheeler Dam is El. 541 and the maximum normal water surface elevation is El. 556.28 (Ref. 2.3). A location map of Wheeler Dam taken from the scanned USGS Quad maps used in this calculation is shown in Figure 1. There are thirty-seven (37) cross-sections in Wheeler Reservoir. Figure 1 shows the location of two of the Wheeler Reservoir cross-sections noted as TRM 274.90 and TRM 276.80. The flow direction is from the higher TRM to the lower TRM (right to left on Figure 1).

All of these cross-sections were individually reviewed, and selected examples are discussed in subsequent sections of this calculation.

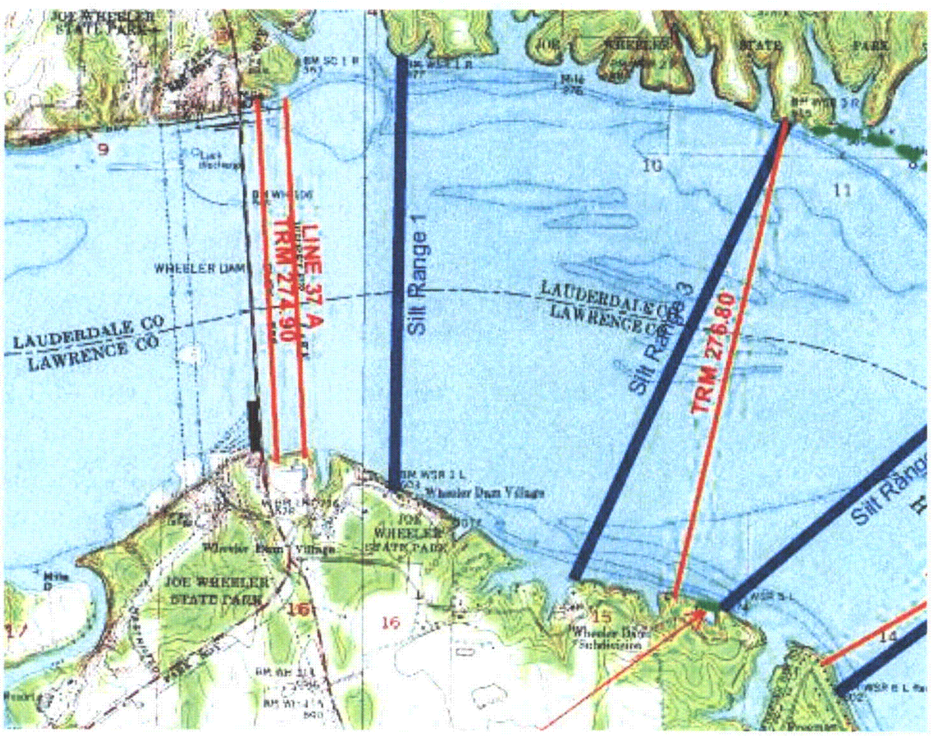


Figure 1 Wheeler Dam, Tennessee River Mile (TRM) 274.90

4.2 Design Input Data

Sect.	Description	Filename	Reference	Attachment No./ FILEKEEPER No.
4.2.1	Scanned copies of USGS topographic maps showing orientation of original cross-section lines and silt ranges in Wheeler Reservoir	Att_01-01_Wheeler_Cross_Section_Location_Maps_rev0.pdf	2.10	Attachment 1-1
4.2.2	Scanned copies of TVA Silt Range plots	Att_01-02_Wheeler_Sediment_Investigation_Range_Plots_rev0.pdf	2.11	Attachment 1-2
4.2.3	Original HEC-RAS files developed by TVA, in 1992 for a Flood Study of the Tennessee River in Wheeler Reservoir, which contain the original Manning's "n" values and cross-section data	Att_01-03_Wheeler_Original_HECRAS.pdf	2.12	Attachment 1-3
GIS Files				
4.2.4	USACE Hydrographic Survey ASCII XYZ point coordinate files	CDQ000020080033_INPUT.ZIP	2.20	FILEKEEPER No. 312879
4.2.5	DEM 10m resolution raster elevation data	CDQ000020080033_INPUT.ZIP	2.15	FILEKEEPER No. 312879
4.2.6	NED 1/3 arc-second (10m) seamless raster elevation data	CDQ000020080033_INPUT.ZIP	2.16	FILEKEEPER No. 312879
4.2.7	DLG Contours, Hydrography, and Survey Monument layers	CDQ000020080033_INPUT.ZIP	2.17	FILEKEEPER No. 312879
4.2.8	NHD data housed in an ArcGIS file geodatabase and containing vector lake boundary shapes	CDQ000020080033_INPUT.ZIP	2.18	FILEKEEPER No. 312879
4.2.9	Seamless DRG raster data accessed on the fly via the USGS ArcIMS GIS Data Server	http://ims.cr.usgs.gov, Layer USGS_EDC_Ortho_DRG, Sub-layer DRG_Z16_24K_TVA	2.19	N/A
4.2.10	NAIP imagery accessed on the fly via the USGS ArcIMS GIS Data Server	http://ims.cr.usgs.gov, Layer USGS_EDC_Ortho_NAIP, Sub-layers NAIP_Z16_AL_002 & NAIP_Z16_AL_004	2.14	N/A

4.3 Methodology for Cross-Section Validation

4.3.1 General

This section outlines the overall approach to the verification of the geometric data for Wheeler Reservoir. The calculations presented in Section 6 follow in the same order as presented here.

The final cross-sections that are incorporated into the SOCH model for Wheeler Reservoir are a composite of the following:

1. The original cross-sections that TVA developed for a 1992 Flood Study of the Tennessee River in Wheeler Reservoir (Ref. 2.12). These cross-sections were provided by TVA housed in a HEC-RAS geometry file.
2. The U. S. Army Corps of Engineers (USACE) Hydrographic Survey data (Ref. 2.20).

3. A review and supplement of the topography in Wheeler Reservoir above the water surface elevation using 10-meter DEM and 1:24,000 USGS quad map DLG hypsography data (Ref. 2.15, 2.17).
4. Adjustment of the cross-sections to account for the effective flow area in Wheeler Reservoir (Appendix F, Section 6.4.4).

Each of the data sources requires traceability or justification, and adjustment of the cross-sections to account for effective flow area requires documentation to verify that the final cross-section geometry is a satisfactory representation of the reach of Wheeler Reservoir in which the cross-section is located.

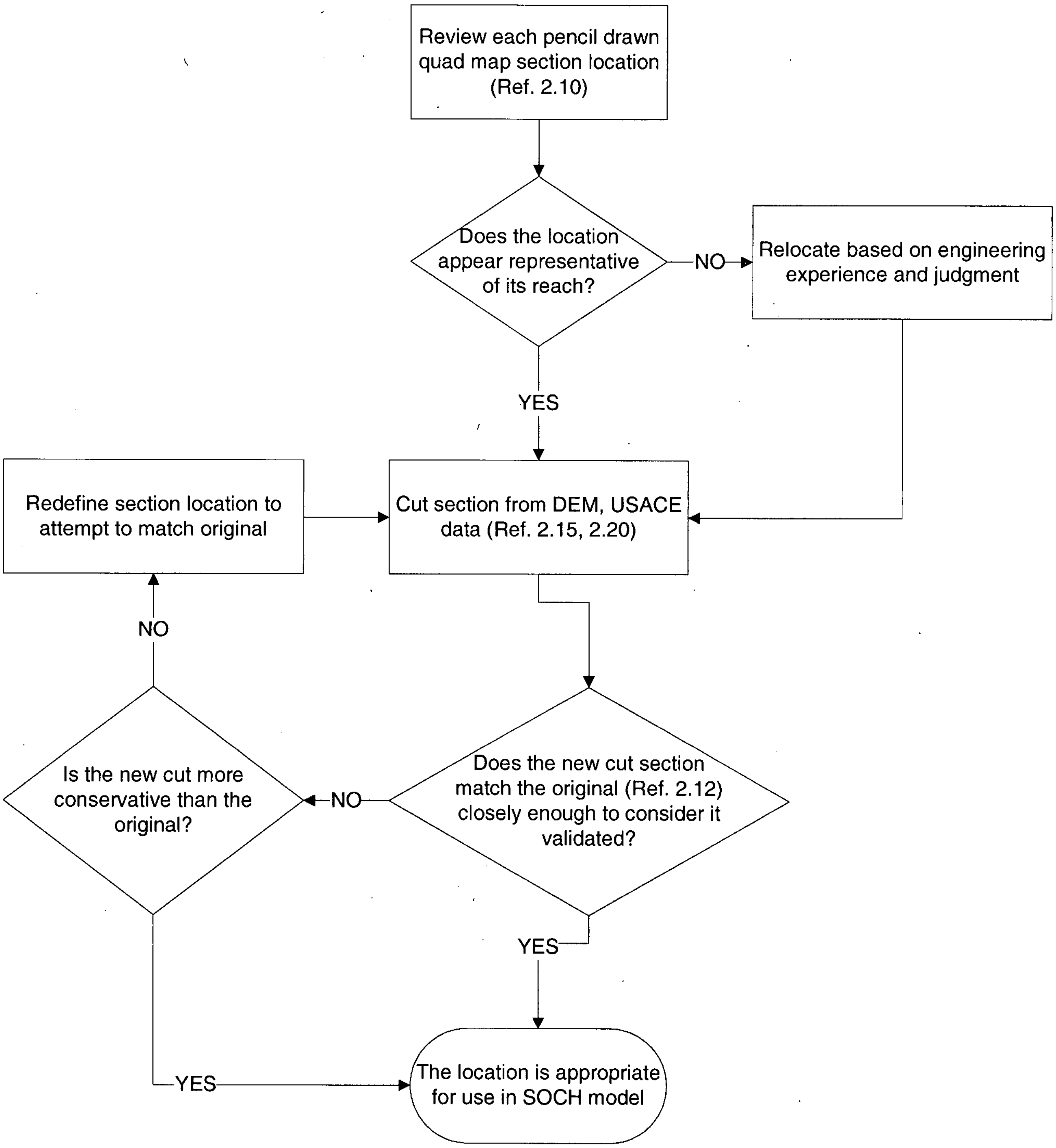
All references to the "original cross-sections" or "original HEC-RAS" in this calculation are to the cross-sections developed by TVA in 1992 for a Flood Study of Wheeler Reservoir (Ref. 2.12). The Wheeler Reservoir Flood Study results were submitted to FEMA to be incorporated into subsequent revisions of their Flood Insurance Studies (FIS) and their Flood Insurance Rate Maps (FIRM) of the communities along the reservoir.

All references to the "initial HEC-RAS" or "final" cross-sections in this calculation are to the cross-sections developed by this calculation for input to WWIDTH and CONVEY (Appendix A) to create the initial SOCH model geometry input files for Wheeler Reservoir.

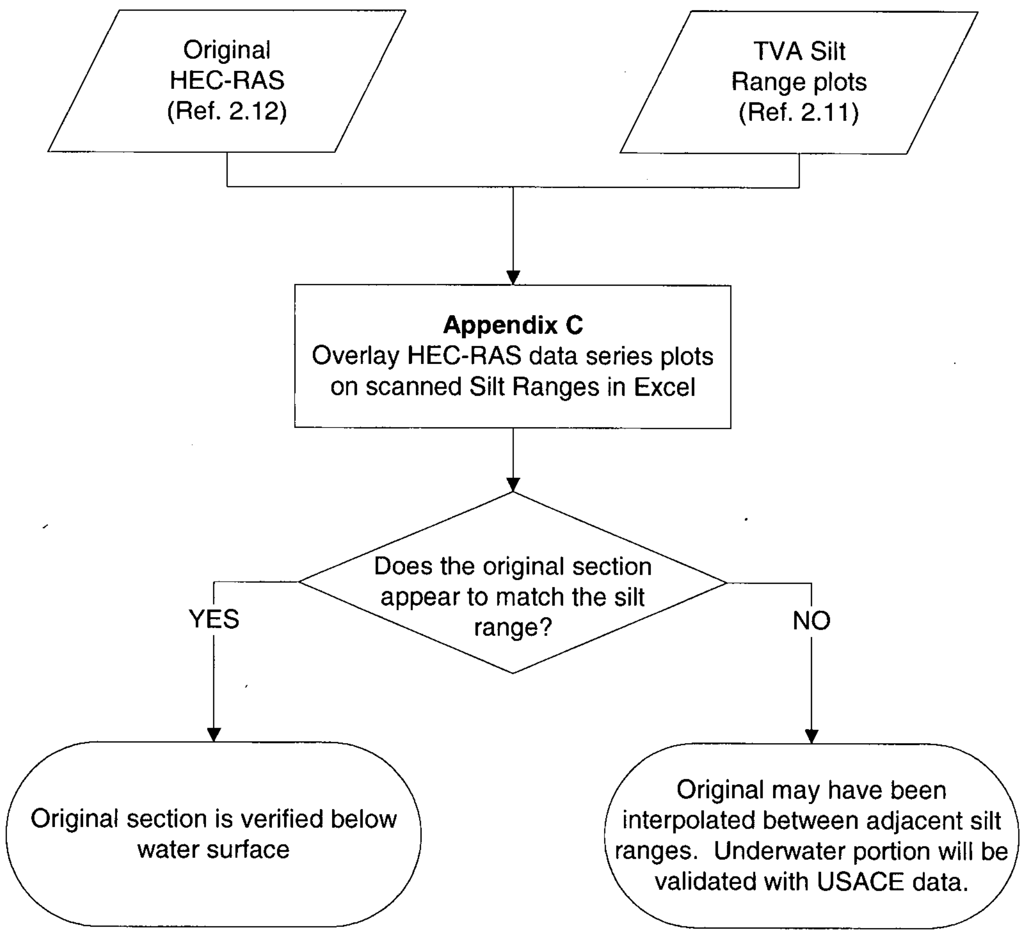
All of the checking requiring GIS work for this calculation was accomplished using ESRI ArcGIS 9.2, ESRI ArcGIS 9.3, and/or Bentley MicroStation v8 2004 Edition with Bentley GeoPak.

The following flowcharts provide a general overview of the processes used to verify the geometric parameters for the SOCH model and to develop the initial SOCH model geometry input files:

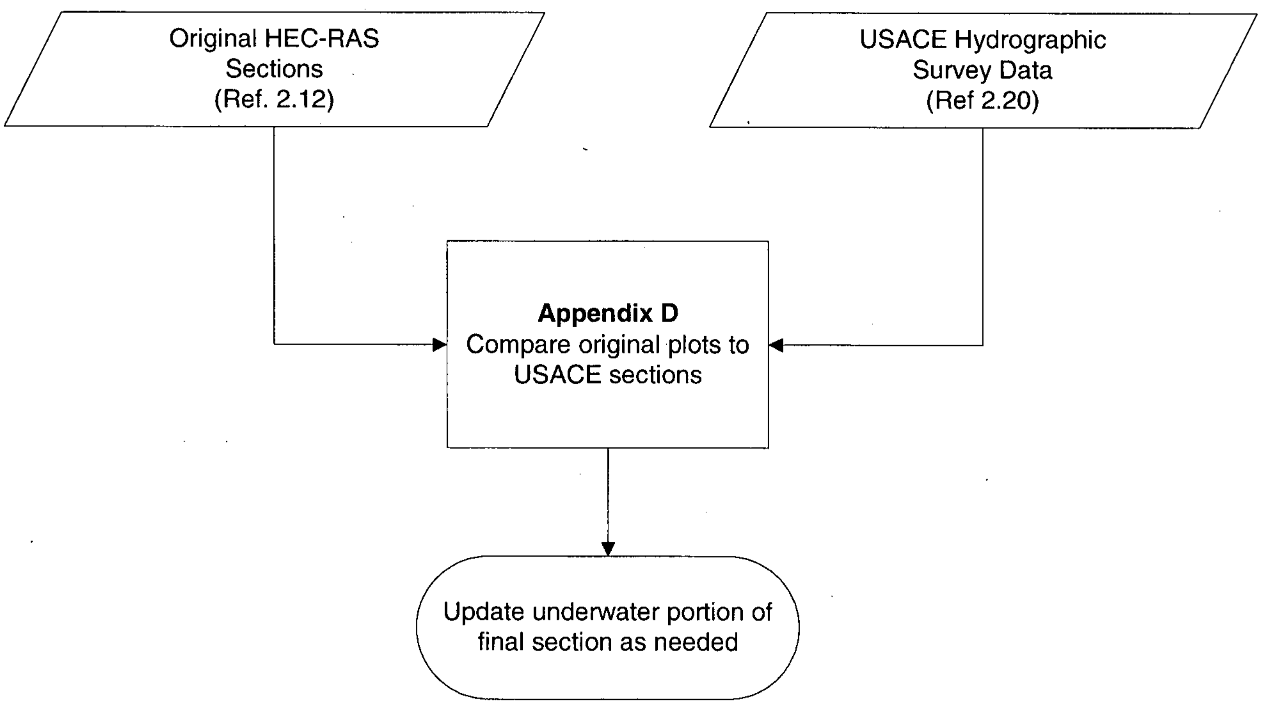
Process Overview – Cross-Section Location and Orientation (Sec. 4.3.2)



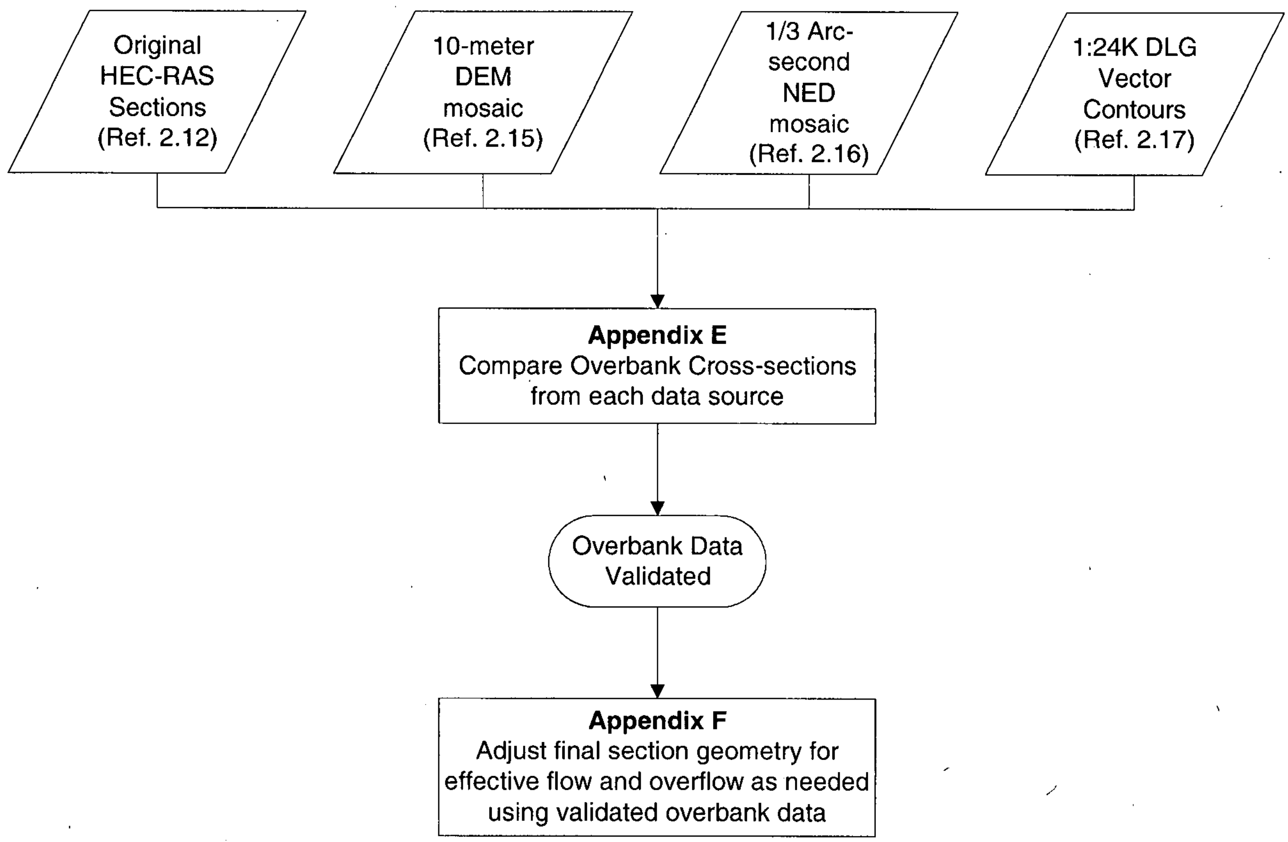
Process Overview – Verify Original Cross-Sections (Sec. 4.3.3)



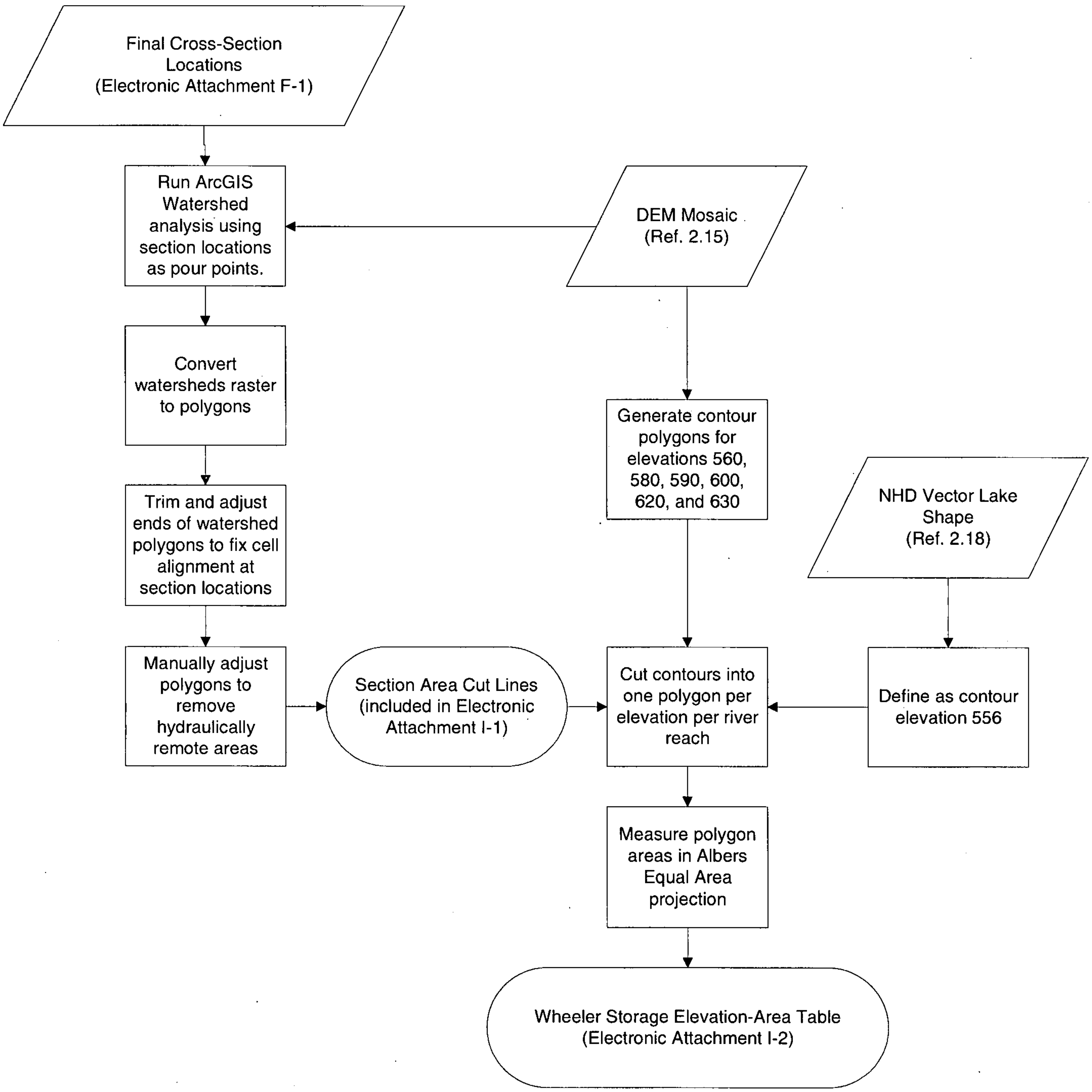
Process Overview – Validate Below Water Surface (Sec. 4.3.4)



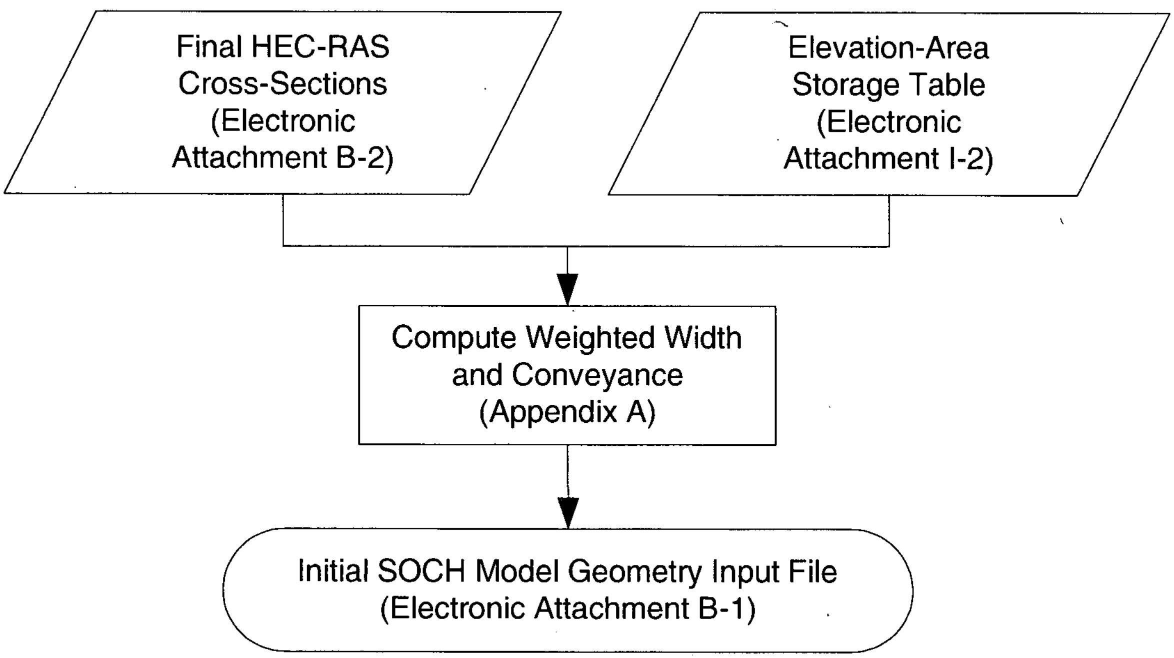
Process Overview – Validate Above Water Surface (Sec. 4.3.5)



Process Overview – Surface Areas (Sec. 4.3.6)



Process Overview – Weighted Width, Conveyance, and Initial SOCH Model Geometry Input File (Sec. 4.3.7, App. A)



4.3.2 Cross-Section Location and Orientation

The original USGS topographic maps that were used to develop the original cross-section locations and orientations could not be located and had to be reconstructed prior to beginning this calculation. To reconstruct these maps, TVA staff was consulted and the cross-section location lines were hand drawn on clean paper copies of USGS maps at the river miles that were associated with each cross-section in the original HEC-RAS geometry file. Initially the cross-section location lines were drawn perpendicular to the main channel, but they were then were adjusted until they provided a good match to the shape and elevations in the original HEC-RAS file. Once a good agreement in shape and elevation were obtained, the cross-section location lines were considered to be reasonable reconstructions corresponding to the original HEC-RAS file. The cross-section location lines were reviewed by TVA staff and provided as Reference 2.10 for use in this calculation.

Attachment 1-1 contains copies of the USGS topographic maps used to define the orientation of the cross-sections and to develop the overbank areas for comparison with the original data. Attachment 1-1 therefore documents the governing locations of the original cross-sections in Wheeler Reservoir. Attachment 1-1 also served as the basis for geo-referencing the cross-sections for use in the GIS mapping for this calculation.

To establish an ESRI geodatabase of the section locations, scanned copies of the paper copies were geo-referenced using a 24K USGS quad grid to align the corners of each quad map. The hand drawn section location line was then used to digitize the locations into the ESRI geodatabase files. This orientation is not necessarily the same as the orientation of the original cross-sections, since it was necessary to manually reconstruct the orientation as discussed above. Consequently, an exact match between the original cross-sections and the reconstructed cross-sections cannot be expected.

The orientation of the cross-sections was also reviewed from the viewpoint of channel hydraulics. In this review, the criterion for assessing the adequacy of the orientation was the following:

- The geometry derived from the original cross-section location provides confirmation of the original cross-section geometry, or
- The orientation for each cross-section adequately represents the effective flow area and geometric characteristics of the reach under consideration.

As long as the orientation shown on the paper copies in Attachment 1-1 met these criteria, the cross-section orientation was not immediately adjusted. All the section locations in Attachment 1-1 were reviewed, and some sections were relocated to represent the limiting geometry in a reach. As will be further described in Section 6.2 and as outlined in the flowchart on page 19, adjustments were made to these original cross-section locations in the ESRI geodatabase following inspection of the cross-section profiles derived from the original locations.

4.3.3 Original Cross-Sections

The original cross-sections were used extensively in the development of the HEC-RAS cross-sections used to derive the necessary geometric parameters for the input to the SOCH model. Consequently, the first step in the overall validation of the input to the SOCH model is to provide verification of the original cross-sections.

The basic data for verification of the original cross-sections consist of copies of TVA Silt Range plots developed between 1936 and 1961 for Wheeler Reservoir (Ref. 2.11). The approach to verifying the original cross-sections is to confirm that the part of the original cross-section below the water surface elevation in Wheeler Reservoir is corroborated by the TVA Silt Range plots (Appendix C).

Completion of these steps provides documentation of the data used for the original cross-sections and verifies that the original sections were correctly incorporated into the spreadsheets used to develop the final cross-sections subsequently used in the calculation of the geometric parameters required for input to the SOCH model of Wheeler Reservoir.

4.3.4 Cross-Section Validation below Water Surface

Between June 2006 and August 2006, the U. S. Army Corps of Engineers (USACE) conducted a hydrographic survey of Wheeler Reservoir (Ref. 2.21). This survey includes only that part of the reservoir that was below the reservoir water-surface at the time of the survey and was focused primarily on the navigation channel. Therefore, the USACE Hydrographic Survey does not include much of the shallow areas outside the navigation channel. A TIN (Triangular Irregular Network) was constructed from the USACE Hydrographic Survey in four segments, and is included as Electronic Attachment D-1. Using this TIN, cross-sections were cut at the SOCH cross-section locations on the Tennessee River in Wheeler Reservoir. For a few select cross-sections as noted on plots found in Appendices D and H, discrete series of USACE Hydrographic Survey data points in proximity to the section location were projected onto the section location line to establish relative station values for each data point, defining a cross-section without the use of triangulation or interpolation of the source data (see Appendix J).

The USACE Hydrographic Survey cross-sections were then compared with the original cross-sections and a composite cross-section was developed. The composite of the original cross-section, USACE data, and overbank data was created with the use of an Excel spreadsheet and corresponding station-elevation Excel chart. The Excel chart facilitated manual construction of a composite section with automatic fill-in of a data table composed of corresponding station and elevation points for the composite section.

The approach to validating the part of the final cross-section below the water surface elevation consists of the following:

1. Check the TIN file and confirm that the extracted cross-sections are reproducible (Appendix K).
2. Verify that the USACE Hydrographic Survey cross-sections have been incorporated correctly into the spreadsheet.
3. Review mapping from the TIN file to permit assessment of the topography established by the USACE Hydrographic Survey and evaluate topographic variations in the reach for the particular cross-section being checked, i.e. evaluate whether the section at the cut location is representative of its river reach.
4. Review and assess the adjustments made for the composite cross-section and document as appropriate.

Completion of the review of the USACE Hydrographic Survey Data provides documentation and justification of the development of the final cross-section geometry below the water surface elevation.

4.3.5 Cross-Section Validation above Water Surface

The original cross-section configuration as shown in the spreadsheets (Appendix E) and contained in the original HEC-RAS geometry file (Ref. 2.12) was compared with 10-meter DEM data (Ref. 2.15), 1/3 arc-second NED data (Ref. 2.16), and 1:24,000 DLG vector contour data (Ref. 2.17). The general approach for creating the final cross-sections to be used to develop the initial SOCH model geometry input files consists of the following:

1. Prepare a map for each cross-section using USGS DRG Quad sheets (Ref. 2.19) showing the locations of the cross-section being reviewed and the immediate upstream and downstream section. Place comments on the development of the cross-sections on these figures.
2. Construct ESRI ArcGIS raster mosaics from the 10-meter DEM and 1/3 arc-second NED data. Obtain cross-sections from these rasters and the DLG data and import into spreadsheets used to compare these cross-sections with the original HEC-RAS cross-sections.
3. Manually adjust a composite section combining original cross-section data, USACE Hydrographic Survey Data from Section 4.3.4, and the overbank data extracted in step two.
4. Review and assess adjustments made for effective flow, and document as appropriate.

Completion of this task provides the requisite justification and documentation of final Wheeler Reservoir cross-section geometry for that part of the cross-section above the water surface elevation.

4.3.6 Surface Area Calculation

The WWIDTH software program requires surface areas as a function of elevation between successive cross-sections as input data. These elevation-areas provide the WWIDTH software program with data necessary to calculate storage volumes outside the reservoir and channel that will be flooded during a PMF event. The following steps outline the process to obtain these areas:

1. Use the Spatial Analyst extension of ESRI ArcGIS to create, from the DEM raster mosaic developed in Section 4.3.5, contours for elevations 560, 580, 590, 600, 620, and 630.
2. Take NHD vector shape for Wheeler Lake (Ref. 2.18) as the water surface contour at elevation 556.
3. Use ArcGIS to calculate the surface areas for elevations 556, 560, 580, 590, 600, 620, and 630 using the contour polylines and cross-section line data (Electronic Attachment F-1) to define a contour polygon per river reach.
4. To meet the requirements of NEPD-2 for non-quality assured software, also measure using MicroStation a portion of the polygons measured in ArcGIS. See Appendix K for a more detailed discussion of the area comparison.

The NHD Wheeler Lake waterbody shape was used to define the surface area at normal water surface elevation 556. This elevation was verified as the water surface elevation published for Wheeler Reservoir on USGS topographic maps (Ref. 2.10). The NHD shape was visually confirmed to match DLG lake boundaries derived from USGS quad maps. The total area of the shape at elevation 556 was compared to the published 1936 elevation-area in Reference 2.3.

Hydraulically remote areas were removed from the total surface areas at TRM309.44-TRM307.73 and TRM317.83-TRM320.18. These areas, while hydraulically connected to Wheeler Reservoir, were considered ineffective storage areas during a PMF event. Removal of the areas will result in a more conservative flood water surface profile, and is considered appropriate for a PMF calculation.

A map with the areas at the given elevations is attached as Appendix I. The area information was used in the weighted width (Ref. 2.7) calculation, which can be found in Appendix A.

4.3.7 Weighted Width, Conveyance and Initial SOCH Model Geometry Input File

The final cross-section data, surface areas, and initial Manning's "n" values were imported into the Weighted Width and Conveyance Version 1.0 programs (Ref. 2.7). See Appendix A for more details regarding the weighted width and conveyance calculation. The following steps outline the process for weighted width, conveyance, and developing the initial SOCH model geometry input file:

1. Manning's "n" values were extracted from the initial HEC-RAS file (Ref. 2.12).
2. The initial center-of-channel Manning's "n" values were not adjusted, since no additional data were available to adjust the values.
3. The initial over-bank Manning's "n" values were compared to the actual surface features on the aerial photos (Ref. 2.14) for each section's reach length, and adjusted as needed.
4. The adjusted over-bank and initial channel Manning's "n" values, and the initial SOCH cross-section data were imported into the Conveyance Version 1.0 program. The surface areas calculated in Section 4.3.6 were imported into the Weighted Width Version 1.0 program. See Appendix A for more details.
5. The Weighted Width and Conveyance Version 1.0 programs outputs were used to prepare the initial SOCH model geometry input file.

The final cross-section geometry from Sections 4.3.4 and 4.3.5, and the Weighted Width and Conveyance Version 1.0 programs output files were combined to form the initial SOCH model geometry input files for Wheeler Reservoir.

5 Special Requirements/Limiting Conditions

N/A

6 Computations and Analyses

6.1 Background

This section provides background information that must be read to understand the reasons why the geometric parameters that are being reviewed and validated in this calculation are developed in this manner.

NOTES:

1. U. S. Standard Units (lb, ft, sec) are used in all computations performed in this calculation.
2. All computations were performed on Personal Computers using the Windows XP operating system.

TVA uses a computer program called "Simulated Open Channel Hydraulics" (SOCH) to route floods through Wheeler Reservoir. The original version of SOCH was developed in the 1960's and 1970's for mainframe computers. It is a legacy code that requires preparation of input files to describe the reservoir geometry and inflow characteristics. This calculation focuses on the geometric input required for the SOCH model for Wheeler Reservoir. The primary geometric input to SOCH includes:

1. a description of the hydraulic conveyance characteristics at each cross-section
2. a description of the reservoir storage characteristics for each reach of the reservoir between cross-sections

The conveyance for a channel cross-section is defined (Ref. 2.1) as

$$C = \frac{1.486AR^{2/3}}{n} \qquad \textbf{Equation 1}$$

and is a measure of the carrying capacity of the channel, since the conveyance is directly proportional to the discharge in the channel. Here A is the cross-sectional area in ft^2, R is the hydraulic radius in feet, and n is Manning's "n". Equation 1 is valid only for U. S. Standard Units. Because TVA uses C to denote conveyance, whereas most standard textbooks use K, TVA's notation will be used in this calculation for consistency with TVA documentation for their software. The term "conveyance" refers to the conveyance characteristics for a cross-section such as the area, A, or hydraulic radius, R, or to the conveyance for the cross-section (or segments thereof), C, as defined by Equation 1.

The hydraulic conveyance characteristics that TVA establishes for a given cross-section for input to the SOCH model are compiled in a table of water surface elevation, cross-sectional area A, hydraulic radius $R^{2/3}$, and weighted width WW.

It should be noted that the value of $R^{2/3}$ as computed for use in the SOCH model is based on the total conveyance for the cross-section and is not the value of $(A_t/WP_t)^{2/3}$ where A_t is the total cross-sectional area in ft^2 and WP_t is total wetted perimeter in feet for the section (refer to Section 6.6 for a complete discussion of the checking of the conveyance values). The "n" value in the conveyance equation references the cross-section channel "n".

The reservoir/channel storage characteristics are represented by a table of weighted width values at that cross-section as a function of water-surface elevation.

The development of the cross-sections used as the basis for SOCH input and the weighted width used for input to SOCH is described in Appendix A.

6.2 Cross-Section Location and Orientation

During the development of cross-section geometry for this calculation, some original section locations (Ref. 2.10) were determined to inaccurately represent the original cross-section geometries (Ref. 2.12). At the time of development of the original cross-sections, the SOCH model software required section locations to be evenly spaced within a reservoir, resulting in original section locations that did not coincide with available underwater silt range data. Consequently, original cross-section geometries were often taken coincident with the silt range locations, but defined to occur spatially at the evenly spaced cross-section locations. This results, in some cases, in the observation of different channel widths between the original cross-section geometry and the geometry observed at the original cross-section location.

Table 1 Section Location TRM Adjustments

Original TRM	New TRM	Adjustment Reason
349.00	349.00	
346.94	346.94	
344.88	344.88	
342.83	342.83	
340.77	340.94	limiting section
338.71	338.71	
336.65	336.90	limiting section
334.59	334.59	
332.53	332.53	
330.48	330.02	limiting section
328.42	328.47	limiting section
326.36	326.36	
324.30	324.20	limiting section
322.24	322.24	
320.18	320.18	
318.13	317.83	match original
316.07	316.07	
314.01	314.25	limiting section
311.95	312.57	limiting section

Original TRM	New TRM	Adjustment Reason
309.89	309.44	limiting section
307.83	307.73	limiting section
305.78	305.78	
303.72	303.72	
301.66	301.66	
299.60	299.60	
297.54	297.54	
295.48	295.62	limiting section
293.43	293.75	match original
291.37	291.37	
289.31	289.80	match silt range
287.25	287.16	limiting section
285.19	285.19	
283.13	283.13	
281.08	281.08	
279.02	278.60	match silt range
276.96	276.80	limiting section
274.90	274.90	

To facilitate reproduction of the final cross-section geometry using modern GIS techniques, some of the evenly spaced original section locations were redefined to be coincident with their corresponding silt range or in a best attempt to match the geometry of the original cross-section. Other sections were relocated to correspond with the limiting geometry observed in each reach. Consequently, some of the final section locations do not match the pencil-drawn locations shown on the paper copies in Attachment

1-1. Additionally, for several sections in Wheeler Reservoir, other cut locations were inspected to establish effective flow and overflow areas as will be discussed in Section 6.4.4.2.

A summary of the location adjustments is provided in Table 1. The revised section location lines and alternate cut locations are provided in an ArcGIS file geodatabase in Electronic Attachment F-1.

6.3 Verification of Original Cross-Section Data

TVA established silt ranges as part of a program to monitor silt deposition in navigation channels and estimate the useful life of reservoirs (Ref. 2.2). Scanned sheets with plots of silt range surveys that were conducted between 1936 and 1961 are included in Attachment 1-2. Although original survey notes have not been recovered, the fact that the silt range data spanning two decades is in good agreement provides confirmation of the reservoir geometry used to develop the original cross-sections.

The original cross-sections were verified by comparison to historical TVA Silt Range data by overlaying the cross-section plot over a scanned image of the silt range. These plots can be found in Appendix C. The cross-sections were generally found to be good matches for the silt ranges, but never exact. An example of a good match taken from Appendix C is shown in Figure 2.

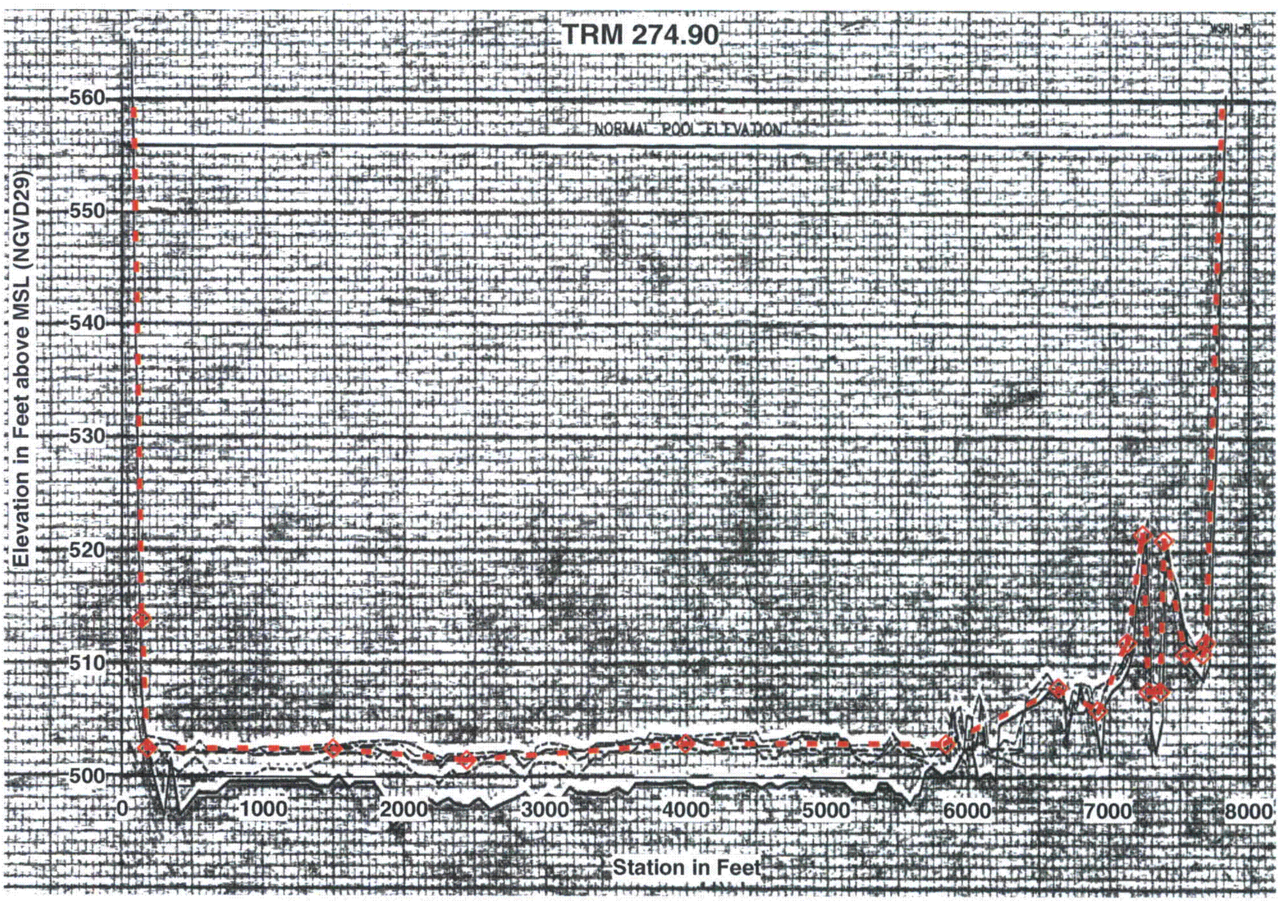


Figure 2 Example of Original Section Matching TVA Silt Range at TRM 274.90

In some cases, where original sections were located between adjacent silt range locations, the comparison plots suggest that the silt range data was interpolated to define the original section geometry. The original and silt range sections at these locations were observed to be similar, but different enough that they could not be considered a good match. An example of a non-matching comparison plot is shown in Figure 3. The comparison at these locations still provides evidence to support verification of the general width and depth of the original cross-sections, with further validation provided by USACE data in Appendix D.

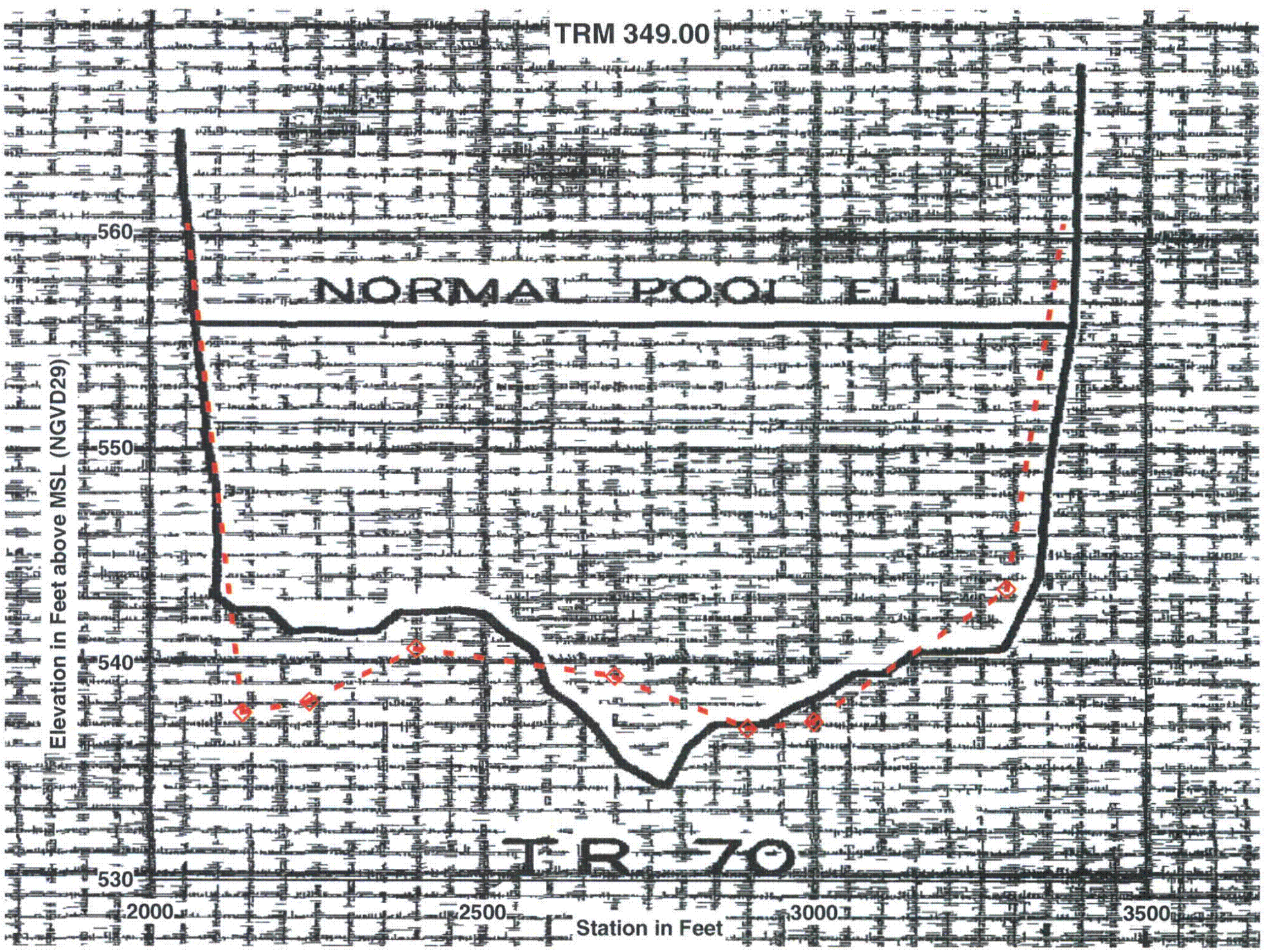


Figure 3 Example of Original Section Not Matching TVA Silt Range at TRM 349.00

6.4 Validation of Cross-Section Data below Water Surface

To validate the under water portion of the cross-section used to develop the initial input to the SOCH model, the original cross-sections were compared to 2006 USACE hydrographic survey data in Excel plots, found in Appendix D. A TIN surface was created from the USACE data using the 3D Analyst ArcGIS extension. Cross-section profiles were extracted from this TIN surface at each SOCH model section location in Wheeler Reservoir using the EZ Profiler add-on for ArcGIS 9.2. MicroStation V8 with GeoPak was used confirm a sample of the USACE cross-sections generated in ArcGIS in order to meet the requirements of NEDP-2 for the use of non-QA software in a QA application (see Appendix K). The cross-sections generated in ArcGIS were compared with the original sections, shown by example for TRM 295.62 in Figure 4. The results shown in Figure 4 and Appendix D corroborate the original sections and provide a basis for adjusting the final HEC-RAS section.

In some cases the original section geometry was retained in the channel bottom, generally where the original demonstrated a shallower, more conservative channel bottom when compared to the USACE data. Additional notes for those sections are provided in Appendix D.

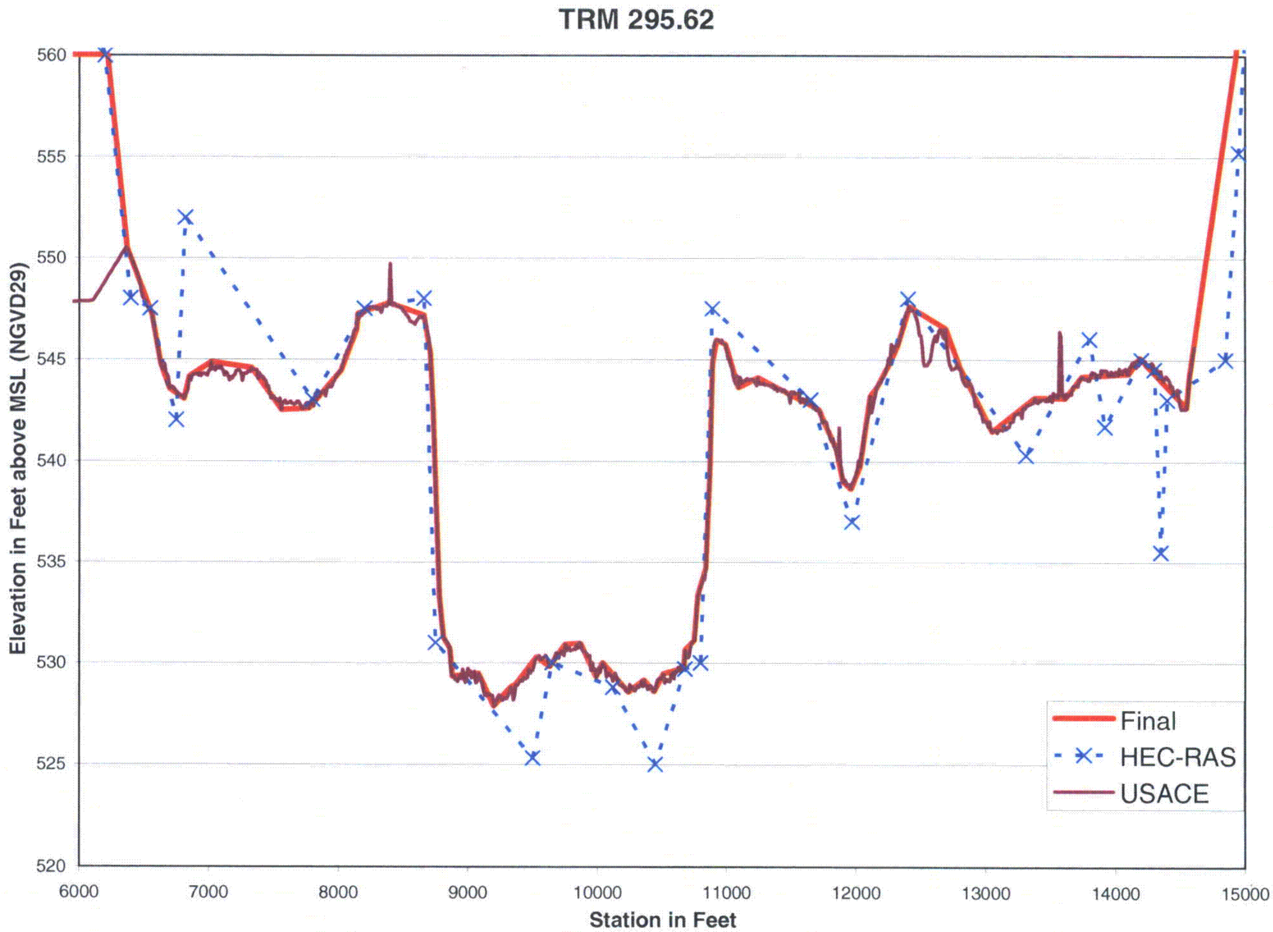


Figure 4 Comparison of USACE Cross-Section to Original HEC-RAS

Several of the USACE cross-sections in Appendix D, like the section in Figure 4, can be considered a good match for the original cross-section data despite having been extracted at a different TRM than the original due to location adjustments as described in Section 6.2. This agreement provides supporting evidence that the final cross-sections are representative of their reach.

No USACE data were available for TRM 283.13. However, the TVA Silt Range data at this location are a good match to the original HEC-RAS (see Appendix C) and the original cross-section can be considered acceptable for use in a PMF calculation as best available data.

6.5 Development of Final Cross-Sections for HEC-RAS and SOCH Models

6.5.1 Outline of Development

Development of the final cross-section configuration for Wheeler Reservoir consists of the following:

1. Combination of the original cross-sections with the USACE Hydrographic Survey to construct an updated cross-section below the water surface elevation in Wheeler Reservoir.
2. Extension of the cross-section above the water surface elevation using 10-meter DEM data and the original cross-sections.
3. Inclusion of off-channel flow areas that will convey flow during extreme flood events.
4. Adjustment of the cross-sections to account for the effective flow area.
5. Verification of the initial Manning's "n" values provided with the initial HEC-RAS files.

Each of these steps is discussed in more detail in subsequent sections of this calculation to document the final configuration of the cross-sections for Wheeler Reservoir that are used to develop the geometric input required for the SOCH model of Wheeler Reservoir.

6.5.2 Development of Composite Cross-Section from USACE Hydrographic Survey and Original Cross-Section Data

The data for the original cross-sections and the corresponding cross-sections obtained from the USACE Hydrographic Survey as described in Section 6.4 were entered into an Excel workbook and plotted. In addition, the underwater topography described by the USACE TIN upstream and downstream from the location of the cross-section being constructed were also visually examined as contours in ArcGIS during the generation of the composite cross-section to determine if the USACE Hydrographic Survey data had any local anomalies that needed to be taken into account in constructing the final cross-section.

Figure 5 shows an example of the combination of the original data and the USACE Hydrographic Survey data to arrive at the final cross-section configuration for TRM 338.71 as shown by the red line. The original section geometry demonstrates a channel bottom adjustment when compared to the USACE data, evidenced by a flat straight line channel bottom. Review of the underwater topography for this reach identifies a local scour hole, justifying the original channel bottom adjustment. The original section geometry is used to define the channel bottom with adjustment while the USACE data exhibiting a shallower section, possibly due to siltation, is used on the right of the final section, shown by the red line.

TRM 338.71 is an example from Appendix D which illustrates that each of the cross-sections had to be examined with consideration given to the original cross-sections, the USACE Hydrographic Survey, and the overall underwater topography between cross-sections upstream and downstream from the particular cross-section being adjusted to obtain the composite cross-section designated by the red line.

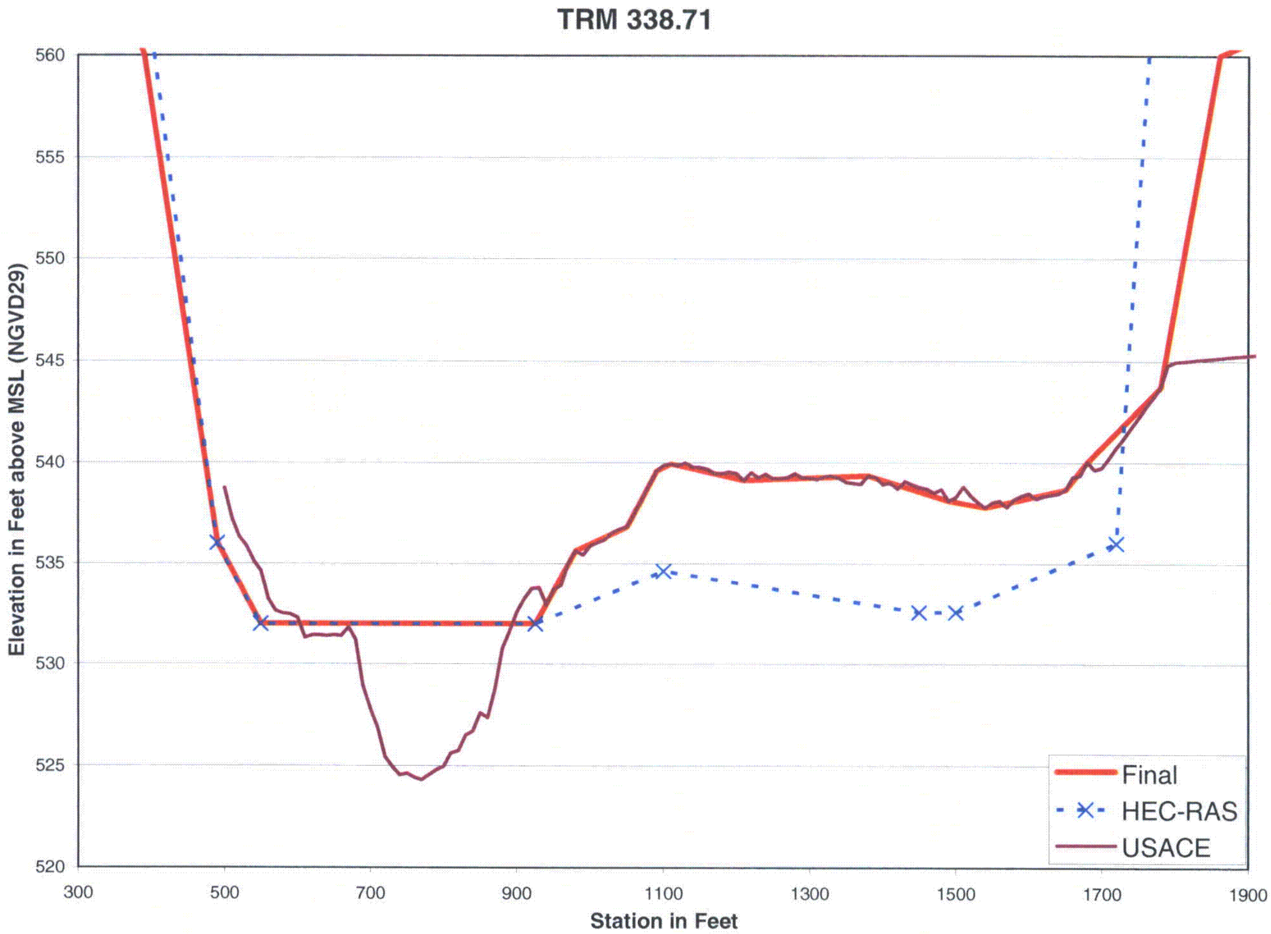


Figure 5 Comparison of USACE and Original Underwater Section at TRM 338.71

Each of the composite cross-sections was reviewed and annotated to document where each part of the final configuration for that cross-section was obtained. The results of this documentation are shown in Appendix H. The composite sections as indicated by the "red line" on each of the cross-sections for Wheeler Reservoir shown in Appendix H are satisfactory for use in the SOCH model for Wheeler Reservoir.

6.5.3 Validation of Cross-Section Configuration Above Water Surface Elevation

For the areas above the water surface elevation, USGS topographic maps were used to develop the original cross-sections and again used in the development of the final orientation of the cross-sections to be used for the SOCH model of Wheeler Reservoir. To check the USGS data above water surface elevation, DLG vector contour data, 10-meter DEM raster data, and 1/3 arc-second NED raster data from the USGS were compared to the original cross-sections.

ArcGIS was utilized to construct raster mosaics of the DEM and NED data and to combine multiple DLG vector datasets into a single GIS feature class. The original NED data was provided in NAVD 88 and was adjusted into NGVD 29 using a datum adjustment grid derived from NGS VERTCON software. Additional info regarding the datum adjustment can be found in Reference 2.23, but the adjusted NED data were not used in any final cross-sections and provided only a comparison to validate the DEM data and original cross-sections.

Sections were generated from the three datasets at each section location using the EZ Profiler ArcGIS add-on. MicroStation V8 with GeoPak was used confirm a sample of the DEM cross-sections generated in ArcGIS in order to meet the requirements of NEDP-2 for the use of non-QA software in a QA application (see Appendix K). Additional locations were cut, as shown on the maps in Appendix F, in order to inspect and check restrictive locations in a reach that did not occur at the exact section location. These sections were plotted in Excel along with the original HEC-RAS data and compared. The plots comparing DLG, DEM, NED, and original cross-section are shown in Appendix E.

The DLG, DEM, and NED were found to be in excellent agreement. The three datasets are all derived from USGS topographic quad map contours, and so their agreement is to be expected. Their agreement in this application provides evidence that the different process path for each dataset has not substantially altered the original data from which they are derived, and validates the data for use in the SOCH model of Wheeler Reservoir

6.5.3.1 Checking of Sections without Adjustment for Effective Flow Area

A comparison of the original and final cross-section with the DLG, DEM, and NED data for TRM 281.08 is shown in Figure 6, taken from Appendix E. The DEM data demonstrates a narrower section than the original; the original section width was defined by the width at the downstream TVA Silt Range 8 (see Appendices F and C for silt range location and geometry, respectively) while the DEM reflects the actual width at TRM 281.08. There are no adjustments to this cross-section for effective flow area, and the DEM section is in general agreement with the original HEC-RAS. Since the data sources agree, the final section was adjusted to match the more conservative limiting geometry of the DEM and DLG data, to facilitate reproduction of the final cross-sections using modern GIS techniques.

DLG data points were used in the final cross-sections to reduce section complexity (number of data points) where possible when the interpolated DEM surface did not contain significant variations not described by the DLG data. Variations between DLG and DEM cross-section profiles do not reflect discrepancies in the data, but differences in the methods of extraction: the DEM is a continuous surface with elevation variations influenced by original USGS topographic quad map contours that are not intersected by the cross-section location cut line; data points in DLG cross-section profiles reflect only those contours intersected by the cross-section location line. Based on the agreement between DLG, DEM, and NED data the updated final sections are verified and satisfactory for use in the SOCH model of Wheeler Reservoir.

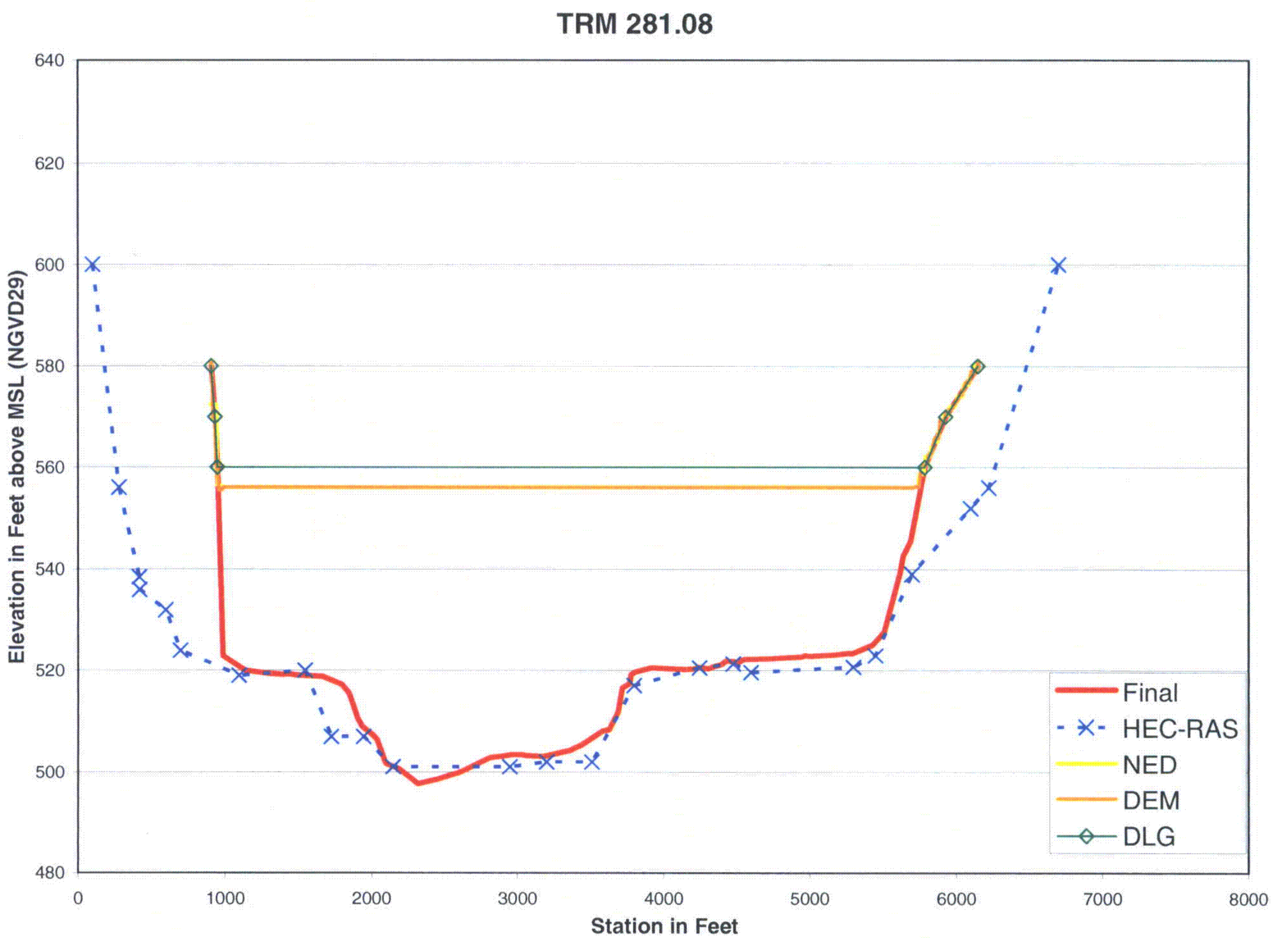


Figure 6 Comparison of Overbank Data at TRM 281.08

6.5.3.2 Checking of Cross-Sections with Adjustments for Effective Flow Area and Overflow Sections

Appendix F contains portions of USGS DRG topographic maps with each cross-section located on the map and labeled with the appropriate river mile designation. The locations of the cross-sections immediately upstream and downstream from the cross-section are also shown and are based on the ESRI geodatabase section location files provided in Electronic Attachment F-1. Where appropriate, the map has been annotated with comments to document adjustment, if any, that was made to the actual cross-section that would be obtained directly from the map to account for the effective flow area within the reach represented by that cross-section. A plot of the corresponding cross-section immediately follows the map for that cross-section in Appendix F.

The criterion used for adjustment of the cross-sections in Wheeler Reservoir was to be conservative in estimating the conveyance of the cross-section. In general, this means that the adjusted cross-section was narrowed to reduce the conveyance through that section relative to the actual section obtained from topography at the SOCH model section location, or that the bottom of the channel in the adjustment for the "red line" as discussed in Section 6.5.2 was raised to reduce the cross-section conveyance.

Overflow cross-sections are also noted in Appendix F. Overflow cross-sections are often located in areas well outside the main Tennessee River channel and will convey water only during exceptionally large floods. Some of these overflow sections are located several thousand feet from the main channel. In the original SOCH model, inclusion of the ground surface between the reservoir and the overflow area imposed serious problems with core storage on the main-frame computers of that era. Therefore, the high ground between the main Tennessee River channel (Wheeler Reservoir) and the overflow channel is excluded from the cross-section. This process gives rise to some rather peculiar-looking cross-sections as will be documented below.

Table 2 summarizes the adjustments, if any, that were made to the cross-sections for Wheeler Reservoir. Both the map and corresponding cross-section plot in Appendix F have been annotated to document and clarify the adjustments made to the cross-sections. Selected examples are discussed to assist in reviewing all of the sections that are presented in Appendix F.

Table 2 Cross-Section Adjustment Summary

	Effective Flow			
TRM	Left	Channel Bottom	Right	Overflow
349.00				
346.94		X		
344.88	X	X		
342.83	X			
340.94		X		
338.71	X		X	
336.90				
334.59	X			
332.53	X			
330.02		X		X
328.47		X	X	X
326.36	X			X
324.20	X		X	X
322.24			X	X
320.18	X			
317.83				
316.07	X		X	
314.25				
312.57				

	Effective Flow			
TRM	Left	Channel Bottom	Right	Overflow
309.44	X		X	X
307.73	X		X	
305.78		X		
303.72	X		X	
301.66	X		X	
299.60	X		X	
297.54	X			
295.62	X			
293.75				X
291.37				
289.80				
287.16				
285.19				
283.13				X
281.08				
278.60				
276.80				
274.90				

Example of Section Narrowed for Effective Flow

The map from Appendix F for the section at TRM 299.60 is shown in Figure 7. The map shows the Tennessee River in Limestone and Morgan Counties, Alabama, as it passes by large open bay areas on the North, with some smaller inlets on the South. Water flow in the bays will not provide effective conveyance during a PMF event, and so the estimated limits of effective flow were delineated on the map with a dashed green line. An alternate section cut location "Line 25A" is also shown on the map.

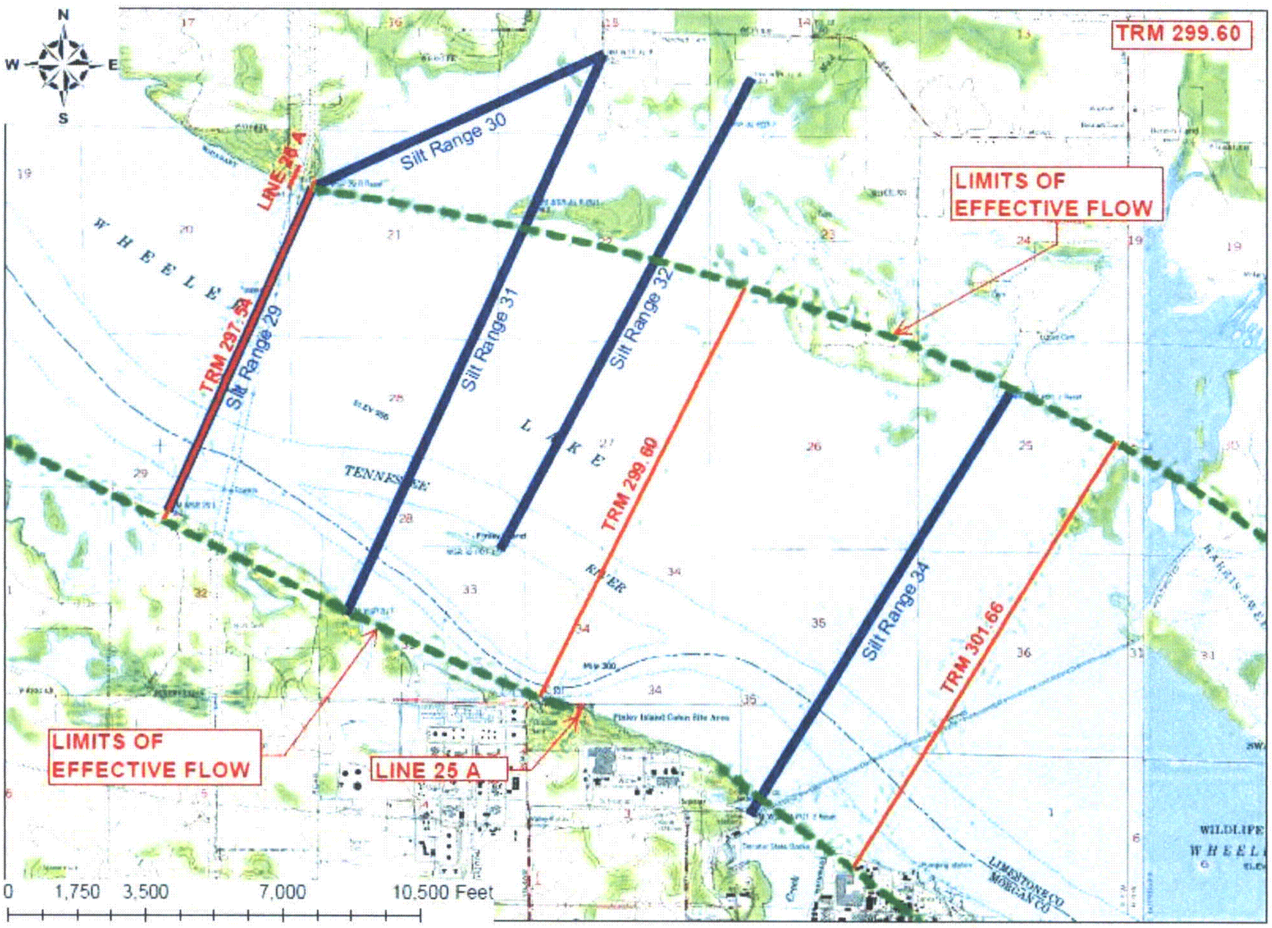


Figure 7 Map for TRM 299.60 Taken from Appendix F

The corresponding cross-section plot from Appendix F for TRM 299.60 is shown in Figure 8. Ineffective flow areas on the right and left are highlighted in gray and labeled. The final section geometry in this plot has been adjusted with a vertical cut-off at the limits of effective flow. A DEM profile extracted at Line 25A is also plotted to provide a basis for the vertical cut-off on the left of the final section.

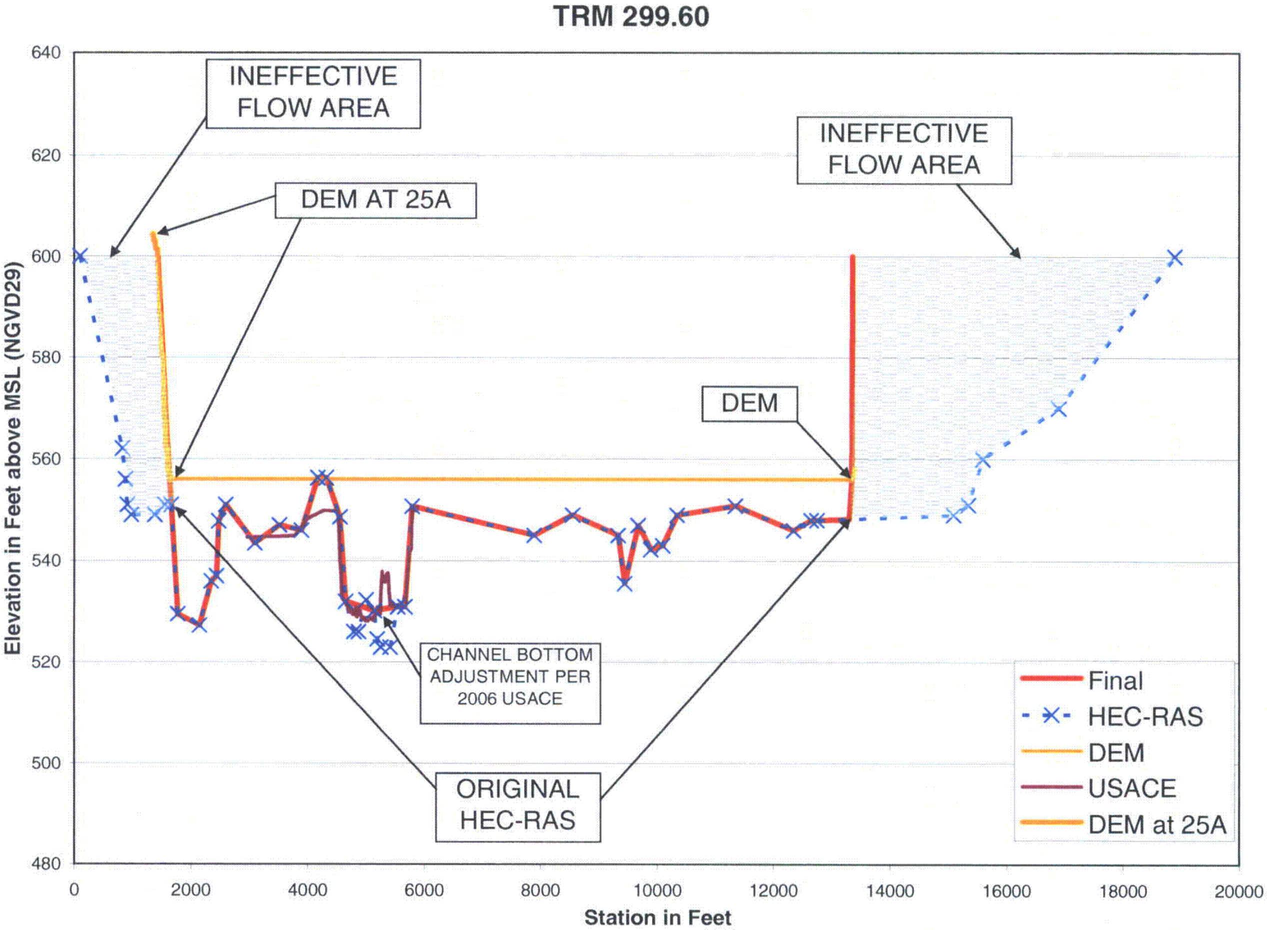


Figure 8 Effective Flow Adjustment of TRM 299.60

Example of Section Bottom Adjusted for Effective Flow

Figure 9 shows the cross-section plot for TRM 340.94 taken from Appendix F. Here, a channel bottom adjustment demonstrated in the original HEC-RAS geometry was retained after a review of the underwater topography defined by the USACE hydrographic survey data to confirm a local scour hole. The excluded area is highlighted in gray and labeled.

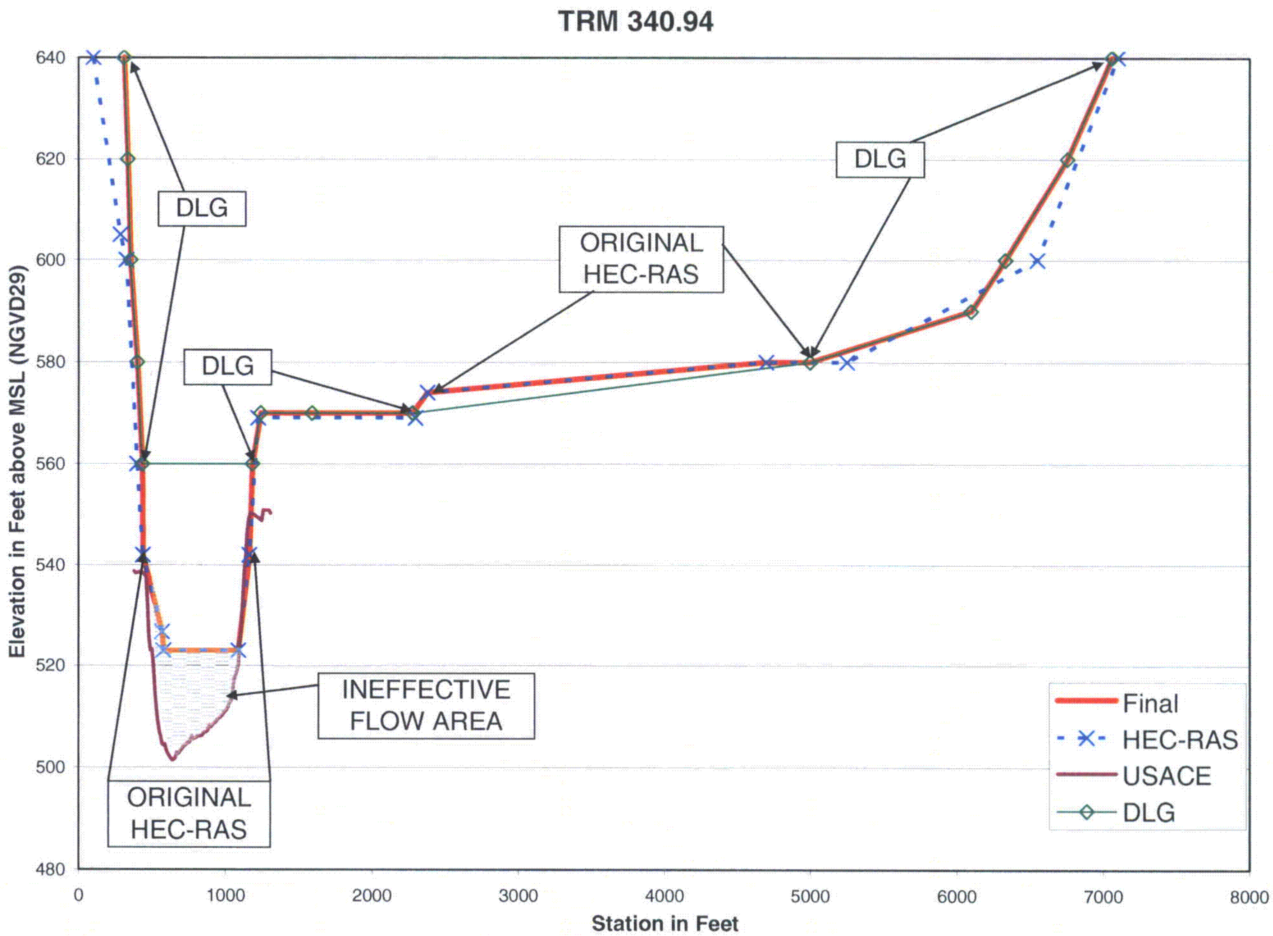


Figure 9 Channel Bottom Adjustment of TRM 340.94

Example of Overflow Addition

The map from Appendix F for the section at TRM 330.02 is shown in Figure 11. Two section lines labeled "overflow" are shown on the map. When flood levels in the Tennessee River reach elevations anticipated for the PMF event, water will flow through these overflow locations, bypassing the normal flow through the main river channel.

The original HEC-RAS overflow section at TRM 330.02 was compared to DEM profiles extracted at the overflow locations, and with a small adjustment to the bottom width as shown in Figure 10, the original overflow section was confirmed and retained. Due to topography at this location along the Tennessee River, water passing through the overflow section at TRM 330.02 will bypass the SOCH model section locations at TRM 328.47 and TRM 326.36. For this reason, the overflow sections at TRM 330.02 are repeated in the two successive downstream cross-sections.

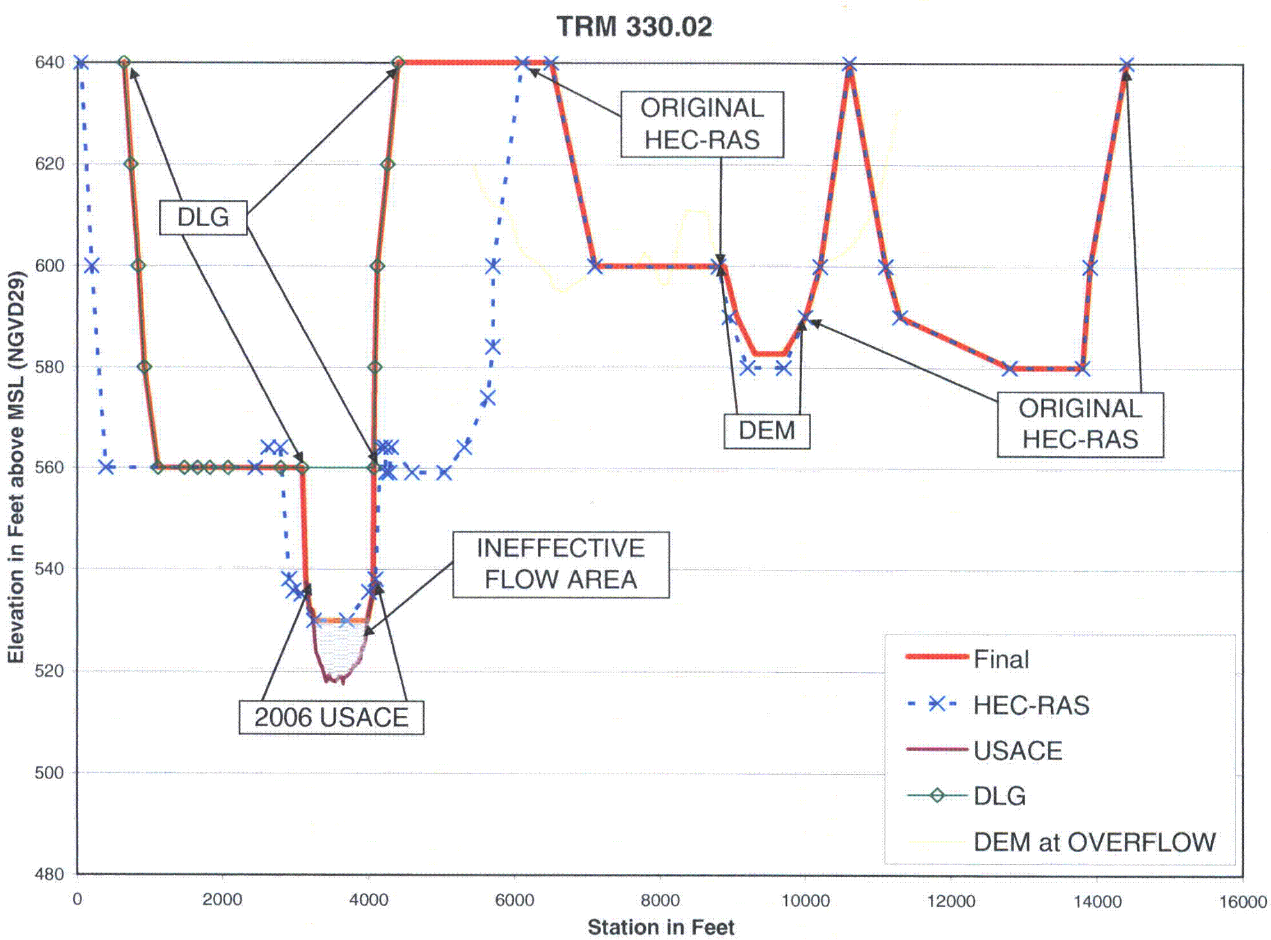


Figure 10 Overflow Addition for TRM 330.02

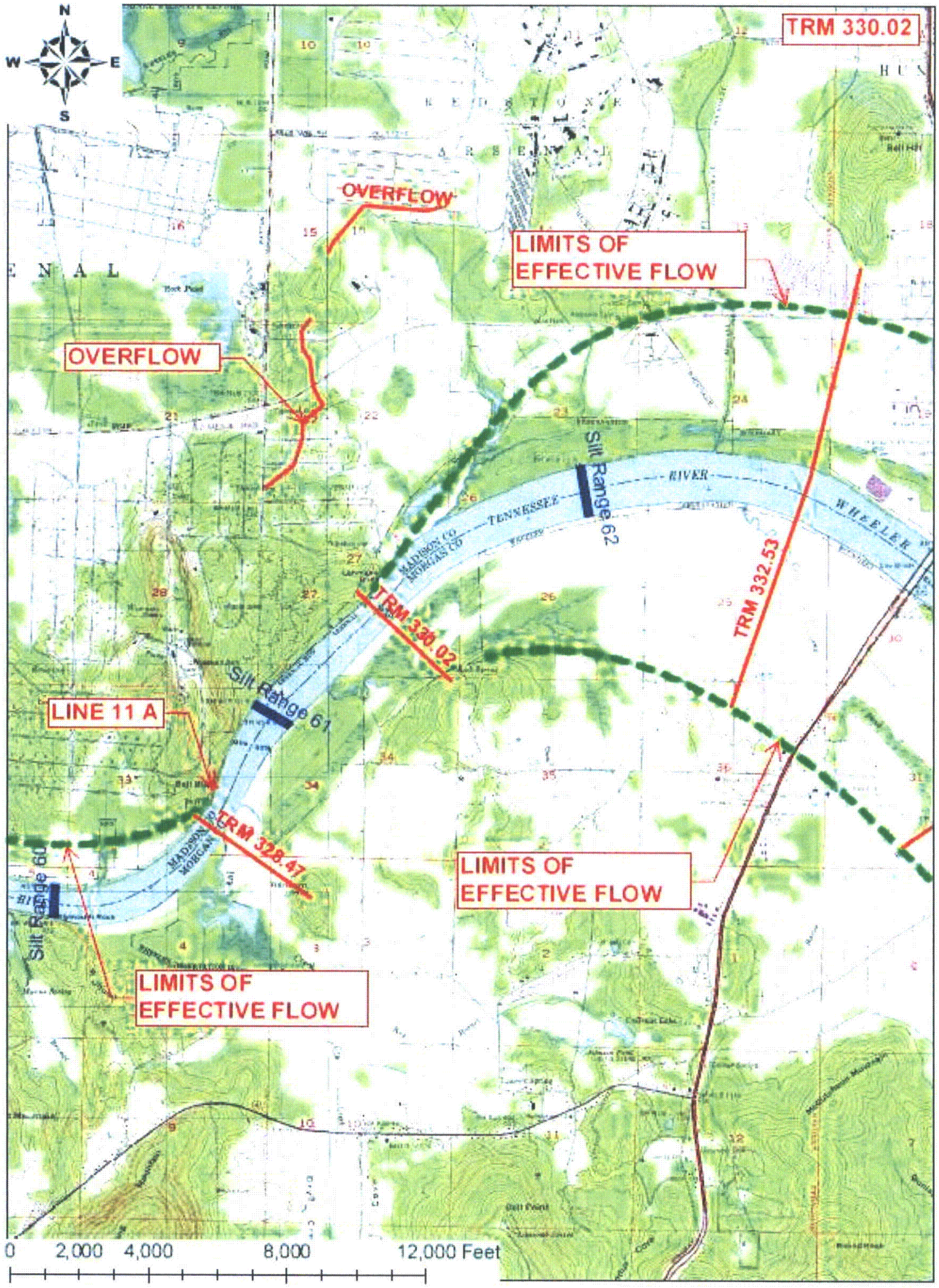


Figure 11 Map for TRM 330.02 Taken from Appendix F

6.5.4 Initial Manning's "n"

The Conveyance software program (Ref. 2.7) and HEC-RAS model requires an initial set of Manning's "n" values to begin computations. The "n" values represent the roughness coefficient for the channel bottom and over banks (left and right banks). The "n" values are an initial starting point for model calibration and will be modified, as needed, during the calibration process.

Original Manning's "n" values were extracted from the original HEC-RAS files (Ref. 2.12) for the channel and overbanks. The original channel Manning's "n" values were not adjusted, since no additional data were available to adjust the values. The original over-bank Manning's "n" values were compared to the actual surface features on the aerial photos (Ref. 2.14, Appendix G) for each section's reach length, and judged to be appropriate if original "n" value was within the acceptable range defined in Reference 2.1 for the features observed in the aerial photos. Original overbank "n" values that did not match observed features were corrected using a value from Reference 2.1 based on the observed features and engineering experience with hydraulic modeling.

The channel "n" values and over-bank "n" values were used for initial SOCH input. The combined "n" values for the initial SOCH input are tabulated in Section 7.2. The use and modification of the "n" values listed in this calculation will be documented in CDQ000020080042. Since these "n" values are simply a starting point for calibration, no additional verification of the values is required.

6.6 Weighted Width for Input to the SOCH Model

The WWIDTH software program (Ref. 2.7) is a verified and validated program (Ref. 2.8), and does not require an additional check of the program's processes. The WWIDTH program calculates the weighted width, which is a quantity that is used in the SOCH computer model to account for storage in the reach of the reservoir or river channel. See Appendix A for a detailed discussion on the WWIDTH modeling of Wheeler Reservoir.

The WWIDTH program requires surface areas as a function of elevation between successive cross-sections as input files. This information provides the program with data needed to determine storage for the reservoir which includes channel and off-channel storage areas. The surface areas in Wheeler Reservoir were calculated using ArcGIS for elevations 556, 560, 580, 590, 600, 620, and 630. A map with the areas at the given elevations is provided as Appendix I. The information was used in the WWIDTH calculation, which can be found in Appendix A.

A sample of the areas calculated by ArcGIS for the different elevations was independently calculated with MicroStation to verify the acceptability of use of non-QA industry standard ArcGIS software in a QA application. See Appendix K for a detailed explanation of the independent check. The check concluded that there was no significant difference in the calculated areas.

6.7 CONVEY for Input to the SOCH Model

The CONVEY software program (Ref. 2.7) is a verified and validated program (Ref. 2.8), and does not require an additional check of the program's processes. The program was developed to determine the cross-sectional area, A, and composite hydraulic radius to the two-thirds power, $R^{2/3}$, as a function of elevation, for each given river cross-section. See Appendix A for a detailed discussion on the CONVEY modeling of Wheeler Reservoir.

7 Results

7.1 Cross-Section Geometry

1. The original underwater part of the cross-sections developed for a 1992 FEMA flood study and used in the development of the initial SOCH model geometry input files are corroborated by TVA Silt Range plots as shown in Appendix C. The comparison of cross-sections obtained by plotting the original cross-sections over the silt range plots verifies that the data in the silt ranges are similar to the original cross-sections in both width and depth below the normal pool elevation in Wheeler Reservoir.
2. A comparison of the original cross-sections derived from TVA Silt Ranges with the Corps of Engineers Hydrographic Survey data (Appendix D) shows that the Corps of Engineers Hydrographic Survey is in excellent agreement with the TVA Silt Ranges in regions where they overlap, except for obvious locations where there is some ongoing scour or deposition in Wheeler Reservoir. The USACE Hydrographic Survey corroborates the silt ranges and the original cross-sections below the normal pool elevation.
3. A comparison of the 10-meter DEM, 1/3 arc-second NED, and 1:24K DLG data and the original cross-section data (Appendix E) verifies that the 10-meter DEM is a reliable above-water-surface data source for developing final Wheeler Reservoir cross-sections for SOCH input.
4. A review of the final cross-section geometry shows that the final cross-sections are representative of Wheeler Reservoir between Wheeler Dam and Guntersville Dam, with appropriate adjustments for effective flow, and are acceptable for use in the SOCH and HEC-RAS models for Wheeler Reservoir to account for the effective flow area in the reach of reservoir at that cross-section location. The effective flow adjustments are similar to that used to define the effective flow area in the U.S. Army Corps of Engineers computer program, HEC-RAS (Ref. 2.6). The adjusted cross-sections are therefore equivalent to the effective flow area that would be defined in HEC-RAS. The adjustment of the cross-sections as used in the SOCH model for Wheeler Reservoir to account for the effective flow area means that, in general, the cross-section geometry used in the SOCH model may not be the same as a surveyed cross-section at that location.

7.2 Initial Manning's "n" Values

Table 3 contains a list of initial Manning's "n" values to begin the modeling computations. The shaded values have been selected as described in Section 6.5.4. Other values were taken directly from the initial HEC-RAS files (Ref. 2.12), in some instances rounding to three decimal places for compatibility with SOCH software, after a review of aerial photography to verify that the values were within the acceptable range of values (Ref. 2.1) for the observed features.

Table 3 Initial Manning's "n" Values

TRM	LOB	Main Channel	Island	Side Channel	ROB	Overflow
349.00	0.120	0.020			0.080	
346.94	0.140	0.020			0.060	
344.88	0.090	0.025			0.130	
342.83	0.055	0.020			0.130	
340.94	0.140	0.024			0.055	
338.71	0.120	0.029			0.091	
336.90	0.110	0.025			0.066	
334.59	0.080	0.022	0.060	0.030	0.101	
332.53	0.085	0.029			0.115	
330.02	0.120	0.027			0.111	0.140
328.47	0.120	0.027			0.130	0.140
326.36	0.087	0.024			0.120	0.140
324.20	0.120	0.021			0.120	0.140
322.24	0.100	0.024			0.120	0.140
320.18	0.122	0.026			0.122	
317.83	0.124	0.029			0.124	
316.07	0.107	0.025			0.107	
314.25	0.100	0.028			0.100	
312.57	0.100	0.028			0.090	
309.44	0.120	0.028			0.110	0.110
307.73	0.140	0.028			0.145	
305.78	0.150	0.025			0.150	
303.72	0.136	0.023			0.120	
301.66	0.150	0.023			0.060	
299.60	0.140	0.023		~~0.035~~*	0.055	
297.54	0.120	0.022			0.070	~~0.120~~*
295.62	0.120	0.022			0.140	
293.75	0.120	0.020			0.120	0.120
291.37	0.120	0.020			0.120	
289.80	0.120	0.020			0.120	
287.16	0.120	0.020			0.120	
285.19	0.120	0.020			0.120	
283.13	0.120	0.020			0.120	0.120
281.08	0.120	0.020			0.120	
278.60	0.120	0.020			0.120	
276.80	0.120	0.020			0.120	
274.90	0.120	0.020			0.120	

* - Strikethrough indicates segments removed from the original cross-sections.

These values will be modified in calculation CDQ000020080042, as needed, during the calibration process for the Wheeler Reservoir.

7.3 Conveyance Calculations

A detailed discussion of the conveyance calculation can be found in Appendix A. The initial conveyance file (*Wheeler Merge 20090929.xls*) for SOCH input can also be found in Appendix A.

7.4 Weighted Width Calculations

A detailed discussion of the weighted width calculation can be found in Appendix A. The initial weighted width file (*Wheeler Wwidth20090929.xls*) for SOCH input can also be found in Appendix A.

7.5 Initial SOCH Model Geometry Input File

The initial SOCH model geometry input file (*Wheeler20090929.geo*) contains the channel geometry, conveyance, and weighed width information for SOCH input and is provided as an Electronic Attachment to Appendix B.

8 Conclusions

1. The cross-section and topographic data of Wheeler Reservoir are documented, acceptable and satisfactory for use in the SOCH model.
2. The geometric parameters derived from the cross-section and topographic data have been checked, verified and are correct. The geometric parameters are satisfactory for use in the SOCH model of Wheeler Reservoir.
3. The data in the HEC-RAS geometry file *Wheeler20090928.g01*, as contained in Appendix B, are satisfactory for use in SOCH analyses for Wheeler Reservoir.
4. The specified cross-section locations in Wheeler Reservoir, between Wheeler Dam and Guntersville Dam, and provided in the SOCH model geometry input file *Wheeler20090929.geo*, as contained in Appendix B, accurately represent the conveyance of Wheeler Reservoir and are acceptable for use in the SOCH model calibration of Wheeler Reservoir.

TVA

Calculation No. CDQ000020080033	Rev: 0	Plant: GEN	Page: 1
Subject: Appendix A		Prepared	JDK
		Checked	JAW

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
James Kelley	9-29-09	Adrian Ward	9/29/09

1. Purpose

The purpose of this appendix is to perform data formatting and calculation tasks to create the Simulated Open Channel Hydraulics (SOCH) geometry files from the data sets captured in the SOCH Geometry Verification for the Wheeler Reservoir (herein referred to as the parent calculation).

2. References

2.1 "Weighted Width (WWIDTH) Version 1.0, Conveyance (CONVEY) Version 1.0 User's Manual", Rev. 1 (EDMS #L58 090213 001), 2Feb09.

2.2 "Weighted Width (WWIDTH) Version 1.0, Conveyance (CONVEY) Version 1.0 Software Requirements Specification (SRS)", Rev. 1 (EDMS #L58 081219 001), 8Dec08.

2.3 "Weighted Width (WWIDTH) Version 1.0, Conveyance (CONVEY) Version 1.0 Software Verification and Validation Report (SVVR)", Rev. 1 (EDMS #L58 090210 005), 0Feb09.

2.4 "Weighted Width (WWIDTH) Version 1.0, Conveyance (CONVEY) Version 1.0 Software Design Description (SDD)", Rev. 1 (EDMS #L58 081219 005), 9Dec08.

2.5 CDQ000020080051, "Reservoir Storage Tables for TVA Reservoirs", Rev 1 (EDMS #L58 090406 004).

2.6 <u>TVA Water Control Projects and Other Major Hydro Developments in the Tennessee and Cumberland Valleys</u> (also known as 'the Blue Book'), Technical Monograph No. 55, Volumes One and Two, Tennessee Valley Authority; Wheeler Reservoir Areas and Volumes information, main TVA on-line resources document dated March 1972, scan of page 10 attached.

2.7 Electronic Attachments:

ID #	ATTACHMENT FILENAME	DESCRIPTION
WHAV.1	WH Reservoir Areas and Volumes.pdf	Scan of page 10, Reference 2.6
WHC.1	Wheeler CONVEY 20090929.xls	Wheeler Reservoir CONVEY input data preparation file
WHC.2	Wheeler CONVEY 20090929.dat	Wheeler Reservoir CONVEY input data file
WHC.3	Wheeler CONVEY 20090929.prt	Wheeler Reservoir CONVEY output printout file
WHC.4	Wheeler CONVEY 20090929.out	Wheeler Reservoir CONVEY output data file
WHW.1	WheelerWWIDTH20090929.xls	Weighted width input data preparation file
WHW.2	Wheeler 1 WWIDTH20090929.dat	Weighted width input data file 1
WHW.3	Wheeler 2 WWIDTH20090929.dat	Weighted width input data file 2
WHW.4	Wheeler 1 WWIDTH20090929.out	Weighted width output data file 1
WHW.5	Wheeler 2 WWIDTH20090929.out	Weighted width output data file 2
WHM.1	Wheeler Merge 20090929.xls	CONVEY & WWIDTH output merge, reservoir volume check, and SOCH geometry file preparation
WHG.1	Wheeler20090929.geo	Wheeler Reservoir SOCH geometry file

Please note, calculation references include page number for multi-page Excel sheets, e.g. WHM.1.4 refers to the 4th worksheet in the Wheeler Merge Excel file. Additionally, extensive notation is included as comments in the Excel sheets as an aid to understanding data flow, formatting and calculation.

3. Assumptions and Methodology

3.1 Assumptions

3.1.1 All assumptions of the parent calculation were applicable to this appendix.

3.1.2 Assumption: Volume below normal pool elevation can be reproduced within an acceptable tolerance by assuming the reservoir surface area was proportional to the surface area at normal pool elevation. Technical Justification: Surface areas at depths below normal pool were required in order to calculate the reservoir weighted widths at depth and thus apportion the pool volume between the assumed conveyance sections and at the correct elevations. Bathymetric data was only available in the navigable channel and does not extend into the off-line storage areas. Pre-reservoir topography was available, however, it was considered unreliable due to age and the effects of erosion, sedimentation and human interaction. Because this volume was already submerged at the start of a PMF storm event, variations in surface area and resulting calculated volumes would have no impact on the attenuation of the calculated peak PMF flows. Therefore, these errors have no impact on the licensing basis design elevation. However, these volumes would have an effect on dam break simulations during drain down and were checked in this calculation against the published values as described in the methodology section in order to include the most accurate data available in the resulting SOCH geometry files. The volume check included during the final data merge also compares the volume errors below normal pool to the total normal pool reservoir volume.

3.1.3 Assumption: Published volumes below the lowest observed conveyance elevation may be ignored.
Technical Justification: Volumes below the bottom of the lowest observed active conveyance elevation were flooded when the reservoir was at normal pool and would, therefore, not provide additional storage during a PMF event storm. Additionally, these volumes represent ineffective flow areas which would not drain and provide downstream flow volume during a dam failure.

3.1.4 Assumption: The Manning's *n* value input to the CONVEY code and included in the SOCH geometry file is the minimum value for each cross section in the HEC RAS model.
Technical Justification: This value was preliminary. The SOCH model uses the Manning's *n* value as the single calibration variable. The geometry file being produced by this calculation will be used in the calibration of the SOCH model as a starting value which will be adjusted as necessary to adjust the model to published storm events.

3.2 Unverified Assumptions
N/A

4. Methodology

4.1 The use of SOCH must properly account for the conveyance characteristics as derived from the area and hydraulic radius of the effective flow area as well as account for the available storage volume in the reservoir. The storage is important because the passage of a flood wave through the reservoir will fill both the effective and ineffective flow areas delineated by a reservoir cross-section and the associated storage area outside the channel.

The primary geometric inputs into the SOCH model include the hydraulic conveyance characteristics at each cross-section and the reservoir storage characteristics for each reach within the reservoir. The conveyance was a measure of the carrying capacity of the channel and was directly proportional to the discharge in the river channel.

In this calculation, the word "CONVEY" refers to a CONVEY computer code which computes the conveyance parameters required for input into the SOCH model. The word "conveyance" used in this calculation refers to the conveyance characteristics of a cross-section such as hydraulic radius and cross-sectional area.

The CONVEY code was developed to determine the cross-sectional area and composite hydraulic radius as a function of water surface elevation at each cross-section. Starting at the channel bottom, elevations were taken at intervals. To verify that the data from the HEC-RAS geometry has been correctly transferred to SOCH from the CONVEY program, the HEC-RAS geometry files were checked against the output from CONVEY. In the V&V documentation Reference 2.3 (Section 6.6.2 and 6.6.3) additional confirmation is provided that the results determined with the CONVEY program were consistent with those determined in HEC-RAS for the same conveyance parameters.

In CONVEY each river cross-section was divided into segments according to transverse variations in Manning's "n" values across the cross-section. The CONVEY input file includes all Manning's "n" values as presented in the HEC-RAS data file from the parent calculation, and the CONVEY code calculates the conveyance parameters based on all input values. Because the SOCH input only allows a single Manning's "n" value, the Manning's "n" shown in the SOCH input was the minimum value for that section used in the CONVEY calculation, and therefore, was not a composite calculated from "n" values assigned to the separate segments of the cross-section. The final values would be determined during the SOCH model calibration which would use historical flow conditions to develop the final Manning's "n" values for each river reach. Other CONVEY output values used as input into SOCH were the total cross-sectional area and composite hydraulic radius raised to the 2/3 power.

When the original SOCH model was formulated, it was recognized that each computational node (reservoir cross-section) requires a table of conveyance characteristics defining the effective flow area for the reach, as discussed above, as well as a table of width versus elevation data that defines the volume of storage in the reach represented by that cross-section. This leads to the concept of the weighted width (see References 2.1 through 2.4).

The weighted width was computed such that the surface area in the reach at a given elevation was equal to the weighted width multiplied by the distance between successive cross-sections. If the surface area as a function of elevation was integrated from the reservoir bottom to the given water surface elevation, then this integration gives the volume of storage in the reach at that water surface elevation. If all reaches in the reservoir were summed up, the result was the volume of storage in the reservoir at the given elevation. SOCH therefore requires a table of weighted width versus elevation at each cross-section to account for storage effects on the routing of floods through the Reservoir.

In general, the weighted width at a particular cross-section would **not** be the top width of the cross-section as defined for the effective flow area. This was particularly true where large storage volumes exist away from the main channel. In short, the cross-section used in SOCH to define the conveyance characteristics generally should not be used to define the weighted width because a cross-section that defines only the effective flow area typically does not define the overall reach storage.

4.2 Data flow and calculation tasks are shown in flow charts at the end of each section. SOCH geometry files consist of a combination of conveyance (active flow area and hydraulic radius raised to the two thirds power) and storage data (weighted width) as described above and in References 2.1 through 2.4. Calculations were performed using CONVEY v1.0 and WWIDTH v1.0 computer codes and Microsoft Excel 2003. Microsoft Excel 2003 was used as the primary tool to reformat and combine output data from the different sources. Methodology for preparing the CONVEY and WWIDTH input files and the combination of the output into the SOCH geometry file are discussed separately below. Please note, calculation references include page number for multi-page Excel sheets, e.g. WHM.1.4 refers to the 4th worksheet in the Wheeler Merge Excel file. Additionally, extensive notation was included as comments in the Excel sheets as an aid to understanding data flow, formatting and calculation.

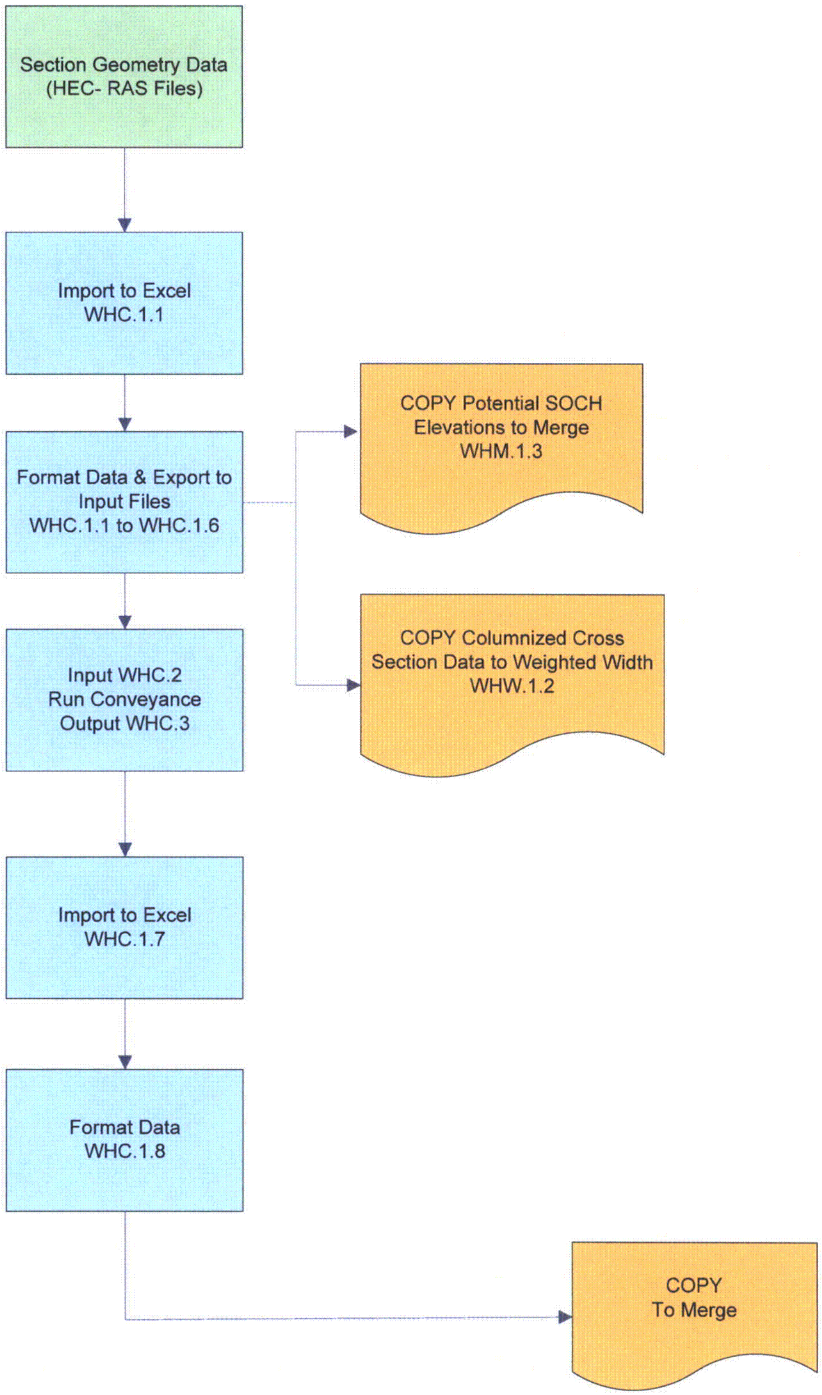
4.3 CONVEY Input File Preparation

4.3.1 Preparation of the CONVEY input data started with importing the channel geometry information from HEC-RAS (Appendix B, parent calculation) as text into Microsoft Excel 2003 (WHC.1.1). Imported data was put into HEC-2 and columnized cross section formats on their respectively named sheets (WHC.1.2- WHC.1.3) using Excel Visual Basic macros developed specifically for that purpose. No calculations were performed in these macros. The formatted columnized cross section data (WHC.1.3) was used in the development of both the CONVEY and WWDITH input data files.

4.3.2 Columnized cross section data was extracted and formatted for use in CONVEY input files using Excel Visual Basic 'Build Dataset' macro developed specifically for this purpose (WHC.1.6). No calculations were performed in this macro. This Excel sheet (WHC.1.6) was then saved as a space delimited text file (*.prn). The file extension was manually changed to .dat and the file was used as input for the CONVEY code.

4.3.3 CONVEY output data was copied into Excel (WHC.1.7) and reformatted to prepare for the data merge using a macro developed specifically for this purpose. No calculations were performed in this macro. However, the CONVEY output (WHC.1.7) does not contain any Manning's "n" values. The macro pulls the minimum value for each section from the columnized cross section data for inclusion in the final output data set (WHC.1.8). See section 4.1 for a further discussion of the Manning's "n" values.

Figure 4.3 Convey Input Data Preparation

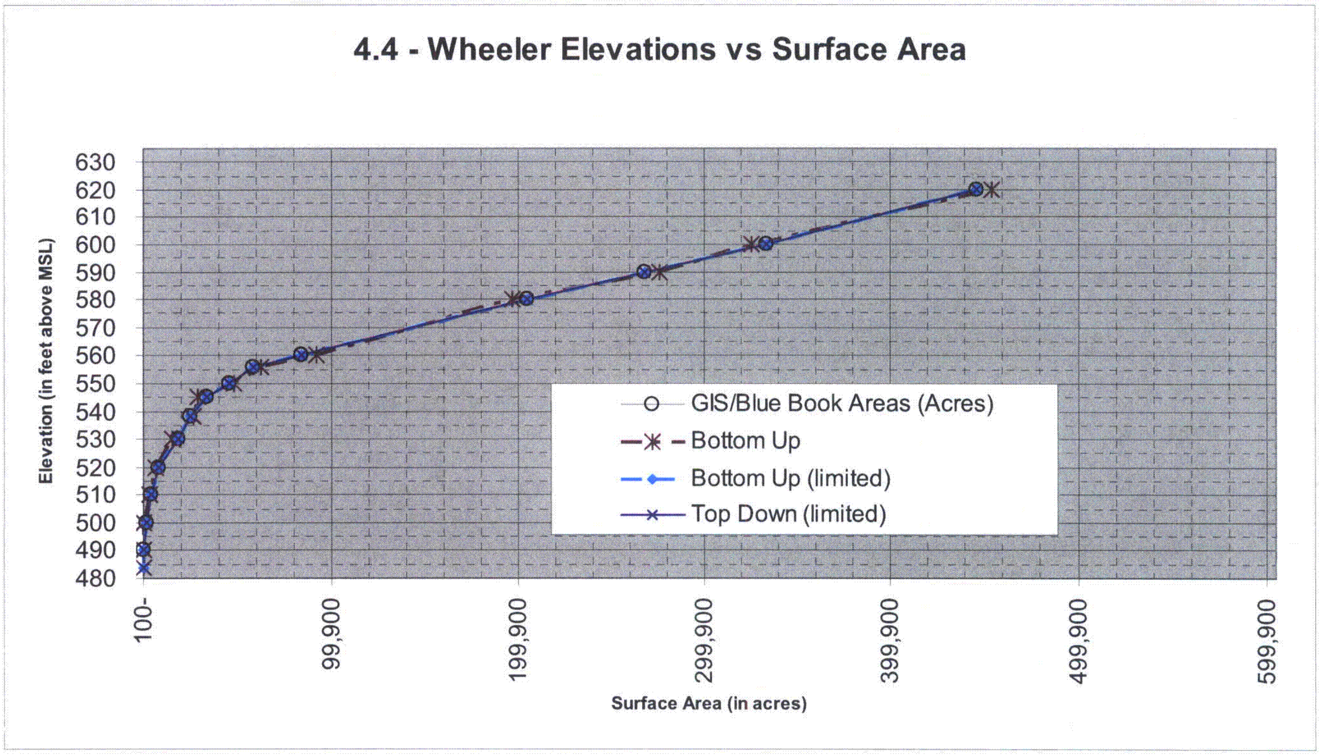


4.4 WWIDTH Input File Preparation

4.4.1 Surface area geometric data above the normal pool elevation was taken from the areas prepared as described in the parent calculation body and provided in Attachment I-2 of that calculation. This data was input into the Excel weighted width workbook (WHW.1.1).

4.4.2 Volumes were determined based on trapezoidal 'slices' at assumed river miles based on the WWIDTH approach as described in Reference 2.1. The slice volume was determined based on the average of the top and bottom areas multiplied by an assumed depth increment. The trapezoid top and bottom areas were determined as follows for the reservoir reaches. No sloping tributary reaches were observed. Areas above normal pool elevations were determined as described in the parent calculation and presented in Attachment I -2. For surface areas below normal pool, areas published in Reference 2.6 were used. This data was input to the Excel spreadsheet (WHW.1.3) and no adjustments to these areas were assumed.

4.4.3 Two methods were checked for suitability in calculating the reservoir areas below normal pool. The final weighted width at the published zero volume elevation was calculated from the adjacent calculated values (see section 7.2 and WHW.1.3). The published volume-at-elevation values do not exactly match the observed conveyance sections. Review of the cross section geometry shows an irregular shape that varies between sections. An equivalent weighted width for this shape would be extremely difficult to calculate and would incorrectly assume a uniform irregular shape between sections and not provide a better overall volume match. This assumption effectively results in a trapezoidal cross section for the lowest slice. The assumed trapezoidal section simplified the calculations and produced variations in the bottom of the storage which were large incrementally, but less than 5% when compared to the normal pool volume. These variations were, therefore, considered to be negligible. The first method checked was the bottom up method (see Eqn. 7.4.1). This method used the published zero volume elevation to calculate the top area of the first slice effectively generating a trapezoidal first slice cross section. The second method used the measured GIS surface areas to calculate the bottom area of the next slice (see Eqn. 7.4.2). A table of the results is shown in section 8.1 and the following figure shows a comparison of these methods.



The functional relationship was approximately geometric, generating oscillations due to the geometric expansion of errors. These errors were expected due to the limited number of published elevation increments, the irregular submerged surface, and the assumed trapezoidal bottom slice section shape. The smoothest fit resulted when the bottom up method was limited by preferentially using published values and measured GIS surface areas and published values from Reference 2.6 where available. This limited bottom up approach was used in the calculation of the surface areas to distribute the published incremental volumes at presumed elevations.

4.4.4 The distribution of the areas below normal pool was calculated based on the assumption that these areas were proportional to the observed normal pool surface area (see section 3.1.2). Two weighting factors were used in the calculation of these areas (see WHW.1.4).

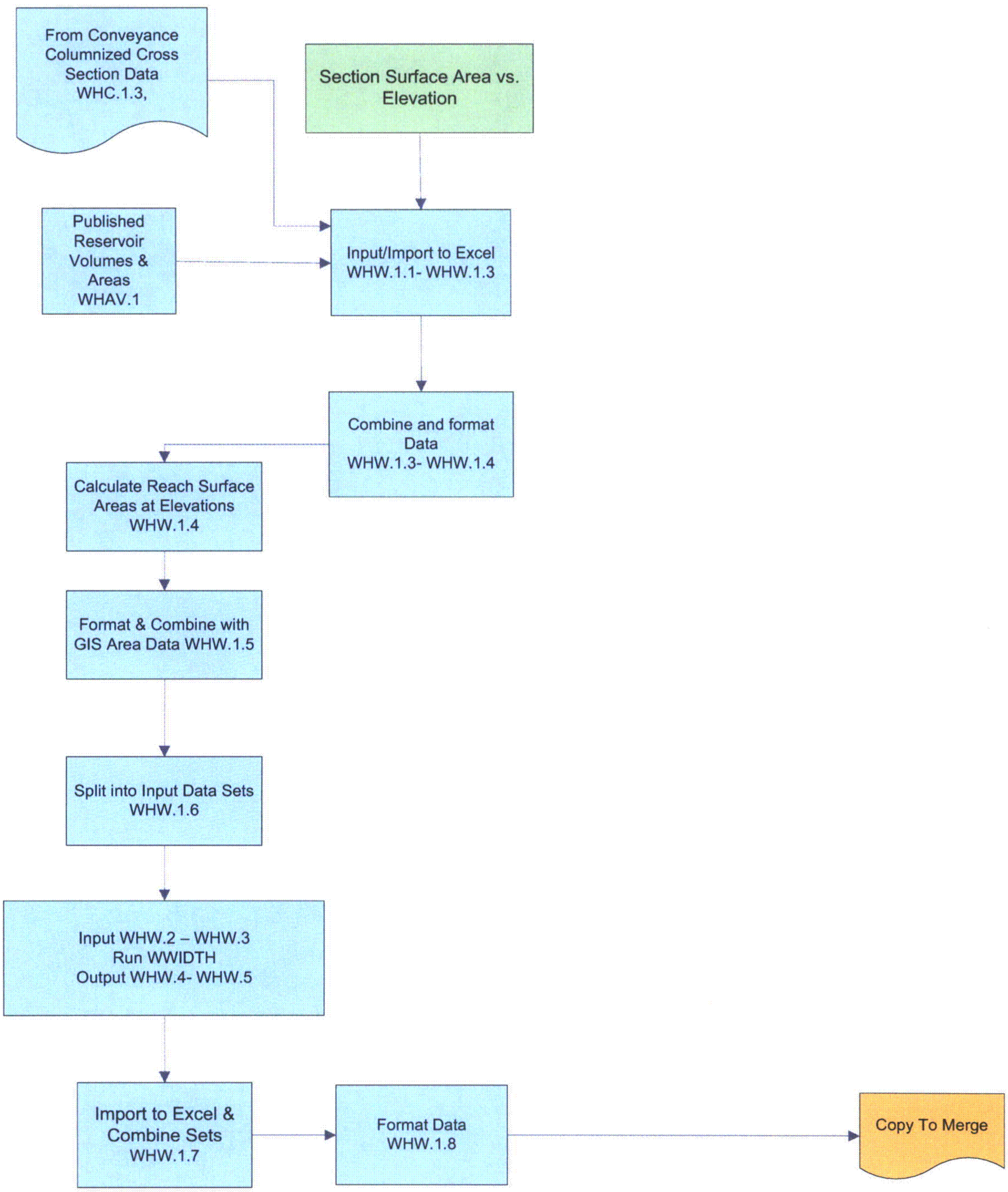
4.4.4.1 The first weighting factor was referred to in the Excel spreadsheet as a slope adjustment. This factor reduces the GIS surface area based on the amount of the assumed slice present in the observed section geometry at the first slice where the section contributes storage. If the assumed depth increment was not contained within the observed section elevations (i.e. the depth increment was 685 to 690 and the section minimum/maximum was 691/760), the section was calculated to contribute 0% to that slice. If the assumed depth increment was partially contained within the observed section elevations (i.e. the depth increment was 690 to 695 and the section minimum/maximum was 693/760), the section was calculated to contribute the appropriate percentage based on elevation. In the cited example (the depth increment was 690 to 695 and the section minimum/maximum was 693/760), the percentage would be 60% (3' of contributing depth in a 5' increment). If the assumed depth increment was fully contained within the observed section elevations (i.e. the depth increment was 695 to 700 and the section minimum/maximum was 693/760), the section was calculated to contribute 100%. This weighting factor was multiplied by the GIS surface area for the reservoir at normal pool to generate the adjusted GIS surface area.

4.4.4.2 The second weighting factor was referred to in the Excel spreadsheet as surface area percent. This factor calculates the surface area for that reach at that elevation as a percent of the total surface areas contributing to that elevation slice. This factor was applied to the adjusted surface area calculated as described in section 4.4.4.1 to distribute the area between reaches. The final distributed surface area was referred to as increment area in the spreadsheet.

4.4.5 The distributed submerged surface areas and measured GIS areas were then reformatted to simplify creation of the WWIDTH input data sets (see WHW.1.5). Data sets were split to generate the maximum number of calculated weighted width values and minimize the number of zero values. Input data sets were overlapped to prevent boundary section influence. The datasets were manually exported to the correct format in the next Excel sheet (WHW.1.6) which was then saved as a space delimited text file (*.prn). The file extension was manually changed to .dat and the file was used as input for the WWIDTH code (WHW.2 - WHW.3).

4.4.6 WWIDTH output data (WHW.4 - WHW.5) was then copied back into Excel (WHW.1.7) and reformatted (WHW.1.8) for use in the merge spreadsheet using Excel Visual Basic 'Format_Wwidth' macro developed specifically for this purpose. WWIDTH data from the reservoir was combined at this point by pasting the data into the Excel sheet in river mile order. No calculations were performed in this macro. The following flow chart outlines the data flow and calculations.

4.4 Weighted Width Input Data Preparation



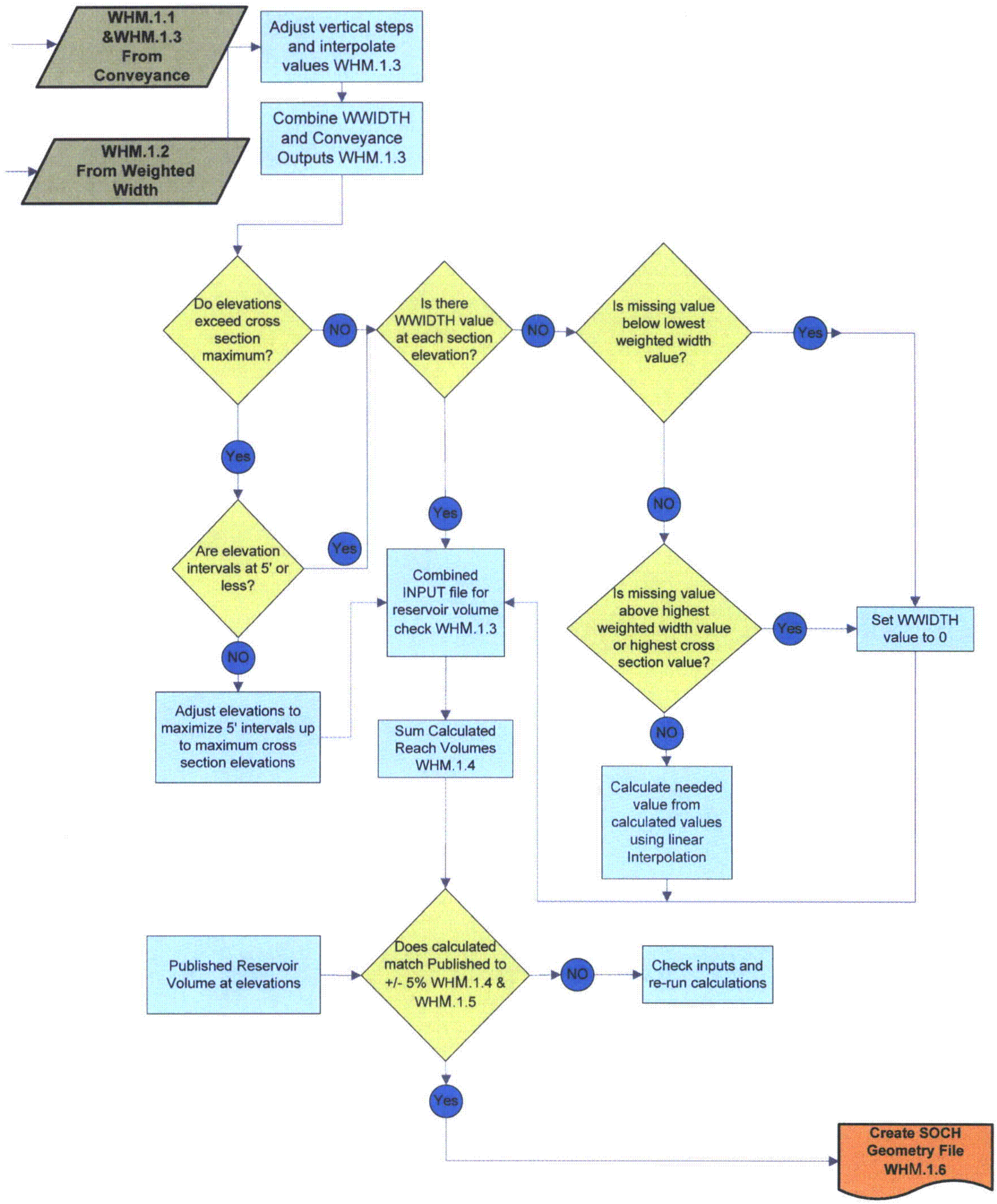
4.5 Merging WWIDTH and CONVEY Output and SOCH Geometry File Preparation

4.5.1 Formatted WWIDTH and CONVEY output data (WHC.1.8 and WHW.1.8) was copied into the Excel merge spreadsheet (WHM.1.1 and WHM.1.2) from the WWIDTH and CONVEY output files. Additionally, the potential SOCH geometry elevations calculated in the CONVEY input spreadsheet (WHC.1.4) were copied to the Excel merge spreadsheet (WHM.1.3) to simplify the merge.

4.5.2 Weighted width and conveyance data was merged with conveyance data kept intact. Weighted width data was interpolated where there was not a calculated value for that elevation increment (see section 7.2). Geometry elevations were calculated to the greater of either the maximum cross section elevation or the maximum surface area elevation. This provided some sections with weighted widths above the maximum cross section elevation. These weighted width values allow vertical extension of cross section elevations during calibration of the model without recalculation of the weighted width.

4.5.3 This data was pulled into the correct format for the SOCH geometry file and into an additional sheet for the volume check. In the volume check, values were put onto the same number of five foot increments to simplify the calculations. Trapezoidal volumes were then calculated, accumulated and compared to the published volumes. A graph of the results is included in section 8. The comparison of calculated volumes to the published cumulative volumes above normal pool was considered acceptable if within plus or minus 5%. Due to the irregular topography and the limited accuracy of the available contour interval, the maximum expected variation in elevation at any point for 20' contours was ±10'. Using the incremental volume of 2,883,000 acre-feet for the 20' interval from elevation 560-580 as an indicator of the expected volume variation compared to the maximum pool volume of 1,050,000 acre-feet at elevation 556 gave a volume variance due to the contour interval of 2,883,000 acre-feet or ±13.04% when compared to the total reservoir volume of 22,095,000 acre-feet at elevation 630. The observed variance of <5% for the volume check was considered to be negligible compared to this value.

Figure 4.5 - DATA MERGE



5. Design Input

5.1	Published Reservoir Volumes above normal pool	Reference 2.5
5.2	Published Reservoir Areas and Volumes	Reference 2.6 (table attached)
5.3	GIS areas for defined reaches	Attachment I-2 (parent calc)

6. Special Requirements/Limiting Conditions

N/A

7. Calculations

7.1 The CONVEY and WWIDTH codes meet the requirements of the 10 CFR 50 Appendix B program (see References 2.1 through 2.4 inclusive. These programs were the primary software used to calculate the weighted width and conveyance values used for the SOCH geometry file.

7.2 Since the CONVEY and WWIDTH codes were determinate in their input and output data intervals, linear interpolation of numerous values were performed to generate needed values at specific elevations. These calculations were performed using the following equation:

$$\text{Value}_i = \text{Value}_2 - \frac{\text{Elevation}_2 - \text{Elevation}_i}{\text{Elevation}_2 - \text{Elevation}_1} \cdot \left(\text{Value}_2 - \text{Value}_1\right) \qquad \textbf{Eqn. 7.2}$$

Where:

Elevation._1 = elevation at calculated value — Value._1 = calculated value at Elevation_1

Elevation._2 = elevation at calculated value — Value._2 = calculated value at Elevation_2

Elevation._i = elevation at desired value — Value._i = desired value at Elevation_i

Note: - elevation and value units must be consistent (i.e. all elevations in feet and all values in square feet)

7.3 Volume adjustments were calculated to remove ineffective volumes below the published volume using the following equation:

$$Vol_{adjusted} = Vol_{published} - Vol_{below}$$ **Eqn. 7.3**

Where:

$Vol_{published}$ = published volume from Reference 2.6

Vol_{below} = published volume from Reference 2.6 below observed conveyance

Note: - units must be consistent (i.e. all volumes in acre-feet)

7.4 Volumes were determined based on trapezoidal slices based on the WWIDTH approach as described in Reference 2.3. Each slice has a defined top and bottom elevation, with trapezoidal end areas. Since there was a published zero volume bottom elevation and a measured GIS normal pool elevation, the equation may be solved two different ways as follows:

$$V = D \cdot \left(\frac{A_{S2} + A_{S1}}{2} \right)$$ **Eqn. 7.4**

Where:
V = slice volume (in acre-feet)
D = slice depth (in feet)
A_{S2} = top area of slice (in acres)
A_{S1} = bottom area of slice (in acres)

this equation may be rearranged to calculate the slice areas from the top down or bottom up assuming either the top area or bottom area as correct:

$$A_{S2} = \frac{2 \cdot V}{D} - A_{S1}$$ Bottom up method - **Eqn. 7.4.1**

$$A_{S1} = \frac{2 \cdot V}{D} - A_{S2}$$ Top down method - **Eqn. 7.4.2**

Both methods were performed and graphed in the WWIDTH Excel spreadsheet. Results are presented in section 8.1.

7.5 An end area variation of equation 7.4 was used in the final reservoir volume check.

$$V = D\cdot\left(\frac{WW_{USU} + WW_{USL} + WW_{DSU} + WW_{DSL}}{4}\right)\cdot\left(RM_{US} - RM_{DS}\right)\cdot K \qquad \textbf{Eqn. 7.5}$$

Where:

V = slice volume (in acre-feet)
D = slice depth (in feet)
WW_{USU} = upstream section upper trapezoid weighted width (in feet)
WW_{USL} = upstream section lower trapezoid weighted width (in feet)
WW_{DSU} = downstream section upper trapezoid weighted width (in feet)
WW_{DSL} = downstream section lower trapezoid weighted width (in feet)
RM_{US} = upstream river mile (in miles)
RM_{DS} = donwstream river mile (in miles)
K = conversion factor
for the listed units, $K = \frac{1\cdot acre}{43560\cdot feet^2}\cdot\frac{5280\cdot feet}{1\cdot mile}$

7.6 The error between the calculated and published volumes was calculated as follows.

$$V_{error} = \frac{V_{calculated}}{V_{published}} - 1 \qquad \textbf{Eqn. 7.6}$$

where:

V_{error} = volume error (shown in percent)
$V_{calculated}$ = calculated cumulative volume using Eqn. 7.4
$V_{published}$ = cumulative volume from Reference 2.6

The results of this equation gave negative values when volumes were underestimated and positive values when volumes were overestimated.

7.7 The potential SOCH elevations sheet in the CONVEY input data preparation spreadsheet took the columnized cross section data, determined the potential elevation data step size and formatted it for the CONVEY input data file. These elevation data steps were also copied into the merge file for use in merging the CONVEY and WWIDTH output data. Excel was used primarily to lookup and format the data. However, calculations for the elevation parameters to use in determining the desired WWIDTH output elevations and the data merge include the following Excel functions.

7.7.1 To find the maximum elevation for the section, the Excel MAX function was used along with an OFFSET function to sort through the columnized cross section data for that cross section. For section 1 (TRM 349.00) the function returned a maximum 640 elevation.

7.7.2 The maximum and minimum elevations were then used to calculate a raw elevation increment based on the SOCH 21 slice standard as follows:

$$Raw = \frac{Max_{\_El} - Min_{\_El}}{20}$$ **Eqn. 7.7.2**

where:

Raw = raw elevation increment
$Max_{\_El}$ = maximum section elevation (in feet)
$Min_{\_El}$ = minimum section elevation (in feet)

7.7.3 The incremental second elevation was then calculated using the Excel MOD function as follows:

$$MOD(Min_{\_El}, Incr_{\_El}) = Min_{\_El} - Incr_{\_El} \cdot INT\left(\frac{Min_{\_El}}{Incr_{\_El}}\right)$$ **Eqn. 7.7.3**

where:

MOD( ) = Excel MOD function
$Min_{\_El}$ = minimum section elevation (in feet)
$Incr_{\_El}$ = incremental elevation (in feet)
INT( ) = Excel INT function - rounds result down to nearest integer value

Example:

$$MOD(818.7, 5) = 818.7 - 5 \cdot INT\left(\frac{818.7}{5}\right) = 818.7 - 5 \cdot 163 = 3.7$$

This was used as input for calculating the incremental second elevation as follows:

$$Elev_{2nd} = Min_{\_El} + Incr_{\_El} - MOD(Min_{\_El}, Incr_{\_El})$$ **Eqn. 7.7.4**

where:

MOD( ) = Excel MOD function (see Eqn. 7.7.3 above)
$Min_{\_El}$ = minimum section elevation (in feet)
$Incr_{\_El}$ = incremental elevation (in feet)

Example:

$$Elev_{2nd} = 818.7 + 5 - 3.7 = 820$$

8. Results/Conclusions

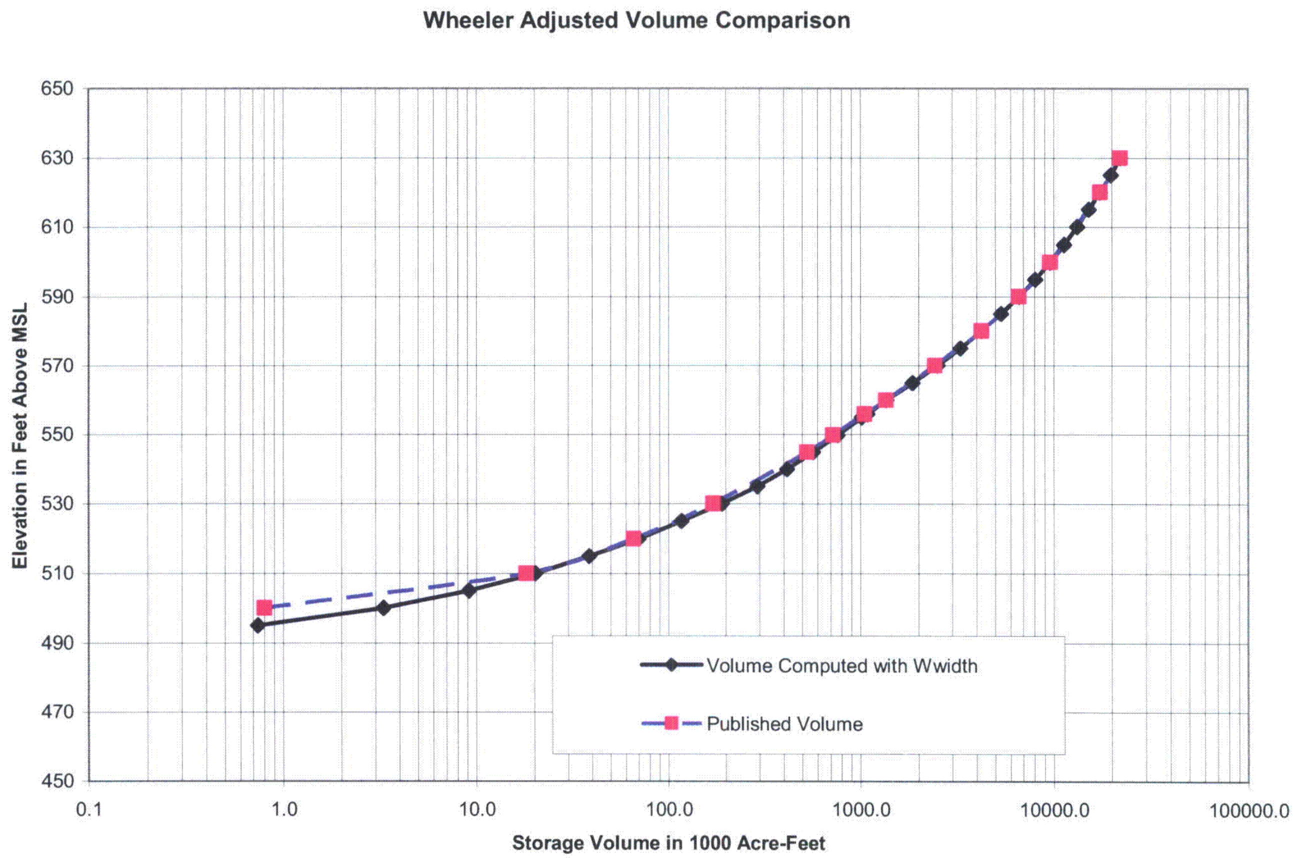
8.1 The areas used in the weighted width calculation were derived using either equation 7.4.1 or 7.4.2 in the attached WWIDTH Excel spreadsheet (WHW.1.3). The surface areas at presumed elevations calculated from the available published reservoir volumes are shown in the following table (see WHW.1.3):

Elevation	Published Cumulative Volume (DSF*1000)	Published Cumulative Volumes (ac-ft*1000)	Incremental Volume (1000*ac-ft)	GIS/Blue Book Areas (Acres)	Bottom Up	Bottom Up (limited)	Top Down	Top Down (limited)
483.8	-	-	-		0	0	0	0
490.0	-	-	-	138	0	138	112,398	138
500.0	0.40	0.8	0.80	1,220	160	1,220	-112,398	1,220
510.0	9.13	18.1	17.30	3,680	3,300	3,680	112,558	3,680
520.0	33	65.6	47.50	8,080	6,200	8,080	-109,098	8,080
530.0	86	171	105.40	18,600	14,880	18,600	118,598	18,600
538.0	169	335	164.00	24,870	26,120	24,870	-97,518	24,870
545.0	266	528	193.00	33,090	29,023	33,090	138,518	33,090
550.0	363	720	191.99	45,450	47,773	45,450	-83,376	45,450
556.0	529	1,050	329.99	58,001	62,225	58,001	160,171	58,001
560.0	685	1,358	308.00	84,169	91,772	84,169	-50,173	84,169
580.0	2,138	4,241	2,883.02	204,171	196,530	204,171	204,171	204,171
590.0	3,328	6,601	2,360.00	267,777	275,470	267,777	267,777	267,777
600.0	4,843	9,606	3,005.00	333,322	325,530	333,322	333,322	333,322
620.0	8,772	17,399	7,793.00	445,947	453,770	445,947	445,947	445,947
630.0	11,140	22,095	4,696.00	493,325	485,430	493,325	493,325	493,325

The oscillations can be seen in both the top down and bottom up methods with the bottom up being more stable particularly when limited to using the measured GIS surface areas where available.

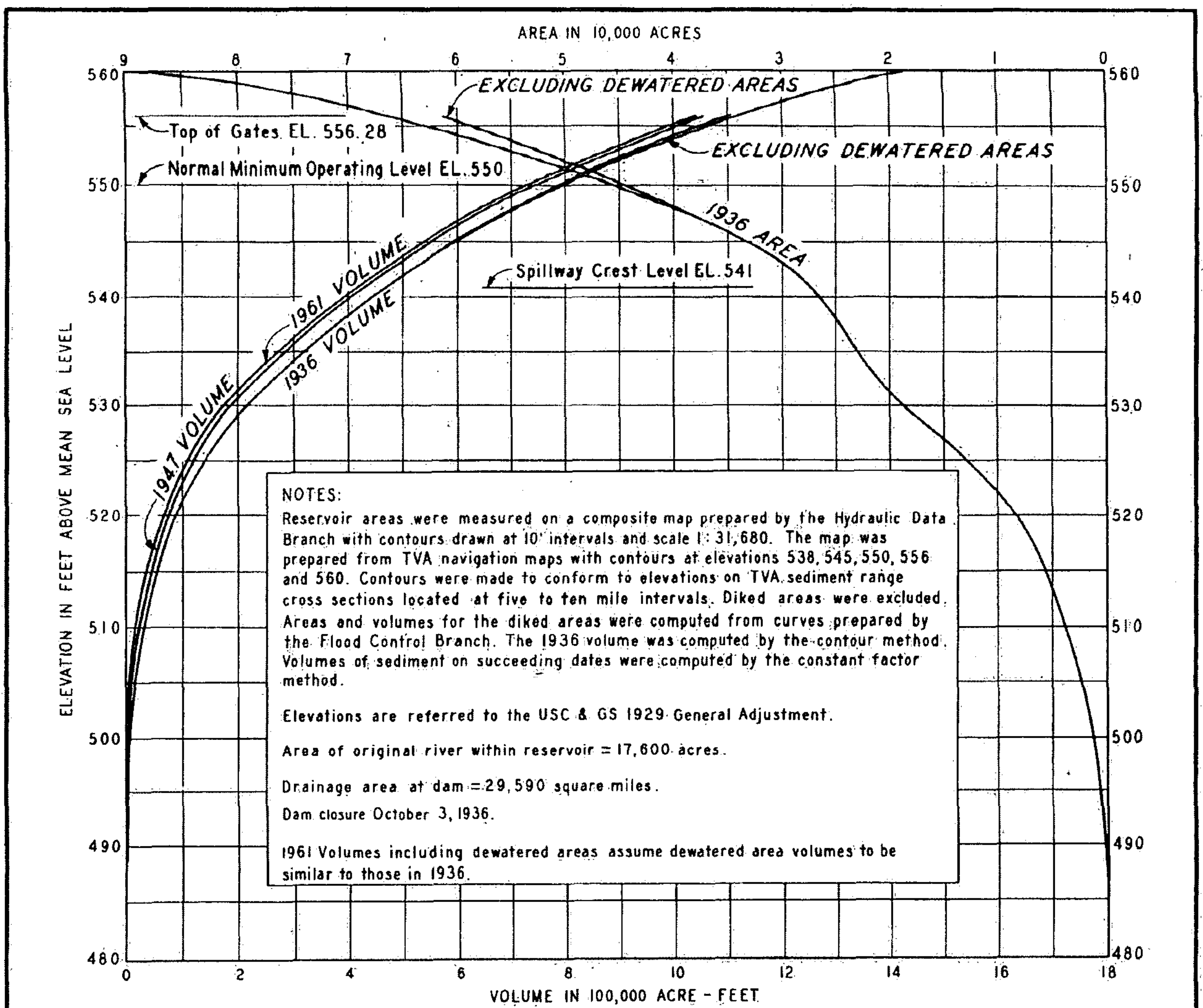
8.2 The final reservoir volume check calculation results are shown in the following table and graph (see files WHM.1.4 and WHM.1.5).

Elevation (in feet >MSL)	Incremental Volume (in 1000 acre-ft)	Cumulative Volume Computed with Wwidth (in 1000 acre-ft)	Published Volume (in 1000 acre-ft)	Computed vs. Published Volumes	Percent Error compared to Normal Pool
490	0.0	0.0		0.00%	0.00%
495	0.7	0.7			
500	2.6	3.3	0.8	311.72%	0.24%
505	5.9	9.2			
510	11.0	20.2	18.1	11.61%	0.20%
515	18.3	38.5			
520	31.4	69.9	65.6	6.59%	0.41%
525	47.3	117			
530	72.8	190	171	11.17%	1.82%
535	102	292			
540	124	416			
545	151	567	528	7.35%	3.69%
550	196	763	720	5.99%	4.11%
555	254	1017			
556		1087	1050	3.50%	3.50%
560	350	1367	1358	0.67%	
565	496	1863			
570	646	2509	2437	2.95%	
575	796	3305			
580	946	4251	4241	0.22%	
585	946	5351			
590	1100	6610	6601	0.14%	
595	1259	8031			
600	1421	9616	9606	0.10%	
605	1585	11353			
610	1737	13231			
615	1878	15249			
620	2019	17408	17399	0.05%	
625	2159	19697			
630	2289	22105	22095	0.04%	



It can be seen that while the errors at each section when comparing the calculated volume relative to the published increment were large, when compared against the normal pool volume the errors were less than 5% and were considered acceptable. Also, because the volume error at normal pool was less than the errors lower (vertically) in the reservoir, this approach has effectively moved incremental volumes up in elevation. This resulted in greater peak flows during dam break modeling and was considered a conservative approach. The volume error for the normal pool volume when compared against an average end area approach using the GIS data was 3.50% and met the assumed acceptance criteria (see section 4.5.3).

8.3 The resulting Wheeler SOCH geometry file was formatted in the Excel spreadsheet (WHM.1.6) and saved as a space delimited text file (*.prn). The file extension was manually changed to .geo (WHG.1) to be used as input for the SOCH code. The attached geometry file is suitable for use in calibration of the models for both the licensing basis design elevation models and the dam break models.



NOTES:

Reservoir areas were measured on a composite map prepared by the Hydraulic Data Branch with contours drawn at 10' intervals and scale 1 : 31,680. The map was prepared from TVA navigation maps with contours at elevations 538, 545, 550, 556 and 560. Contours were made to conform to elevations on TVA sediment range cross sections located at five to ten mile intervals. Diked areas were excluded. Areas and volumes for the diked areas were computed from curves prepared by the Flood Control Branch. The 1936 volume was computed by the contour method. Volumes of sediment on succeeding dates were computed by the constant factor method.

Elevations are referred to the USC & GS 1929 General Adjustment.

Area of original river within reservoir = 17,600 acres.

Drainage area at dam = 29,590 square miles.

Dam closure October 3, 1936.

1961 Volumes including dewatered areas assume dewatered area volumes to be similar to those in 1936.

ELEV FT	INCLUDING DEWATERED AREAS			EXCLUDING DEWATERED AREAS					
	1936		1961	1936		1947	1953	1956	1961
	AREA AC	VOLUME AC-FT	VOLUME AC-FT	AREA AC	VOLUME AC-FT	VOLUME AC-FT	VOLUME AC-FT	VOLUME AC-FT	VOLUME AC-FT
560	89,100	1,429,000	1,358,000						
556.28	68,000	1,142,000	1,071,000	62,000	1,122,000				
556	67,070	1,121,000	1,050,000	61,190	1,108,000	1,058,000	1,048,000	1,047,000	1,037,000
550	45,450	792,000	720,000	44,810	790,000	740,000	727,000	728,000	718,000
545	33,090	596,000	528,000	33,060	596,000	549,000	538,000	538,000	528,000
541	27,260	472,000		27,260	472,000	432,000	420,000		
538	24,870	393,000	335,000	24,870	393,000	355,000	344,000	343,000	335,000
530	18,600	220,000	171,000	18,600	220,000	190,000	178,000	177,000	171,000
520	8,080	88,600	65,600	8,080	88,500	74,400	67,800	67,300	65,600
510	3,680	31,300	18,100	3,680	31,300	22,200	19,800	19,100	18,100
500	1,220	7,140	800	1,220	7,140	1,810	1,240	1,040	800
490	138	344	0	138	344	0	0	0	0
483.8	0	0.	0	0	0	0	0	0	0

REV NO.	DATE	MADE	CHKD	SUPV	INSP
1	3-1-72	RHL			
Add 1961 vol incl dewatered area					

DRWN........ COMPUTED

TRCD. D.C.W. ...... ENGINEER

CHKD........

THIS DRAWING SUPERSEDES 3-DA-1-321A14R1

TENNESSEE RIVER-MILE 274.9

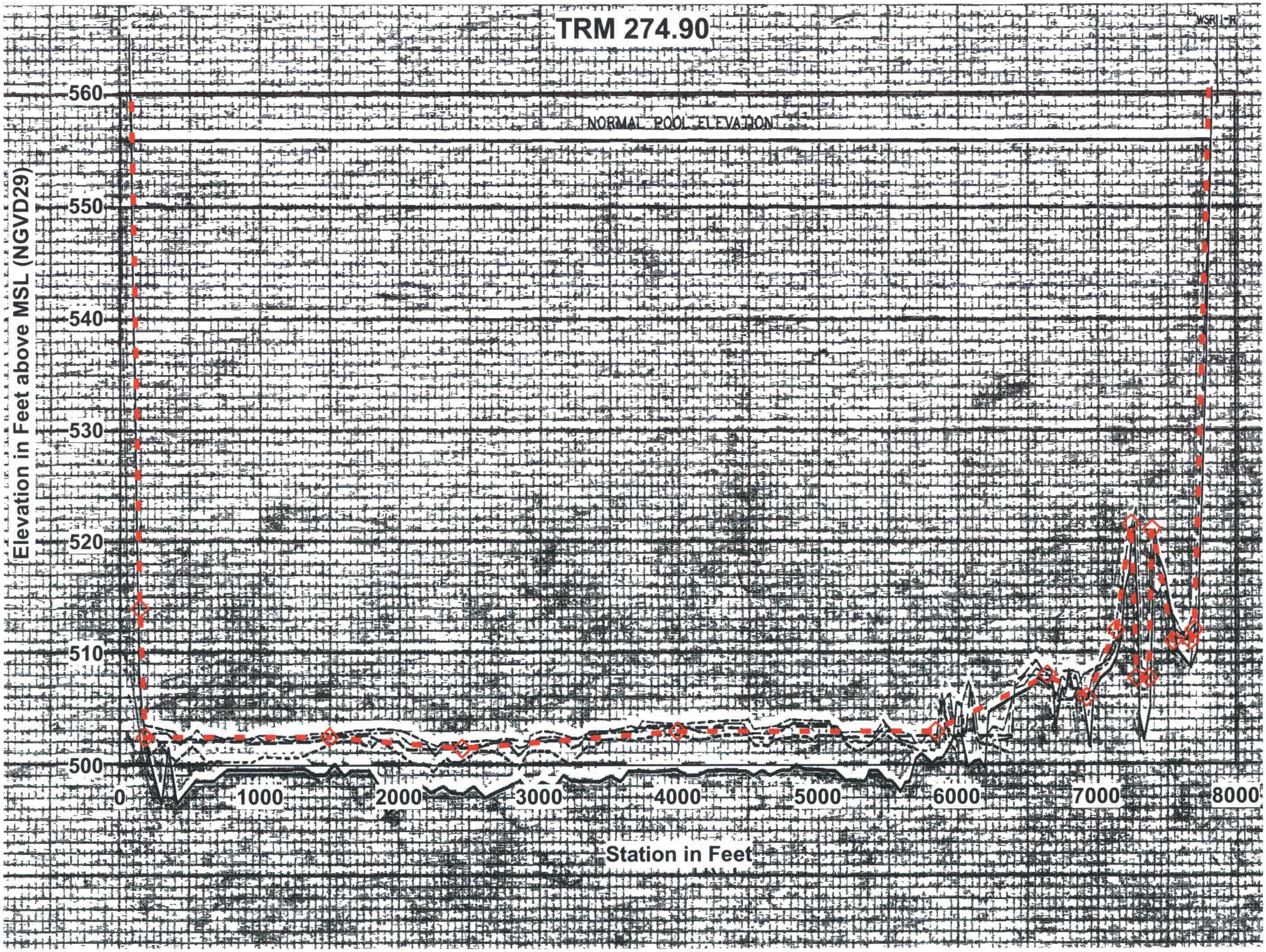
RESERVOIR AREAS AND VOLUMES

WHEELER PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
Edwin B. McCain	Paul C. Spott	Reed A. Elliot

KNOXVILLE | 12-28-62 | 3 | DA | 1 | 321G784 R1

Initial HEC-RAS and SOCH Model Geometry Input Files
and Master Excel Geometry File


TRM 274.90
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Elevation in Feet above MSL (NGVD29)
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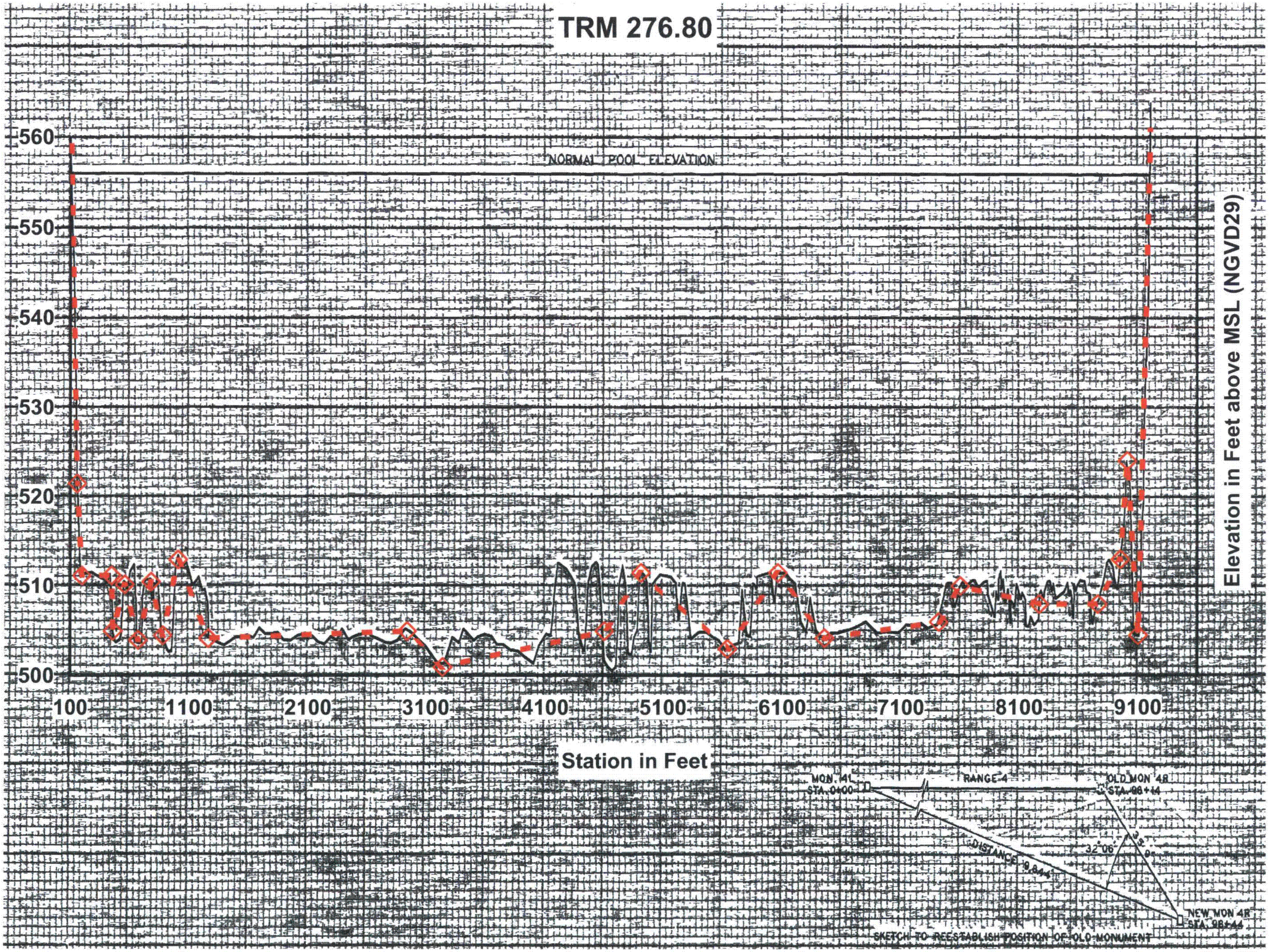
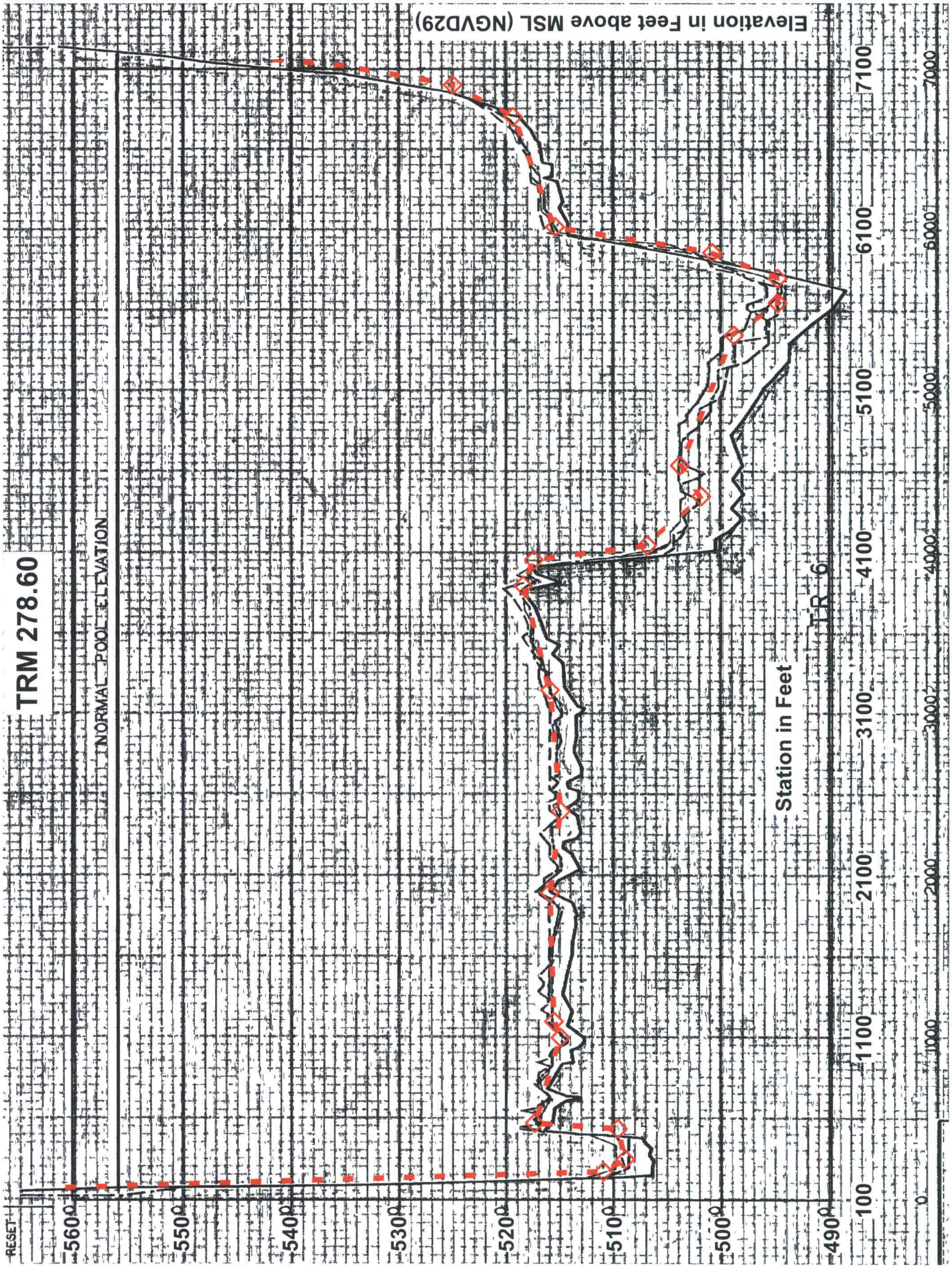
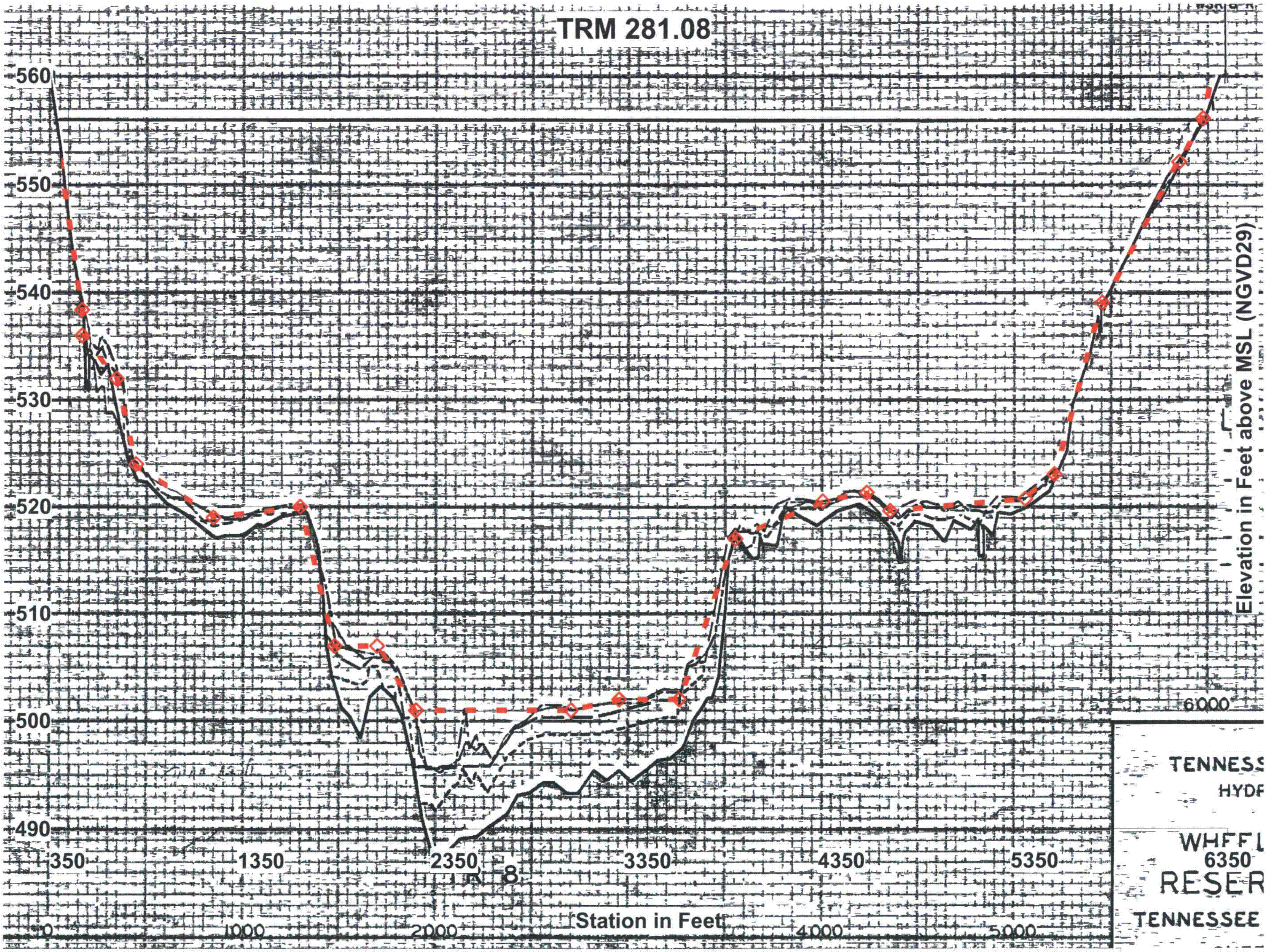
550
540
530
520
510
500
0
1000
2000
3000
4000
5000
6000
7000
8000
Station in Feet


TRM 276.80
NORMAL POOL ELEVATION
560
550
540
530
520
510
500
Elevation in Feet above MSL (NGVD29)
100
1100
2100
3100
4100
5100
6100
7100
8100
9100
Station in Feet
MON. 4L
STA. 0+00
RANGE 4
OLD MON 4R
STA. 98+14
NEW MON 4R
STA. 98+44
SKETCH TO REESTABLISH POSITION OF OLD MONUMENT


TRM 278.60
NORMAL POOL ELEVATION
Elevation in Feet above MSL (NGVD29)
Station in Feet
TR 6
560
550
540
530
520
510
500
490
100
1100
2100
3100
4100
5100
6100
7100
0
1000
2000
3000
4000
5000
6000
7000
RESET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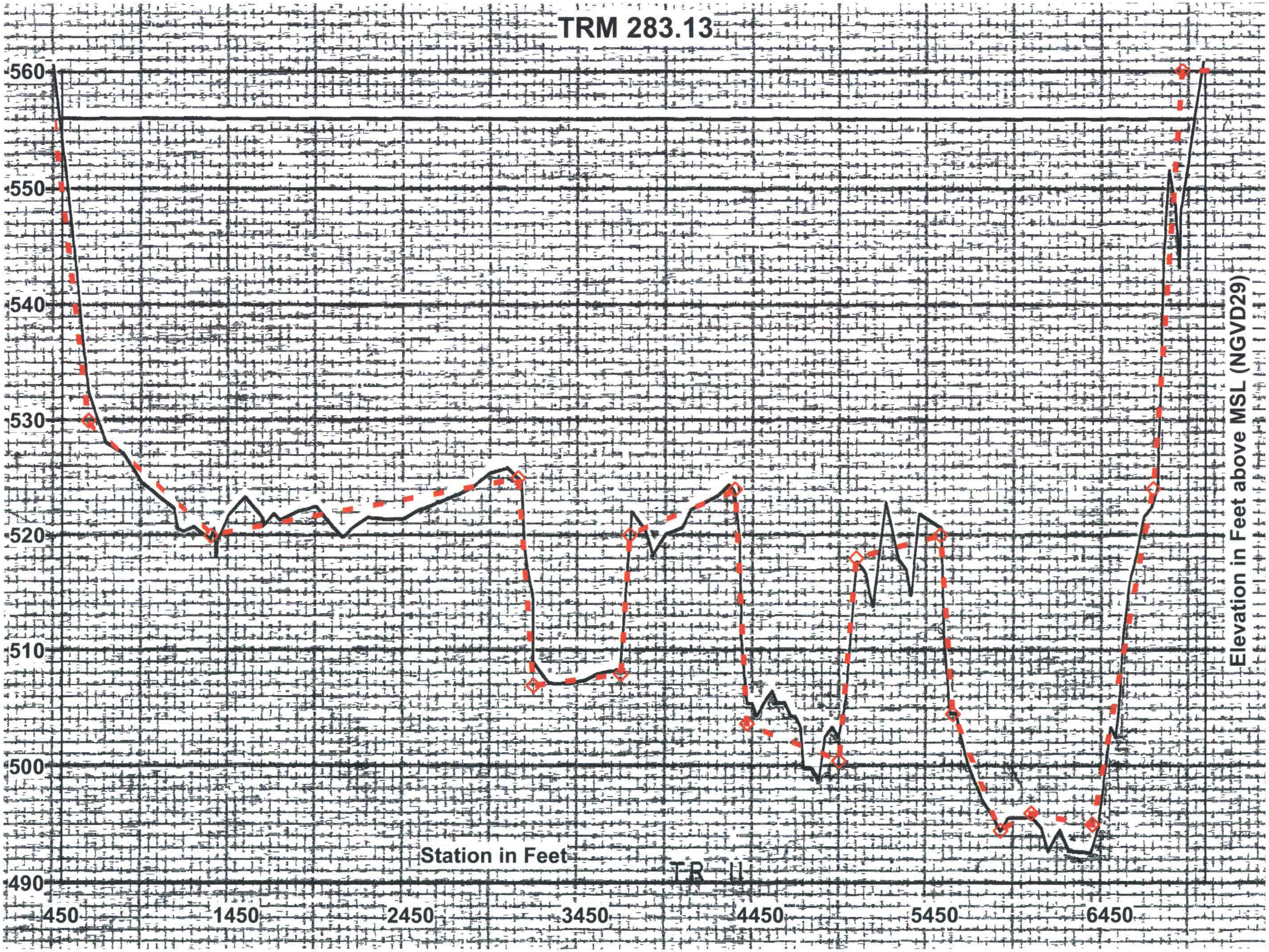
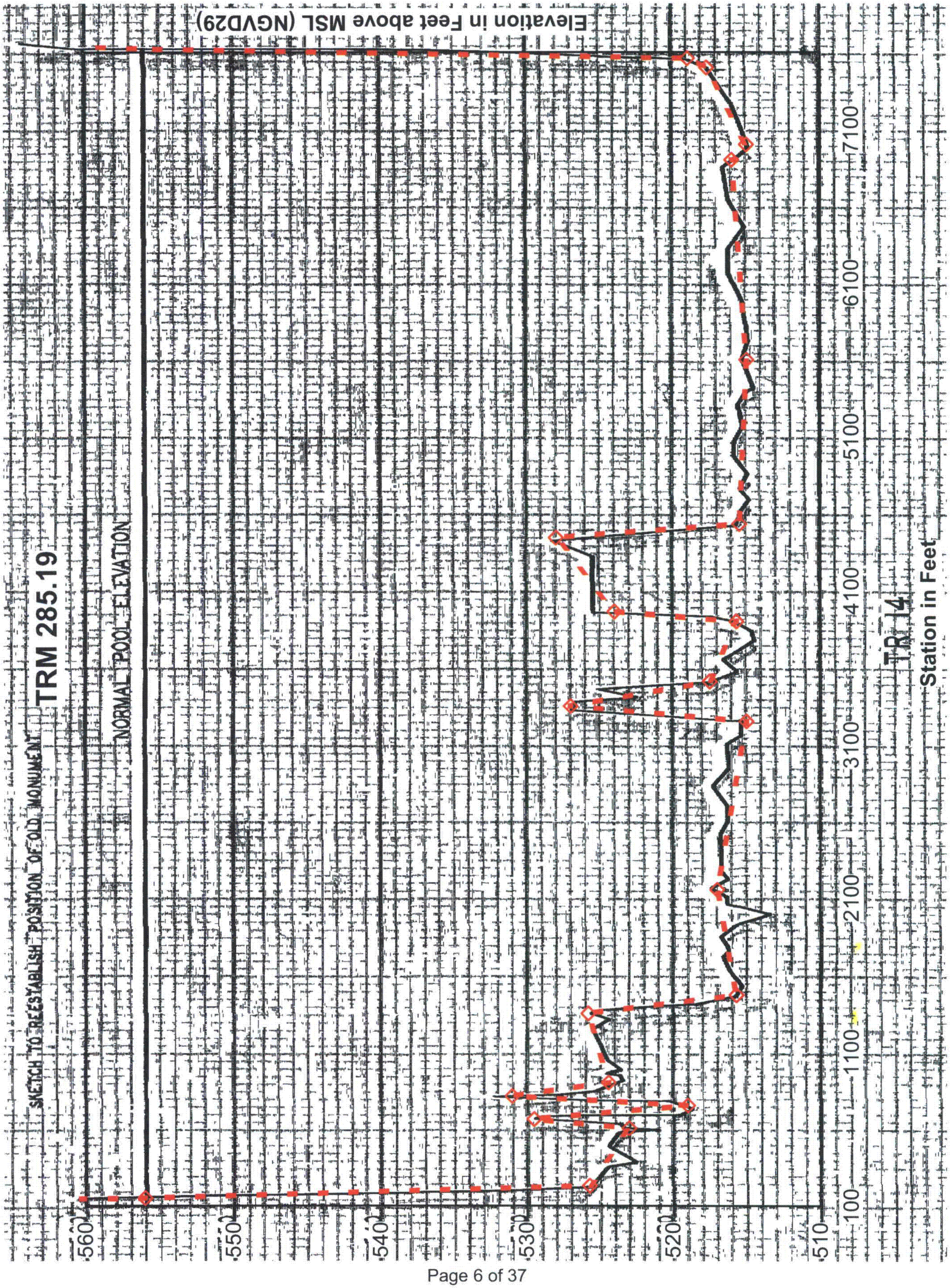
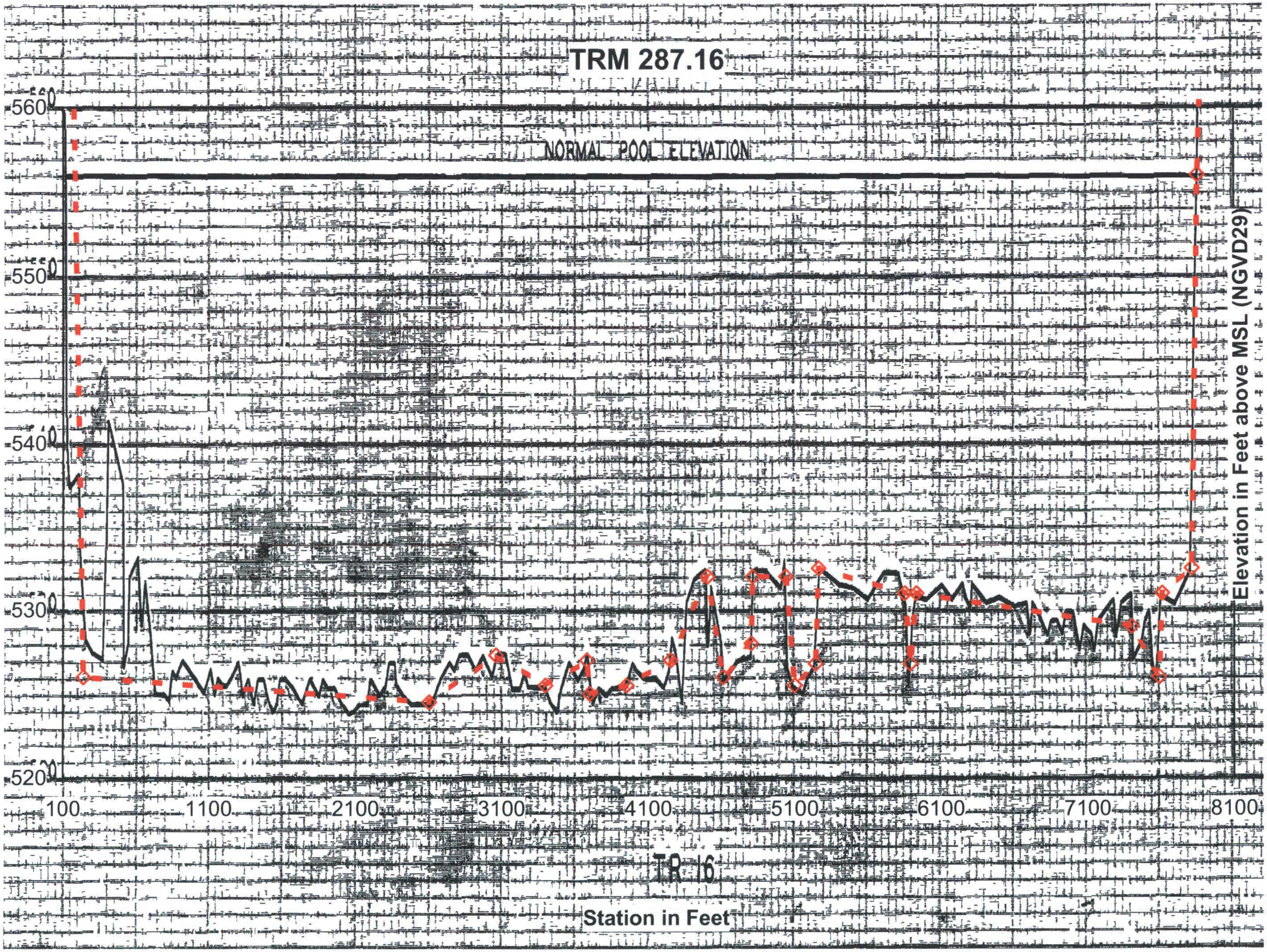
550
540
530
520
510
500
490
350
1350
2350
3350
4350
5350
6350
0
1000
2000
4000
5000
6000
Station in Feet
Elevation in Feet above MSL (NGVD29)
TENNESS
HYDF
WHEEL
RESER
TENNESSEE


TRM 283.13
560
550
540
530
520
510
500
490
450
1450
2450
3450
4450
5450
6450
Station in Feet
Elevation in Feet above MSL (NGVD29)


Elevation in Feet above MSL (NGVD29)
TRM 285.19
SKETCH TO REESTABLISH POSITION OF OLD MONUMENT
NORMAL POOL ELEVATION
TR 14
Station in Feet
560
550
540
530
520
510
100
1100
2100
3100
4100
5100
6100
7100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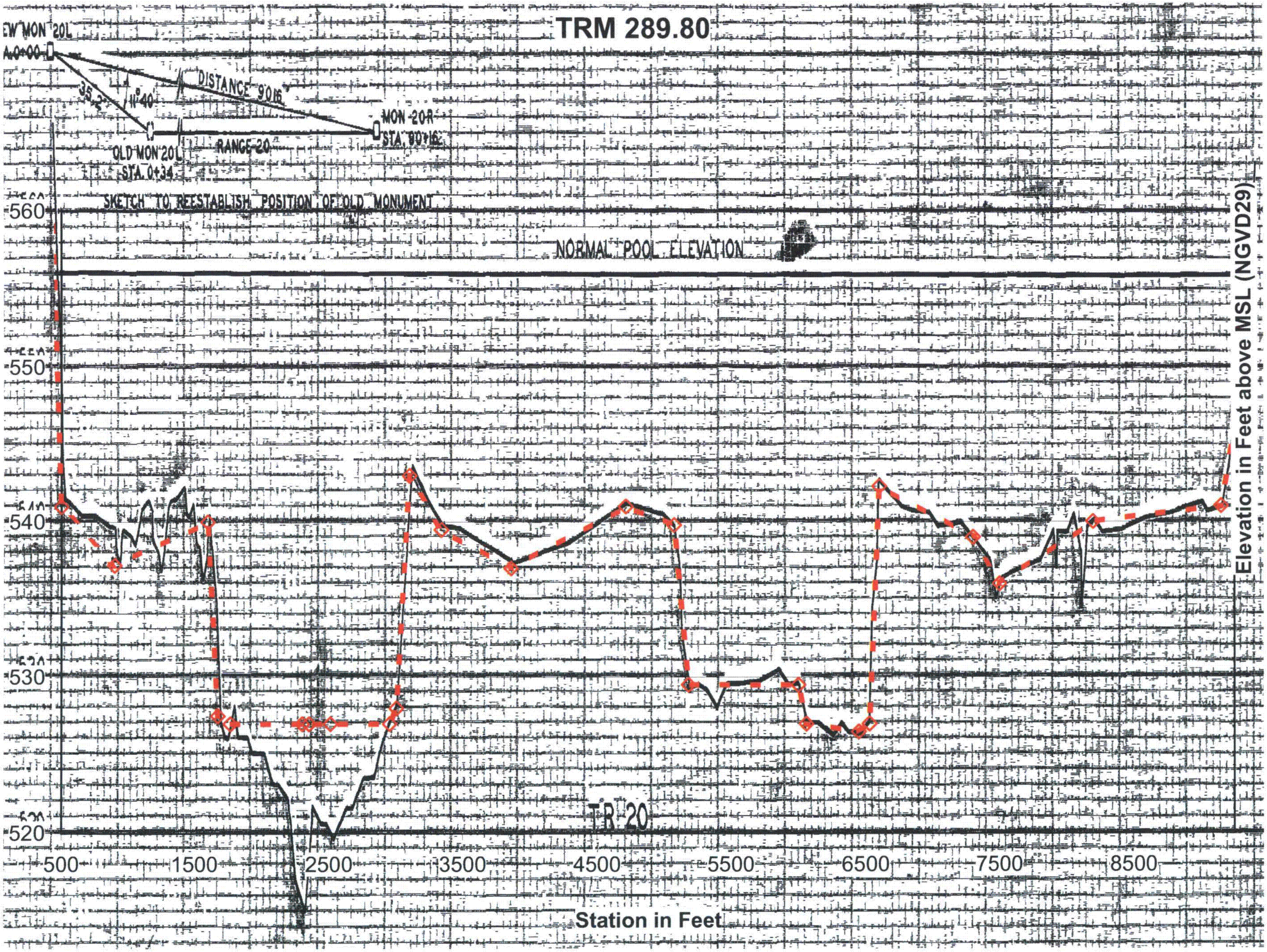
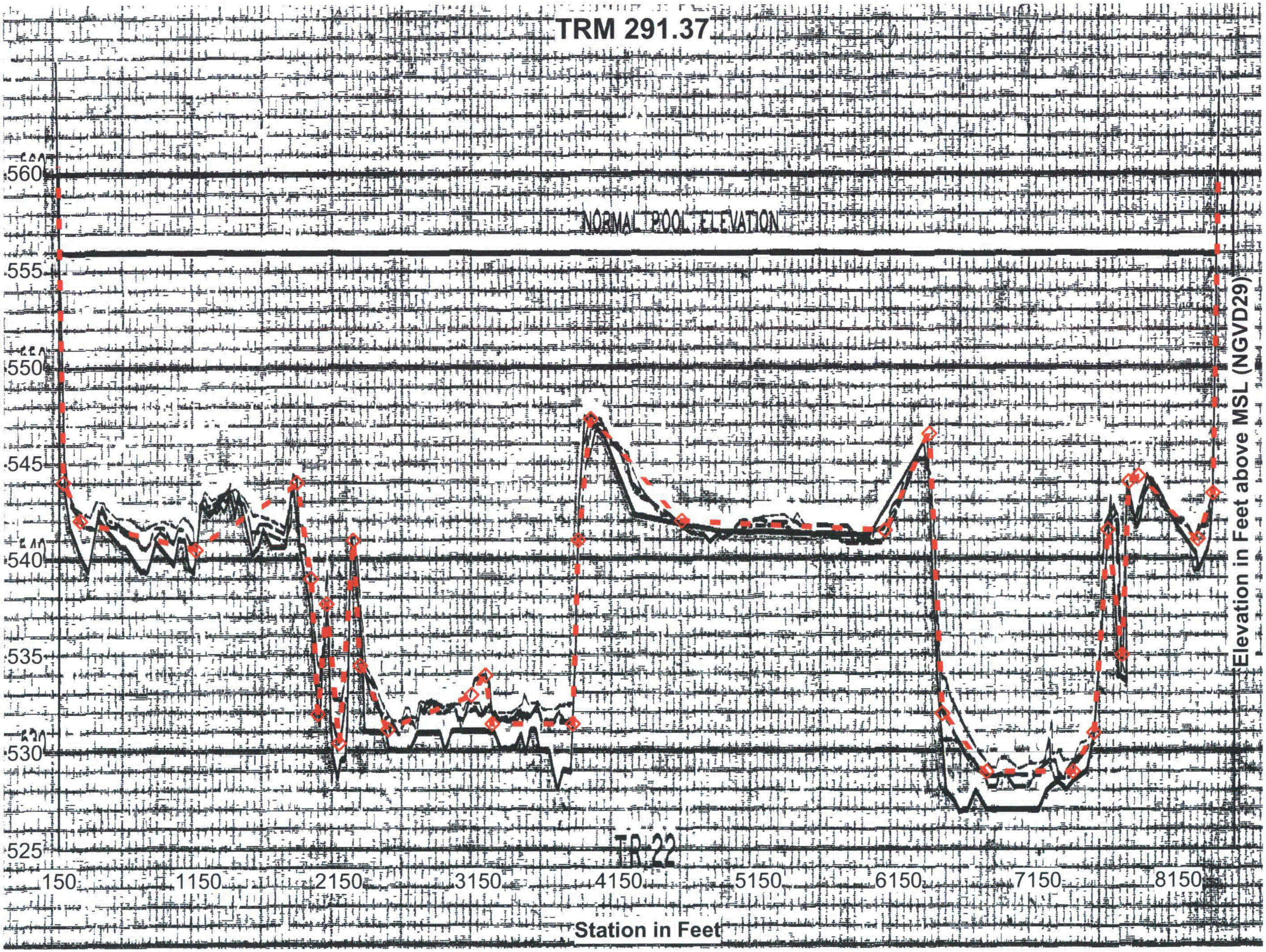
NORMAL POOL ELEVATION
560
550
540
530
520
100
1100
2100
3100
4100
5100
6100
7100
8100
TR 16
Station in Feet
Elevation in Feet above MSL (NGVD29)


TRM 289.80
NEW MON 20L
STA 0+00
35.2'
11°40'
DISTANCE 9016
MON 20R
STA 90+16
OLD MON 20L
STA 0+34
RANGE 20
SKETCH TO REESTABLISH POSITION OF OLD MONUMENT
NORMAL POOL ELEVATION
TR 20
560
550
540
530
520
500
1500
2500
3500
4500
5500
6500
7500
8500
Station in Feet
Elevation in Feet above MSL (NGVD29)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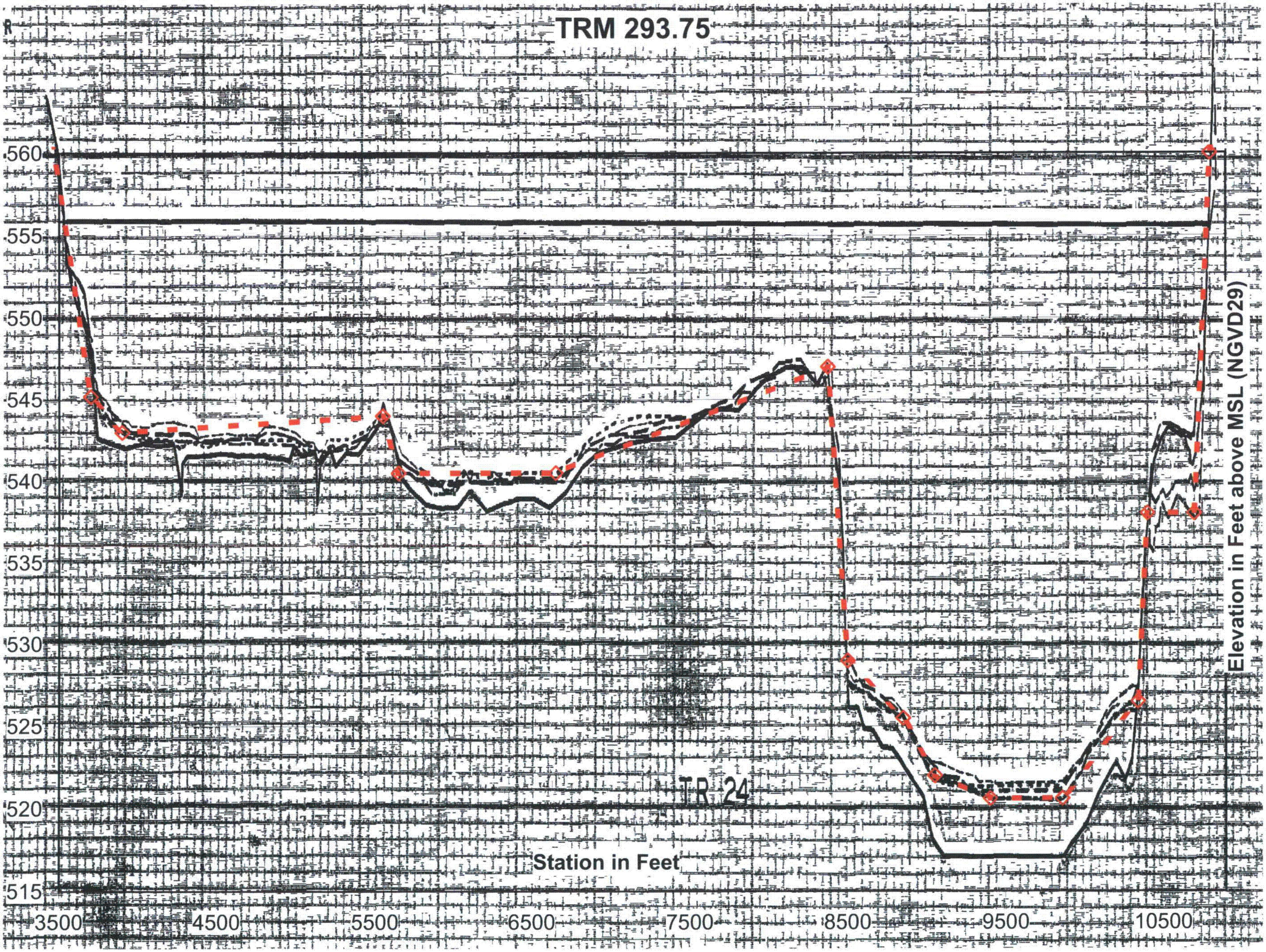
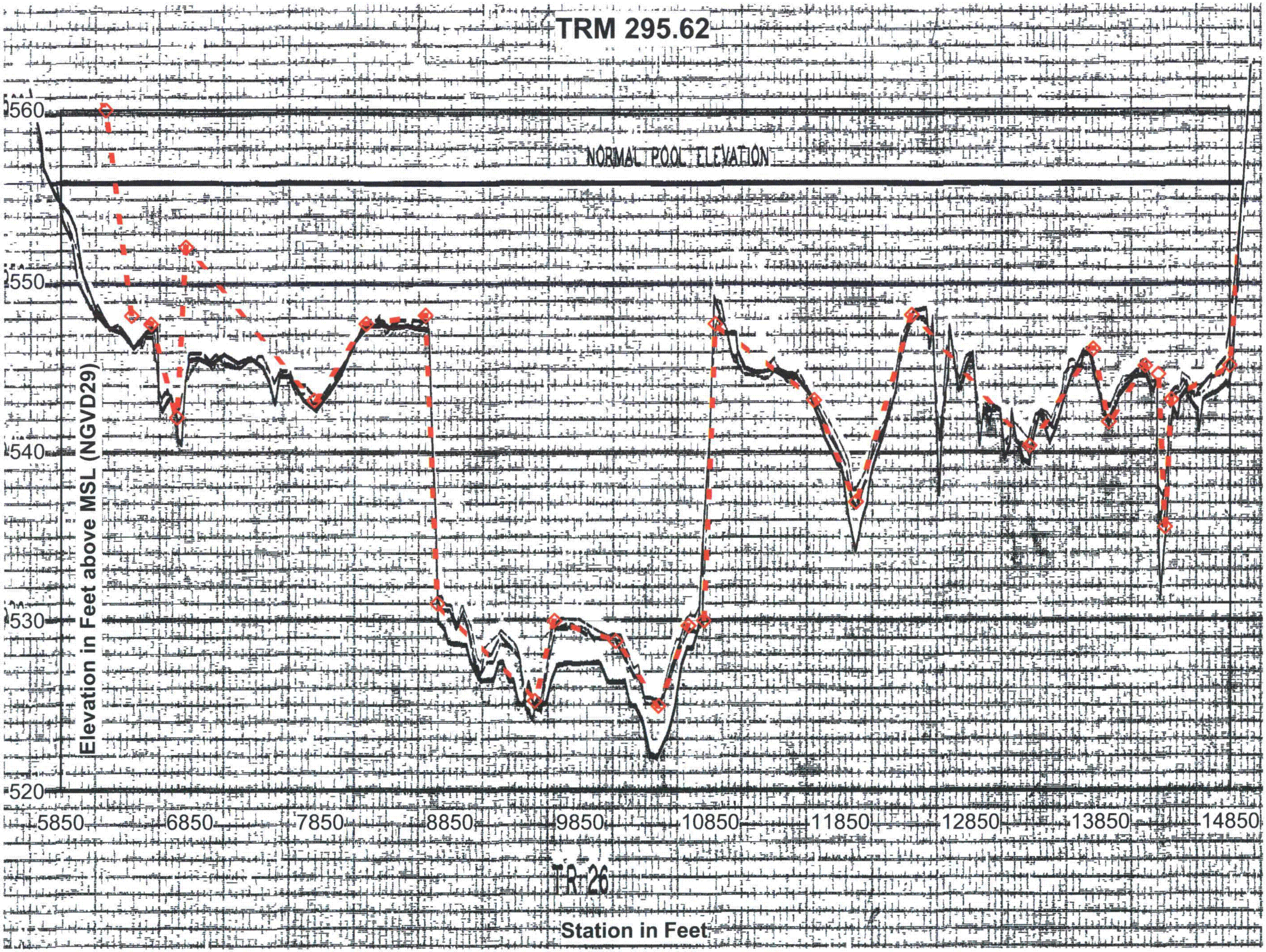
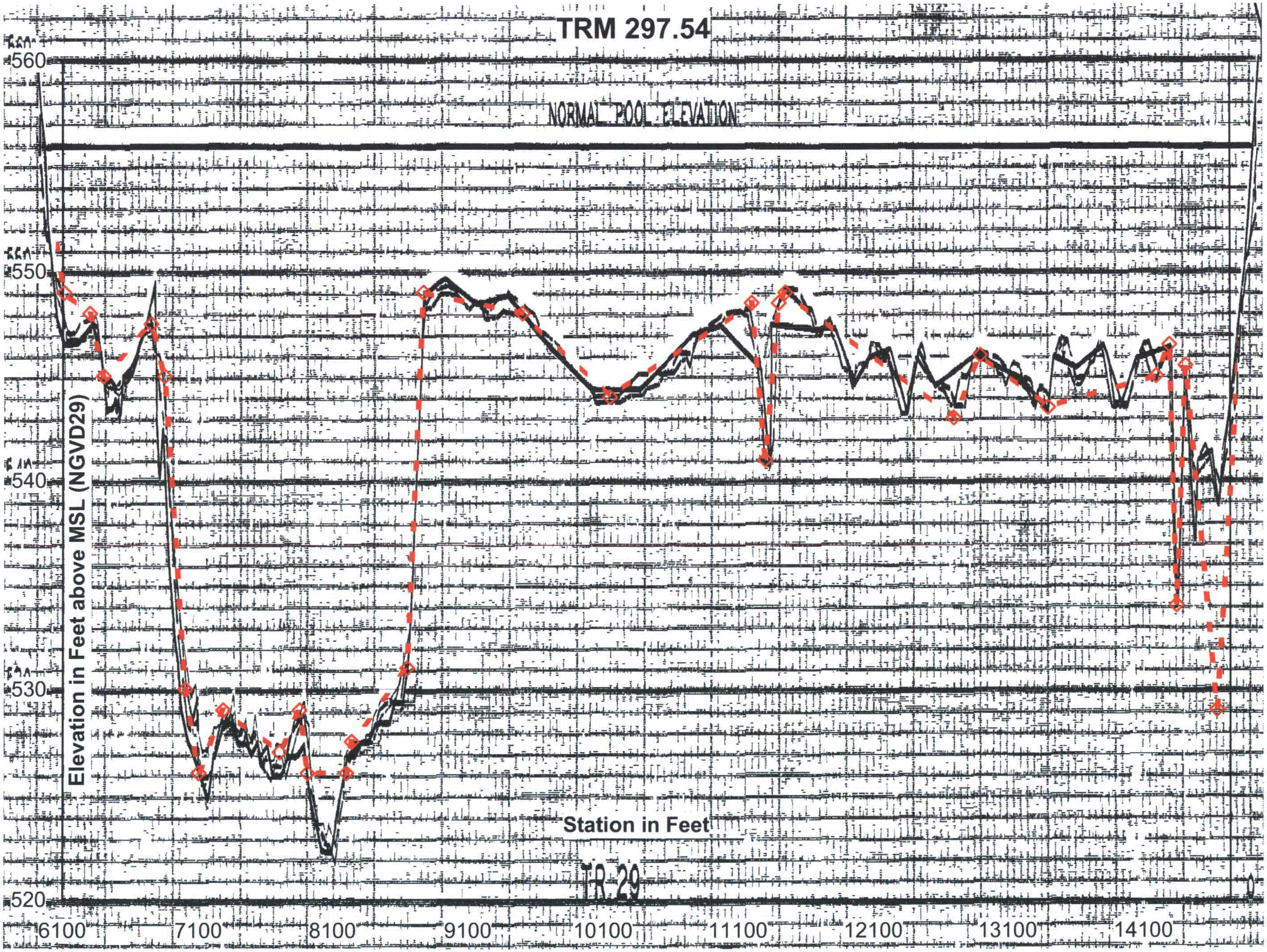
NORMAL POOL ELEVATION
560
555
550
545
540
535
530
525
150
1150
2150
3150
4150
5150
6150
7150
8150
Station in Feet
Elevation in Feet above MSL (NGVD29)
TR 22



TRM 293.75
560
555
550
545
540
535
530
525
520
515
3500
4500
5500
6500
7500
8500
9500
10500
Station in Feet
Elevation in Feet above MSL (NGVD29)
TR 24


TRM 295.62
NORMAL POOL ELEVATION
560
550
540
530
520
Elevation in Feet above MSL (NGVD29)
5850
6850
7850
8850
9850
10850
11850
12850
13850
14850
TR 26
Station in Feet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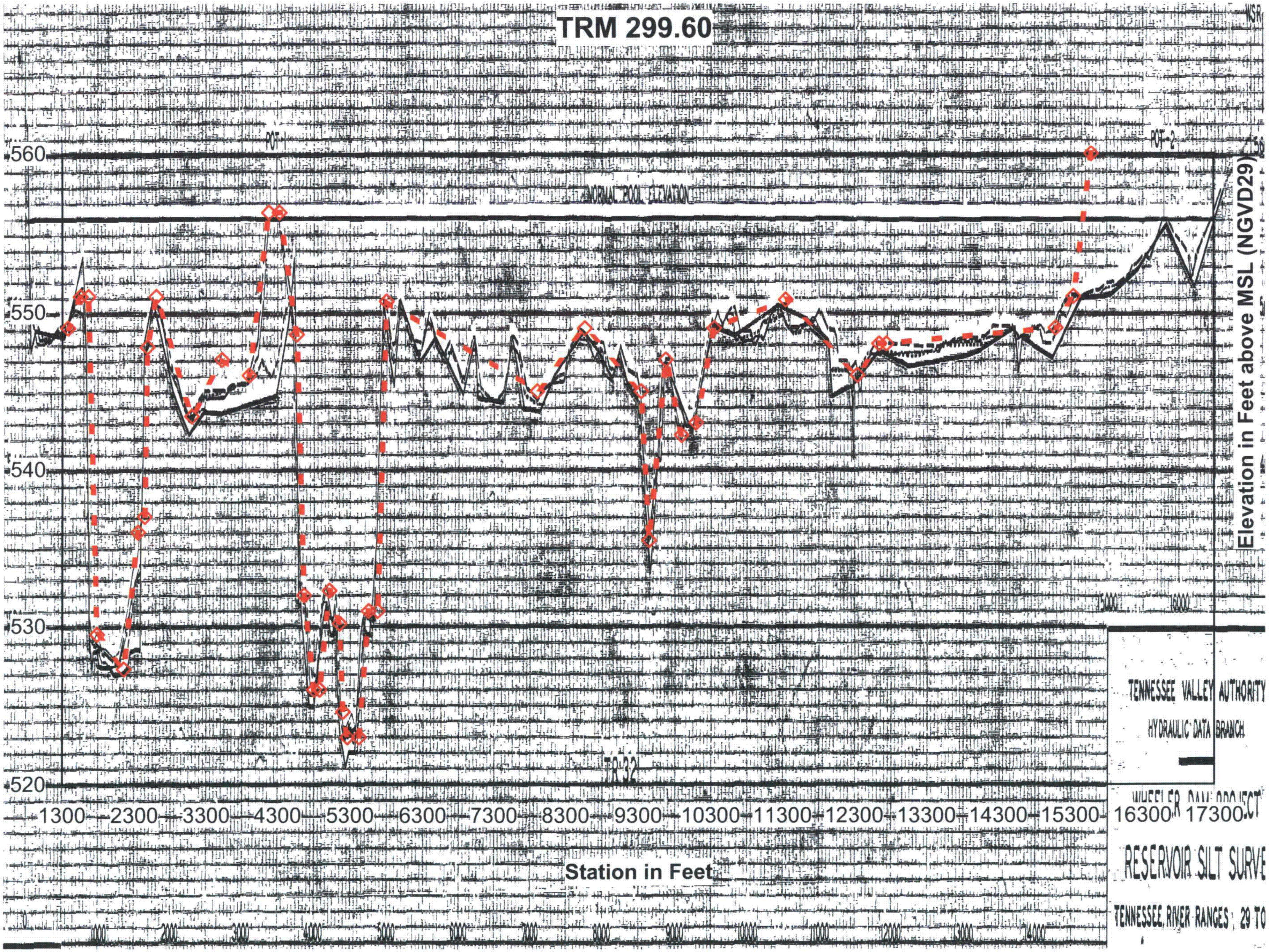
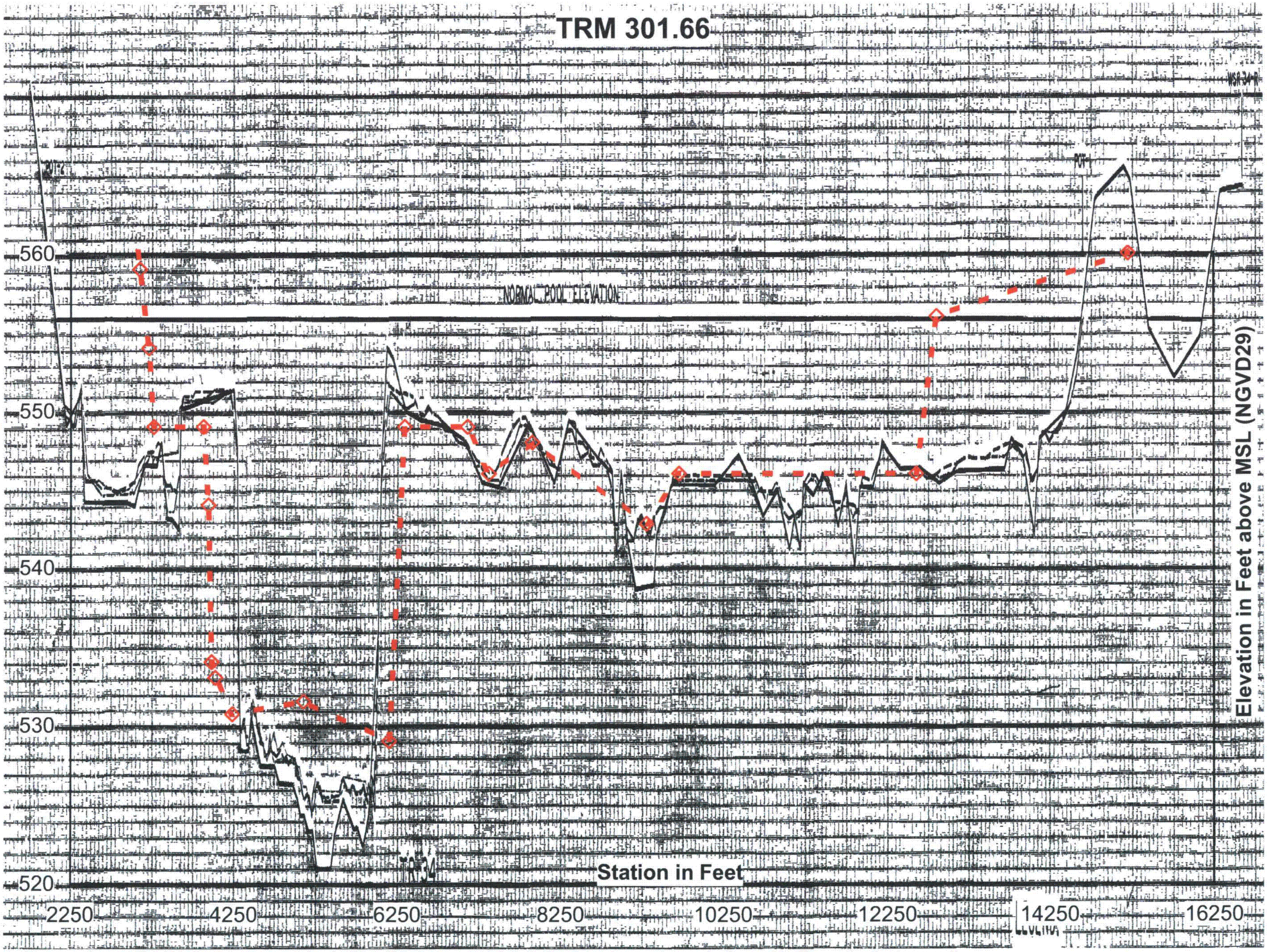
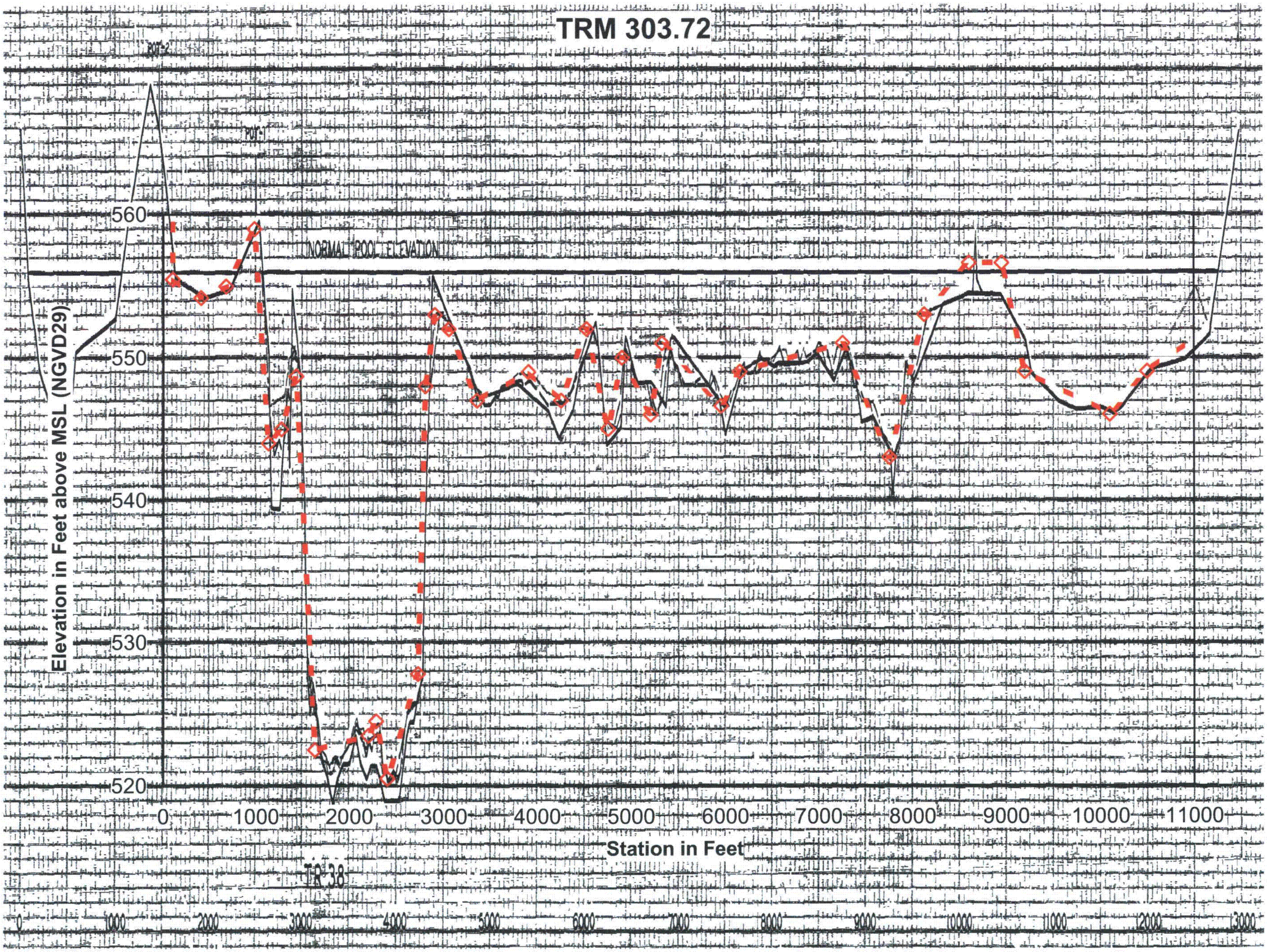
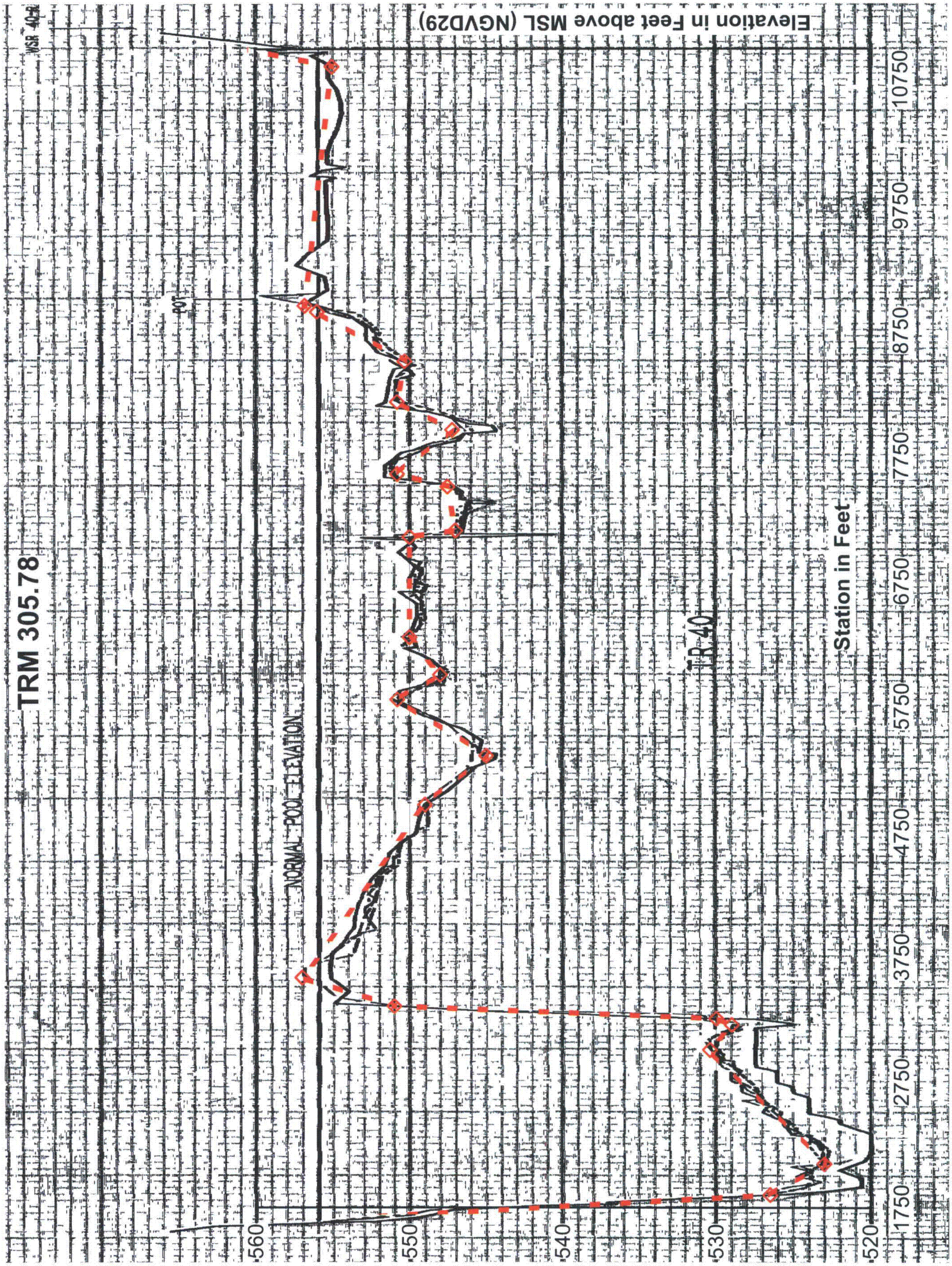
Elevation in Feet above MSL (NGVD29)
560
550
540
530
520
6100
7100
8100
9100
10100
11100
12100
13100
14100
Station in Feet
TR-29


TRM 299.60
Elevation in Feet above MSL (NGVD29)
560
550
540
530
520
NORMAL POOL ELEVATION
1300
2300
3300
4300
5300
6300
7300
8300
9300
10300
11300
12300
13300
14300
15300
16300
17300
Station in Feet
TENNESSEE VALLEY AUTHORITY
HYDRAULIC DATA BRANCH
RESERVOIR SILT SURVE
TENNESSEE RIVER RANGES: 29 TO


TRM 301.66
NORMAL POOL ELEVATION
560
550
540
530
520
Station in Feet
2250
4250
6250
8250
10250
12250
14250
16250
Elevation in Feet above MSL (NGVD29)


TRM 303.72
POT-2
POT-1
NORMAL POOL ELEVATION
Elevation in Feet above MSL (NGVD29)
560
550
540
530
520
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
Station in Feet
TR 38


TRM 305.78
Elevation in Feet above MSL (NGVD29)
Station in Feet
NORMAL POOL ELEVATION
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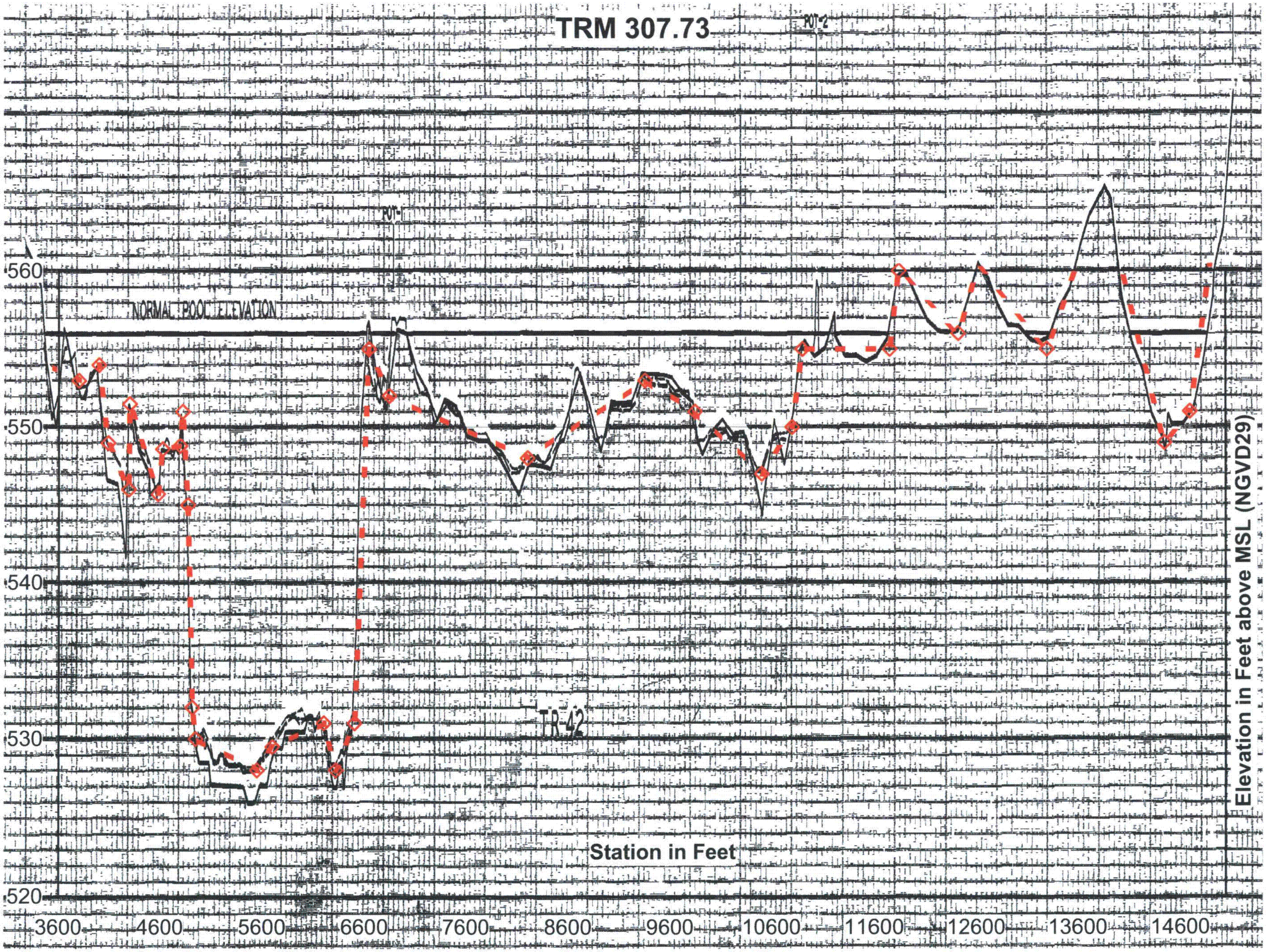
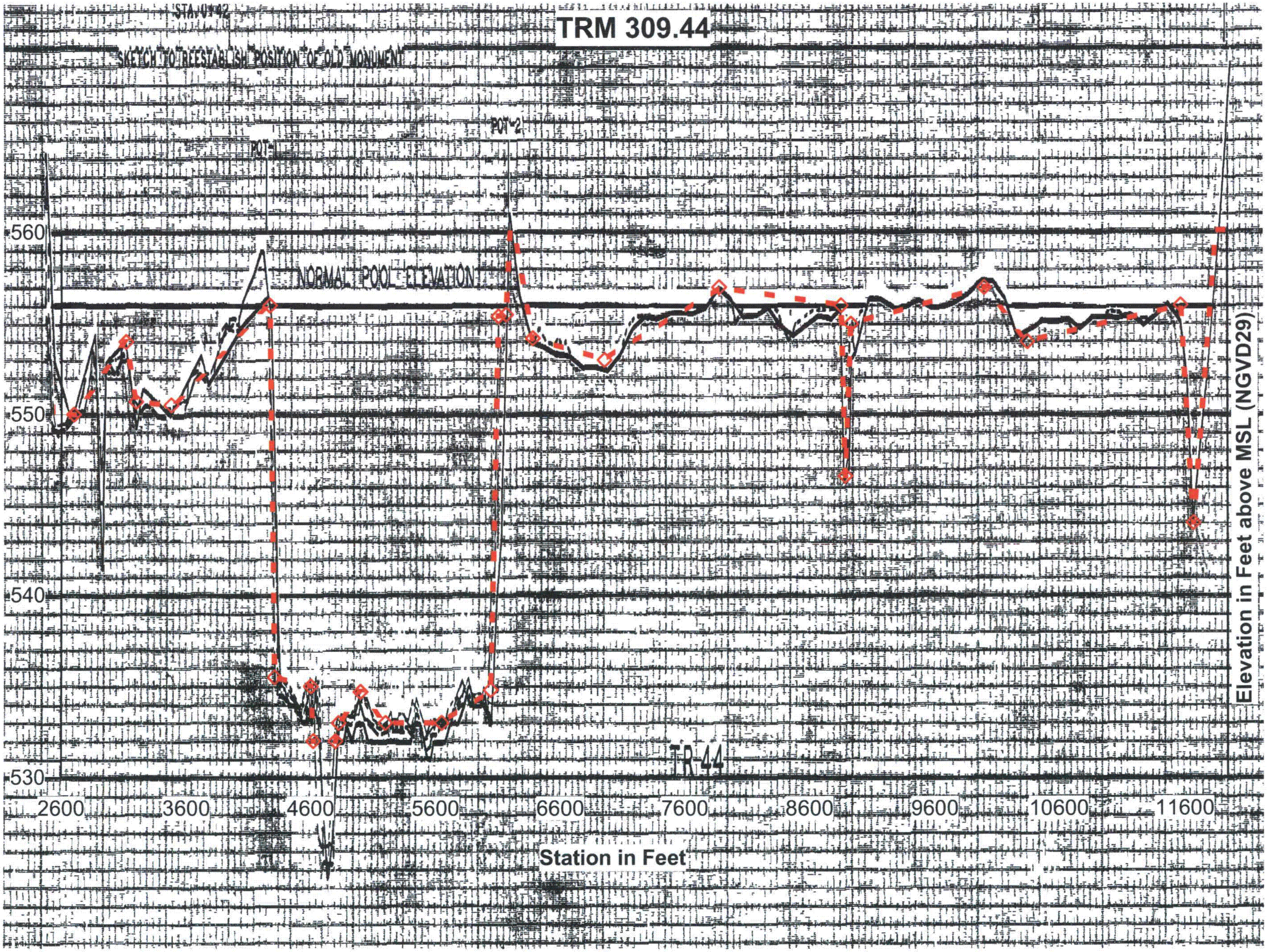
560
550
540
530
520
1750
2750
3750
4750
5750
6750
7750
8750
9750
10750


TRM 307.73
POT-2
POT-1
NORMAL POOL ELEVATION
TR-42
560
550
540
530
520
3600
4600
5600
6600
7600
8600
9600
10600
11600
12600
13600
14600
Station in Feet
Elevation in Feet above MSL (NGVD29)


TRM 309.44
SKETCH TO REESTABLISH POSITION OF OLD MONUMENT
NORMAL POOL ELEVATION
POT-1
POT-2
TR-44
560
550
540
530
2600
3600
4600
5600
6600
7600
8600
9600
10600
11600
Station in Feet
Elevation in Feet above MSL (NGVD29)